SESSION XIII

OPEN END

Thursday, August 31, 1972
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OPENING REMARKS OF SESSION CHAIRMAN:

I would like to make a few brief statements before beginning our last session. First, I would like to express your appreciation, as well as my own, to Clifford Burchsted of ORNL, who is the Local Arrangements Chairman. I think he's done a wonderful job, and all of us appreciate greatly the enormous ease and speed with which all of the functions of the Conference have proceeded.

I would like to thank, as well, several of the people who have been his principal assistants. I speak particularly of Charles Normand, of the Personnel Section of ORNL, and James Corum, of the Engineering Division, who have been excellent hosts. In addition, we thank the three ladies at the desk, Marianne Hiskell, Arnetha Johnson, and Bonnie Reasor who have been of inestimable assistance to all of us. We would also like to thank the three gentlemen who have been responsible for our audio-visual services; Mr. Crowell, McCoy, and Hall; and the two gentlemen in the front who have been doing the taping and transcribing in such an excellent way; Mr. Walter Brandenburg and Mr. Jimmy Hasty. We thank you all very much.

I know you join me in thanking all the Session Chairman who did such a wonderful job of presenting the papers, keeping us on time, and making very important and penetrating comments on the papers that were delivered.

I would especially like to thank my colleague at Harvard, Dade Moeller, who was the Chairman of the first Session and who performed so ably at the dinner meeting at the Country Club. He has participated fully in the planning and the decisions and has acted as a Co-Chairman, although not so designated. Dade, I thank you very much.

GILBERT: Excuse me. I should like to interrupt at this point. You are aware that Harvard University for years has been carrying on these AEC air cleaning conferences in a rather flawless fashion. Moreover, Harvard has been performing the task so long that we just take their good job for granted. I feel sincerely that we should thank Harvard University at this time for the excellent arrangements and running an interesting meeting.

FIRST: Thank you Mr. Gilbert, and thank you, all. I would now like to open the final session. We have 13 who wish to speak. Time is limited so we will be able to give each one only a very short time. In fairness to all the people who wish to speak, I would like to ask those who present commentary after the speakers to be equally brief.

HEPA-FILTER TESTING: COMPARISON OF DOP AND NaCl AEROSOLS*

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Abstract

We measured the penetration of high-efficiency-particulate-air (HEPA) filters by test aerosols of sodium chloride (NaCl) and dioctyl phthalate (DOP). Our purpose was to study the NaCl method for testing the efficiency of these filters and to compare the NaCl method with the DOP method. The NaCl-aerosol generator was built using the standard British system as a guide, but it included some modifications to the sampling and photometric-readout systems. This generator produces polydisperse particles with a diameter of 0.68 µm in a range of 0.02 to 2 µm. The thermal DOP-aerosol generator (0.3 µm) was located at the Hanford Environmental Health Foundation.

Thirty-two filters were tested using both aerosols. In general, the penetration of the DOP through the filter was about two times greater than NaCl at both 200- and 1000-cfm (rated flow). The NaCl, although not as penetrating as the DOP aerosol, could be used effectively to test the efficiency of HEPA filters in the 0.001-to-5% penetration range.

Introduction

The penetration of high-efficiency-particulate-air (HEPA) filters has been measured by a number of methods(1). The two most common standard test aerosols are sodium chloride (NaCl) used in the United Kingdom(2,3) and dioctyl phthalate (DOP) used in the United States(4). DOP, however, has several disadvantages. First of all, because of its solvent properties, it can adversely affect the filter media being tested(5). Secondly, a liquid monodisperse (0.3-µm) aerosol is not normally encountered in field conditions. Hence a solid, polydisperse test aerosol would be more appropriate and yield more meaningful efficiency data. Other advantages of a NaCl system include its shorter test period, easier operation during in-place testing, and generally lower cost.

The purpose of our study was to compare the NaCl and DOP methods of testing HEPA filter efficiency and to determine the relationship between the two types of penetration measurements.

Description

NaCl Test Apparatus

The NaCl aerosol system (shown in Fig. 1) was assembled using the British system(3,6,7) as a guide and reflected the changes outlined by Dorman(8). The apparatus basically consists of an air-flow control system, an atomizer, and a NaCl analyzer.

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*Work performed under the auspices of the U.S. Atomic Energy Commission.

Filtered air is moved through the ductwork using a blower. The flow is controlled using two adjustable dampers and is measured by noting the pressure drop across a calibrated orifice plate.

The test aerosol is produced by aspirating a 2.0 wt% NaCl solution into four atomizers (only two shown) using compressed air. The resultant droplets dry as they move down the duct and produce the solid, polydispersed aerosol. A circulation pump provides a continuous flow of solution into the spray box. Baffles are placed in the duct to ensure homogeneity of the aerosol when it reaches the filter.

The NaCl in the air entering and leaving the filter was determined by flame photometry. Continuous samples were passed close to a hydrogen flame. The resultant emission in the 5890Å region was measured with a photomultiplier (PM) tube, and the total integrated count was shown on a scaler-timer(9). In this way, large variations in light output could be averaged electronically, and reproducible readings were easily obtained.

Performance of the NaCl Generator

Figure 2 shows the particle-size distribution of the NaCl obtained using a Model 202 Royco Particle Counter.* The count mean diameter was 0.68 μm with a σ_g of 1.7. The salt concentration was also measured at nine equidistant points across an empty filter casing. The total salt concentration, as well as the distribution, varied by less than ±3% indicating good mixing.

Flow rates tested were 200 and 1000 cfm (rated flow). Triplicate 20-sec readings were taken at both up and downstream sampling positions. A neutral density filter of 3.0 was used when sampling the upstream concentration, since the excessive light output would flood the PM tube. Background readings were taken by deactivating the atomizer with the HEPA filter in place and sampling at the downstream position.

Results and Discussion

All filters were tested with both the NaCl generator at Lawrence Livermore Laboratory (LLL) and the thermal DOP generator at the Hanford Environmental Health Foundation (HEHF), Richland, Washington. The double-exchange test series involved 12 damaged filters from HEHF, and 10 damaged and 10 stock filters from LLL.

The penetration data are compared in Table 1 and Fig. 3. All points given in the table as <0.001% are plotted as 0.001%. Percent penetration, P, is calculated from:

$$P = \frac{100(C_D - C_B)}{C_U - C_B},$$

where C_D, C_U, and C_B are the downstream, upstream, and background count readings from the scaler-timer. Figure 3 also shows the best first- and second-degree polynomial fits to the data, made using a least-squares plotting routine. The equations for these lines are:

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*Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Atomic Energy Commission to the exclusion of others that may be suitable.

$$\log P_{DOP} = 0.121 + 0.872 \log P_{NaCl}$$

$$\log P_{DOP} = 0.244 + 1.099 \log P_{NaCl} + 0.0659 (\log P_{NaCl})^2.$$

In general, a linear relationship exists between the results of the DOP and NaCl methods, and the DOP aerosol shows about twice the penetration of the NaCl aerosol ($P_{DOP}/P_{NaCl} \cong 2$). Figure 4 shows the penetration ratio of DOP to NaCl over the entire range. Note that as the penetration of NaCl increases, the ratio gradually approaches 1.

Earlier, less-extensive measurements also show greater penetration by DOP(6,7). The differences between the two methods are generally attributed to the differences in particle size, particle density, electrical charge, filter loading, agglomeration, and shatter on impact(10). Although these variations exist between the two test aerosols, NaCl exhibits sufficient penetration to be used as a material for testing HEPA filters.

The data from Table 1 are plotted in Fig. 5 to compare penetration at 200 and 1000 cfm. Again, a least-squares plotting routine yields the following equations for a first- or second-order fit:

$$\log P_{1000} = -0.356 + 0.795 \log P_{200}$$

$$\log P_{1000} = -0.287 + 0.975 \log P_{200} + 0.0577 (\log P_{200})^2.$$

In general, more penetration is observed for both the NaCl and DOP test aerosols at the 200-cfm flow rate, especially at the higher penetration percentages (0.1 to 3%). This is consistent with theory, which predicts that, as face velocity is decreased, more of the test aerosol passes through holes and imperfections in the filter media.

Summary

We have measured the penetration of 32 HEPA filters by a 0.68-μm polydisperse NaCl aerosol and a 0.3-μm monodisperse DOP aerosol. The DOP aerosol shows about twice the penetration at both 200 and 1000 cfm. The NaCl method was found, however, to be an adequate test method in the penetration range desired. Both aerosols showed greater penetration at the lower flow rate of 200 cfm.

References

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Table 1. Comparison of HEPA filter efficiency in tests with NaCl and DOP test aerosols.

	Percent penetration			
	1000 cfm		200 cfm	
Filter source and No.	NaCl	DOP	NaCl	DOP
HEHF (Damaged)				
1	0.019	0.030	0.044	0.050
2	0.029	0.066	0.045	0.12
3	0.025	0.076	0.034	0.12
4	0.001	0.002	0.001	0.001
5	0.021	0.066	0.057	0.12
6	0.042	0.074	0.063	0.084
7	0.085	0.040	0.17	0.044
8	1.7	4.0	3.0	6.0
9	<0.001	0.005	<0.001	0.003
10	<0.001	0.004	<0.001	0.005
11	0.030	0.074	0.10	0.120
12	0.35	0.58	0.49	0.88
LLL (Damaged)				
13	0.45	0.75	0.93	1.5
14	0.004	0.014	0.002	0.003
15	0.091	0.28	0.20	0.50
16	0.018	0.032	0.034	0.046
17	0.001	0.018	<0.001	0.026
18	0.008	0.018	0.001	0.002
19	0.003	0.004	0.005	0.006
20	0.020	0.030	0.034	0.042
21	0.13	0.38	0.26	0.68
22	0.095	0.14	0.14	0.22
LLL (Stock)				
23	0.002	0.008 (0.012)[a]	<0.001	0.002 (0.004)[a]
24	0.001	0.004 (0.010)	0.001	0.002 (0.004)
25	0.001	0.006 (0.010)	<0.001	0.002 (0.004)
26	0.002	0.014 (0.016)	0.001	0.004 (0.006)
27	0.001	0.004 (0.008)	<0.001	0.002 (0.002)
28	0.003	0.010 (0.014)	<0.001	0.004 (0.004)
29	0.001	0.004 (0.004)	0.001	0.002 (0.004)
30	0.001	0.006 (0.004)	<0.001	0.002 (0.002)
31	0.001	0.004 (0.002)	<0.001	0.002 (0.002)
32	0.002	0.006 (0.014)	<0.001	0.002 (0.004)

[a] Results from manufacturer DOP testing are shown in parentheses.

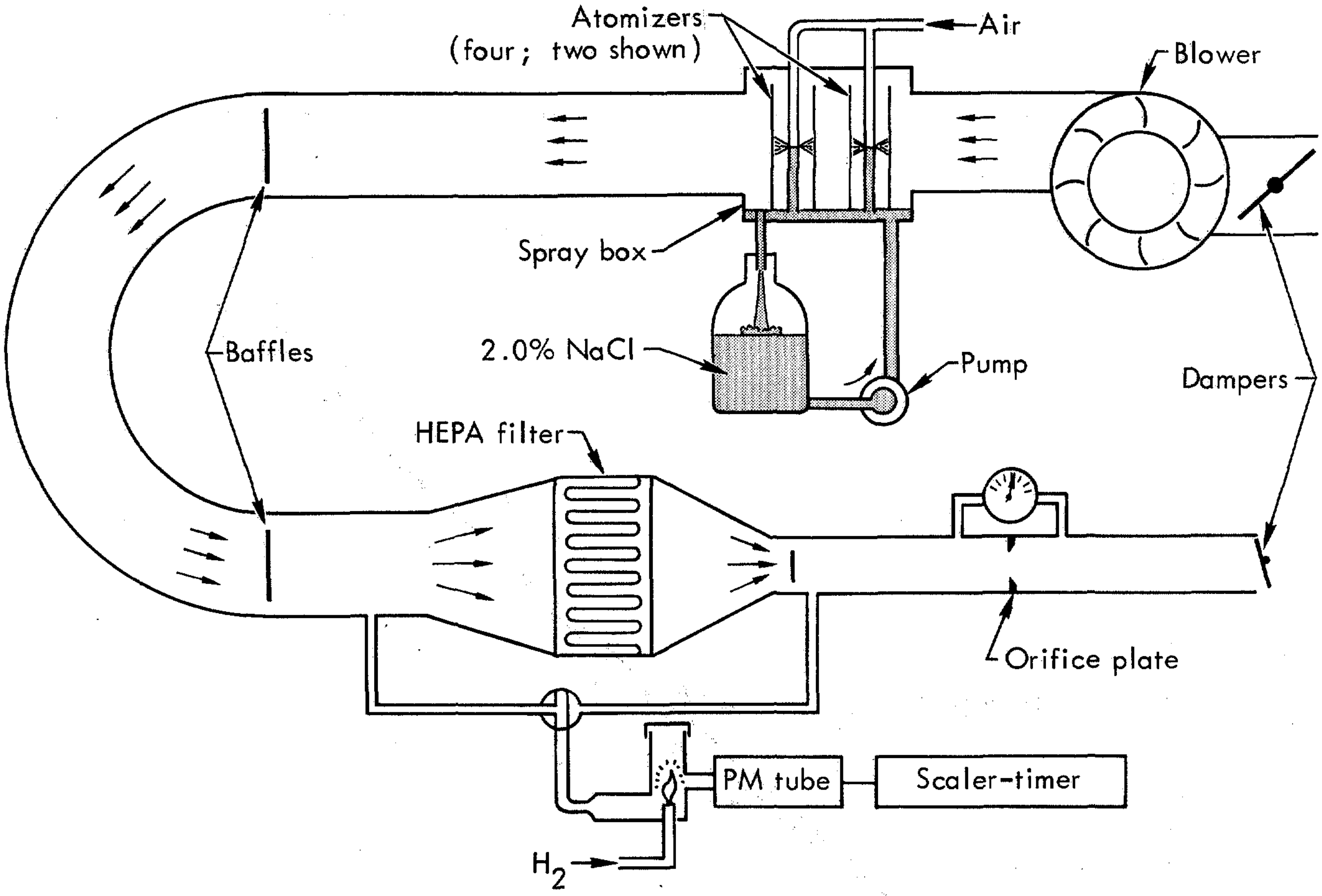

Fig. 1. System for testing HEPA filters using a NaCl aerosol.

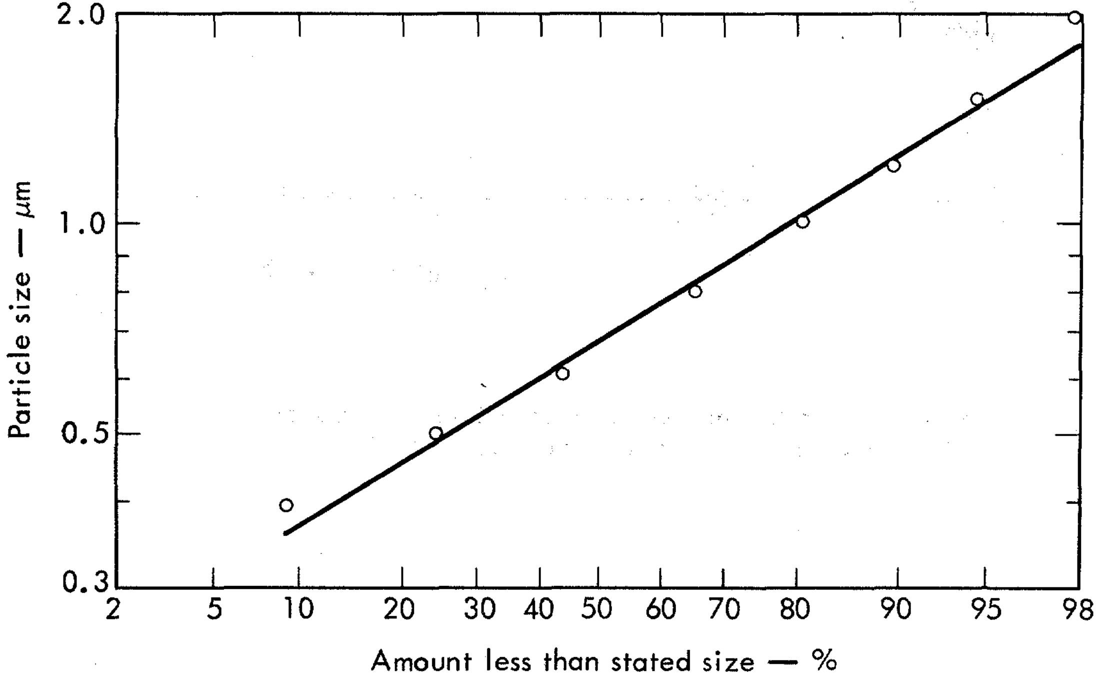

Fig. 2. Particle-size distribution of NaCl aerosol. The count mean diameter is 0.68 µm with a σ_g of 1.7.

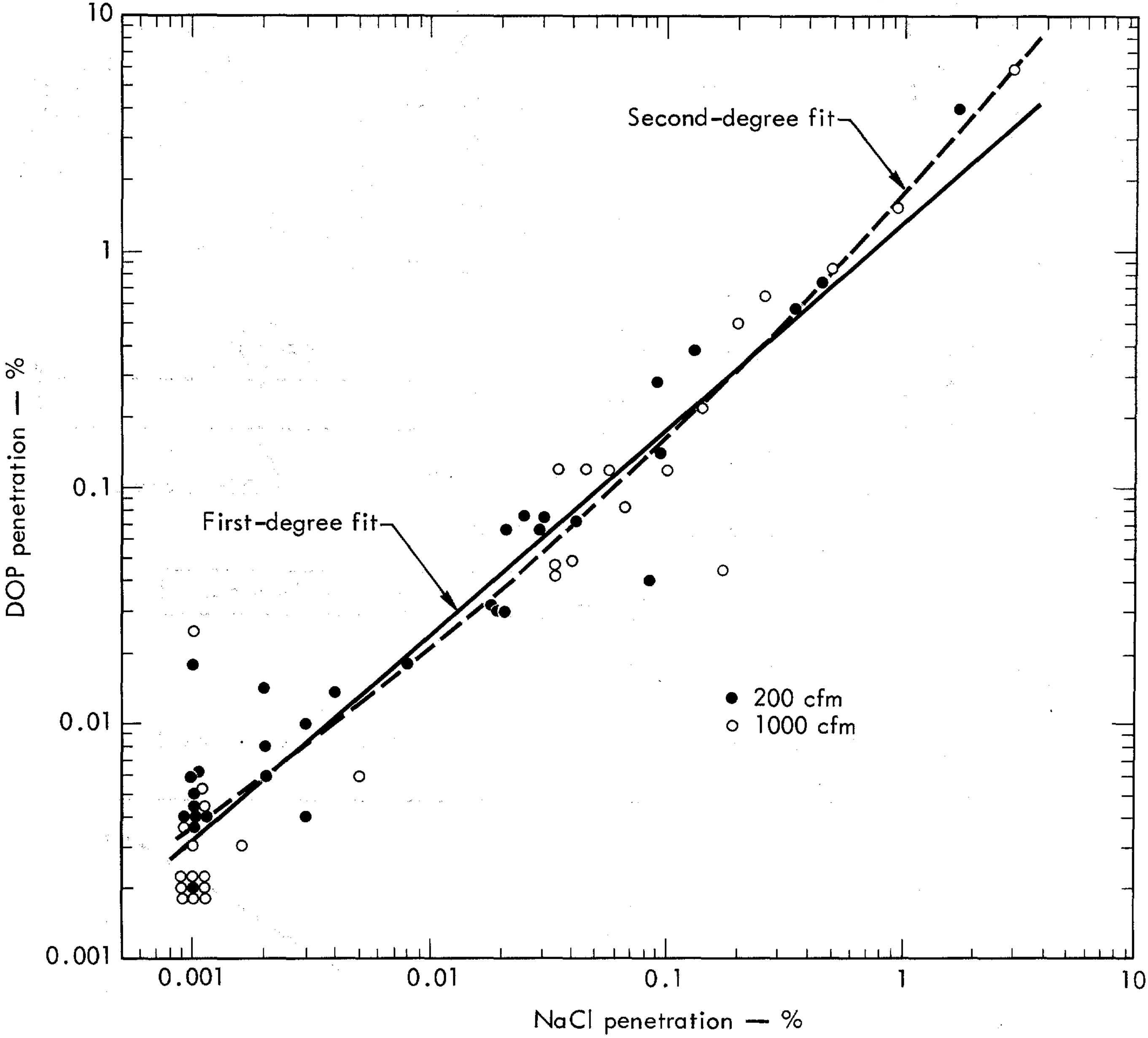

Fig. 3. Comparison of NaCl and DOP penetrations at 200 and 1000 cfm. Points listed in Table 1 as <0.001% are plotted as 0.001%.

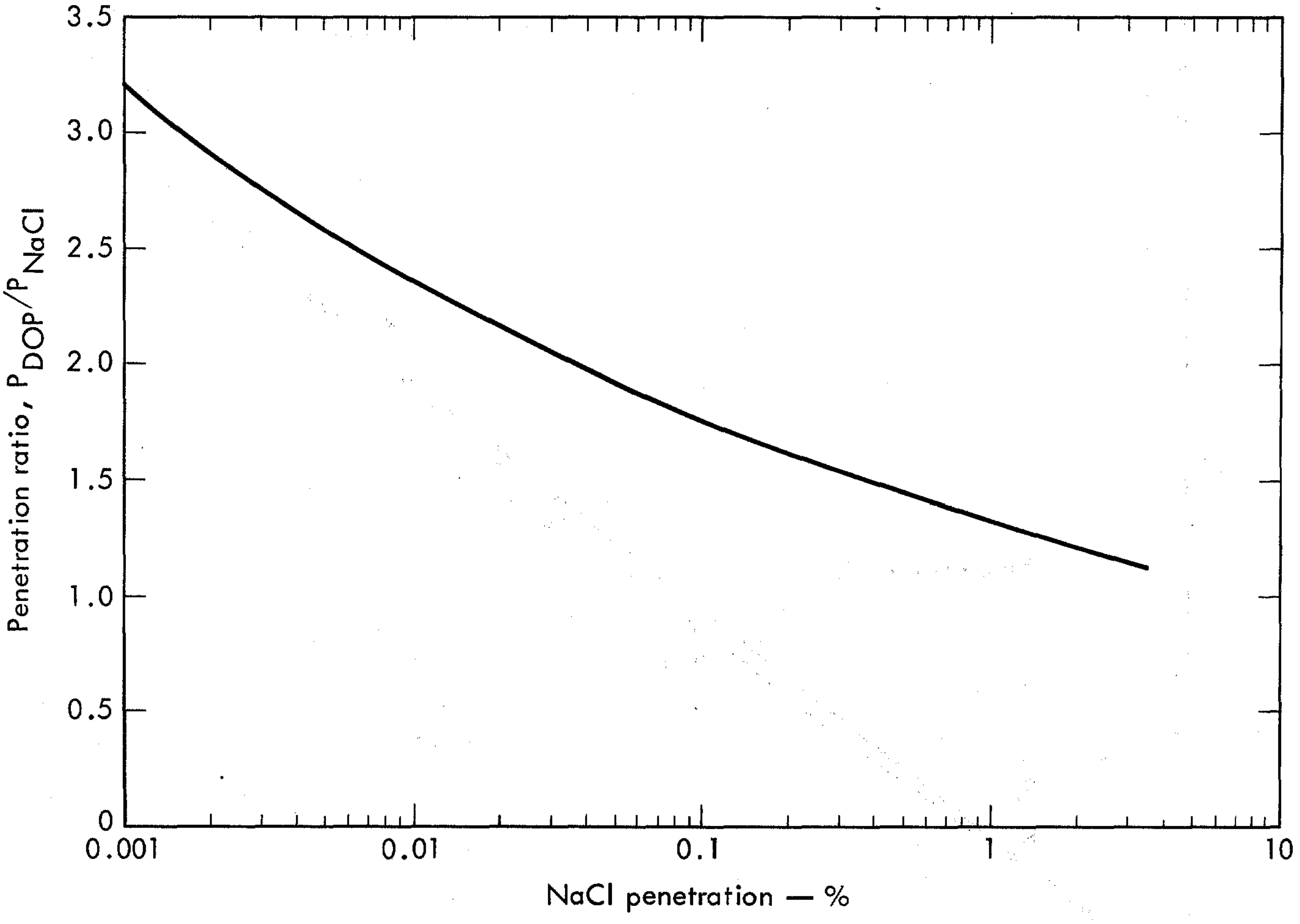

Fig. 4. Ratio of DOP to NaCl penetration as a function of increasing NaCl penetration.

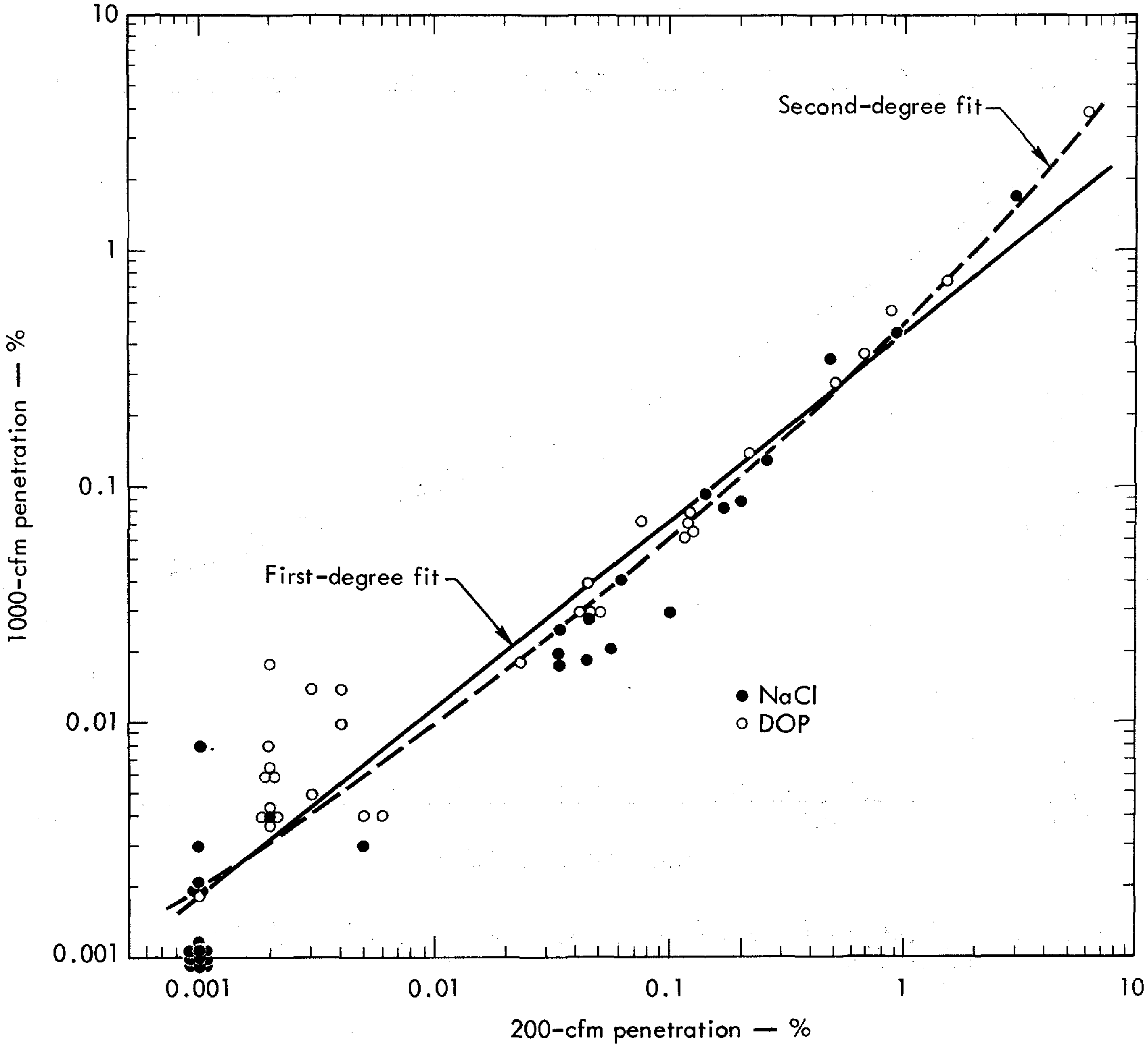

Fig. 5. Comparison of 200- and 1000-cfm penetrations using NaCl and DOP aerosols. Points listed in Table 1 as <0.001% are plotted as 0.001%.

DISCUSSION

ETTINGER: What were the size characteristics of the salt aerosol?

MURROW: We checked it with a Royco model 220 and it came out pretty much as the British have reported for a long time.

NELSON: The count mean diameter was about 0.6 μm and geometric standard deviation was 1.7.

STEINBERG: Did you make a value-for-value comparison of DOP and sodium chloride penetration? Do you have a chart showing that?

NELSON: Yes, that will be shown in the published paper.

HUTTEN: You state in your paper that because of possible solvent effects, DOP may affect HEPA media adversely. Have similar studies been done on the adverse effects of sodium chloride?

NELSON: I don't know of any.

FILTER TESTING DEVELOPMENTS IN GREAT BRITAIN

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Abstract

Most HEPA filter testing in the United Kingdom is carried out with an aerosol of sodium chloride. The aerosol, of mass median diameter 0.65μm, is generated by pressure atomization of a 2% salt solution and in the original Porton design is detected by hydrogen flame photometry. A variation of the method has been developed at Harwell; in this variation a cadmium sulphide cell is used as detector, instead of a photomultiplier. Recent improvements to the Porton design permit testing of filters of less than 0.0001% penetration at flow rates of 1000 cfm. Work at the Atomic Weapons Research Establishment, Aldermaston, has been devoted to the design of a thermal generator of sodium chloride aerosol, giving a compact device for use in in-place testing in conjunction with the standard sodium flame detector.

I. Introduction

Since the original paper (1) on the sodium flame test was presented to the USAEC Air Cleaning Conference at Oak Ridge in 1963 there have been improvements to its sensitivity so that filters of less than 0.0001% penetration can now be tested. The test has been a British Standard since 1965 and was re-issued with some modifications in 1969. It is now possible that the Porton or Harwell design will be adopted as the European Standard for HEPA filters. In order to make use of the sensitivity of flame detection, work was undertaken by AWRE on the thermal generation of salt for in-place testing. This work is reported in this paper by courtesy of AWRE, who have now discontinued research and development in the field of filtration. Further development of the thermal generator in the United Kingdom is likely to take place at the Chemical Defence Establishment, Porton.

II. Thermal Generator

The apparatus (2) consists basically of a powder deposition torch (Figure 1) which is an oxy-acetylene burner with facilities for passing a stream of prepared sodium chloride powder into the flame. The powder flows from the base of the hopper under the venturi action of the gas mixture, passing through a series of jets. It was necessary to modify this arrangement to avoid blockages so the powder feed valve of the type shown in Figure 2 was introduced.

The method of use is indicated diagrammatically in Figure 3. The torch is operated in a small fume hood and excess salt which does not evaporate remains in the hood. The aerosol output is drawn away by the fan for use as

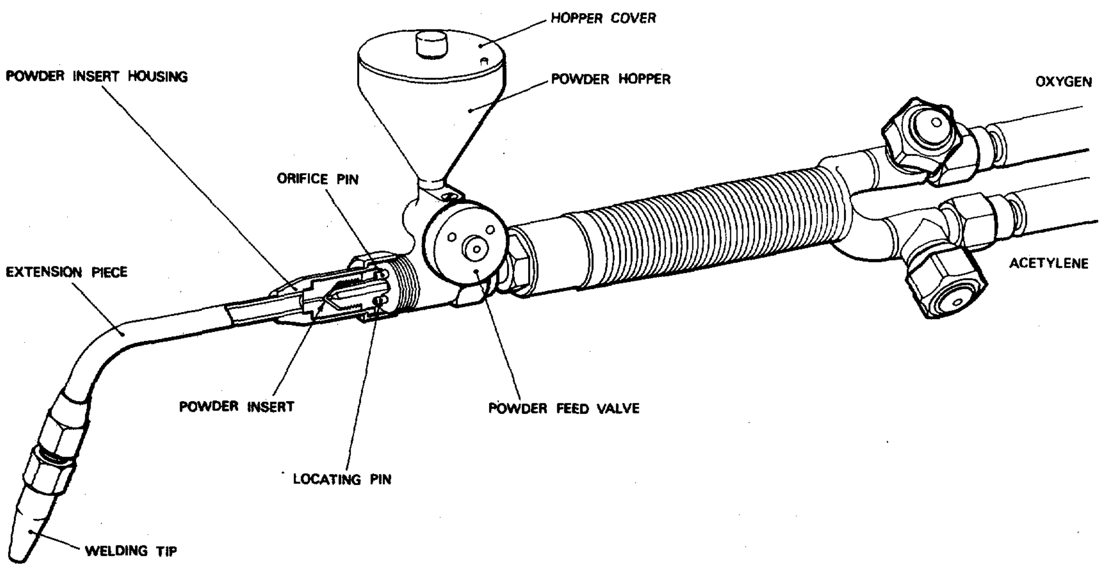


FIG. 1 POWDER DEPOSITION TORCH

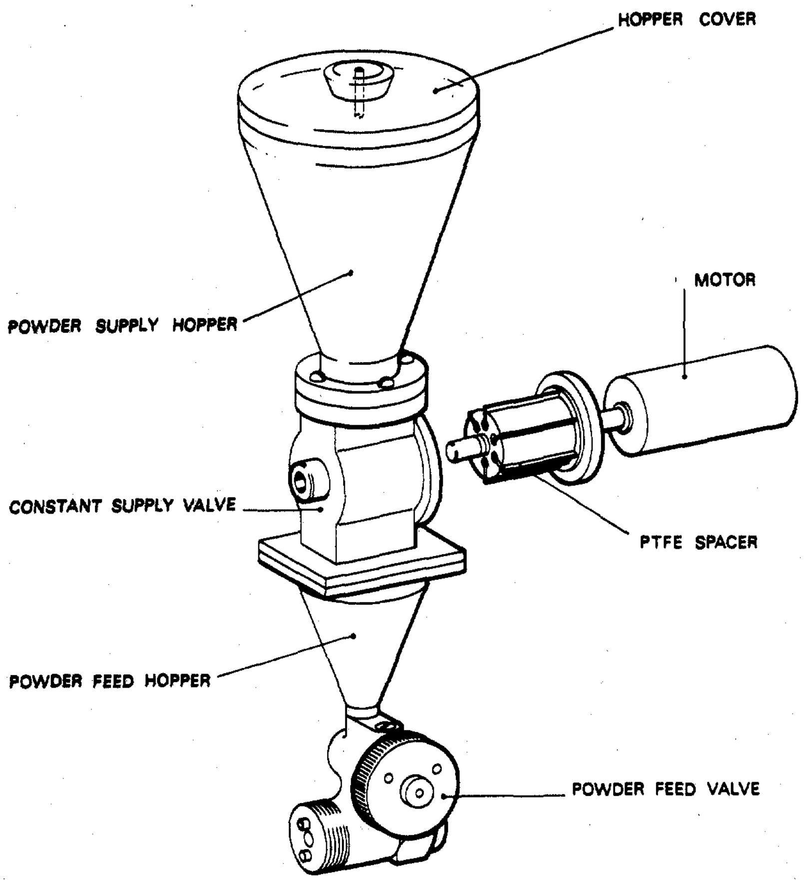


FIG. 2 CONSTANT SPEED POWDER FEED UNIT

required. The aerosol produced (Figure 4) has a mass median diameter of 0.3 to 0.4µm (Figure 5), which is rather smaller than that obtainable by solution atomization with a Collison atomizer as specified in the British Standard Sodium Flame Test (BS 3928:1969). With an acetylene consumption of 4 to 5 litres per minute an output of 3 to 4 grams per minute of aerosol is obtained, which is approximately 100 times the output of a single enlarged Collison nozzle of the type mentioned above. This output may be increased or decreased by varying operating conditions.

The apparatus is compact. Figure 6 shows the assembly in the laboratory: the following can be seen: fan, hearth or combustion chamber, hopper, rotary valve, torch, vibrator, and motor drive to the valve. Figure 7 gives another view showing the drive to the valve more clearly.

Figure 8 shows in outline a prototype unit developed for use in routine in-place testing at AWRE and it is planned to make this available commercially.

Work at the Chemical Defence Establishment so far has been directed to simplifying the method of pre-treating the salt. By mixing the salt with 1% of calcium aluminium silicate (CAS), grinding for 1 minute and passing through a 150 mesh sieve, a free flowing powder has been obtained. This powder has retained its free flowing properties for some days when exposed in open trays to laboratory air. Some effort has also been devoted to simplification of the salt-feed to the burner and to design of a nozzle less subject to salt build-up. So far the few data obtained show rather inefficient conversion of salt to sub-micron particles.

III. Improvements to the Sodium Flame Test

Figure 9 shows a schematic diagram of the equipment. Salt solution (2% concentration) is sprayed from the atomizers, A, and dries in passing with the test air down 30 - 40 ft of trunking. A small sample (about 30 litres/minute) of the air which has penetrated the filter is led to the flame photometer where the increase in yellow colouration is detected by the photomultiplier, the current change being measured on a galvanometer.

Since 1963 the original ceramic burner has been replaced by a simple copper burner which is less susceptible to contamination by salt. This change has permitted testing up to 100% penetration as well as in fractions of percentages. Perhaps the other most significant change has been to back-off to zero the standing signal from the clean flame by means of a reverse current. By so doing it has been possible to remove neutral density optical filters from in front of the photomultiplier, allowing more light to strike the cathode. In most systems this increases the sensitivity by 5 to 10 times. The signal in the modified version is fed to an operational amplifier and displayed on a 100 µA ammeter and, if required, on a pen recorder. Figure 10 shows a typical pen recording at 0.00002% penetration; the time between 'salt on' and 'salt off' is about 3 minutes. The accuracy of the result is probably within ± 30%. The base line shows a clean flame drift of about 3mm during the test which was on the highest sensitivity range available.

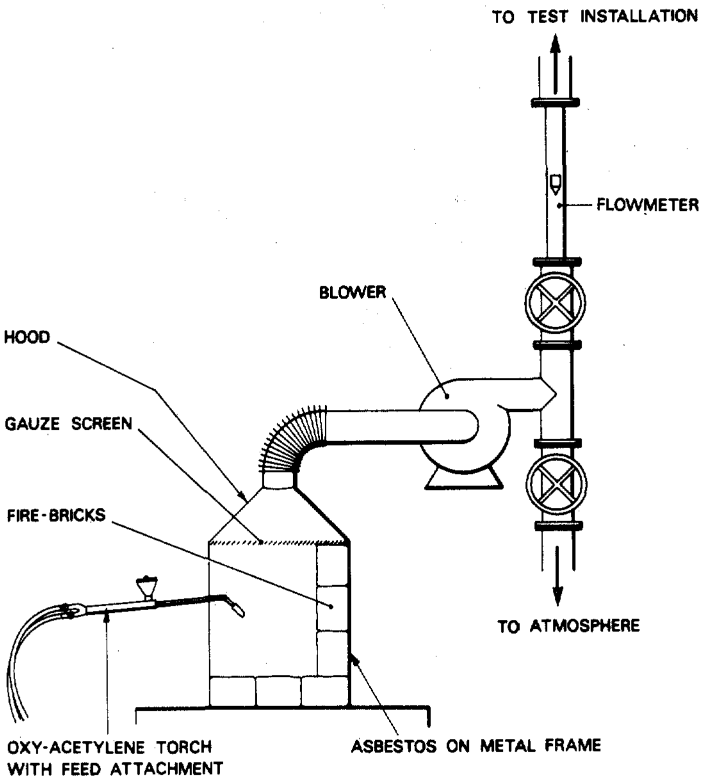


FIG. 3 EQUIPMENT FOR AEROSOL GENERATION

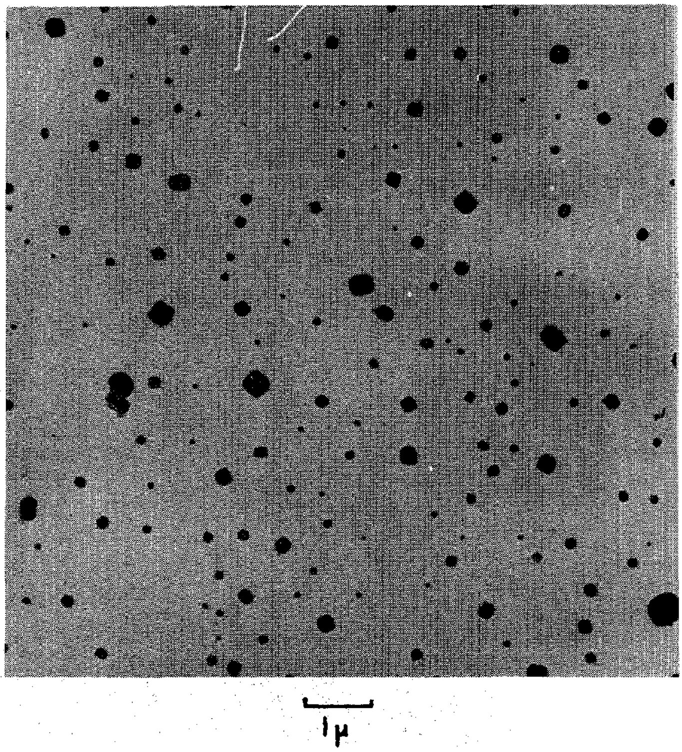


FIG. 4 ELECTRON MICROGRAPH OF FLAME DISPERSED NaCl PARTICLES

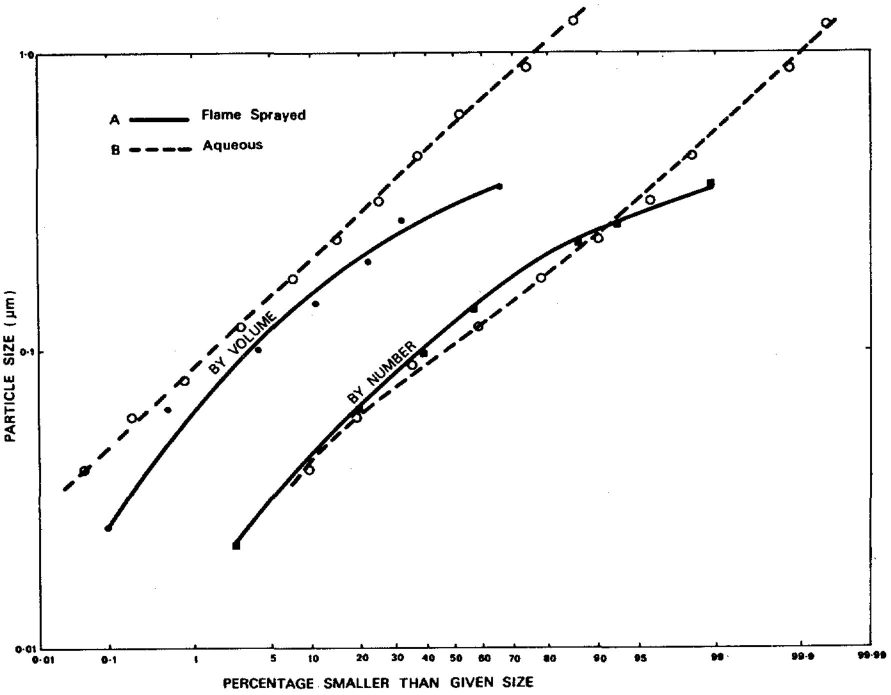


FIG. 5 SIZE DISTRIBUTION OF NaCl AEROSOLS

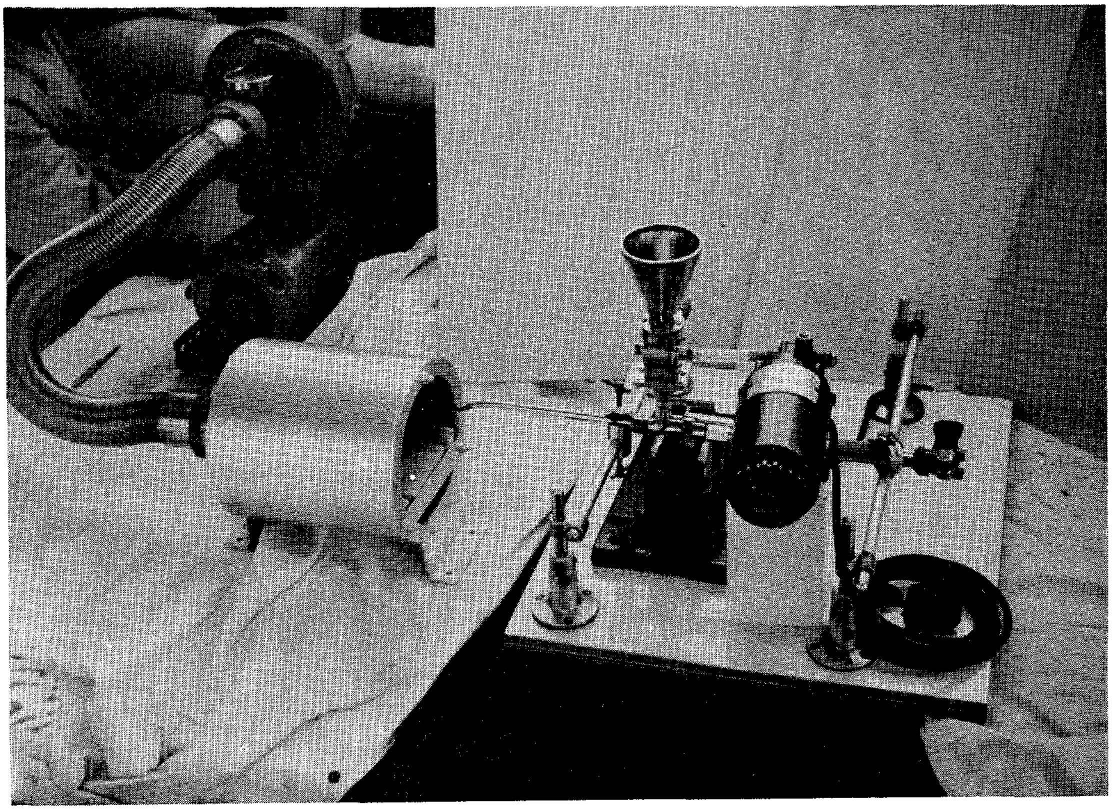


FIG. 6 THERMAL GENERATOR IN LABORATORY

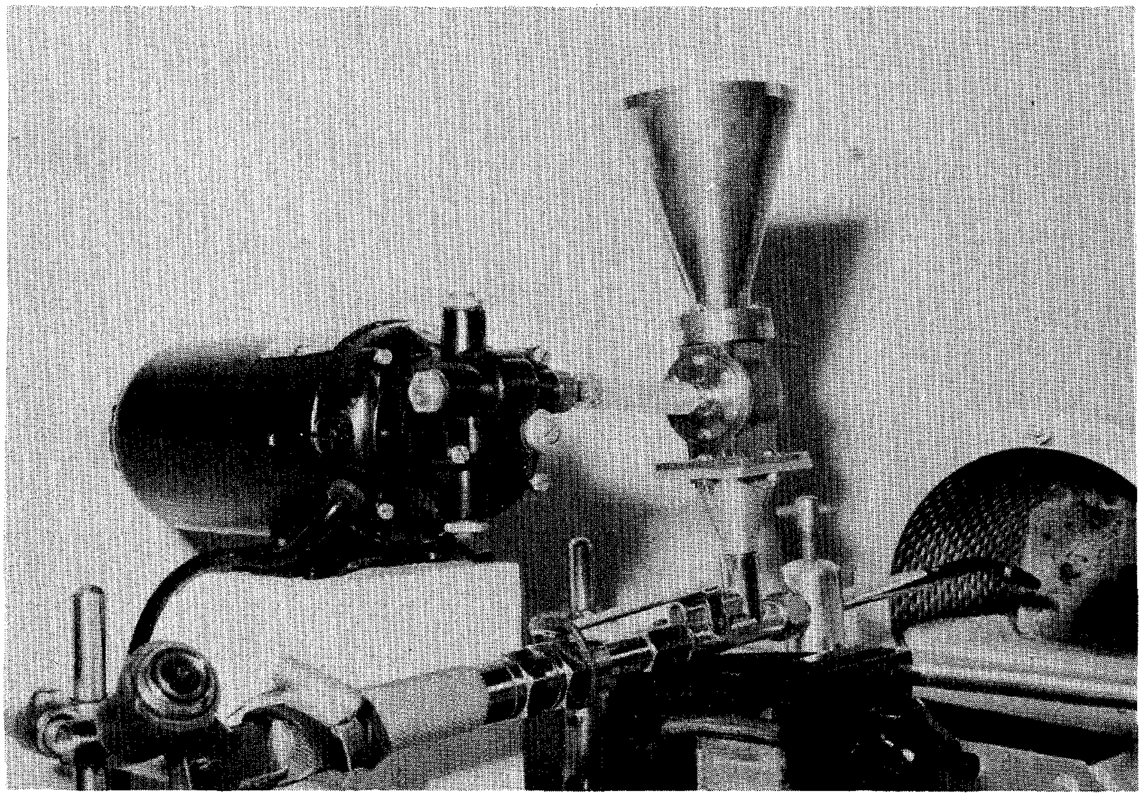


FIG. 7 DRIVE TO POWDER FEED VALVE

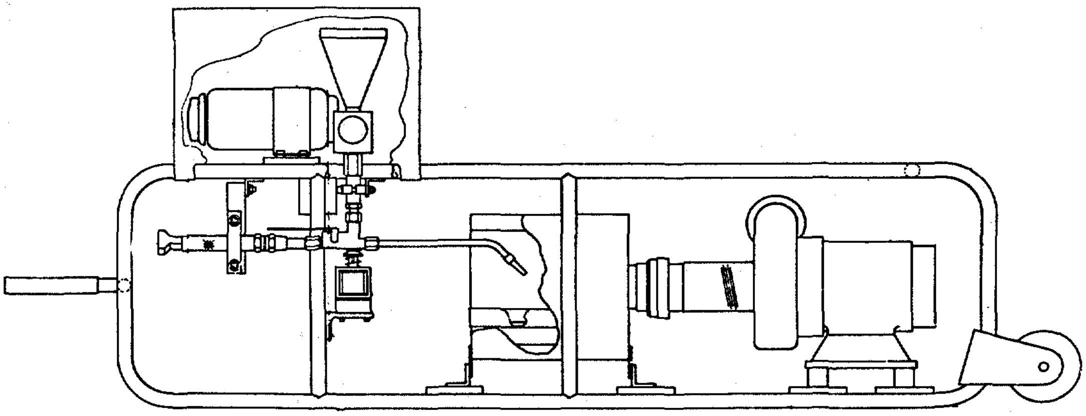


FIG. 8 PORTABLE THERMAL GENERATOR FOR IN-PLACE TESTING

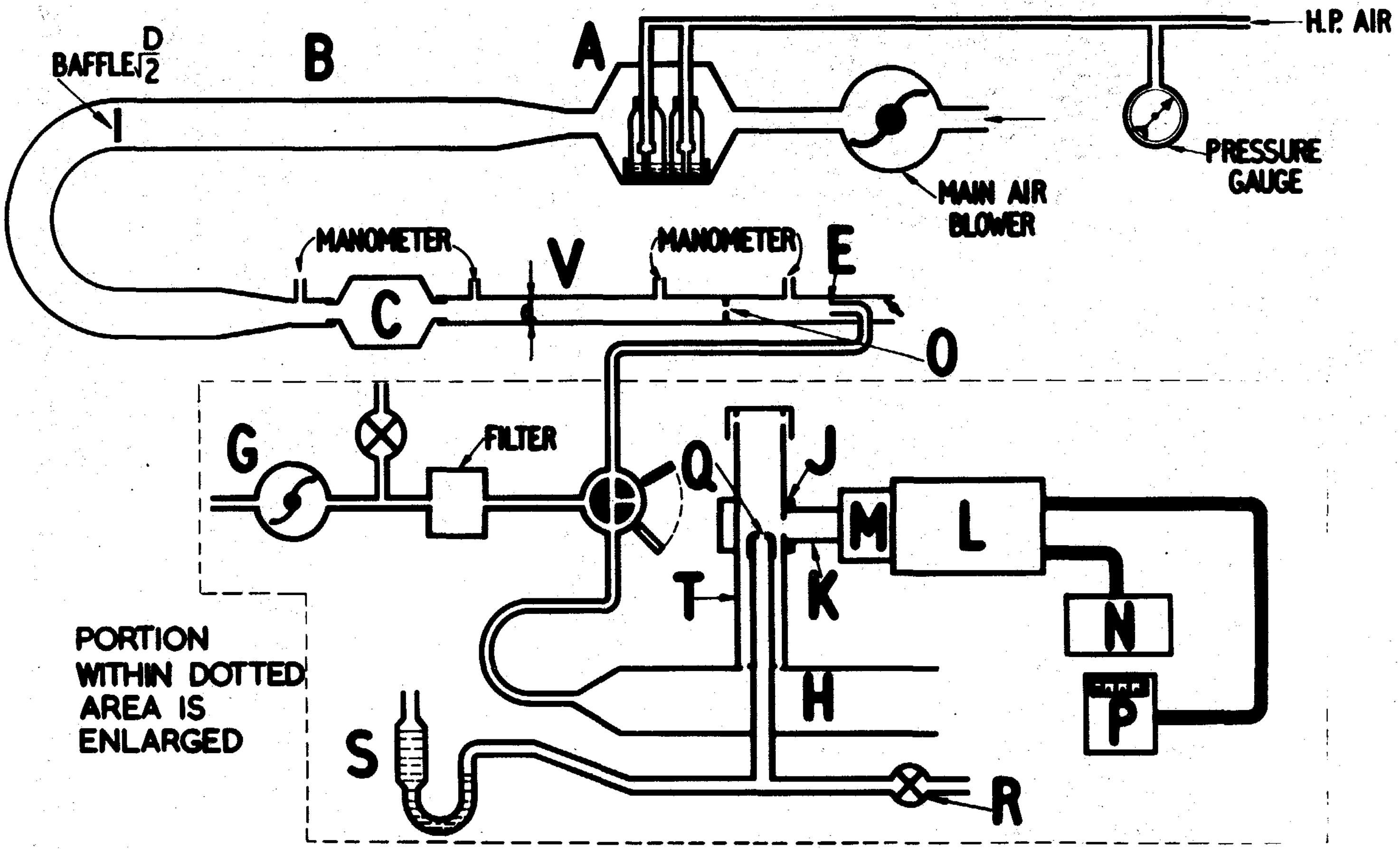
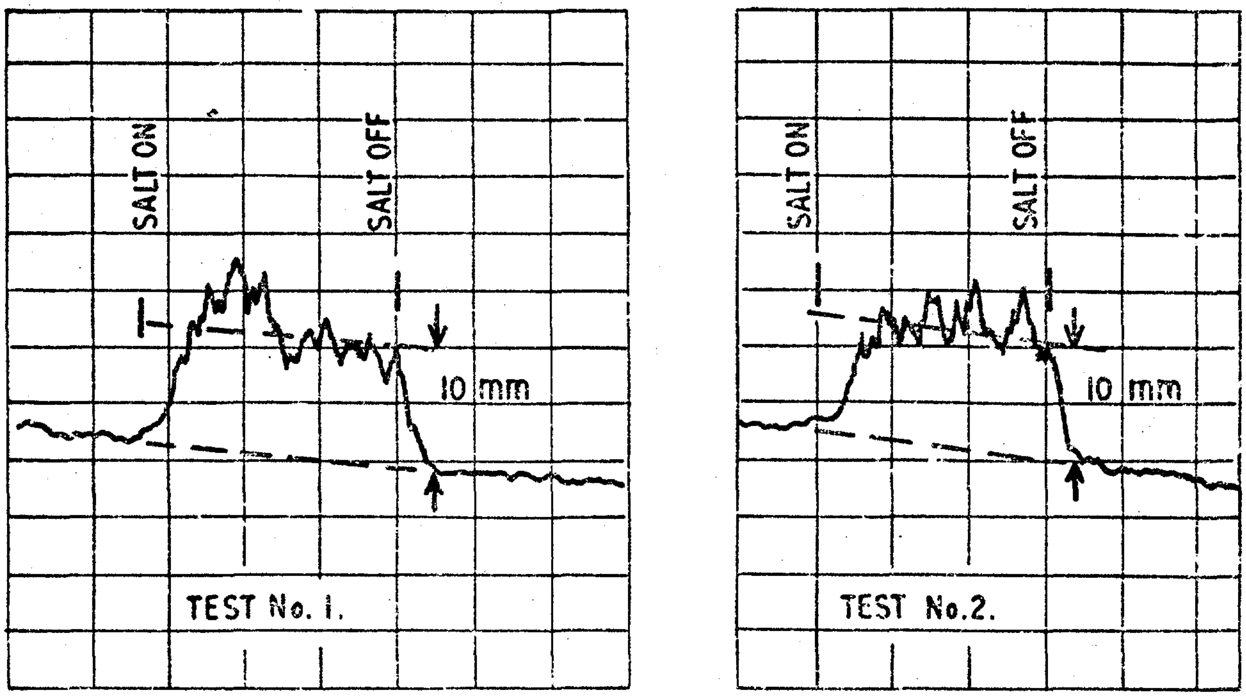


FIG. 9 SCHEMATIC DIAGRAM OF NaCl TEST EQUIPMENT



PENETRATION = 0·00002 PER CENT.

FIG. 10 PEN RECORDING OF FILTER TEST

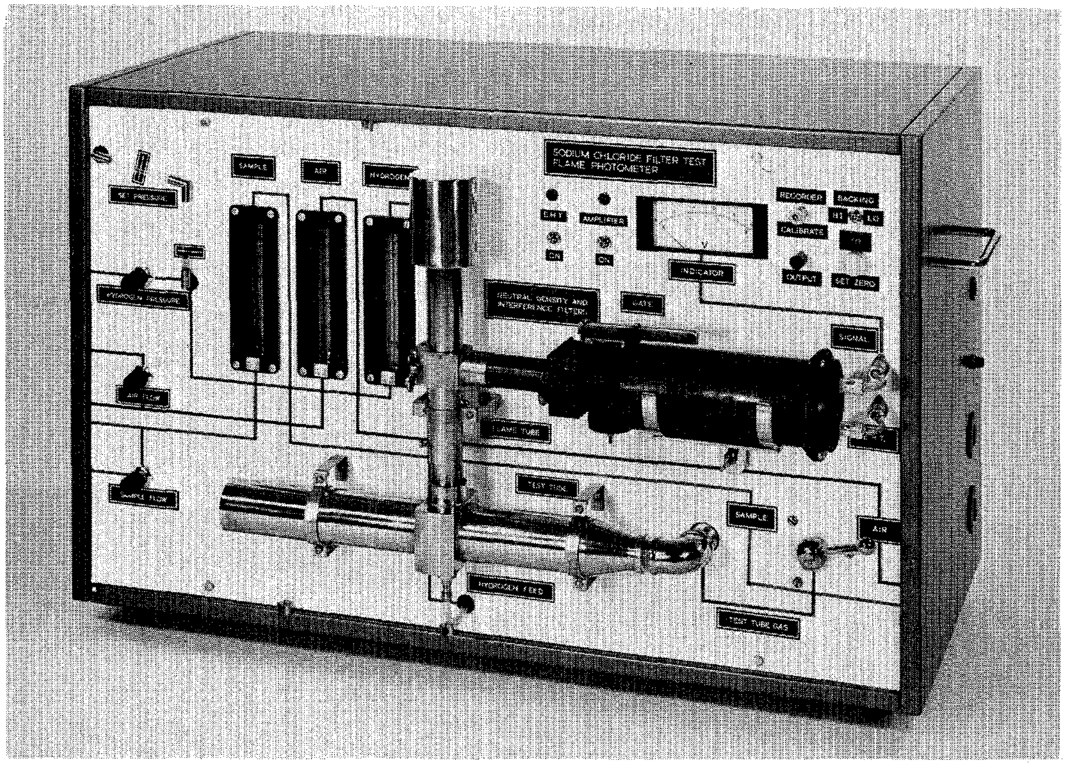


FIG. 11 NaCl DETECTION AND MEASURING EQUIPMENT

There is no appreciable drift when sensitivity is decreased by a factor of 5 and the 'grassy' edges on the signal then virtually disappear.

Additional refinements are better control of hydrogen flow to the flame and closer control of the flow rate of sampled air to the flame - this latter is only important below the 0.0001% level and then only within ± 2 litre/min (30 ± 2 litre/min). Optical interference filters have also improved in the past few years, giving a somewhat better signal to noise ratio. The detection and measuring equipment is shown in Figure 11.

When work began on the first sodium flame equipment for testing HEPA filters (in 1959) it was decided that the particle size of the aerosol should be the same as that of its predecessor, methylene blue, so that results would be similar. This decision was in many ways a mistake. Penetration values would have been higher if a smaller size distribution had been adopted. In experiments with a form of Dautrebande atomizer a mass median diameter of between 0.4 and 0.5 µm has been obtained. The penetration of this aerosol through a HEPA filter is about twice that of the Collison aerosol. It has other advantages in that it requires a lower generation pressure (80 lbf/in^2 instead of 100 lbf/in^2), is less likely to block and there is less water associated with the spray, so that the humidity of the trunking is less affected. The increased trunking humidity when Collison atomizers are employed has a small depressant effect on the flame - significant at the 0.0001% level, but there is no measurable depression when Dautrebande atomizers are used.

The few available data, for some six HEPA filters only, show the salt penetration with Collison atomizers to vary between equality with, down to one half of DOP values, so an increase of nearly two with Dautrebande atomizers gives a bracketting of DOP results.

The concentration of sodium chloride in the normal 1000 cfm test is 6 mg/m^3 so, assuming an exposure of 2 minutes, less than 0.4g of salt is deposited on the filter. If filters of relatively low efficiency are being proofed - say of 0.01% penetration - the aerosol concentration can be reduced by more than an order of magnitude - leading to deposition of only a few milligrams of aerosol on the filter; at the same time generation problems are eased as a smaller compressor can be used.

The detection and measuring equipment is now in production in the United Kingdom, the design shown in Figure 11 being suitable for the assessment of filters varying in size from respirator canisters to 2 - 3000 cfm, or indeed for in-place tests of large installations.

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DISCUSSION

STEINBERG: If you increased the concentration upstream, would you get a subsequent increase in penetration downstream?

DORMAN: If we increased the concentration upstream, keeping the size distribution the same, which of course we would do, we would get twice the concentration upstream and twice the concentration down; so the percentage penetration would remain the same. We have, in fact, worked with concentrations from about 2 up to 20 milligrams of salt per cubic meter of air and we get the same answer with all concentrations. But we don't like to have too high a concentration because it might clog the filter, and high concentrations pose more difficulties in aerosol generation.

ETTINGER: Do you think that the aerosol you are generating, since it's a nebulized aerosol, is highly charged and that this may be a significant removal mechanism?

DORMAN: It is charged. We carried out some experiments a good many years ago and it's roughly what has been predicted by most aerosol people; i.e., 40% positive, 40% negative, and 20% neutral. But, it's a very low level of charge. When you discharge the cloud completely at about the 0.1% penetration level, penetration increases from 0.1% to 0.12 or 0.13%. So, a neutral cloud penetrates rather more easily than does one carrying a normal charge.

HIGH EFFICIENCY GASKETLESS ADSORBER

H. L. Barnebey
Barnebey - Cheney
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Banks of activated charcoal adsorber cells of the multifold type in thicknesses of 1" and 2", the horizontal double panel or drawer-type of the 2" thickness, and cylindrical canisters in thicknesses from 1" to 6" have been used singly and in multiple for the removal of iodine 131, methyl iodide 131, and other radioactive species from air or gas mixtures. Typical cells of these types are shown in Figures 1, 2, and 3. High efficiencies can be obtained under most conditions of operation at suitable velocities and temperatures, and it has been shown that activated charcoal adsorption is a suitable containment method for retaining the unwanted gases within the cell banks for a sufficient time for them to decay to nonradioactive form. In the construction of cell banks (a typical small mounting frame is shown in Fig. 4) from the individual cells, it is necessary to use gaskets which must be installed correctly to avoid initial leakage and which can develop leaks due to degeneration of the gasket material or a shifting of the surfaces. For this reason, the efficiency indicated by the charcoal bed depth is not allowed in the design of the system. Typically, 90% removal has been allowed, although it is known that the charcoal bed thickness, without the possibility of gasket leakage, has an efficiency above 99%.

To take advantage of the inherent efficiency of the charcoal bed and eliminate gasket leak troubles (which could, of course, be more serious than a simple drop in efficiency), a new type of adsorber has been developed, having the extended surface needed for large volume air flow, low resistance to flow, and completely without the use of gaskets. The elimination of gaskets does not, in this design, require special fabrication accuracy or the welding of leakproof joints. The internal filter components are not built gastight. They are built charcoaltight, which requires less accuracy. Leaks from the upstream chamber to the downstream chamber are not avoided, but the design is made so that any leakage must be through a thickness of activated charcoal greater than the charcoal adsorber bed thickness. In this way, leakage can cause no harm, as the air or gas stream can pass through, but the radioactive contaminant is held back as effectively as at any other place through the charcoal bed.

A principal feature of this design is the use of a large charcoal bed which makes its own seal, all around, without gaskets, but which is arranged upstream and downstream with "air fingers" reaching into the bed so the designer has control over the amount of air flow resistance through the bed. This is, therefore, not just an improvement over the present gasketed filters, but an entirely new concept, which is based on work Barnebey-Cheney has been and is doing to provide the necessary confidence that it will perform in accordance with specifications.

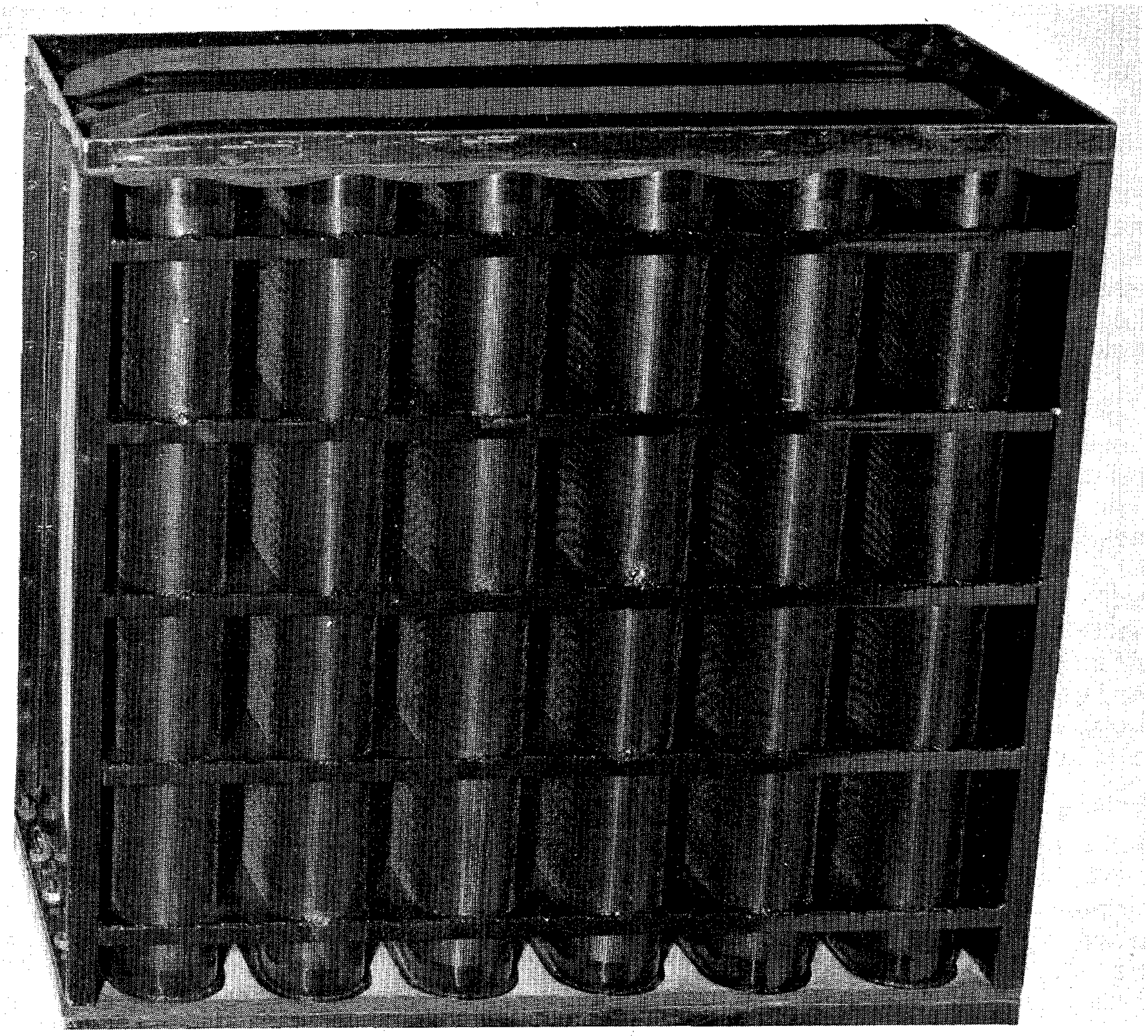


FIGURE 1

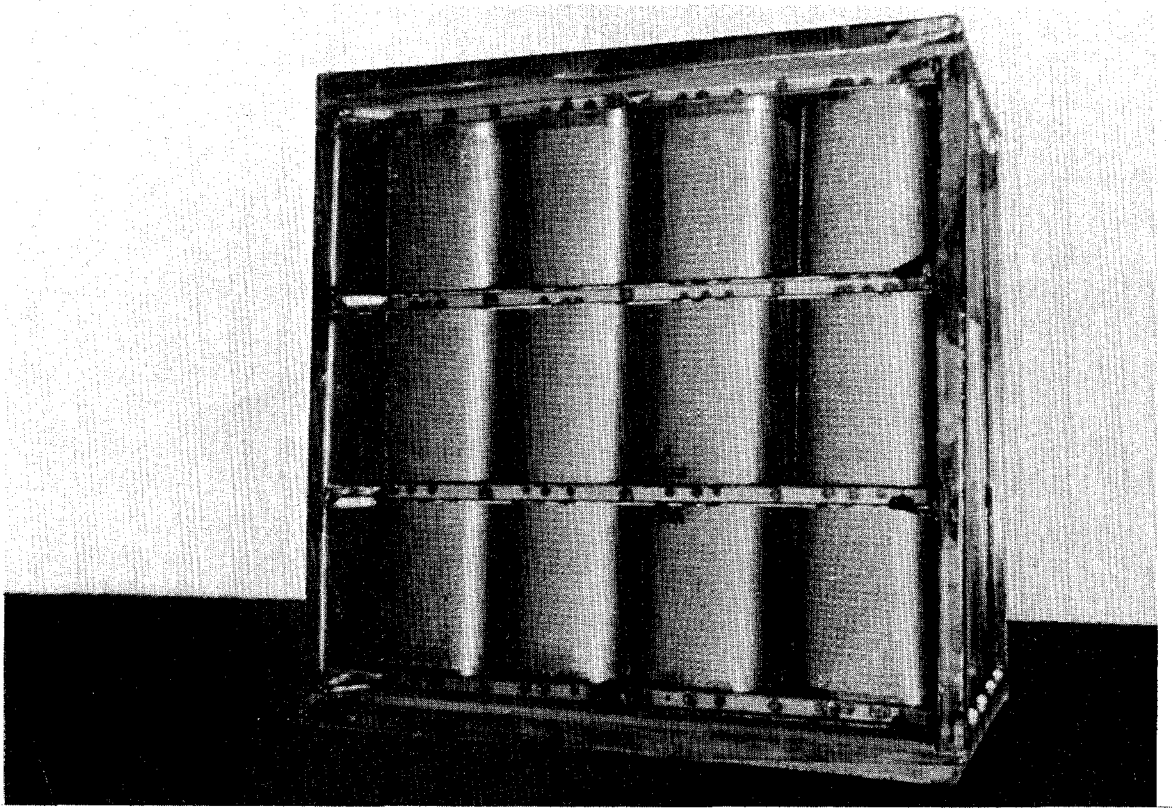


FIGURE 2

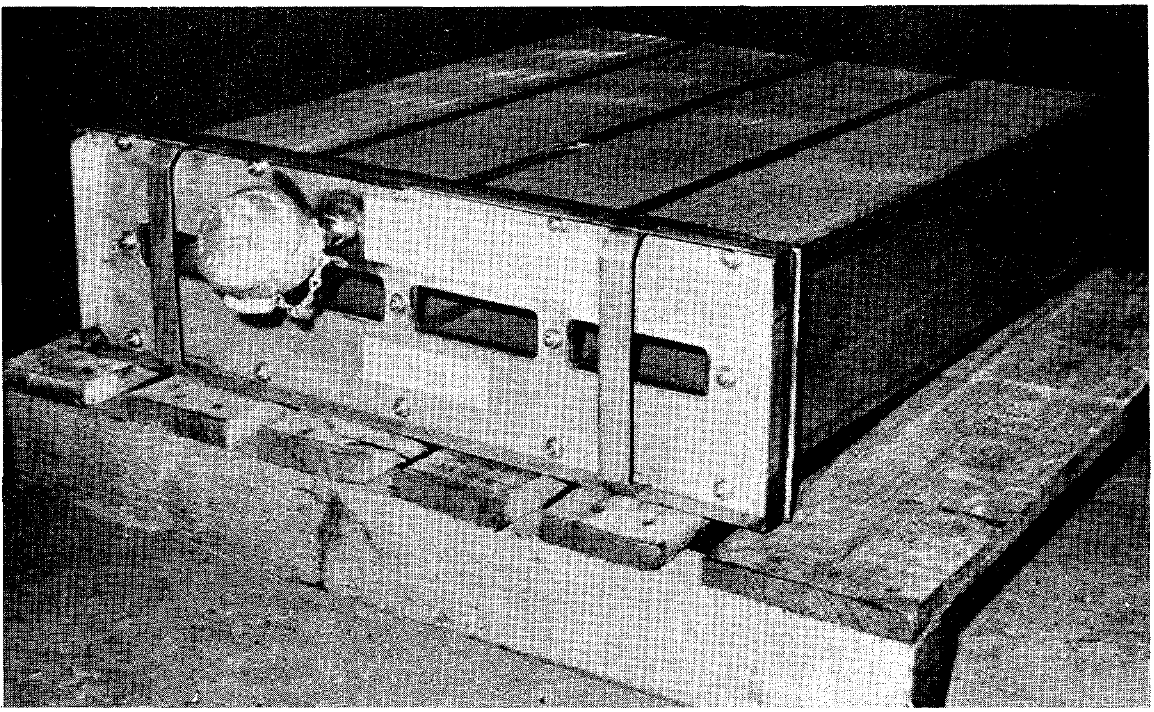


FIGURE 3

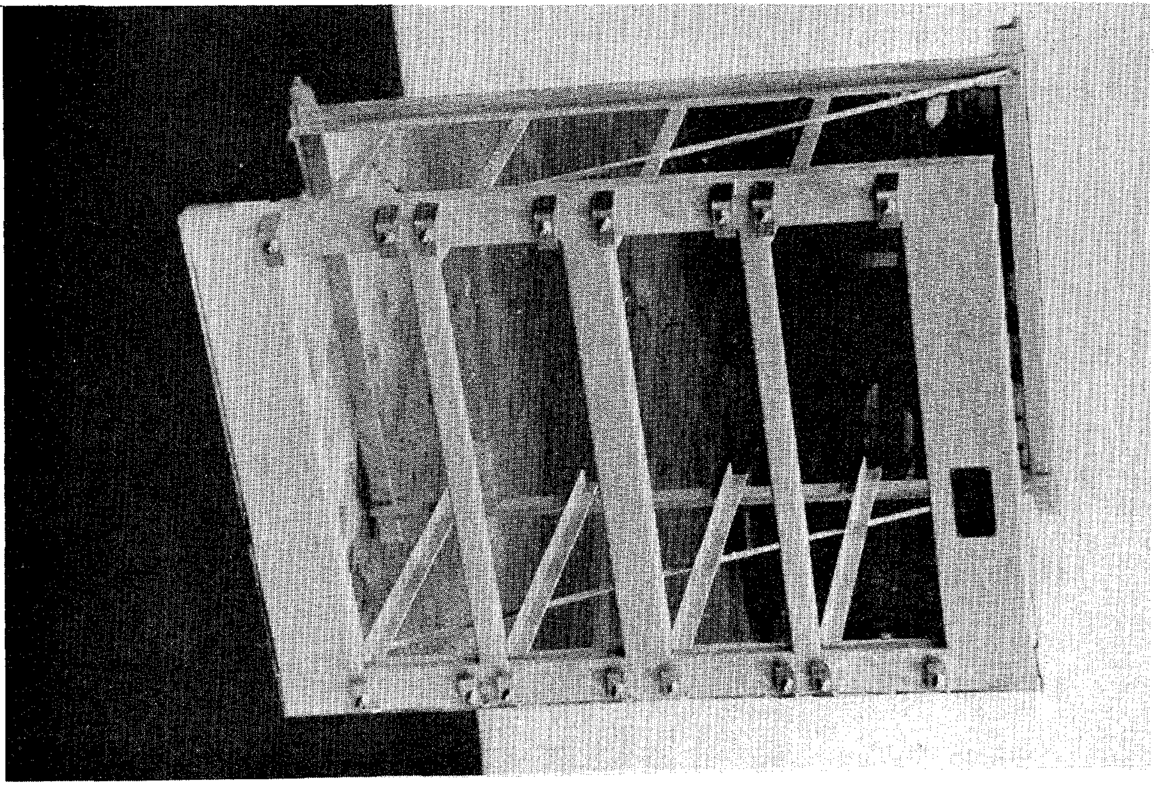


FIGURE 4

Within our own organization, we call this adsorber "gasketless adsorber", "high efficiency adsorber", and "submerged air space adsorber". All these names logically apply because it does not have gaskets for gas tightness, it does have high efficiency because of the elimination of gaskets and because deep beds can readily be used if desired, and it is a filter turned inside out where the inlet and outlet air spaces are submerged.

Figure 5 shows the essential features of a gasketless adsorber: The discrete submerged air inlet space, the air outlet space, the continuum of activated charcoal, and the perforated sheet which separates the air space from the charcoal space. This slide shows a typical gasketless adsorber, including the important features that make it function.

The function of an activated charcoal filter is to adsorb a substance (or mixture) from an airstream so that the substance is eliminated (to purify the stream) or the contaminant can be recovered because that adsorbed substance is desired. Or, it is used to convert a substance to another form. In the case of nuclear containment, the function can be either to remove by physical adsorption a substance unwanted because it is radioactive or to act as a delay trap (a) delaying passage through the bed by adsorption for a sufficient length of time to cause decay of the unwanted species, (b) containing enough of the unwanted radioactive elements in isotopic form so that the radioactive species is exchanged within the charcoal bed for the nonradioactive species, or both. In this manner, activated charcoal is used to remove radioactive iodine or methyl iodide, or to exchange radioactive for nonradioactive iodine. It is used also as a delay trap for species with long half-lives; in this case, a much longer delay is used to allow substances such as radioactive noble gases, especially krypton and xenon, to lose their radioactivity within the charcoal bed and not discharge to the atmosphere any of these radioactive gases. In general, radioactive containment has the feature, as a purification process, that it must be of very high efficiency because, in most cases, the level of radioactivity is sufficiently high so that 100-fold, 1,000-fold, or 10,000-fold reduction in concentration is necessary to do the needed purification job.

It is common practice in large-capacity filtration systems to use a modular approach and build into one or more banks or batteries, groups of individual cells which are sealed in place by gaskets. The bank contains a sufficient number of cells to give the efficiency and capacity required. Gaskets are subject to leakage in themselves, misalignment, or other faulty installation, and during operation due to mechanical or thermal stresses (there can be relative movements of the cells and holding frames, giving the possibility of disrupting gasket seals). Various attempts have been made to make gasketing more reliable or to substitute various types of seals (liquid, semiliquid, or solid) to eliminate or diminish a gasket leakage problem. Most of these have their own problems even greater than normal gasket seals. The idea of sealing with activated charcoal, using the same grade as for purifying the air or gas, is especially appealing because an absolute seal is not required. There can be leakage because

GASKETLESS ADSORBER

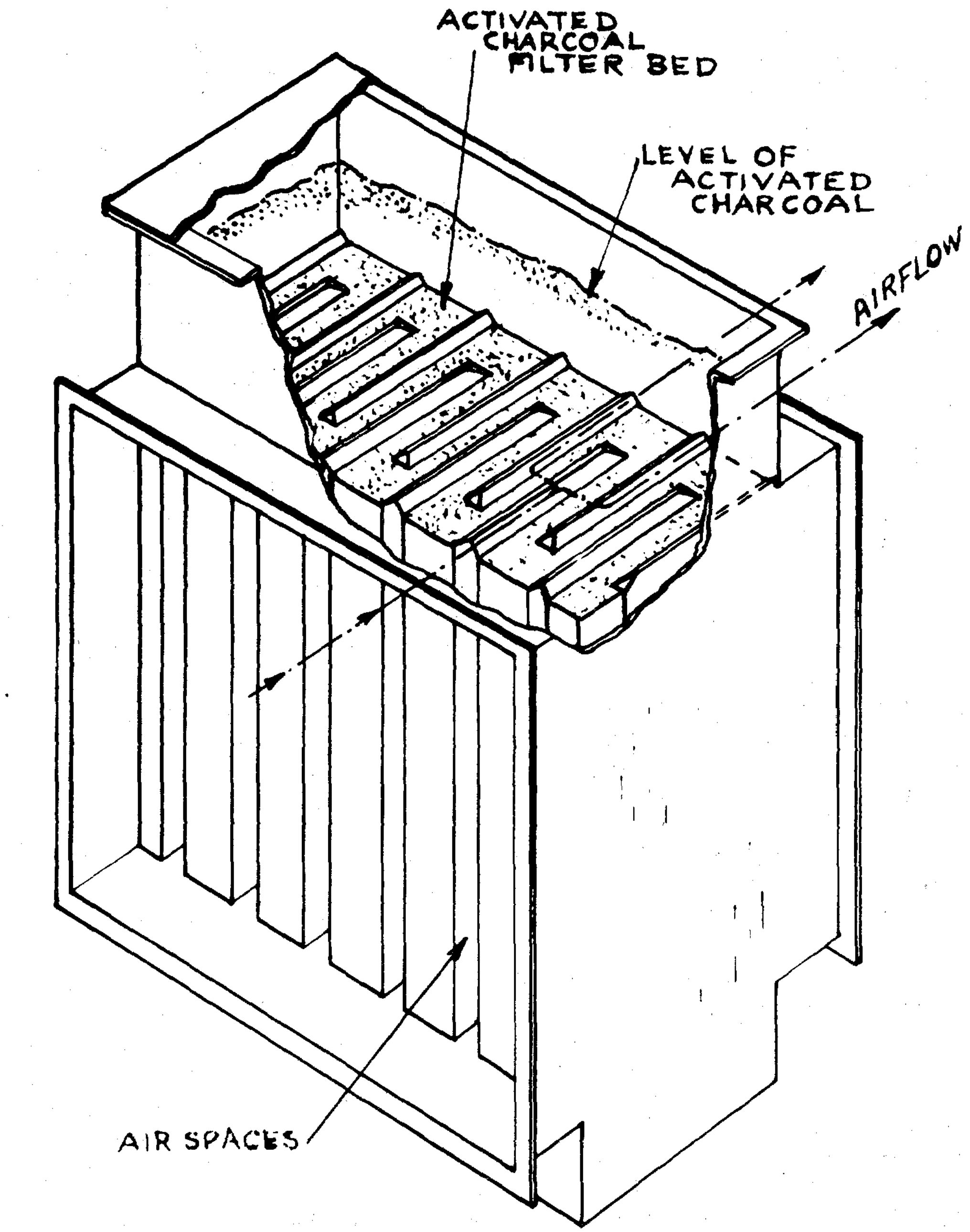


FIGURE 5

the leakage is directed through a column of activated charcoal at least equal in thickness to that used in the filtering portion of the structure. Normal modular charcoal cells using frames adapted to the use of charcoal seals could be employed, but the entire structure and application becomes simpler and more desirable if the cell structure is turned inside out, having discrete air inlet and discrete air outlet panels built into the continuum of activated charcoal. This, in essence, is the gasketless adsorber which I am describing in this paper.

Typical charcoal adsorber cells for radioactive iodine and methyl iodide containment are made in sizes to handle 400 or 1000 cfm per unit and having neoprene gaskets with circumferences of about 5 feet and 8 feet, respectively. These gaskets are designed to be tight and every precaution is taken to see that they are tight, including an in-place leak test of the entire bank to ascertain tightness. There have been some problems in obtaining or assuring tightness and there is always the question of definite continuing tightness during the operation of the system, including normal surges and shocks. The construction labor which must be used in assembling the equipment on the site is not always completely reliable and there may be some mystery with regard to how well the cells are installed and how tight they are and will continue to be. The gasketless adsorber, on the other hand, achieves its tightness without close fits and without the use of extreme care in tightness and evenness of bolting or clamping. There may be many imperfections in the construction and still have complete and reliable tightness because the tightness is in the features of the design rather than the skill of fabrication and installation. The gasketless adsorber was designed initially to overcome the objections of the usual bolted and gasketed banks and to present complete reliability in spite of all of the problems normally occurring in construction of the equipment, its installation, its operation, and its maintenance.

In a normal bank containing sufficient filters to handle 20,000 cfm, there are about 150 to 300 feet of gasket; this is a considerable length to make tight in the first place and to maintain tight through all conditions of operation, with pneumatic and mechanical shocks and temperature changes. It is logical that the inherent efficiency of the charcoal bed is downgraded for design purposes because of the possibility of gasket problems.

Typical normal containment systems are shown in Figures 6 and 7.

If an accident occurs in a typical system with individual gasketed cells, it is difficult to replace the activated charcoal and put the system back into operation. It generally requires that the cells be removed and replaced or refilled with charcoal, and reinstalled in the system, together with tests of the bank to be sure that the cells and gaskets are again tight.

In the gasketless adsorber, there is no gasket to be made tight. If an accident occurs, the charcoal can be withdrawn from the system and replaced without the necessity of breaking gasket seals, removing

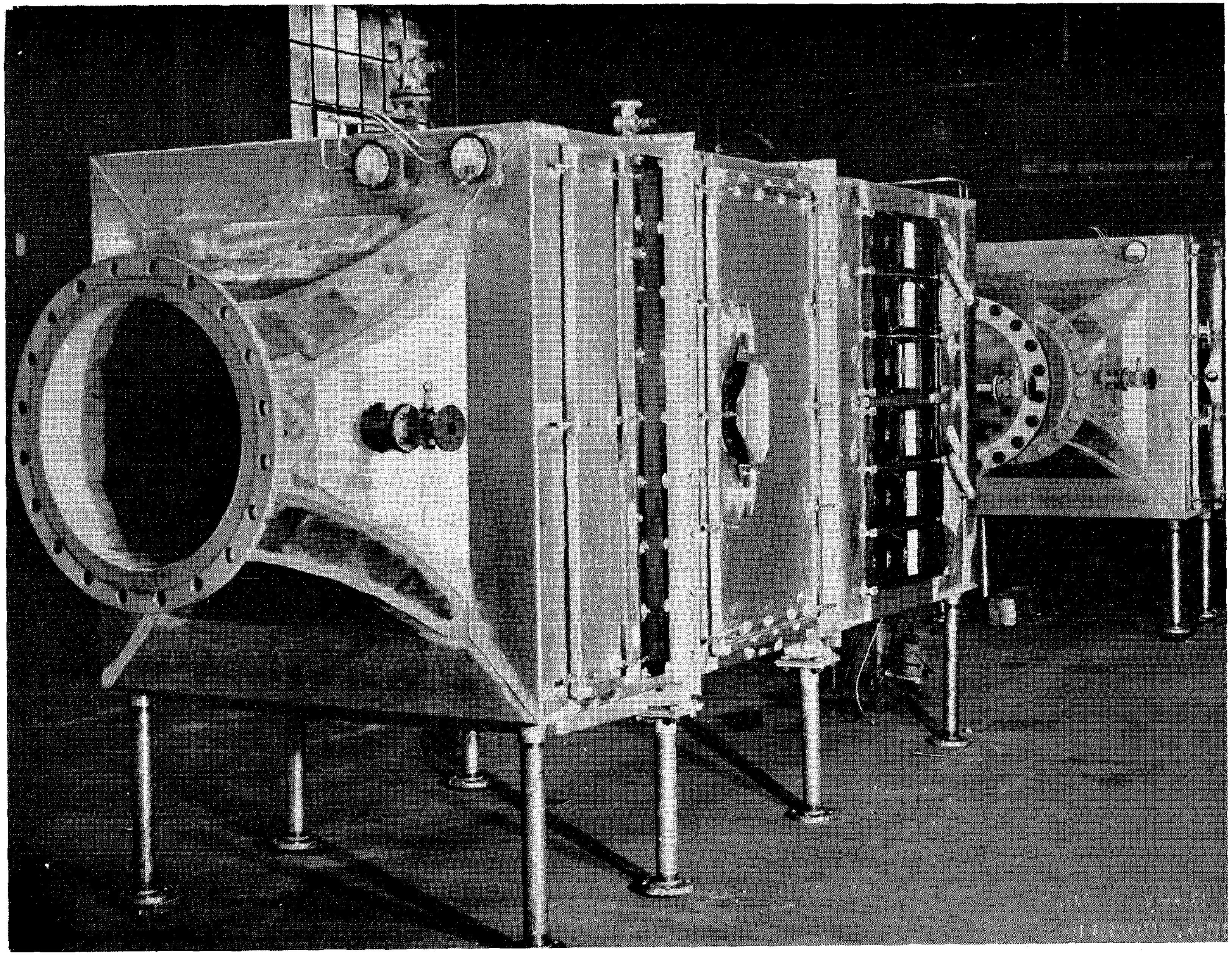


FIGURE 6

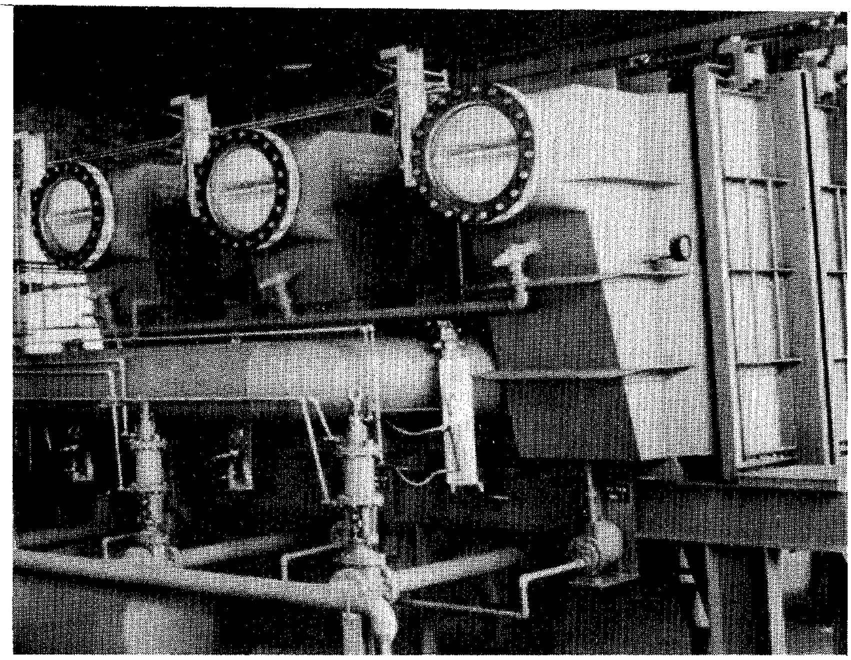


FIGURE 7

individual cells or other metal parts. If, after withdrawal from the system, the charcoal is in satisfactory condition, it can be placed back into the system or any fraction of it can be reused, or a completely new charge used in its stead. If there is any question about the integrity of the bed, it can be recompacted, using the built-in mechanical device which was used in the original compaction of the bed. This should be necessary only in case something rather drastic has happened to the bed, an accident or occurrence which would probably cause the complete destruction of at least part of a normal activated charcoal adsorber bank.

Laboratory and field operations have demonstrated that efficiencies and pressure drops can be calculated, based on information available for charcoal beds of the same thickness and operated under the same velocity and gas composition conditions. These tests have confirmed that there are no bypass losses, that the edge sealing is completely accomplished by the use of an activated charcoal seal, and that charcoal can be withdrawn from and added to the bed without the necessity of entering the filter chamber. We do not recommend the withdrawal of charcoal from a bed in operation (at full air or gas flow) unless the design was made with that feature in mind.

If one wishes to analyze the condition of the bed, one can pull out any portion of the charcoal and test it, then replace the charcoal in the adsorber, or samples can be taken at successive levels. Some of the designs are made so that there are separate columns of charcoal within the bed subject to the same air flow and contaminants, and which can be withdrawn separately.

While the efficiency of the activated charcoal for the removal of radioactive iodine is very high (99.99+%) even at high relative humidities and 2" bed thickness, the removal efficiency for radioactive methyl iodide is reduced when the relative humidity exceeds about 75%, tapering off to about 75% efficiency at close to 100% relative humidity. By using a 6" thick bed and extrapolating these same data in accordance with the method indicated by D. A. Collins et al(1) and J. H. Swanks(2), we find that at 95% relative humidity, the methyl iodide removal should still be in the order of 99.9+%.

Concern has been expressed about how to handle the situation when the charcoal bed catches on fire because of high heat release within the bed. Such a fire must be extinguished by closing off the filter chamber so that it goes out because of lack of oxygen and dissipation of the heat, or by flooding with water with the air flow shut off. As soon as the temperature decreases to a suitable lower point, the air flow can be re-established. It is not suggested that one should attempt to extinguish a fire in a charcoal bed with the air flow maintained. In the gasketless adsorber, the extinguishing of a fire is much easier because the charcoal bed can be drenched at right angles to the air flow direction. As soon as the temperature has been reduced to a suitable point, the water is shut off and the air flow is re-established. If the charcoal bed is not in good condition because too much of it has been burned away or the impregnant has been volatilized or washed off, the charcoal can be easily replaced by withdrawing the spent charcoal from the bottom and adding new charcoal at the top. This means that the only significant down time is that required to cool off the bed with a water deluge. The water deluge system can be easily built into the gasketless adsorber and this is considered to be a standard feature when requested. Another way of handling the fire is to discharge the entire mass out through a hopper bottom into a suitable metallic container (provided for in advance and ready for such use), and then refill the adsorber with a new charge of charcoal which is on hand ready for the purpose.

A series of tests were run to demonstrate extinguishing of a fire in the gasketless adsorber. A prototype unit was set up and operated at rated velocities. The bed was set on fire in one spot with a torch and allowed to spread enough to give a good size fire. The air flow was shut off. The bed was deluged from top to bottom (perpendicular to the air flow direction). After a period of five minutes, the air flow was re-established and it was determined that the fire had been completely extinguished. We do not recommend that the extinguishment of a fire be attempted with full air flow maintained. It should either be shut completely off or reduced greatly. The extinguishing is done rapidly and the air flow can then be reestablished.

It is difficult to ignite charcoal and it is doubtful that it is possible for the charcoal to be ignited by decay heat. This is because, as the temperature rises, the iodine or iodides will be volatilized and there will be less heat generated in the charcoal.

Figure 8 shows a gasketless adsorber test unit which has seen service in the field, has been set on fire in our pilot laboratory, and has been generally put through its paces as far as air flow, resistance, performance, charcoal inlet, charcoal outlet, and the other important features are concerned. Pressure drops at various air flows and for three charcoal mesh sizes are given in Figure 9.

The design and construction of the gasketless filter are such that the operation can be scaled up or down, using data obtained from other sizes of units. Laboratory and pilot sizes are available for test work. The results obtained from these are of direct utility in the design and building of large units. There are no difficult structural limitations in the construction of gasketless adsorbers. They can be built in as large a size as needed for any job, either in a single unit or in multiple units. It adapts itself well to modular construction. Standard elements can be assembled with any reasonable number in a suitable enclosure and the entire inside construction submerged in activated charcoal.

The gasketless adsorber can be used in series with hepa filters to remove fine particulate contaminants as well as the gas and vapor species, or it can be used in a deep bed which will serve both functions, although the amount of activated charcoal needed to remove the particles to a high degree is much greater than is necessary to remove iodine and methyl iodide. The total cost of the system as compared with hepa filters and charcoal filters in series is not greatly

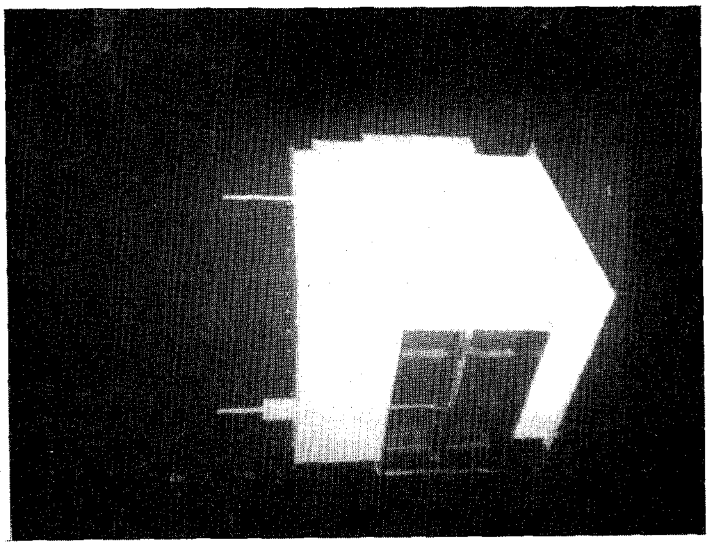


FIGURE 8

GASKETLESS ADSORBER

AIR PRESSURE DROP AT 40 FPM SUPERFICIAL BED VELOCITY
FOR DIFFERENT CHARCOAL PARTICLE SIZES.

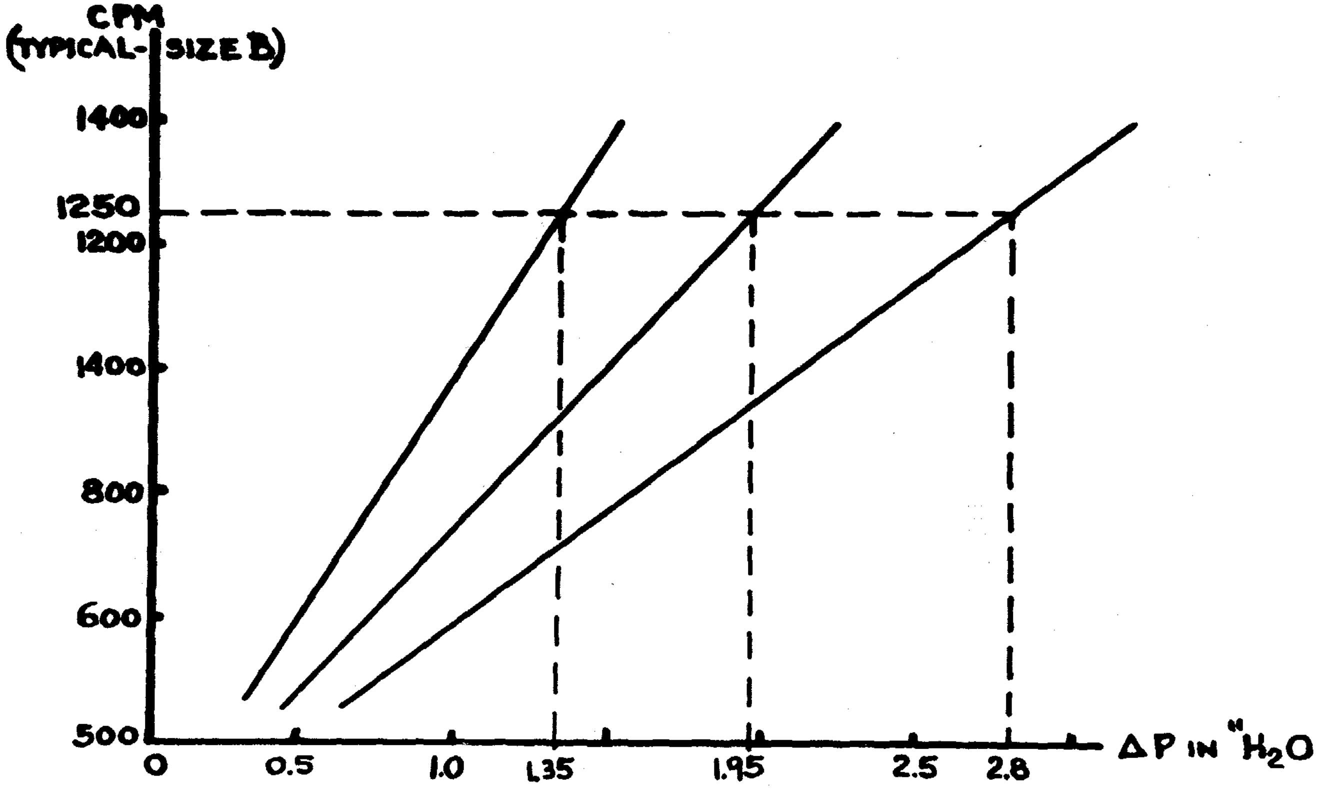


FIGURE 9

different and the gasketless adsorber has the advantage of simplicity and its ability to renew both portions of the filter (particulate and gas) without entering the filter chamber. Also, at the same time, the possibility of gasket leakage around the hepa filters is eliminated because the thick charcoal bed does both jobs.

Figure 10 shows a gasketless adsorber with the related features that may be necessary in a specific application.

The means for withdrawing the used charcoal may be in the form of a portable vacuum system or other suitable device of such nature or by gravity through a hopper bottom. Portholes through which the charcoal is to be removed can be covered with caps or covers and likewise have charcoal seals. Inspection openings with screw-on caps can be provided at the top of the housing above the charcoal bed to permit periodic inspection. The design of the agitator can be such that it may likewise be used for compacting or settling the activated charcoal when desired at times of periodic inspections or otherwise when the occasion arises, whether the charcoal is replaced or not. Ample bolted-on access and inspection covers are provided on top and bottom of the housing for access to the activated charcoal spaces. In addition, bulkhead type, hinged access doors can be provided upstream and downstream of the charcoal bed. The structure which retains the activated charcoal bed provides for suitable perforated or air-permeable supporting walls with necessary back-up and supporting structure to assure sufficient rigidity, integrity, and constant uniformity of the charcoal bed dimensions. All metal parts in contact with the charcoal generally are of type 304 stainless steel. The supporting structure and housing are low carbon steel, with rust-resistant coating. The discharge can be arranged for bag-out of the charcoal or placement of it inside containers. This is simpler with the gasketless adsorber than with a bank of individual cells. Figure 11 shows a typical filter box for both hepa and charcoal filters and arranged for bag-out technique of the individual cells. The removal of charcoal from the gasketless adsorber can be directly into whatever type of containers are desired and can be done without danger to personnel or surrounding atmosphere.

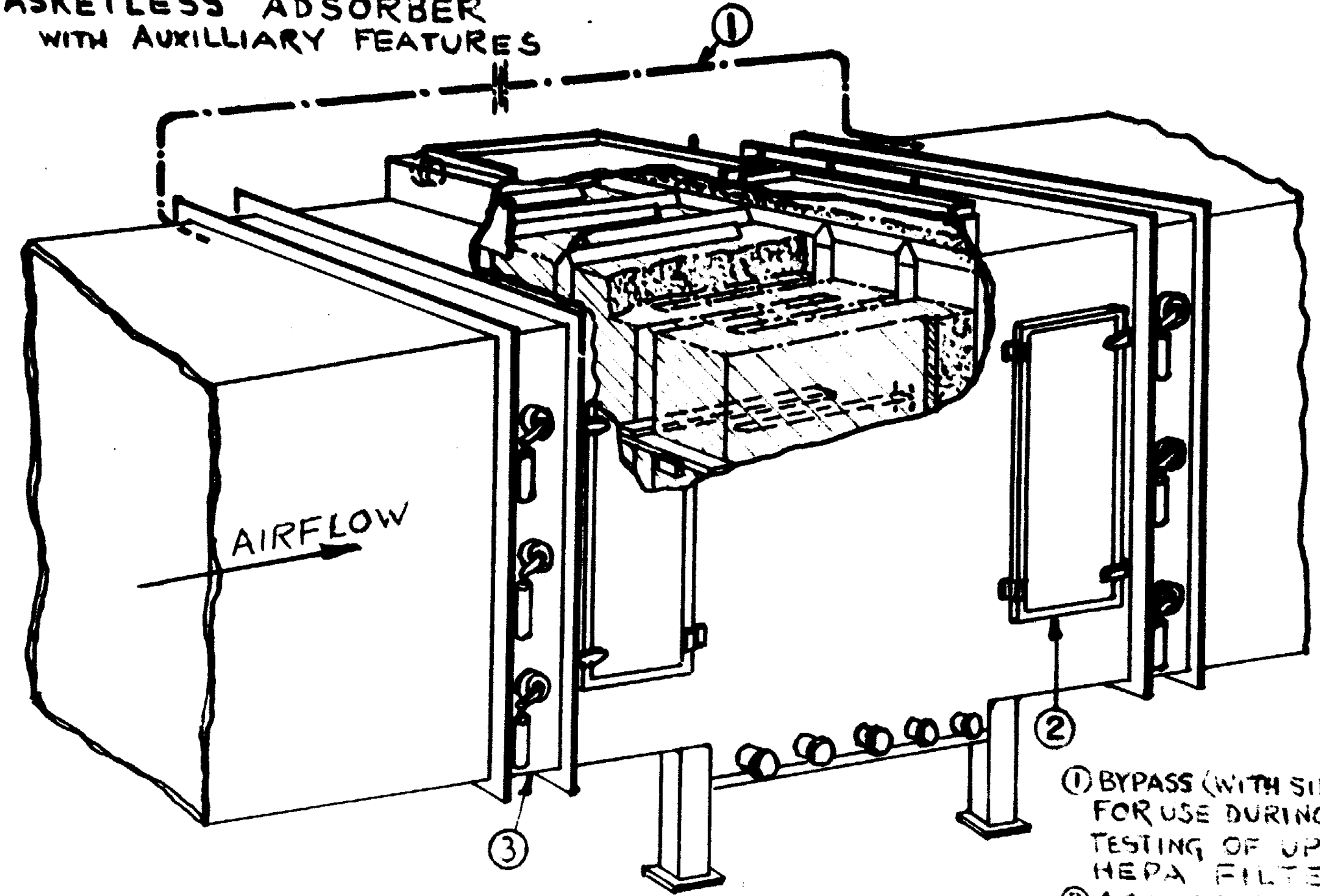
Figure 12 shows a series of sizes of gasketless adsorbers up to 10,000 cfm. This particular group is based on a 6" activated charcoal thickness and a pressure drop of 2.8" w.g. (the pressure drop depends on mesh size of charcoal used, bed thickness, and velocity). Units of any desired size can be constructed and for any charcoal thickness that is determined to be adequate for a specific application.

The following auxiliary features can be built into the gasketless filter, if desired or required:

Charcoal addition and removal systems.

Test cell portion built into adsorber so that the condition of the bed at any level can be determined without withdrawing the entire mass of charcoal.

GASKETLESS ADSORBER
WITH AUXILLIARY FEATURES



① BYPASS (WITH SIDE CLOSURE) FOR USE DURING DOP TESTING OF UPSTREAM HEPA FILTERS
② ACCESS DOORS
③ MULTIPLE BUTTERFLY VALVES TO CLOSE CHARCOAL SECTION DURING STANDBY

FIGURE 10

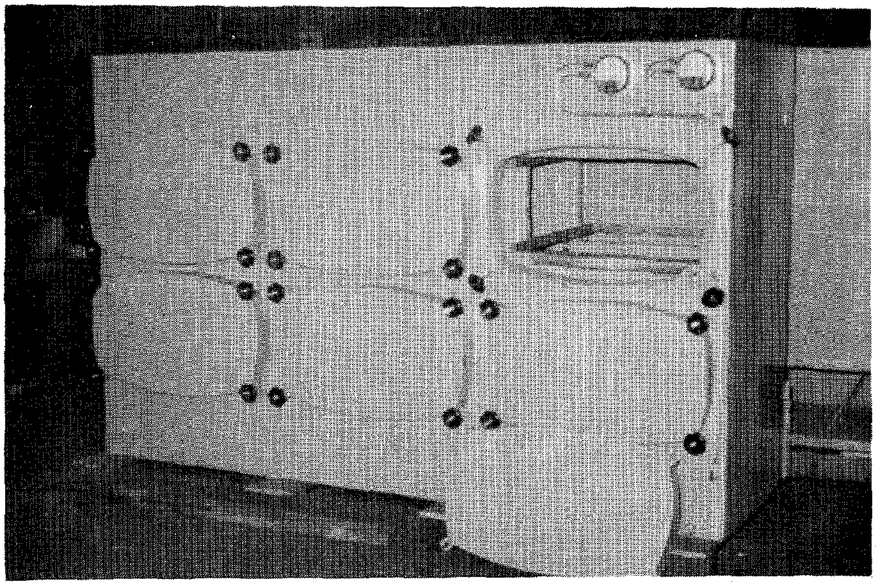
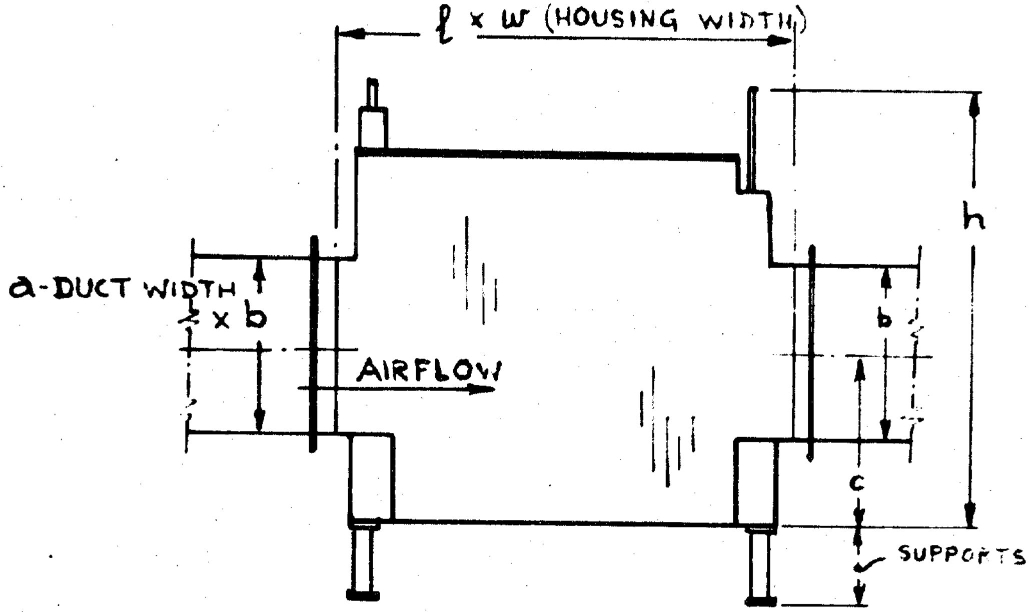


FIGURE 11

FIGURE 12

GASKETLESS ADSORBER



SIZE	RATING CFM	DIMENSIONS in inches						MATCHING 24" SQ. HEPA'S NO. CELLS WIDE x HIGH
		a	b	c	h	ℓ	w	
A	1000	33	$21\frac{1}{4}$	$21\frac{1}{2}$	54	46	$35\frac{1}{2}$	1 x 1
B	1250	33	$21\frac{1}{4}$	$21\frac{1}{2}$	54	56	$35\frac{1}{2}$	1 x 1
C	1650	$44\frac{1}{4}$	$21\frac{1}{4}$	$21\frac{1}{2}$	54	56	47	2 x 1
D	2000	$44\frac{1}{4}$	$21\frac{1}{4}$	$21\frac{1}{2}$	54	64	47	2 x 1
E	3400	$44\frac{1}{4}$	$45\frac{1}{4}$	$33\frac{1}{2}$	78	64	47	2 x 2
F	4300	$44\frac{1}{4}$	$45\frac{1}{4}$	$33\frac{1}{2}$	78	78	47	2 x 2
G	7000	$44\frac{1}{4}$	$69\frac{1}{4}$	$45\frac{1}{2}$	102	78	47	2 x 3
H	10000	$66\frac{3}{4}$	$69\frac{1}{4}$	$45\frac{1}{2}$	102	78	$69\frac{1}{2}$	3 x 3
I	17500	$89\frac{1}{4}$	$93\frac{1}{4}$	$57\frac{1}{2}$	126	78	92	4 x 4
J	22000	$111\frac{3}{4}$	$93\frac{1}{4}$	$57\frac{1}{2}$	126	78	$114\frac{1}{2}$	5 x 4

Other filter steps, such as demister, roughing, high capacity particulate, and high efficiency particulate filter into the same system.

Temperature-sensing arrangements to actuate water-flooding facilities.

Water-flooding arrangements as a precaution against possible fires.

Valving arrangements for isolating a portion of the system for service or inspection.

Use of any type of charcoal or other granular adsorbent material.

Remote arrangements for complete operation of purification system, including removal and addition of activated charcoal.

Single step construction to provide same purification capacity as a multi-step system (generally consisting of a roughing filter, hepa filter, and charcoal filter).

The possibility of washing or impregnating the charcoal without removing it from the system.

Submerged air space or gasketless adsorbers should be considered for the following types of applications:

Nuclear containment systems

Toxic gas elimination systems

Solvent recovery

Military shelters

Air pollution control

Recovery of valuable vapors

Industrial gas purification

Vent gas purifiers

Elimination of highly odorous substances

and similar applications in which a high degree of efficiency and reliability are required.

References

(1) D. A. Collins, L. R. Taylor, and R. R. Taylor (Sellefield, England), "Redevelopment of Impregnated Charcoal for Trapping Methyl Iodide at High Humidity".

(2) J. H. Swanks (ORNL), "In-Place Filter Testing", 9th Air Cleaning Conference.

Illustrations

1. 1-inch thickness multifold adsorption cell, nominally for 1000 cfm.
2. 2-inch thickness multifold adsorption cell, nominally for 600 cfm.
3. 2-inch thickness drawer-type cell with temperature-sensing element, nominally for 333 to 400 cfm.
4. Mounting frame for four drawer-type cells.
5. Basic principle of gasketless adsorber.
6. Typical multistage containment systems with demisters, electrical re-heaters, drawer-type charcoal cells, and hepa cells.
7. Three-charcoal filter-mounting boxes which contain banks of 1000 cfm cells.
8. Prototype gasketless adsorber used for laboratory and field tests.
9. Pressure drop curves obtained for gasketless adsorber.
10. Gasketless adsorber with auxiliary parts.
11. Charcoal adsorber and hepa filter mounting box provided for bag-out of filters.
12. Schedule of standard sizes for gasketless adsorbers.

DISCUSSION

FIRST: We heard some comment during the course of several of the papers about the need for new materials and new construction techniques. I think the equipment manufacturers are responding, slowing, but responding, and this is a good example of what is being done in this area.