PROGRESS REPORT OF THE HIGH VOLUME ELECTROSTATIC SAMPLER (HIVES)

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ABSTRACT

The high volume electrostatic sampler (HIVES) was developed for sampling large volumes of air at 1000 to 2000 cfm for trace amounts of radioactive contaminants. This report contains a detailed description of the two-stage electrostatic precipitator and its component parts. Theoretical collection efficiencies of two-stage electrostatic precipitators are discussed and efficiency calculations are made using two different approaches. Field tests are described and the methods of determining actual collection efficiencies are discussed.

To date, two methods have been used to determine the HIVES collection efficiency and both methods indicate efficiencies of greater than 99.9% at a flow rate of 1000 cfm.

In October, 1960, a proposal was made for the construction of a high volume, 1000-2000 cfm, electrostatic air sampler for use in studying low air concentrations of strontium-90 and cesium-137. One of the major justifications for this particular type sampler was that a flow rate of 1000-2000 cfm, which is necessary for the detection of present air concentrations of the long-lived fission products, cannot be obtained by presently used (20-70 cfm) air samplers.

Construction was begun, and by the end of March, 1961, fabrication and wiring were completed and the flow rate was calibrated over the HIVES operating range. In April, 1961, a study of the HIVES collection efficiency was initiated to compare the theoretical efficiency with actual field determinations using several generated aerosols.

SAMPLER DESCRIPTION

The sampler is truck mounted on a 3/4 ton pickup (Figure 1) and can be quickly moved to and operated in remote areas. The truck is equipped with a 150 volt AC gasoline motor generator which allows the unit to be completely independent of external power sources.

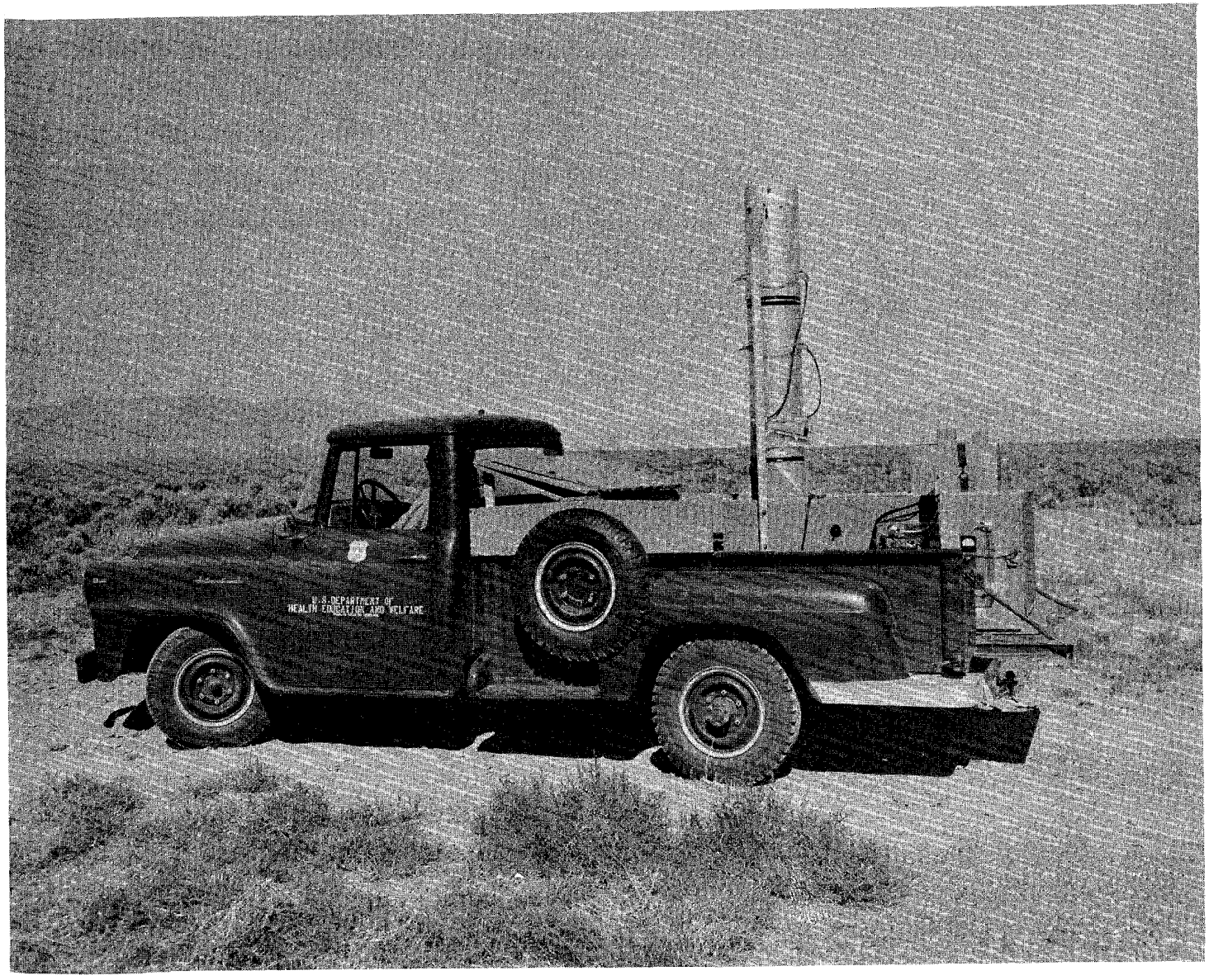


Figure 1

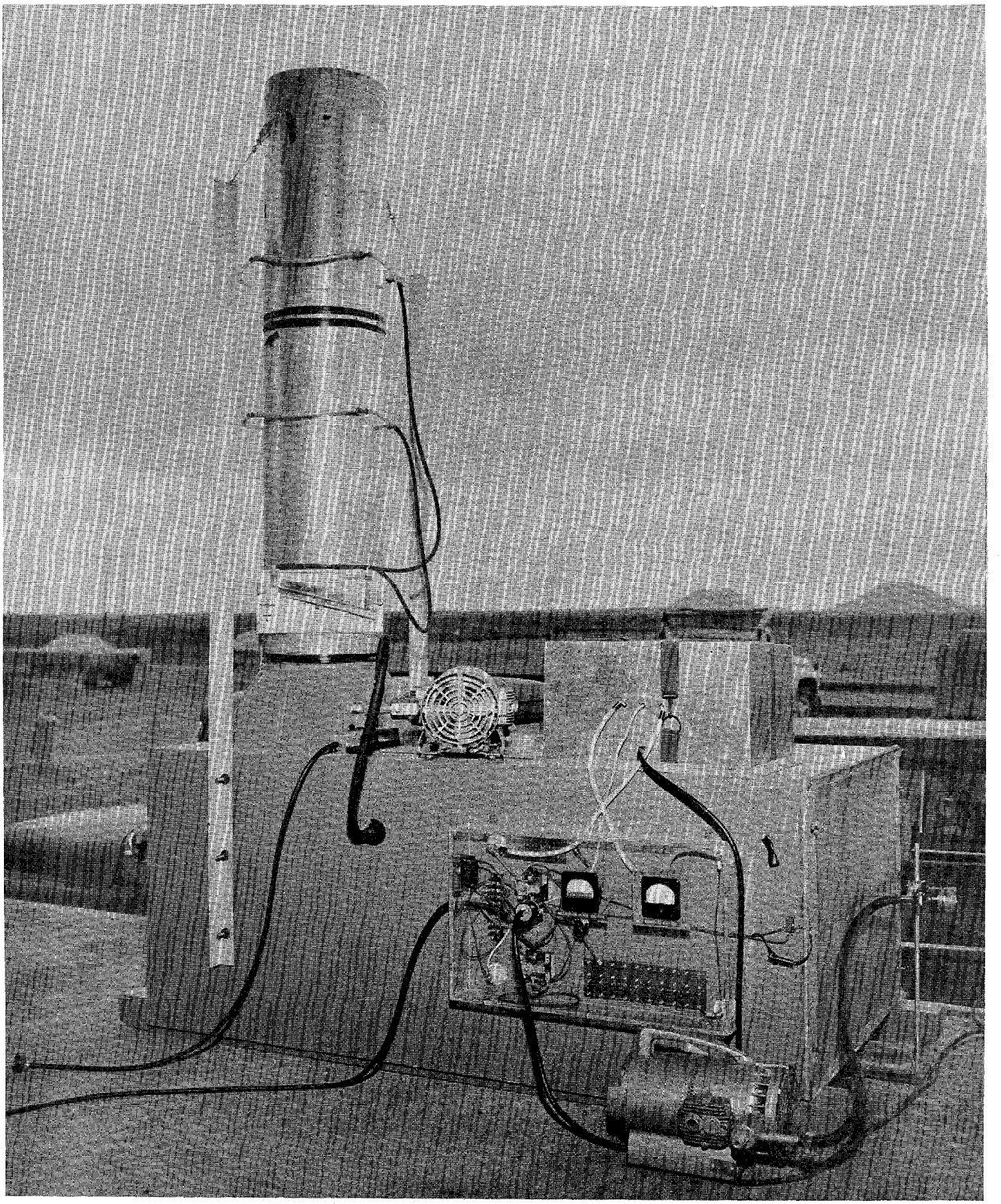
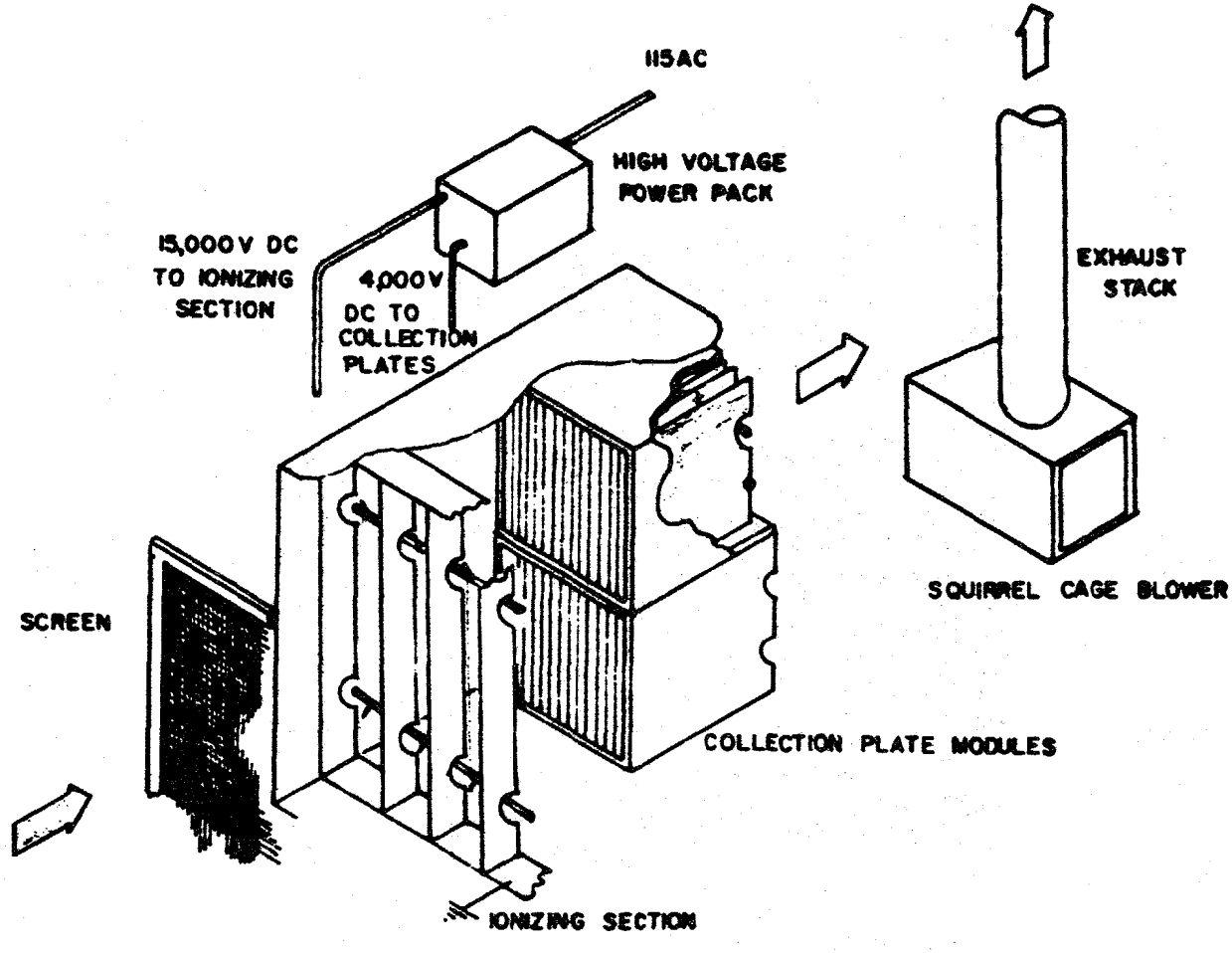


Figure 2



HIGH VOLUME ELECTROSTATIC SAMPLER

Figure 3

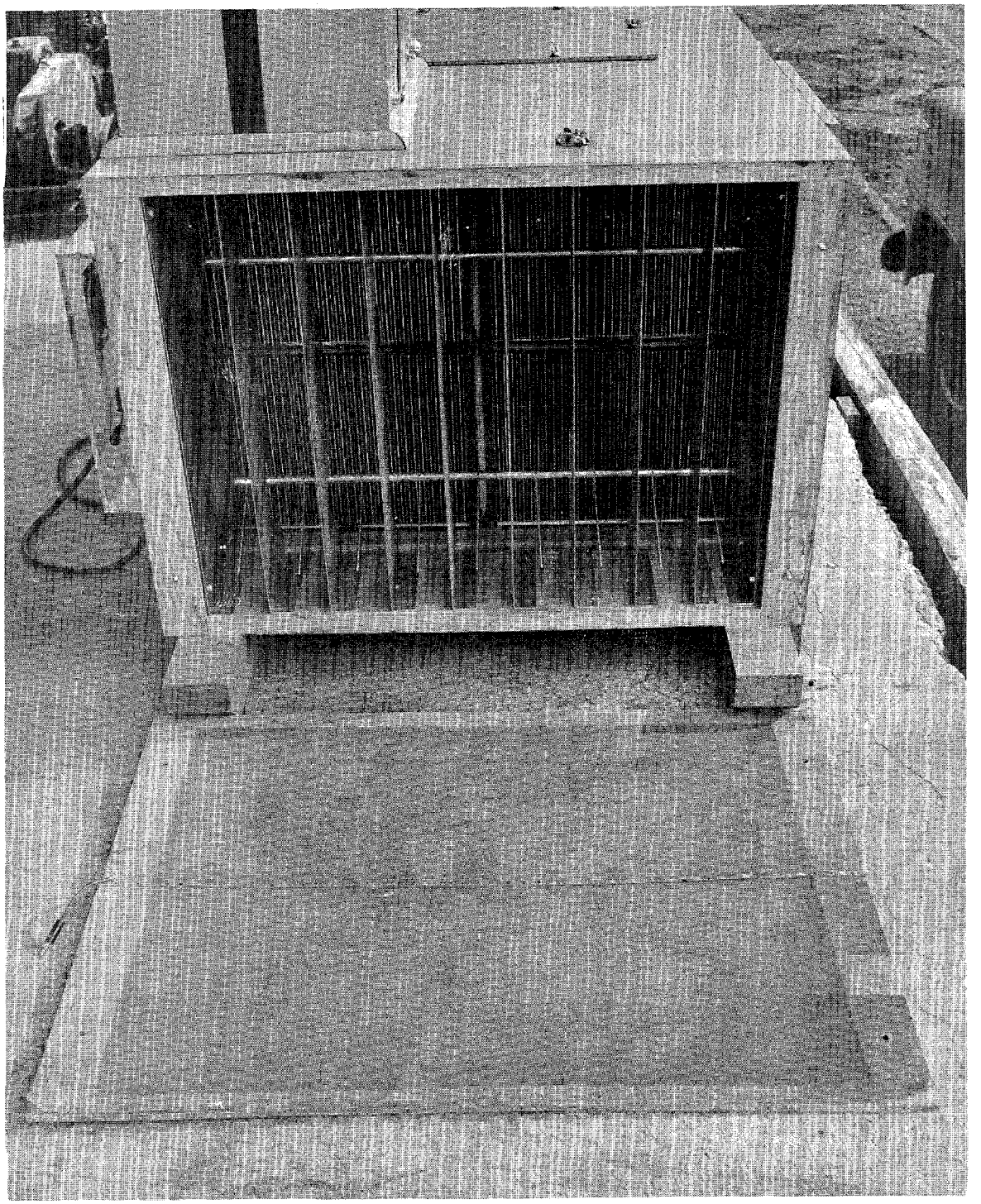


Figure 4

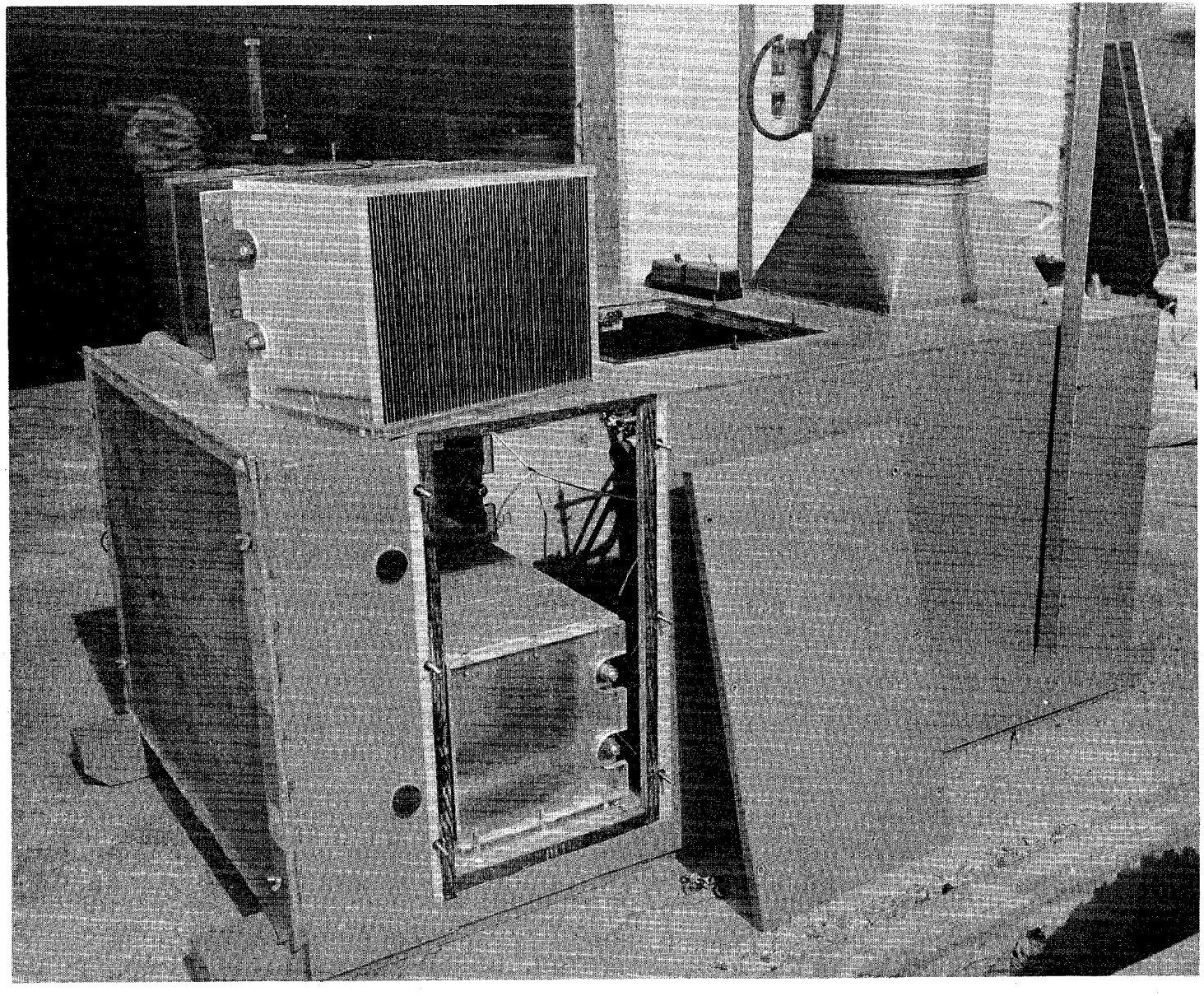


Figure 5

Figure 2 shows the complete unit with exception of the generator. The overall dimensions of the sampler are 5' x 2' 8 1/2" x 2' 4" with a 5' 6 1/2" long, 12" diameter duct mounted vertically at one end. The HIVES total weight is approximately three hundred pounds. Two radio frequency D. C. power supplies provide the potentials of 12,000-15,000 volts to the ionizing section and 4500 volts to the collection plates. The power supplies are contained in the rectangular sheet metal housing on top of the sampler. Located immediately below it on the side of the sampler is a Lucite safety enclosure for protection from the external high voltage connections. The meter on the left indicates the potential on the collection plates and the one on the right measures the current flow to the ionizing section.

Figure 3 is a schematic drawing through the center of the HIVES. The air passes horizontally through one end of the sampler first into the ionizing section where a positive charge is imparted to the airborne particles and then through the closely spaced (0.17") parallel collection plates where the charged particles are forced by an electrostatic field to deposit on the ground potential plates. The clean air then passes through a variable-speed squirrel-cage blower (1000-2000 cfm) which discharges into the vertical duct.

Figure 4 shows the ionizing section subdivided into 9 sections by 4" deep parallel aluminum strips spaced 3" apart. Although it cannot be seen in the figure, 0.05" tungsten wires are stretched between metal pegs attached to the two high voltage bus bars and centrally located between the parallel aluminum strips. The 60 x 60 mesh copper screen was found to be a very essential addition to the sampler especially in the summer. The screen keeps out small gnats and bugs which cause the collection plates to arc and discharge their voltage. This results in the re-entrainment of collected particulate and the loss of quantitation.

Access to the collection plates is shown in Figure 5. The collection section is divided into four modules with each consisting of an open-ended four-sided lucite box which contains 65 parallel aluminum plates. Outside dimensions of each module are 14 3/4" x 10 1/2" x 11".

Alternate high voltage and ground potential connections are made to the plates in each module by two insulated and suspended wires inside the sampler enclosure. These are connected to the modules by two individual rods attached to alternate plates by spacers and a lock nut.

Microswitches are installed on all access panels to eliminate high voltage hazards. When a panel is opened, the supply voltage is shut off and a bleeder circuit is activated to discharge any residual potential on the ionizing and collection sections.

The basic theory on electrostatic phenomena was begun in the 1920's and 1930's with little engineering application to the problems of air cleaning until shortly after World War II. Since this time, extensive work has been done in the comparison of the operation of one-stage precipitators, but not for two-stage precipitators.

According to Lapple (3), there are three forces acting on a particle that is near an ion:

(1) Attractive force due to the electric field strength.
(2) Attractive force due to the ion-image effect.
(3) Repulsive force due to the Coulomb effect.

For particles of less than 1 u diameter, the charging due to ion diffusion and the ionic image effect predominates and the mechanism is independent of the external field. The ultimate acquired charge by spherical particles less than 1 u in diameter may be approximated ($\pm$ 30%) by an empirical equation

$$n = 6.8 \times 10^3 \, a \, T \qquad (1)$$

where n is the number of elementary charges (electrons), "a" is the particle radius in centimeters and T is the absolute temperature in degrees Kelvin. For particles greater than 1 u , the ionic image effect is negligible and charging is due to electronic or ion bombardment and the charge may be expressed by:

$$n = \left[1 + 2 \frac{(D-1)}{(D+2)}\right] \frac{E_1 \, a^2}{e} \frac{t}{t + T_o} \qquad (2)$$

where:

D = dielectric constant of the particles
(expression $\left[1 + 2 \frac{D-1}{D+2}\right]$ ranges from 1 for materials with a dielectric constant of 1 to 3 for conductors.)
E_1 = electric field intensity, dynes/statcoulomb
e = electron charge, 4.8×10^{-10} statcoulombs
t = time in field, seconds
T_o = time in which 1/2 of the limiting charge is reached

Once a small particle is charged and placed in an electrostatic field, there are two forces which act upon it; the force

$$F = qE_2 \qquad (3)$$

due to the field "E_2" acting upon the charge "q" and the resistive force due to viscous drag and defined by Stokes as

$$F = 6 \pi \eta a v \qquad (4)$$

where η is the coefficient of viscosity and "v" is the particle velocity. As the particle's diameter approaches the mean free path of air molecules, the medium can no longer be considered as continuous and the particles "slip" between the air molecules faster than predicted. For particles whose diameter is of the order of

10^{-5} cm, this slip can no longer be neglected and the well known Cunningham correction factor (4) is applied

$$F = \frac{6 \pi \eta a v}{1 + A \frac{L}{a}} \tag{5}$$

Where L is the mean free path of the gas molecules (6.47×10^{-6} cm in air STP) and A is a numerical factor measured by Millikan as 0.874. It has been found that A is not truly constant but varies with the particle radius in accordance with the equation

$$A = 1.25 + 0.44 \exp - 1.09 \frac{a}{L} \tag{6}$$

Equating the electrostatic force to viscous drag and solving for v, an expression for the migration velocity results

$$v = \frac{qE_2 \quad (1 + A \frac{L}{a})}{6 \pi \eta a} \tag{7}$$

It may be seen from Table 1 that, beginning from diameters less than 1 u , the migration velocity decreases until a diameter of 1 u is reached where the velocity then begins to increase.

TABLE I

CHARGE AND MOTION OF A SPHERICAL PARTICLE IN AN ELECTRICAL FIELD

Where:

E_1 = 10 statvolts/cm = E_2
D = 2, T = 70°F (294°K)
e = 4.8×10^{-10} statcoulombs
η = 1.8×10^{-4} poise at STP

Particle Diameter Microns	Electron Charges n	Total Charges q	Cunningham Correction Factor	Migration Velocity cm/sec
.1	10	4.8×10^{-9}	2.86	8.06
.25	25	1.2×10^{-8}	1.67	4.72
.5	50	2.4×10^{-8}	1.33	3.76
.75	75	3.6×10^{-8}	1.21	3.41
1.00	100	4.8×10^{-8}	1.16	3.27
1.50	175	8.5×10^{-8}	1.11	3.68
2.0	313	1.5×10^{-7}	1.08	4.76
3.0	528	2.54×10^{-7}	1.05	5.22

The migration velocity increases linearly with the square of the particle diameter for particles larger than 1 u in diameter. This phenomena explains the conflicting reports of early investigators concerning the particle selectivity of electrostatic precipitators. Fraser (5) shows by experiment that although the median particle size of a sample collected at the inlet of an electrostatic precipitator was less than that of a sample taken further inside, there was penetration of smaller particles toward the rear and collection of large particles on the inlet sample.

White (6) derives the theoretical collection efficiency for a duct type single-stage precipitator as

$$\text{eff.} = 1 - e^{\frac{A_v}{U}} \qquad (8)$$

where A is the total collecting surface area, U is the rate of gas flow through the precipitator, and v is the particle migration velocity. Lapple (3) states that the collection efficiency for a two-stage precipitator may be expressed as the exponent of White's equation due to the close collector plate spacings, neglecting re-entrainment. In practice, however, extraneous factors, may cause the efficiency equation to approach that defined by White.

According to Lapple, the collection efficiency is directly proportional to the particle migration velocity and length of collecting electrode in the direction of fluid flow and inversely proportional to the gas velocity and the plate spacing. For a given precipitator, the only variables are the migration velocity and gas velocity. The HIVES has only been operated at approximately 1000 scfm for all its efficiency checks to date, therefore, all theoretical calculations were made using this flow rate. Particle migration velocity is variable with diameter and defined by two different equations, hence, the collection efficiency was calculated for particle sizes of 0.2 u (theoretical limit of resolution of microscope), 1 u , least efficiently collected particle, and 7.2 u , the largest size particle which can be determined with the Porton graticule on the microscope.

Theoretical calculations of collection efficiency were made using both White's and Lapple's equations and the results are given in Table 2.

TABLE 2

Particle Diameter u	Theoretical Efficiency White %	Lapple %
.2	97.6	100
1	77.4	100
7.2	100	100

It should be noted that these calculated efficiencies are the theoretical minimum obtainable under the most adverse conditions. An example of one of these conditions is the value of 2000 volts used in the calculations as the minimum charging potential. Actually, there is a total of 15,000 volts across the ionizing section and the 2000 volt value was obtained by measuring the potential at the far corners of these sections. These corner sections represent a rather small percentage of the total ionizing volume; hence, the actual charge acquired will be considerably greater than that shown.

In calculation of the theoretical efficiency of the 7.2 u diameter particle, it was assumed that the time factor in the equation was 1. This appears to be a reasonable assumption because the saturation charge is approached for large values of t, and 91% of the final charge is reached at $10T_o$. White (6) states that T_o is of the order of 10^{-3} seconds so that charging, under electrical precipitation conditions, is essentially complete in about 10^{-2} seconds. The gas velocity through the HIVES is 5.36 ft/sec, hence, the particle would travel approximately .64 inches in the 10^{-2} seconds required for essentially complete charging of the aerosol. Although the ionizing section is physically only 4" deep, the electrical field extends beyond this on both upstream and downstream sides so that it is felt that the aerosol-field contact time is more than adequate for complete aerosol charging.

Additional investigation would be necessary to ascertain the effective corona diameter; therefore, this statement on contact time has not been experimentally proven, however, one rather interesting fact about the effective corona diameter has been noted and roughly measured. The 60 mesh screen in front of the ionizing section was observed to acquire a significant negative charge.

The ungrounded screen's charge was measured at various positions with an electrostatic voltmeter and the results are shown in Table 3.

TABLE 3

Distance Ionizing Section (cm)	Screen Charge (volts)
4.4	> 5000
10	4800
20	4050
30	3250

This was eliminated by replacing the copper screen with a nylon screening material. No charge buildup was noted on the nylon.

FIELD COLLECTION EFFICIENCY TESTS

Two methods were used in determination of the actual collection efficiency of the HIVES. One method involved operation of the sampler at 1000 scfm downwind of an aerosol generator and measuring the air concentration of the aerosol upstream and downstream of the electrostatic precipitator. Air stream samples were collected on 2" diameter type HA Millipore filters sampling at 1.65 cfm for periods ranging from 10 to 25 minutes depending upon the distance from the aerosol generator. The aerosol was produced by spraying a solution of sodium fluorescein dye through a nozzle. The sampler was operated downwind of the aerosol generator for a sufficient period so that the upstream sampler would collect a maximum number of distinguishable particles per unit area which would not interfere with the counting and sizing of neighboring particles.

Since the relationship of particle size and collection efficiency was of interest, the dye particles on the filters were counted and sized by an optical microscope with a 97X oil-immersion lens and Porton graticule.

The errors present in particle sizing and counting are due to a combination of statistical and observation errors. To counterbalance the statistical errors (2) in particle sizing, 300-400 particles per filter were sized with at least 100 in the modal class, the latter restriction governing. For average particle counting, 200-500 particles per filter were counted on 37 microscopic fields per filter. The number of fields to be counted was determined empirically to yield the desired total number of particles. When the distribution of the particles was more dense, 1800-2000 particles per filter were counted on 10 microscopic fields. These counting procedures allowed a maximum statistical error of 0.2%. Naturally, it is difficult to estimate the observation error for it will vary with the individual.

The procedure used in particle counting was to select at random 10 or 37 fields on the filter depending upon closeness of the particle as mentioned above and count all particles that were seen within the six rectangles in the microscope's graticule. This was done while varying the focus of the microscope due to particle penetration of the Millipore filter.

The counting efficiency was then estimated by the ratio of the difference in counts per unit area on the upstream and downstream filters to the particle count per unit area on the upstream filter. This is by no means an exact efficiency, but it is adequate as an estimate.

Two runs were obtained that indicated no particles were bypassing the collection plates, i.e. no particles were found on downstream filter. Although the variation of frequency of the particles versus particle size was not determined for these two runs, two previously rejected runs indicated that the modal class diameter was in the range of 0.45 μ and smaller with 88% of the particles less than 2.8 μ in diameter. Figure 6 illustrates the frequency distribution with the dye particle size of a representative sample.

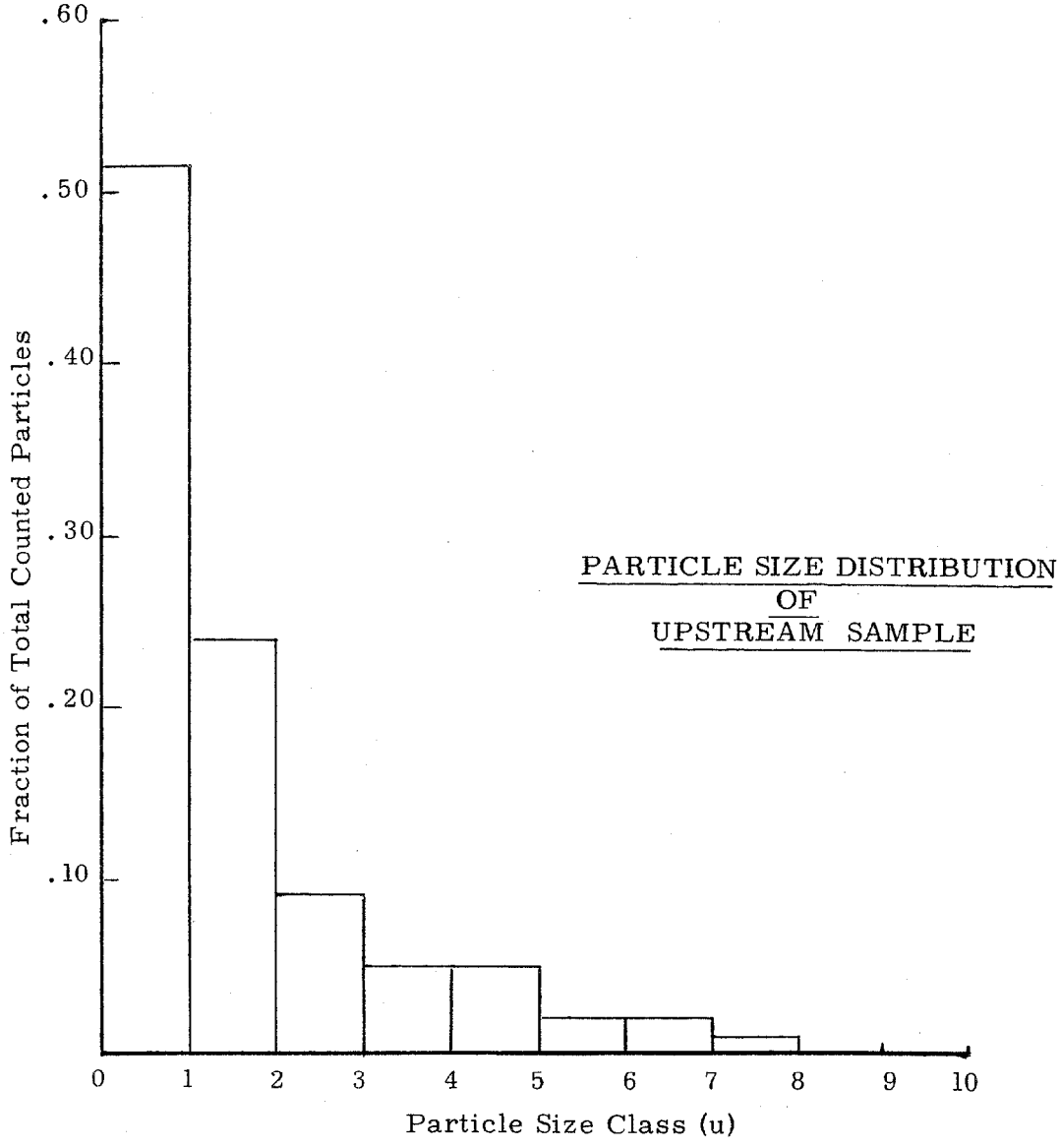

.60
.50
.40
.30
.20
.10
Fraction of Total Counted Particles
PARTICLE SIZE DISTRIBUTION
OF
UPSTREAM SAMPLE
0
1
2
3
4
5
6
7
8
9
10
Particle Size Class (u)

Figure 6

The second method of determining actual efficiency utilized a Sinclair-Phoenix Smoke Photometer and a DOP generator developed by Naval Research Laboratory. A rather simple equipment arrangement was used to establish the efficiency of the HIVES. The dioctyl phthalate, DOP, smoke generators were located approximately ten inches in front of the ionizing section and operated at 25 psi to generate a 0.9 u particle. The intake probe of the Sinclair Smoke Photometer was placed inside the exhaust stack so that a sample was taken of the downstream air only. This arrangement allows one to make an immediate determination of the aerosol concentration without the tedious sample preparation and counting procedures used in the above mentioned method of determining actual efficiency.

Results of the test are shown in Figure 7. The air intake blower was operated continuously throughout the test. Photometer readings were made of atmosphere with the HIVES off, atmosphere - HIVES on, DOP smoke - HIVES on, etc. Figure 7 serves as an excellent graphical illustration of the HIVES collection efficiency for two different aerosols, DOP and atmospheric dust. We see a marked reduction in concentration for both atmospheric dust and DOP aerosol when the sampler is collecting. Calculations using these results indicate a collection efficiency of greater than 99.9 percent.

There are one of two points about Figure 7 which should be considered. In the time interval from 14 minutes to 21 minutes, it is apparent that some particulate matter is being detected in the first two or three minutes after the collector is turned on. This may also be observed in the time interval 34 minutes to 40 minutes. These particles represent those that are already past the ionization section and/or the collection plates and still in the air stream. The sampler's case is so large that it would contain considerable dead air space which could retain particles for several minutes. This appears to be substantiated by the fact that the collection efficiency is higher for DOP smoke from times 21 to 27 minutes than it is for 34 to 40 minutes. It has also been discovered that some of the aerosol may have bypassed the collection section of the precipitator due to the use of sponge rubber gaskets. Visual inspection indicated several light leaks around the compressed sponge rubber material. This material will be replaced with more reliable gaskets and seals to insure that no air bypasses the collection section.

CONCLUSION AND FUTURE WORK

Calculations of theoretical collection efficiencies indicate efficiencies of approximately 100% for all but the 1 u particle depending upon which theoretical equation is used. The calculations for 1 u particle indicate 77%, using White's equation, and 100% using Lapple's. Due to the experimental results obtained to date, it is felt that the actual collection efficiency follows very closely the values predicted by Lapple. Actual field tests have shown collection efficiencies of greater than 99.9% for both fluorescein dye and DOP aerosols.

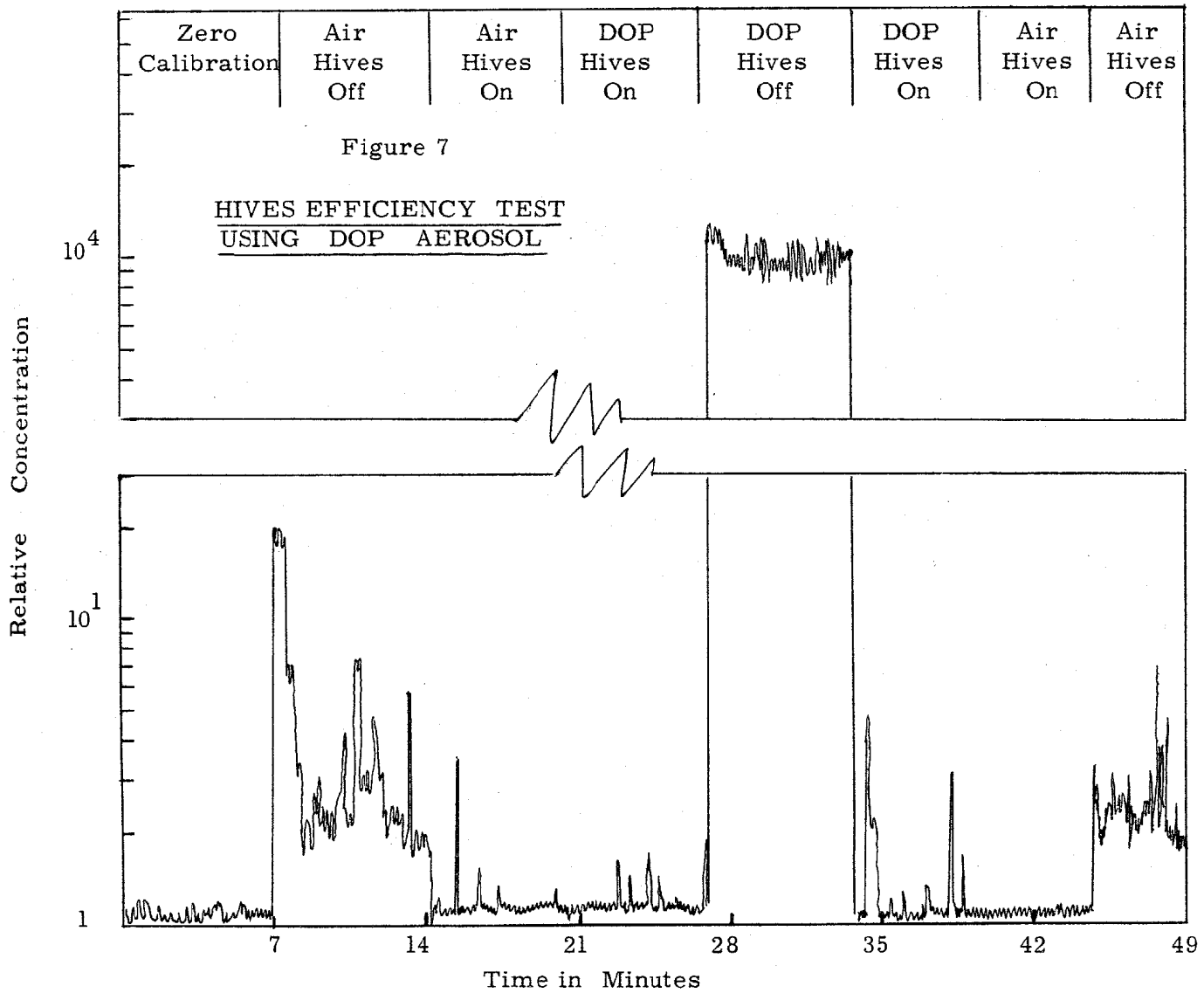

Zero Calibration
Air Hives Off
Air Hives On
DOP Hives On
DOP Hives Off
DOP Hives On
Air Hives On
Air Hives Off
HIVES EFFICIENCY TEST
USING DOP AEROSOL
Relative Concentration
10^4
10^1
1
7
14
21
28
35
42
49
Time in Minutes

Figure 7

Future plans call for more field runs to substantiate the actual collection efficiency over the HIVES entire operating range, 1000 to 2000 cubic feet per minute, as well as the relative collection efficiencies of the bug screen, ionizing section and collection section. An investigation will also be made to determine the most feasible method for the removal and complete recovery of collected air particulate from the aluminum collection plates for radiochemical analysis. Consideration is being given to ultrasonic cleaning methods.

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DISCUSSION

BILLINGS: Are there any questions relating to Mr. Western's presentation?

SILVERMAN: I was wondering why you used such tremendous surface area for your plates? How are you going to analyze this set of plates by dunking it in a bathtub and washing if off?

WESTERN: We have considered using an ultrasonic cleaner to clean these plates. This caused our chemist to become concerned because we will end up with volumes of 2 to 3 gallons of liquid. The one solution that I have shied away from, and that has been suggested to me numerous times, is dismantling the sampler and cleaning each one of these plates individually. I will be open to suggestions on this, but it looks as though the only thing we can go to is an ultrasonic cleaner.

SILVERMAN: This may be an embarrassing question to answer. Who set up the criteria and then went ahead and built it without thinking what you were going to do with it when you got it?

WESTERN: I have been associated with the project for only a few months, therefore, I am not familiar with the planning stages. The basic approach of utilizing a large collection surface area does appear sound. If we are successful in recovering the collected aerosol, we will benefit by being able to sample large volumes of air at a low cost in pressure drop.

SILVERMAN: What strikes me is that a single stage Cottrell type precipitator could meet the same requirements and you would have much less wall surface to purge.

WESTERN: If this had been initiated I think we would still face the problem of particle recovery. Surface area is important in collection efficiency and we do definitely need a large surface area, but as the surface area increases, so do the problems of recovery of particulate matter. Our four collection modules have dimensions of 14 x 10 x 11 inches and there are ultra sonic cleaners commercially available with containers of this size which can adequately clean these plates.

DENNIS: I would like to ask if you have made any test on the so-called germicidal treatment that can be applied to filter coatings. Have you actually done any work on that yourself?

DECKER: In this monograph that is to be published, we have discussed this subject. The inclusion of a germicidal compound in any particular filter to date that we know of has no effect on the filtration efficiency. First of all, for a filter which contains a germicidal compound to be at all effective, it would have to be surrounded in an atmosphere of very high relative humidity. When I say "high relative humidity" this is up in the 90's. Normally, conditions of this sort do not prevail. We ran a series of tests on some of these types of filters and we noticed no change in the filtration characteristics, as far as arrestance of particles is concerned.

AIR FILTRATION OF MICROBIAL PARTICLES

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In recent years, the subjects of microbiological air pollution, air sanitation, and air cleaning equipment have gained importance. Considerable information is now available concerning the immediate and latent ill effects caused by inhalation and retention of foreign airborne particles and bacteria. Further impetus has been given to the subject of air filtration as a result of the emphasis being placed on the nations civil defense program.

Present knowledge indicates that those biological particles approximately one to five microns in diameter and those less than 0.1 micron in diameter are of importance in the respiratory transmission of disease. However, larger particles bearing many organisms may be of importance in the infection of open wounds. Although fully aware of the difference of importance of the various size particles, it is suggested that due emphasis be given to the removal or inactivation of biological particles of all sizes from the air used in critical areas.

In general, most air cleaning equipment used to remove dust, mist, or fumes from air will also remove some bacteria. There are available many types of air cleaning equipment, which in most cases have been designed for special purposes such as the removal of zinc fumes with particle sizes less than 0.1 micron and particles of chemical sprays such as acid mists (Figure 1). Physical methods involved in air cleaning include (a) gravitational, (b) inertial, (c) filtration, (d) washing, and (e) electrostatic precipitation.

When complete removal of bacteria or radioactive particles from the air is required, filtration should be used because it is by far the most efficient and practical method of removing the small particles from air, particularly when an approach to sterility is required.

In considering biological air cleaning, we have divided filters into four categories according to their efficiency and use. The terminology selected should not be considered as identical to that used by manufacturers of air cleaning equipment. These categories are (a) roughing filters, (b) medium-efficiency filters, (c) high-efficiency filters, and (d) ultrahigh efficiency filters. In general, most air cleaning equipment will remove from the air amounts of bacteria in the one-to five-micron particle size range shown in Table I. However, if the bacteria are associated with dust particles to give a particle size greater than five microns, the efficiency will be higher than indicated.

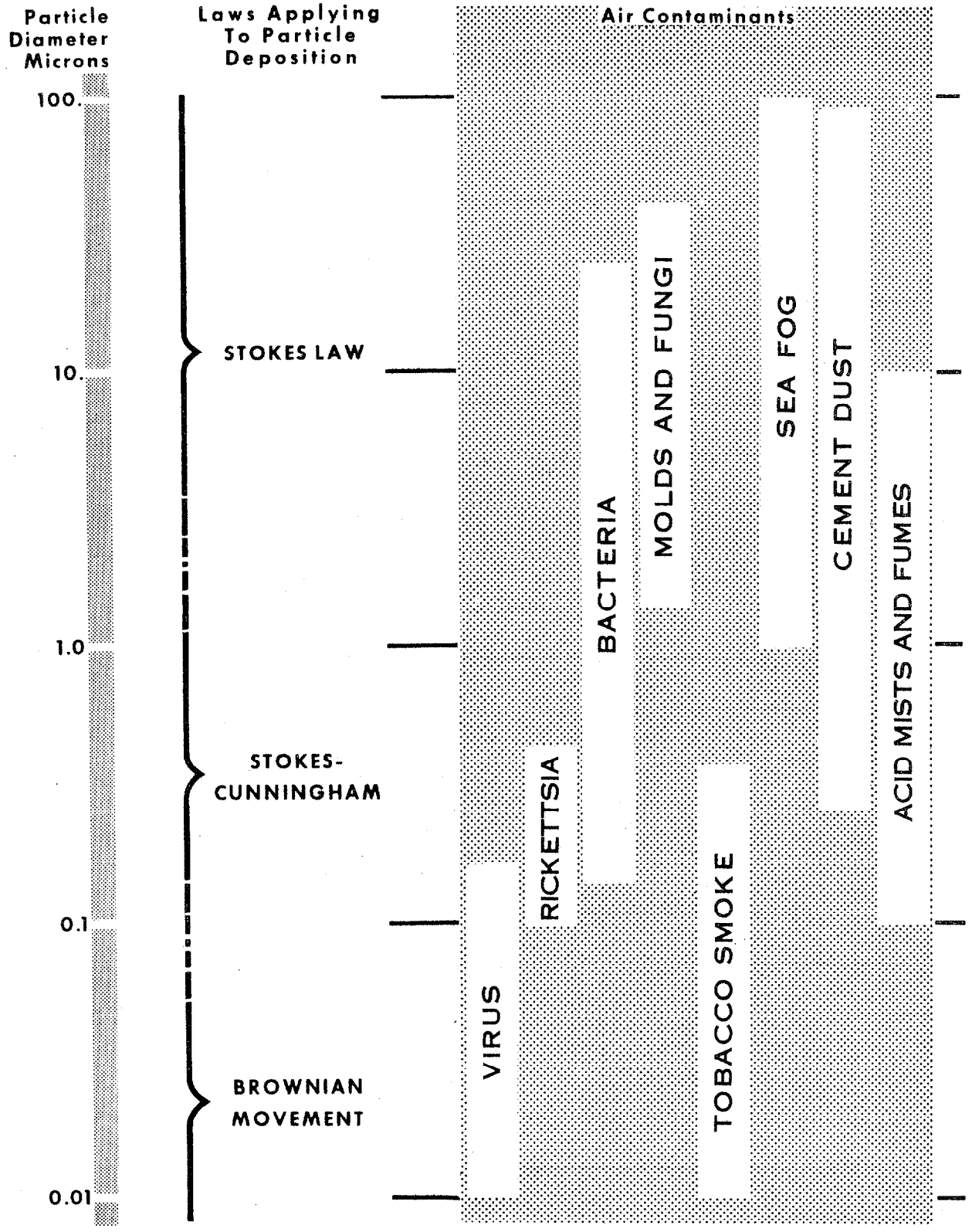


FIG. 1 SIZE RANGE OF AIRBORNE PARTICLES

TABLE I

Efficiency Range of Devices for Removing Biological Particles (1- to 5-u) From Air

CLEANING DEVICE	Bacterial Removal To Be Expected, %
Ultrahigh Efficiency Filters	99.99+
High-Efficiency Filters	90 to 99
Medium Efficiency Filters	60 to 90
Roughing Filters: Fibrous, metallic, oiled and screen types	10 to 60
Electrostatic Precipitators	80 to 90
Air Washers and Scrubbers (low-pressure-drop type)	20 to 80

The roughing filters are commonly used when large amounts of contamination and debris are in the air. They will remove the bulk of large airborne particles and 10-60 per cent of the bacteria and other particles of a similar size, however most remove less than 50 per cent of the one- to five-micron particles. The filters may be used as prefilters for higher-efficiency filters to remove the "sticks and stones" and to reduce "loading" of the more expensive filters. Medium efficiency filters are used where larger particles is desired and relatively clean air is required without a large reduction in flow rate. The high-efficiency filter is used where a high percentage of particles are to be removed from the atmosphere. Ultrahigh efficiency filters are used to achieve maximum removal of small biological and radioactive particles from the air. Ultrahigh efficiency filters also are used in such industries as the pharmaceutical, electronics and spacecraft, to supply particle-free air to certain processes. Illustrations of the various types of filters evaluated are shown in figures 2, 3, 4, and 5.

Air washing is another method of air cleaning. However, this method has not been developed extensively for removing bacteria. Air washing is used chiefly for removing dust and other particles from air, although it has been used in some instances for removing bacteria. Spray towers, zig-zag baffles, metal screens, and glass fiber capillary cells constitute some of these types of air cleaning devices. The most efficient air washers are those in which the suspended matter is impinged on a wet surface and then washed off. Air washers tested have been found to remove 20 to 80 percent of the bacteria in the one- to five-micron range. In some instances, where the wash water is recirculated, the actual bacterial count of the air increases because of re-aerosolization of the bacteria that accumulated in the water.

Electrostatic precipitation is another method of air cleaning. Although electrostatic precipitators can remove a high percentage of bacteria and dust from air, they may not be as satisfactory as filters where a constant supply of clean air is required. In case of power failure, it would be possible for contaminated air to pass through the devices, a condition which could not be tolerated in many situations. Automatic closures could, of course, prevent this occurrence but would increase the cost of the

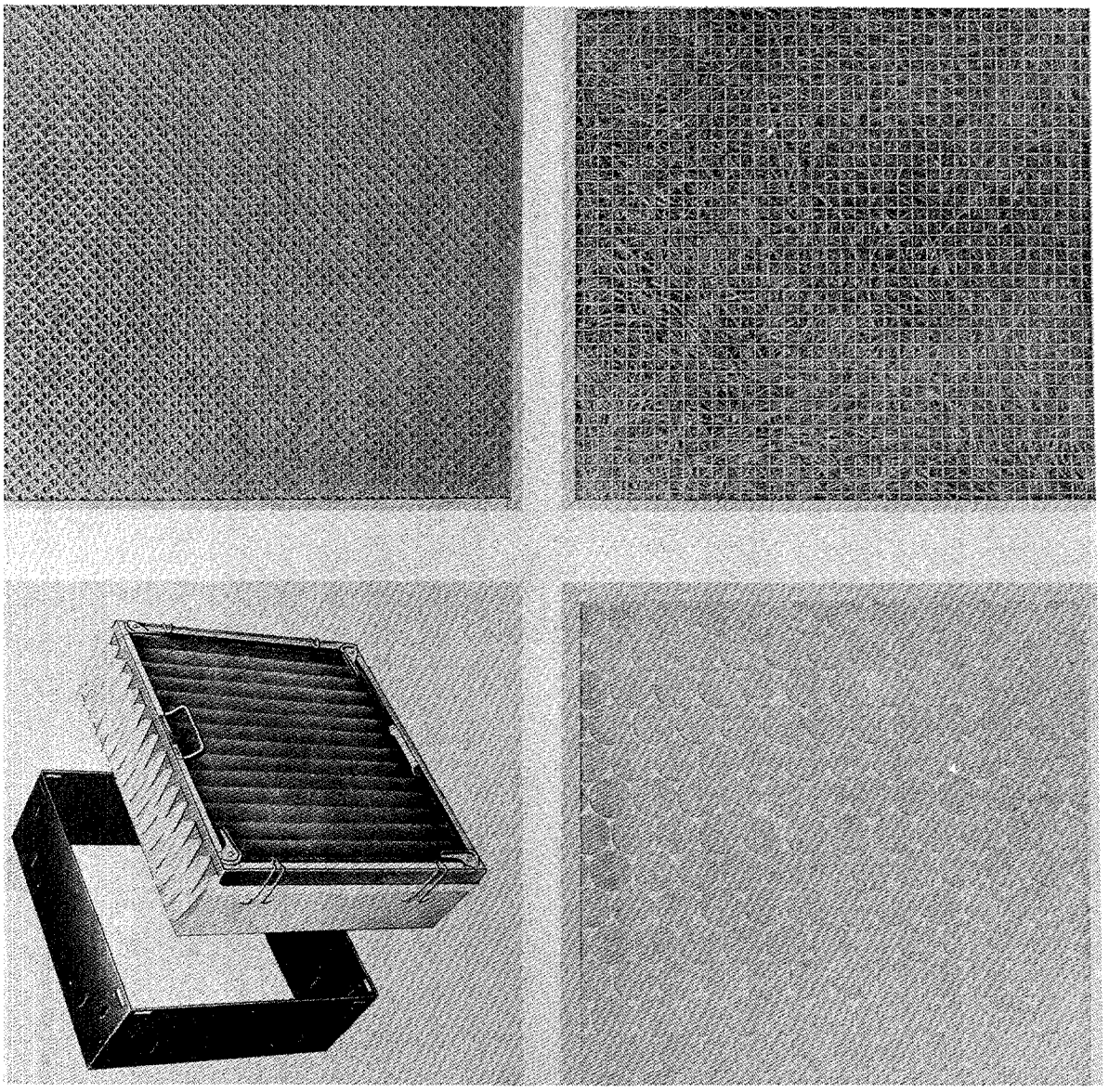


Figure 2. Roughing Filters.

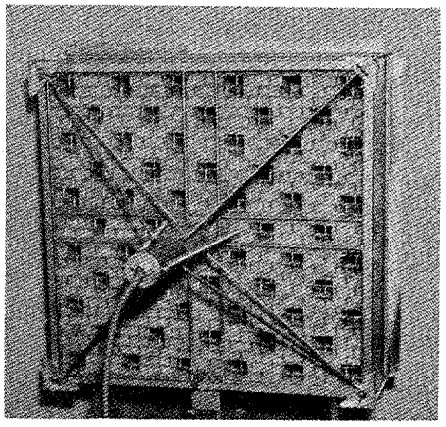
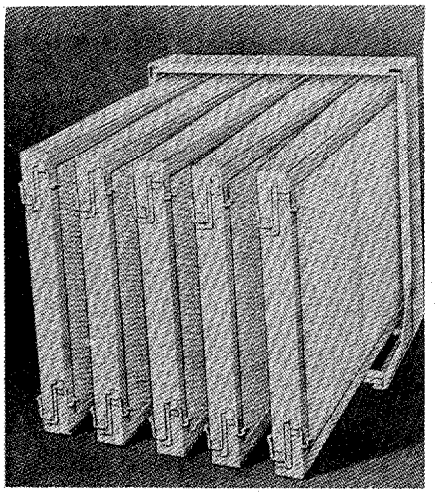
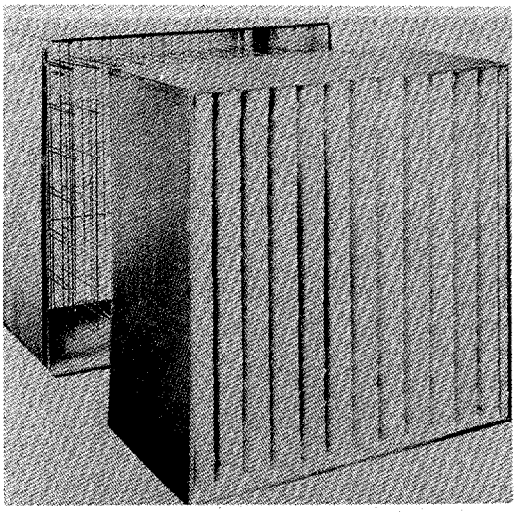


Figure 3. Example of a Medium Efficiency Filter.





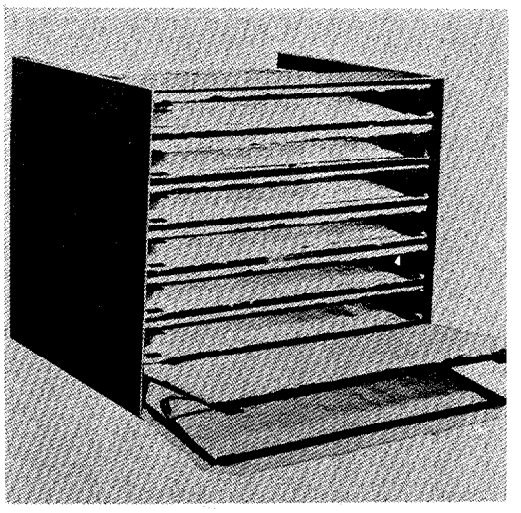


Figure 4. High-Efficiency Filters.

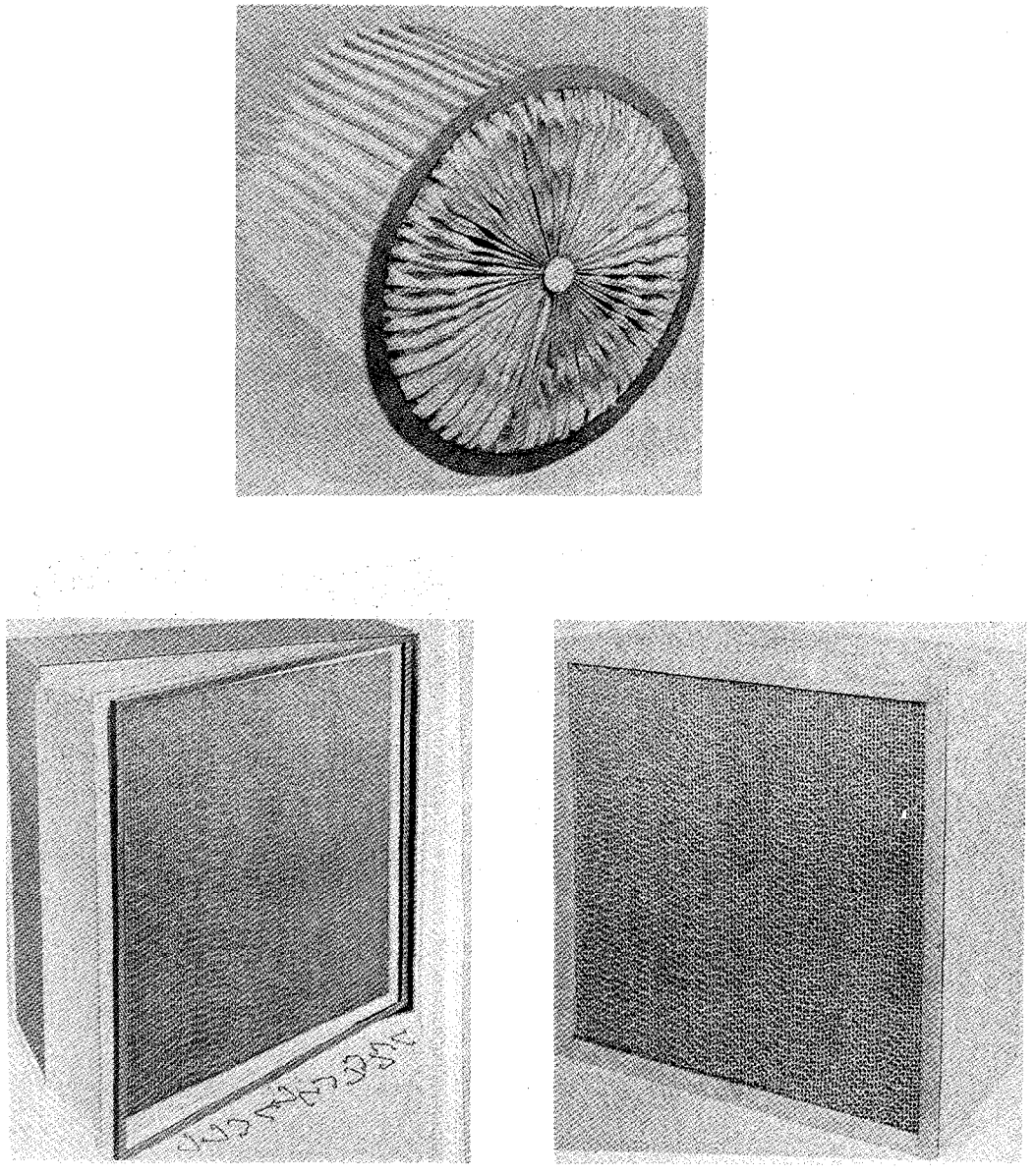


Figure 5. Ultrahigh Efficiency Filters

installation. Some units also shut off for a specific period to allow for cleaning, during such periods no cleaning is provided. Electrostatic precipitators that receive maximum maintenance have been shown in laboratory tests to remove or destroy approximately 90 per cent of the microorganisms in the air. However, tests of some units under normal operating conditions have shown much lower efficiencies.

Removal of bacteria by filtration is satisfactory in most situations; however, under certain circumstances, incineration of air is necessary for maximum safety. In research laboratories, for example, where infectious diseases are studied, high concentrations of microbial aerosols may be generated. Even though ultrahigh efficiency filters are very satisfactory, if the concentration generated is extremely high (millions of organisms per cubic foot of air) passage of a few organisms will occur. Under such circumstances, if the exhaust air is discharged to an atmosphere where people may come in contact with these organisms, incineration is the method of choice.

Ultraviolet (UV) air sterilizers have been reported as being effective for inactivating organisms in an air stream; however, they have the distinct disadvantage that the UV lamps must be cleaned and tested frequently. Furthermore, UV has limited penetrating ability, and those organisms protected by dust may not be killed. Therefore, UV treatment of air is probably most useful against droplet nuclei and of less value against dust carrying organisms. Maintenance requirements and operation monitoring are even more severe and critical for UV installations than for electrostatic systems.

Results of our evaluations have been provided to you. It is appropriate that a few minutes be devoted to our filter evaluation methods. The system shown in figure 6 is a typical test arrangement which permits accurate determination of the bacterial arrestance of filters or filter media when spores are used as the test organism. The same system may be used with vegetative organisms for evaluating filters; however, a different type of sampler than that shown must be used, since cotton collectors are efficient only for the collection of spores. The system is simple, and can be set up quickly. The bacterial organisms are nebulized into a cloud chamber, where the cloud of bacteria is mixed with air. The aerosol is then drawn into the duct through the filter under evaluation at the rated face velocity and is then exhausted through a blower to the outside. Aerosol samples are taken before and after the filter. If the test filter is not the most efficient type, it may be advisable to place an ultrahigh efficiency filter in the blower discharge to prevent contaminating the atmosphere with the test bacteria.

The test equipment and methods of evaluating the bacterial penetration of filters have been standardized for several years at the Biological Laboratories. However, we are just getting into the area of determining the efficiency of filters for virus aerosols. Work is in progress at Fort Detrick on the development of a viral aerosol test method. Differential centrifugation has been used to purify and concentrate T-3 bacteriophage suspensions. Logical sequence of the work will be the determination of the aerosol particle size distribution, followed by sampling and aerosol viability studies. The final phase of the investigation will be the use of the purified phage in air filtration and purification studies.

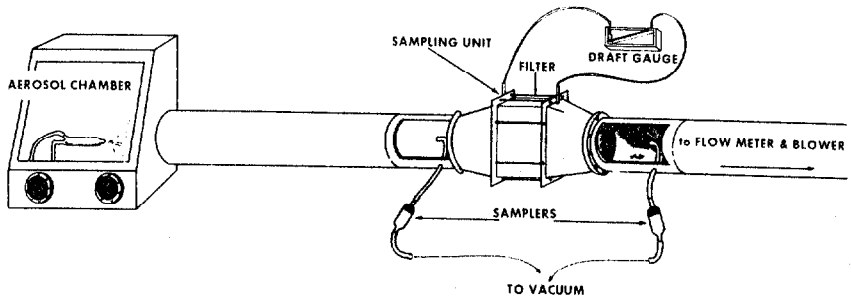


Figure 6. System for Determining Bacterial Arrestance of Filters Using Bacterial Spores as a Test Organism

In addition to knowing whether a filter is efficient, a few points regarding installation suggestions should be mentioned. The installation of an efficient biological air cleaning system to serve certain areas of hospitals, research installations, industrial plants, and civil defense shelters does not in itself necessarily ensure freedom from biological contamination. To maintain the atmosphere of one or more rooms at a low level of bacterial contamination, it is necessary to establish a system of differential pressurization within the building. Use of a pressurized air system, for example, in a hospital permits a minimum interchange of air from areas such as corridors and work rooms, or from other parts of the hospital where the concentration of bacteria will be higher than that normally found in operating rooms (Figure 7).

Now let us assume that one is working in a bacteriological laboratory handling considerable quantities of pathogenic microorganisms. In such a situation, it is necessary that the laboratory be under a reduced air pressure, and that the laboratory air, which may contain pathogens, is discharged through an efficient exhaust cleaning or incineration system and not permitted to enter hallways or areas where personnel can come in contact with the organisms (Figure 8).

Air supplied to shelters, such as an air raid shelter, should be filtered; however, contamination may enter a room or shelter through windows, cracks or any small openings. Sealing of all unnecessary openings, where practical, is recommended. Contamination will be kept to a minimum if the inside air is maintained at a higher pressure than the outside air. Air required for normal ventilation may provide the necessary pressure (0.1 to 0.6 inch of water); however, if it is not sufficient, then additional sealing of air locks or an increase in air supply by means of a higher capacity or additional blowers will be required.

If an air cleaning system is to operate efficiently it must be properly installed. A small leak which could allow contaminated air to bypass the filter will negate the effect of the best air cleaner as well as that of the less efficient cleaner. If particulate-free air is required, the seal between the filter and its supporting frame must be gasketed and an adhesive applied, or any other procedure which renders an air-tight seal can be used. Ducts carrying contaminated air under pressure must be air-tight if they are within the clean area.

Summarizing what has been said, if the incoming air must be kept entirely bacterial free, then a roughing filter followed by an ultrahigh efficiency filter is the system of choice. Normally, however, cleaning the air to the extent is not necessary and a lower efficiency filter is adequate. High efficiency, medium efficiency, or even good roughing filters may be used where lower standards are satisfactory. Ultraviolet light and air incineration normally are not applicable for the problem under consideration.

The subject of air filtration of microbial particles has been covered very briefly. For additional information on this subject you might refer to a forthcoming monograph that will be published early next year by the Government Printing Office entitled: "Air Filtration of Microbial Particles" authored by personnel at Fort Detrick and the Public Health Service.

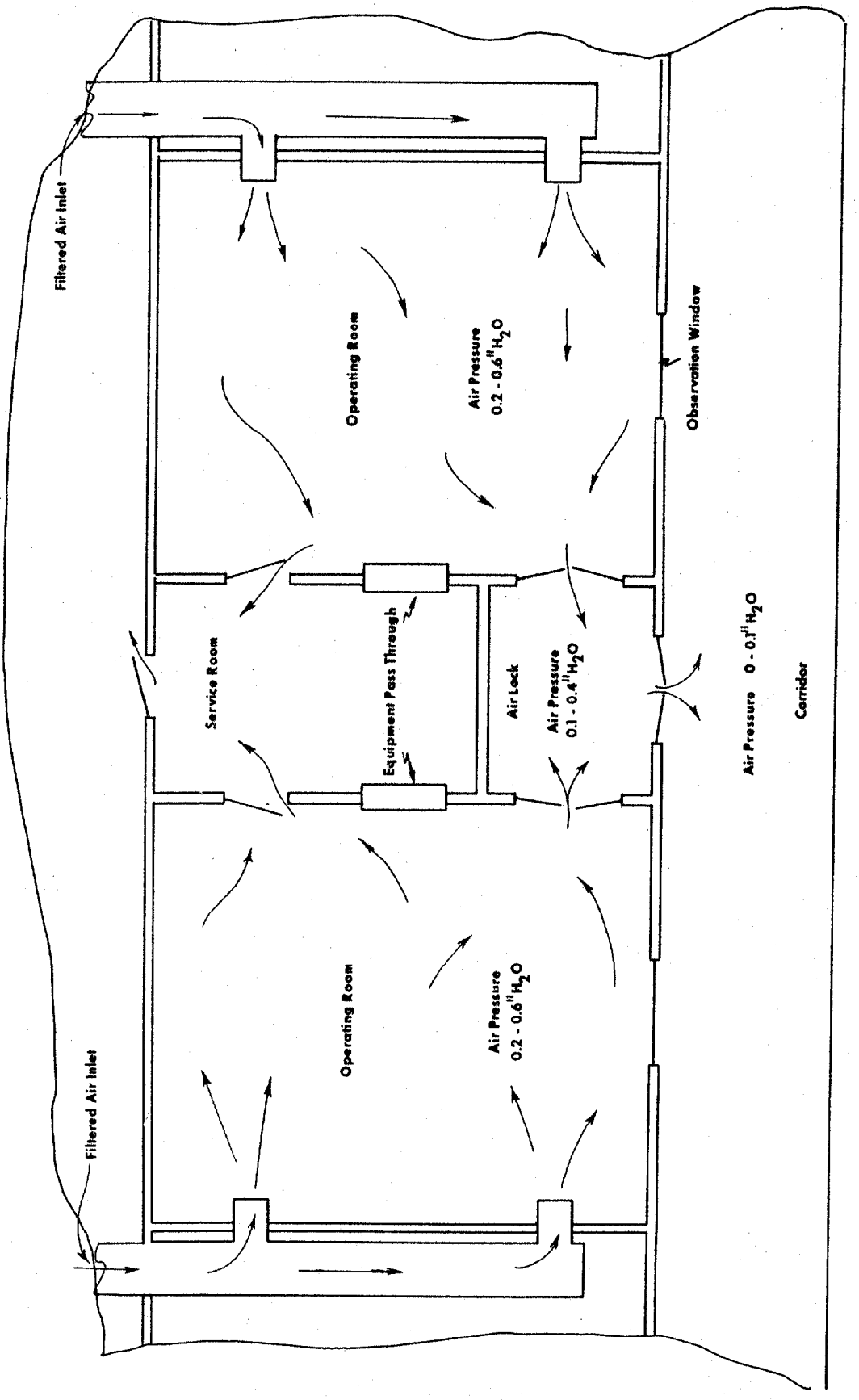


Figure 7 Air Lock to Reduce Infiltration of Contamination.

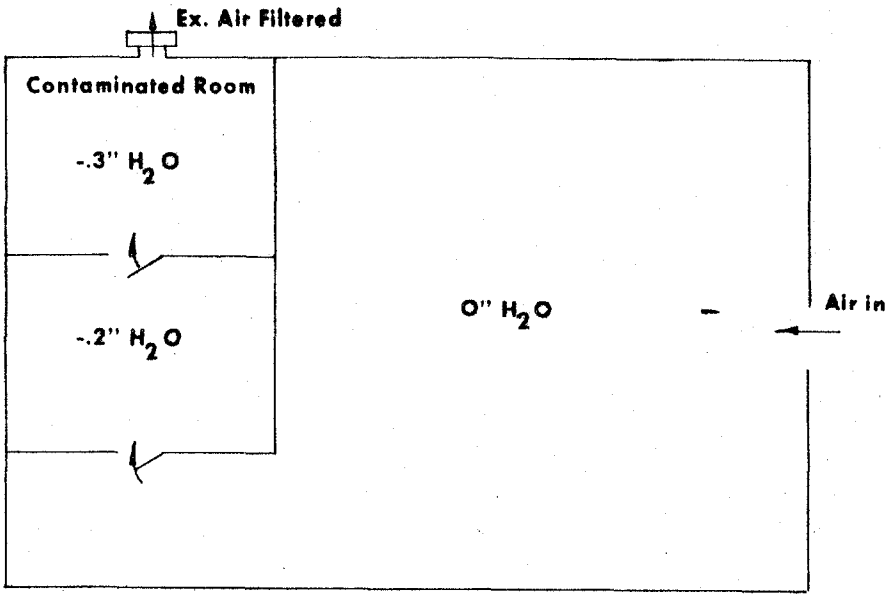


Figure 8 Pressurized System for Bacteriological Laboratory.

EQUIPMENT AND PROCEDURES FOR STACK GAS MONITORING AT ORNL

J. F. Manneschmidt
Oak Ridge National Laboratory

SUMMARY

The Oak Ridge National Laboratory is engaged in a wide variety of operations related to nuclear research, development and production. Among these are the production of radioisotopes, the operation of nuclear reactors, and other activities which generate gaseous waste containing varying amounts of radioactivity. Routine monitoring of gaseous waste was started in 1956, when manually operated tape monitors were placed on each of the three process stacks. In 1959 the development of a monitoring system was intensified and certain improvements were made to the Principal Stack. These included the addition of a step-moving tape monitor for better particulate detection, a charcoal trap monitor for adsorbable-gas detection, and an ion chamber detector in the off-gas system discharge, which carries the bulk of activity released into the stack. Inventory-type samplers, consisting of a filter and a charcoal cartridge, were placed on all stack samplers for the purpose of estimating stack activity discharges. In 1961 an experiment, using a triple sample withdrawal probe with tape monitors, was initiated at the Principal Stack to establish the criteria for a new sample withdrawal system. A temporary in-stack sampler was installed to replace the less efficient external samplers and design is under way on a permanent installation which may be operated with greater simplicity and safety. An improved tape monitor which will give both beta/gamma and alpha detection, and which has many other advanced features, is planned for future use on the stack and on the ducts. The filter-charcoal cartridges will then be used on the smaller tributaries. A gross-gamma monitor, consisting of scintillation detectors mounted at the top of the stack, is in the concept stage.

EQUIPMENT AND PROCEDURES FOR STACK GAS MONITORING AT ORNL

The Oak Ridge National Laboratory is a vast complex of research development, and production operations. Its research and development groups conduct a wide variety of studies, which include reactor fuel reprocessing, disposal of high level waste, and isolation and purification of transuranic and transplutonic elements, and basic research in many other fields. There are at the Laboratory five reactors, of different power levels. The production of radioisotopes is a major function of the Laboratory; over one hundred different radioactive preparations are produced, ranging in quantity from millicuries to kilocuries, and requiring, in most cases, chemical

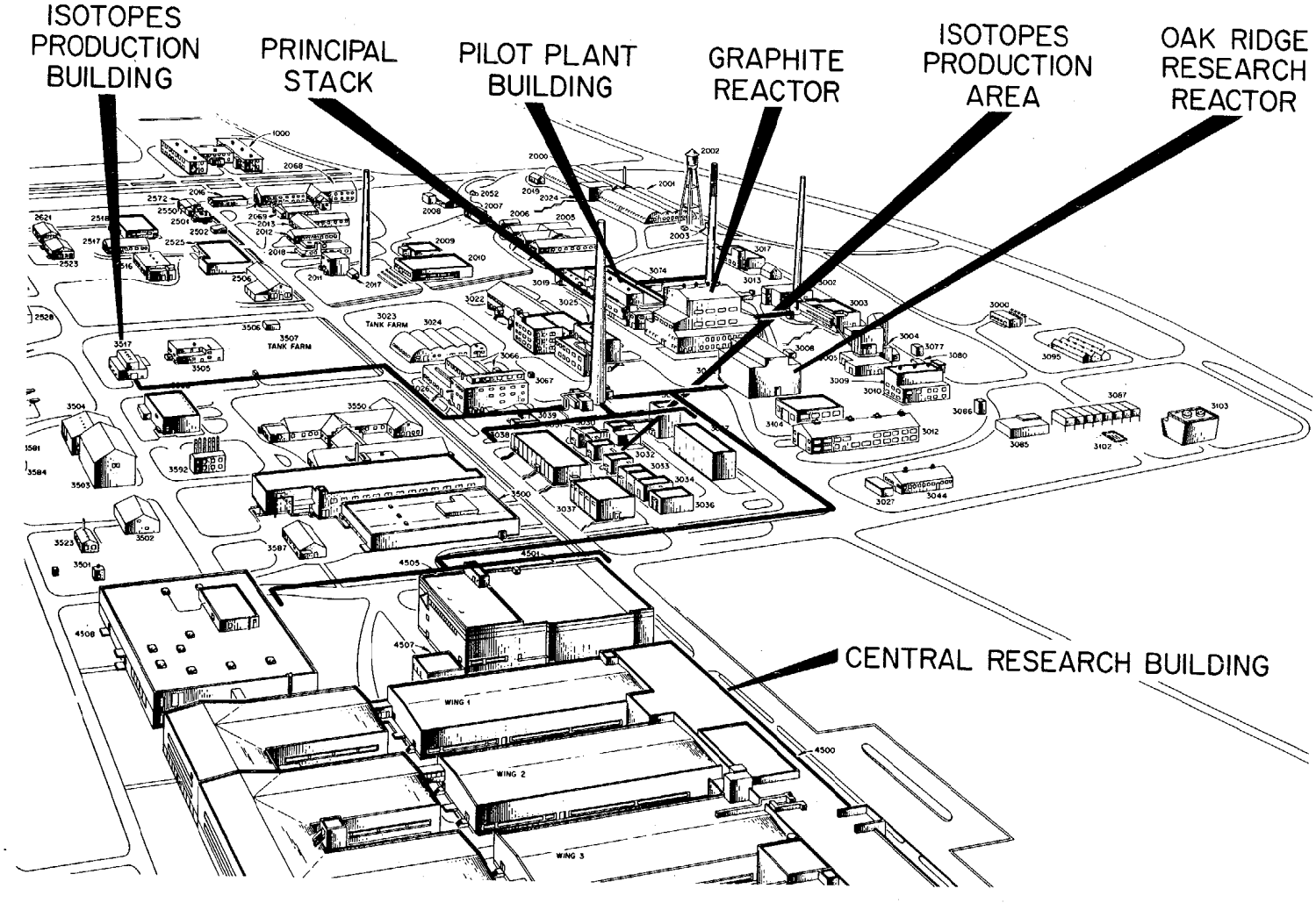
purification and processing. All of these varied operations produce quantities of gaseous waste, usually containing some degree of activity, which must be treated for removal of the dangerous contaminants and then discharged to the atmosphere.

There are three stacks at the Laboratory to which are routed all of the gaseous waste and which discharge to the atmosphere. I would like to describe these stacks in order of ascending importance, activity-wise, and describe briefly the operations associated with each (Fig. 1). The Pilot Plant stack discharges ventilation air at the rate of approximately 40,000 cfm from the cells and operating areas used at various times for processing irradiated reactor fuel elements of several types and from the high level analytical laboratory in the same building. The gaseous waste from this area passes through absolute filters but is found to contain I^{131} and traces of the thoron daughters when it is discharged to the atmosphere.

The reactor area stack releases cooling air from the graphite reactor at the rate of approximately 120,000 cfm. Here too, the most predominant of the measured activities is I^{131}. Large volumes of rare gases are released from the reactor stack also, but these are not sampled or measured. This stream of air is likewise filtered before discharge.

The third stack, which I would like to term the principal Laboratory stack, accomodates the remainder of the Laboratory gaseous waste; it discharges approximately 138,000 cfm of gas and at least 90% of the total measured gaseous activity generated by the Laboratory. Principal contributors of activity to this stack are the radioisotope processing areas, from which come quantities of I^{131}, the Oak Ridge Research Reactor, and the large complex of buildings which houses the research and development groups. There is a variety of equipment employed both at the stack and in the work areas for cleaning up the gaseous discharges; however, I shall not discuss that phase of the system at this time. Although a wide variety of operations is tied into this stack the predominant activity here, as elsewhere, has always been I^{131}. However, during the past year, at least fourteen other nuclides have been identified in trace amounts.

Because monitoring is vital to any radioactive waste disposal system, at the Oak Ridge National Laboratory, much emphasis has been placed on developing and maintaining a reliable monitoring system. Gaseous waste monitoring at the Laboratory serves two important functions. First, it enables supervision to maintain better control over the many activities and operations which generate gaseous activity. At the same time, a sensitive monitoring system will alert the laboratory in the event of a serious discharge into the atmosphere and the necessary steps can be taken to best protect personnel and property from fallout or radiation danger. Secondly, a complete monitoring system will provide sufficient information on a periodic basis to compute with reasonable accuracy the total amounts of all important nuclides being released to the environment. Being able to state "how much" went up "when" will enable the Laboratory to safeguard its position with respect to existing or future MPC_a values. Inasmuch as the bulk of the discharged activity comes from the Principal Stack, it was decided to make it the pilot stack for the development of our monitoring system. There are monitoring devices on the Graphite Reactor Stack and the Pilot Plant Stack; however, they are similar to those on the Principal Stack and so will not be discussed here in detail.



Location of Process Stacks and Main Contribution to Gaseous Waste System.

Figure 1

Routine monitoring of the Laboratory gaseous waste discharges was first started by our Health Physics Division in 1956 when a filter tape monitor was installed on the Graphite Reactor Stack. In 1957 a similar device was put into operation at the Pilot Plant Stack and in 1959 coverage was extended to the Principal Stack. Prior to these dates grab sampling was done but not routinely. This first monitor is a very simple affair (Fig. 2) which consists of a 2-in. filter tape through which is drawn a measured stream of the stack gas. A side window G-M tube is located adjacent to the tape in such a manner as to detect the build-up of activity during the collection period. The tape is changed daily by manually pulling through the collection block and cutting off. The deposited activity is then allowed to decay for 72 hr., after which a gross beta-gamma count and an alpha count are made. There is no nuclide identification and no attempt is made to calculate stack discharge. The buildup of activity, as seen by the G-M tube, serves as a measure of stack behavior. Should the buildup occur at an abnormal rate and exceed preset limits, an alarm is sounded and immediate steps are taken to determine the full extent of any possible release and to locate and bring under control the source of the activity.

Of interest is the type of sample withdrawal probe used in conjection with these monitors. This probe (Fig. 3) is a 1-in. stainless steel pipe inserted across the diameter of the stack (at the 50-ft level in the case of the Principal Stack). The sample stream is withdrawn through perforations in the pipe and carried to the monitor at ground level. Inspection shows that a system of this design is grossly inefficient for many types of air-borne activity. Centrifugal losses, plate-out (amplified by the great length of connecting tubing), and losses occasioned by horizontal runs all take their toll, particularly in a system where one would like to make quantitative measurements or where the detection of large particles is of importance. Such factors were not seriously considered at the time of installation, however, and it was not until late 1959, after a rather spectacular ruthenium release, that the entire gaseous waste disposal system was examined critically and the first steps taken to develop a complete, efficient monitoring system.

The Operations Division, of the Laboratory which is responsible for the operation of the gaseous waste system, made, in cooperation with our Health Physics and Instrumentation Divisions, certain immediate improvements. Remote surveillance of the tape monitor, just described, was brought about in such a manner as to give better round-the-clock coverage, and the alarm system was improved. Other monitoring devices were then added in parallel to preclude loss of coverage because of the failure of any one piece of equipment.

The first of these devices was a monitored charcoal trap (Fig. 4). This consists of an aluminum cylinder 14 in. long x 4 in. in diameter filled with about 750 g of 14-mesh charcoal. Into a well through the center of the cylinder is inserted an ion chamber (Reuter Stokes Co. Type RSG-1). The cylinder is attached to the sample line previously described and a stream of stack gas, approximately 0.5 cfm, is drawn through the charcoal. Adsorbable nuclides are held up here and their activities are detected by the ion chamber, the signal from which is amplified by an electrometer and recorded. This has proven very sensitive and has required little other than occasional maintenance on the pump.

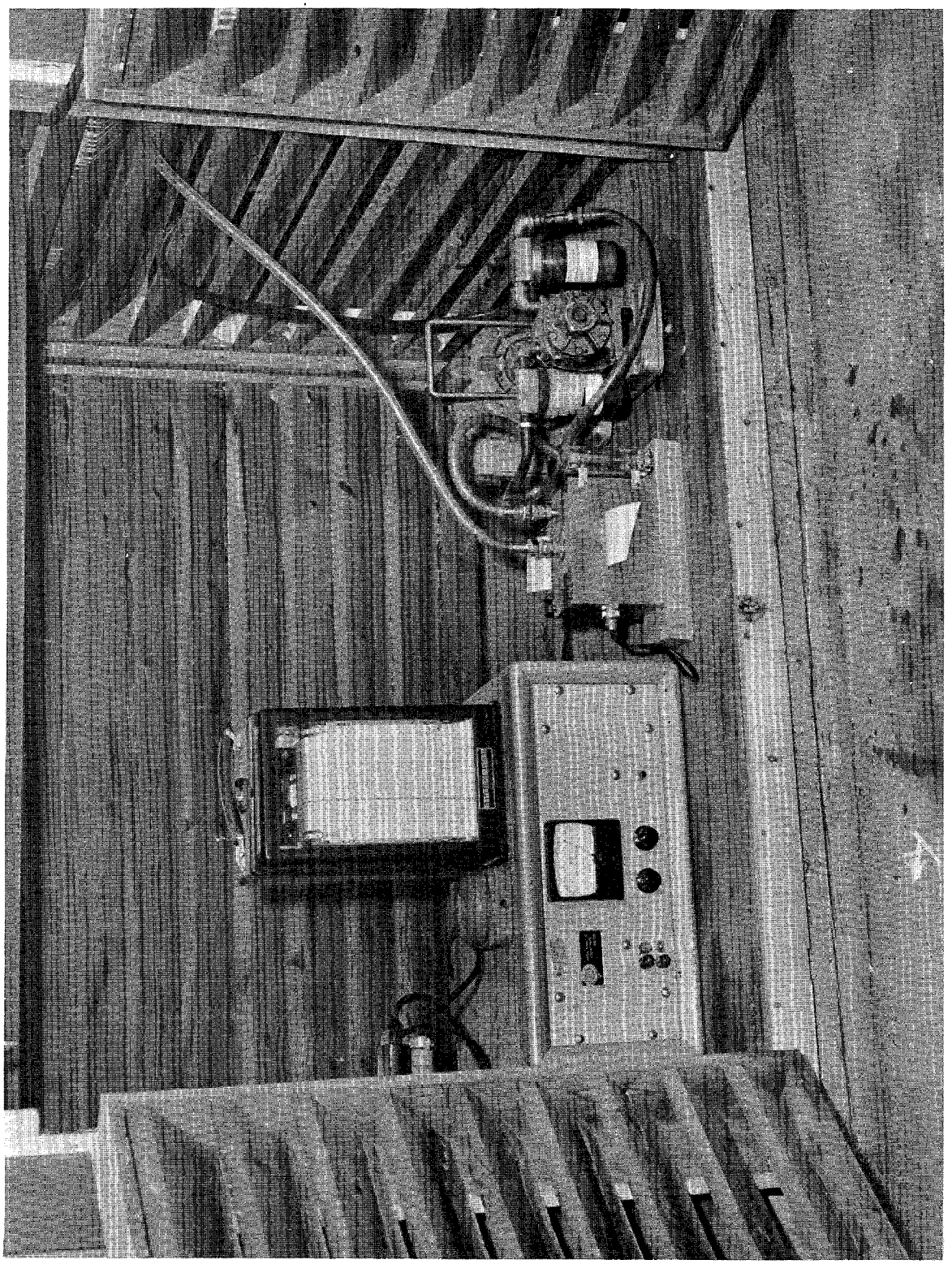
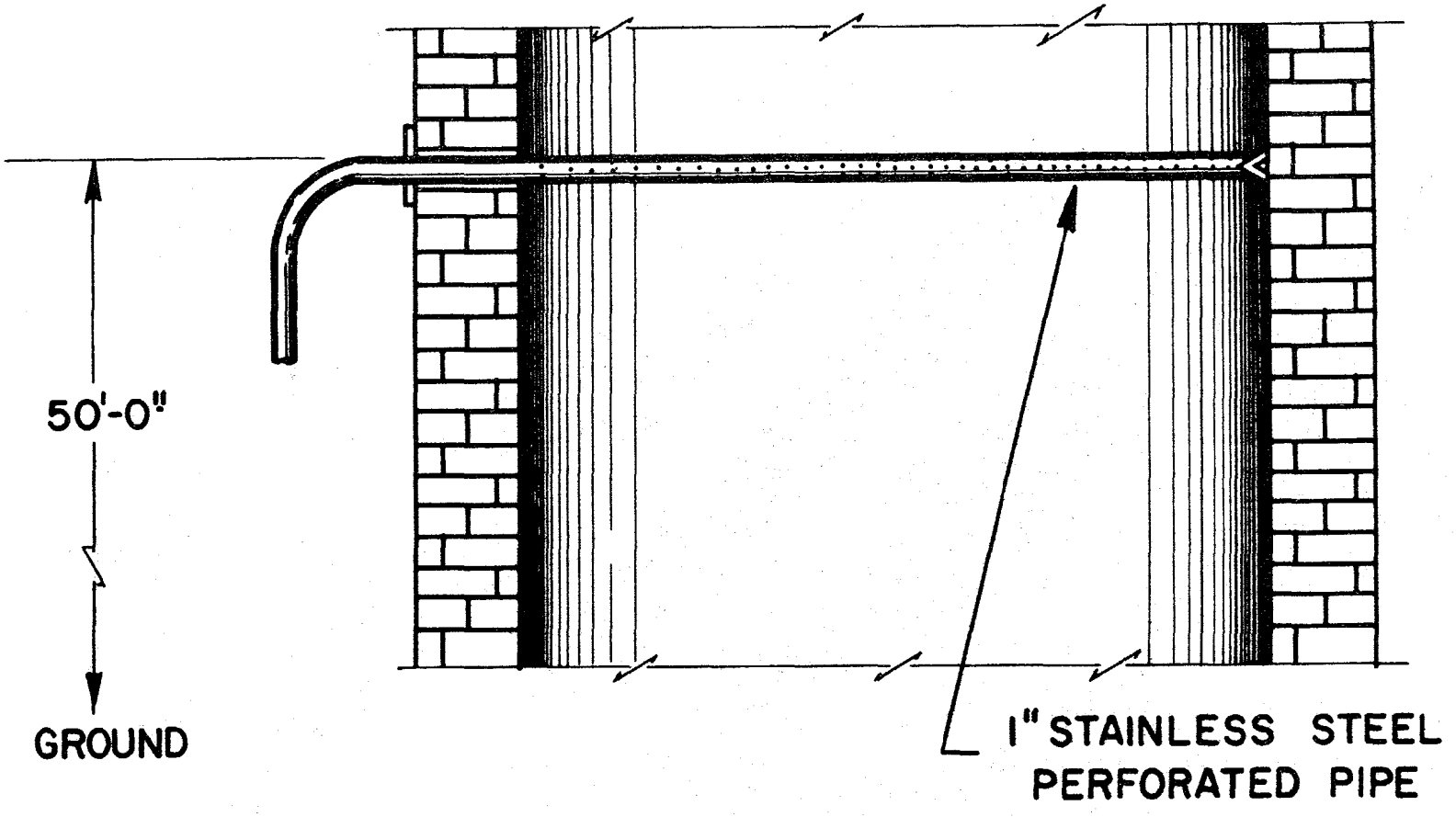


Figure 2



TRAVERSE TYPE SAMPLER - PRINCIPAL ORNL STACK

Figure 3

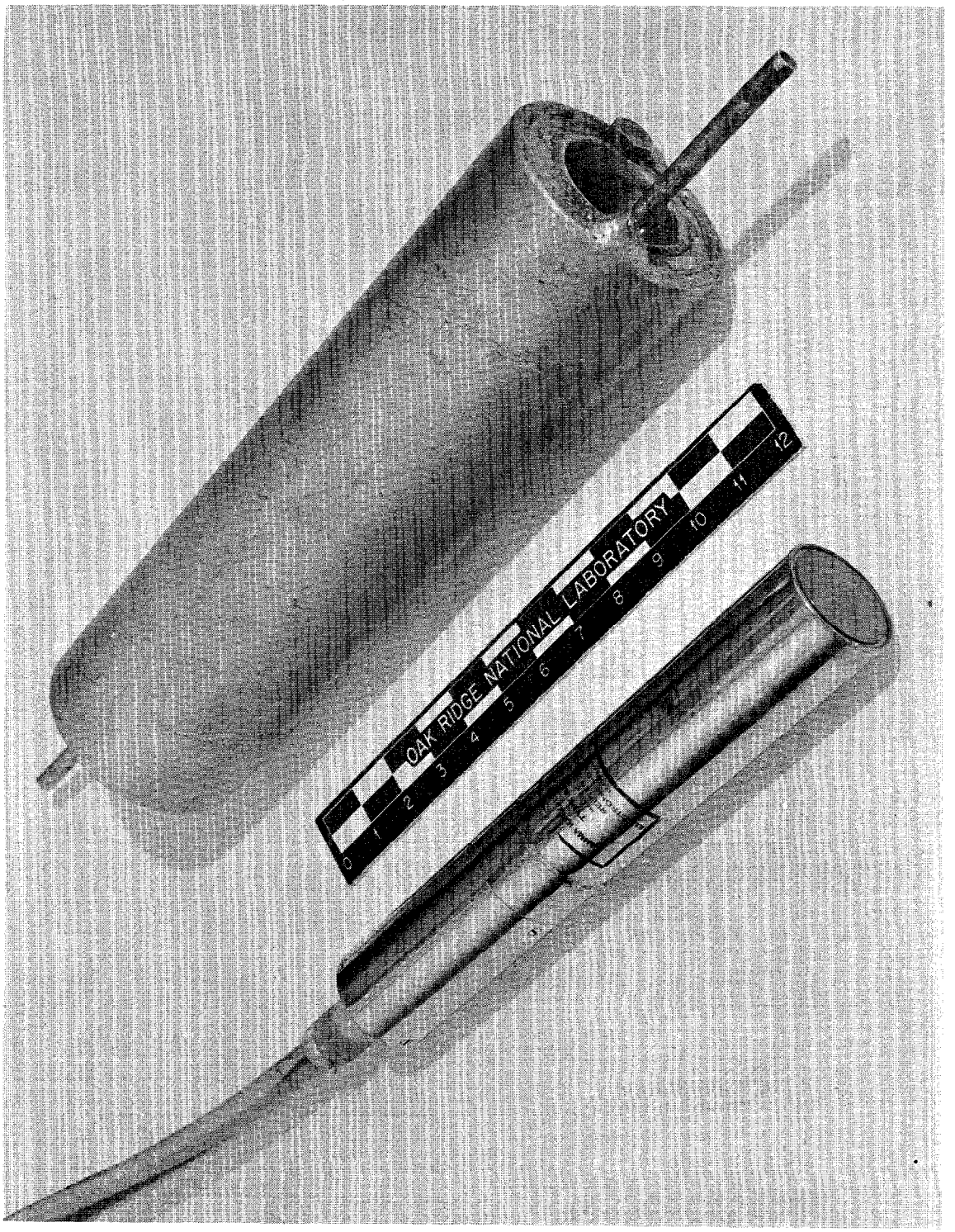


Figure 4

The use of a similar ion chamber detector in the off-gas was the next addition to our continuous monitoring array. Off-gas is the name given to the ventilation service which is connected directly to dissolvers, evaporators, and other process vessels containing radioactive material. The volume of this stream is small (only about 2% of the total); however, its activity is quite high, and special scrubbers and filters are used to decontaminate the off-gas before it reaches the stack. In view of its special hazard a separate detector was inserted directly into the discharge from the off-gas clean-up facility to provide a continuous indication of the activity contributed by this source.

The third improvement to the monitoring system was the acquisition of a moving-tape monitor (Fig. 5). This instrument employs a 1-1/2 in. tape which automatically moves stepwise according to a preset cycle. The gas sample stream passes through the tape during the sampling part of the cycle; and then the accumulated deposit is moved under an end-window G-M tube where the activity is detected and recorded through the use of a linear count rate meter and strip chart recorder. The detector used here has a 2.0 mg window and is sensitive to betas with energies as low as 50 kev. A microswitch attachment on the tape transport automatically sounds an alarm if the tape breaks or runs out. This monitor was first attached to the common sample line at ground level, but was later placed immediately adjacent to the sample probe for use in an experiment to be described later.

In order to maintain an approximate inventory of the activity discharged from the Principal Stack a filter-charcoal sampler was attached. Figure 6 shows such a sampler. The sample collector consists of a Gelman filter holder containing a 2" membrane type filter (Gelman Green 7) followed by a holder containing a small charcoal cartridge. These cartridges are of plastic, approximately 1 1/2 in. long x 5/8 in. in diameter, and contain about 3 g of 16-mesh charcoal. The pump (Fig. 6) commonly used for air sampling at the Laboratory is a positive-displacement type (Gast, Model 0211) with a rated capacity of 1 cfm. Included in each sampling assembly is a 2 cfm purge-type rotameter. In order to simplify the measuring of sample volumes, totalizing meters are being considered as possible replacements for the rotameters at those stations where the total volume of sample must be known with some accuracy. One meter has been ordered for testing; it is quite small, totalizes to the nearest cu ft, and costs little more than the rotameter it will replace.

The filter-charcoal cartridge combination on the stack sampler is changed daily, is analyzed with a single channel gamma spectrometer, and the filter is alpha control. The activities thus detected are measured and converted, by applying a sample-flow-rate to stack-discharge-rate factor, to daily stack discharge. Similar samplers were attached to a number of the larger ventilation ducts discharging into the stack; however, these samplers do not contain the charcoal cartridge but only the filter, which is removed daily, and beta counted but not scanned.

While the samplers attached to the stack give information which we call quantitative, those on the ducts, of which there are five in the immediate vicinity of the stack, indicate only the relative levels of activity carried by the various ducts. In the event one of the continuous monitors shows abnormally high activity in the stack discharge,

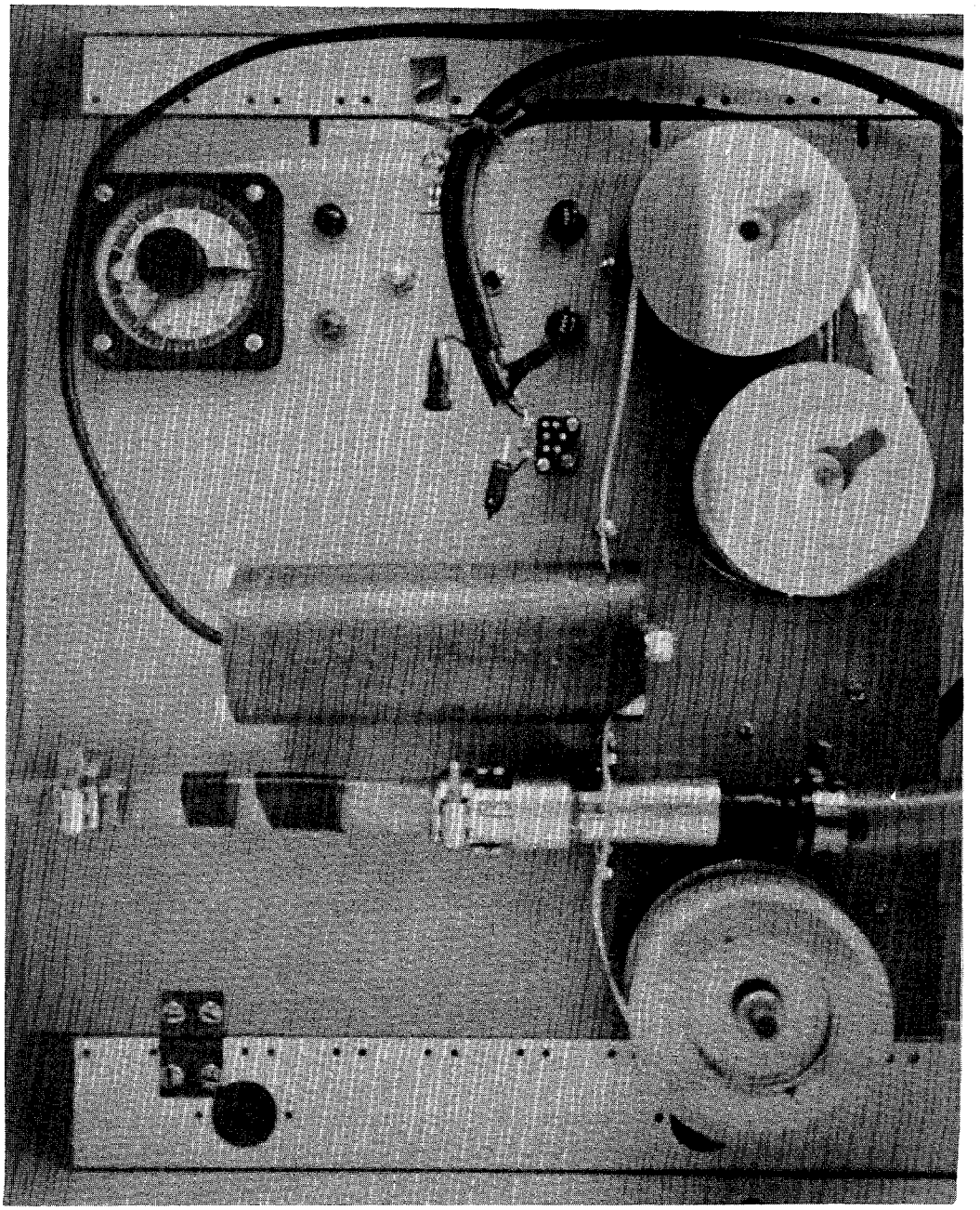


Figure 5

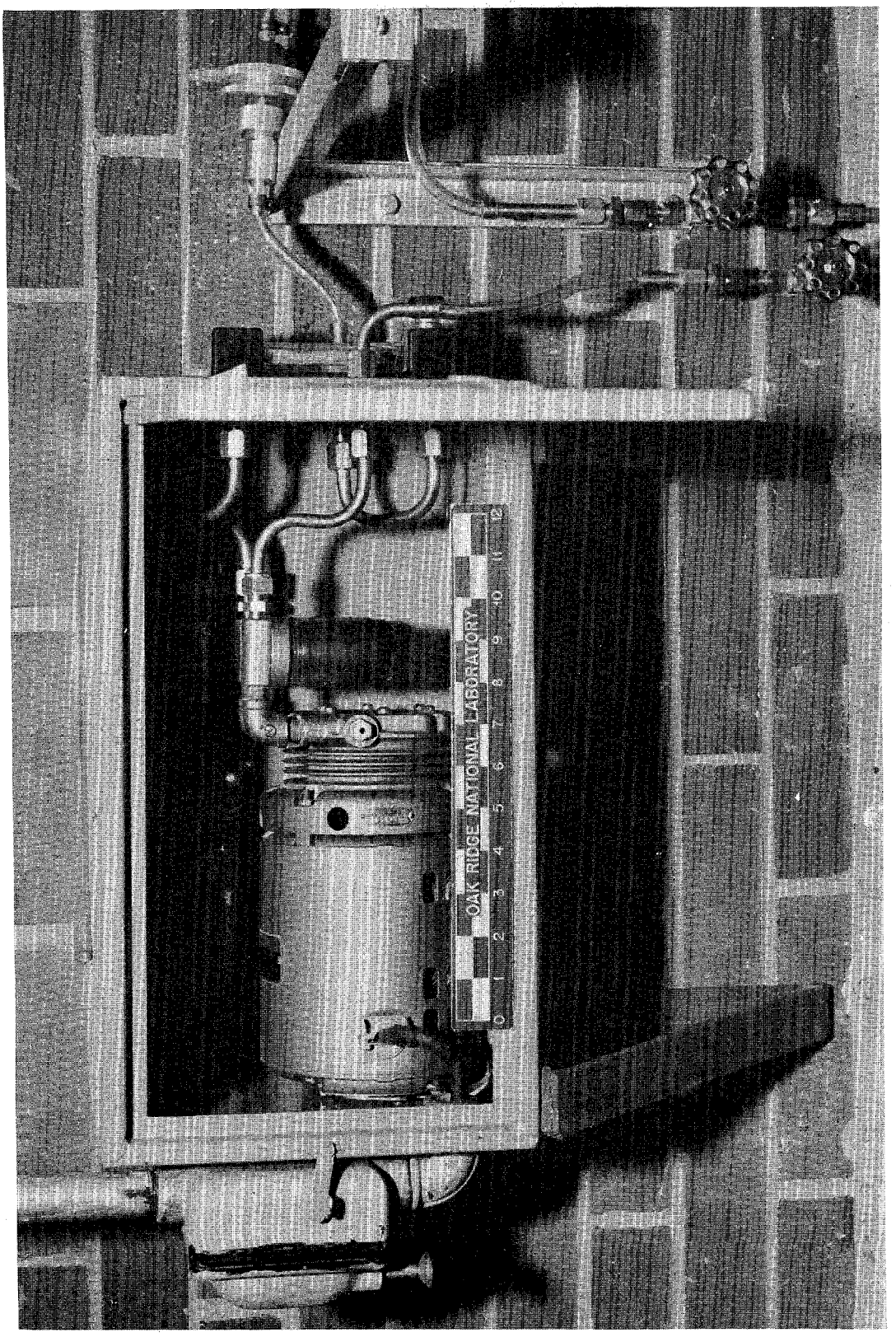


Figure 6

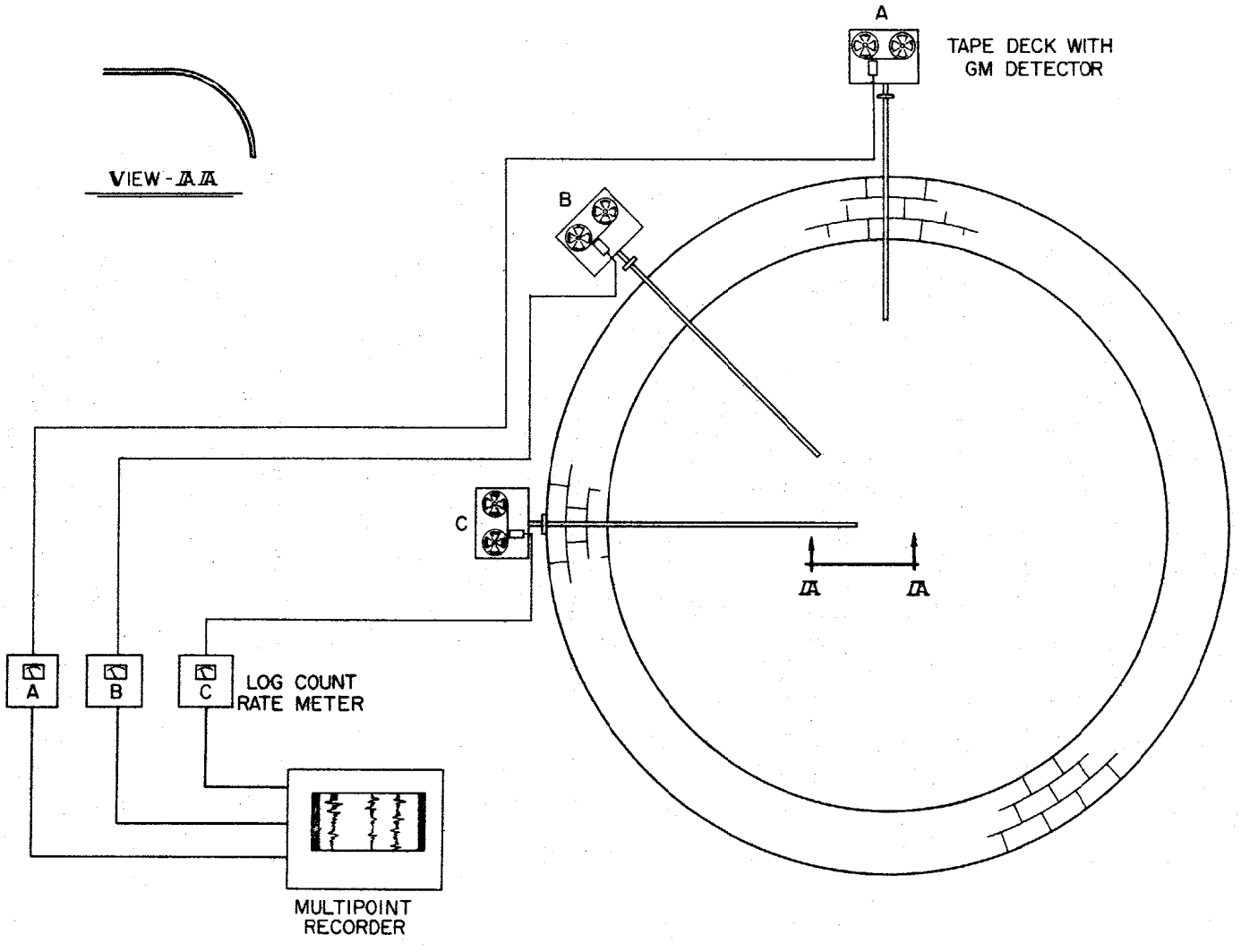
the filter from each duct is immediately removed and counted; in the majority of cases, the source of the activity release can thereby be quickly isolated.

In recent months development work on the gaseous-waste monitoring system has gained momentum, and I would like to describe some experimental work in progress and tell you of our thoughts for the future. The sample withdrawal system is now under close scrutiny. Much evidence has convinced us that the optimum system for withdrawing a sample of contaminated gas for examination at some point external to the stack is one which has minimum length and no sharp bends, and one through which the sample is withdrawn isokinetically, i.e., at a linear flow rate equal to that of the stream being sampled. In our case there also remained the questions of where to locate the withdrawal probe and whether one probe would be sufficient. At the Principal Stack at ORNL the ducts discharge into the stack 15 ft above ground level, while the ports available for sampling devices are located at the 50 ft level. With a linear flow rate within the stack of only about 500 fpm there has always been some doubt as to the completeness of mixing of the various duct discharges in the 35 ft between these levels.

An experiment (Fig. 7) with three probes and tape monitors was set up in an effort to resolve these questions of number and location of probes. Three 12-ft probes were fabricated of 1 in. stainless steel tubing, each with its collection end curved downward on a 30 in radius. The tips were beveled to a sharp edge. The probes were inserted in the stack at the 50 ft level; one went to the center, the second about 5 ft from the wall, and the third midway between the other two. A step-moving tape monitor, described earlier, was attached to the end of each probe. The G-M tube detectors in the monitors are connected through transistorized preamps to individual log count rate meters which read out on a single multipoint recorder. There is a pumping and flow-metering system attached to the probes which is not shown here. Every effort was made to create three identical probe-monitor systems and to eliminate every variable except probe tip location. Many mechanical and electronic difficulties have been encountered since this equipment went into operation and no conclusive data have yet been produced.

An injection test is planned for the near future; in one phase a measured quantity of activity will be released into a breeching at the foot of the stack. A second phase will be the injection of particulate matter of several densities and diameters. The Response of each of the three monitors will be observed. If reasonably good mixing is occurring in the stack and the probes are withdrawing similar samples, the three curves on the multipoint recorder should follow the same trend. The rates of rise should be the same, the peak heights should be approximately equal, and the return to background of each instrument should follow the same pattern. The collected deposits will be examined by optical microscope to determine the efficiency and similarity of particle collection.

A fourth sample will be collected during the test in a filter-cartridge assembly located directly in the stack. Such a sampler, consisting of a simple curved-end probe with the collector on the end, has been in use for several months and is producing good data. Due to its inaccessibility and other features which make it difficult to manipulate, the sample is taken only once a week. These shortcomings are being rectified, however, and it is anticipated that in the near future our routine daily inventory samples will come from the in-stack sampler.



TAPE MONITOR EXPERIMENT AT PRINCIPAL ORNL STACK

Figure 7

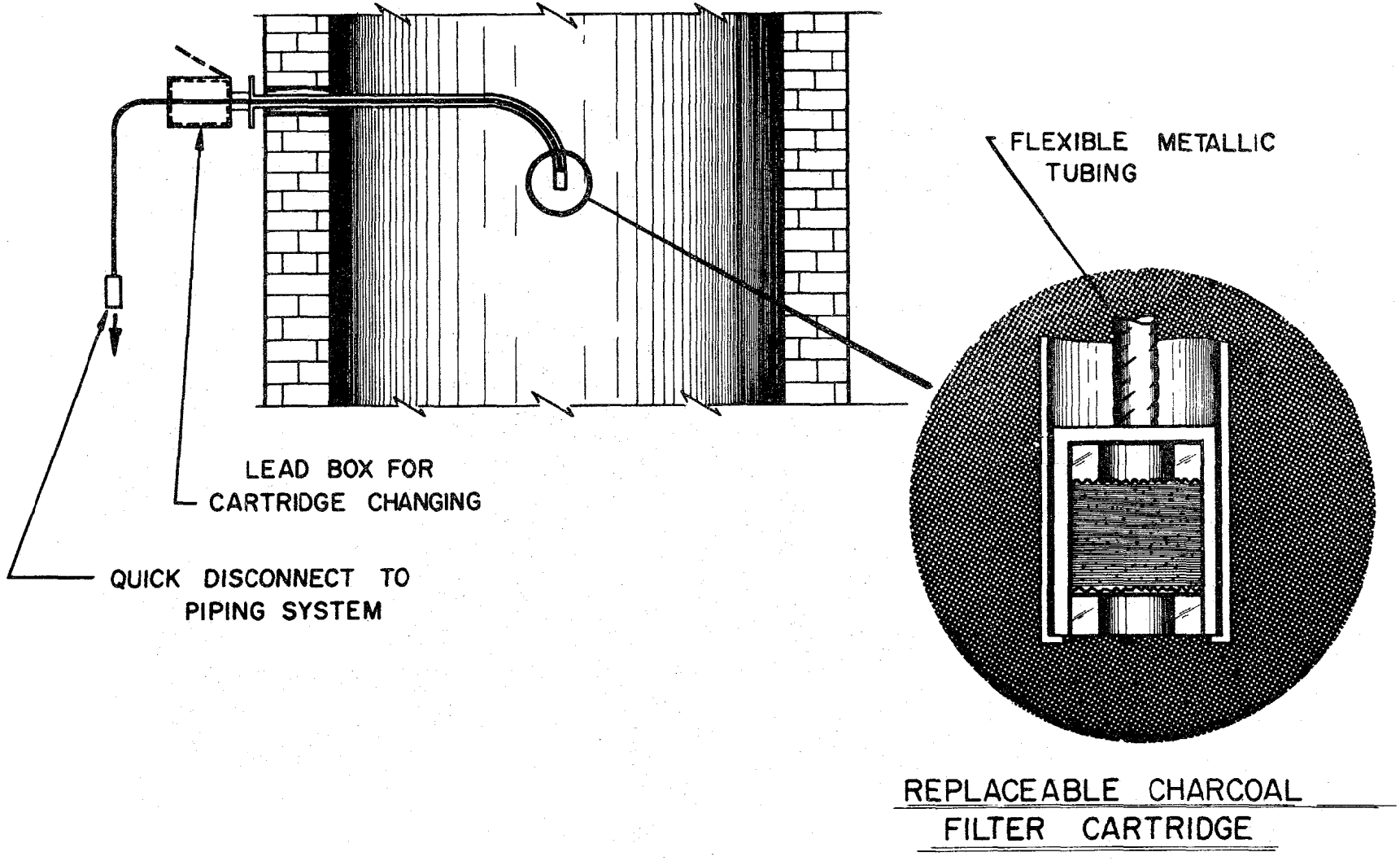
A conceptual sketch of a revised type of in-stack sampler is shown in Fig. 8. This design features a large (2 to 3 in.) rigid pipe permanently attached to the stack. Within the rigid pipe would run a flexible, bellows-type tube with a rabbit on the end which would contain the charcoal-filter cartridge. Stops within the guide pipe would seal the cartridge when in the sampling position. To change cartridges, the flexible tube would be withdrawn from the guide pipe until the rabbit was in a small lead box immediately outside the stack. The cartridge would then be changed, the assembly pushed back into the sampling position, and the pumping system reconnected. Quick-disconnect fittings would be used to facilitate the latter step.

Eventually we expect to replace the step tape monitor described earlier with a revised model now available at the Laboratory (Fig. 9). In this model 3" tape may be advanced stepwide on cycle, continuously, or on demand. It has one feature of the early model which was manually advanced in that the detector is located at the point of collection and thus detects activity as it is deposited. Shown here is the side window beta/gamma detector which is placed within the cylindrical shield; however, the instrument may be modified to provide alpha detection. Guard switches signal a tape break or a shortage of tape supply. The new tape monitor will not only be used on the stack sampling system but monitors will also replace the filter samplers now located on the ducts in the immediate stack area. These samplers, in turn, will be moved upstream to locations as near as possible to the individual processing and operating areas.

An improved sampler has also been devised which may, at certain locations, eventually replace the two-unit combination described earlier. In sampling the off-gas system, which operated at a negative pressure of 25 in. of H_2O, the two-unit device was found to leak badly. After many modifications and the use of much collodion and pipe dope, a completely new sampler was designed; this is shown in Figures 10 and 11. This sampler uses the conventional 1 1/2 in charcoal cartridge but only a 1 in filter, both elements being contained in a single unit. The two halves of the unit are sealed with an O-ring, and the use of a nut for closing prevents any possible damage to the filter due to twisting. Only one of these samplers has been fabricated and it has not yet been tested.

Another device for continuous stack monitoring, still in the design stage, is the gross-gamma or "stack shine" monitor. The rather unique design seen in Figure 12 envisions a group of four scintillation detectors positioned at the top of the stack in such a manner as to be exposed to any radiation from the stack effluent. Care must be taken that the detectors are not within the plume; otherwise, contamination will quickly become a problem. Also, their position must be slightly below the rim of the stack so that the radiation from the highly contaminated inner wall will not be detected. For maintenance and inspection purposes the detectors may be lowered by a pulley and cable arrangement in a manner similar to the way aircraft warning lights are manipulated. The first model of this device is under test; however, it is at ground level and obviously lacks sensitivity because of the distance involved.

The monitoring of gaseous waste presents a many-sided problem. We at ORNL have approached it in a manner which we hope will produce in a minimum time a system giving maximum security. It is our obligation and responsibility to strive for such security if the Laboratory is to operate in a safe manner and not become a hazard to our environment.



CONCEPTUAL DESIGN OF INSTACK SAMPLER - PRINCIPAL ORNL STACK

Figure 8

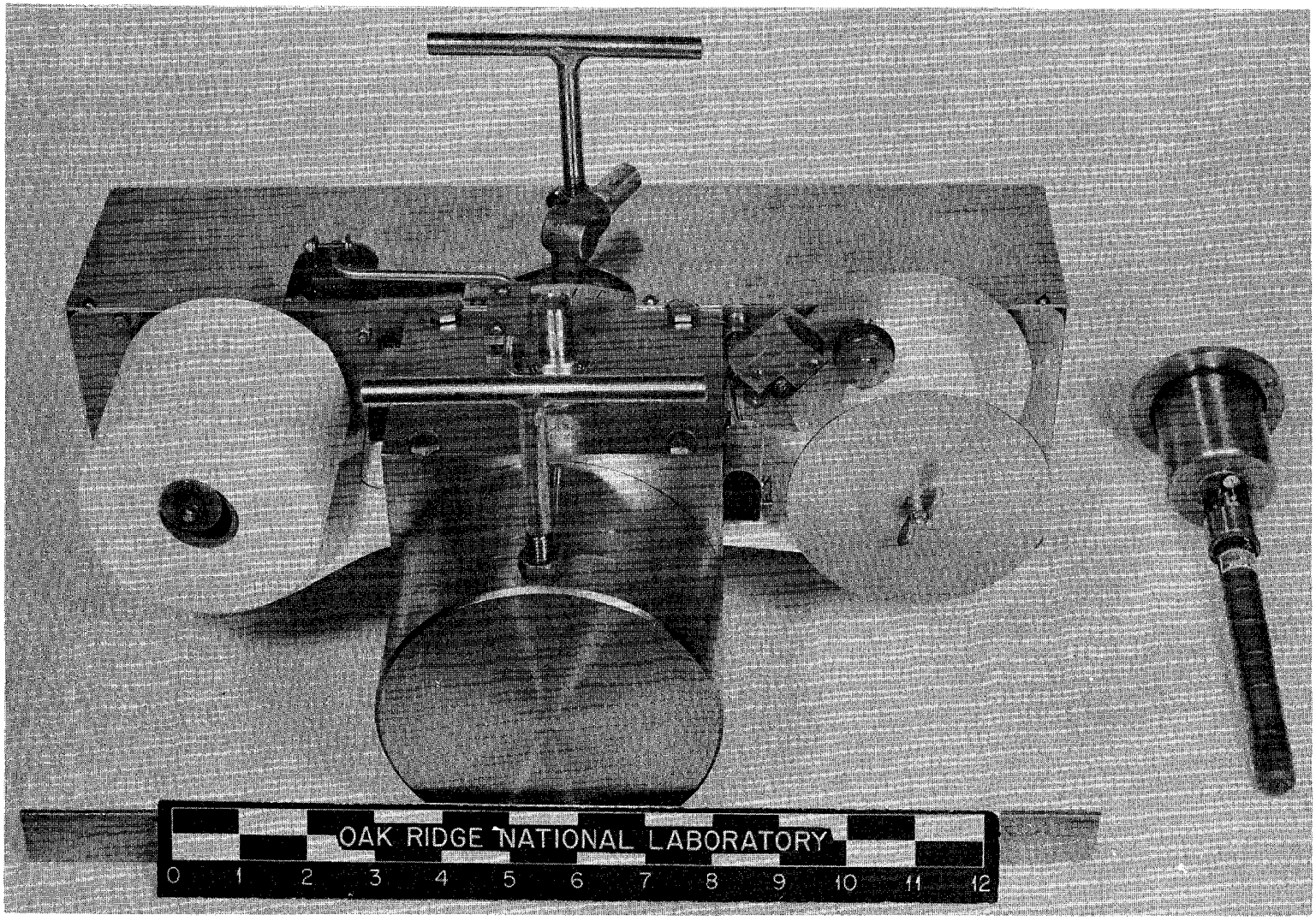


Figure 9

Figure 10

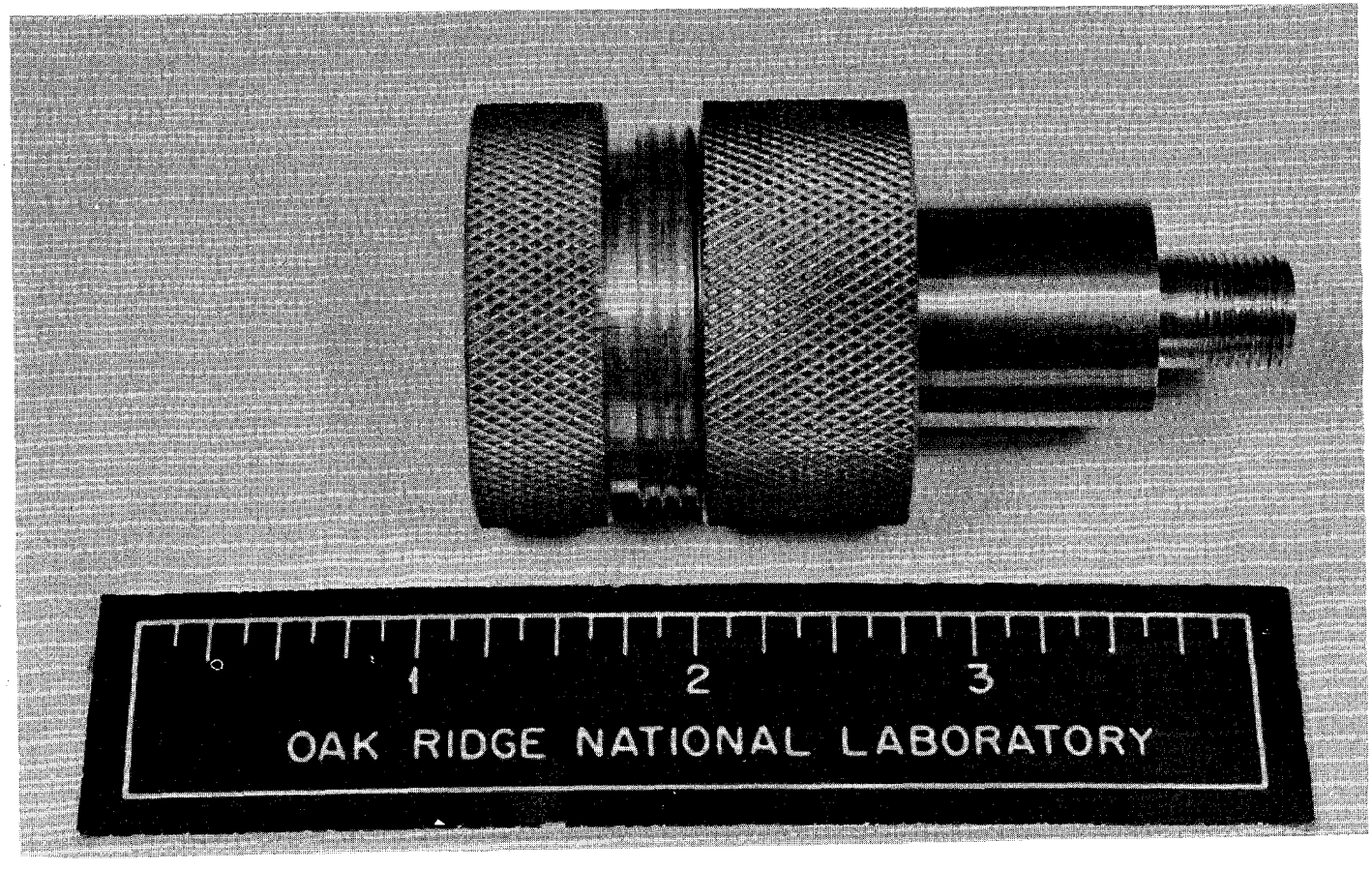
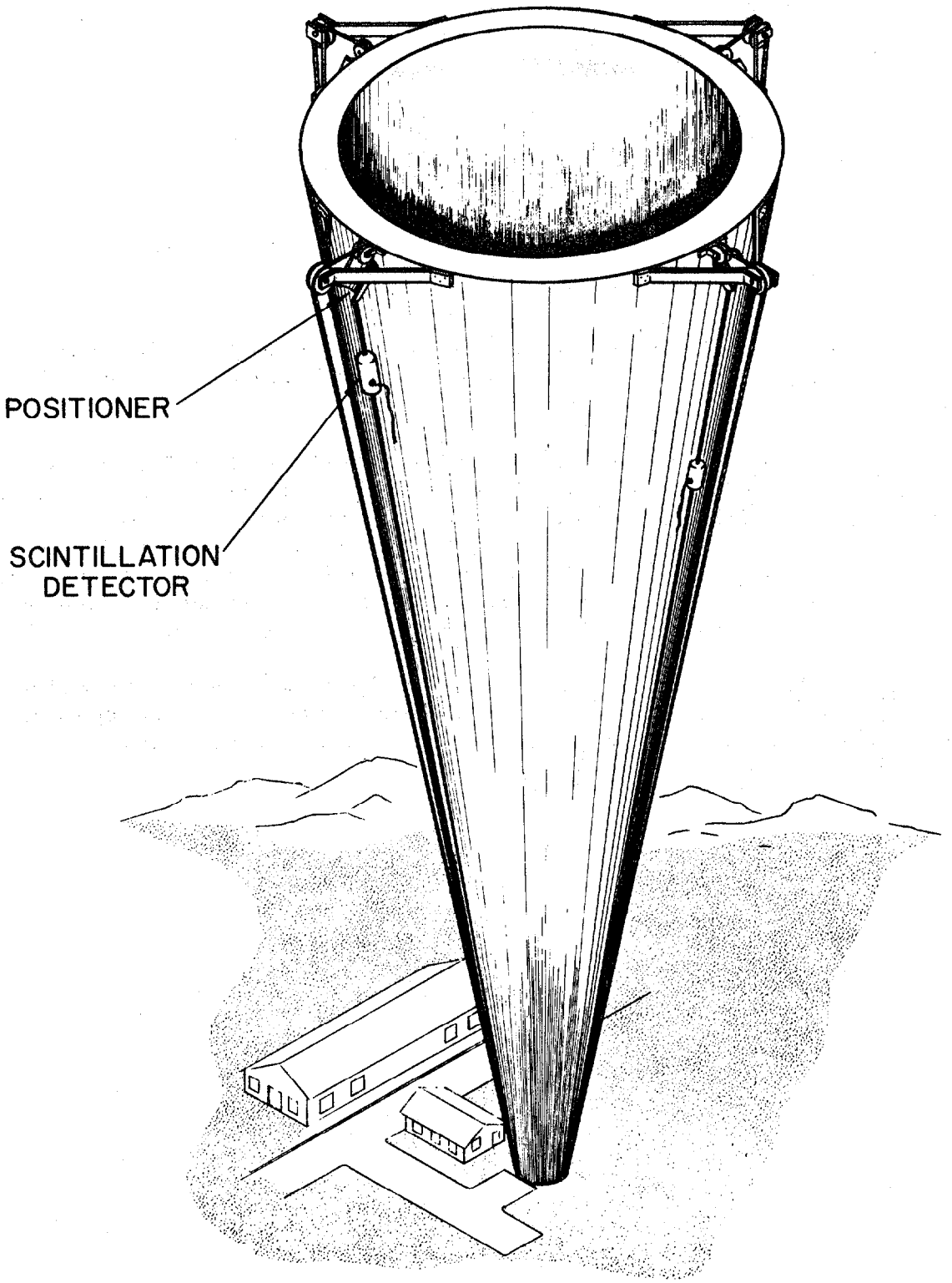


Figure 11



CONCEPTUAL DESIGN OF STACK SHINE MONITOR - PRINCIPAL ORNL STACK

Figure 12

DISCUSSION

CHAMPAGNE: Could you give us information as to the particle sizes associated with your various reactor stack effluents as well as data concerning the total activity released?

MANNESCHMIDT: I can't say much about particle sizes. In 1959, when we had the previously mentioned ruthenium release, we estimated particle sizes to be as great as 130u. These were found in the environment. I suspect that the size of the overage radioactive particle discharged is much less than this. As to total activity discharged, I would say it runs from three to fifteen curies per month, exclusive of the rare gases. Of course the calculated value depends greatly on where the sample is taken, hence the rather wide range.

BILLINGS: Thank you very much. The Oak Ridge problem has concerned them for a good many years, we know, because of the complexity of their operations and the inability to predict what is going to come out, in many cases.

PROCEDURES FOR TESTING HIGH PERFORMANCE FILTERS AT ORNL

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The application and importance of high efficiency filters in atomic energy installations for the removal of sub-micron radioactive particles is well known. In fact, such filters are the keystone of exhaust systems for the prevention of atmospheric contamination.

During the Sixth AEC Cleaning Seminar in 1959, emphasis was placed on the fact that significant quantities of high efficiency filters stocked by AEC contractors were found to be defective in a nine months period preceding the Conference. As a result of this development, a filter inspection and testing service was established by the United States Atomic Energy Commission on a voluntary basis for participants in the Atomic Energy Program.

The Oak Ridge National Laboratory participated in the quality assurance program, as described in AEC Accident and Fire Prevention Issue No. 105, and all filters were independently inspected by the Chemical Corps Arsenal, Edgewood, Maryland, before shipment to the Laboratory. While this resulted in a significant improvement in the situation, shipping and handling damage continued to be a problem. As an immediate consequence of this experience, the Laboratory embarked on an exploratory quality assurance program of its own. The investigation was divided into two major categories, namely: (1) to find an effective and practical method of testing filters upon receipt and prior to stocking, and (2) to find a practical method of testing filter installations.

As a result of this program, the Laboratory is now checking new filters, prior to stocking, for penetration efficiency and general condition and some progress has been made in testing filter installations. The purpose of this paper is to report on the status of the project to date pointing out problems which have been overcome and problems yet to be solved.

CATEGORY 1 - TESTING NEW FILTERS PRIOR TO STOCKING

Before a shipment is accepted each filter is given a visual inspection and also checked for penetration efficiency in accordance with MIL-STD-282, Method 102.9.1, "DOP-Smoke Penetration and Air Resistance of Filters".

Fig. 1 illustrates the visual inspection of a 24" x 24" high efficiency filter. The principal defects found by this method of inspection are cracks or tears in the filter medium, occurring typically, but not exclusively, at the glue-medium joint. Such defects constitute cause for rejection. Evidence of incipient cracks is noted since their existence is often reflected in the subsequent filter efficiency test by abnormal instrument fluctuations.

Fig. 2 shows the rig which the Laboratory developed for measuring the penetration efficiency of filters. A polydisperse aerosol is produced by the atomization of liquid dioctyl-phthalate (DOP) with compressed air in the chamber at the right hand end of the rig. The aerosol fog is swept through the rig by the incoming air, since the rig is on the suction side of the blower, passes through the filter under test and is then discharged to the atmosphere. The concentration of DOP upstream and downstream of the filter is measured by means of a Sinclair-Phoenix forward scattering photometer from which the filter efficiency may be readily calculated.

It should be noted that the filter testing rig has served its purpose as an experimental piece of equipment and that a new unit is to be built reflecting the experience gained to date. The problems associated with the present rig are:

1. Since it is on the suction side of the blower the pressure is sub-atmospheric and inward leakage of room air becomes a source of annoyance from time to time.

2. The short section of constant cross section upstream and downstream of the filter under test complicates metering of the air flow.

3. Filters smaller than 24" x 24" are installed in the test section with transition pieces but this makes pressure drop measurements inaccurate due to the resulting air turbulence on either side of the filter.

Other limitations of the test rig are probably apparent. To overcome these limitations the new installation will be designed with the following features:

1. The rig will be on the discharge side of the blower with the DOP injected into into the blower suction, since the blower is an excellent mixing plenum. In addition, this will alleviate the condition caused by operating the unit under sub-atmospheric pressures.

2. Means will be provided for installing filters of various sizes quickly and easily without sacrificing accuracy in pressure drop measurements.

3. A by-pass will be installed so that DOP generation and air flow can be maintained while switching test filters. The constant shutting off and starting up of the aerosol generators may alter particle size, in any case, it represents lost motion.

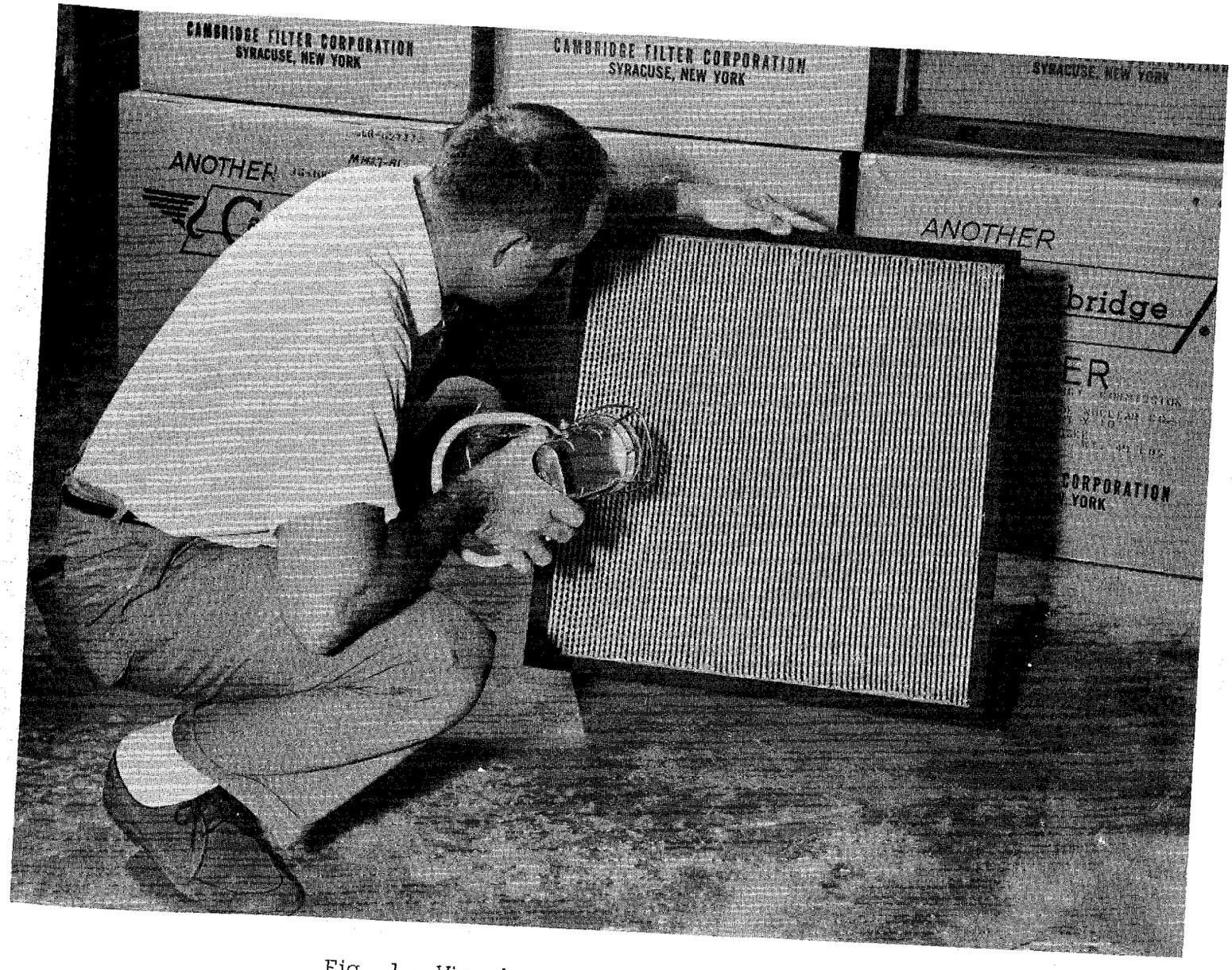

Fig. 1 - Visual inspection of a 24" x 24" filter

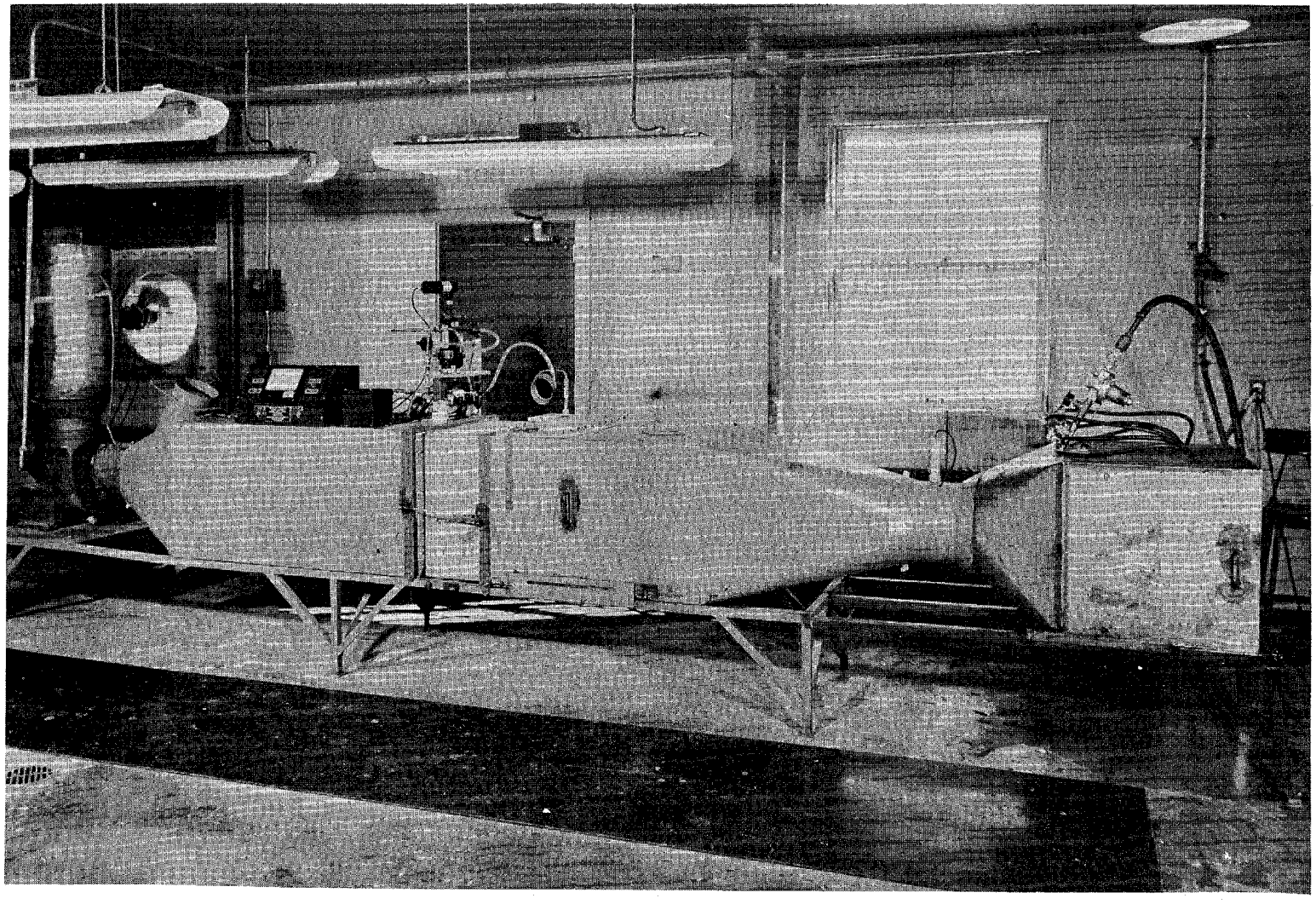

Fig. 2 - Filter test rig

The DOP or aerosol generators shown in Fig. 3, were built to approximate the generator described in Naval Research Laboratory Bulletin 6140-98/54 amc.

High efficiency filters are especially prone to damage from shock or puncture by tools and fingers as clearly indicated in Fig. 4, whereas Fig. 5 shows a suggested method of removing the filter from its carton. Fig 6 demonstrates one way of lifting a filter to avoid puncturing the filter medium.

The instrument which is used to measure the concentration of aerosol upstream and downstream of the filter under test is shown in Fig. 7. The instrument is a Sinclair-Phoenix smoke detector which measures the mass concentration of DOP by utilizing the small angle forward scattering of light from the smoke particles drawn through the chamber. The forward scattered light illuminates a photomultiplier tube and a logarithmic amplifier measures the phototube current and indicates the reading on a single scale meter.

The meter reading is converted to mass concentration by referring to a calibration curve supplied by the instrument manufacturer. Fig. 8 shows such a curve wherein Meter Reading is plotted versus Mass Concentration of DOP in micrograms per liter. The lower curve was supplied with the instrument. The Laboratory decided, however, to develop its own calibration curve and called upon the Naval Research Laboratory for assistance. The test rig was run at various concentrations of DOP and at each point the concentration of DOP was measured with the Naval Research Laboratory instrument and the Sinclair-Phoenix meter reading was recorded. Upon completion of these tests, and without touching any of the adjustments on the instruments, optical filters were inserted into the photometer and meter readings versus optical filter numbers were again recorded. This step provided the means of re-establishing the proper setting of the instrument at any time. The upper curve shown on the slide was thus developed and has been used ever since in the filter testing program.

MIL-STD-282, Method 102.9.1 states that the average particle size should be 0.3 microns diameter. In the course of our investigation to date we have not checked particle size produced by the DOP generators. In February and March of this year 66 new filters were tested in the rig for penetration efficiency as described above. The filters had been previously checked by the manufacturer and by the Army Chemical Center, Edgewood, Maryland, under the AEC Quality Assurance program. The efficiencies determined by ORNL were compared with the average of the efficiencies reported by the filter manufacturer and the Army Chemical Center. The comparison showed (1) 65% of ORNL efficiency measurements to be within $\pm$ 0.005 percentage points of the average of the reported value, (2) 29% to be within $\pm$ 0.005 and $\pm$ 0.010 percentage points, and (3) only 6% slightly in excess of $\pm$ 0.010 percentage points. In addition, the probability curve is essentially symmetrical with respect to the average of the reported efficiences. Fig. 9 illustrates these points. This seems to indicate that the calibration curve and the particle size of the DOP aerosol are sufficiently correct for such an investigation.

During the exploratory program there was speculation as to the effect on efficiency of a small hole in the filter medium. A single 1/8" diameter rod was

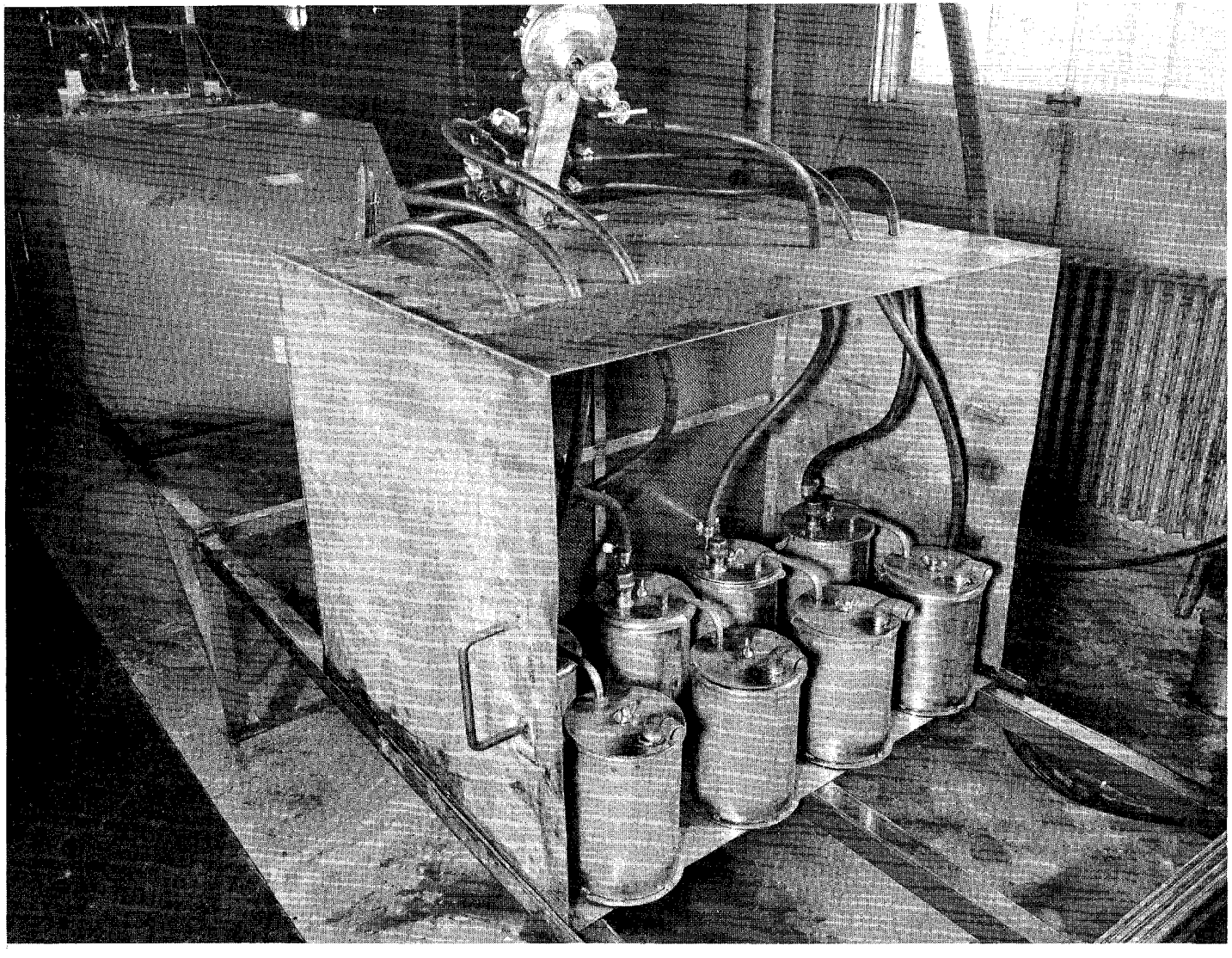

Fig. 3 - DOP generators installed in filter test rig

Fig. 4 - Filters are prone to damage

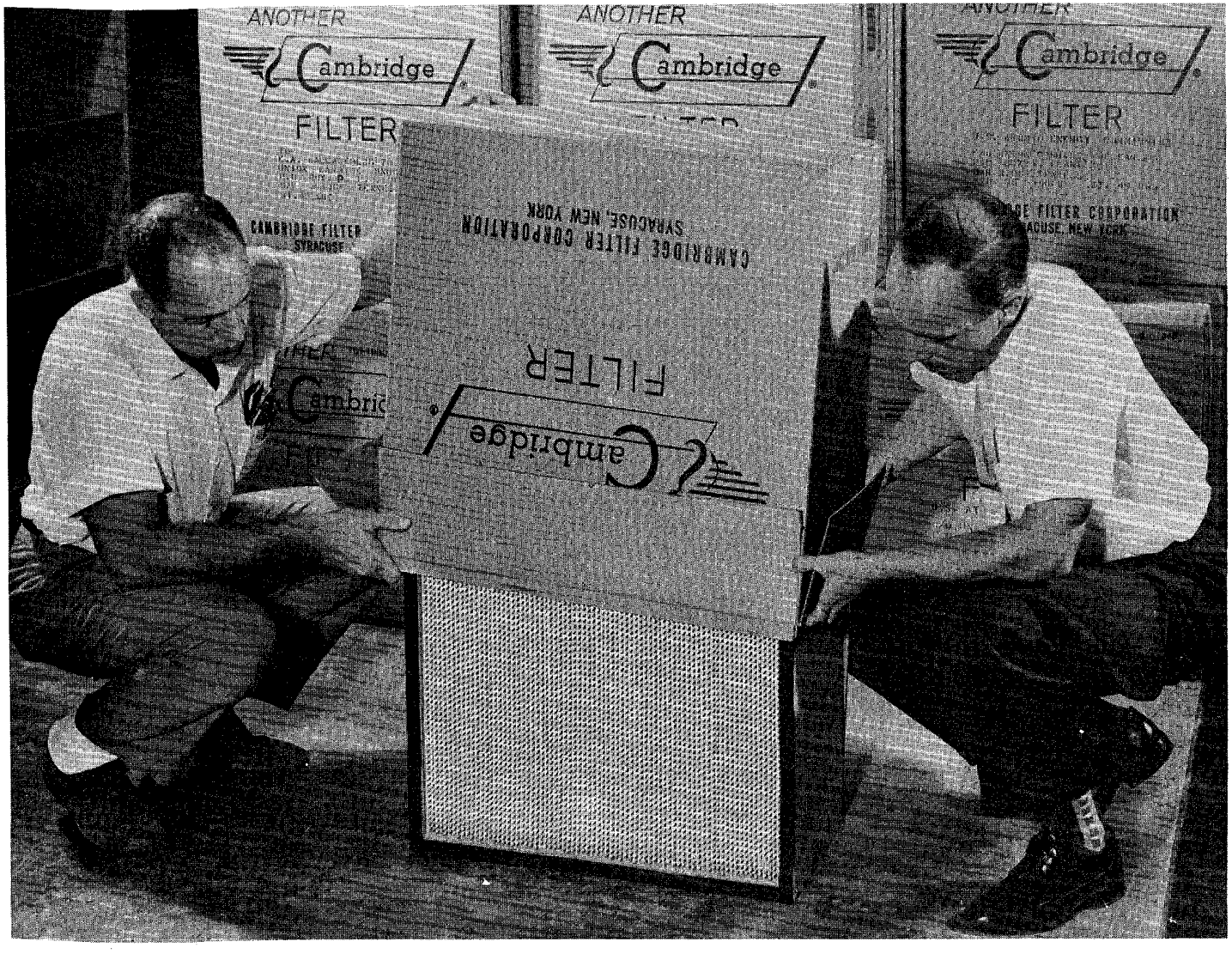

Fig. 5 - Suggested method of removing filter from carton

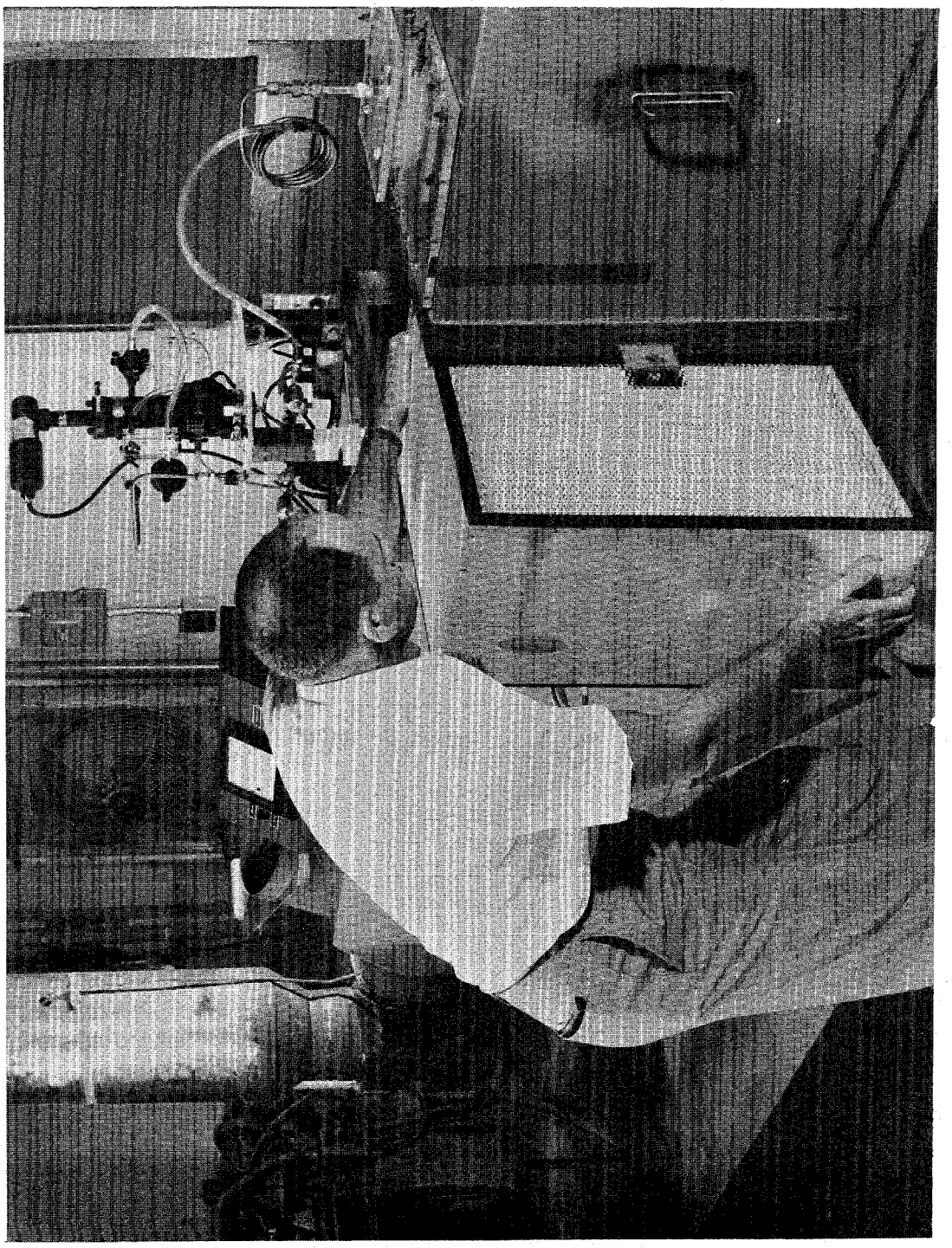

Fig. 6 - A proper method of carrying a filter

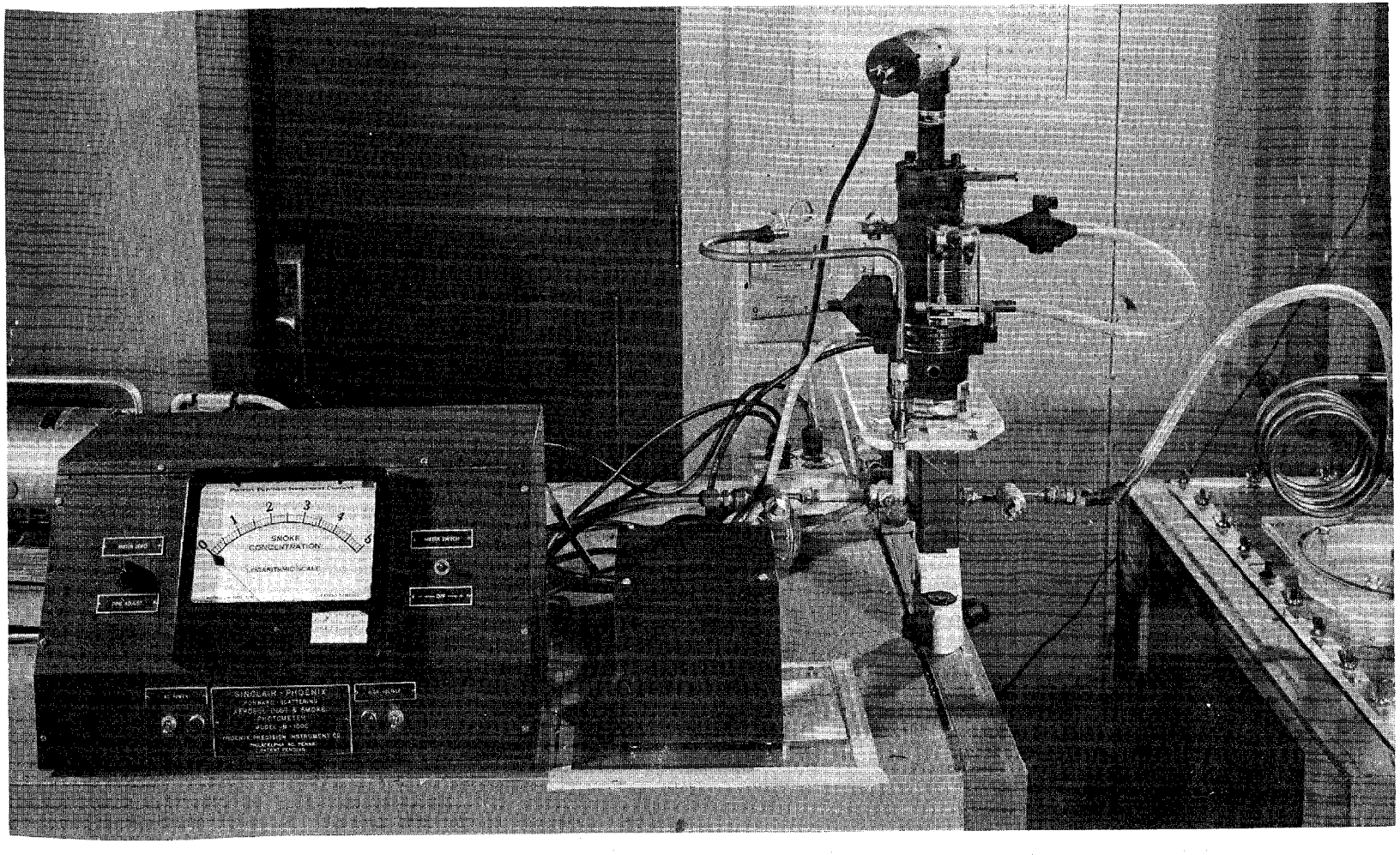

Fig. 7 - Forward scattering photometer

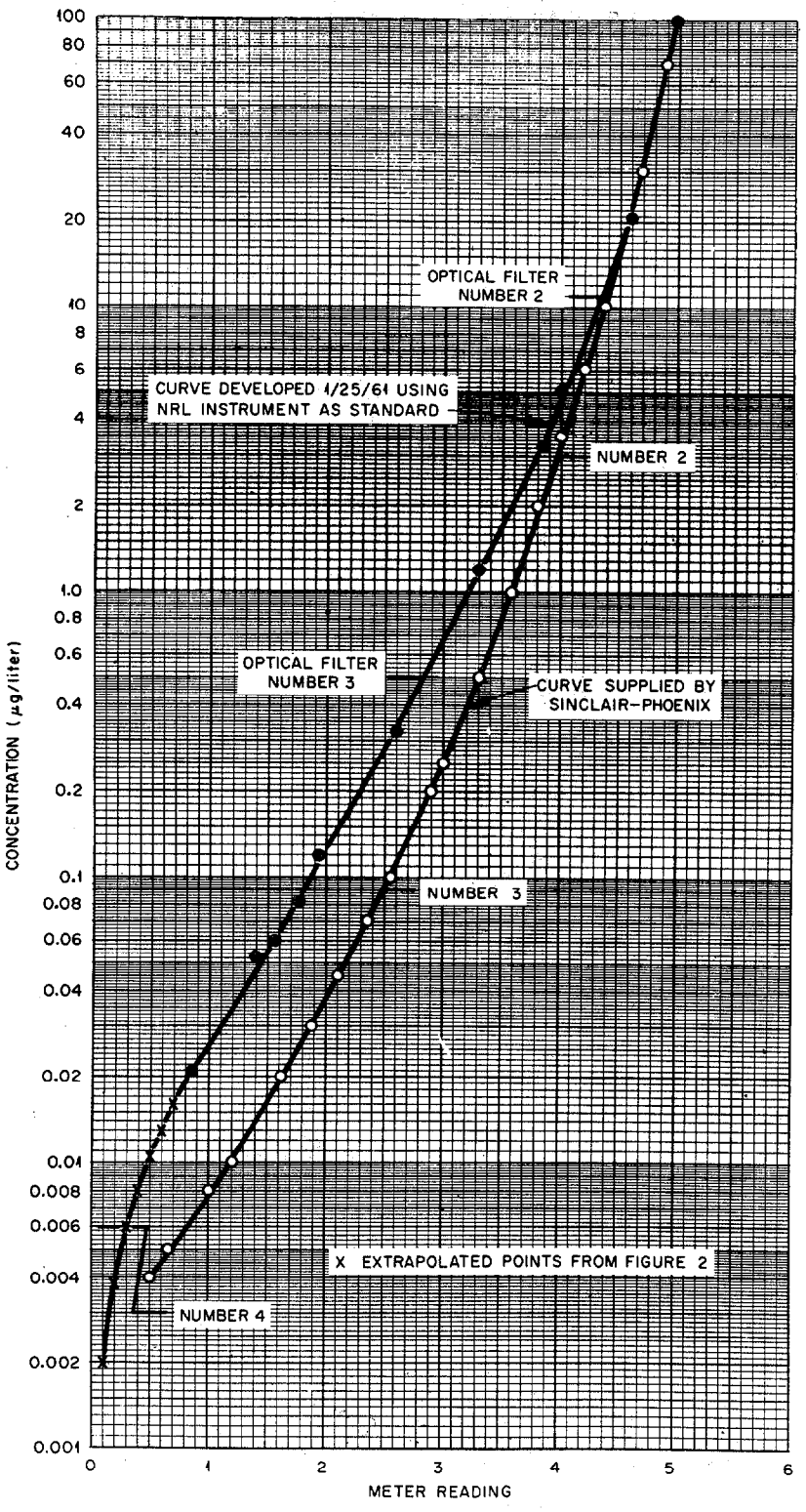

Fig. 8 - Instrument calibration curves

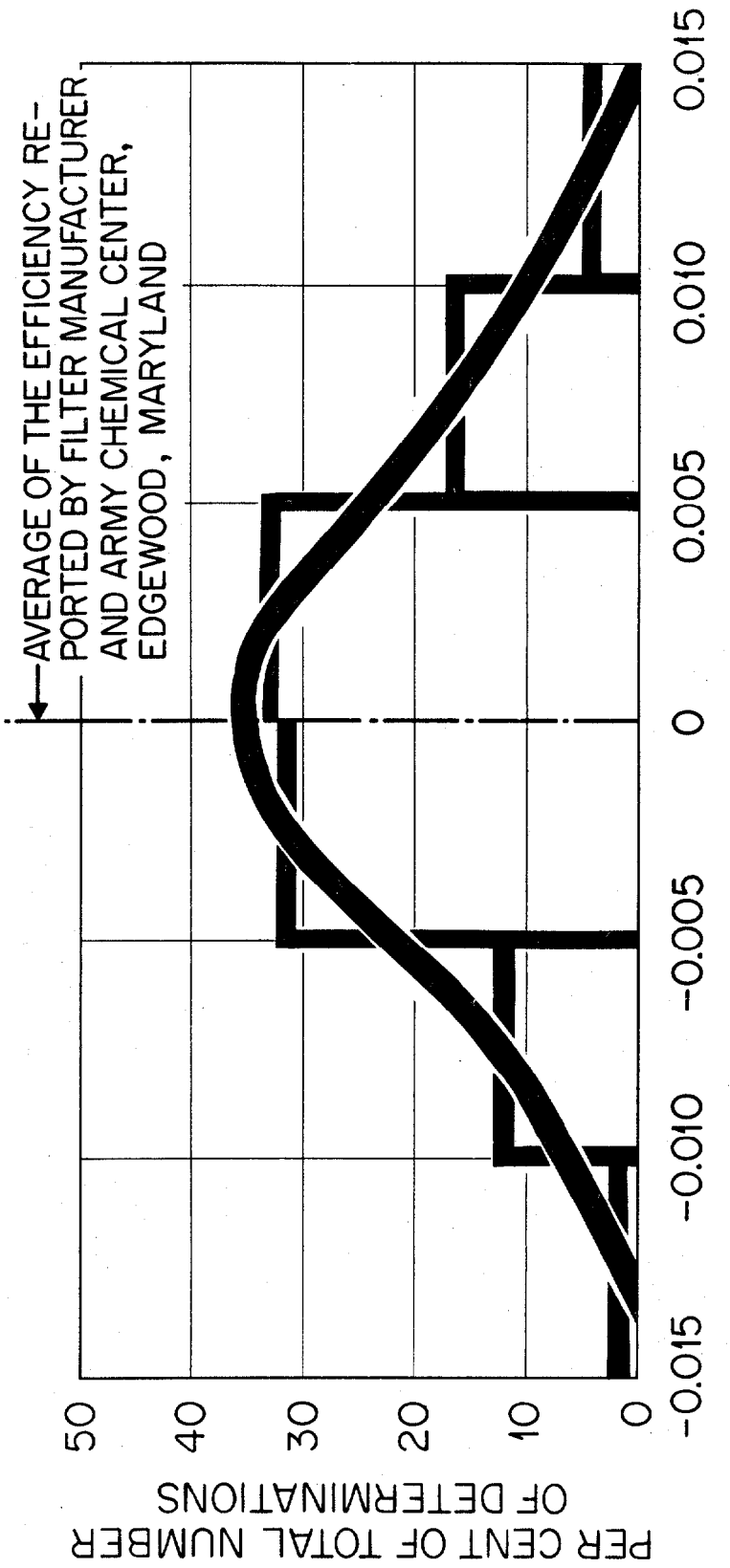

Fig. 9 - Efficiency distribution curve

pushed through a 24" x 24" filter and then removed. This lowered the efficiency from 99.98% average to 99.94% average. While the drop was only 0.04 percentage points this represented a change in the downstream meter reading of about 1/10 full scale or about 5 small scale divisions. The hole, in addition to making a significant difference in the downstream meter reading, caused the meter to be unstable, which, in itself, is a good indicator of a damaged filter.

CATEGORY 2 - TESTING FILTER INSTALLATIONS

Some progress has already been made in testing actual filter installations. Several relatively small uncontaminated off-gas systems have been checked using the same principle as employed in the rig. Fig. 10 shows one such exhaust system. DOP was introduced in the suction side of the system and its concentration measured with the forward scattering photometer through sampling ports upstream and downstream of the filter. The efficiency in this case is influenced by both DOP penetration through the filter as well as by-passing through leakage paths. The efficiency is therefore system efficiency and the only significant value insofar as atmospheric contamination is concerned. The system efficiency was measured four times each with a different CFM air flow. The system efficiency determined from each of the four tests was 99.970%, 99.969%, 99.970% and 99.965%. Comparing these values with the manufacturer's reported filter efficiency of 99.972% shows (1) that the filter was properly installed in a properly designed casing and (2) the ability of the DOP penetration testing technique to reproduce the manufacturer's data.

In another instance, several new Laboratory exhaust systems were checked by the same technique. In each case a low system efficiency was found. Subsequent investigation disclosed that the seams in the filter housing were of the crimped interlocking type which produced a continuous leakage path. In addition, the pressure drop across the filter, which was being used to seat the filter against its gasket, was ineffective.

Fig. 11 shows the obvious method of introducing DOP for measuring the system efficiency of Laboratory exhaust installations and Fig. 12 illustrates a bank of Laboratory filter units. A relatively large experiemental generator, intended for use in medium capacity exhaust systems, is compared with the small generators used in the filter test rig in Fig. 13.

The results so far have been encouraging, however, much work remains to be done, particularly in the direction of developing a technique for testing both small and large contaminated off-gas systems on a periodic basis. This is the next step to be taken as a part of the filter and filter system quality assurance program at the Oak Ridge National Laboratory.

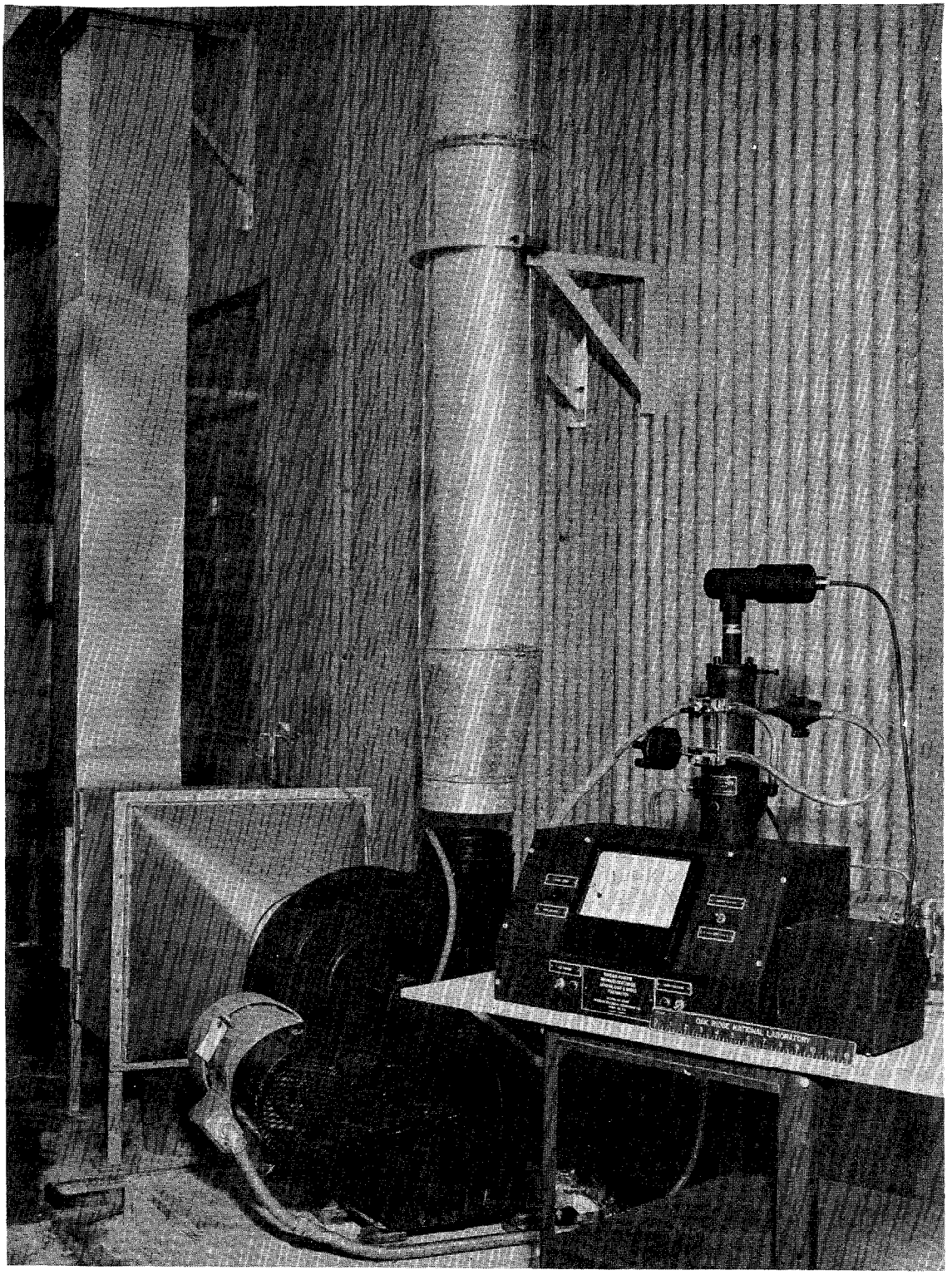

Fig. 10 - A small exhaust system

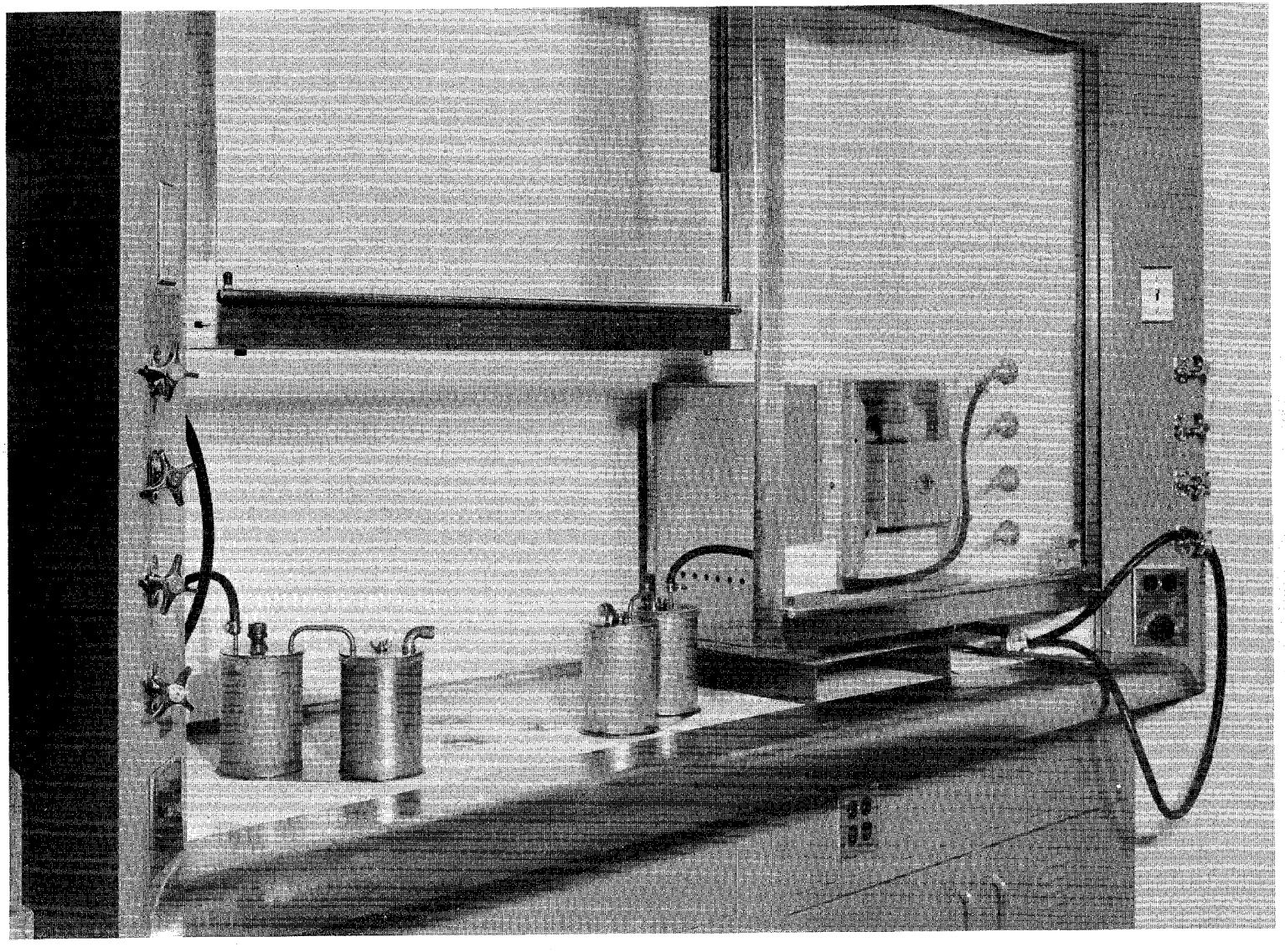

Fig. 11 - Introducing DOP for testing a laboratory exhaust system

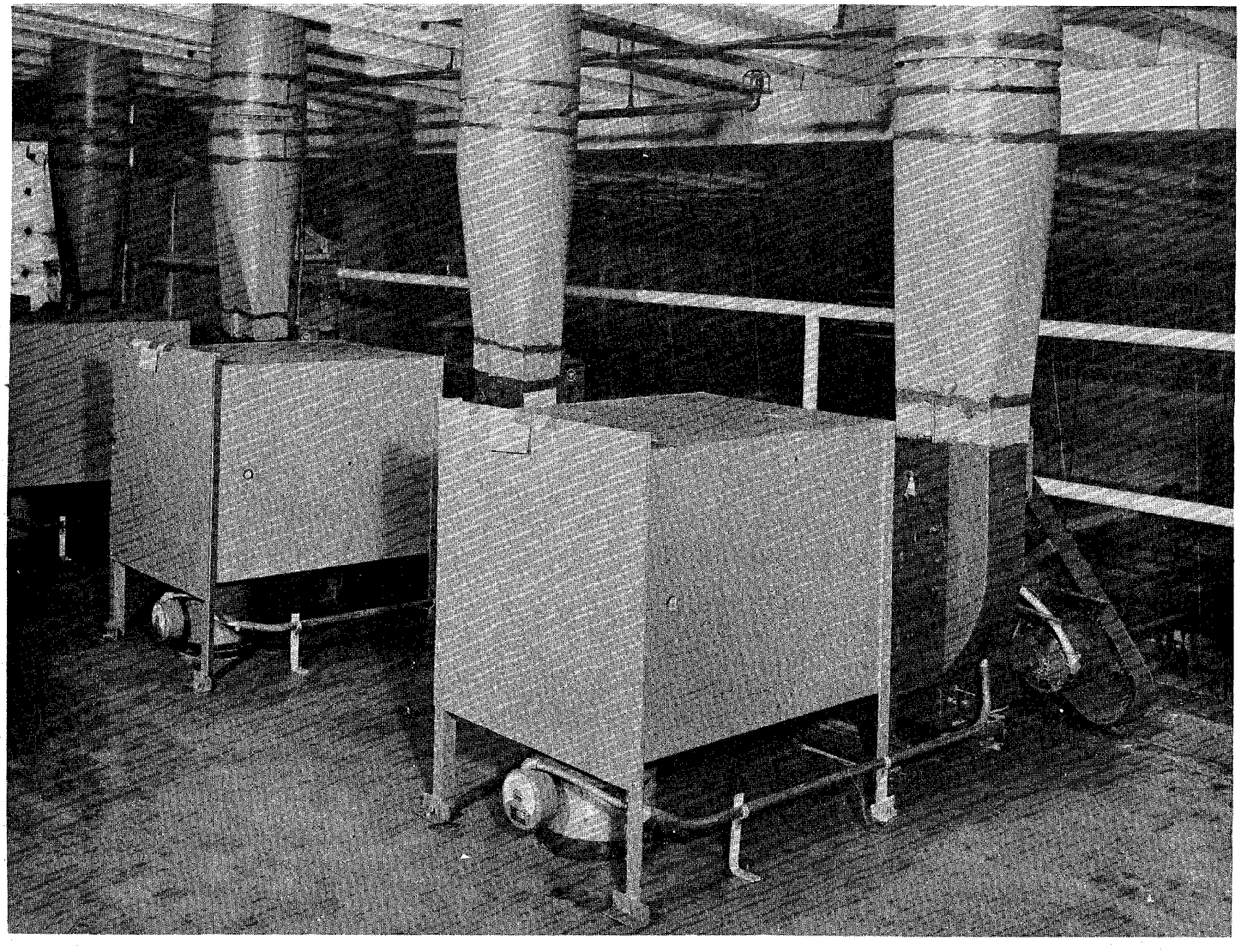

Fig. 12 - A bank of laboratory filter units

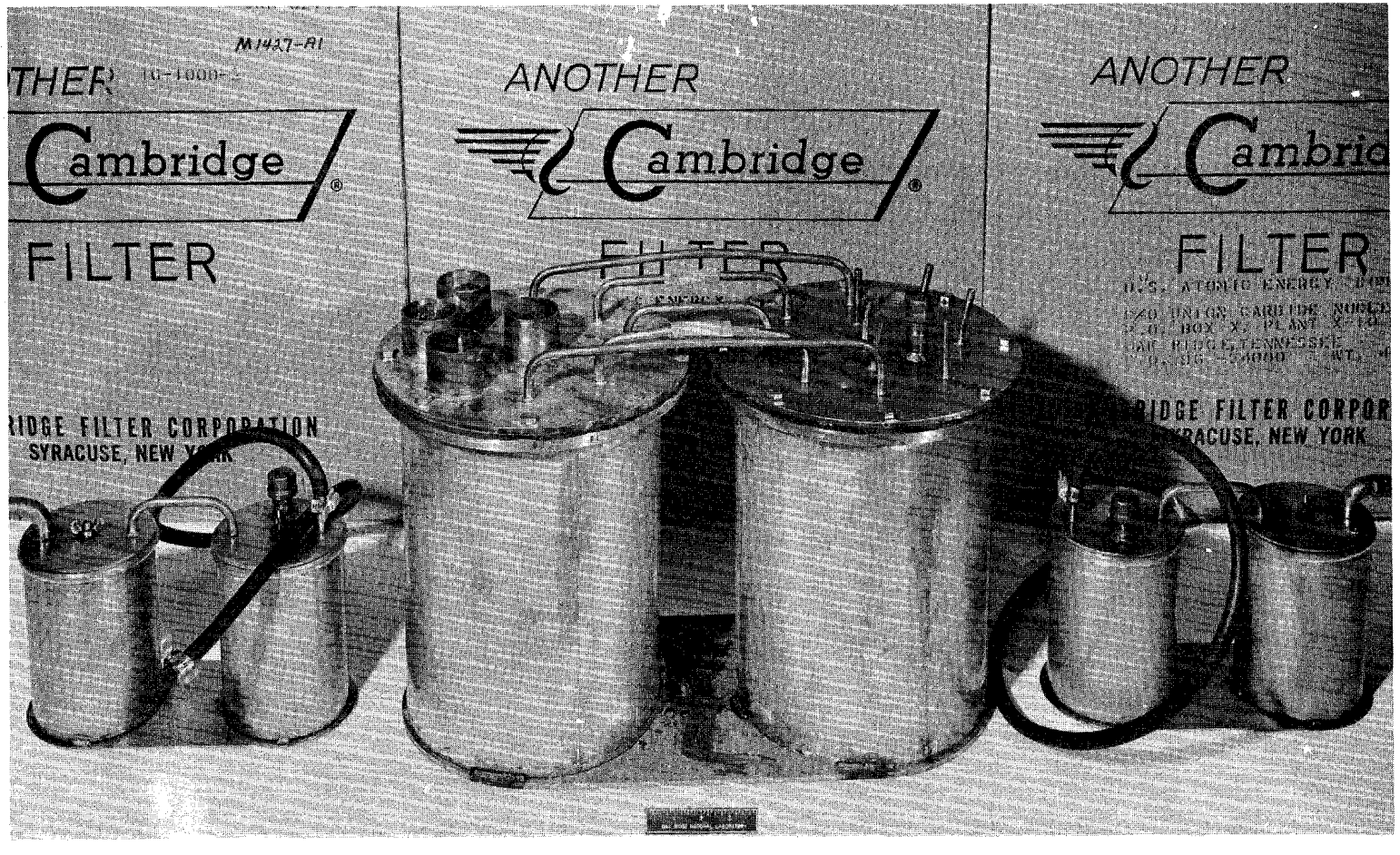

Fig. 13 - Small and large DOP generators

DISCUSSION

BILLINGS: Are there any questions relating to this presentation of Mr. Schneider's, the filter evaluation program at Oak Ridge?

COSTELLO: Did you find a variance between the testing efficiency reported by the filter manufacturer and that reported by the Edgewood, Maryland, Army Chemical Corps installation?

SCHNEIDER: In most cases there was some variation between the reported efficiencies and this is the reason that we took the average, at least for the first try, to see how we stacked up against it. The difference between that reported by the manufacturer and that reported by Edgewood was about the same order of magnitude as we found between the average. Any time that we had an obviously defective filter, we did not include it in the probability distribution data. We believed that this was the proper thing to do for what we were trying to show.

MURROW: Did you find the level of your liquid DOP in your generator having any effect on particle size or concentration?

SCHNEIDER: At no time, up to the present, have we checked the particle size. We have run the rig at different air flows for the same size filter and within the capabilities of the instrument and we detected no difference in the measured filter efficiency. We felt that it was not of immediate importance to check particle size, but instead to see if we could duplicate the efficiency reported by the manufacturer and by Edgewood. In other words, we wanted to get into business. We think we are in business and we have a few other immediate problems, but as soon as time permits I hope that we can go off on a tangent and investigate a few of these other points of interest.

BILLINGS: I would like to take the prerogative of the chair and summarize briefly what has been presented in this session, as an introduction to a general discussion.

We have done five things, according to my notes. We have talked about the AEC filter quality assurance program, which is essentially checking what the manufacturer stamps on the ultra-high efficiency filter, first, on receipt for acceptance and, second, for test prior to installation and the handling type of evaluation. We have discussed the forthcoming installation, handling, and maintenance manual, which is a very handy and useful compilation. We have

heard filter research discussed and some additional information from the Naval Research Laboratory on their research programs, and about our own research with regard to the in-place testing and also some additional information about what is going on at Oak Ridge. We have heard discussion on the relative merits of pre-filter, whether one should pre-filter or whether it is economically unfeasible.

In addition to this, a discussion has been presented on filtration of microbal particles related to a previous question regarding biological efficiency for filtration devices. Deposition of aerosols in sampling lines was also discussed, based on work done at Hanford on the collection efficiency of a sampling line and also from the standpoint of present and proposed programs at Oak Ridge for sampling their principal stack where major discharge occurs. Finally, we heard some information about two programs regarding electrostatic precipitators, the Naval Research precipitator for submarine atmosphere and for high volume sampling.

With regard to the AEC filter evaluation program, whether or not your own filters can be subject to this acceptance test, the answer is, apparently, yes. There are programs going on at Hanford and they would like to include everybody who has responsibility in this area. This is an invitation, in effect, to at least negotiate at this point. Mr. Gilbert has not mentioned cost. Is there a cost associated with this service?

GILBERT: This is all prepaid by the Commission, but there is a cost for lump sum construction. This is all covered in the bulletin.

MITCHELL: We have studied the retention of cigarette smoke in the lung and delved into the literature on deposition, on particle size and there is a dip at 0.3u to 0.4u which goes up quite rapidly in the 0.6u range and there are some pretty good figures. There is 20 per cent retention around 0.3 and you get your maximum retention at about 1.5u.

CRAIG: Even though the deposition of particles in the 0.3 to 0.4u size range may be a minimum, this is also the region of maximum stability of an aerosol. Particles of this size may, therefore, greatly outnumber those of both smaller and larger diameters, so that even though their percentage retention is low, the actual retention is not.

MITCHELL: I agree with you. The total retention would consist of the lower percentage retention times the higher concentration of aerosol in the 0.3 micron size range.

BILLINGS: This is also related to the problem of deposition in sampling lines, where the particle sizes are very important, as is the length of the line.

THAXTER: The question of aerosol stability may become a little academic, because in many of the radioactive effluents it is an extremely dilute aerosol, where you have many linear feet separating a 0.05u particle. That gets to be pretty academic, I think.

BILLINGS: This is true and apparently there is work going on with this in mind, as to how much activity associates itself with very small particles. This is the direction that research is moving in with regard to filtration as well. The HASL group is dealing with submicron particles because it doesn't take too many in this size range, where their radioactivity is high.

SILVERMAN: We have heard of at least two DOP generators. My understanding is that the 0.3u unit is a conventional boiler system. Does the Navy have one where they raise the pressure and get a smaller size particle?

YOUNG: Actually, since 1952, the Navy has developed three models of portable, air operated, DOP generators. The original device, now called Model 1, was developed for laboratory use. Models 2 and 3 are similar but have been modified for use in studies of filter efficiency, gas mask face leakage, glove box leakage and a number of similar problems. In all three models, the aerosol is generated by the action of high velocity air jets immersed in the liquid to be dispersed. Models 1 and 3 utilize a single nozzle immersed in DOP contained in a pint (or quart) sized paint can. The aerosol is conducted to a stripping can containing a jet impactor. The larger size particles are removed by impaction. The maximum size particle contained in the resultant aerosol depends on the air velocity and the design of the jet impactor. Model 2 generators are designed to operate at an air pressure of 25 psi. The four (0.080 inch) holes contained in the nozzle of the Model 3 generators are flow-controlling, and we find that air pressures above 25 psi do not increase the total concentration significantly. The generators Mr. Schneider used for his studies are based on the design of our Model 3 units. It is designed so that the average size on a light-scattering scale is of the order of 0.7 microns. Numberwise it will approximate 0.6 microns in average size with no particle larger than one micron. These Model 3 generators are designed to study filtration systems up to a capacity of 5000 cfm.

For use with larger capacity systems, we have designed the Model 2 generator. It would consist of a five gallon can containing six nozzles immersed in liquid DOP. This generator does not utilize a jet impactor and the average size particle will approximate 0.8 microns. We have evaluated filtration systems up to 50,000 cfm using these generators.

We have completed a study of these generators, which includes all the factors affecting aerosol concentration and size, which should be published in 1962.

SILVERMAN: If this is the case, why do you use DOP? The intent of DOP was to get a material that boiled at a certain temperature and gave a vapor that condensed to a certain particle size. You might as well use Diol-55 or anything else that has a comparable vapor pressure.

YOUNG: The total concentration and average size also depends on viscosity. The reason we use DOP is that it is available and inexpensive. It also has the advantage with its high boiling point of being a low fire hazard.

SILVERMAN: Yes. It turns out, really, that Schneider's test ought to agree with the manufacturer and, perhaps, be a little higher.

YOUNG: The accuracy is such that he is getting the same order of magnitude, it should be a little lower.

SILVERMAN: That is what I mean. His efficiency is higher.

LIPPMANN: The particles are not monodispersed and we say we can cut off the upper size range, but what about the lower sizes? How small will the smallest particles be?

YOUNG: I don't know what the minimum size is. I can't detect it. Actually, our curves show we will have 90 some per cent, which will be less than 1u. This will go down to the order of 0.1u or less.

SILVERMAN: Is that with the light scattering equipment?

YOUNG: Yes. The ends of our curve are very poor. We are using the straight linear part to determine the average size. In all these cases, the curve fades off at both ends.

SILVERMAN: You don't really know what is down below 0.1?

YOUNG: That's right.

BILLINGS: Did you not measure smoke particle size by means of jet impactors?

YOUNG: Yes. We determine the average size by the use of a series of calibrated jet impactors. We measure the percentage getting through each impactor and obtain the average size by use of a log-probability graph.

WHEELER: I would like to hear more discussion about light scattering devices. What are their limitations; what particle size and aerosol concentration can be determined? How expensive is a light scattering device?

YOUNG: The logarithmic amplifier type light-scattering instrument such as Sinclair-Phoenix costs about $1500.

WEHMANN: We actually have one that cost about $2600 with recorder.

WHEELER: Is that 90 or 180 degrees?

BILLINGS: This is a concentration measuring device; this is not an Owl. Does this give you particle size information?

YOUNG: Only by derived methods, as I illustrated here. The Owl is about $600 to $1000. This is where you can get particle size.

ANDERSON: What is the cost of the ROYCO particle counter?

BILLINGS: $7800.

YOUNG: The light-scattering meters and the "owls" differ in that the former are used to measure the light scattered from the particles contained in the illuminated chamber. The "owls" in contrast are used to measure the polarization angle of the scattered light. For more detailed information and theory, I refer you to the AEC Handbook on Aerosols or the recent book of Green and Lane which contain excellent reviews of these instruments.

SILVERMAN: We can also buy a light scattering photometer from American Instrument Co. They have had one on the market for a long time. There are half a dozen less elaborate ones by Frank Gucker and others who put these things together. One of the difficulties with all of them, really, is the question of how much amplification you have to put in to get readings at low concentration. I am not familiar enough with the Navy to know what the minimum concentration is, but it is pretty high, relative to some of the numbers we have been talking about. It is milligrams per cubic meter.

YOUNG: It reads to .001 per cent.

SILVERMAN: Dividing 80 milligrams per cubic meter -- you divide that by 1000. If you are starting with a filter that is 99.9, you have another thousand factor to push your concentration up to read this at the bottom. This is the whole point of the system. As contrasted to particle counting, which of course is the most difficult test for any filter to pass, that is the actual number of particles penetrating, I don't think that this is really a practical system for

large-scale testing, but this is what Royco has proposed and then you obtain a count efficiency. These people are trying to sell these gadgets for white rooms and it is probably the last thing that anybody with a white room needs. All he needs essentially is a Bausch & Lomb dust counter as a measurement of the average performance from day to day. There are a lot of systems for measurement of this type.

Getting back to the system we described earlier, where you use uranine, this calls for only a spectrophoto fluorimeter, which is about a $1000 instrument. It is used for measuring fluorescence and several laboratories are equipped to measure uranium with this device.

From that standpoint, the analytical procedures are simple. I would think that in the not too distant future one of the methods of choice will be activation analysis, since we are getting better methods of producing less expensive sources of neutrons for this purpose. If we get an aerosol that can be activated, we will be able to make the measurements in comparable ranges.

BILLINGS: There was an additional comment regarding Royco and another instrument made by Southern Research, and it is in about the same price range. We might also mention Lindekin's works on the West Coast, where they used naturally-occurring airborne activity.

GILBERT: Is the Southern Research unit now commercially available?

SILVERMAN: One of the problems in the white room business is that these people want to get hold of Bausch & Lomb dust counters. This device is a jet impacter with a microscope and you can count the slide directly with a dark field microscope in place. They make these up in batches of a hundred. They wait until they get enough orders before they start to make another batch. It is one of those instruments that is on again, off again, but there are quite a few of them in use in dust control.

ANDERSON: We have been informed that the company has completed their engineering study and have forwarded the pre-production unit to SRI for evaluation. It is our understanding that they are anticipating production of the completed unit.

LIEBERMAN: We also have a single particle counter that we don't sell, by the way. We use it ourselves. My question, though, is that we have used this instrument in evaluation of absolute filters and we have noticed that when we tighten down on the sponge rubber gaskets the per cent of infiltration decreases until the point where we are deforming the wooden frame. When we replace the sponge rubber with impervious tubing, we get a good seal. With that, we get a very good (low) penetration figure. Does anybody have anything comparable on the penetration through the sponge rubber.

YOUNG: Gasket leakage is a notorious source of trouble and may arise from a number of factors including: (1) the use of porous gasket material such as open cellular sponge, (2) compression setting which in time can provide leakage channels, (3) poor seals at gasket joints, and (4) distortion or tearing of the gasket caused by the non-planarity of filter frame or sealing surfaces on the framework supporting the filters. The best gaskets we've found are molded, refrigerator type gaskets but these are, of course, more expensive. There was some work done at Hanford a few years ago on the pressure required to seal a filter in its framework, but no one to our knowledge has done a complete study of the gasket problem. We have initiated some studies on the gasket problem but are not able to make any conclusions at this time.

STERN: I would like to extend the data, in a general sense, for the I.P.C. paper. In this connection we have used very dilute aerosols of polystyrene latex and have used a polio virus to determine the penetration or collection efficiency. Where you find no data in Posner's paper between 5 to 50 feet per minute, it turns out that the collection efficiency of the I.P.C. filter actually increases. Our work has been done at reduced pressures and, for example, I can recall that at 17 millibar pressure and a face velocity of 5 ft/min the collection efficiency for the polio virus goes up to 100 per cent. You get a complete reversal in collection efficiency and this is equally true at ambient pressures for particles as small as -- well, about 0.1u. The polystyrene, at 0.1u might have a collection efficiency of the order of 35 per cent, somewheres near 3 feet per minute. We have studied this particular collection in the diffusion regime quite thoroughly and we have been able to show that the single-fiber efficiency is related to the peclet number. The same trend is equally true at ambient pressures and we have data on that.

BILLINGS: This data is for ambient pressure at sea level, approximately?

STERN: Yes. At 3-1/2 feet per minute the collection efficiency of the 0.138u particle is in the order of about 53%. The 0.365u particle has a collection efficiency of about 48%.

BILLINGS: Same velocity?

STERN: Yes. The 0.55u particle has a collection efficiency of about 38%. The 1.1u particle has a collection efficiency of about 32%.

SILVERMAN: I would like to raise one point here that I think is important in this business of testing filters with solid aerosols, because I think you have to recognize that the DOP test is an initial evaluation and has nothing to do with how the filter will perform in continuous operation with solid aerosols. This is not so true of absolute filtration, but it is certainly true of the pre-filter types that go all the way up to 95 per cent.

After you get a significant dust deposit, it is the adhesive force that becomes important and you have re-entrainment problems that become important. You reach a point where it starts coming off and any tests you had made indicating a base efficiency could be off in this regard. The one DOP characteristic that is important here is that it is a wet aerosol and is absorbed by the fiber. It can actually plasticize membrane filters and you can get into some difficulty. I think, in the practical aspects, this isn't too serious, but it applies to filters that have been in service for some time. The problem of re-entrainment becomes something to be concerned about.

ANDERSON: We appear to have some discrepancy in the reported penetration values for filter materials at low face velocities. Would you please comment?

SILVERMAN: There are two things important here, whether we are in the impact range or in a fuzzy range -- you have to remember that all the solid aerosols that have been described today have specific gravities that are significantly higher, so that you get impactability as an effect on the larger sizes, for example at .27u Fitzgerald used potassium permanganate aerosols, which are high in specific gravity in comparison to uranine.

There are small differences between DOP and uranine, but there are big differences between DOP and potassium permanganate. Fitzgerald and Detwiler also used aluminum aerosols, which would be about 2.6 in specific gravity. There are two factors that have not been pinpointed: One is the specific gravity and the other is the shape factor. Everybody that tries to produce a spherical aerosol feels confident that he had a shape that is reproducible, but if you take a crystal and find that it rehydrates, you may no longer have the original spherical shape factor.

ANDERSON: It appears that we have a sharp division. We have virus and bacteria (solid) and DOP (liquid) agreeing on one side and Fitzgerald (solid) and NYO (solid) data on the other. Yet if one compares all of the data, some disagreement is evident. There must be some difference in filtration mechanism or discrepancy in experimental technique.

ANDERSON: The bacteria won't follow that reasoning.

SILVERMAN: Not all the bacterial studies.

ANDERSON: The General Mills' data fits right in with that.

SILVERMAN: They used the material as an aerosol rather than as a viable agent.

STERN: We used both.

SILVERMAN: One thing has to be explained. You are not using the same measuring system. You are converting the DOP to weight equivalent, but it is by light scatter, which is a particle surface phenomena. I don't recall your work except that the polystyrene latex was pretty well controlled in size and would probably fit it should be comparable to uranine.

ANDERSON: We agree that if the data should be comparable to uranine, but we also believe that a close inspection will show differences especially at the low particle sizes.

SILVERMAN: The fuzzy range is between 0.4 and 0.05. As far as I know, I think everybody that has done any rechecking has confirmed the fact that in the diffusion range regime your efficiency is going to climb and the point at which it starts to climb is ill defined. Fitzgerald said it was velocity dependent, but other people say it is not. All I can do is put a cross-hatched area between 0.3 and.05 and say that some place in there it goes through a valley and starts climbing. There is a difference here in how far impaction extends. La Mer claims it extends down to less than 0.1u.

BILLINGS: Apparently there has been considerable revision or re-evaluation of Fitzgerald's data.

ANDERSON: We can't reproduce Fitzgerald's penetration curves.

SILVERMAN: We agree with you. I have not been able to check Fitzgerald. We tried to examine his original membrane filters. It is almost an impossibility to distinguish the particles from the background, if you look at his photograph. We have tried to reproduce the study with uranine at different sizes. Instead of the jet impaction force, we used impingers at different velocities.

When we get down in the range where we get the penetrations he says you get, we don't check his numbers. We find that we can penetrate H. A. millipore to about 30% at a size when he says the penetration should be only 5 per cent. We are inclined to doubt his data at the moment.

BILLINGS: Millipore is a tricky one.

SILVERMAN: It has a charge effect.

BILLINGS: Therefore, you have another whole area of no parameters to work with and no theory to work with.

ANDERSON: I think we are in agreement and we are just saying different things.

SILVERMAN: I think we had some data from Savannah River and some from Oak Ridge that showed that we have to take this on the basis of actual field performance -- it showed that if you had dust-stop filters in front of absolute filters -- the life of the absolute was doubled and there was enough confirmation of this to lead you to believe that maybe there is something in the Hanford air. The size distribution is not representative and I still raise a lot of doubt about redispersing settled dust as an aerosol that would simulate the original dust.

YOUNG: About four years ago, the Navy and Chemical Corps completed a joint survey to compare electrostatic precipitators and high-efficiency filters. Three stations were set up; one at Yuma Arizona, one at Edgewood, Maryland, the third at Brooklyn Navy Yard. Yuma was hot and dusty; Edgewood hot and humid and Brooklyn was hot and dirty. This study included a three year period using normal atmospheric contamination. A part of this study was to evaluate the lifetimes of high-efficiency filters with and without prefilters. The criterion used was the time required to double the initial pressure drop across the filter at rated flow. We got the same result; namely that with a prefilter, the life was doubled at all three locations.

BILLINGS: Has this been reported?

YOUNG: In NRL and Chemical Corps documents. The Chemical Corps reference is CWL Technical Memo 32-27 of May 1958.

HEACOCK: A few comments regarding the Hanford filter installation appear to be in order to clarify some of the preceeding discussion. As most of you are aware, we have proceeded with the installation of filters in our confinement system without providing a roughing filter upstream of the absolute filters. Our basic decision to proceed in this manner was based in part upon the filter tests performed by Mr. Wisehart which were reported at the last Air Cleaning Conference and earlier in today's discussion. These tests indicated that while roughing filters would remove the larger dirt particles, they would not remove the smaller sized material which effectively determines the absolute filter loading. The results of these tests may be peculiar to the building arrangements and atmospheric conditions at Hanford; however, we believe our conclusion in this regard valid.

In our particular installation, reactor down time for filter replacement and personnel radiation exposure during the replacement process are both very critical. Since Mr. Wisehart's tests did not indicate that the use of roughing filters would provide any significant extension of the life of the

absolute filters the installation of roughing filters was not felt to be justified. Another relevant factor is that the installed cost of a bank of roughing filters would be nearly equal that of a bank of absolute filters. Our tests also indicate that change out of roughing filters would be required on a frequency two to three times that of the absolute filters. Thus the additional expenditure of funds for installation of roughing filters did not appear to be justified unless a substantial increase in absolute filter life was obtained.

There are a number of factors which contribute to our conclusions regarding the use of roughing filters which may be considered somewhat different from the normal absolute filter installation. Among these is the fact that in our air supply system the air washers are routinely operated and effectively remove most of the large sized dirt particles prior to introduction into the reactor building, which would otherwise be removed by a roughing filter. A roughing filter similar to those which would be installed upstream of the absolute filters is also included in the ventilation supply system in a non-radioactive zone.

Secondly, due to the relatively large size of our reactor buildings we have found that they effectively act as a settling chamber or plenum for any of the larger sized dirt particles which may enter the building by leakage or through the supply system. We have also raised the intake of our supply system some distance into the air to reduce the amount of dirt which is normally carried into the supply system.

In order to verify our proposed design, several test installations of filter banks were made in representative reactor building exhaust ventilation air streams. Tests have been made on parallel systems both with and without roughing filters installed upstream of the absolute filters. After 12 to 18 months operation we have found that the roughing filters have not significantly reduced the loading of absolute filters in further support of Mr. Wisehart's initial test results. We have also found the loading of these filters has been relatively insensitive to outside atmospheric conditions. It has been found however, that the absolute filter loading has been influenced by maintenance and other related dirt generating activities within the buildings and that significant increases in filter pressure drop can generally be related to a specific maintenance or housekeeping operation. It should also be recognized that normal atmospheric conditions at Hanford do not correspond to the relatively dirty atmosphere normally found in many other parts of the country.

I would like to emphasize that the conditions which led to our decision to omit roughing filters may be peculiar to our installation and not generally applicable to other filter systems. However, our experience to date has justified our decision. For example in one of the eight areas involved, the pressure drop across the filters after one year's operation is only 1.2 inches w.g. and other areas are correspondingly good. This together with the high labor cost of changing a filter bank has provided substantiation for the decision that the installation of roughing filters in our reactor confinement system was not justified.