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CHEMICAL TECHNOLOGY DIVISION

EVALUATION OF A COTTRELL ELECTROSTATIC PRECIPITATOR ON A RADIOCHEMICAL PROCESS OFF-GAS SYSTEM

J. C. Suddath

DATE ISSUED

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1.0 Abstract

A Cottrell Electrostatic Precipitator, installed on an off-gas system of the ORNL Iodine Recovery Operation and the ORNL Special Isotope Recovery Operation, was evaluated to determine its radioactivity removal efficiency. The sampling of the gas contaminated with radioactivity was studied and a satisfactory technique developed.

2.0 Introduction

The off-gas from radio-chemical processing at ORNL is routed to a central cleaning area. A Cottrell Electrostatic Precipitator was installed in the central cleaning area to collect the particulate radioactivity carried by the off-gas. The Cottrell has a design capacity of 2000 CFM and it received off-gas from the Iodine Recovery Operation, the Special Isotope Recovery Operation and the Isotope Production Area.

Tests were made to determine the general composition of the off-gas, concentrations of radioactivity in the off-gas, effect of voltage on the cleaning efficiency of the Cottrell, and the effect of circulating wash water through the tubes on the cleaning efficiency of the Cottrell.

To make these tests, it was necessary to develop a technique of sampling and subsequent analyses of the samples. Two sampling methods were employed, (1) filtering a sample of the off-gas through Chemical Warfare Service No. 6 Filter Paper and (2) collecting the particles from a sample of off-gas with a Cascade Impactor. The filter samples were counted for radioactivity, radioautographed for particles and leached for radiochemical analyses of fission products. The particles collected by the Cascade Impactor were photomicrographed and analysed radiochemically.

3.0 Summary

It was shown that the Cottrell Electrostatic Precipitator would collect more than 99.9 percent of the solid radioactivity in the off-gas, when the voltage was 50 to 55 kilovolts, and the concentration of radioactivity as solids was greater than 5.0×10^{-4} microcuries per cubic centimeter of off-gas.

The radioactivity in the off-gas was essentially all radioiodine, except during a Special Isotope Recovery Operation. The concentration of radioiodine varied from 1.0×10^{-8} μc per cc. to 1 μc per cc.; the concentration of radiobarium varied from less than 1.0×10^{-7} μc per cc. to 7.6×10^{-2} μc per cc.; and the radiostrontium varied from less than 1.0×10^{-7} μc per cc. to 1.1×10^{-5} μc per cc.

The collecting efficiency of the Cottrell increased when the voltage on the Cottrell was increased, with the concentrations of solid radioactivity constant.

At a constant radiobarium concentration of 7×10^{-4} μc per cc. the removal efficiencies were:

99.1%	with	30 kilovolts
99.8%	with	40 kilovolts
99.9%	with	50 kilovolts
99.98%	with	55 kilovolts

The collecting efficiency at a given voltage and concentration was not increased by using wash water, to wet continuously the collecting walls of the precipitator but the voltage must be limited to prevent arcing when using wash water. Since higher efficiencies can be obtained at higher voltages, the precipitator is more efficiently operated <u>without</u> wash water.

Summary (continued)

The presence of large amounts of radioiodine obscured analytical results obtained either with the radioautographic technique or with gross counts of activity collected on the sample filters. The presence of water droplets and radioiodine obscured results from Cascade Impactor slides except for particle size range determinations.

Radiochemical analyses of the radioactivity collected by the sample filters established the identity and concentrations of solid radioactivity in the off-gas before and after cleaning and was used to evaluate the Cottrell for particle removal.

4.0 Description of Equipment

The process off-gas and the cell ventilation air from the radiochemical processes are cleaned separately and subsequently discharged to the atmosphere through a common 250 foot stack. Figure I is a schematic sketch of the waste gas cleaning area at ORNL, showing the separate cleaning equipment and the origin of the waste gases.

The gases evolved from the Special Isotope Recovery dissolver are scrubbed with a caustic scrubber and travel to the off-gas cleaning equipment through a 2" stainless steel pipe. The other gases from the Special Isotope Recovery Operation are scrubbed with a water scrubber and travel to the off-gas cleaning equipment through a 4" stainless steel pipe.

The gases evolved in the Iodine Recovery Operation are scrubbed with caustic scrubbers and travel to the off-gas cleaning equipment through another 4" stainless steel pipe. All other gases that which have been in contact with radioactive solutions in the Isotope Production Area are collected by a 6" stainless steel pipe and go to the central cleaning area.

All of the off-gas streams are fed into a header and are then carried stepwise through the Cottrell, a heater, a filter bank, a blower and into the 250 foot stack. Figures II and III are pictures of the Cottrell Electrostatic Precipitator and associated equipment.

The points where samples of the off-gas were taken are shown in Fugure I. Point A is prior to cleaning and gives a sample of the combined off-gases. Point B is after the gas is cleaned by the Cottrell and Point C is after it passes

Description of Equipment (continued)

through the filter bank. Samples were taken simultaneously from the off-gas at all three points and filtered separately through C.W.S. No. 6 filter papers. Caustic Scrubbers were installed as back-up units to the filter papers in each sampling line. Samples of the off-gas at points A and B were also passed through a Cascade Impactor.

The Cottrell Precipitator consists of twenty-three vertical collecting pipes with an ionization wire centered in each pipe. The inside surface of the pipes serve as the collecting walls and can be flushed by means of spray nozzles located at the top of each pipe. The water which is used for flushing is continuously recycled over the collecting walls, while voltage is applied to the electrodes and particles are being precipitated (this is termed "wet operation"). "Dry operation" is the term applied to operation without continuous flushing. The water rate required to wet the walls evenly is 35 GPM.

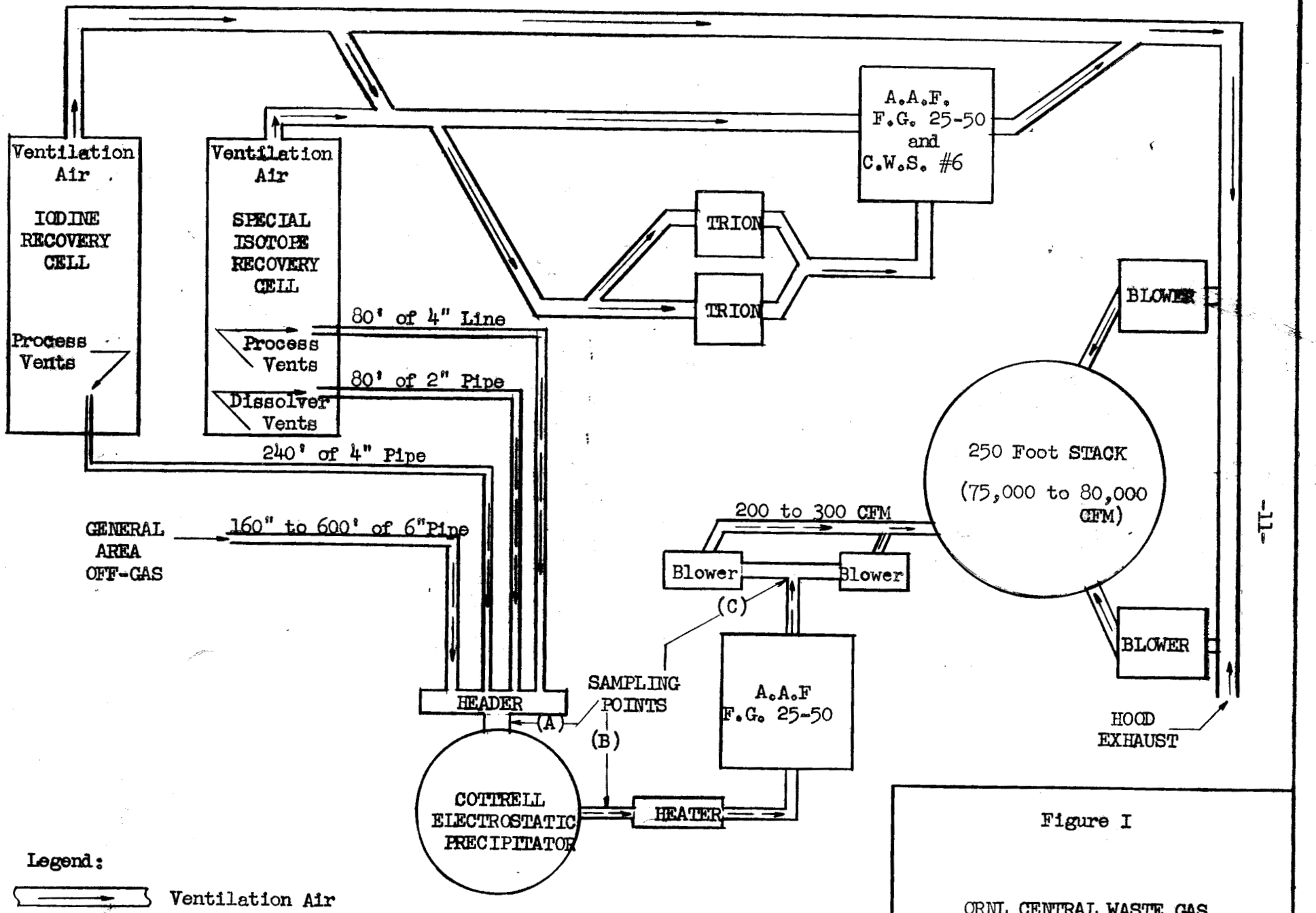

Figure I

ORNL CENTRAL WASTE GAS COLLECTION SYSTEM

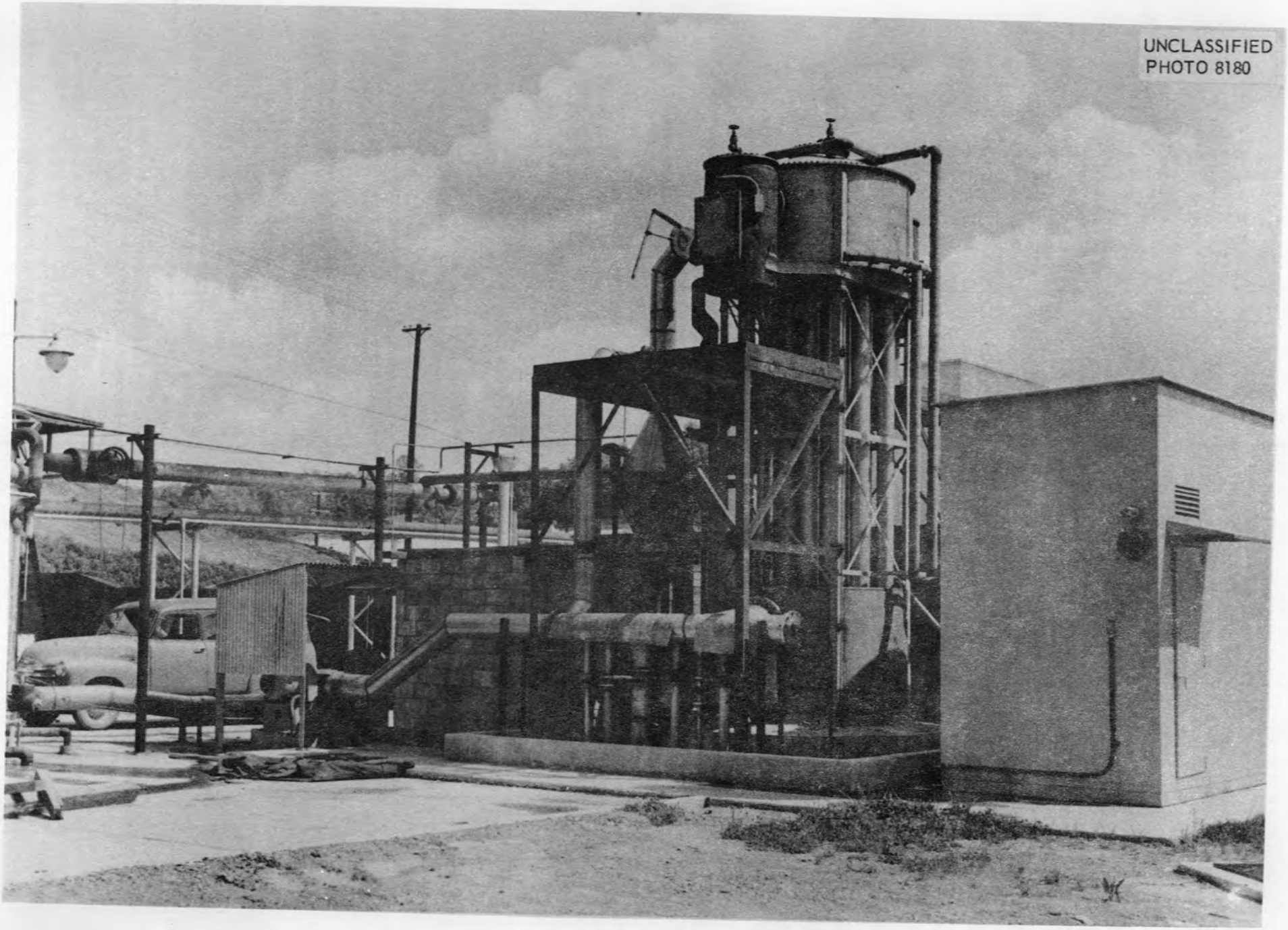

Fig. 11 – ORNL CENTRAL OFF-GASS CLEANING EQUIPMENT

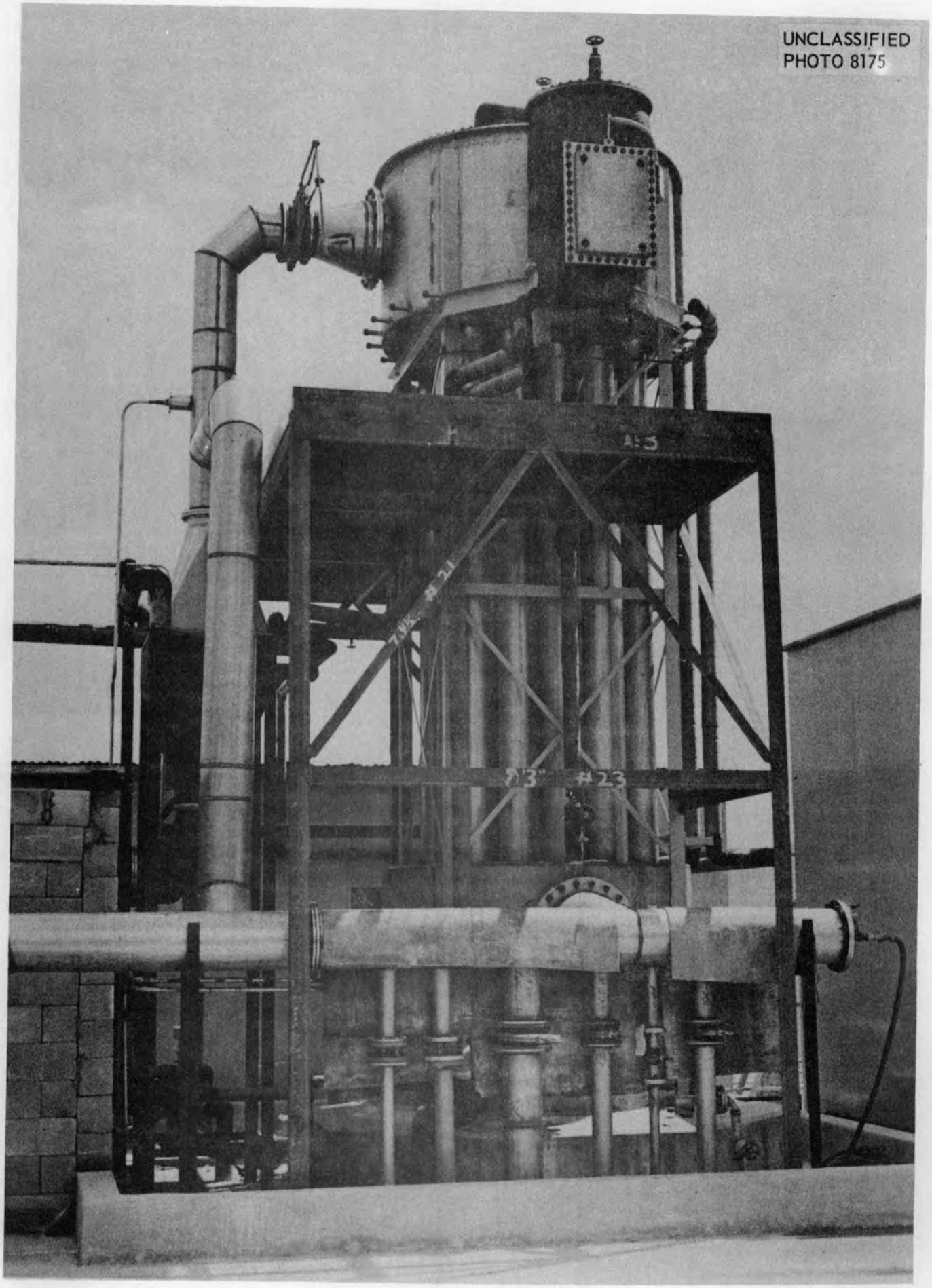

Fig. III – COTTRELL ELECTROSTATIC PRECIPITATOR

5.0 Evaluation Techniques

Samples of off-gas were taken to determine the composition and concentration of particulate radioactivity in the off-gas at the various stages of the cleaning operations. The particles in the samples were collected on filter paper and in a Cascade Impactor.

5.10 Filter Samples

Chemical Warfare Service No. 6 has a high efficiency for the removal of particles down to 0.1 micron and has been used widely as a standard for particle removal. Therefore, it was employed to filter the off-gas samples and serve as a standard of comparison to evaluate the off-gas cleaning equipment. Samples were taken simultaneously from the off-gas stream before the Cottrell, after the Cottrell and after the back-up filter bank (Points A, B, and C), on a 9 inch diameter filter.

5.110 Radiochemical Analyses

The filter papers, which had been used to sample the off-gas, were leached with a nitric acid solution to obtain the radioactivity in a solution form. The leaching procedure was as follows:

(1) Gross count of radioactivity on filter.

(2) Boil filter in 3N Nitric Acid, with agitation.

(3) Filter off the solution and wash the residual undissolved bulk.

(4) Make fission product analyses of solution.

(5) Gross count of undissolved bulk.

(6) Heat undissolved bulk to drive off gases.

(7) Gross count of residue.

5.110 Radiochemical Analyses (continued)

The concentrations of solid fission products are determined from standard radiochemical analyses of leach solution. Steps 5, 6 and 7 give a measure of remaining radioactivity not dissolved and of the volatile portion of the residue.

Sample calculation:

Volume of off-gas filtered	-	15.3 cu. ft
Volume of leach solution	-	210 ml.
Radiobarium found in leach solution	-	1.16×10^{-3} mc/ml
Radiobarium in off-gas (μc/cc)	-	C

$$C = \frac{1.16 \times 10^{-3}\,\text{mc}}{\text{ml}} \times 210\ \text{ml} \times \frac{10^{3}\,\mu\text{c}}{\text{mc}} \times \frac{1}{15.3\ \text{cu. ft.}} \times \frac{\text{cu. ft.}}{2.83 \times 10^{4}\,\text{cc}}$$

$$C = 5.64 \times 10^{-4}\,\mu\text{c/cc.}$$

5.120 Iodine Determinations

Analyses of radioactivity collected on sample filters during only an Iodine Recovery Operation revealed that essentially all of the radioactivity was radioiodine. The total amounts of radioiodine collected by the sample filters was determined by a gross gamma chamber reading of the filter paper. The caustic scrubbers, installed downstream of the sample filters (See Figure IV), did not collect any radioiodine when the amount of radioiodine collected by the sample filters did not exceed 30 to 50 microcuries. After the filters had collected 30 to 50 microcuries of iodine, traces of radioiodine were caught in the caustic scrubbers. Accordingly, the sampling time was therefore limited to prevent penetration by the radioiodine.

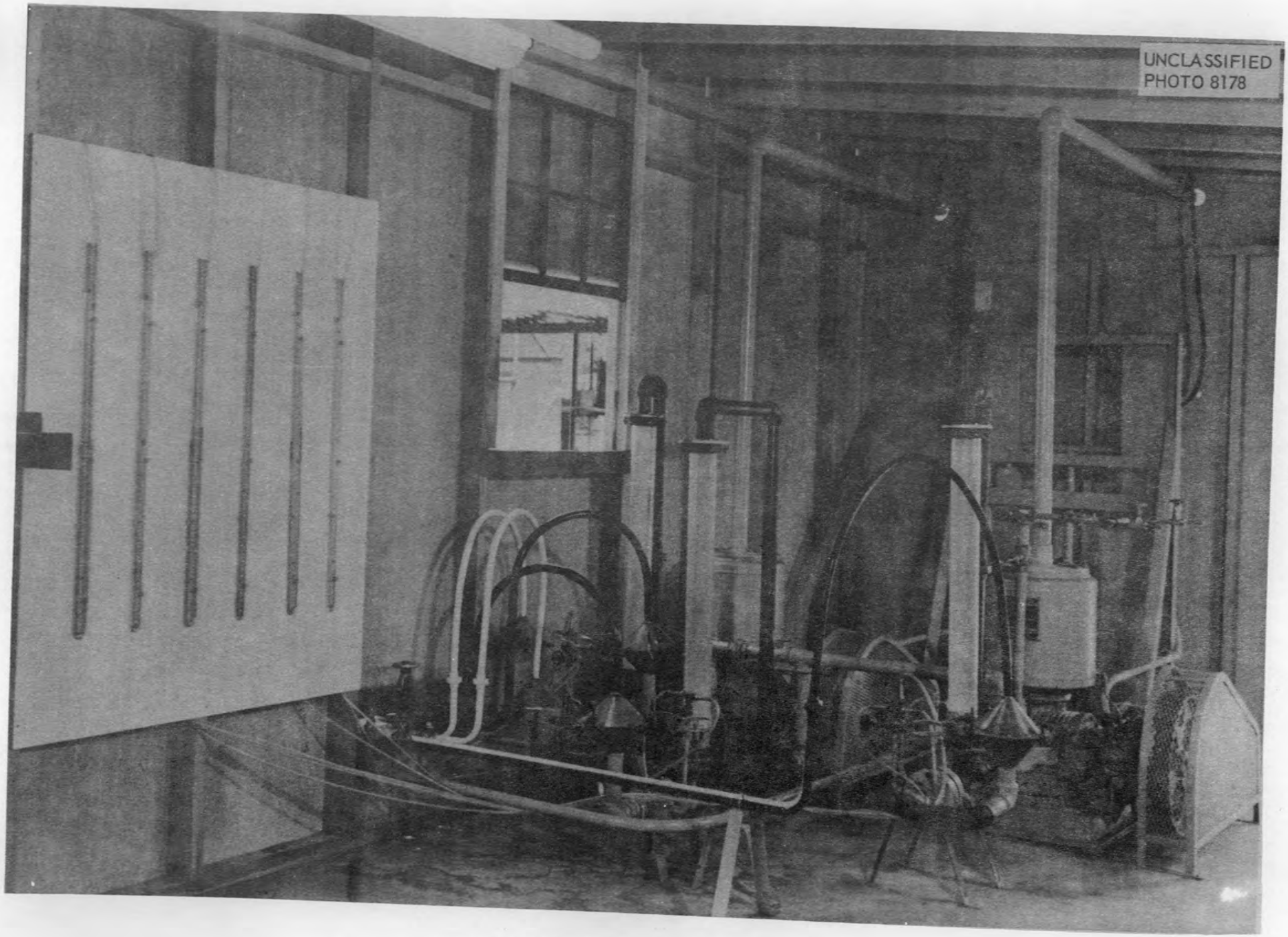

Fig. IV – OFF-GAS SAMPLING EQUIPMENT

5.130 Volatility of Radioactivity on Filter Paper

An attempt was made to drive off the gaseous radioactivity (iodine) collected by the sample filters without disturbing the particulate radioactivity by heating the filters under vacuum. The results of these tests are shown in the following table:

Sample	Temperature	Time Heated	Percent of Radioactivity Lost
A	90°C	3 hr.	None
B	90°C	3 hr.	"
A	180°C	3 hr.	None
B	180°C	3 hr.	"
A	240°C	3 hr.	50%
B	240°C	3 hr.	45%
A	300°C	3 hr.	64%
B	300°C	3 hr.	66%

The filter paper began to decompose when the temperature was raised to 240°C; it was therefore decided that the gaseous radioactivity could not be driven off by heat without disturbing the particulate radioactivity. Apparently the iodine is tightly housed in the chemical structure of the filter material.

5.140 Radioautographs

Radioautographs of sample filters taken during IRO and SIRO revealed several spots of radioactivity upon a general background of radioactivity. The background radioactivity was due to the gaseous radioiodine captured by the sample filters. The spots of radioactivity were possibly particles or localized concentrations of radioiodine on condensed moisture. Because of masking by the gaseous radioiodine and interference by moisture, the radioautographs were deemed inaccurate for particle counts determinations.

5.20 Cascade Impactor

A Cascade Impactor (See Figure V) was employed to collect particles in the off-gas, during an Iodine Recovery Operation only, to determine particle size, number of particles, and radioactivity associated with the particles.

5.210 Number and Size of Particles

Photomicrographs were made of the particles collected on each stage of the Cascade Impactor. The particles were associated with liquid and would coalesce on the Cascade Impactor stages, preventing an accurate count of the particles. Size measurements were made of particles that had apparently not coalesced.

5.220 Radioactivity

Analyses of the radioactivity collected by the Cascade Impactor were made, and the radioactivity was found to be radioiodine. Since the Cascade Impactor did not collect all of the particles in the off-gas, it could not be used to distinguish between particulate and gaseous radioiodine.

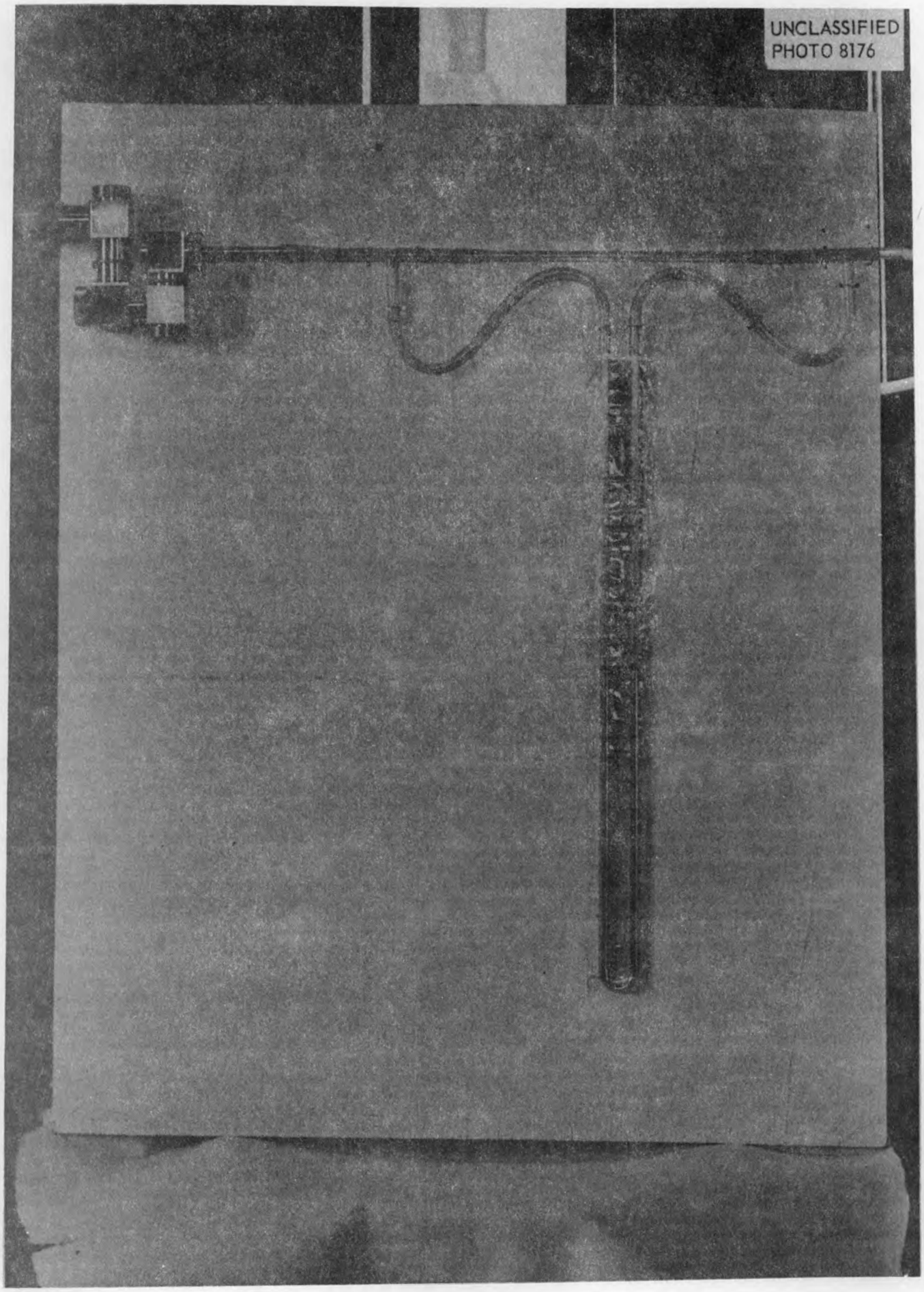

Fig. V – CASCADE IMPACTOR SAMPLER

6.0 Off-Gas Composition

The combined volume of off-gas from the chemical processes, which is cleaned by the Cottrell Precipitator, varies from 200 to 300 CFM from the present sources. There is no appreciable change in the off-gas volume when there is a Special Isotope Recovery Operation over that when there is not a Special Isotope Recovery Operation.

6.10 Radioactivity

The type of radioactivity found in the off-gas is dependent on the process in operation and the stage of the process. During an Iodine Recovery Operation, the concentration of radioiodine in the off-gas varies from less than 1×10^{-8} μc per cc. to as high as 3.6×10^{-4} μc per cc. When both the Special Isotope Recovery and Iodine Recovery Operations were in progress, the radioactivity concentrations were for: (See Table 1)

(1) Radiobarium from $<1\times10^{-7}$ to 2.6×10^{-2} μc per cc.

(2) Radiostrontium from $<1\times10^{-7}$ to 1.1×10^{-5} μc per cc.

(3) Total (including radioiodine) from 6×10^{-5} to $\underline{1}$ μc per cc.

TABLE I

Concentration of Radioisotopes in Off-Gas Prior to Cleaning With Both Special Isotope and Iodine Recovery Operations

Total Radioactivity As I^{131} (μc/cc)	Radiobarium (μc/cc)	Radiostrontium (μc/cc)	Date & Time May 1951 (Day - Hour)
6.5×10^{-4}	0.1×10^{-6}	0.03×10^{-6}	14th - 0830
3.0 "	--	--	0915
8.7 "	---	----	1040
21.7 "	--	--	1055
11.9 "	--	--	1835
10.6 "	0.3×10^{-6}	0.1×10^{-6}	15th - 0845
3.8 "	--	--	0945
2.3 "	0.1×10^{-6}	0.4×10^{-6}	0950
3.7 "	--	--	1000
3.3 "	--	--	1225
2.2 "	0.2×10^{-6}	0.2×10^{-6}	1245
1.3 "	0.4 "	0.2×10^{-6}	16th - 0100
1.2 "	--	--	0200
0.8 "	0.7×10^{-6}	0.7×10^{-6}	0300
1.3 "	--	--	0850
13.5 "	--	--	0920
1.2 "	1.3×10^{-6}	0.8×10^{-6}	1020
3.6 "	--	--	1310
9720.0 "	$26{,}000.0 \times 10^{-6}$	--	1335
1840.0 "	8,225.0 "	--	1405
0.8 "	1.6 "	0.2×10^{-6}	1455
0.7 "	1.1 "	--	1515
9.6 "	105.0 "	--	17th - 0935
9.3 "	108.0 "	--	1025
0.7 "	1.6 "	--	1310
0.5 "	0.2 "	--	1355
3.3 "	34.5 "	--	18th - 0935
11.6 "	103.0 "	--	1000
2.3 "	18.2 "	7.4×10^{-6}	1020
4.9 "	47.8 "	--	1225
1.1 "	0.3 "	--	1340
0.7 "	0.7 "	--	1405
0.9 "	9.0 "	- --	19th - 0925
0.6 "	4.3 "	--	0950
87.3 "	963.0 "	--	1020
58.3 "	645.0 "	--	1230
60.7 "	687.0 "	--	1340
53.0 "	564.0 "	11.4×10^{-6}	1420

6.20 Moisture

The off-gas carries entrained water in addition to the moisture which is contained as humidity. The water that is present is in excess to that which corresponds to 100% relative humidity at the temperature of the gas; therefore, the gas is heated prior to measurement of wet and dry bulb temperatures and calculations made to determine the humidity at the temperature of the off-gas prior to heating. These calculations indicate that the relative humidity of the off-gas is always 100% and some entrained water is present during sparging of solutions at elevated temperatures. The temperatures of the off-gas when it reaches the Cottrell Precipitator varies from 20°C to 30°C.

6.30 Particles

A Cascade Impactor was employed to collect particles from the off-gas for size measurements and counts. The impactor, which is made up of four collection stages and a back-up filter, was calibrated to remove the following average sizes of U_3O_8 particles:

1st Stage	--	4.8 microns
2nd Stage	--	2.0 microns
3rd Stage	--	1.06 microns
4th Stage	--	0.71 microns
Filter	--	0.41 microns

Microscopic analysis of the particles collected from the off-gas by the impactor revealed that each stage collected the same average size particle, due to the moisture present. The particles could not be counted as the moisture present caused coalescence.

6.30 Particles (continued)

Figures IA and IB show the particles collected on Stage 2. Figures IIA and IIB show the particles collected on Stage 3. Figures IIIA and IIIB show the particles collected on Stage 4. Figure IVA was made shortly after the sample was collected and Figure IVB was made of the same sample after the moisture was allowed to evaporate. Figures VA, VB, and VC were then taken at the periphery of particle deposits after evaporation.

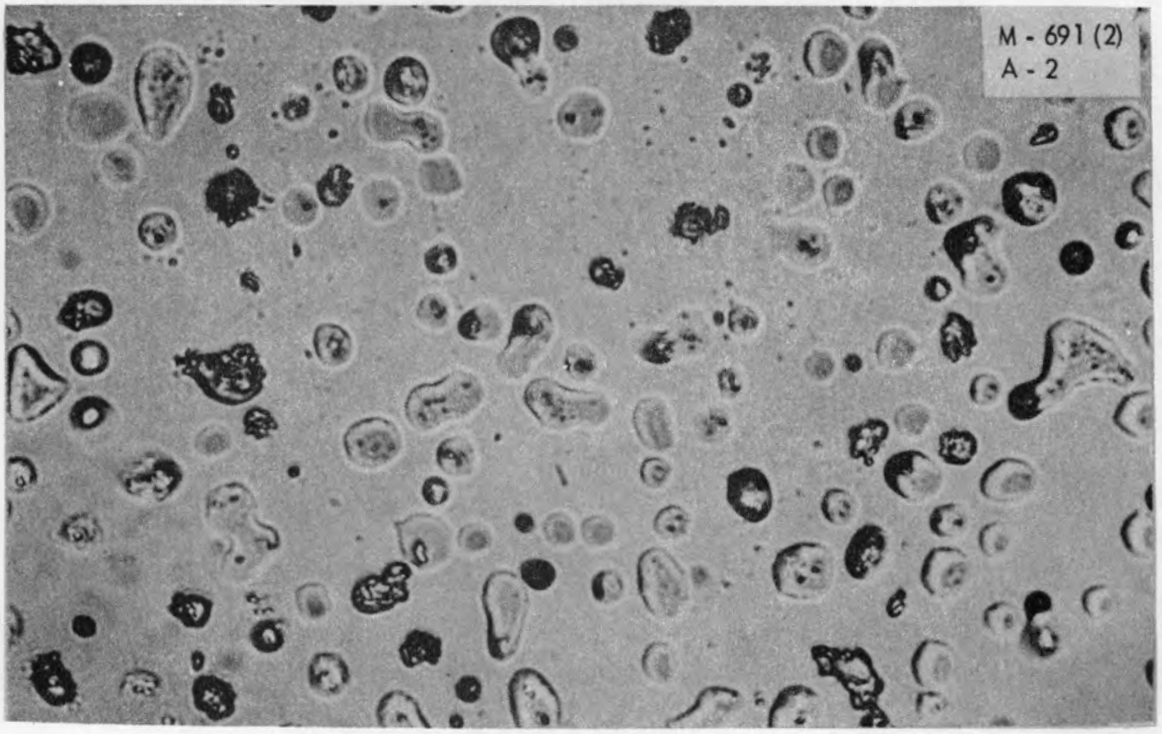

Fig. IA – PARTICLES COLLECTED ON 2ND STAGE

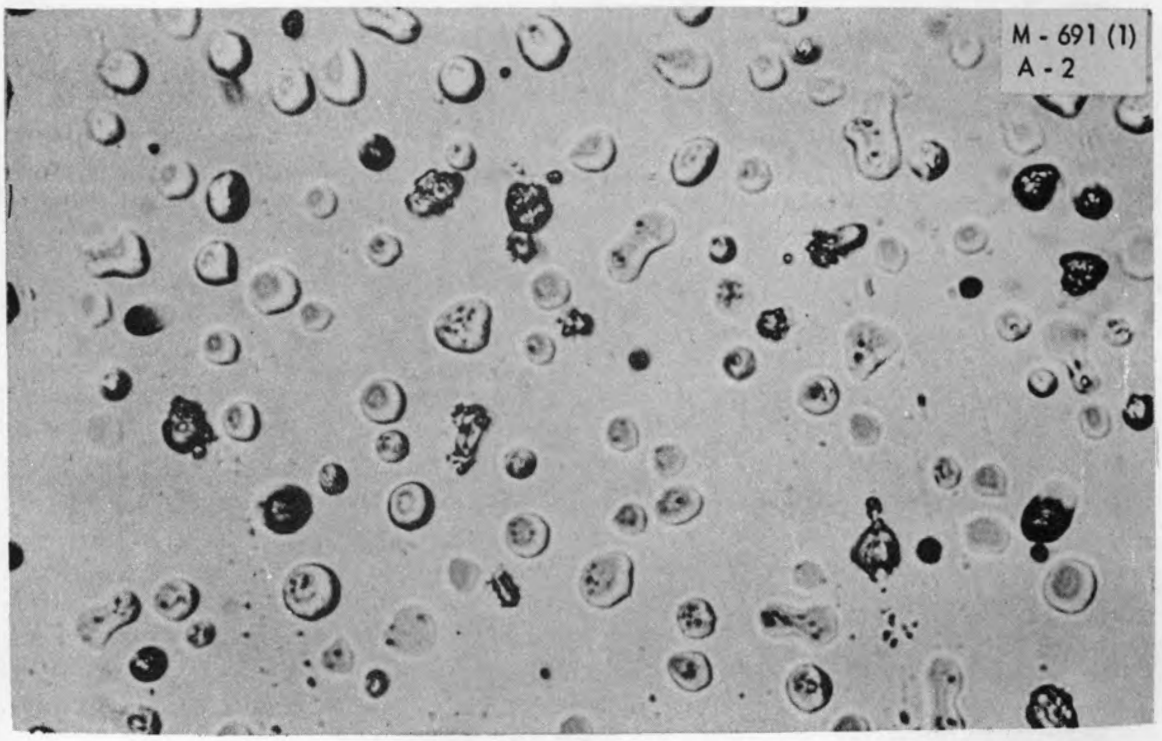

Fig. 1B – PARTICLES COLLECTED ON 2ND STAGE

PARTICLES ON STAGE 2 RANGE FROM LESS THAN 1 TO APPROXIMATELY 1.75 MICRONS WITH THE MAJORITY OF THE PARTICLES IN THE ORDER OF 1.0 TO 1.5 MICRONS.

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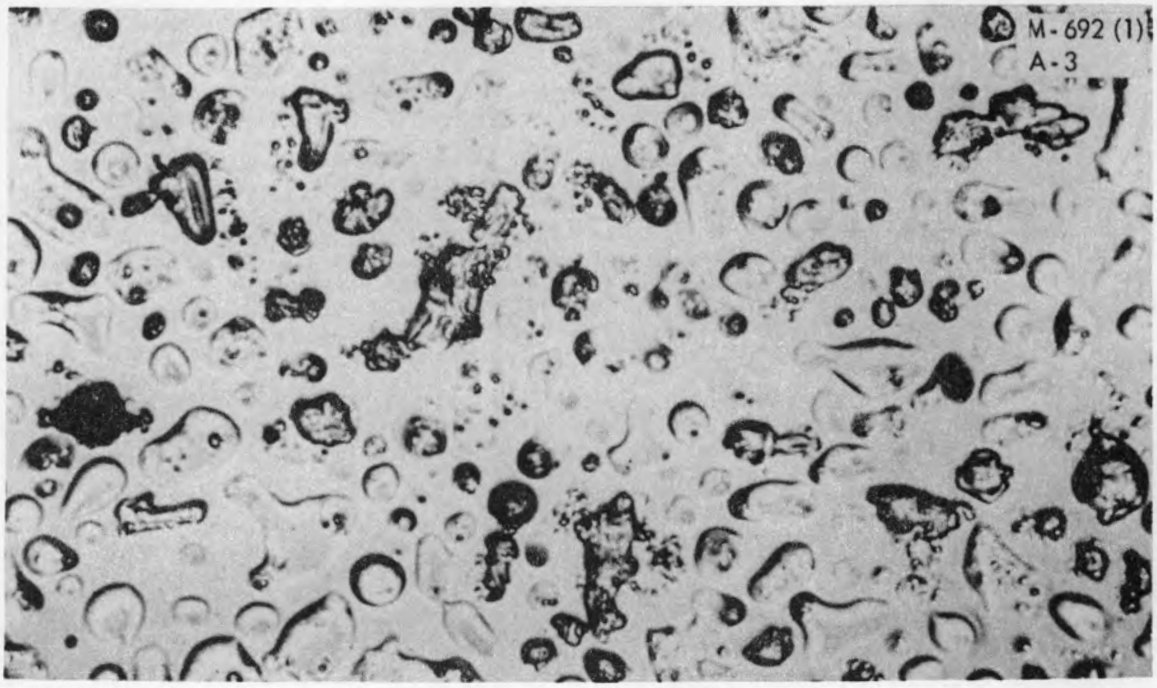

Fig. IIA – PARTICLES COLLECTED ON STAGE 3

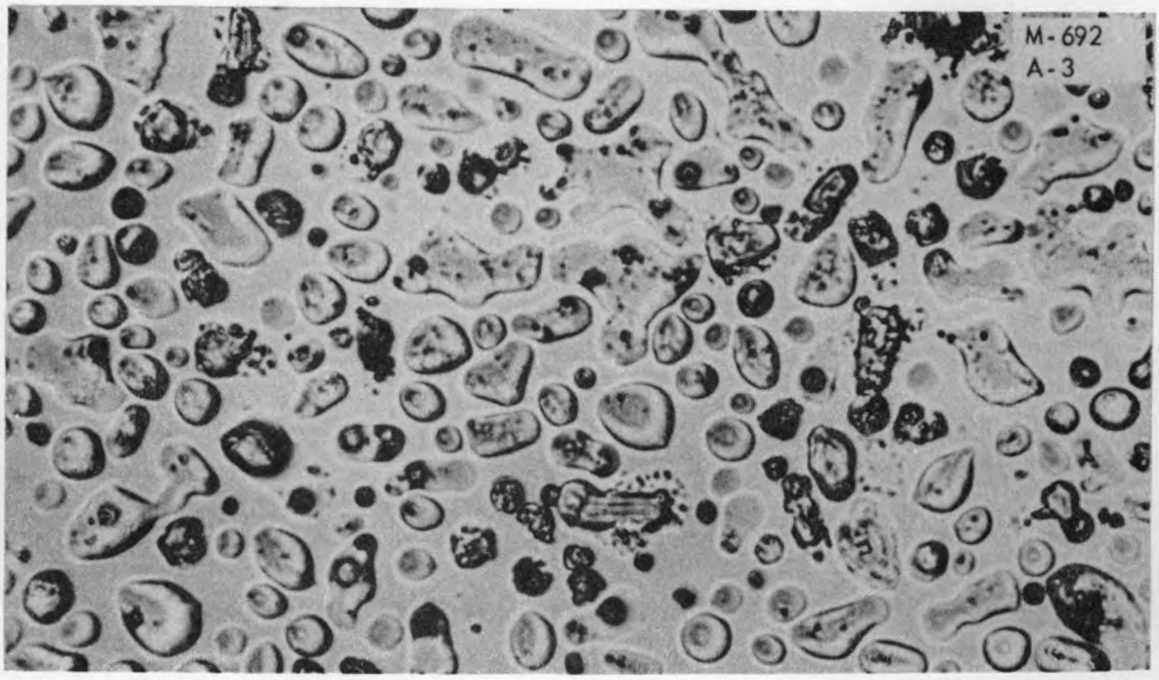

Fig. IIB – PARTICLES COLLECTED ON STAGE 3

MORE PARTICLES OCCURRED ON STAGE 3 THAN ON STAGE 2 BUT THERE WAS NO APPARENT DIFFERENCE IN PARTICLE SIZE.

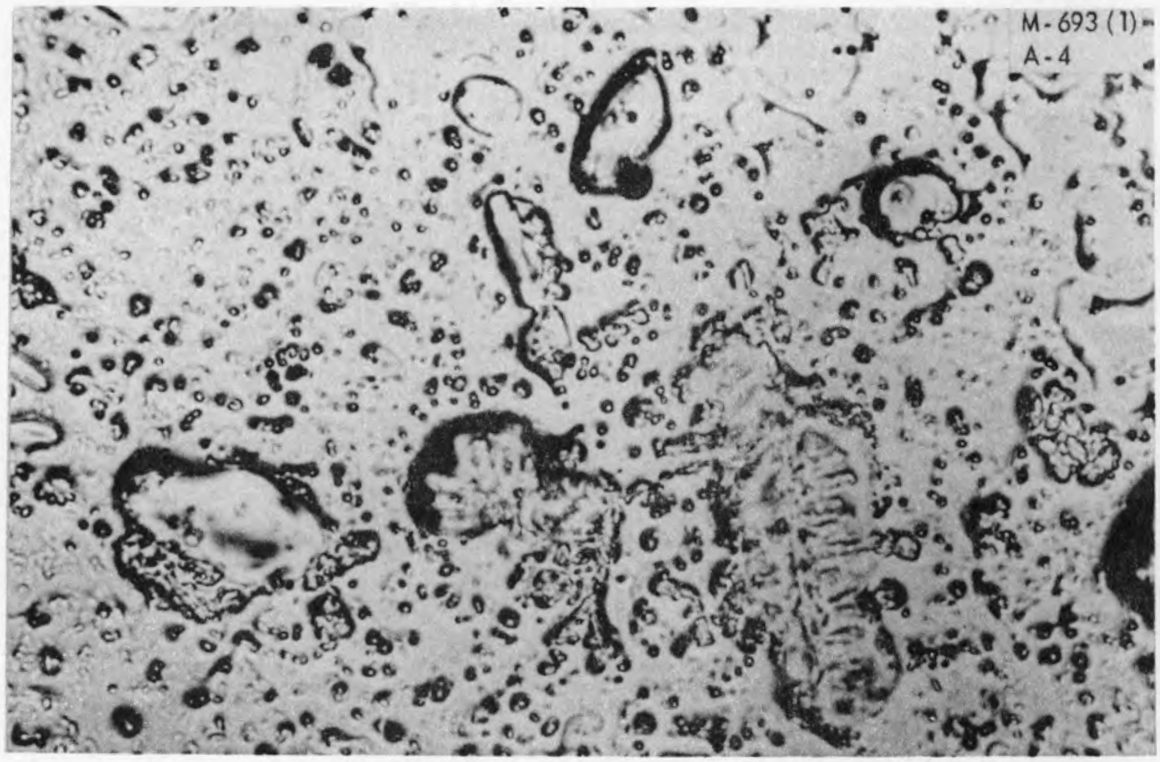

Fig. 111A – PARTICLES COLLECTED ON STAGE 4

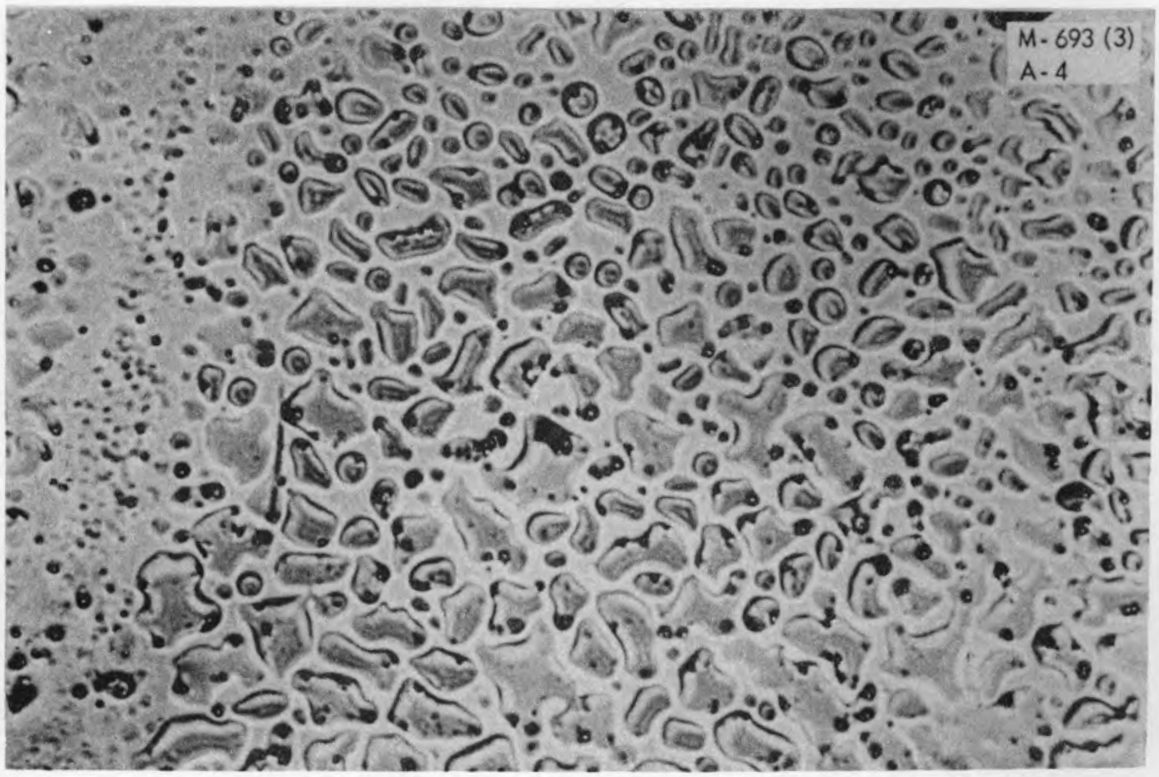

Fig. IIIB – PARTICLES COLLECTED ON STAGE 4

THERE WERE MORE PARTICLES COLLECTED ON STAGE 4 THAN ON STAGE 3 BUT THE PARTICLES WERE IN THE SAME SIZE RANGE.

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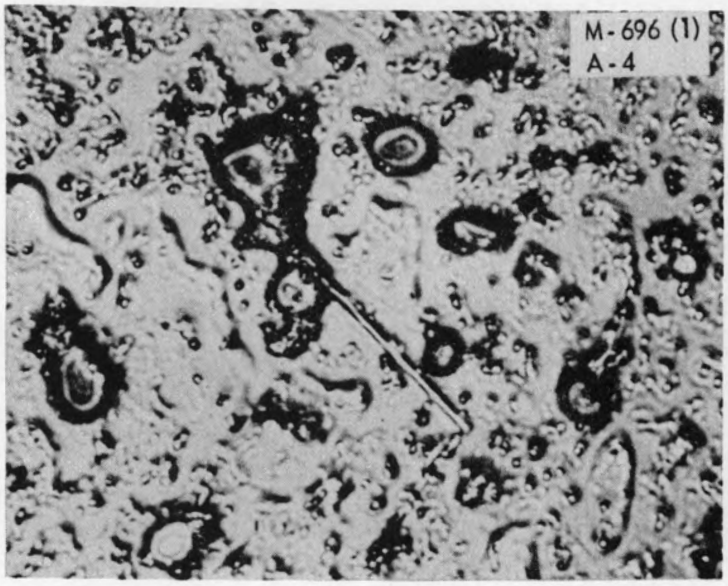

Fig. IVA – STAGE 4 BEFORE MOISTURE EVAPORATION

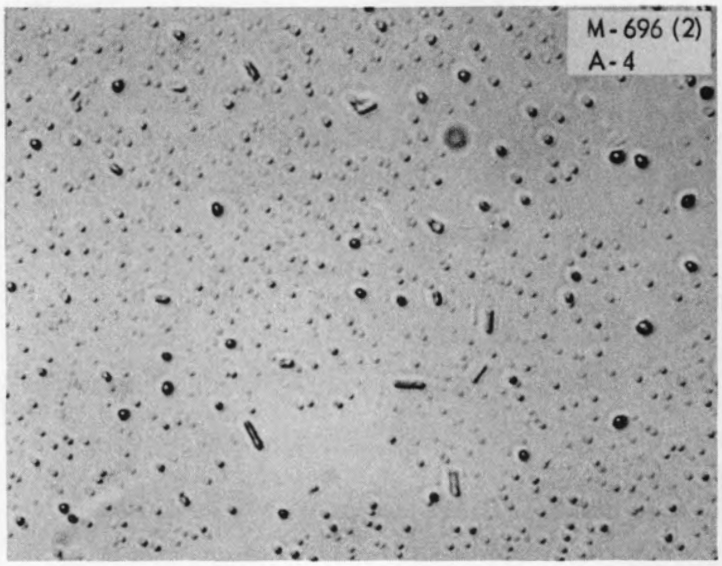

Fig. IVB – STAGE 4 AFTER EVAPORATION

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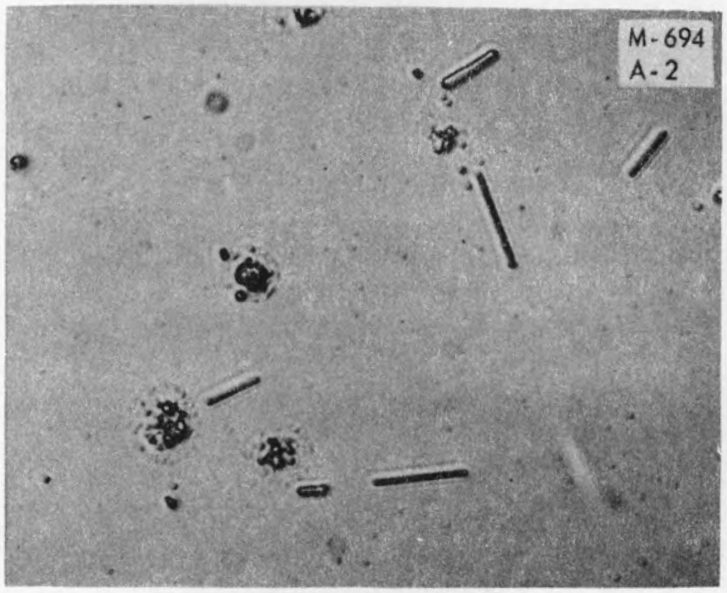


Fig. VA – STAGE 2

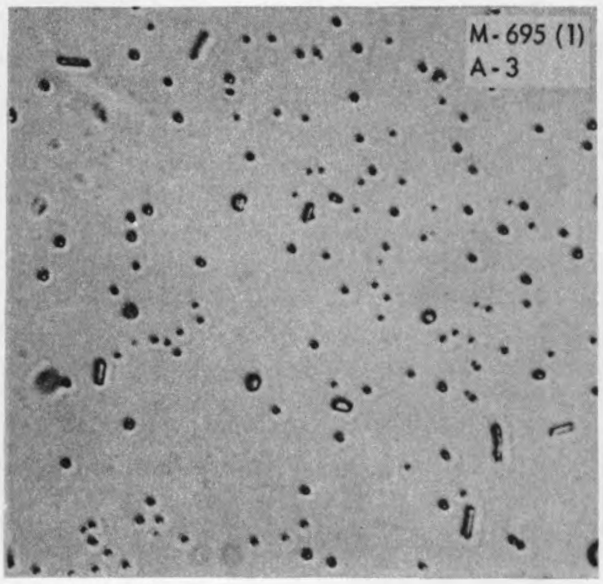


Fig. VB – STAGE 3

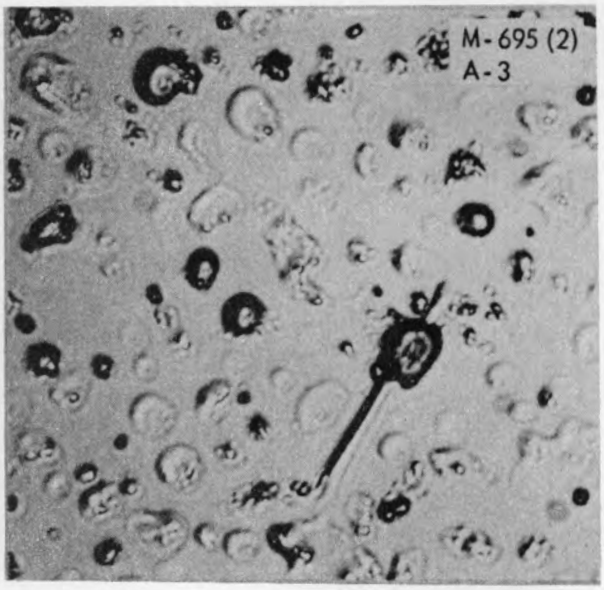


Fig. VC – STAGE 3

FIGURES VA, VB, AND VC WERE MADE AT THE PERIPHERY OF THE DEPOSITS WHERE THE MOISTURE DROPLETS WERE FEWER AND SMALLER.

7.0 Evaluation on Radiobarium Removal Basis

The radiobarium removal efficiencies of the Cottrell were calculated from the inlet and exit concentrations of radiobarium in the off-gas. These efficiencies along with operating conditions are tabulated in Table II.

7.10 Efficiencies of Wet and Dry Operation

When the precipitators operated dry and at 30 kilovolts or above, the removal efficiencies increase with increasing voltage and/or increasing radiobarium concentration. The removal efficiency was 90% or greater at all times when the voltage was 30 kilovolts or more and the radiobarium concentration was $1 \times 10^{-6} \mu c/cc$ or more. When the radiobarium concentration was below $1 \times 10^{-6} \mu c/cc$, the presence of radioiodine would contaminate the sample to such an extent that accurate determination of radiobarium was not possible, as the radioiodine was greater than 99% of the total radioactivity. The radiobarium concentration happened to be rather low at all times when the Cottrell was operated wet, but the efficiency did not appear to change significantly with increased radiobarium concentration. It is known, that as the concentration of radioactivity increases in the wash water, the entrainment causes increased radioactivity passage by the precipitator. The precipitator collected over 99.9 percent of the radiobarium (at high concentrations) when operating dry and at high voltages, but it collected only 90 percent when operating wet.

7.20 Discussion of Graphs

The percent of radiobarium passing through the Cottrell is a function of the voltage and the inlet concentration of radiobarium. Graph No. I is a plot of

7.20 Discussion of Graphs (continued)

the percent passage versus concentration for several voltages. The percent passage is equal to 100% minus the percent removal by the Cottrell.

The equations of the curves on Graph No. I are:

$$\log (100-E) = (-\ 0.878) \log C - 4.6 \quad \text{for 55 kilovolts}$$

$$\log (100-E) = (-\ 0.749) \log C - 3.46 \quad \text{for 50 kilovolts}$$

$$\log (100-E) = (-\ 0.688) \log C - 3.07 \quad \text{for 40 kilovolts}$$

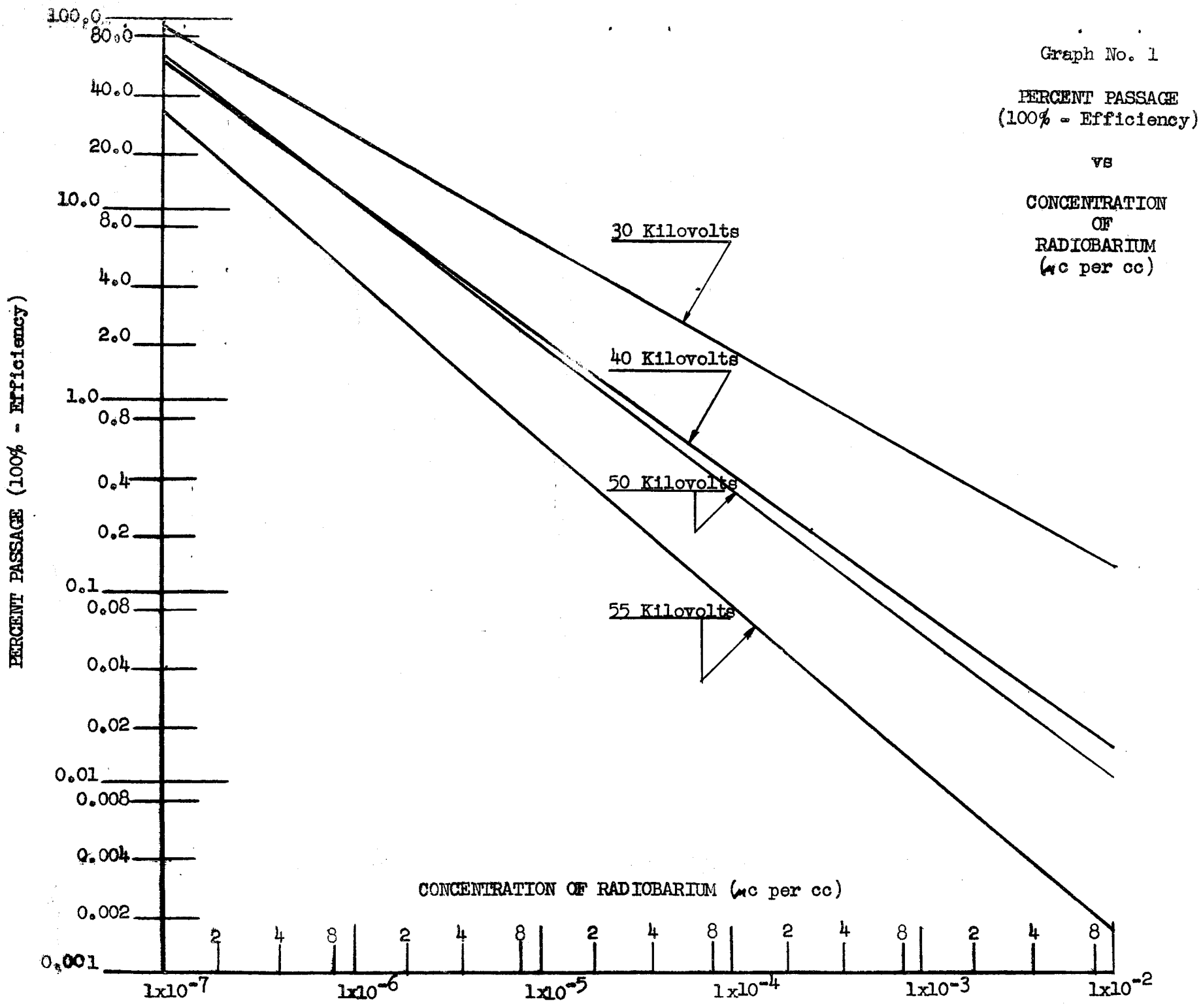
$$\log (100-E) = (-\ 0.50\ ) \log C - 1.91 \quad \text{for 30 kilovolts}$$

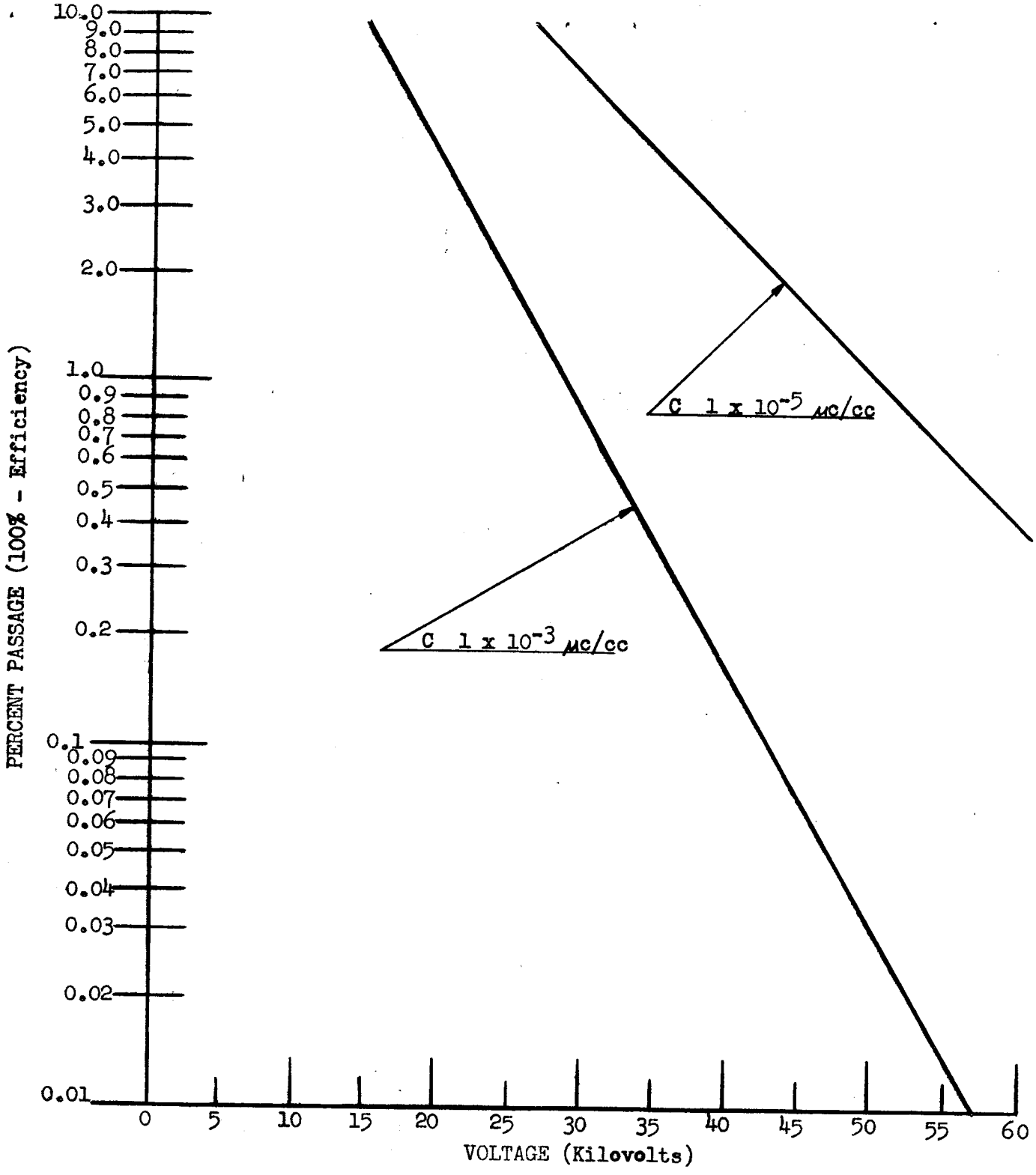
Where (100-E) is the percent passage and C is the concentration of radiobarium in μc/cc of the inlet gas.

The percent of radiobarium passing the precipitator is plotted versus voltage for constant concentrations of radiobarium in the inlet gas. (See Graph No. 2.) The equations of these curves are:

$$\log (100-E) = -0.0715V + 2.00 \quad \text{when } C = 1.0\text{x}10^{-3}\ \mu\text{c/cc}$$

$$\log (100-E) = -0.0417V + 2.08 \quad \text{when } C = 1.0\text{x}10^{-5}\ \mu\text{c/cc}$$


Graph No. 1
PERCENT PASSAGE
(100% - Efficiency)
vs
CONCENTRATION
OF
RADIOBARIUM
(μc per cc)
PERCENT PASSAGE (100% - Efficiency)
100.0
80.0
40.0
20.0
10.0
8.0
4.0
2.0
1.0
0.8
0.4
0.2
0.1
0.08
0.04
0.02
0.01
0.008
0.004
0.002
0.001
30 Kilovolts
40 Kilovolts
50 Kilovolts
55 Kilovolts
CONCENTRATION OF RADIOBARIUM (μc per cc)
2 4 8 2 4 8 2 4 8 2 4 8 2 4 8
1x10^-7
1x10^-6
1x10^-5
1x10^-4
1x10^-3
1x10^-2



Graph No. 2

PERCENT PASSAGE
(100% - Efficiency)

vs.

VOLTAGE
(Kilovolts)

7.30 Comparison of Wet versus Dry Operation

The operation of the precipitator with the collecting walls being continuously flushed, has several disadvantages not encountered during dry operation.

7.310 Entrainment to Filter Units

During wet operation, there is considerable entrainment to the filter units. This entrained water carries radioactivity which has been washed from the collecting walls of the precipitator and washes radioactivity through the filter units.

7.320 Lower Voltages

The maximum voltage (45 kilovolts), which can be continuously applied to the electrodes of the precipitator without arcing, is lower during wet operation than during dry operation (55 kilovolts). It has been shown that higher efficiencies are obtained with higher voltages.

7.330 Liquid Waste Volume

The wash water has to be discharged periodically to the liquid waste system and fresh water used when the concentration of radioactivity in the wash water builds up to tolerance. Tolerance here is set by how much radioactivity is added to the off-gas by the entrainment of flushing water. For example:

Assumed:	Inlet concentration of radiobarium in gas	- 1×10^{-3} μc/cc.
Measured:	Gas flow	- 300 CFM
	Entrainment	- 8.6×10^{-9} $\frac{\text{lb } H_2O}{\text{cc gas}}$
	Water being recycled	- 2250 lbs.

7.330 Liquid Waste Volume (continued)

Calculated:	Concentration in wash water first hour	- 221.4 μc/lb.
	Radioactivity added to cleaned off-gas at end of first hour	- 1.9×10^{-6} μc/cc
	Radioactivity added to cleaned off-gas at end of ten hours	= 1.9×10^{-5} μc/cc

It can be easily seen that the radioactivity, which is entrained after ten hours of flushing with the same water, is twice that which would be passing the precipitator due to only 99 percent efficiency. The flushing water would have to be changed quite often to minimize discharge of radioactivity, thus increasing the liquid waste volume, which must be evaporated at a cost of at least $0.10 per gallon.

TABLE II

Radiobarium Removal Efficiency
by the
Cottrell Electrostatic Precipitator

Wash Water Rate (GPM)	Voltage (KV)	Inlet Radiobarium Concentration (μc/cc)	Current (MA)	Removal Efficiency (%)
0	10	9.0×10^{-6}	0	45.8
		3.5×10^{-5}	0	--
	20	1.3×10^{-6}	1	61.4
		4.3×10^{-6}	1	60.6
		1.0×10^{-5}	1	52.3
	30	1.8×10^{-5}	10	97.3
		9.6×10^{-4}	10	99.1
	40	4.8×10^{-5}	55	99.7
		6.4×10^{-4}	55	99.8
		2.6×10^{-2}	55	99.99
	50	0.3×10^{-6}	130	35.7
		0.3×10^{-6}	120	--
		0.4×10^{-6}	140	89.5
		6.9×10^{-4}	125	99.9
		8.2×10^{-3}	132	99.99
	55	0.1×10^{-6}	170	92.9
		0.2×10^{-6}	180	$\sim$100
		0.7×10^{-6}	175	77.8
		1.0×10^{-4}	155	99.96
		1.1×10^{-4}	190	99.8
		5.6×10^{-4}	175	99.98
35	45	0.1×10^{-6}	80	--
		0.2×10^{-6}	80	--
		0.7×10^{-6}	80	93.0
		1.1×10^{-6}	80	91.8
		1.6×10^{-6}	80	90.4
		1.6×10^{-6}	80	88.7

8.0 Removal of Radioiodine

The radioiodine in the off-gas exists as a gas and associated with particles. The precipitator apparently had a high removal efficiency for the particulate radioiodine, but the absolute removal of particles could not be determined, when only radioiodine was present, because the particles could not be separated from the gas.

8.10 Application of Techniques

The filter paper employed to sample the off-gas removed both particulate and gaseous radioiodine, while the cascade impactor removed only part of the particles. Radioautographs were not efficient in distinguishing between particulate and gaseous radioiodine. The radioactive gas masked most of the particles and concentrated in spots appearing to be particles. Radiochemical analysis could not distinguish between gaseous or particulate radioiodine collected on the filter paper. The cascade impactor would be the best method of determining the radioiodine particle removal if simultaneous samples could be taken on both sides of the precipitator.

8.20 Effects of Wash Water, Voltage and Radioiodine Concentration

The efficiencies based on removal of radioiodine were inconsistent and lower than expected considering all of the radioiodine to be particulate. The ratio of particulate to gaseous radioiodine, (an important variable) could not be determined. The efficiencies of the precipitator for the removal of radioiodine are listed in Table III. The removal efficiencies appear to decrease with increasing wash water rate and increase with increasing voltage, but these changes

8.20 Effects of Wash Water, Voltage and Radioiodine Concentration (con't.)

are not always consistent, probably because of changing proportions of particulate and gaseous iodine. The concentration of radioiodine (both particulate and gaseous) has no appreciable effect on removal efficiencies.

TABLE III

Radioiodine Removal Efficiency
of the
Cottrell Electrostatic Precipitator

Voltage (KV)	Wash Water Rate (GPM)	Radioiodine Concentration (μc/cc)	Removal Efficiency (%)
0	20	1.15×10^{-5} 3.84×10^{-5}	35.9 83.6
	30	4.6×10^{-6} 2.5×10^{-5} 1.8×10^{-4}	50.9 59.5 59.3
	40	1.2×10^{-5} 9.5×10^{-5}	82.7 56.1
	50	9.9×10^{-6} 5.6×10^{-5}	43.2 69.4
	80	4.0×10^{-5}	38.4
10	80	6.1×10^{-6} 2.5×10^{-5}	44.4 74.3
20	0	3.11×10^{-4}	25.00
	20	1.4×10^{-5} 4.4×10^{-5}	68.1 86.0
	30	1.7×10^{-5}	48.0
	40	9.0×10^{-6} 2.7×10^{-5} 2.3×10^{-4}	71.0 58.2 72.3
	50	5.1×10^{-6} 2.6×10^{-5}	70.7 90.2
	80	3.5×10^{-5}	79.2
30	20	2.1×10^{-5}	87.4
	30	3.85×10^{-4}	84.8
	40	1.04×10^{-5} 2.33×10^{-4}	67.8 87.1

TABLE III (continued)

Radioiodine Removal Efficiency
of the
Cottrell Electrostatic Precipitator

Voltage (KV)	Wash Water Rate (GPM)	Radioiodine Concentration (μc/cc)	Removal Efficiency (%)
30	50	1.07×10^{-5}	71.0
	60	8.03×10^{-5} 1.85×10^{-4}	88.0 82.6
	80	6.8×10^{-5}	89.2
40	0	1.5×10^{-5} 2.5×10^{-5}	79.6 88.1
	20	2.65×10^{-5}	91.9
	30	1.7×10^{-5} 3.7×10^{-4}	29.6 93.2
	40	5.1×10^{-4}	72.6
50	0	1.0×10^{-5}	69.4
55	0	1.2×10^{-5}	83.6