## OPEN DISCUSSION SESSION

FIRST: I would like to take a moment if I may and extend my own thanks, as well as those of the entire group, to the local Committee that has been so instrumental in making this meeting go as smoothly as it has. There have been a number of people involved and I am sure you all appreciate the work they have done. Let me remind you who they are. In addition to Mr. Marshall Mills there is Mr. G. R. Yesberger who has been in charge of the registration and the finances for the Conference. Mr. H. G. Hicks has been in charge of the tours. Mr. F. J. Williams has been in charge of the auditorium arrangements. Mr. R. L. Kathren was in charge of the Health Physics Society dinner last Tuesday. Mr. W. L. Koop has been in charge of the publicity for the meeting and I hope you have seen some of the notices in the papers. Mr. R. H. Wilson has been in charge of transportation. Mary Sharp has performed above and beyond the call of duty in transcribing the record. To this lady and to all of these gentlemen I extend your thanks as well as my own and a commendation for a job very well done.

The rules for the Open Discussion Session are very simple. These presentations are comments, questions, and discussions which have been left over from the preceding sessions or entirely new topics. The only rules are that the speakers be brief. Five or ten minutes will be allotted for a presentation and we will then follow the discussion wherever it goes. Kindly be aware of the fact that if you make a presentation before this group over 100 people will hear you, your remarks will be taped and transcribed and there is no possibility that they can be considered "off the record." With this brief introduction the first item on the agenda will be presented by Mr. Baurmash.

# MEASUREMENTS OF PARTICULATE FILTRATION EFFICIENCIES OF BUILDING*

C. Nelson
J. Granger
R. Koontz
L. Baurmash

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## ABSTRACT

The release and transport of effluents generated during hypothetical major Liquid Metal Fast Breeder Reactor (LMFBR) accidents are being characterized for application to safety and engineering safeguards design, since the doses at the site boundaries are based on the leaked mass of hazardous materials.

This paper describes experiments and results which show that the airborne mass is considerably reduced as it passes through concrete and other porous materials. Experiments indicate that as much as a $10^5$ attenuation of sodium oxide aerosol can be expected as it passes through as little as 1-1/2 in. of concrete. Leakage through cracks and capillaries are evaluated experimentally, to show the role of impaction, settling, and diffusion in reducing the leaked mass.

## I. INTRODUCTION

The doses at reactor site boundaries are based on the leakage of hazardous materials through reactor buildings. The degree of containment required is dependent on the maximum accident hypothesized, the resultant quantity of hazardous material, pressure, and leaktightness of the enclosure. If one can demonstrate that the mass of airborne material is considerably reduced, as it passes through concrete or other porous material, economic savings in building construction and site acreage are possible.

This paper presents data from experiments in which air leakage rate and attentuation of airborne particulates through concrete and other porous materials are measured.

## II. DESCRIPTION OF CRACKS IN CONCRETE

The theoretical and experimental causes of cracking in concrete, and their effects on air leakage, have been reported in various documents.[1-3] Cracks in low-leakage reinforced concrete buildings are

*Work performed under USAEC Contract AT(04-3)-701.

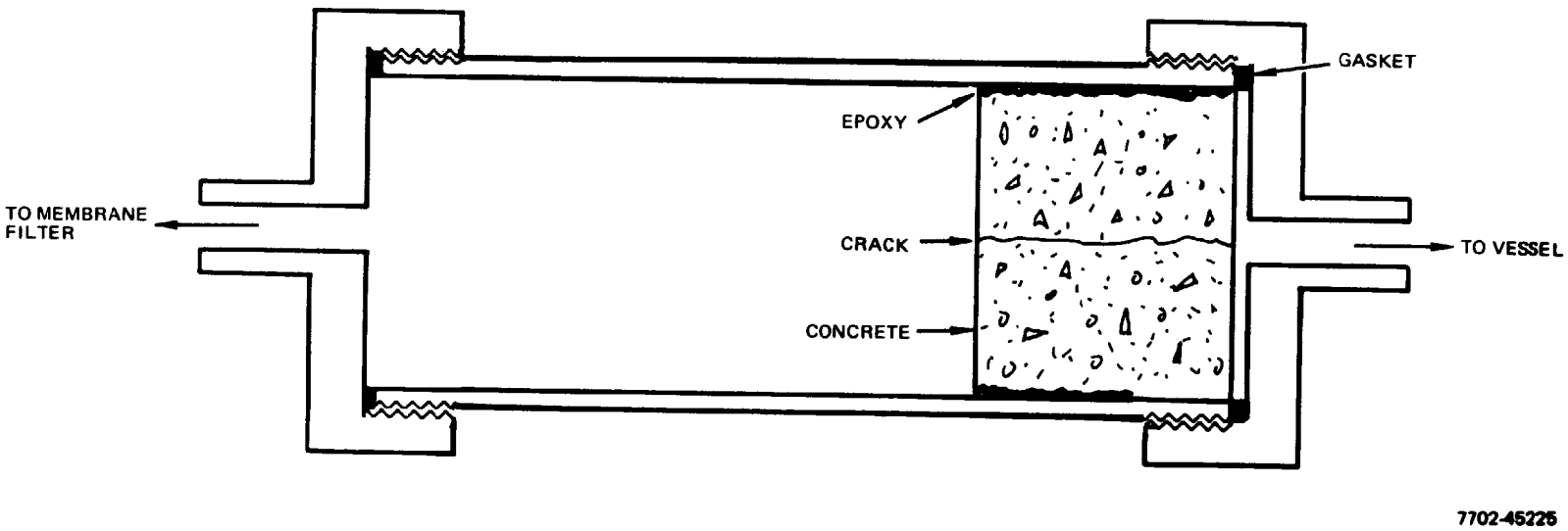


Figure 1. Test Specimen

normally caused by loading stresses, thermal expansion and contraction of fixed members, differential shrinkage, and differential expansion. In properly designed reinforced structures, cracks will penetrate only in the tension region of the concrete, and will stop short of the neutral axis, so that cracks seldom penetrate more than 50% of the wall thickness.

Assuming most of the parameters other than pressure differentials and size of openings are constant, the following equation[3] can be used to express the leakage of air through leak paths:

$$q_T = C_1 P + C_2 P^{1/2} \quad , \qquad \ldots (1)$$

where:

$q_T$ = total volumetric leak rate of parallel leak paths and series leak paths in a test specimen

$C_1, C_2$ = empirical constants (orifice, $C_1 = 0$; crack, $C_2 = 0$)

$P = P_i - P_o$

$P_i$ = internal or upstream pressure

$P_o$ = outward or downstream pressure.

The flow of gas through uncracked concrete, and concrete with small hairline cracks, can best be approximated by assuming $C_2 = 0$. Presently, the ratio, $(\Sigma q_T)/V$, is defined as the leaked mass fraction from a containment structure. The summation sign represents the total leakage in the structure.

## III. EXPERIMENTAL METHOD AND SPECIMEN PREPARATION

The concrete test specimens were prepared by filling several pipes (2 in. diameter) with ready-mix concrete (design mix unknown) to a depth of 1.5 in. Sleeves of various thicknesses were placed in the pipe, prior to pouring the concrete. After curing, the specimens were removed, cracked, coated with epoxy, and replaced in the pipe (See Figure 1). Measurements were made of the air-leakage rates through the specimens, to determine the effective crack width and flow rate at various pressure differentials (See Table 1). The aerosol leak experiments were performed during the sodium fires experiments (spray and pool) which are currently in progress at Atomics International. The specimen under test is attached directly to the test vessel where the particulates are formed. In these studies, the Laboratory Test Chamber and the Spray Test Chamber were involved. All aerosols which penetrate the specimen are captured on a membrane filter. The total gas flow through each specimen is measured during the test.

## IV. EXPERIMENTAL RESULTS

The results of the preliminary filter experiments (Table 1) show that the reduction factor for sodium oxide varies from 150 for Concrete Specimen No. 4 to $10^5$ for Specimen No. 1.

TABLE 1

EXPERIMENTAL TEST DATA

| Parameters | Porous Alundum Crucible | Concrete Specimen | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 3′ | 5 |
| Diameter (in.) | 1.5 | 2 | 2 | 2 | 2 | 2 | 2 |
| Thickness (in.) | 1/16 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Initial Flow at 5 psig (ℓ/min) | 25 | 1.2 | 11.2 | 24 | 24 | 24 | $1.3 \times 10^{-3}$ |
| Flow at 5 psig After Test (ℓ/min) | - | 1.2 | 10 | 1.4 | 12.5 | 1.0 | $<10^{-4}$* |
| Type of Leak† | Porous | Crack | Crack and Orifice | Crack | Crack and Orifice | Crack | Porous |
| ΔP Across Specimen During Test (psig) | <0.5 | 5 | 0.5 to 1 | 2.5 | 2.5 to 4 | 2.5 to 3 | 3 |
| Crack Width (mil) | None | ~1.8 | ~3.8 to 4.5 | ~5 | ~5 to 6.3 | ~5 | None |
| Reduction§ Factor for Sodium Oxide | $4 \times 10^4$* | $>10^5$* | $5.5 \times 10^3$ | $2.5 \times 10^3$ | 150 | $10^3$ | $>5 \times 10^3$* |
| Reduction§ Factor — Agglomerated $I_2^{131}$ | $>10^3$* | - | - | - | - | $10^3$ | - |

*Limit of detection

†Type of flow characterized by Equation 1

§Ratio of sodium or agglomerated $I_2^{131}$ entering concrete as crucible to that on membrane filter.

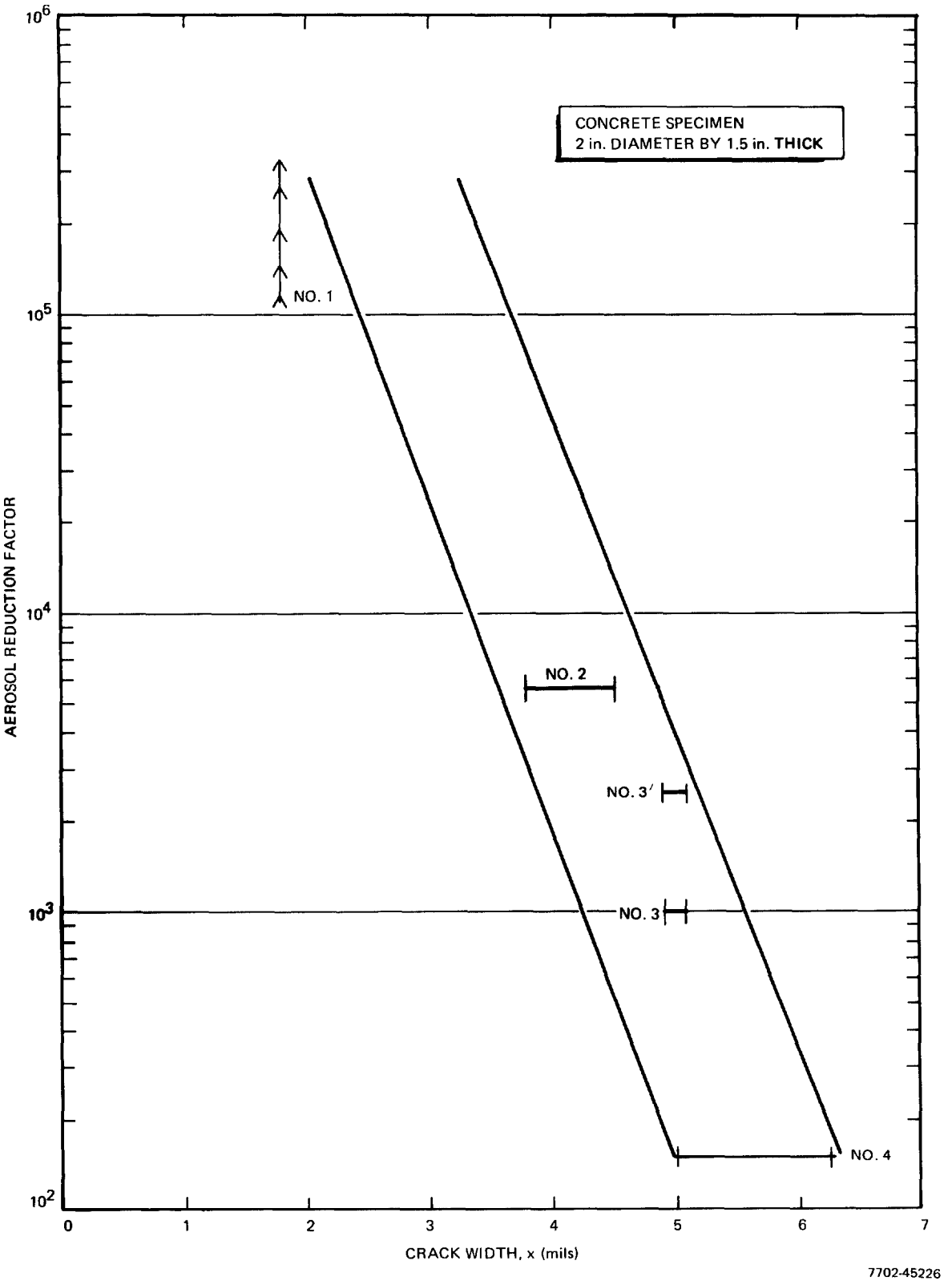


Figure 2. Aerosol Reduction Factor vs Crack Width

There was no sodium oxide detectable on the membrane filter when uncracked concrete was tested. One may assume that the reduction for the uncracked concrete is at least as high as $10^5$ (value for Concrete Specimen No. 1). The difficulty in measuring filter efficiency for uncracked concrete is the small leakage gas, and thus small mass which is carried along with the gas. Specimen No. 5 had an initial flow rate of $1.3 \times 10^{-3}$ ℓ/min, as compared to 24 ℓ/min for Specimen No. 4, which had a crack.

Notice that, during the test, the flow through Specimen No. 3 reduced from 24 ℓ/min to 1.0 to 1.4 ℓ/min (1.4 for Specimen No. 3, 1.0 for Specimen No. 3′ – two tests on same specimen), indicating that the crack clogged. After clogging, the flow rate for Specimen No. 3 approached that of Specimen No. 1. The clogging occurred in approximately the first minute, when the aerosol concentration was ~20 to 40 $\mu g/cm^3$ sodium oxide. After clogging, the reduction factor for sodium oxide was probably $>10^3$, and may have approached the $10^5$ value for the 1.8-mil crack.

The experimental data produced (Table 1) illustrates that concrete with no cracks can act as an absolute sodium oxide filter. Concrete with very small cracks can also act as a filter, to attenuate the particulates which penetrate through the specimen. This depends on the effective crack width, as shown in Figure 2. It can be seen that the attenuation varies inversely exponentially with effective crack width.

## V. CONCLUSIONS

The siting of liquid metal fast breeder reactors is influenced by the potential hazard of released fuel and fission product aerosols. At the present time, the site boundary is determined by the gas leaktightness or leak rate of the reactor building, and no credit is given for the reduction of airborne mass as the particulates pass through the leakage paths in the containment barrier. Study of the filtration efficiencies of building materials may result in a more realistic assessment of the mass of fuel and fission product aerosols which may enter into the environment.

## REFERENCES


1. Michael Chi and Arthur F. Kirstein, "Flexural Crack in Reinforced Concrete Beams," American Concrete Institute Journal, 29, (July 1957-June 1958)
2. R. L. Koontz et al., "Conventional Buildings for Reactor Containment," NAA-SR-10100 (1965)
3. C. T. Nelson, A. S. Gibson, and R. L. Koontz, "Production and Control of Leakage Through Cracks and Capillaries in Reinforced Concrete Buildings Used to House Reactors," NAA-SR-Memo-9429 (1964)

## DISCUSSION

PARKER: I would like to mention that this brings to mind a paper that was written by Browning and Fontana of Oak Ridge on the theoretical leakage of particles through small openings. I think it is known as NSIC-1. It was a real early treatment and confirms essentially what you say here, Mr. Baurmash.

FIRST: The next paper will be presented by Mr. Sims.

# RETESTING SELECTED USED HEPA FILTERS TO DETERMINE OPTIMUM FILTER LIFE UNDER VARIOUS OPERATING CONDITIONS: A PROGRESS REPORT

L. L. Sims
Hanford Environmental Health Foundation

HEPA filter installations at AEC facilities are exposed to exhaust ventilation air of various qualities ranging from those having minimal effect on filters other than light loading to those which are highly detrimental to filter integrity. Some of the atmospheres which are deleterious to filter components may contain corrosive chemicals, have a high moisture loading or temperature extremes. Frequently, filters are subjected unknowingly to such stresses and usually the condition or performance of the filter is in question after exhaust ventilation conditions return to normal.

In many of the AEC facilities, HEPA filter installations are given DOP tests by portable equipment to evaluate in-place efficiency. Although this standard in-place test is acceptable for field conditions for semi-quantitative data, it is not comparable to thermally generated DOP test data obtained at the AEC quality assurance test stations in which the filters are tested prior to installation.

The replacement of HEPA filters in practice is decided by various criteria such as:

1. Pressure drop changes.
2. Reduced efficiency as indicated by in-place tests.
3. Visual observation of deterioration.

Since it is not normally feasible to continuously monitor HEPA filters for efficiency, it is not possible to know accurately at all times the degree of air cleaning that is achieved. Moreover, increases in the pressure drop only reflect on the load imposed on the filter and do not demonstrate the efficiency of air cleaning.

In view of the foregoing considerations, it is evident that HEPA filters as used in AEC facilities are subjected to stresses which change their efficiency with respect to air cleaning and consequently change the concentration of effluent gas contamination discharged to the environment. The purpose of the current study is to gather performance data on HEPA filters at the termination of their use which will be directly comparable with their measured efficiency and pressure drop prior to installation. This is possible since the Environmental Health Sciences Filter Testing Station has on file the original performance data on each filter in service. The filters will be tested with the same DOP tester and under essentially the same conditions as for their initial tests.

For this project, used filters, as they become available, are carefully removed, packaged and sealed, then taken to a contaminated equipment storage area.

People in charge of HEPA filters in the various areas here at Hanford have been contacted with respect to obtaining used filters before they are removed to contaminated waste burial. In obtaining these filters, emphasis is placed

on careful handling during removal to insure that the filter will be in the same condition as it was while in service. Several filters have thus been obtained but have not been tested pending checkout of the greenhouse and its equipment.

To facilitate testing and radiological safety, actual testing is being conducted in a disposable, mobile plywood "greenhouse," (Figure 1) which can be easily moved out of the testing laboratory between periods of testing. The test aerosol, generated by the E-18 penetrometer, is passed from the upstream plenum of the E-18 tester to the greenhouse (see Figure 2) which contains a simple chucking arrangement (Figure 3) which permits measurement of both filter efficiency and pressure drop. Greenhouse air is exhausted through a clean HEPA filter (Figure 4). Measurements will be taken in such a way that the tester can be restored to its original condition with minimal decontamination.

Problem areas uncovered during the checkout of the greenhouse have included resistance contributions of the downstream mixing and sampling plenum and leaks in the system. These problems have been remedied and testing of clean filters has proceeded. Clean filters were first tested on the E-18 tester and then in the greenhouse arrangement. Data on pressure drops and efficiencies for both tests have shown the data to be comparable.

Historical data regarding the service conditions of the used filters will be correlated with data obtained from this study to provide information

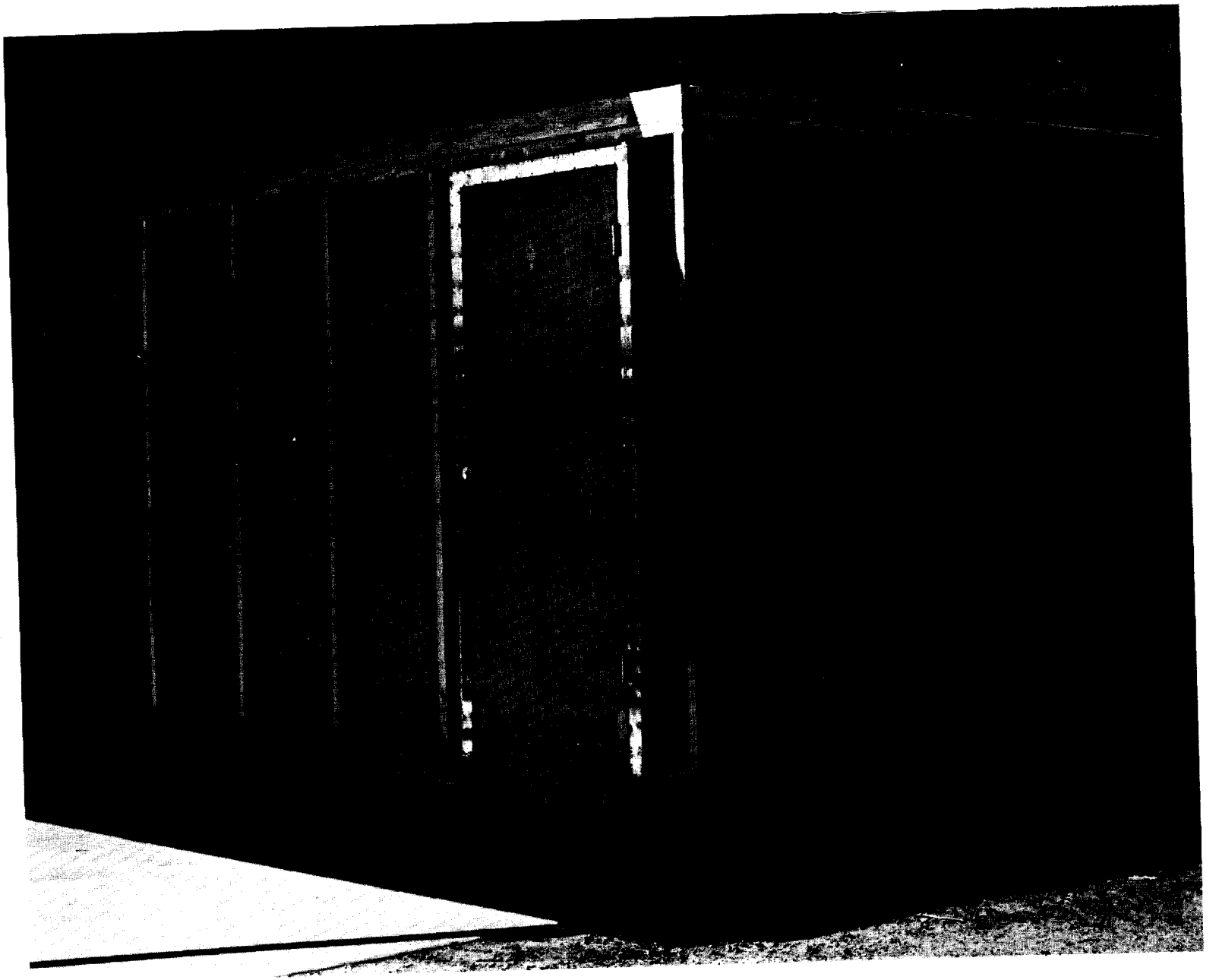

Figure 1. Mobile Greenhouse

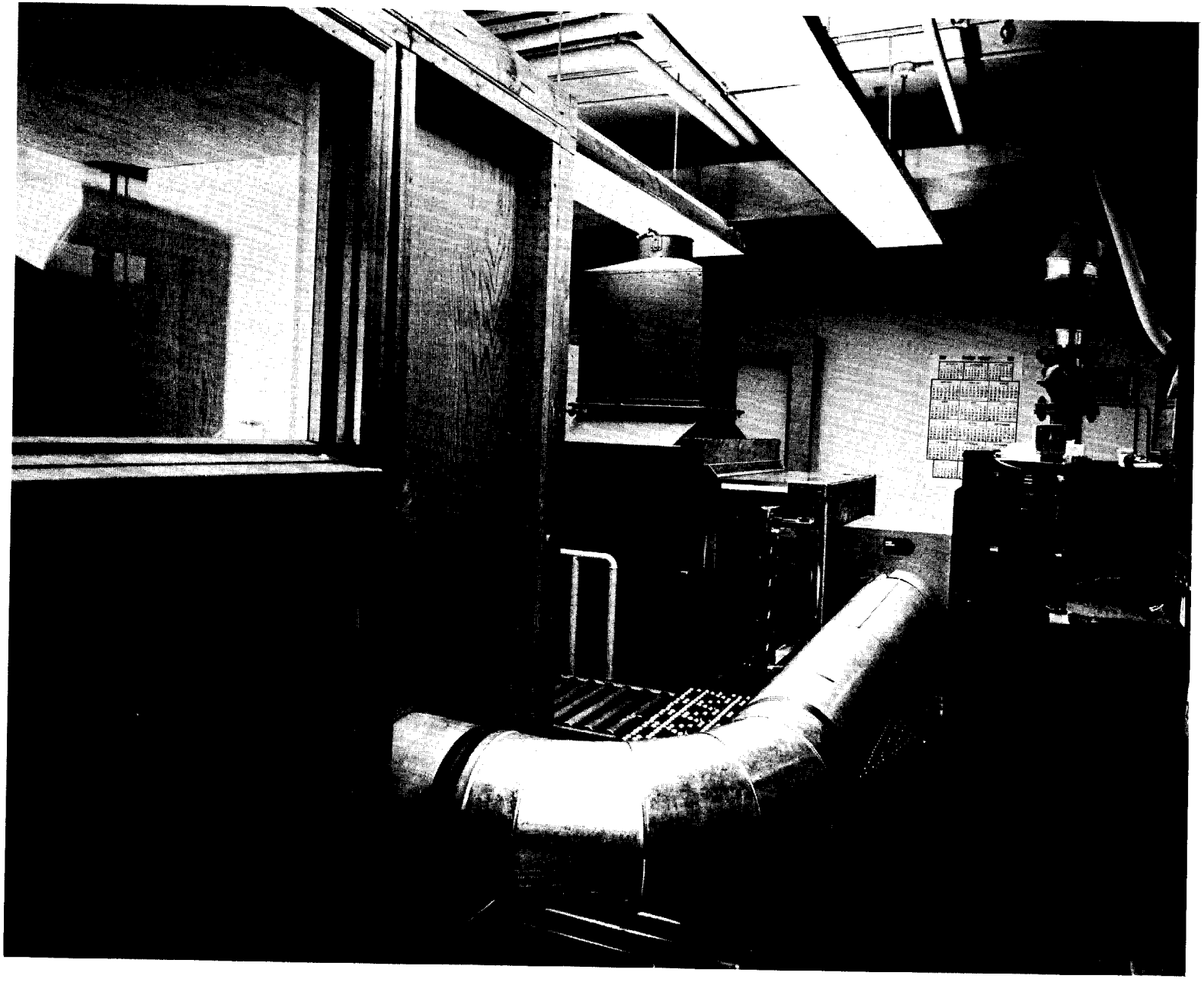

Figure 2. Smoke Plenum to Greenhouse.

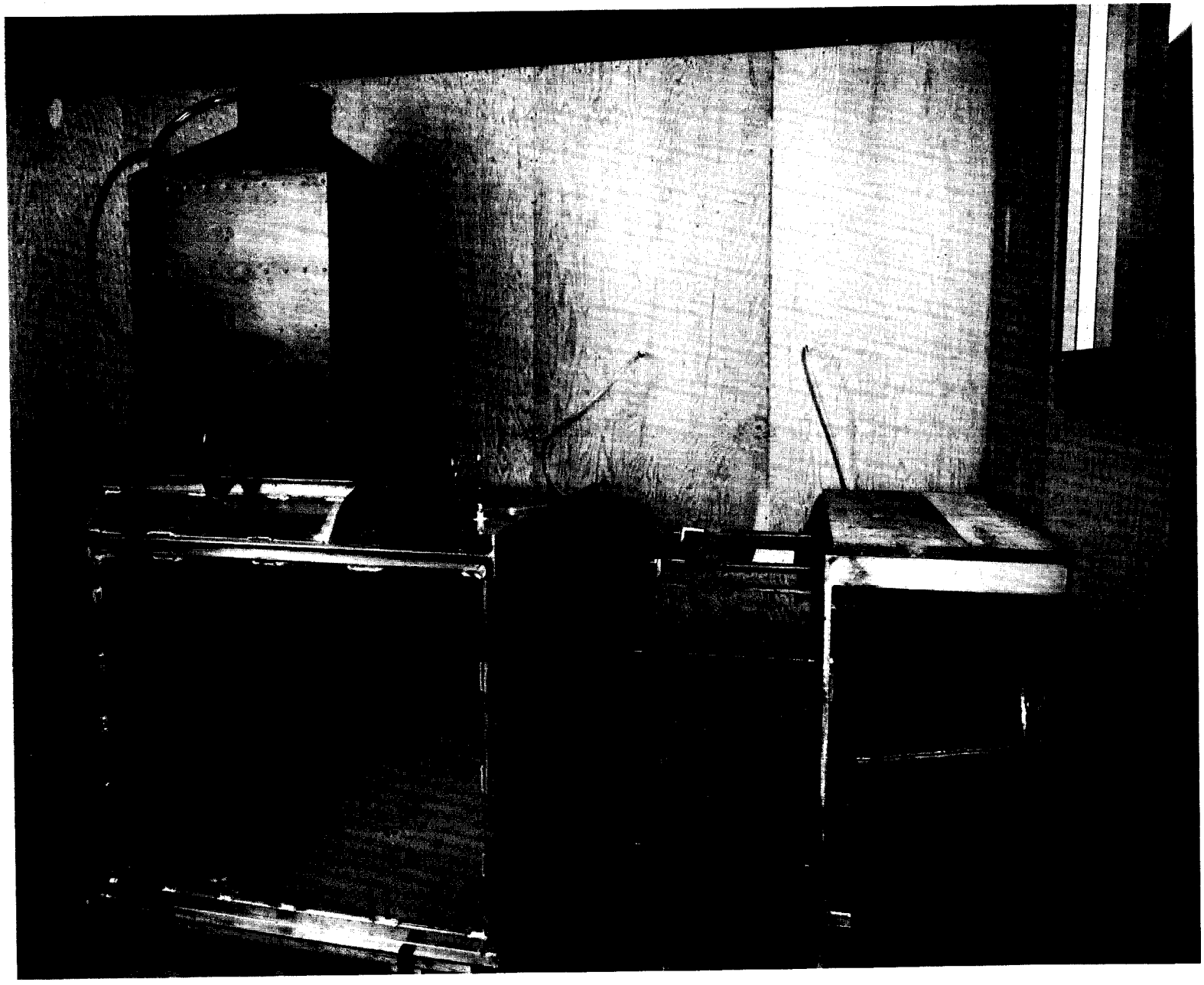

Figure 3. Chucking Arrangement

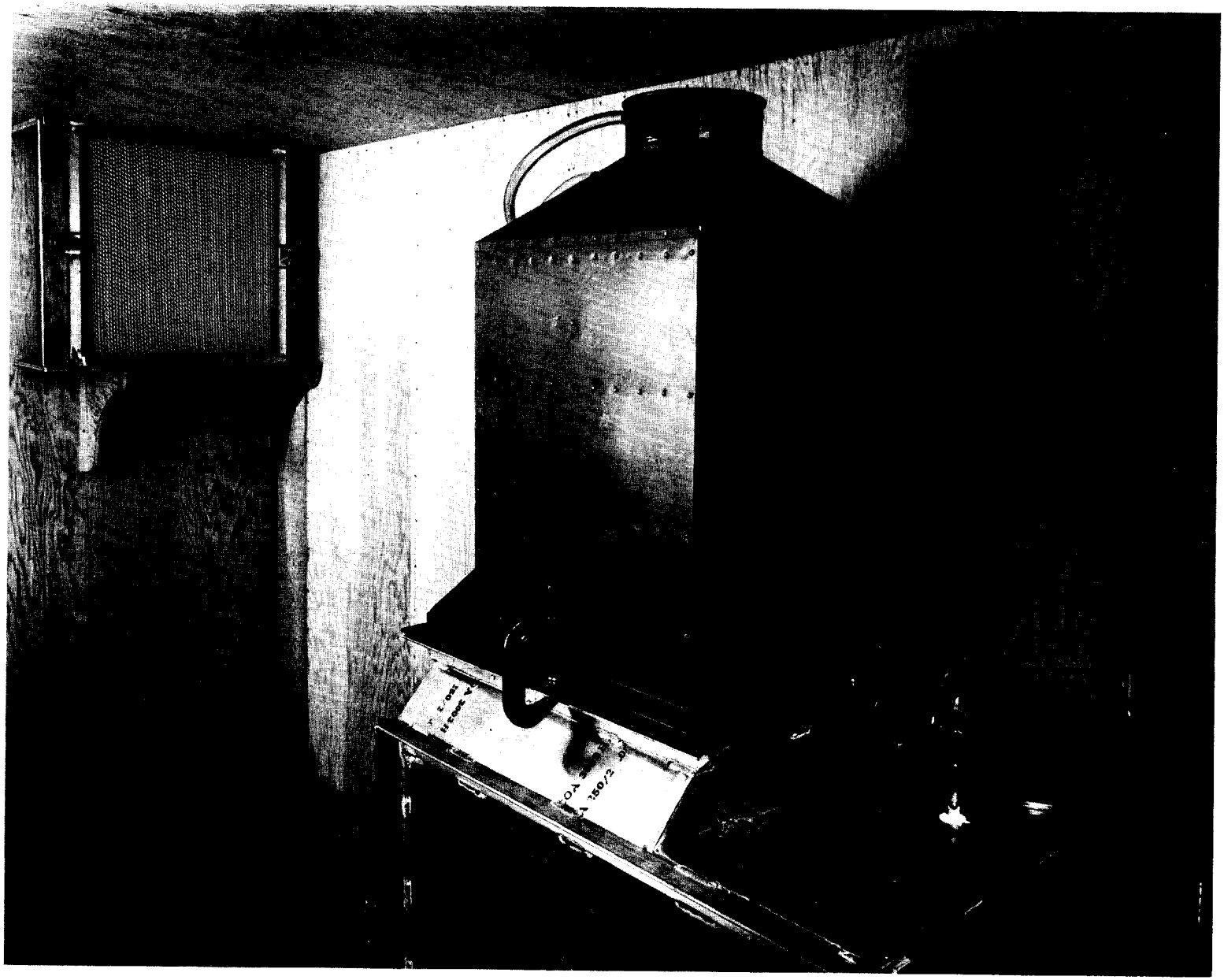

Figure 4. Mixing Plenum and Exhaust Filter.

concerning expected HEPA filter service life under various operating conditions. This information will enable maintenance and service groups to make better decisions concerning filter replacement schedules. It will also offer a means for more realistic interpretation and evaluation of in-place DOP tests in cases where such tests have been performed at some time prior to filter removal.

## DISCUSSION

FIRST: Thank you very much, Mr. Sims. Do I assume you can use that filter house for a camping trailer when not otherwise occupied testing filters?

SIMS: In the woods it might be a little warm.

YORK: Did you make any attempt to repair gasket damage on these old filters before you attempted retest?

SIMS: If there is any obvious damage to the filter we do not retest it. This includes gasket damage. On the mounting surface of the plenum we have another gasket that can take care of the problem encountered in the over compression of the gaskets during its service life. There are no repairs attempted with these filters, they are as removed.

STEINBERG: Did you say that you did not have any results or that you are still working on them on the retests?

SIMS: I have no results on the used filters. I have results on the clean filters including filters that have been rejected for various reasons such as penetration or obvious damage. This was done to check the system out.

STEINBERG: You have no relationship on these original tests or a retest?

SIMS: No, I have not.

FIRST: The next presentation will be by Mr. Douglas Smith.

# INVESTIGATION OF A NUCLEAR FUEL REPROCESSING PLANT UPON ITS ENVIRONMENT

D. G. Smith
Northeastern Radiological Health Laboratory, USPHS

I mentioned the other day in my discussion of $^{85}Kr$ field detectors that with the increasing number of nuclear power plants and the associated need for fuel reprocessing facilities, professional and public interest in $^{85}Kr$ and other waste products (and their movement into the environment) will continue to mount.

The public, as I am sure you all know, sometimes has difficulty believing that the AEC's Division of Reactor Development and Technology and its Divisions of Licensing and Compliance are sufficiently independent to always act in their best interest. Thus, the public exert pressure on their state health departments, and directly or indirectly, the Public Health Service to carry out environmental monitoring programs around nuclear facilities to verify the information that they are getting from the facility operator or the AEC.

To prevent unnecessary expenditures on hastily conceived environmental sampling and monitoring programs around the several planned nuclear fuel reprocessing plants, the Division of Environmental Radiation of the Bureau of Radiological Health has a project for development of a recommended methodology to enable agencies to carry out their responsibilities economically and accurately with a minimum of cost or inconvenience to the operators of these facilities. The objectives of this study are:

1. To develop minimum and optimum requirements for environmental surveillance programs around nuclear fuel reprocessing plants.

2. To develop a uniform set of surveillance methods that can be adopted by other states and companies in meeting surveillance needs.

3. To identify specific radionuclides that mya be released in liquid and gaseous waste discharges and the pathways by which they are dispersed in the environment.

4. To relate the levels of released radionuclides to levels in critical pathways in order to specify the most beneficial sampling and analyses to perform.

(Innacurate or improper measurements do a dis-service to both the public and the facility operator.)

The objectives of the air studies part of this project shown in the first slide can be similarly applied to the liquid waste studies part:

(a) Source characterization

(b) Environmental surveillance

(c) Instrumentation development

(d) Dose determination

Our first field studies in the summer of 1969 have helped accomplish a substantial portion of the first three objectives. (I'm not in a position to discuss the liquid waste studies.) The initial findings from these studies, both air and water, are presented in more detail in a series of four BRH/NERHL reports that are in process. The first report, NERHL 70-1, "An Estimate of Radiation Doses Received by Individuals Living in the Vicinity of a Nuclear Fuel Reprocessing Plant in 1968," has been published and is available from the Clearinghouse. The second, NERHL 70-2, "Liquid Waste Effluents from a

Nuclear Fuel Reprocessing Plant" will not be available until January. NERHL 70-3 is just off the press; its title is, "An investigation of Airborne Radioactive Effluent from an Operating Nuclear Fuel Reprocessing Plant." NERHL 70-4 is a backup report for NERHL 70-3 with a similar title but slightly greater detail than the paper included in this conference, "Calibration and Initial Field Testing of $^{85}Kr$ Detectors for Environmental Monitoring Around Nuclear Fuel Reprocessing Facilities."

I want to return very briefly to the future of the air studies group in this project. As I suggested in trying to answer a question about the health hazards of $^{85}Kr$ around such a facility, the results of our two field tests implied that in the sectors where diffusion models adequately describe the actual situation, the dose to an individual at the site boundary would probably be insignificant compared to natural background. Our continued interest in field monitoring is partly to demonstrate with long term precise measurements that this is indeed the case. In addition, we would like to carry the investigation far enough to determine how the plume behaves when the wind blows across the valley, and whether this could possibly result in a lower dilution factor at some point (a worst case) than the minimum dilution factor predictable from diffusion theory for the minimum allowable wind speed and/or inversion height that can presently limit the timing of fuel dissolutions. It is hoped that with establishment of the reliability of plume projections in some sectors, and identification of any worst cases in the rougher terrain areas, routine measurements in a few field locations with routine reporting of source strength and concurrent meteorological conditions should suffice to convince the public that they are being adequately protected.

## DISCUSSION

GILBERT: You said that you were getting the persuasion for environmental surveillance from the Divisions of Compliance and Reactor Development. You didn't mean Reactor Development, did you? Licensing and Regulation perhaps?

SMITH, DG: No, we weren't getting the persuasion from those groups. I was saying that the public was somewhat alarmed and mistrustful of the AEC results in light of the fact that all the interest groups in AEC working for different reasons. This leaves them to exerting a pressure on the state health agencies and somewhat through them on the Public Health Service as Public Health Service provides technical assistance to many of these agencies.

JUNKINS: I had a question regarding the dose figure that you mentioned, the 12 millirem and five millirem. What organ are you speaking of and is this an annual dose?

SMITH, DG: This was total body.

JUNKINS: Penetrating radiation?

SMITH, DG: Krypton-85; immersion in an infinite cloud of Krypton-85.

JUNKINS: Then it is an annual dose?

SMITH, DG: Yes, it is an annual dose. That 12 millirem, as I recall, is the number given in that report 70-1 I was talking about. I recall it as being for the maximum individual so you should look into the assumptions made in identifying that maximum individual. The kinds of numbers we were coming up with in the field study make it look like it should be much lower than that.

WATSON: What document do you have that explains how you determine that you are at the maximum concentration at ground level off-site?

SMITH, DG: We were not at the maximum concentration off-site. We used meteorological predictions to find out just where we were in relation to that maximum and what the relative concentration would be at the maximum and at our location.

WATSON: Recalling your paper of a couple of days ago I noticed that you had type C listed on one of the graphs. What meteorological parameters did you measure to determine that the atmospheric condition was type C?

SMITH, DG: The plant has information on the temperature profile, it only has two temperature points. That certainly tells when they are having inversion condition and they also had wind speeds and direction indications on the stack and we had a portable wind speed and direction system. We also had a trained meteorologist with us to judge what stability conditions existed. It is amazing how good a job a trained meteorologist can do just from experience.

FIRST: We have our own personal Cassandra at these meetings in the person of Mr. Keigher who, each time we meet, comes to tell us his experiences, to ask the questions for which there are no answers, and to make predictions. Once again, Mr. Keigher is with us, and he has a two-part presentation.

KEIGHER: I'm not wholly certain of your definition of a Cassandra in this instance, Dr. First, but I accept it as a compliment. Unfortunately as a paid pessimist, and most professional safety and fire protection engineers are, I often bring concerns for losses -- particularly catastrophic fire losses in air cleaning systems -- to these conferences.

However, my first item this morning is a bit of positive progress in air cleaning activities at my new employer the National Aeronautics and Space Administration. In the past I've heard some uncomplimentary remarks about the quality of filters used and air cleaning practices within the aerospace industry. It won't be true in the future.

# NASA EXPERIENCE (POLICY) WITH HEPA FILTERS

D. J. Keigher
National Aeronautics and Space Administration

Next month the National Aeronautics and Space Administration will be issuing a revised "Facilities Engineering Handbook," NHB 7320.1. The "Facilities Engineering Handbook" incorporates both design and operating guidance to all NASA Centers and its direct contractors. It is similar to the AEC's Chapter 6301 "Design Criteria," but incorporates far more detail particularly in the operating areas. Safety, fire protection, and health considerations are emphasized throughout.

The sections applicable to air cleaning are greatly expanded and revised to reflect the developments in high efficiency air cleaning, clean room operating experience and the atomic energy program's knowledge in containing radioactive particulates. Although NASA has only one major operating nuclear reactor -- at Plum Brook, Ohio -- and a few experimental or test reactors, radioactive materials exist and are handled regularly at virtually everyone of the 16 different NASA centers or installations. Air cleaning, especially the huge clean rooms at Houston, Goddard, Kennedy and Jet Propulsion Laboratory -- is a major activity of all NASA sites and even more so at the NASA "hardware" manufacturers. The aerospace industry has been the major purchaser of HEPA filters for the past eight years. So we have a dual concern for quality HEPA filters performance in the clean rooms, and in the facilities handling radioactive materials. A unique user of many HEPA filters is the Lunar Receiving Laboratory at the Manned Spacecraft Center, Houston, to which the astronauts of Apollo 11 and 12 and their harvest of moon rocks returned after their historical flights.

The NASA "Facilities Engineering Handbook" now includes the following provisions:

a. "All HEPA filters shall be Underwriters' Laboratories, Inc., listed as fire resistive type and shall be tested at an approved quality assurance station before installation. Each HEPA filter installation have prefilters installed in the air stream." (Par. 4.21.4)

b. All filter systems associated with clean rooms and facilities wherein radioactive particulates are handled shall be periodically in-place

tested for cleanliness and efficiency. (ORNL-NSIC-65, "Design, Construction and Testing of High Efficiency Air Filtration Systems" by Burchsted and Fuller is the recommended guide.)

c. "Clean rooms should be provided with adequate fire protection e.g., automatic sprinklers and/or automatic detector systems, as appropriate to hazards and valuation at risk. Adequate fire separations and emergency exits shall be provided." (Par. 4.3.4.6)

We have not as yet issued a NASA standard specification for HEPA filters. It is still under study, meanwhile Mil-F-51079A and Mil-F-51068c is the guide to the NASA field offices.

I'm also pleased to report that NASA has had three students to date in the Harvard Air Cleaning Laboratory Filter Workshop Course, and we've budgeted in the NASA Safety Office for another six to eight candidates in the coming year.

The close cooperation of NASA's Office of Facilities, the Environmental Health Division and the NASA Safety Office has brought about significant changes in NASA policy in air cleaning. The battle is not won, it may take years to up-grade and protect all of the NASA air-cleaning systems, but we are well on our way.

# A RECENT SIGNIFICANT CLEAN ROOM FIRE

D. J. Keigher
National Aeronautics and Space Administration

About 9:35 p.m., November 24, 1969, the Fire Department in Inglewood, California was called by a passing motorist to report a fire in what subsequently was identified as a large privately-owned clean room facility. Ultimately the fire resulted in a near total loss of building and contents, exceeding $350,000. Although the plant was not NASA or Government owned, a $40,000 shipment of valves for the Apollo 16 flight were lost in the fire. The plant regularly did ultra cleaning and packaging of delicate hardware for numerous NASA Centers and NASA contractors.

The building, a one-story brick and plywood structure, about 50' x 120' with a built-up roof on plywood sheeting on unprotected steel supports, did not have an automatic fire detection system, nor automatic sprinkler protection. The building interior was finished with a number of small clean rooms, containing quantities of acids, toluene, acetone, alcohols, and other flammable cleaning agents, also combustible wiping and packaging materials.

Cause of the fire is believed to be the failure of a thermostat to a gas heating element in a liquid nitrogen system, which overheated and ignited other combustibles.

Factors contributing to the large loss include:

a. High unprotected construction; result, rapid fire spread and early collapse.

b. Lack of automatic detection or protection; result, delayed alarm and fire attack.

c. Concentration of solvents, flammable liquids, plastic sheeting, styrofoam and other combustible packaging materials; result, surprisingly high fuel loading.

d. Concentration of high value, high importance materials; result, a fire loss that averaged about $600/sq. ft., a very high "dollar density."

Although the combustible HEPA filters -- yes they were combustible -- added to the overall fuel loading, fire resistive filters would not have controlled or prevented the magnitude of the fire in this instance.

I've asked the question before -- I'll ask it again -- does your clean room facility have these same conditions?

It is of interest that other clean room fire and property losses have occurred in the past year. The Factory Mutual Research Corporation contacted me recently about a proposed booklet they plan to issue before the end of this year. If you are interested, contact Mr. R. C. Merritt at the FM's Norwood, Massachusetts office for advance information.

FIRST: The next paper is by Mr. Hanthorn.

# LEAKAGE FROM A CONTAINMENT VESSEL

Howard E. Hanthorn

Plant Safety

ENGINEERING SERVICES AND SAFETY

WADCO, RICHLAND, WASHINGTON

## Introduction and Summary

Pursuing a suggestion of E. C. Watson[1/], an attempt was made to obtain a unified expression for leakage flow from a nuclear reactor containment vessel. It was felt that such an expression would be useful particularly in investigations of the consequences of postulated reactor accidents occurring within containment vessels. It was found that the curves for leakage rate vs. containment vessel overpressure for the three flow regimes (viscous, turbulent, and orifice) were of the same general form and could be fitted with ample accuracy by empirical mathematical formulas of the same type, though the range of flow rate covered was six orders of magnitude.

A single empirical formula was obtained covering all three flow regimes with sufficient accuracy for source term calculations without regard to the actual flow regime, between 0.3 and 5 atm. overpressure.

## Physical Basis

There are three possible regimes of leakage from a containment vessel: (1) through small openings ∿ 1 mm dia., (2) through moderate-size openings ∿ 1 cm dia., and (3) through large openings ∿ 10 cm dia. (resulting from missiles produced by the postulated accident). These flow regimes have the following characteristics:

| Opening | Flow Type | Thermal State of Flow | Condition of expansion in vessel |
|---|---|---|---|
| 1 mm | viscous | isothermal | isothermal |
| 1 cm | turbulent | adiabatic | isothermal |
| 10 cm | orifice | NA | adiabatic |

Standard theory predicts mathematical expressions of very different form for these regimes:

Viscous flow:

$$w = \frac{-1 + \sqrt{1 + A\,(P^2 - 1)\,\ln P}}{B \ln P}$$

Turbulent flow:

$$\left.\begin{aligned} w &= A \log V + B\left(1 - \frac{1}{V^2}\right) \\ P &= \frac{1}{V}\left[\,1 + C\,(1 - V^2)\,\right] \end{aligned}\right\} \quad \text{to be solved simultaneously}$$

---

1/ Battelle-Northwest, Nuclear Safety

Orifice Flow:

$$\left.\begin{aligned} w &= A\sqrt{B\,\rho\,(P-1)} \\ \rho &= \frac{P}{CTM} \\ T &= DM^{\kappa-1} \end{aligned}\right\} \text{To be solved simultaneously}$$

In these expressions, w is the rate of efflux, kg/sec., P is the absolute pressure in the vessel, atm., V is the flow velocity, cm/sec., $\rho$ is the density of the air in the vessel, g/cm$^3$, T is the absolute temperature, °K, M is the mass of air remaining in the vessel, kg, $\kappa$ is the ratio of specific heats, and A, B, C, and D are dimensional constants which differ for each case.

## Method

The constants for air were substituted into the various formulas. The hole dimensions postulated were 1 mm dia.×1 cm long, 1 cm dia.×1 cm long, and an orifice of a diameter (about 7 cm) to give a flow at 3 atm overpressure of 10,000 kg/hr. The equations were solved for w, leak rate, kg/sec., vs P, absolute pressure, atm. The three curves obtained are shown in Figure 1.

It was found that these curves could all be fitted closely by equations of the form

$$w = A\,(1 - e^{-b(P-1)}) + C(P-1)$$

where A, b, and C are empirical constants.

Using these equations, the time behavior of the outflow was determined. Again it was found that the function of outflow rate vs. time and its integral, the integrated total leakage vs. time, could be closely approximated by equations of the form

$$W = W_4\, e^{-(at + bt^n)}$$

where W is the leak rate in kg/day, $W_4$ is the leak rate at P = 4.0, t is the time in days, and a, b, and n are empirical constants.

## Results

The results are shown in Figures 1 and 2, and the following values for the constants a, b, and n:

| Constant | Regime ⟼ Viscous | Turbulent | Orifice | Unified |
|---|---|---|---|---|
| a | 0.04239 | 0.05203 | 3.33 | 0.047112 |
| b | 1.00 | $2.15 \times 10^{-12}$ | 10.625 | $2.889 \times 10^{-9}$ |
| n | 3.52 | 8 | 4 | 6 |

The work was done by hand calculations. A computer program could have been used for the calculation of the variation of W with t, probably with more precise results; however, it was noted that the hand calculations were remarkably stable, errors being self-corrected after four or five steps using finite time intervals. The curves and the empirical equations are therefore believed to be correct representations of air leakage from a containment vessel under the assumed conditions.

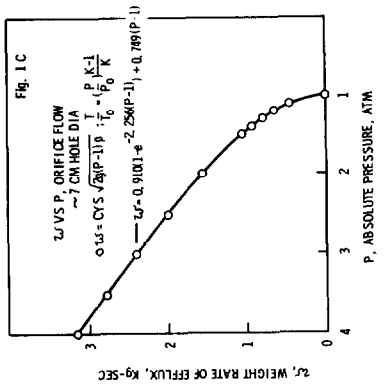
Fig. 1 C
τ VS P, ORIFICE FLOW
~7 CM HOLE DIA
τ, WEIGHT RATE OF EFFLUX, kg-SEC
P, ABSOLUTE PRESSURE, ATM

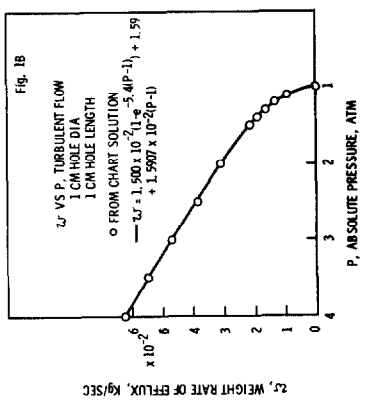
Fig. 1B
τ VS P, TURBULENT FLOW
1 CM HOLE DIA
1 CM HOLE LENGTH
O FROM CHART SOLUTION
τ, WEIGHT RATE OF EFFLUX, kg/SEC
P, ABSOLUTE PRESSURE, ATM

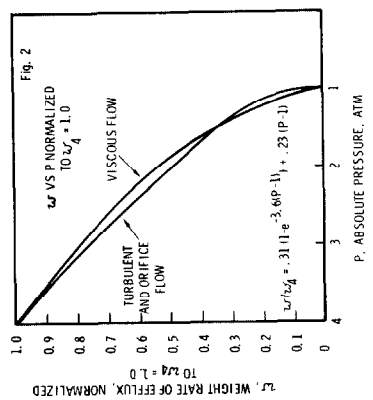
Fig. 2
τ VS P NORMALIZED
VISCOUS FLOW
TURBULENT
AND ORIFICE
FLOW
τ, WEIGHT RATE OF EFFLUX, NORMALIZED
P, ABSOLUTE PRESSURE, ATM

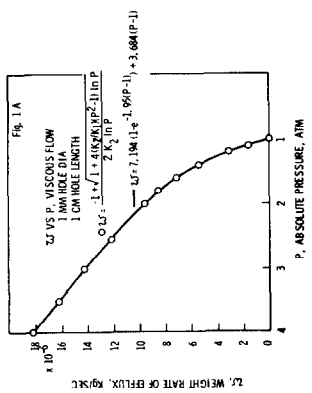
Fig. 1 A
τ VS P, VISCOUS FLOW
1 MM HOLE DIA
1 CM HOLE LENGTH
τ, WEIGHT RATE OF EFFLUX, kg/sec
P, ABSOLUTE PRESSURE, ATM

The plots of w vs P were normalized to $w_4 = 1$ and plotted on the same graph, Fig. 2. This plot suggested at once that a single equation could be found that would be a good approximation for efflux in all three regimes. A single equation was fitted to all of the calculated points:

$$w/w_4 = 0.31\ (1 - e^{-3.6\ (P-1)}) + 0.23\ (P-1)$$

This formula underestimates efflux in viscous flow by a little less than 3% of $w_4$ through the range of pressure 1.3 to 6.0 atm. absolute, and is quite precise for both turbulent and orifice flow in the same range. This formula, with the constants adjusted for the initial values of w and P, can be used for all practical approximate studies requiring a knowledge of the variation of efflux from a containment vessel with time. It cannot be used when great precision is required, as in leakage rate tests of containment vessels.

## APPENDIX

### Data and Assumptions

M = mass of air in vessel at time t

P = pressure of air in vessel at time t, atm abs.

T = temperature of air in vessel at time t, $^{o}K$

t = time, sec or days as defined for w and W

subscript o indicates conditions of these variables at the time immediately after the accident when the pressure is at its peak

w = flow rate, kg/sec

W = flow rate, kg/day

For the two relatively slow flow cases with the expansion of the air in the vessel assumed isothermal, T = To = 293K was assumed. For the rapid flow case with adiabatic expansion in the vessel, To = 435.4K (permitting expansion back to 293K at P=1.0), and T is a function of P. Therefore, Mo was the same for the first two cases and smaller for the third, for the same containment vessel. Po was assumed to be 4 atm for all cases.

The nomenclature and equations for the various flow regimes were taken from Perry.[1]

f = Fanning friction factor

L = length of flow path

G = mass velocity $= \frac{4w}{\pi D^2}$

R = gas constant

g = gravity conversion

$R_H$ = hydraulic radius of flow path

= D/4

D = diameter of flow path

$\mu$ = viscosity

$W_m$ = molecular weight

= 29 for air

$\kappa$ = ratio of specific heats

= 1.4 for air

V = flow velocity

Case 1

For isothermal flow, the equation is

$$P^2 - 1 = \frac{fLG^2RT}{gR_H W_m} \left( 1 + \frac{2R_H}{fL} \ln P \right) \tag{1}$$

For viscous flow

$$f = \frac{16\mu}{DG} \tag{2}$$

Substituting this expression and the alternate values for G and $R_H$,

$$P^2 - 1 = \frac{16^2 RLT\mu w}{\pi g D^4 Wm} \left( 1 + \frac{w}{8\pi L\mu} \ln P \right) \tag{3}$$

Further,

$$\mu = \mu o \left(\frac{T}{273}\right)^n = \mu o \left(\frac{293}{273}\right)^n \tag{4}$$

$\mu o = 0.01709$

$n = 0.768$ for air

Defining:

$$k_1 = \frac{16^2 \, RLT\mu}{\pi g \, D^4 \, Wm} \tag{5}$$

$$k_2 = \frac{1}{8\pi L\mu} \tag{6}$$

$$P^2 - 1 = k_1 \, w \, (1 - k_2 \, w \ln P) \tag{7}$$

$$= k_1 \, w - k_1 \, k_2 \, w^2 \ln P \tag{8}$$

$$w = \frac{-k_1 + \sqrt{k_1^2 + 4 \, k_1 \, k_2 \, (P^2 - 1) \ln P}}{2 \, k_1 \, k_2 \ln P} \tag{9}$$

$$= \frac{-1 + \sqrt{1 + 4 \, (k_2 / k_1) \, (P^2 - 1) \ln P}}{2 \, k_2 \ln P} \tag{10}$$

$R = 82.057$ cc-atm

$L = 1$ cm

$D = 0.1$ cm

$T = 293$ K

$\mu = 1.804 \times 10^{-4}$ poise

$g = 980.6$ cm/sec$^2$

$Wm = 29$

$k_1 = 124.285$

$k_2 = 220,558$

$$w = \frac{-1 + \sqrt{1 + 7.09846\,(P^2 - 1)\ln P}}{441,116 \ln P} \qquad (11)$$

$$w_\theta = \frac{1 + \sqrt{1 + 7.09846\,(16-1)\,(1.09861)}}{441,116\,(1.09861)}$$

$$= 18.30 \times 10^{-6} \text{ kg/sec}$$

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| P, atm | 4.0 | 3.5 | 3.0 | 2.5 | 2.0 | 1.8 | 1.6 | 1.4 | 1.2 | 1.1 | 1.0 |
| w, kg/sec x $10^{-6}$ | 18.30 | 16.30 | 14.36 | 12.19 | 9.71 | 8.55 | 7.19 | 5.49 | 3.14 | 1.63 | 0 |

These points are plotted on Figure 1. In fitting the curve with an empirical equation, advantage was taken of the fact that the high pressure end of the curve is almost a straight line with an exponential falling away toward zero differential pressure. An initial rough fit gives a good value for the exponent; final fit of the linear constants was done by least square methods.

$$w = 6.9944 \times 10^{-6}\,(1-e^{-2(P-1)}) + 3.7512 \times 10^{-6}(P-1) \qquad (12)$$

For a reasonable expenditure of time and effort in computations with a desk calculator, an initial flow rate W of 5% per day was assumed, and time periods of one day were taken. A check computation using time periods of 0.1 day was made, and found to give an average rate for a day of 95% of the assumed rate. The computation was also found to be remarkably self-correcting, so the departure from a computer computation with small time steps is believed to be small.

After tabulating the computation, the calculated points were fitted with an empirical equation of the type

$$W = Woe^{-(at + bt^n)}$$

<u>Case 2</u>

For adiabatic turbulent flow, the equations are (1)

$$\frac{fL}{R_H} = \frac{-(\kappa+1)}{\kappa} \ln \frac{V_2}{V_1} + \frac{1}{\kappa} \left[ \frac{c_1^2}{V_1^2} + \frac{\kappa-1}{2} \right] \left( 1 + \frac{V_1^2}{V_2^2} \right) \qquad (13)$$

$$\frac{P^1}{P^2} = \frac{V^1}{V^2} \left[ 1 + \frac{(\kappa-1)\,V_1^2}{2c_1^2} \left( 1 - \frac{V_2^2}{V_1^2} \right) \right] \qquad (14)$$

Where $c_1$ is the initial acoustical velocity

$$= \sqrt{\kappa g R T_1 / W_M} \qquad (15)$$

These equations could be put in terms of w and used directly to tabulate data of w vs p. However, it is more convenient to use the charts published by Lapple[2] (cited in Ref. 1). This results in the following data points:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| P, atm | 4.0 | 3.5 | 3.0 | 2.5 | 2.0 | 1.5 | 1.4 | 1.3 | 1.2 | 1.1 | 1.0 |
| w, kg/sec | .0626 | .0548 | .0470 | .0389 | .0310 | .0215 | .0191 | .0165 | .0134 | .00935 | 0 |

These points are plotted on Figure 1. A curve was fitted by the same method as in Case 1.

$$w = 1.500 \times 10^{-2} \left(1-e^{-5.4(P-1)}\right) + 1.5907 \times 10^{-2} (P-1) \qquad (16)$$

An empirical curve of the same form as Case 1 was then fitted to calculated points relating W to t.

Case 3

For flow through an orifice, and for adiabatic expansion of the air in the containment vessel, the equations are[1]

$$2.2046w = CYS_2 \sqrt{2g\,(P-1)\,\rho\,(14.7)\,(144)} \qquad (17)$$

$$\frac{T}{To} = \left(\frac{P}{Po}\right)^{\frac{\kappa-1}{\kappa}} \qquad (18)$$

$$To = 435.4K$$

$$C = 0.62$$

$$Y = 1-0.41\left(\frac{P-1}{P\kappa}\right) \qquad (19)$$

$S_2$ = area of hole, $ft^2$
= 0.05 (assumed)

$\rho$ = density of air in vessel, $lb/ft^3$

$$\rho_o = \frac{4}{1} \times \frac{273}{435.4} \times \frac{29}{359} = 0.2026\ lb/ft^3$$

Substituting values at t = 0 in (17)

$$w_o = \frac{0.62}{2.2046}(.4838)(.05)(287.675)$$

$$= 1.957\ kg/sec$$

Substituting values in equations (17) and (18), the following points were calculated relating w and P:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| P | 4.0 | 3.5 | 3.0 | 2.5 | 2.0 | 1.5 | 1.4 | 1.3 | 1.2 | 1.1 | 1.0 |
| w | 31.56 | 2.784 | 2.398 | 1.993 | 1.556 | 1.050 | 0.930 | 0.798 | 0.646 | 0.453 | 0 |

These points were fitted by the empirical equation

$$w = 0.910\ (1-e^{-2.256\ (P-1)}) + 0.749\ (P-1) \qquad (20)$$

The fit is excellent down to P = 1.5 and gives slightly low values of w between 1.5 and 1.0. This is a pressure region of comparatively little importance, at least in studies of consequences of accidents. This equation is plotted in Figure 1.

Using this equation (which, it should be noted, accounts for the variation of temperature with pressure), values of w vs. t were calculated. Since $w_o$ for this case is fifty times the initial leakage rate from an (approx.) 1 cm hole (Case 2), Wo was taken as 25% per day. Time increments of 0.02 day were used so $W_o \Delta t$ was 0.05 as in the other cases.

The relation between W and t was fitted with an equation of the same form as for Case 1.

## REFERENCES


(1) Perry, J. H. (Ed.) "Chemical Engineers Handbook", Third Ed. McGraw-Hill, New York (1950)

(2) Lapple, C. E. Trans. Amer. Inst. Chem. Engrs. 39, 385 (1943)

## DISCUSSION

FIRST: Thank you very much, Mr. Hanthorn. Could you please explain to me what you mean by "the weight rate normalized?"

HANTHORN: You will notice that these curves are plotted backwards. The high pressure end is at the left. These curves are in chronological order for the time after the accident. Normalizing to one is simply dividing all of the values in any one curve by the initial weight rate. In every case you start with initial weight rate of one. Weight rate at 4.0 atmospheres should be substituted for initial weight rate.

FIRST: Is it a ratio in other words?

HANTHORN: Yes, it is a ratio and puts everything on the same scale.

FIRST: It is a very interesting conclusion that these two curves coincide.

Mr. Burchsted would like to present some comments on several of the papers concerning extinguishment of fires in air filter components.

BURCHSTED: This will be very brief. There have been three papers this morning involving fire problems. I think it is important to relate the three of them because, considering the destruction that would result when attempting to extinguish a HEPA filter fire, and the inability to put out a carbon fire, we must design a system to prevent a fire from ever getting started in these systems. Moreover, harking back to the first fire tests that were made in the carbon unit which were made with K-I impregnated carbon, we have also got to design to prevent temperatures ever reaching the levels at which desorption of iodine would take place. You will recall that Mr. Davis stated that significant desorption starts at about 300°F.

In the initial carbon fire tests, we observed the tremendous cloud of iodine running about 30 feet downstream from the duct at an indicated temperature of about 250°F. I say indicated because it is very probable that in areas adjacent to the temperatures thermocouples were considerably higher. Such desorption in an operating system would mean that we have lost containment. We would also have lost containment if, by some reason, we had had to suppress a fire in a HEPA filter and had to put water on that filter to put the fire out. So, the design of air cleaning systems has got to take into account this new parameter. Some of us realized it before, but with Mr. Murrow's and Mr. Domning's presentations, it becomes even more apparent.

RAY: I quite heartily agree with attempting to eliminate or prevent ignition of filter burdens and filter fires. Having had some experience with burning filters I am aware that they are rather hopeless once ignition has started. However, in some situations, such as where one is dealing with zirconium fines in the atmosphere, one has to learn to live with filter fires.

Although it entails some additional expense, one expedient is to break up a filter bank into modules of modest dimensions (not over four filter units per module) which can be quickly and automatically isolated by snap-off dampers actuated by a deferential thermostat monitoring the air flowing through each module to detect when a fire on a filter occurs. Without shutting down the whole bank, fires are automatically confined to a module and various quenching mechanisms can be used, including inert gases. To get the last embers extinguished you will probably end up spraying water into the mess.

FIRST: Mr. Murrow, I have been thinking about your extinguishment procedures and, as you know, putting steam on glowing charcoal is a standard method for generating water gas which is largely hydrogen. We then have the possibility of an explosion. It has been suggested that that is the way to put the fire out, just blow it out. I wonder if you would care to comment on why you did such an elaborate study with water when this hazard, or perhaps I should say potential hazard, exists?

MURROW: I believe I should say that water seems to be the obvious thing to use to try to extinguish a fire. The possibility of having hydrogen generated did not occur at the beginning. In the tests we have talked about today we probably had no trouble because the fire was relatively small and, at least, in subsequent tests the quantity of water was relatively large. For those of you who saw the movie film, when the water hit there was some increase in fire -- but it seemed to be a carbonaceous type of fire rather than a pure hydrogen fire, or perhaps it was methane rather than hydrogen that was formed. The effect could also have been the result of knocking loose some very fine particles of carbon that became airborne from the physical shock of the water hitting it. These particles could then have ignited in the atmosphere downstream. I really don't know the cause but thought that it might be interesting to somebody. We never realized that this condition occurred because it happened so rapidly that we did not see it by eye. It was only through the high-speed motion pictures that we did see it. The phenomenon lasted considerably less than a second, real time. Probably ignorance and good fortune prevailed.

HANTHORN: As a chemical engineer I might be able to add something to that. The water-gas reaction is a highly endothermic reaction. I think very likely that the water would be a satisfactory means of putting out a charcoal fire because it would cool the charcoal so fast that there would be very little water-gas reaction take place.

FIRST: The main trouble is that under this manner of operation, water does not get into the charcoal except in limited quantities; most of it rolls down the face. I think it will be obvious that if one puts on 20 or 30 gallons of water per square foot of face area and is able to get it through the charcoal it would extinguish the fire very promptly. But, in actual fact, water just seeps through the beds, so there is not this prompt cooling that you mentioned.

BURCHSTED: I recall the fact that many commercial systems are specifying that water nozzles be installed in the charcoal beds to extinguish fires. I also recall a cartoon sometime ago that showed a mouse with a large pointer tapping a mouse trap, with the caption: "One test is worth a thousand words." Mr. Murrow's tests have made believers of a lot of people.

FIRST: Our next speaker will be Mr. I. C. Roberts, USAEC, who will talk about Reactor Development and Technology (RDT) standards.

ROBERTS: In Session 1, I mentioned the need for engineering standards and now I would like to give a short summary report of what the Reactor Development and Technology Division is doing to develop such standards. I would like to avoid confusion by pointing out that these are standards applied to RDT activities, and are not those standards used by the regulatory and licensing part of the AEC.

Experience in the RDT and in the nuclear industry indicated that standards were absolutely essential. Early in 1967, Oak Ridge National Laboratory and the Liquid Metal Engineering Center were directed to act as focal points for the development and application of standards for the design, construction, and testing of materials, processes and for components. Thus far, 88 standards have been approved and over 100 are in various stages of preparation. In the development of these standards existing industrial standards are used as much as possible. These initial standards, are mainly concerned with materials of construction but some process standards are included such as welding electrical components, and plant protection systems.

As a result of the publication of document NSIC-65, "Design, Construction and Testing of High Efficiency Air Filtration Systems for Nuclear Applications," by C. A. Burchsted and A. B. Fuller of the Oak

Ridge National Laboratory, the need for several engineering safeguard standards in air cleaning became apparent. For example, HEPA filters, activated charcoal, in-place testing of high efficiency air cleaning systems, in-place testing of charcoal leak-testing of housings and ducts, and others. Attention is being given to the most urgently needed of those and four standards are now in draft form; Mr. Burchsted is handling that effort.

THOMAS: Regarding these standards I would like to mention that there should be a standard on sampling lines. The standards should be very simple. Several years ago I worked out that the best flow rate in sample for minimum loss of particles is where the flow rate is 150 times the pipe diameter in cgs units. In other words, if you have a pipe one centimeter in diameter it should be sampled at 150 cubic centimeters per second. I am mentioning this although it has already been published in the IAEA book in 1967, Assessment of Airborne Radioactivity. I think that is one of the areas in which there should be standards.

FIRST: Mr. Domning of the Dow Chemical Company at Rocky Flats has indicated he has some comments to share with us that relate to the fire that took place there some time ago.

DOMNING: I think that it may be of interest to those of you who have glove box type of installations to let me describe a little bit about how glove box fire progresses and what things we have done to prevent a recurrence of our recent fire. Obviously, the thing to do is not to have a fire. If you have nothing flammable in the glove box there is no problem. We normally handle plutonium metal which burns but that doesn't seem to be the problem. The problem seems to be plastic used in both windows and cut-out bags.

The genesis of the glove box fire is rather unique. I think this is one of the areas that has been lacking, that is, the recognition of how one progresses. If you have a fire that propagates inside of the box it will burn for a short period of time and will then eventually reach a glove. Incidentally, we have found that gloves used in nitric acid service can form lead nitric in the lead lining and this in itself makes the glove much more flammable. Once you lose the glove you now have a large hole. A large amount of air rushes in increasing the combustion rate and temperature and eventually involves the plastic windows. If the self-extinguishing mechanism for the plastic windows is one of vapor-phase, then it is very possible the time that the self-extinguishant will be available in the vapor-phase may be very short because of the increased air flow through the box. So, therefore, your choice of plastic window material must be tested under air flow conditions.

Earlier somebody said something about shutting off air flow from a burning glove box. If air were shut off at the proper time, probably the fire would go out; we have demonstrated this. Also, in many of our glove boxes we are likely to find things such as cutting oils and things that are fairly volatile and if you shut off the air to the box and do not cool the box then I am sure you might split a few box seams from an explosion.

We have had a number of explosions in our test chamber and this occurs when we get some material stuck in the inlet duct during a fire test. The fire is burning and a quite a bit of CO is formed then it enters the filter plenum as a fire ball. The possibility of an explosion is also something to consider in shutting off air flow or isolating filter plenums. There may be times when one would shut the damper on a glove box plenum but (under most fire conditions) we will continue ventilation with a much reduced air flow.

As shown earlier, glove box fires produce quite a bit of heat very rapidly, making it a difficult fire to fight. Another problem in fighting a glove box fire is the smoke. You cannot let it out of the building. It is difficult to find the fire because of the smoke. We had problems in fighting the fire in that people had difficulty locating the fire and finding their way around the building.

We are looking at other shielding materials, things like water instead of combustible plastic and pressed wood. There are ways of immobilizing water to keep the criticality people satisfied.

We are looking at glass for windows. I mentioned earlier that we had a floating glass seal on some of our windows. When we tested that, we found that the gasket burns away very rapidly and the window falls in which opens up another hole in the glove box allowing more air to get in. We have designed a protector to keep the glass in place.

We advocate the use of intumescent paint on combustible shielding. It doesn't keep it from burning but it gives about 25 minutes of protection before the shielding becomes involved in the fire. We also have tried a number of glove covers and we find that they are not effective in keeping the glove from catching fire but they prevent the glove from burning up to five to ten minutes depending upon the design of the glove cover.

The alarm system that is put in a glove box should not have a long delay in time. We deduced from our studies that about 20 minutes of burning in the glove box was necessary to raise the temperature of the detector to the alarm point.

We have redone our complete detection system to provide a shorter time-to-alarm. We are putting detection in individual plutonium storage locations, and over-temperature detectors in glove boxes throughout the box and close to the air outlet. Fortunately our outlets are on top.

We have also mounted and installed wired glass in the top of our glove boxes. We find that the window on top will always burn out first. The wired glass prevents loss of the top window.

I thought someone would come unglued when I said earlier you should put no water on filters.

FISHER: It would seem to me that you might follow a technique which we have followed by installing a spring loaded blast damper of a wedge design protecting the rubber glove openings. This can be activated either by a thermal detection or air flow device either of which is quite satisfactory. That gives you a backup from your burned-out rubber glove.

DOMNING: We have available glove covers for burned-out rubber gloves.

KEIGHER: Since you asked to be challenged on water in filters, I'll take the opposite position. In fact, we seem to be recycling many of the things we did here at Hanford from 1955 through 1957 and on into 1959. In 1958, in an experiment or test conducted by J. H. Palmer and others in G. E.'s Plutonium Fabrication Plant we had a situation in which moisture saturated air was applied to the filters to the point that the water was running down the face of the HEPA filters, four of them in a bank, and we were still getting 60 to 65 percent of the air capacity through those filters. I disagree that automatically per se putting water on HEPA filters blinds them, and there is danger to do. A water mist can be applied to the air stream going into the filters for extended periods -- it was an actual operating phenomenon at Hanford in the early 1960's.

DOMNING: I didn't say that.

KEIGHER: You implied it.

DOMNING: Most people like to put water on filters to put out filter fires. That's not the place to put out the filter fire. My contention is don't have a filter fire.

KEIGHER: Well, I don't think there can be any quarrel in that case. There are those who believe that any extinguishing agents striking

the HEPA filter would be a mistake. R. R. King of G. E.'s Hanford Laboratories, about 1959, proved the conclusively not true in using dry powder extinguishing agents in glove box fire control tests. As long as it didn't directly strike the filter you could apply the dry powder anywhere in the glove box effectively on all fires except the pyrophoric metal fires; it would not block the filter. If you directed it straight into the filter it might be blocked in a matter of minutes. Oily smoke and/or oil vapor will block it even more quickly.

BURCHSTED: I have a couple of comments. First, I would like to talk back to Mr. Neigher. There have been tests at another laboratory which showed that if you permit drops of water from sprinklers, for example, to impinge on the filter, you would probably punch holes in it. This would give you loss of containment also.

Going back to the discussion you just mentioned, I think this is a very good addition to what you said earlier. I think we should consider the filters and similar items at the glove box and immediately downstream of the glove box as being sacrificial. The comments I made earlier regarding prevention of fire in the final (or Principal Filter, if you will) are still valid. I agree wholeheartedly that you've got to stop the fire back down in the glove box. Even though we often have HEPA filters at that point, these are merely one in a series of HEPA filters; we can sacrifice that filter, but we have got to prevent fires from possibly occurring in that Final Filter.

MURROW: From comments I have heard since I spoke this morning I would like to say that there must be other ways of extinguishing fires in carbon adsorbers. I did not try everything. I can say from my tests that if a fire once starts in a carbon adsorber the water sprinkler or spray is not the way to extinguish it. I would like to emphasize what others have just been saying here and that is to stop the fire before it gets to the air cleaning system. But be aware that if under accident conditions there should be a very uncommon combination of circumstances where you get a fire within a carbon bed then realize that you have a serious problem as long as the air is flowing. The elimination of carbon adsorbers is not the answer; prevention of fire is the proper way.

DYMENT: I would like to ask everyone assembled here, particularly those interested in economic operation of HEPA filter systems, whether they have any views on the use of roughing filters, or pre-filters, to prolong the life of the HEPA filters?

BURCHSTED: I think the obvious comment is the one stated in NSIC-65, that in at least 95 percent of the cases you should have a roughing filter. In some cases that roughing filter might be the sacrificial HEPA filter upstream.

FIRST: In other words, it not only prolongs life of the absolute filter, in your opinion, but it may have some fire extinguishing properties as well.

If there are no further questions, I think we have come to the end of our 11th Air Cleaning Conference. I know that Dade Moeller and Jim Morgan join me in thanking all of the excellent session chairmen who have kept us so well on schedule. We thank all of you for coming and wish you all a safe journey home. We hope to see you again two years from now.

The 11th AEC Air Cleaning Conference is concluded.