THE ANALOG COMPUTER AS AN AID IN CRITICAL VENTILATION SYSTEM EVALUATION

T. W. Pickel
Oak Ridge National Laboratory

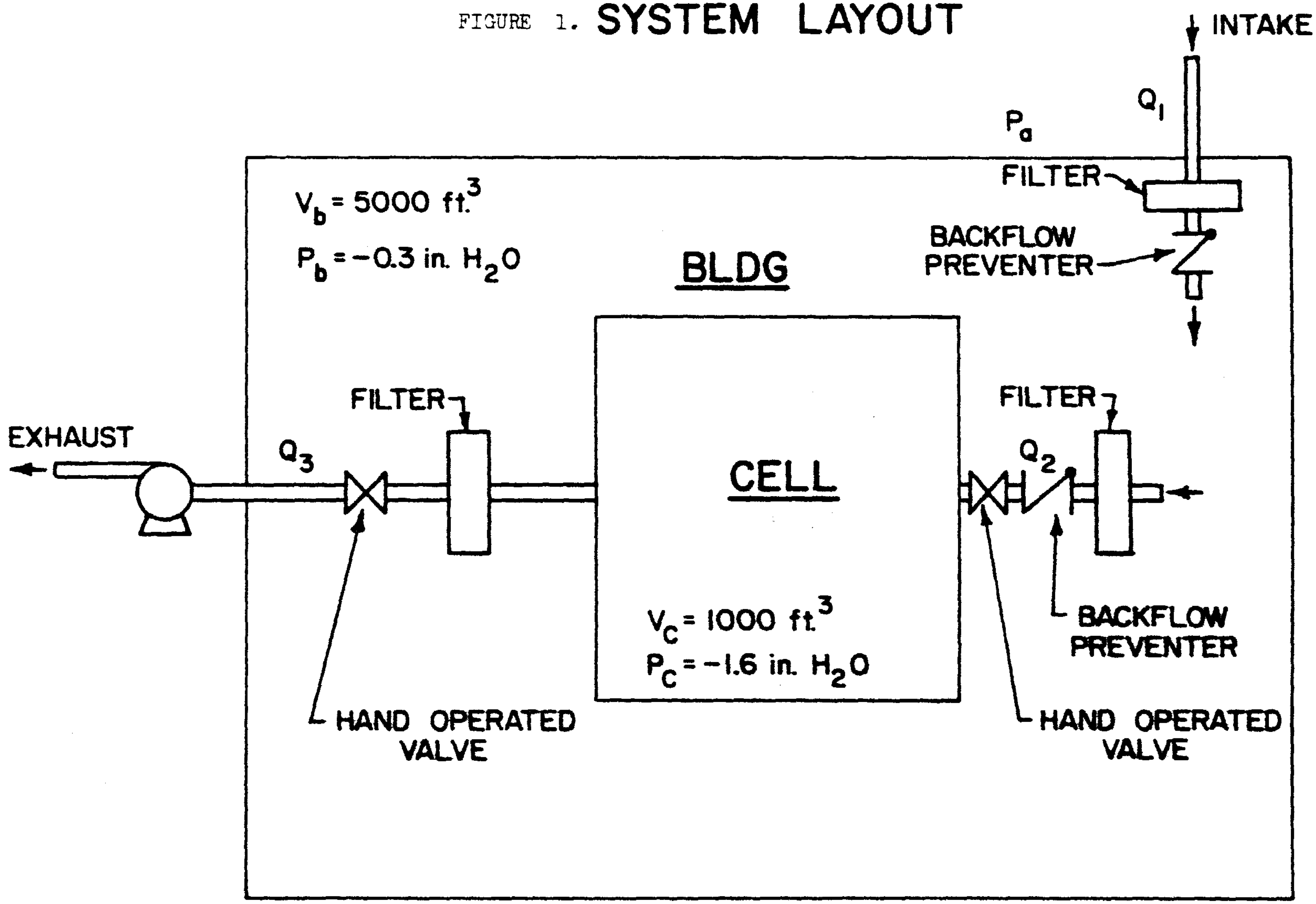
The purpose of this report is to indicate some advantages of using analog computers in the analysis of air handling systems and to present an illustration of an analysis of a simple system.

The analog computer can be of assistance in evaluating several areas of a ventilation system. First, simulation of the system on the computer can help the designer select the proper components and test their compatibility with the rest of the system. This would involve a study of static flow conditions over a range of the operating variables such as filter resistance. Second, it can help in the operation of the system. This is particularly true for the startup of a complicated system in which a proper balance of air flows is difficult to obtain and maintain. It is also true of operation after startup when increases in filter resistance will cause a shift in the air balance. Third, the computer can be used to evaluate upset or transient conditions. The ability of the analog computer to handle differential equations makes it an extremely valuable tool in this type of analysis. Items of interest here may include the stability and response time of the system and the effect of dynamic changes on component performance. The length of time to recover from such disturbances as explosions, fires, accidental release of fire extinguishing systems, and opening of air locks is of interest in a hazards evaluation.

The complexity of the system that can be analyzed is limited only by the computer equipment available and the ingenuity of the analyst. The accuracy of simulation may be limited by the data available on the performance characteristics of the components. For this discussion, I am considering a rather simple system. The layout is shown in Figure I. The system consists of a building containing a single cell. Air enters the building through a filter and backflow preventer. Air from the building enters the cell through a filter, backflow preventer, and hand-operated valve. The exhaust system consists of a filter, hand-operated valve, and a fan. Flow resistance in the filters is considered to be proportional to the flow rate. Resistance in valves, ducts, and backflow preventers is assumed to be proportional to the square of the flow rate. In this illustration, it is assumed that the fan curve is linear over the range of flow rates to be covered. In many problems this assumption would not be adequate. In these cases the complete pump curve could be simulated by a function generator.

Figure 2 shows the equations used. The first three equations give the static pressure drop in building intake, cell intake, and cell exhaust systems respectively. The symbols C_1, C_3, and C_6 represent the filter resistances, and C_2, C_4, and C_7 represent the duct, valve, and backflow preventer resistances. The symbols C_5 and f represent the intercept and slope of the fan curve respectively. The last two equations relate the rate of change of the building and cell pressures to the flow rates. K_b and K_c may be considered to be the

FIGURE 1. SYSTEM LAYOUT



NORMAL FLOW: $Q_1 = Q_2 = Q_3 = 300$ CFM

FIGURE 2. EQUATIONS

$$(1)\quad P_a - P_b = C_1 Q_1 + C_2 Q_1^{\,2}$$

$$(2)\quad P_b - P_c = C_3 Q_2 + C_4 Q_2^{\,2}$$

$$(3)\quad P_a - P_c = C_5 - f Q_3 - C_6 Q_3 - C_7 Q_3^{\,2}$$

$$(4)\quad \frac{dP_b}{dt} = K_b (Q_1 - Q_2)$$

$$(5)\quad \frac{dP_c}{dt} = K_c (Q_2 - Q_3)$$

reciprocals of the capacitances of the building and cell respectively. For this model these values are considered constant. A more accurate representation would be to express them as functions of pressure. However, for this illustration the maximum error introduced by this assumption is two per cent.

The computer diagram is shown in Figure 3. The diagram is divided into areas that correspond to particular portions of the system. The area labeled "Building Intake" includes the computer components that relate the flow rate entering the building to the pressure drop across the intake duct and associated equipment. A similar correspondence exists for the areas marked "Cell Intake" and "Cell Exhaust". Since we are interested in cases in which the cell pressure is higher than building pressure, it is necessary to simulate the action of the backflow preventer in the cell intake line. This is done with a comparator. When the building pressure is greater than cell pressure, the switches are closed and the circuit calculates the cell intake flow rate. When the cell pressure is equal to or greater than building pressure, the switches are open, giving a zero flow rate. The areas indicated as "Building" and "Cell" represent the buildup or decay of pressure due to transient conditions.

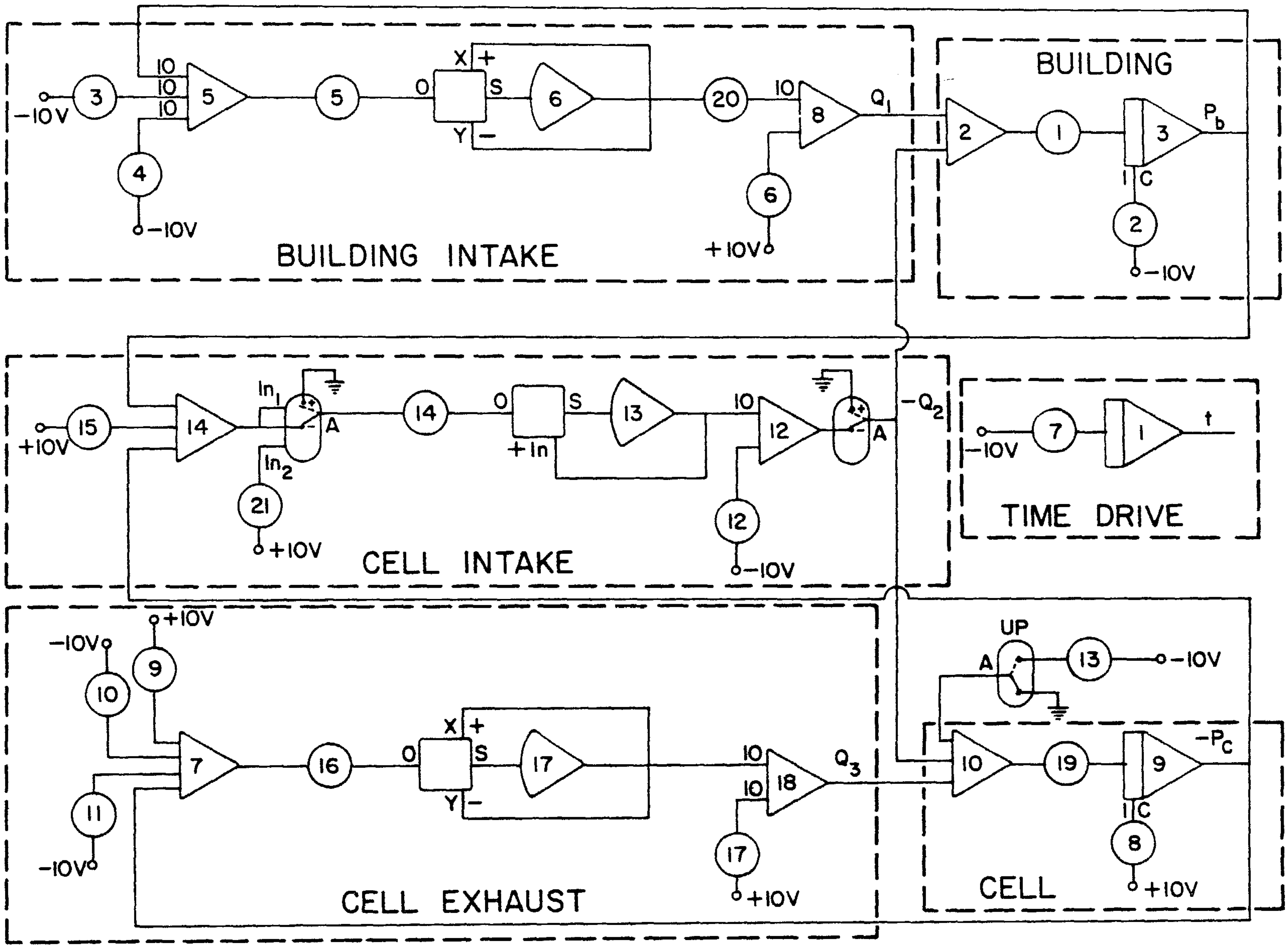
The computer being used for this problem is an Electronic Associates, Inc., Model TR-10. This unit has twenty high-gain (10^7) amplifiers, two quarter-square multipliers, one x^2-function generator, twenty-four potentiometers, one comparator, and two manual switches. For this problem we have used fourteen amplifiers, both multipliers, the x^2-function generator, twenty potentiometers, the comparator, and one manual switch. Additional cells, separate building exhausts, automatic control equipment, and multiple fans can be added to this model. However, more computer equipment would be needed than is available on the TR-10.

Four possible upset conditions are considered. First, Figure 4 shows the response of this system to a sudden opening of a door to the cell. The building and cell pressure quickly equalize at a value between the two initial pressures. The flow of air into the cell increases rapidly, then decreases to a new equilibrium value. The flow rate into the building also increases to a peak, then decreases slowly to the new equilibrium position. The change is not as abrupt for the building intake as for the cell intake. The exhaust flow rate increases to the equilibrium quantity at a slower rate. The pressures equalize in less than one second, but the flow rates take approximately five seconds to reach a new static condition.

The second condition considered is an explosion in the cell. The system response is shown in Figure 5. The cell pressure is assumed to suddenly increase and then decay. The building pressure increases and then returns slowly to its initial value. As the building pressure increases the flow rate into the building decreases. After the building pressure reaches its peak value and starts to decrease, the flow into the building starts increasing and returns to its initial value. The cell intake flow rate drops to zero and remains there until the cell pressures drop below the building pressure. The cell exhaust rate increases with the cell pressure, then decreases to the equilibrium value. Approximately six seconds are required for the system to reach steady-state conditions after the explosion.

The third condition considered is an accidental release of compressed CO_2 into the cell. This is shown in Figure 6. It is assumed that this causes a reduction in cell temperature which results in a reduction in cell pressure. Since the model has no backflow preventer in the exhaust system, the flow of air in the exhaust system is into the cell rather than out of the cell for a short period of time. About five seconds are required for the system to recover.

FIGURE 3. COMPUTER DIAGRAM



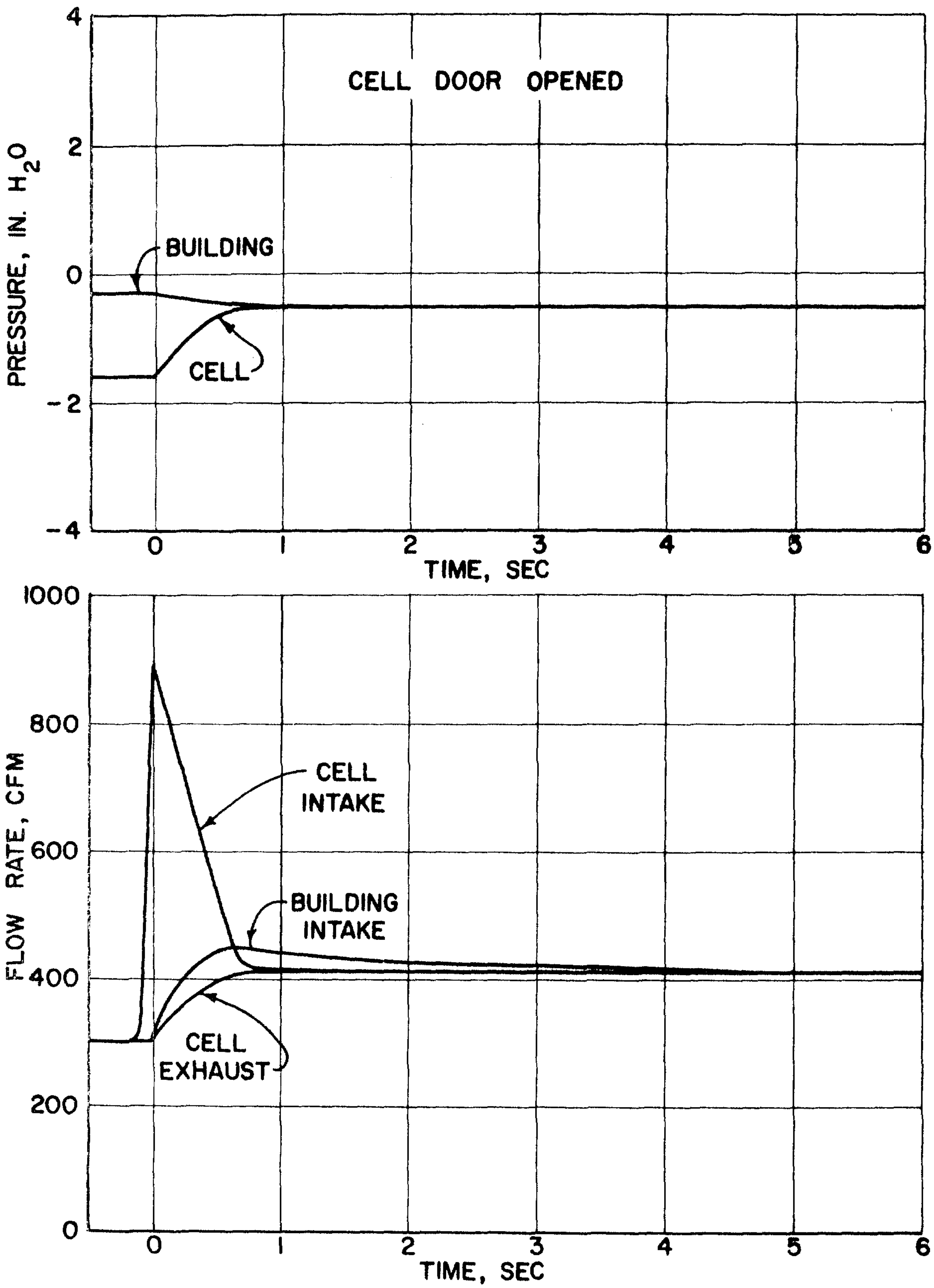


FIGURE 4. System Response to Sudden Opening of a Cell Door

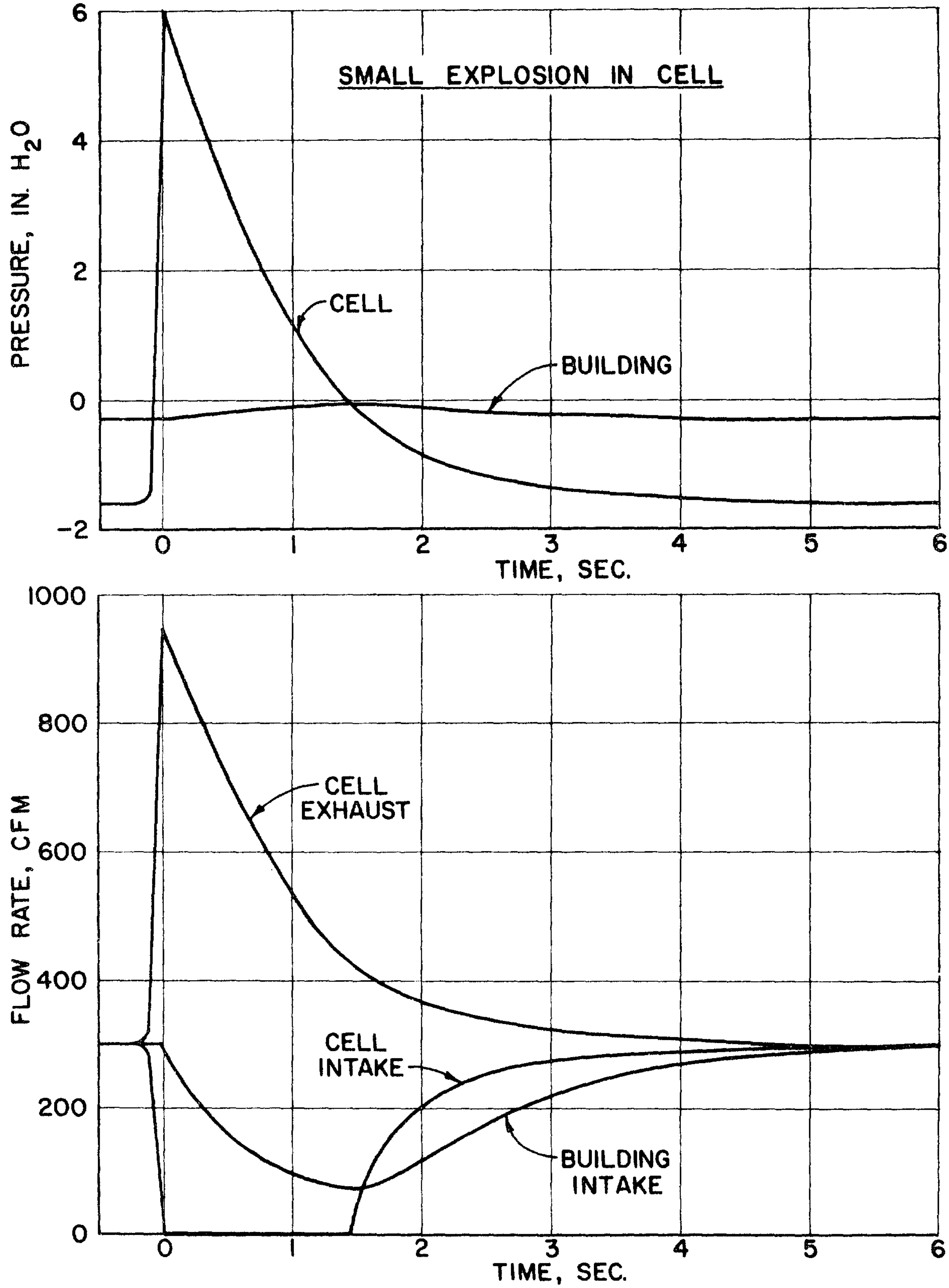


FIGURE 5. System Response to a Small Explosion in the Cell

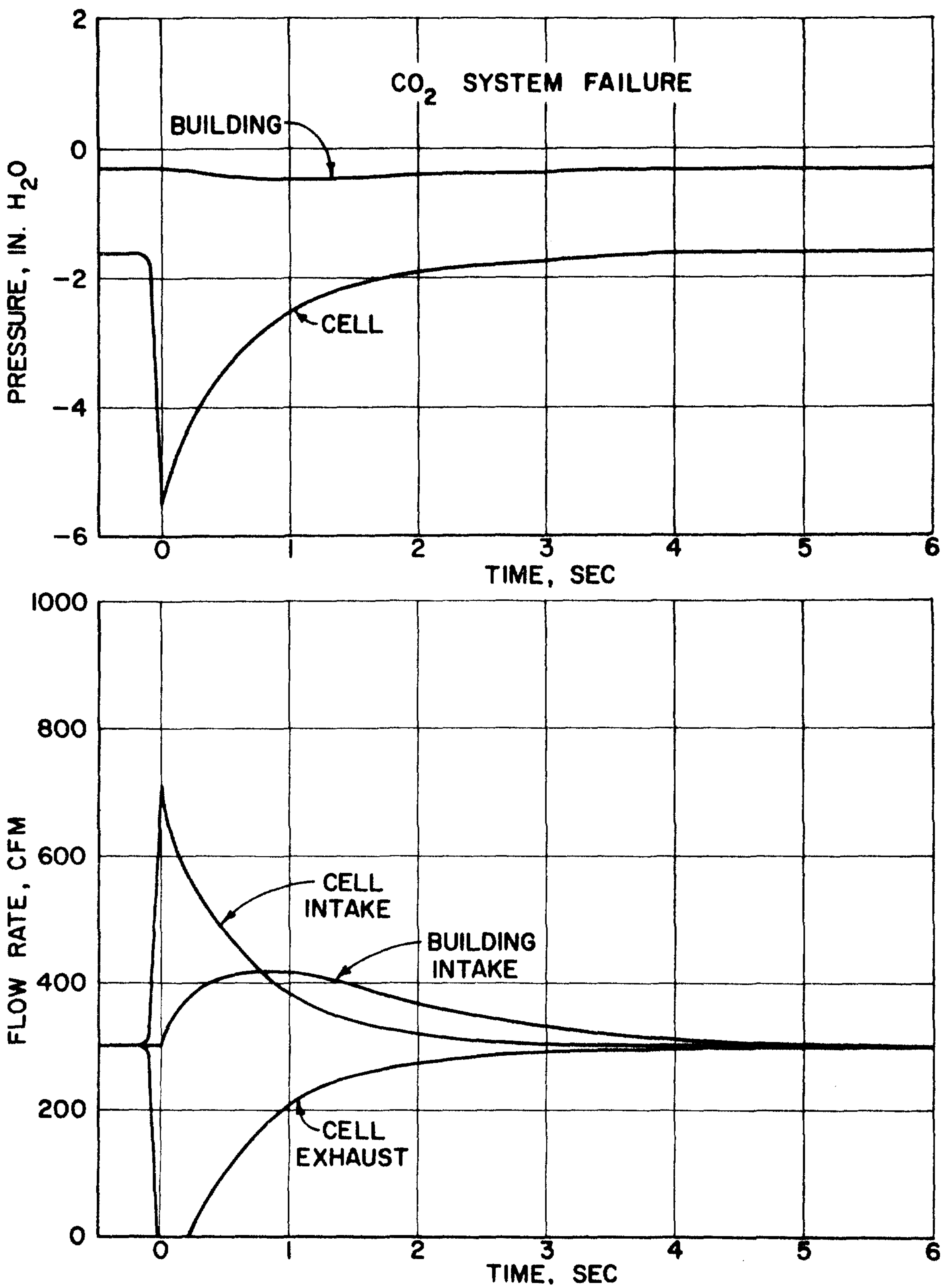


FIGURE . 6. System Response to a Sudden Release of CO_2 in the Cell

The fourth case, which is shown in Figure 7, is an example of a fire in the cell. This example assumes a constant rise in cell temperature. The fire is assumed to last for 3.5 seconds. After this, the system returns to equilibrium. About five seconds are required for the system to return to equilibrium after the fire is stopped.

The model considered here is a cell. The same techniques can be used for glove boxes, building ventilation systems, exhaust systems, vessel off-gas systems, and other air handling problems. Although the examples shown are of drastic changes to the system, a study of less drastic changes may be of equal or greater importance in evaluating the system. The value of the computer as an aid in designing and operating a complex system applies to all air handling problems and not just to critical systems as the title of this paper implies. Several important features were excluded from this model for simplicity. Some of these are covered in a study by J. J. Perona, W. E. Dunn, and H. F. Johnson and reported in Calculated Transient Pressures Due to Impulse and Ramp Perturbations to Ventilating Systems in Buildings 3019, 3026, 3508, and 4507, ORNL-3086 (1961).

In summary, the analog computer can be a valuable aid in the design, operation, and hazards evaluation of all air handling systems. Although the system considered here is simple, complex problems can be analyzed with a modest amount of analog computer equipment.

TABLE I

Input Data for Steady-State Condition

Variable	Definition	Value
Q_1	Building Intake Flow Rate	300 cfm
Q_2	Cell Intake Flow Rate	300 cfm
Q_3	Cell Exhaust Flow Rate	300 cfm
V_b	Building Volume	5,000 ft^3
V_c	Cell Volume	1,000 ft^3
P_b	Building Pressure	-0.3 in. H_2O
P_c	Cell Pressure	-1.6 in. H_2O
P_a	Atmospheric Pressure	0 in. H_2O
C_1	Building Intake Filter Resistance	0.25 in. H_2O/300 cfm
C_2	Building Intake Line and Valve Resistance	0.05 in. $H_2O/(300\ cfm)^2$
C_3	Cell Intake Filter Resistance	1.00 in. H_2O/300 cfm
C_4	Cell Intake Line and Valve Resistance	0.3 in. $H_2O/(300\ cfm)^2$
C_5	Intercept of Pump Curve	4.0 in. H_2O
C_6	Cell Exhaust Filter Resistance	1.0 in. H_2O/300 cfm
C_7	Cell Exhaust Line and Valve Resistance	0.2 in. $H_2O/(300\ cfm)^2$
f	Negative Slope of Pump Curve	0.004 in. H_2O/cfm

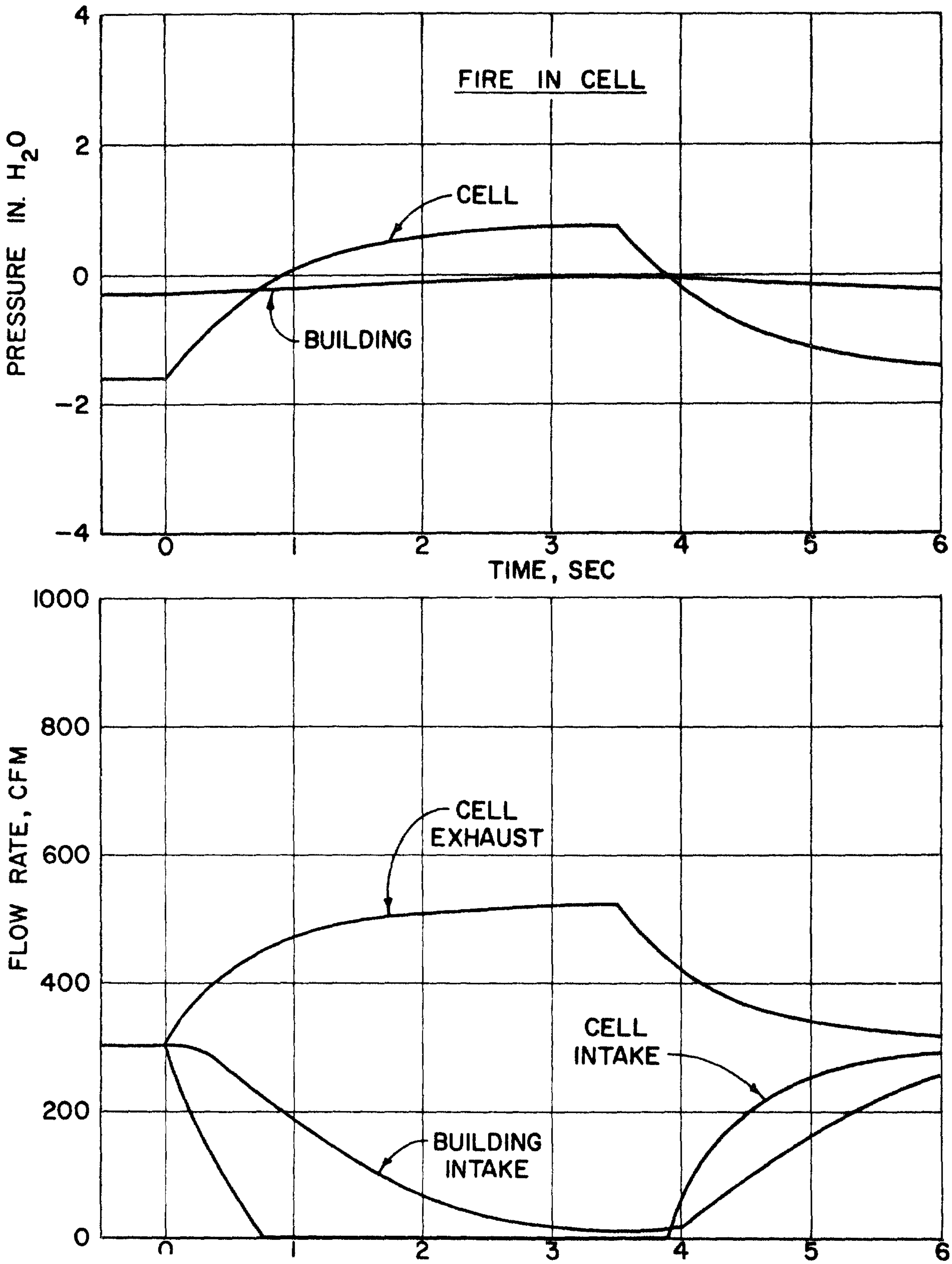


FIGURE 7. System Response to a Fire in the Cell

TABLE II

Potentiometer Settings

Potentiometer Number	Quantity	Setting
1	$K_b/2.4$	0.034
2	$P_{b0}/20$	0.485*
3	$P_a/20$	0.500*
4	$c_1^2/80\ c_2$	0.0156
5	$10^{-6}/5\ c_2$	0.360
6	$c_1/2000\ c_2$	0.750
7	K	0.100
8	$P_{c0}/20$	0.420*
9	$P_a/20$	0.500*
10	$c_5/20$	0.200
11	$(c_6 + f)^2/80\ c_7$	0.303
12	$c_3/2000\ c_4$	0.500
13	A	0.600
14	$10^{-6}/5\ c_4$	0.060
15	$c_3^2/80\ c_4$	0.0416
16	$10^{-6}/5\ c_7$	0.90
17	$(c_6 + f)/20{,}000\ c_7$	0.165
19	$K_c/2.4$	0.170
20	10/10	0.3162
21	$c_3^2/80\ c_4$	0.0416

*Five volts corresponds to a gage pressure of 0 in. H_2O.

DISCUSSION AND COMMENT

Analysis has not been performed on a real system to check computer results against actual measurements; therefore, no data is available to check a simulated system. We hope to do so in a few years, both cells and glove box facilities will be simulated.

Session Chairman: Thank you, Mr. Pickel.

The second paper, "Safety Aspects of the Design of Filter Ventilation Systems," has been prepared by S. E. Smith, F. J. Hall and W. E. Holmes, all of the UKAEA. The paper will be presented by S. E. Smith.

SAFETY ASPECTS OF THE DESIGN OF FILTERED VENTILATION SYSTEMS

by

S.E.Smith, F.J.Hall, W.E.Holmes

UNITED KINGDOM ATOMIC ENERGY AUTHORITY

Atomic Weapons Research Establishment

Aldermaston

SYNOPSIS

A number of safety aspects of the design of filtered ventilation systems for radioactive and toxic buildings have been considered.

These include theoretical and experimental assessments of the heat release from fires of various kinds in workrooms, fume cupboards, glove boxes, and extract systems, the use of spark and flame arrestors, the ignitability of dust deposits in extract systems and filters, the cooling of hot gases in exhaust ducts.

As a result of this work, it is possible to formulate principles which should be followed in the layout and design of such systems, in the future; existing systems have been found not to require any serious modification apart from installation of glass paper filters.

1. INTRODUCTION

In the recent past, considerable attention has been paid at AWRE, as in other parts of the UKAEA, to the problem of fire protection in filtered ventilation systems of radioactive and toxic process buildings.

A major contribution to this has been the adoption of non-combustible filters based on the use of filter papers made from glass fibres, in place of the combustible filters, constructed either from cellulose-based paper, or from the resin-wool, asbestos-wool, and cotton-asbestos pad materials previously employed. At AWRE, glass-paper filters were first used experimentally in 1958, but were not accepted for general use until commercially available glass-paper filter units had undergone a number of modifications. These were due to AWRE insistence on a completely non-combustible construction, and on various other mechanical features, to avoid failure (refs. 1,2). At about this time, AERE (Harwell) tests had demonstrated that ordinary paper filters in wooden frames could not be satisfactorily fire-proofed.

The standard filter, now in use in all modern installations in the UKAEA consists of the 1000 cfm. 2' x 2' x 1' high-temperature absolute filter insert, which contains approximately 250 sq.ft. of thin (0.025"-.03") glass paper, pleated around spacers of corrugated aluminium and sealed with a fire-resistant cement into a steel frame. The metal spacers have beaded edges to avoid perforation of the paper at the folds. Such filter inserts are either used in a "honeycomb" wall pattern, bolted directly onto duct flanges, or, as at AWRE, sealed into an outer steel canister which is mounted in the ductwork headers. These canisters contain one or more inserts in series.

This paper is not concerned with the adoption of glass-paper filters, but with a number of safety aspects of the ventilation systems in which glass-paper filters are now used, which have also been investigated at AWRE in the last two to three years, and with the safety philosophy which has evolved as a result of these various investigations.

The safety aspects of filter installations which have been covered include:

(1) experimental work on spark and flame arrestors, and an examination of the need for flame and spark arrestors in filter systems

(2) experimental investigations, and theoretical calculations, of the possible temperatures which could arise in the extract air, and at adjacent filters, as a result of fires of various materials in (a) workrooms and process enclosures, etc. and (b) the extract ducts and filters

(3) experiments and calculations on the cooling of air in the ducts, to arrive at safe distances of separation of filters in ductwork in the absence of dilution effects

(4) isolation of ventilation systems in emergency, by the use of dampers and fan cut-outs, and the installation of fire detection equipment in filtered ventilation systems

(5) examination of the design of existing systems at AWRE, and of the condition of the systems with regard to dust deposits

(6) data on the ignitability of various dust deposits in the beryllium extract systems and filters at AWRE, as well as limited data from uranium and plutonium filter deposits, and on some synthetic dusts.

As a result of this work, it is possible to set out the principles which are now being followed at AWRE with regard to the safety aspects of the design of filtered ventilation systems of radioactive and toxic buildings.

In the following sections the work which has been carried out under each of these headings is summarised. Fuller details of the various investigations are available.

2. FIRE HAZARDS IN RELATION TO GLASS PAPER FILTERS

2.1 The fire resistance properties of glass paper filters may be stated to be as follows:-

(1) Although these filters are non-combustible, they are only fire-resistant up to approx. 500°C, (1000°F). Above this temperature failure occurs by melting of the glass paper, which is the weakest material present.

(2) They are not intended for routine or continual operation at elevated temperatures, but are expected to remain intact after accidental heating to a temperature not above 500°C. Most important is the fact that they do not themselves catch fire although burning material caught on the filter could cause a breach of the filter by melting the glass-paper medium.

(3) Under accident conditions such as a solvent fire in close proximity to the filter, when very high temperatures are involved, failure will occur quite rapidly.

(4) Hence where inflammable material, hot gases or incandescent sparks can reach it, some means of protecting the filter is essential if failure of the filter concerned cannot be tolerated.

2.2 In considering the effects of fires on filters it is necessary to distinguish between fires in which the material involved is solid, and gives rise to solid combustion products, and fires of solvents, etc., where the combustion products are gaseous. The important difference is that in the former case, heat transmission occurs by radiation and conduction, as well as by convection from the solid material to the gas stream, with an additional hazard of transport of solid debris, while in the latter case, heat evolved is mostly transferred directly to the gas stream with great rapidity.

3. SPARK AND FLAME ARRESTORS

At the time that the development of glass paper filters was taking place, investigations into the selection and performance of spark and flame arrestors were initiated at AWRE, and in early 1960, a working party was appointed to examine the necessity for flame and spark arrestors in the ventilation systems of radioactive and toxic buildings.

3.1 Spark Arrestors

An experimental programme carried out in the Chemical Engineering Branch at AWRE in 1960 led to the conclusions that, as far as spark arresting was concerned, glass-fibre was a satisfactory material to use, and that a coarse glass fibre pack, of quite low filtration efficiency, would adequately intercept any incandescent particles which were large enough for them to have a sufficiently long life to endanger filters within a few feet of the arrestor. It was concluded that a coarse loosely packed glass-fibre pad, 2" thick, operating at a face velocity of 300 ft./min., should be installed at the entrance to extract ducts, whever a spark hazard could be said to exist (e.g. machining boxes, welding booths, casting operations).

Suitable filter pads of this type are commercially available, are inexpensive, and have a low flow resistance. These pads could also be used as spark arrestors in the first stage of a composite filter to protect the main filters, although some economic advantage will normally accrue from the use of a more efficient prefilter of the pleated glass mat type, to extend the life of the main filter, and this will also serve a spark arresting function.

A prefilter of this type would acquire a heavy burden of any combustible material present in the extract gases and consideration was also given to the propagation of secondary fires in such filters and prevention of debris from these penetrating further downstream. For this purpose experiments were carried out to determine the duration of burning of different sized particles of various materials in a current of air so as to determine the mesh size of a debris arrestor in relation to the size of particle to be arrested, consistent with a low pressure drop contribution.

Carbonaceous materials, being slower burning, had a longer distance of travel than metal particles, but the temperature of carbonaceous particles is lower, and hence the ignition danger to a subsequent main filter is less.

For general use, a spark guard of stainless steel wire BS40 mesh has been adopted; this will give burning distances of 20 ft. for carbonaceous sparks and less than 5 ft. for magnesium; the location of the main filter should be decided accordingly.

3.2 Flame Arrestors

Flame arresting presented a much more difficult problem, and discussions which were held with the Group Safety Officer and the Fire Research Station at Boreham Wood, led to the general conclusion that commercially available flame arrestors were likely to be effective in only a limited range of conceivable conditions, and for only a very short period of time.

It was agreed that the most satisfactory approach in the light of the current state of knowledge of this subject was to restrict the use of highly inflammable materials (certain organic solvents, celluloid, etc.) in sensitive areas, and where their use was essential, to impose strict limits on the quantity of such solvents which might be introduced into ventilated boxes or fume cupboards and to provide sufficient air flow to reduce the concentration of vapour in the event of total spillage to below the inflammable limit (refs. 3, 4, 5).

4. THE TEMPERATURE OF AIR AND COMBUSTION GASES AS A RESULT OF VARIOUS TYPES OF FIRE

The effects of fire involving inflammable solvents, metals, whether massive or finely divided, and certain inflammable materials of construction (e.g. perspex) in raising the temperature of air extracted from open workrooms, fume cupboards or glove boxes, were considered, both by theoretical calculations and by practical experiments. Similar consideration was given to the effect of fires in the extract ducts and filters themselves.

4.1 Room extract

Solvent fires constitute the worst hazard in these circumstances; it was concluded that the temperature of air entering the main room extract duct is unlikely to exceed 500°C from this cause.

4.2 Fume cupboards

In fume cupboards where the volume of extract is normally in the region of 1000 cfm. solvent fires again constitute the principal hazard; the local extract temperature might reach 1000°C, in the event of a solvent fire although in general this would be reduced by dilution with air from other sources, further down the duct. Temperatures to be expected from metal (Pu, Be) fires, even when the metal is finely divided, are lower.

4.3 Glove boxes

Fires in air filled glove boxes, or inert gas boxes where a breach of containment has allowed some air to be drawn in, and where the emergency high velocity extract is in operation at 50 cfm., might give rise, in the case of burning beryllium swarf, to extract gas temperatures as high as 2000°C; for solvent fires the figure is about 1000°C, for massive beryllium it is below 1000°C and for massive or finely divided plutonium below 500°C.

The findings of separate investigations to consider certain aspects of box fire hazards (refs. 7,8) include recommendation for the cancellation in the event of a box fire, of high velocity extract (this is a system whereby air at high velocity is sucked in to preserve containment). With this precaution the probability of damage of main extract filters by fire arising in inert-gas-filled boxes is considered to be negligible. Local filters would however, be expected to fail rapidly.

4.4 Filters

(a) Where glass fibre filters (which having a comparatively loose structure, have a large surface area) are concerned, ignition of a deposit consisting essentially of all metallic dust, would raise the air passing through the filter to a very high temperature (1700°C), which could cause damage to another filter downstream, unless it were a considerable distance away, so that the air cooled before reaching it.

(b) For a dust of a more likely composition, i.e. partly organic, and partly inert inorganic, with only a small proportion of metal dust, providing the metal is not more than 80 gm. approximately and the rest is not more than 50% combustible organic material, the heat release is not enough to raise the air to a temperature sufficient to damage another filter, even though this is close to the filter containing the combustible dust.

It is possible that the materials would not burn readily if the total diluent were sufficient, i.e. a fully loaded filter but containing only this quantity of metal dust.

(c) In the case of a glass paper filter, owing to the lower surface area available for heat transfer purposes, calculations indicate that even if the dust accumulated were all metallic, the consequent increase in temperature of air passing through the filter would not exceed 500°C, although the filter itself would probably disintegrate eventually.

Where the fire is due to ignition by gases which are already at 500°C then the existing gas temperature could be raised beyond this, and might therefore approach 1000°C for the cases quoted.

5. RATES OF COOLING OF HOT GASES IN UNLAGGED DUCTS

5.1 Theoretical Assessment

Calculations based on conventional heat transfer data have been made, to determine the expected rate of heat loss from hot gases passing through unlagged mild steel ducts (see Fig. 1).

The initial maximum temperature was assumed to be 1000°C; the only condition under which any extract gases might conceivably exceed this figure is that of a major beryllium swarf fire in a glove box under high velocity extract at 50 cfm. and stringent operating precautions are taken to avoid such a condition.

A flow of 1000 cfm. of gas through a 1' diameter duct is one of the conditions considered, since this is the highest flow rate for which (in a solvent fire in a fume cupboard) a temperature of 1000°C might be attained; above this flow, dilution with cold air from other sources could be expected to reduce the temperature. Since the supply of gas at this temperature and flow rate would be of comparatively short duration, the unsteady states at up to 2 mins. were considered, and graphs were drawn of the temperature profiles along the duct, under unsteady and steady-state conditions. From this it could be seen that the duct lengths required to cool the combustion gases to 450°C for 1 and 2 mins. are 110' and 130' respectively, while the steady-state requirement for the same degree of cooling is 160'.

The other case considered is for a flow of 50 cfm. through a 4" duct, the condition for standard glove box high velocity extract. Since a fire involving a normal quantity of solvent might be expected to last for a longer period at this extract rate, the steady-state condition only is considered, and it is calculated that the direct length required under these conditions to reduce the temperature to 450°C is not more than 25' to 30'.

5.2 Experimental verification of cooling rates

It was considered advisable to carry out a practical check on heat transfer conditions approximating to those under review.

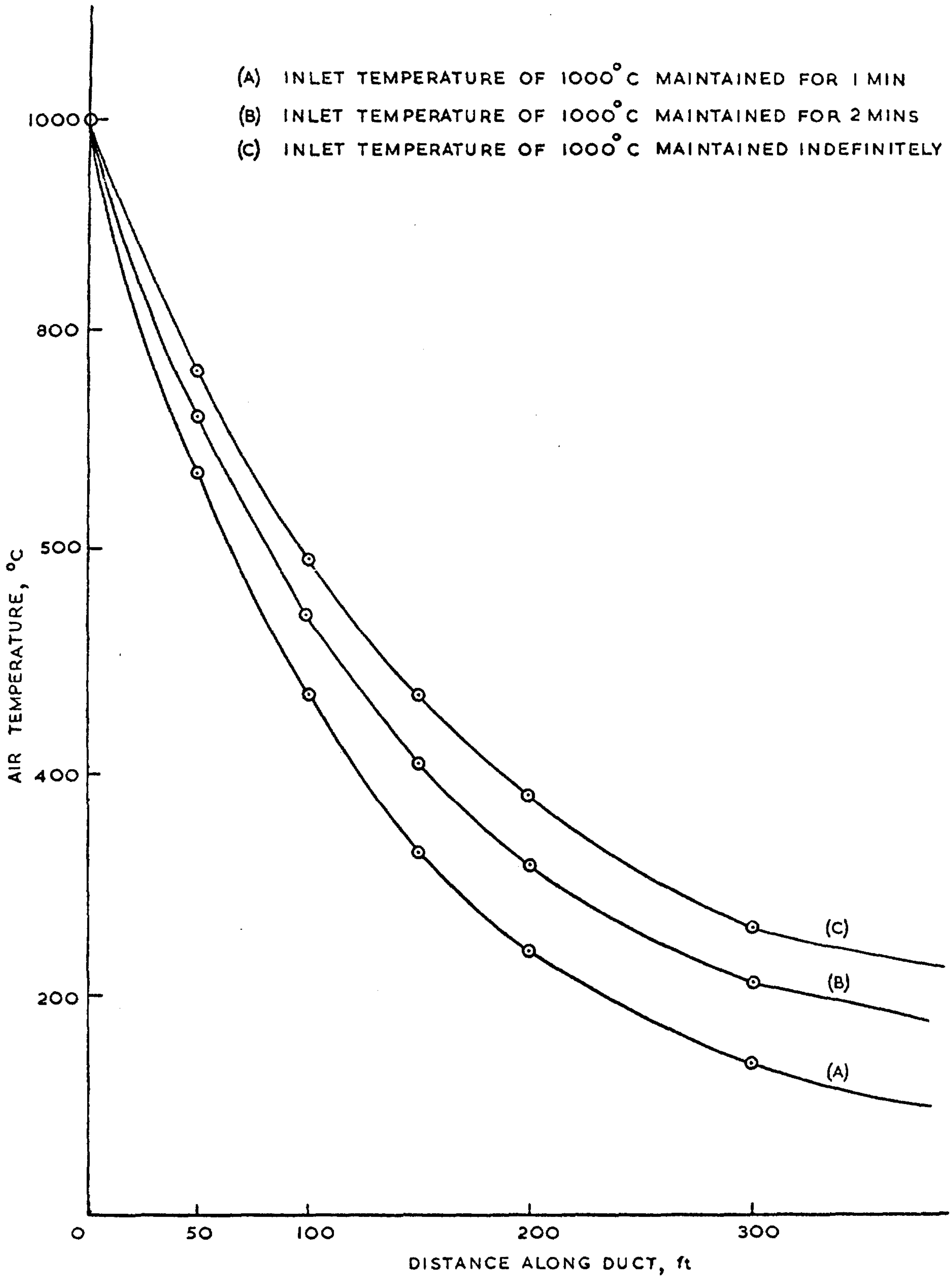


FIGURE 1. MAXIMUM AIR TEMPERATURES ATTAINED ALONG A 12 in DUCT WITH AIR FLOWING AT 1000 SC fm, AND INITIALLY AT 1000°C

A small research contract was therefore placed with the Chemical Engineering Branch, Department of Scientific and Industrial Research, Warren Spring Laboratory, who happened to have suitable equipment available to investigate this (ref. 10).

The air was heated by a paraffin burner, the maximum capacity of which was insufficient to heat 1000 cfm. of gas measured at STP. A reduced duct diameter of 8" was therefore adopted, and three flow rates were chosen to give about the same linear velocity as in our original calculations, the same Reynolds number and one value intermediate between the previous two. Gas temperatures were measured at 3', 32' and 61' and wall temperatures at 3' and 32', over a period of 5 mins.

Theoretical calculations of duct length versus temperature were made for these experimental conditions; the duct lengths, calculated for the three different flow rates as giving the temperatures observed at 61' from the entrance after 2 mins. were 70', 65' and 62.6' respectively, confirming our belief that the method of calculation used for the conditions in sections 3.1 and 3.2.1 was valid.

6. HEAT TRANSMISSION BY RADIATION AND CONDUCTION

The worst case which can be envisaged, i.e. that leading to the highest temperature and rate of heat release, is the case of a heavily loaded filter or prefilter containing essentially 100% beryllium dust, or a similar dust accumulation anywhere in the ductwork.

In this case, assuming a temperature of burning beryllium of over 2000°C, then a main filter located adjacent to it would suffer a severe temperature increase due to radiant heat. Aluminium spacers, if present, would constitute the main heat sink, but even so the temperature would reach at least 750°C, and whether aluminium were present or not, glass paper would certainly fail.

There would not be much heat loss by conduction to the ducting, until the filter collapsed. Then the temperature of the burning mass would rapidly cause the steel duct to melt through.

With a more likely filter dust deposit, as postulated in 3.1.4, if this ignited, then the heat release by radiation could still cause failure of a second glass paper filter, downstream, but it is doubtful whether with these compositions, combustion could be sustained, unless the metal content exceeded 80 gms.

Experiments to check this on the rig shown in Fig. 2 and 3 using filters loaded with atmospheric dust, with and without added magnesium powder in quantities up to 100 gms., and filters loaded with carbon and tarry matter from the rag-and graphite crucible-burning extract in a uranium building, showed that even when combustible matter ignited on the filter and the local temperature rose above 1000°C., the temperature of air passing through at 1000 cfm. rose only from 450°C. to 500°C.

A fire in the prefilter only damaged the main filter when burning debris was carried onto the latter.

7. THE USE OF ISOLATION DAMPERS AND FAN CUTOUTS IN AN EMERGENCY

7.1 Local Isolation

Whilst it might seem to be desirable to be able to isolate a part of an extract system in which a fire occurs from other parts of the system, if the system is designed so as to avoid the transmission of both burning debris and hot gas to the main or secondary filters then it is preferable to keep the extract going in such circumstances.

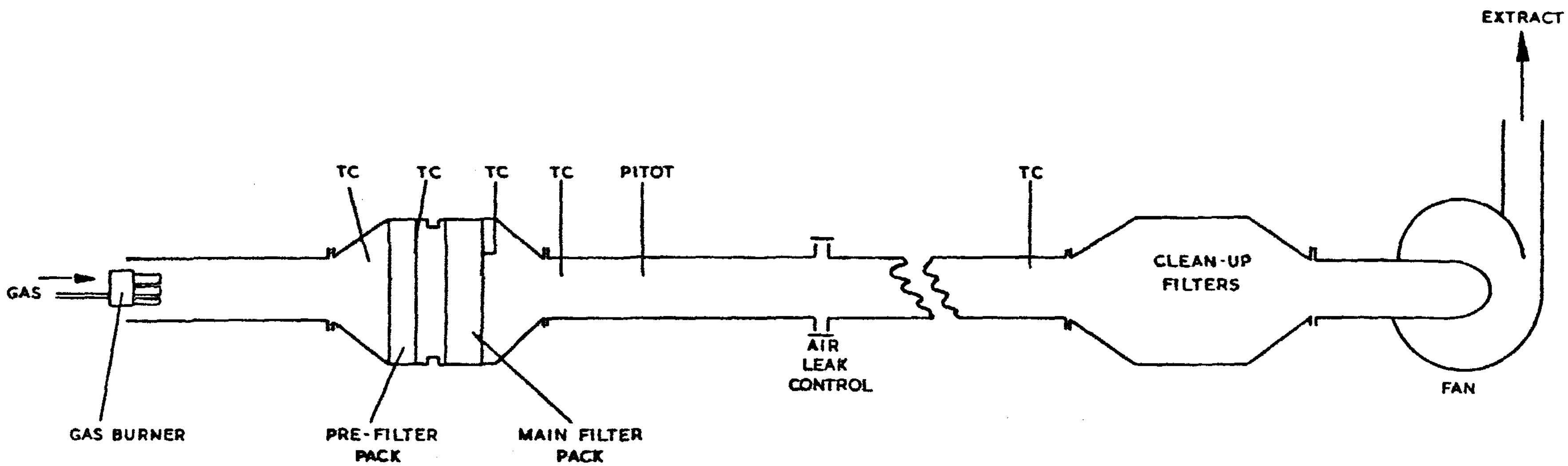
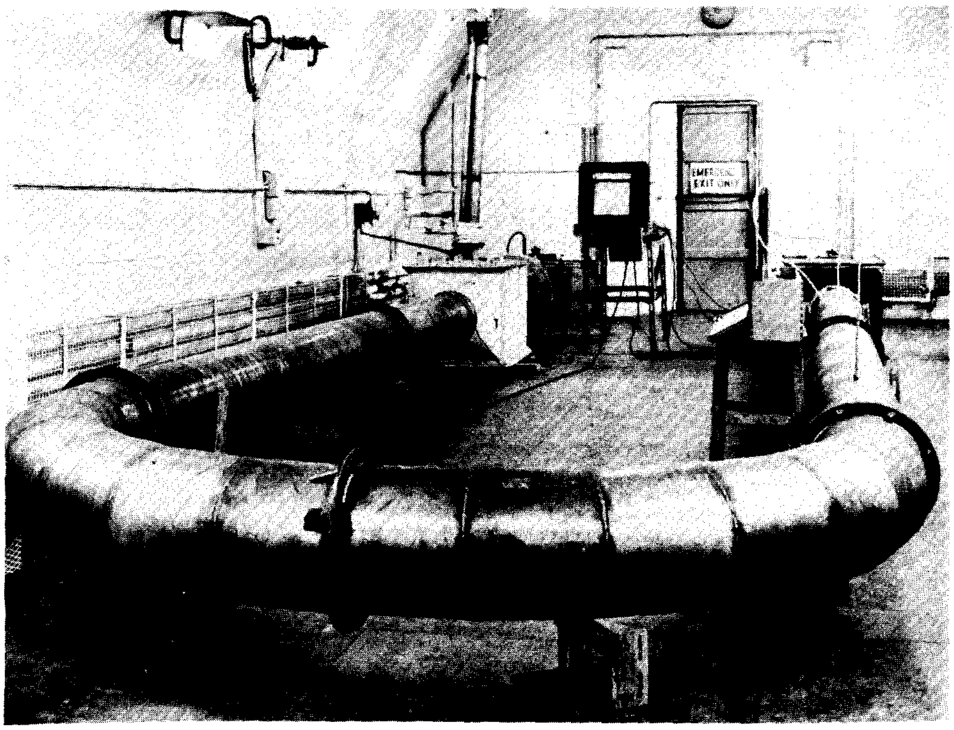
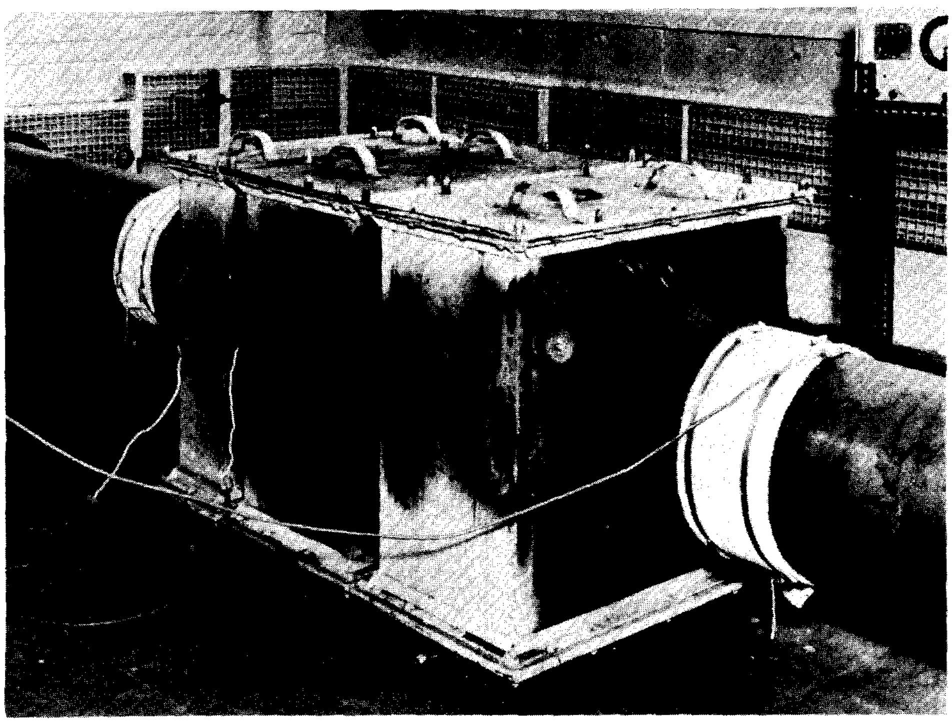


FIGURE 2. FILTER BURNING RIG



A. FILTER BURNING RIG



B. FILTER AFTER TEST

FIGURE 3

This however does not preclude the control of a fire by, for example, shutting down openings in fume cupboards.

Hence it is not necessary to fit special local isolation dampers in filter systems for this purpose.

7.2 Complete Isolation

It has always been possible at AWRE to shut down main fans without undue difficulty or delay. It is envisaged that this decision would be taken only after due deliberation and while adequate time remained for the necessary action to be carried out. Existing plant control rooms provide for this with sufficient accessibility.

Also as a last resort, the systems at AWRE have main isolation dampers at the stack which could also be operated as in 7.2 above.

8. FIRE PRECAUTIONS

Separate investigations were set up to cover fire detection in filters, in work boxes and in workspaces.

As far as filters and extract systems are concerned, recommendations for the fitting of certain types of fire detector were formulated so that in future all filter systems will have installed fire detectors of a recommended type.

9. BERYLLIUM EXTRACT SYSTEMS

9.1 Review of Beryllium Extract Systems at AWRE

In view of the high fire risk involved in handling beryllium powder, a special review was made of the operating and extract conditions in the beryllium metallurgy buildings at AWRE.

(a) Non-combustible prefilters and main filters are employed.

(b) Primary collectors are provided at extract points where beryllium dust concentrations are high, reducing the quantity of beryllium reaching the main extract system.

(c) No continuous collection system was provided for swarf arising in machining operations (this has since been provided).

(d) Production and handling of beryllium powder are carried out in argon-filled boxes.

(e) Machining boxes are provided with spark arrestors.

(f) Certain minor buildings still used combustible filters. These have been replaced by glass paper filters.

(g) Main filters are adequately protected by separation distances and dilution.

(h) Spark guards should be fitted after local filters on machine boxes.

9.2 Examination of Deposits in Extract Systems

A detailed examination was made of the extract systems in all beryllium buildings at AWRE; the total quantity of deposits present in the ducts was assessed and samples were taken for chemical analysis and determination of ignition temperatures. Ignition temperatures were determined by a differential thermal analysis technique, using the apparatus shown in Fig. 4.

In general the beryllium content of all deposits was low (0.01 to 1.5%), although isolated instances of high metal content in machine extract systems have occurred. These systems are being modified to confine contamination to the immediate vicinity of the boxes.

The deposits fell into three groups, those (consisting mainly of organic matter) which ignited at various temperatures below 500°C, those (containing metallic dusts) which ignited above 500°C, and those (consisting of inert inorganic dust) which failed to ignite up to 950°C.

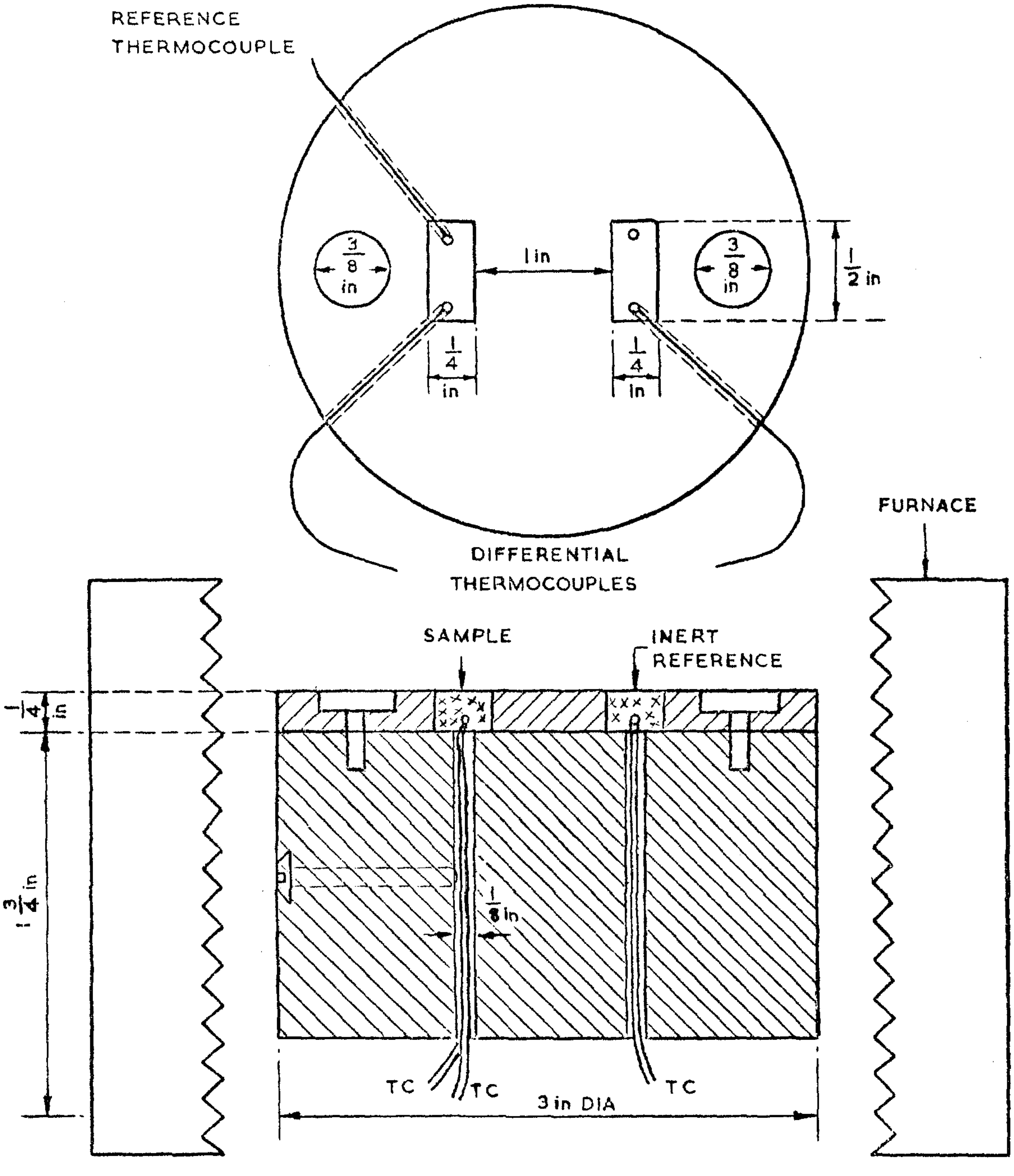


FIGURE 4. IGNITION BLOCK FOR DIFFERENTIAL THERMAL ANALYSIS

In none of the cases where ignition took place below 500°C was the heat released sufficient to raise the temperature of the burning mass above 500°C, although in a few instances, further external heating of the sample gave successive ignition points above 500°C. The inference drawn from this is, that dusts arising in the course of normal operation in beryllium buildings, which have these low ignition points, could not constitute a serious hazard to the integrity of glass paper filters, which are heat-resistant up to 500°C.

The samples showing ignition points above 500°C produced in most cases a very small temperature rise, indicating a low metal content, and the quantities of such deposits were so small that they are considered unlikely to constitute a serious hazard to the filters, unless in contact with them, in which case the filter would be expected to fail before ignition took place. The only possible exception to this was in the exhaust duct from the hot press, where the deposit contained 10% of beryllium, and ignited at 800°C with a considerable temperature rise. If deposits were allowed to accumulate in this duct a fire arising in the hot press might be transmitted to the filters. A local filter has now been fitted.

9.3 Synthetic Beryllium Dusts

Tests carried out on samples of beryllium powder showed ignition temperatures in the region of 750°C with a rapid temperature rise to well above 1000°C.

9.4 Effect of Glass Filter Material

Mixing beryllium with glass fibres from high efficiency glass paper, and from low efficiency glass fibre prefilters had no effect on ignition temperatures, although on ignition the coarse glass fibres fused round the dust and stopped the combustion. When actual dust deposits were combined with glass fibres they showed the same or higher ignition temperatures, and samples taken from fully loaded glass-fibre prefilters and glass-fibre main filters did not ignite below 950°C although another prefilter which was heavily loaded with oil ignited with a very small temperature rise at 360°C and again at 500 and 550°C.

It is concluded that glass fibres and glass paper do not affect the ignitability of dust arising in the course of beryllium metallurgy operations.

9.5 Possible Methods of Ignition

(a) Tests using Dewar flasks have established that spontaneous heating does not occur in dusts from the extract system, either alone or intermixed, or mixed with glass fibres.

(b) The possibility of build-up of static electricity when dry air passes through glass-paper filters with metal separators was also explored, but in all cases the static charge developed was found to be negligible.

9.6 Combustibility of Filter Material

Samples of cotton-asbestos and resin-wool filter materials from obsolete types of filter ignited at 240°C and 430°C respectively with low ($\sim$30°C) temperature increases, although these would be expected to be higher if a complete filter were ignited; this would, in any case, be completely destroyed, with consequent release of toxic material held on it.

10. URANIUM EXTRACT SYSTEMS

Samples were taken in 1958 from loaded 300 cfm. glass fibre filters in a uranium metallurgy building in order to find out whether there was enough uranium on them to be economically recoverable.

The total dust burden was estimated to be about 500 gms., and this included about 6 gms. of uranium in the filter from the foundry extract and about 1 gm. on the filter from the machine shop extract.

The dust deposits had low ignition temperatures (below 400°C) but produced a temperature rise of less than 50°C on the standard test. Attempts to produce sustained ignition of a complete filter in a current of air, by application of sparks or a flame were unsuccessful, even on a filter removed from the crucible and rag-burning system, which was heavily loaded with tarry and carbonaceous material (see 3.3 and Fig. 3).

It is concluded that deposits accumulating in extract systems from this type of building are unlikely to contribute seriously to a fire hazard.

11. PLUTONIUM EXTRACT SYSTEMS

Samples have been taken from a resin wool filter which has been in use in a plutonium metallurgy building for nearly 10 years on the extract from a high-activity area. These samples ignited at temperatures between 200°C and 400°C

Plutonium analyses on filter samples, and on material deposited in electrostatic precipitators, indicate that the total plutonium burden accumulating on main extract filters in 5 years is about 1 gram. Deposits in duct work and high velocity box extract filters probably total no more than this, and those in the filters on the argon box circulation system about the same.

12. DESIGN RECOMMENDATIONS

12.1 The UKAEA standard non-combustible high efficiency glass paper filter is sufficiently fire-resistant for use in all normal extract systems; although special consideration will need to be given to installation design to protect it from heating above its failure temperature (450-500°C). Some advantage may be obtained by elimination of the aluminium-foil spacers and this should be one aim of further development.

12.2 Glass-fibre spark arrestors should be used to protect the glass-paper filters from damage by incandescent sparks entering the system. Such spark arrestors should be located close to all extract points. A wire mesh spark guard should be fitted downstream of each pre-filter. A 2" thick low density coarse glass-fibre mat of the "Versil" or "Renuglas" type, operated at about 300' per min. face velocity, constitutes a satisfactory spark arrestor at a low cost and low pressure-drop. Considerations of economy in replacement of main filters may however dictate the use of a more efficient glass-fibre prefilter/spark arrestor, of the type shown in Fig. 5.

12.3 In certain cases (solvent fires, metal swarf fires), glass-paper or other filters installed locally to glove boxes, fume cupboards or room extracts will be breached.

12.4 The present use of spark arrestors in ventilated machine hoods is correct.

12.5 No known flame arrestor is likely to provide adequate protection from a major fire at the high flow rates involved in ventilation systems. Wherever possible the use of inflammable solvents, etc., should be restricted and the integrity of the main filter system should be ensured by providing a sufficient length of ducting to cool combustion gases below the temperature at which the filters will fail, unless adequate dilution with cool air is available.

12.6 Where the dust burden involved consists essentially of normal atmospheric dust the spark-arrestor and filter need be no more remote from the area extracted than is necessary to protect them from direct exposure to flames within the area.

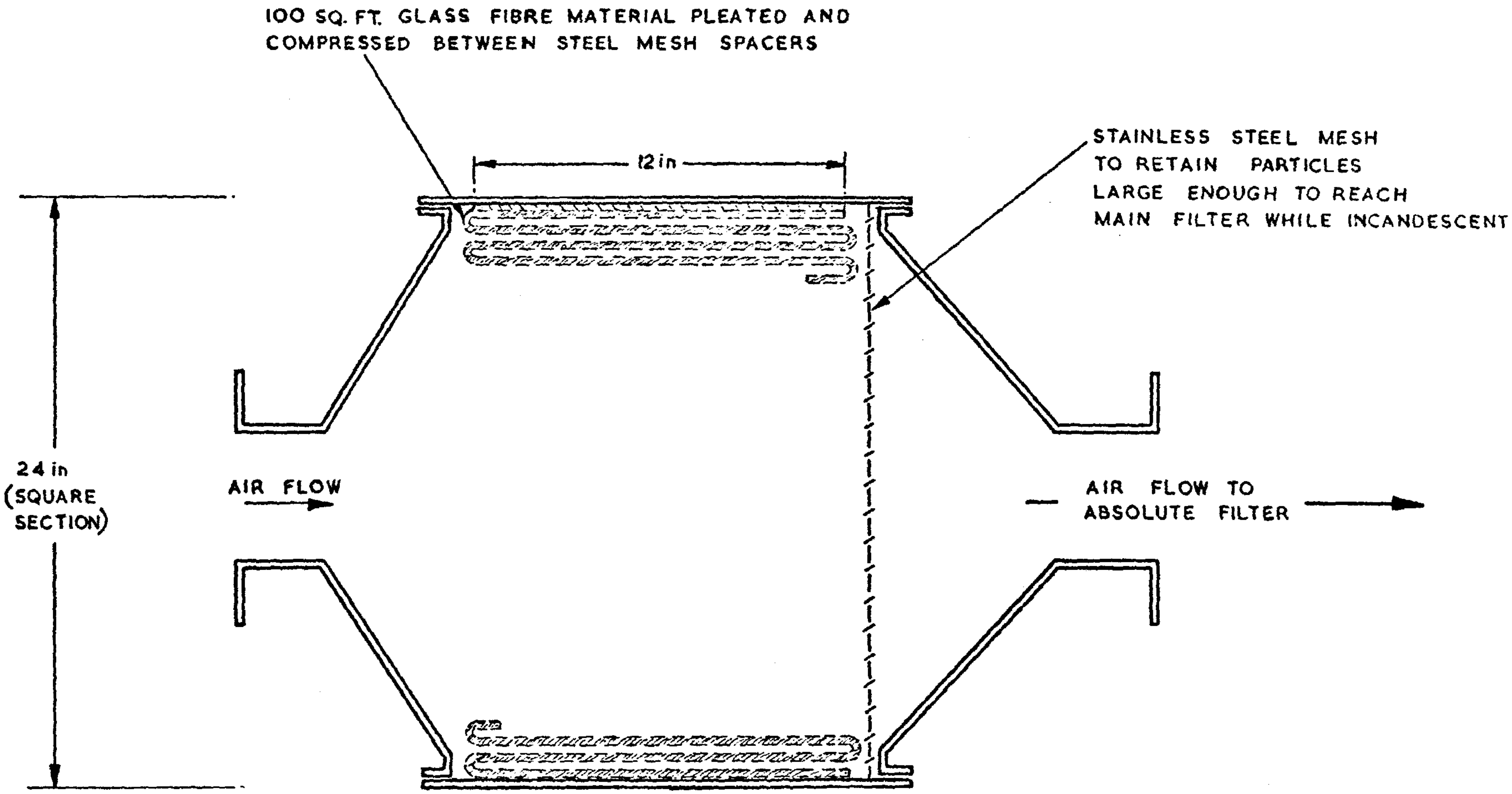


FIGURE 5. DIAGRAMATIC ARRANGEMENT OF PRE-FILTER FOR 1000 C.F.M

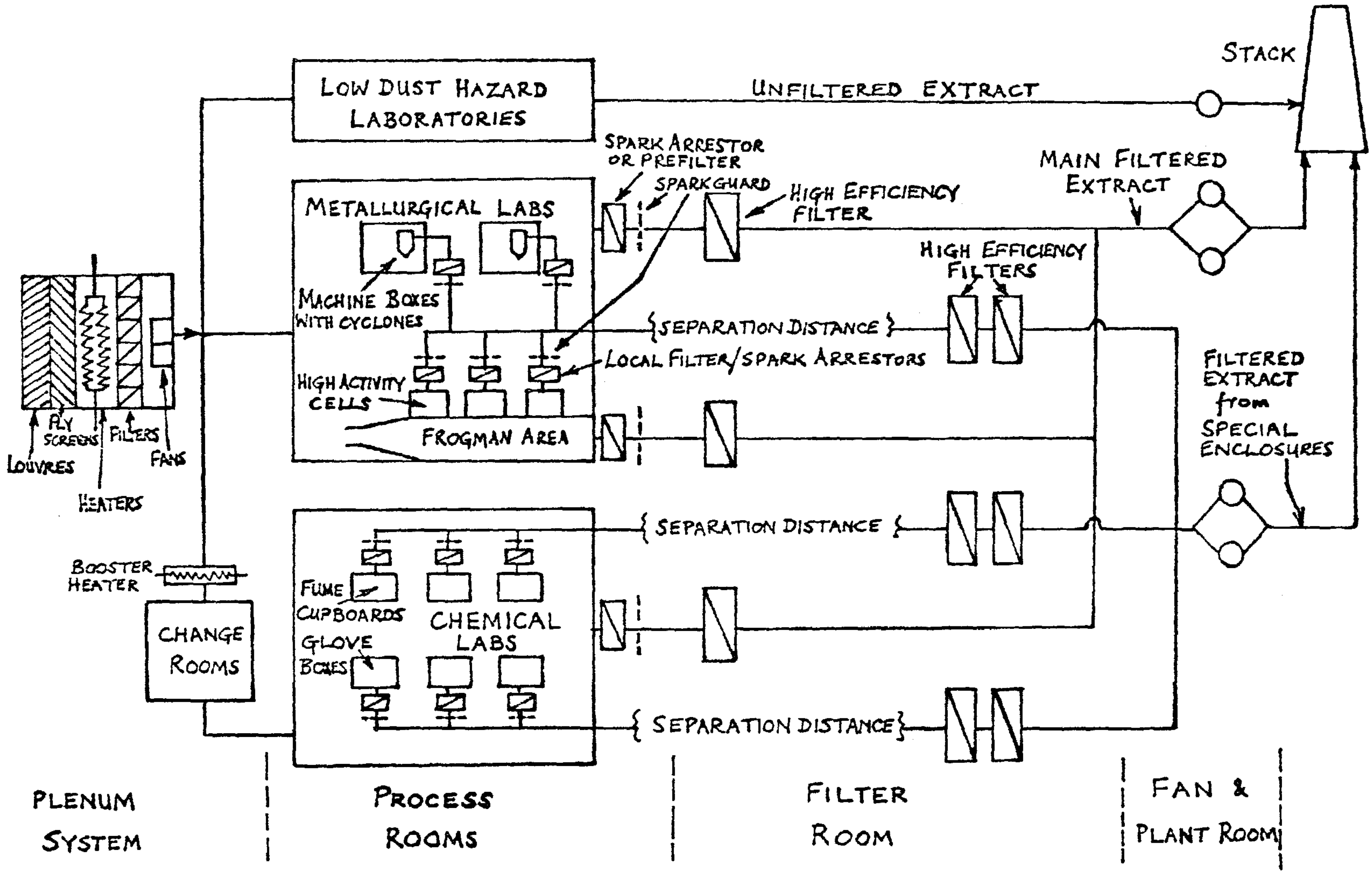


FIG. 6 : PROCESS BUILDING FILTERED VENTILATION SYSTEM

12.7 Where combustible dusts are involved, as in machining box extracts, a local dust removal system terminating in a filter should be employed, to keep the duct work and main extract system free from combustible matter.

Such a system is vulnerable to fire hazards and would itself add to the fire if material in it ignited, the main filters should therefore be protected

(a) by location where they cannot receive direct heat radiation from the local filters

(b) by installation of a spark arrestor between the local and main filters

(c) by providing either for a mixture of cool air from other sources, or for a sufficient length of duct, to cool the gases below 450°C in the worst credible conditions.

12.8 Where inflammable gases or liquids are handled in an extracted enclosure, the danger of damage to the main extract and filter system should be guarded against by ensuring that the air flow is sufficient to maintain the concentration of inflammable vapour below the lower explosive limit under all operating conditions. Provisions 12.7 (b) and (c) should also be followed.

12.9 Temperature sensitive elements should be fitted to main filters to give warning of high temperatures as an additional safeguard.

12.10 No special provision need be made for local isolation dampers to cut off parts of the system in an emergency.

A diagrammatic layout sketch of the type of extract system recommended is given in Fig. 6.

13. ACKNOWLEDGMENTS

The assistance of Mr. J. Dyment and Mr. A. F. George of the Chemical Engineering Branch and members of the Metallurgy, Safety and Maintenance Engineering Divisions in providing advice and information, is gratefully acknowledged. This paper is published by permission of the UKAEA.

14. REFERENCES

1) Dyment J., SSCTD Tech. Memo. 3/59 AWRE 1959.
2) White P. A. and Smith S. E., Paper to Board of Management, AWRE 1960.
3) AWRE Safety Instruction No. 2/60.
4) AWRE Safety Instruction No. 1/61.
5) AWRE Materials Department Safety Notice No. 1/62.
6) Addison R. A. et al. - Fire Detection in Ducts & Filters, AWRE March 1962.
7) Wilson E. et al., Report of Working Party on Fire-Fighting in Boxes, AWRE, 1961.
8) Smith S. E. et al. Report of Working Party on Extract Ventilation Safety, Part A - High Pressure Extract System, AWRE 1961.

10) Poll A., D.S.I.R. Report No. RR/CE/28, March 1962.
11) Addison R. A. et al. - Fire Detection in Room Spaces, AWRE Feb.1962.

DISCUSSION AND COMMENT

While you speak of a fire-resistant filter, we tend to use the term non-combustible in the sense that this construction would not contribute any heat itself. The construction was one which we arrived at in cooperation with the manufacturers. We did not accept the readily available units, and these underwent certain modifications to make them satisfactory to us. Essentially, the filter consists of a glossed paper filter medium, an all-steel case, not an impregnated, wooden case, and a suitable cement. I say that guardedly. There are alternative ways of achieving the cementing of the filter. There are at least two acceptable possibilities.

Session Chairman: Mr. Smith that was a most interesting paper and we are fortunate to have had the opportunity to hear your presentation.

The third paper in this Session is by A. B. Fuller of Oak Ridge National Laboratory and the title is, "Design Considerations for Exhaust Systems Involving Radioactive Particulates."

DESIGN CONSIDERATIONS FOR EXHAUST SYSTEMS INVOLVING RADIOACTIVE PARTICULATES

A. B. Fuller
Oak Ridge National Laboratory

ABSTRACT

The dependability required of exhaust ventilation systems handling radioactive particulates makes it essential that: (1) thorough investigations concerning needs be made, and (2) good engineering practices be applied. Many features peculiar to such systems are not clearly understood by inexperienced designers. A number of these "designer shortcomings" are discussed, with references listed, to enable designers to brief themselves prior to planning, reviewing, and designing such exhaust systems.

Just ten years ago the subject of air handling and air cleaning was a far step back of where we think it is today. Knowledge and know-how of twenty years ago concerning air handling and cleaning would now be termed primitive. Before World War II, few college-level courses were offered beyond elementary tutoring in heating, ventilation, and air conditioning. Many basic fundamentals were not stressed.

Things have changed--along came the nuclear age--the space age. Now everyone is, or should be to some degree, concerned about the air he breathes and how clean it is. Air is one of the few necessities of life that is plentiful and still free. This resource has been abused by mankind and still is being abused. We must learn better how to preserve and care for it. That knowledge should then be applied whenever the opportunity can be created. This is one reason we are here this week.

The engineer is the "doer" who is expected to apply his skills to design new air handling systems. These systems, then, will never be any better than the engineering knowledge he is capable of designing into them. Is your engineering designer sufficient for the job? Maybe he is the best man available, but is he experienced in this field? Do his designs accomplish their objectives? As in any field, there is no substitute for <u>good</u> experience.

The design of an exhaust system handling radioactive particulates demands good engineering judgment and experience to achieve safe, acceptable performance and needed dependability. It is necessary for an exhaust system to function as planned to ensure the proper operation of its air cleaning components. Good engineering judgment can only result from good factual conditions: complete and concise criteria, a clear understanding of design objectives, and the freedom to act.

We who are representatives of AEC contractors often find ourselves in the roll of preparing criteria and reviewing the design work of others. By our standards, we at the Oak Ridge National Laboratory have found most air handling designers employed by Architect-Engineer firms incapable of doing this type of job well. They lack know-how for this particular type of design assignment. Review effort therefore has been heavy; resubmission of review materials is frequently required, and confusion results. Much time is lost. It is also necessary that our own designers be sufficient for this job of reviewing, as well as doing direct design assignments. Experience is needed in all phases of design, construction, and operation; good experience, not just an exposure. This experience is difficult to find and, therefore, the price is high.

The design of exhaust systems involving radioactive particulates is a rather narrow field. Certain aspects are peculiar to this type system. This specific knowledge does not exist in one book. What little that is written is scattered, difficult to correlate, and very time-consuming to search out and evaluate. Therefore, it is difficult, near impossible, to know all the "best methods" of solving every problem that will arise.

The type and complexity of exhaust systems varies widely. I would like to point out some of the problem areas that we find need particular attention:

1. Many designers are short on the evaluation of maintenance needs and how to keep maintenance costs reasonable. This is very clearly reflected in their choice of equipment, space allowances, and access to items requiring routine attention.

2. Design calculations are poorly prepared, if prepared at all, for the final arrangement of the system. Operating and maintenance limitations are not given the users of the systems.

3. Designers are forever designing system components to meet the maximum demands and leave the lesser conditions to chance. These "less-than-maximum" conditions represent as much as 99 per cent of the operating time. Therefore, they too must be analyzed and designed for good operability.

4. The selection of fans and their application are areas often slighted, especially when space is limited. The needed compensation for a poor arrangement of ducting is frequently neglected, sometimes at a flow dedeficiency equal to 20 per cent of tabled ratings for fan performance.

5. Designers are found to be weak in the proper application of instrumentation and controls. The area of pressure control and monitoring is difficult to keep within practical limits of cost and good operability.

6. Filter selection and their proper application for the particular use is the pinnacle of the designers' problems. High efficiency filter applications are new to the inexperienced man; and having radioactive particulates further complicates the picture. It is here that designers need the greatest assistance and guidance. Too, it is here that much developmental work must yet be done to ensure installations of good dependability and reasonable maintenance.

These six categories seem to cover all the aspects in designing an exhaust system. Though this is near the truth, a particular designer is not necessarily weak on all counts. Having the services of competent designers is all important in getting the job done well.

I have compiled comments concerning design considerations for various aspects of this subject. These are attached.

These remarks do not cover all phases of design but attempt to offer guidance on the controversial items and those often causing trouble.

CODES GOVERNING DESIGNS (USAEC INSTALLATIONS)

All design effort for USAEC installations is governed by the AEC Design Manual, with its local interpretations. AEC instructions in this manual include compliance with local codes as well as certain other nationally recognized codes that are in the interest of constructing safe facilities and in providing for their safe operation.

Design References

See Ref. 11 and 13. State and local codes for the location under consideration.

Design Considerations

1. A designer must make himself thoroughly familiar with the AEC Design Manual, and applicable codes, during early planning of any work.

2. Radiation safety features and control do not always remain compatible with the usual interpretation of NFPA Fire Codes. Therefore, early establishment of the governing consideration must be ascertained from the jurisdictional authority. To this end the designer must arrange systems to maximize compliance with both considerations.

3. A basic guide to all ventilation work can be had in the ASHRAE Guide and Data Book. From this publication, and its referenced information, a designer can secure much of the written materials concerning exhaust systems.

ARRANGEMENT OF SYSTEM COMPONENTS

Planning the arrangement of components can provide advantages that are paramount to the success of a system. The order, or sequence, of components may vary for different types of exhaust systems. Therefore, considerations of features such as shielding, containment of contaminants, and access must be studied and evaluated.

Design References

See Ref. 1, 3, and 5.

Design Considerations

1. It is desirable to have all ductwork and other components under a negative pressure during all operations of a system(s). This means the fan power is situated near the terminus of the system; i.e., before release to the atmosphere or stack.

2. TID 7023 (Ref. 3) suggests the physical separation of roughing filters from high efficiency filters to minimize the spread of fire. See "Filtration" for other considerations.

3. Ductwork under negative pressure is subject to collapse. The arrangement of components must be considered for their pressure loading. The nearer the filter component(s) can be situated to the fan, the less heavy ductwork is required. Filter resistances most frequently constitute a major portion of total systems flow resistance.

4. The exposure to weather of system ductwork, housings, etc., can create problems of condensation. Such surfaces should be minimized to lessen the expense of items such as insulation, weather painting, and internal drainage apparatus. Where drainage can be tolerated and handled, condensation need not be a serious problem and can be the cheapest approach.

5. Convenience of access must be carefully studied and arranged. Shielding, if required, must be given preferential treatment to minimize cost and maximize operational convenience. Maintenance provisions must be planned; good conditions do not happen by accident.

6. Systems that will include alpha particle contamination must consider needed containment of components to allow maintenance by an acceptable method. Cleanup provisions are needed to prevent the spread of loosed contamination. Features required of this type system must be designed to prevent the release of intolerable amounts of radioactivity, not just to allow for the cleanup of materials that may be released. Penetration of the system at points where negative pressure conditions will be encountered is a prime consideration. Penetrations downstream of filtration, where feasible for the particular need, is another preference.

7. The atmosphere is not a dump for radioactive particulates. Maximum allowable concentrations and rates of release are closely regulated by the USAEC. Advice from the AEC must be obtained.

FILTRATION

Where chemically neutral exhaust gases are to be handled, particulate filtration is best achieved by a method that does not entail secondary wastes such as washing solutions, water, or oil additives. Dry type filter units serve this requirement better than other type devices. Where particulate loading in the air stream is low (i.e., <0.05 grains per 1000 cubic feet), high efficiency filter life can be expected to last well beyond twelve months' continuous usage. Prefilters are desirable for long filter life when a significant part of particulates is over one micron. Where atmospheric air is being handled (not previously filtered on intake systems), prefiltering is mandatory.

Exhaust streams containing chemically active ingredients present a formidable hazard to filtration equipment, both framing and medium. It is essential that investigations predetermine all the constituents to be encountered by the filtering devices. Systems arranged to serve multiple sources of effluent, from perhaps unrelated operations, present an even more difficult filtration problem to solve. Costs soar as a result of attempting to meet complex criteria of incompatible effluents. It is advisable to provide separate filtration facilities for each basic need and, if necessary, combine effluents downstream from filtering points in the system. This permits filtration to be best suited to the particular needs of each exhaust source.

The delicate construction of most filters, especially high efficiency of the absolute type, requires that precautions be taken in their application and use that guarantees the integrity of the installation throughout the filter life.

Special consideration must be given to ensure dependability commensurate with the hazards involved. Particulate filtration facilities in radioactive exhaust streams must serve as defense against release of air-borne activity, both to downstream portions of the system as well as against the release to the atmosphere.

Design References

See Ref. 1, 3, 4, 9, and 12.

Design Considerations

1. Investigate the nature of the intended effluent very carefully to allow a proper selection of medium and dust-holding capacity for each component.

2. Physically separate prefilters from final filters where combustibles are involved. Consider whether or not the system flow can be stopped in case of fire within, or near, the filter section. Does a radiological air-borne release have a greater potential of hazard than a contained filter fire? If yes, the fans should be stopped upon the detection of a fire and the fire contained insofar as possible. If the fans are stopped, what effect does this deficiency have upon the area that was being exhausted?

3. What safeguards are to be considered for fire prevention and control? Use of: (1) equipment that is noncombustible wherever possible, (2) separation of combustibles, (3) a fire extinguishment system consistent with size and application of combustibles, (4) smoke and/or heat detection equipment for early warning and preaction, flow diversion, and isolation--all are measures worthy of consideration by the designer. The potential hazard involved in having a fire and the results from a fire must be the paramount concern upon which a decision is reached and costs are justified.

4. During initial investigation, determine the method of handling and replacement that must be applied to filters and removable framing. If direct contact is to be allowed, the designer must stay within physical limits of an individual to carry and maneuver filter and frame units during changes. Filter bank heights over 6 feet should be avoided unless access is included as part of the designed facility. Steps must be minimized. Weights over 50 pounds become very tiring when lifting is involved. If the use of protective clothing, respirator (or mask), etc., is to be necessary, areas of abnormal heat, lifting, and handling weighty objects can become very acute to the problem of filter change or replacement. Where radiation fields and/or high contamination levels preclude direct contact for maintenance, many additional considerations must be made. The requirements for containing highly contaminated components will involve the need for good closures and sealing. Preplanning must establish an acceptable handling procedure to afford the designer criteria with which to work. Filter handling and replacement facilities must afford the worker and the surrounding area ample protection against excessive radiation exposure and the accidental spread of radioactive contamination. Positive means for effective cleanup must be evaluated.

5. Provide for drainage from each compartment of a filter section. The method of decontaminating inside surfaces could involve washdown using water or other agents needing drainage of appreciable amounts of liquids. If surfaces are exposed to outside winter temperatures, condensation may occur. Any entrapment of moisture droplets that loads a high efficiency filter will cause an air flow blockage that can result in sudden failure of the filter bank. A fire protection scheme involving liquid sprinklers

must be limited to a system that has air flow stopped in the event the sprinklers are applied.

6. In the absence of exact data concerning the gradation of particulates by size and weight to be expected in exhaust streams, the following is suggested for initial design:

   Prefilter (up to 35 per cent NBS efficiency, or equivalent): Provide for pressure drops, at normal flow, that are at least three times the initial resistance (clean), or 0.5" wg, whichever is the greater value.

   High Efficiency (from 35 to 95 per cent NBS): Provide for pressure drops, at normal flow, that are at least three times the initial resistance (clean). Never exceed the manufacturer's recommended limit for pressure drop, or as framing strength may limit the loading, at any flow rate that will be produced.

   High Efficiency--Absolute Type (99.95 per cent, or better, per DOP testing): Provide for pressure drops, at normal flow, that are at least three times the initial resistance (clean), except where preceded by a filter bank of equal efficiency. In such event, a resistance allowance of 1.25 times the initial resistance for the second stage of filters will afford reasonable life, insofar as particulate pickup is concerned. Maximum resistance for high efficiency units of the corrugated separator type unit should seldom exceed 4" wg, except where the application approaches the "ideal conditions" of dryness, chemical neutrality, filter position, temperature, and smoothness of air flow. From a practical viewpoint, such an ideal situation will never exist. Where resistances exceed 3" wg, particular care must be taken concerning the conditions under all phases of operation, more from the consideration of filter deterioration than from dirt pickup. It should be remembered the 24" x 24" x 5 7/8" and 24" x 30" x 11 1/2" size units are weaker construction than are other standard size units such as the 24" x 24" x 11 1/2"; therefore, their application can become more critical in achieving satisfactory performance. Gaskets will present problems where loading is applied to extremes and filter life is maximized.

7. Sealing faces for filter gaskets must be prepared initially as flat, smooth surfaces that are accessible for cleaning and inspection. It is essential that crack leakage be eliminated at the sealing face; this is done best by welding all joints with continuous seal welds. After welding the sealing face must be ground smooth, flat, and free from weld spatter. Then the surface must be prepared with a coating to preserve its smoothness. Tolerances not to exceed ±1/16" from a true, flat plane should be required of seal faces prepared for high efficiency absolute type 24" x 24" size filter units. Smoothness of surfaces before coating should be comparable to 250 P (microfinish) or better at all contact faces. While calking can be termed acceptable for prefilter frame sealing, it is unacceptable for high efficiency absolute type filter banks. Welded joints (ground at seal faces) are best and are reasonable in cost.

8. Provisions for in situ testing should be made for all high efficiency filter installations of the absolute type. If DOP smoke penetration tests are applied for routine system quality assurance, it is necessary that appropriate openings be provided to introduce DOP smoke ahead of the filters, sample upstream, and sample downstream. ORNL-3442 gives the requirements for such testing, along with other test experiences.

9. Filter unit hold-down must provide uniform gasket pressures. Individual filter unit mounting is preferred where contact maintenance is to be applied, with liberal spacing to provide easy handling. Hold-down attachments must be kept simple to operate and require a minimum of time to perform. Small pieces requiring positioning or alignment are to be avoided. Filter unit framing should be provided aligning guides and weight rests that minimize the chance of poor positioning. The hold-down pressure to compress gaskets must be spread sufficiently to prevent damage to the filter framing that may later release pressure by fatigue or breakage. Initial gasket pressures will vary by the type of material used. Approximate value for 5-10 durometer neoprene sponge (1/4 inch thick) would be 2 psi for 50 per cent depression (i.e., to 1/8-inch thickness). Clamping and framing strength must account for a safety factor of at least 4. No deflection of framing can be tolerated that would shift or shear gaskets or filter frames.

10. Good lighting is an absolute must for contact maintenance filter change areas. It is essential that operators be able to clearly see how to position filters, align clamping, and inspect framing and medium.

11. When conditions of maintenance will allow physical contact, filters should be considered for upstream mounting, thus taking full advantage of increased gasket sealing as filter resistance increases. This means gaskets are to be limited to the downstream edges of filter unit framing. Should contamination levels prevent direct contact with the filter units and framing, other mounting schemes are necessary. Mounting filters on downstream faces of seal framing will mean gasket pressures are lessened as filter resistance increases. Also, as gaskets loosen, their "blow out" is more likely to occur. Therefore, in applications involving heavy filter resistance, such as high efficiency absolute types, greater dependability and longer life expectancy can be achieved with filters arranged upstream of the seal framing.

12. High efficiency filters of the absolute type must be mounted in a particular way to maximize strength and life. A strong preference is given for their having framing in a vertical plane (or near so) with the air flowing horizontally. Filter pleating must be vertical. Filter mounting should install the marked test flow arrow correctly to match the system's flow. Filter installations of this absolute type which have vertical air flows increase the chance of bulging and breaking the medium.

13. Provide pressure drop indicators across filter banks, individually. Provide means to correlate this pressure drop data with the flow rate through the bank. Good evaluations of filter dirtiness can only be made by having pressure drop and corresponding flow rates.

FAN SELECTION

The heart of the system is the fan, or fans, that provide for the movement of air. Good operation is dependent chiefly on the fan and its installation matching the flow characteristics of the system. A fan that is oversized can be as critical to good system performance as one that is undersized. Designers must respect the importance of a proper selection to suit both normal and maximum system demands. Fan selection must be finalized after all other features of the system are designed and are carefully analyzed to anticipate system characteristics.

Design References

See Ref. 1, 2, 7, and 10.

Design Considerations

1. Make a final selection of a fan only after the system is designed and its characteristics are calculated and analyzed. If a system is being designed or modified to suit an existing fan unit, be certain its performance is known. Use certified data from the manufacturer.

2. Remember--seldom, if ever, is a fan applied to a system in a manner equal to AMCA test conditions. Therefore, the fan performance to be expected in a system application is different from the catalog data given by a manufacturer. The variation must be compensated for in the selection of the fan and its drive. Conditions in a practical application are always more adverse to good performance than those for AMCA test conditions. Factors such as temperature variations, inlet configuration, inlet approach, discharge configuration, voltage variations, and belt slippage are to be considered.

3. Select fans having non-overloading characteristics for systems having major variations in static pressure due to filters, automatic, or manual adjustments. Fan performance must be stable during any condition of the system, meaning the selection of the operating point must always be well beyond the peak of static pressure for the speed being used. For an application of a fan with a backwardly inclined wheel, flow will increase as static resistance of the system decreases in a predictable manner, and vice versa. Where operating points are selected too near the peak of maximum static pressure, operation is unstable; a slight variation in system characteristics can easily upset the flow level.

4. Dependability of system flow must be considered in fan selection. The arrangement of a fan unit is a prime part in providing dependability. A unit having a direct drive is more dependable than a V-belt-driven unit. Arrangements 4 and 8 can be termed more dependable, but less versatile, in an application than arrangements 1, 2, and 9.

DAMPERS

To regulate and control flow and pressure in an exhaust system, a means of varying the system's characteristics is required. Dampers can offer this type of performance. They function as orifices, having variable restriction, that produce pressure drop, thus regulating flow. Many types exist having various identifications, such as: multi-blade, parallel blade, opposed blade, butterfly, single blade, etc. Some names are synonymous with others; no standardized identification is complete for all the types in use.

Design References

See Ref. 1.

Design Considerations

1. The most common fault with damper applications is in oversizing them. This means added costs and less effectiveness as an adjustment to system characteristics. To be a control, a damper must provide resistance to the flowing stream.

2. A damper may be applied only for shutoff uses, thereby limiting its control to two positions only, open and shut.

3. Damper construction for exhaust systems must provide for: (1) needed strength to suit maximum suction or pressure conditions to be experienced; (2) minimum leakage, both through the blade cracks and from the outside; (3) reliability and ease of movement; and (4) desired characteristics.

4. Metal bladed dampers of multi-blade construction are preferred to be metal-to-metal, free of edge gaskets, when access is limited. Maintenance costs for edge gaskets can be intolerable in corrosive and contaminated locations.

5. Clear, concise information must be established in the specification of dampers concerning strength, leakage, and operability during operation. Static water tests are suggested to prove strength. A stipulation of maximum crack area (by percentage of the net free area) is necessary to establish leakage parameters. Operability must be controlled by stating torque limits for required operating conditions. All dampers do not require a complete listing of all these features. However, when a feature is critical to the needs of the system's operation and safety, such features must be formulated into detailed requirements.

6. Where damper operation is planned, as two-position action, employ spring power to make the device fail in the safer position of operation.

7. Be certain there is a position indicator on all dampers where blades are obstructed from view.

8. Supply all dampers with setting and locking quadrants. Provide means for marking damper positions after the balancing of system flows and pressures.

9. Dampers for heavy vacuum or pressure service (-8" wg to -60" wg, and +8" wg to +60" wg), having low leakage features, are difficult to obtain as standard items of manufacture. Construction more common for these levels of pressures is the butterfly type. This type can be found for pressure limits of 5 psi, or above, but not readily available for the 2-psi limit. Therefore, many applications will, of necessity, include values having heavy weight and pressure capabilities far beyond the other features, such as the ductwork that connects to the damper.

DUCTWORK CONSTRUCTION

Ductwork is the controlled route for the air or gases for the exhaust system. Large systems can involve ductwork of complex design, whereas small systems may be arranged to employ standard metal or plastic pipe or tubing. Choice of construction is complex. The need for good aerodynamic qualities should always be a paramount consideration to the designer. The most economical arrangement of ductwork does not consistently stay the same; it will be influenced by items such as: size, quantities, tolerances for fit, basic materials, coatings, method of jointing, sequence or space limitations for installation, field connection requirements. There is no substitute for test experience in evaluating life versus costs.

Design References

See Ref. 1, 2, and 8.

Design Considerations

1. Wherever space will allow use round ductwork on exhaust systems. The round shape provides many advantages over rectangular shapes: (1) the round shape is the most economical use of metal, by weight; (2) the round duct is stronger as a section, retaining its shape when under more abnormal pressure conditions than will rectangular shapes; (3) velocities can be kept more uniform in round ducts without requiring internal vanes or other aids; (4) internal drainage is less of a problem to control in round ducts; and (5) supports can remain more simple with round ductwork. The one principal disadvantage of round ductwork is it makes less efficient use of critical space than do rectangular shapes. However, the more round ductwork used instead of rectangular shapes, the less will be over-all weight of metal and the lesser wetted areas subject to needed coatings, insulations, or expensive construction.

2. For air-tight construction in metal ductwork an appropriate method of welding is preferred for all longitudinal and girth seaming between disconnect points. Flanged joints, gasketed and bolted, are best at disconnects. A minimum number of joints should be applied consistent with the needs of erection, coating, inspection, etc.

3. Coating requirements, as well as other surface preparations, must respect the size of pieces being applied in the system. Example: Interior surfaces on small duct sizes are difficult to prepare and coat. The spray coating of sizes less than 12" diameter is not reasonable. These should be hand brushed, with lengths limited to four (4) feet to say within arms reach from either end. Sizes 8" and less are not practical for even hand brushing. Dipping may be considered for small sizes (less than 8").

4. Where fire protection and radiation safety regulations permit, plastic ductwork may be applied at substantial savings in low pressure systems. As suction (or pressure) increases in the system of ductwork, thereby increasing the loading on the surfaces, full plastic materials become less attractive to needs. For systems having medium and high pressure conditions (approximately 4" wg or higher) dipped or coated metal ductwork is more appropriate. Plastic materials, such as polyvinyl chloride (PVC) and polyethylene (PE) cannot resist heat beyond 150°F without some adverse effects. A system having a serious potential of hazard should be given very close evaluation before applying ductwork sections that are all plastic.

5. Any ductwork system intended to handle radioactive materials deserves a pressure-leak testing, before initial service, to prove its capability for the intended use(s).

6. The recommended ductwork construction listed in the ASHRAE Guide and Data Book does not list a test pressure for each style of sizing. The ASHRAE recommendations are applicable, more directly, to uses having internal positive pressure conditions. Extreme care should be given to their use as suction systems. For suction applications, their capabilities are not the same. The type of joint and choice of reinforcement method greatly affect the suction strength of sections. Further care must be exercised in specifying the test pressure for such types of constructions.

   The following types of construction have been used successfully over extended periods (years):

Exposed Round Ductwork Systems Operating Up to 8" wg Suction
12" wg Test Pressure

Size	Material	Joints	Reinforcing
6" thru 12" dia	16 ga carbon steel, metal arc welded; interior coated (or dipped) exterior painted enamel.	Flanges of 1/4" plate up 8 or 1 1/2" x 1 1/2" x 3/16" angles on 10" and 12" dia; gasketed and bolted (5" o.c., max) 4' lengths	None, except for girth rings of angle at support points.
Above 12" thru 36" dia.	14 ga carbon steel, metal arc welded; interior-exterior painted enamel.	Flanges of 1 1/2" x 1 1/2" x 3/16" rolled angle, gasketed and bolted (5" o.c., max) 4' and 8' lengths, depending upon coating needs.	1 1/2" x 1 1/2" x 3/16" angle girth rings (welded) at midpoint between flanges of 8' lengths.

SYSTEM INSTRUMENTATION

Instrumentation for exhaust systems can be selected to: (1) monitor system conditions, (2) provide for the automation of certain system functions, or (3) the combination of these two features. Reliability is borne out of simplicity.

Design References

See Ref. 1.

Design Considerations

1. Simplicity of controls and instrumentation is always to be desired over arrangements involving greater numbers of items and more interdependability of control action. Never choose two when one will do.

2. To determine conditions of system performance, both flow rate(s) and pressure must be obtained.

3. For systems that must provide for standby fan startup, never rely on monitoring motor current failure alone to initiate automatic action. Basically, flow or pressure, whichever is deemed more critical, must be sensed with an abnormal status being detected to cause standby startup or changeover of fan units.

4. In choosing whether to allow dual exhaust fan operation or single fan (standby) operation, the analysis of dual fan effect on the system must be made. Excessive flows or pressures must be tolerable and not jeopardize the integrity of filters, ductwork, or other components.

5. Manual adjustments of system pressures and flows are to be preferred in applications where changes are minor and/or infrequent. Manual adjustment of devices such as valves and fan speeds provides a high degree of simplicity and reliability where fast response time is not a factor. For situations needing a fast response to an abnormal situation, such as an electrical power failure, automated correction is mandatory.

6. Controls must be selected to fail to the safer condition of operation.

PERFORMANCE TESTING

Testing the performance of a system is as basic as designing the system. It proves, or disproves, the system will accomplish the design objectives originally established as criteria. Only through testing can this convincing knowledge be gained.

Design References

See Ref. 1 and 6.

Design Considerations

1. Testing is essential to gain the required knowledge for good system operation. Actual system capabilities must be demonstrated by testing. Carefully record all test data acquired in a form clearly legible for anyone to decipher.

2. Standard methods of flow measurement must be used. Multi-point traverses should be prepared in a systematic manner to allow repetition.

3. Test points and traverse stations must be preplanned and have access provisions made to afford maximum use.

4. Refer to ASHRAE Guide and Data Book, 1963, Chapter 16, "Measurements and Instruments," for the accuracies of different types of measuring instruments.

REFERENCES

1. ASHRAE Guide and Data Book, 1963, Fundamentals and Equipment, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 345 East 47th Street, New York , New York.

2. Fan Engineering, Sixth Edition, Buffalo Forge Company, Buffalo, New York.

3. Gilbert, Humphrey, Palmer, James H., High Efficiency Particulate Air Filter Units, TID-7023, USAEC, Washington 25, D. C.

4. Govan, Francis A., Selection and Maintenance of Air Filters, Report No. 34, for the Federal Construction Council by Task Group T-28, Building Research Advisory Board, Washington, D. C.

5. American Standard Fundamentals Governing The Design and Operation of Local Exhaust Systems, ASA Z9.2-1960, American Standards Association, Inc., 10 East 40th Street, New York 16, New York.

6. Industrial Ventilation, A Manual of Recommended Practice, Seventh Edition, American Conference of Governmental Industrial Hygienists.

7. Trickler, C. J., Is the System Correctly Designed?, Air Conditioning, Heating and Ventilating, May, 1960.

8. Brown, Robert A., What You Should Know When Designing Plastic Ventilation Systems, Heating, Piping and Air Conditioning, September, 1962.

9. Building Materials List, Underwriters' Laboratories, Inc., 207 East Ohio Street, Chicago 11, Illinois.

10. Standard Test Code for Air Moving Devices, Publication 210, Air Moving and Conditioning Association, Inc., 2159 Guardian Building, Detroit 26, Michigan.

11. AEC Manual (Design Criteria), Chapter 6306, "Heating, Ventilating and Air Conditioning," USAEC.

12. Parrish, E. C., Schneider, R. W., Tests of High-Efficiency Filters and Filter Installations at ORNL, ORNL-3442.

13. The National Fire Codes, National Fire Protection Association, Vol. III, Building Construction and Equipment, and Vol. IV, Fixed Extinguishing Equipment.

Session Chairman: Gentlemen, the last prepared text in Session II is a joint effort by ORNL personnel. The paper, "Containment and Ventilation Systems in the Transuranium Processing Plant," by W. D. Burch, B. F. Butterfield, W. E. Unger, O. O. Yarbro, and J. P. Nichols. W. D. Burch will deliver the paper.

CONTAINMENT AND VENTILATION SYSTEMS IN THE TRANSURANIUM PROCESSING PLANT

B. F. Bottenfield
W. D. Burch
J. P. Nichols
O. O. Yarbro
W. E. Unger

ABSTRACT

The unique features of the ventilation and containment systems incorporated into the Transuranium Processing Plant, which is under construction at the Oak Ridge National Laboratory, are described. This facility is designed to recover from irradiated target rods by solvent extraction and ion exchange techniques gram quantities of many of the heavy actinide elements for research in many laboratories throughout the country. Containment of process solutions is insured by surrounding the equipment with multiple negative-pressure systems, including final containment by maintaining the entire building at a - 0.3 in. pressure. The effects of operational and accidental activity releases from the facility are discussed.

The Transuranium Processing Plant (TRU) is a new facility currently under construction at Oak Ridge National Laboratory designed to recover for research purposes gram quantities of many of the very heavy actinide elements including americium, curium, berkelium, and californium. Target rods, containing initially Pu-242, will be irradiated in the High Flux Isotope Reactor (HFIR), then dissolved and the products recovered in TRU, and the lighter isotopes refabricated into recycle rods for further irradiation. The containment problems for TRU are in many respects completely unique. Shielding requirements were dictated by neutrons from the spontaneous fissioning of Cf-252 and Cf-254, but very high levels of gamma emitting fission products are also routinely handled. Containment criteria are very stringent because of the extremely high level of alpha emitters. For instance, the facility will contain up to 300 gm of Cm-244. In comparison with alpha decay from plutonium, this is equivalent to 430 kg of Pu-239. The problem is extremely acute because of the very high specific activity; the sources are extremely concentrated. One gram of Cf-252 contains 645 alpha curies, emits 3×10^{12} neutrons/sec from spontaneous fission and represents 4×10^{10} body burdens of activity.

In addition to the normal methods of containment, three additional features have been incorporated into the building to insure positive containment. First, the major equipment has been installed within secondary enclosures within the hot cell bank. These enclosures, termed cubicles, are maintained 0.3 in. of H_2O pressure below the cell proper. Secondly, the master slave manipulators, provided to operate the equipment within the cubicles, will be double booted and a pressure monitoring system will be incorporated into the space between the boots to insure against leakage from this vulnerable source. Finally, as a more positive means of insuring against total loss of containment from the facility, the entire building will be maintained at - 0.3 in. H_2O with respect to atmospheric pressure.

BUILDING DESCRIPTION

The building is a two-story structure, approximately 120 feet square (Fig. 1) roughly divided into two equal parts, the first containing the cell bank, limited access area and cell operating areas, and the other containing eight laboratories, building service and office areas. The cell bank contains nine cells, seven for process use and two for analytical purposes. Each cell is divided internally by a two-foot shielding wall (Fig. 2). In the operating side is the cubicle containing the equipment racks. In the rear is the tank pit area where process storage tanks, evaporators, and waste tanks are located. Equipment is removed from and installed in the cubicles by another special containment device, the equipment transfer case, shown on top of the cubicle in Fig. 2. The door in the cubicle ceiling is sealed and locked to the transfer case door while both doors are raised into the transfer case. After the equipment has been lowered into the cubicle by means of a hoist within the case, the doors are lowered into their normal positions, unlocked, and the transfer case removed. For handling contaminated equipment, a one-foot thick concrete shield is provided; and the transfer case can be operated through the shield. Similar double-door, mechanically-sealed closures are provided on the conveyor access openings in each cubicle (see Fig. 1) to limit the spread of contamination from one cubicle to the others and to the transfer area at the end of the cell bank. To date, the mechanical operations of both these seal systems have been adequately tested, but actual demonstrations with contaminated equipment and cells have not been performed.

The second floor (Fig. 3) contains the remainder of the laboratories, a chemical make-up area for servicing the cell bank, and the recirculating cooling water equipment.

VENTILATION SYSTEMS

Four primary zones of containment, defined by the degree of activity contained, are included in the cell bank ventilation system (see Fig. 4). The process equipment is vented to a caustic scrubber system maintained at - 10 in. of H_2O while the cubicles are held at - 1.7 in. by a control valve. The cell pressure is controlled at - 1.4 in. of H_2O and the building surrounding the cell at - 0.3 in.

Cubicle Ventilation System: Both the vessel off gas and cubicle vent systems exhaust through the same scrubber, filter, and blower system. Air flow requirements here are approximately 20 CFM for the vessel off gas and 500 CFM for the cubicle purge. Cooling of each cubicle is achieved by separate

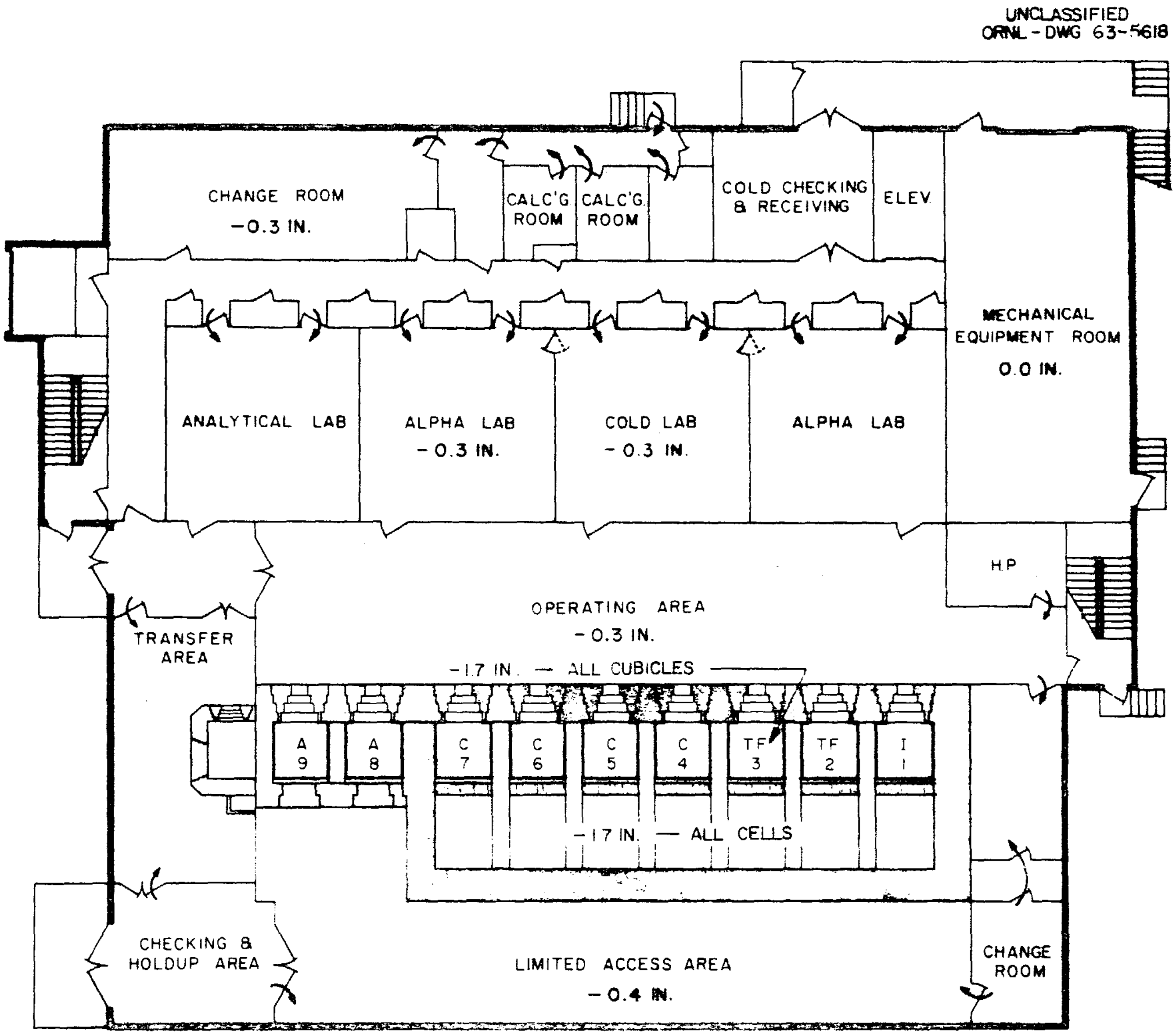
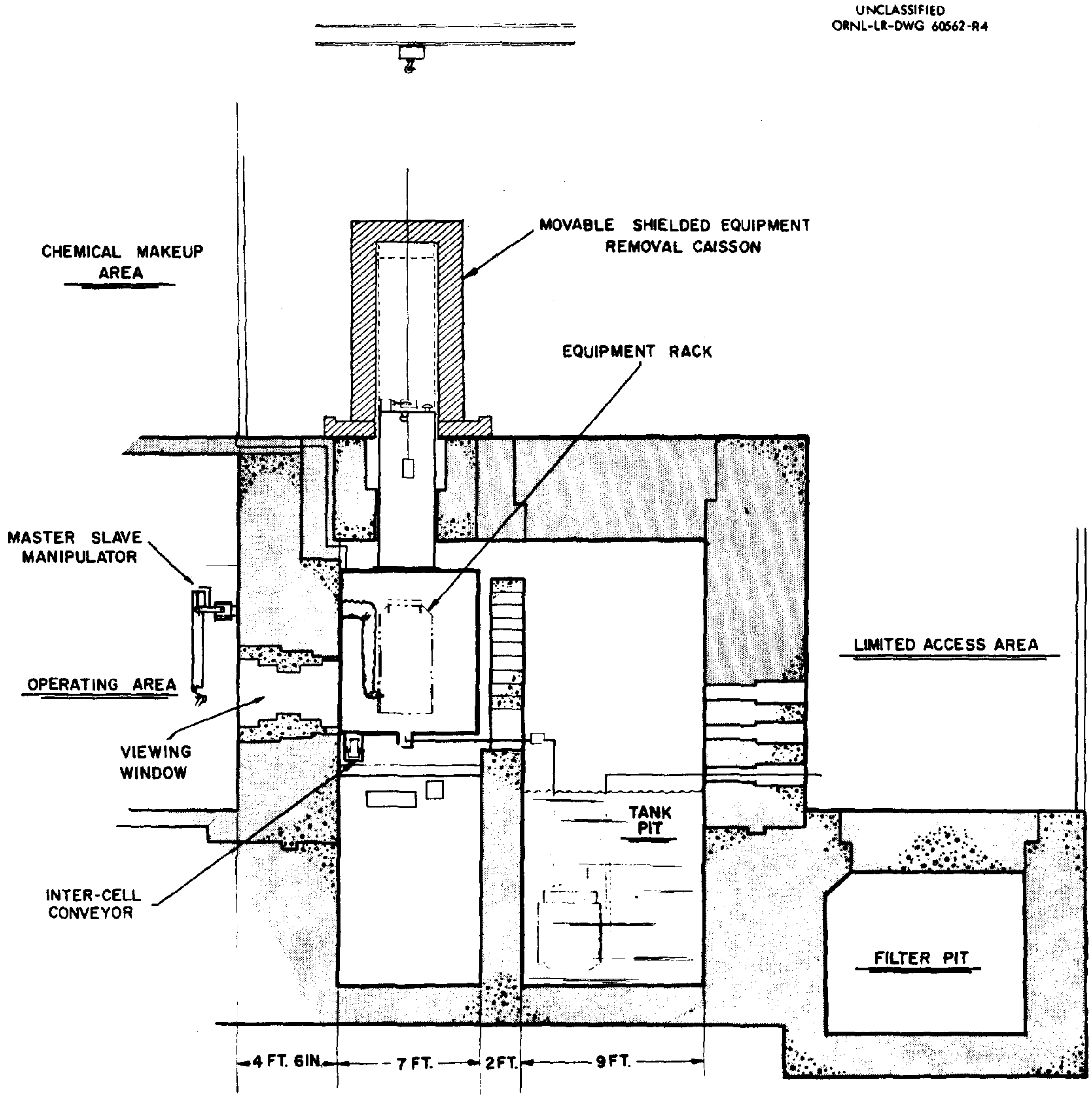


Figure 1 TRU FIRST FLOOR PLAN--VENTILATION FLOWS AND PRESSURES

UNCLASSIFIED
ORNL-LR-DWG 60562-R4



Transuranium facility cell cross section.

Figure 2

UNCLASSIFIED
ORNL-DWG 63-5619

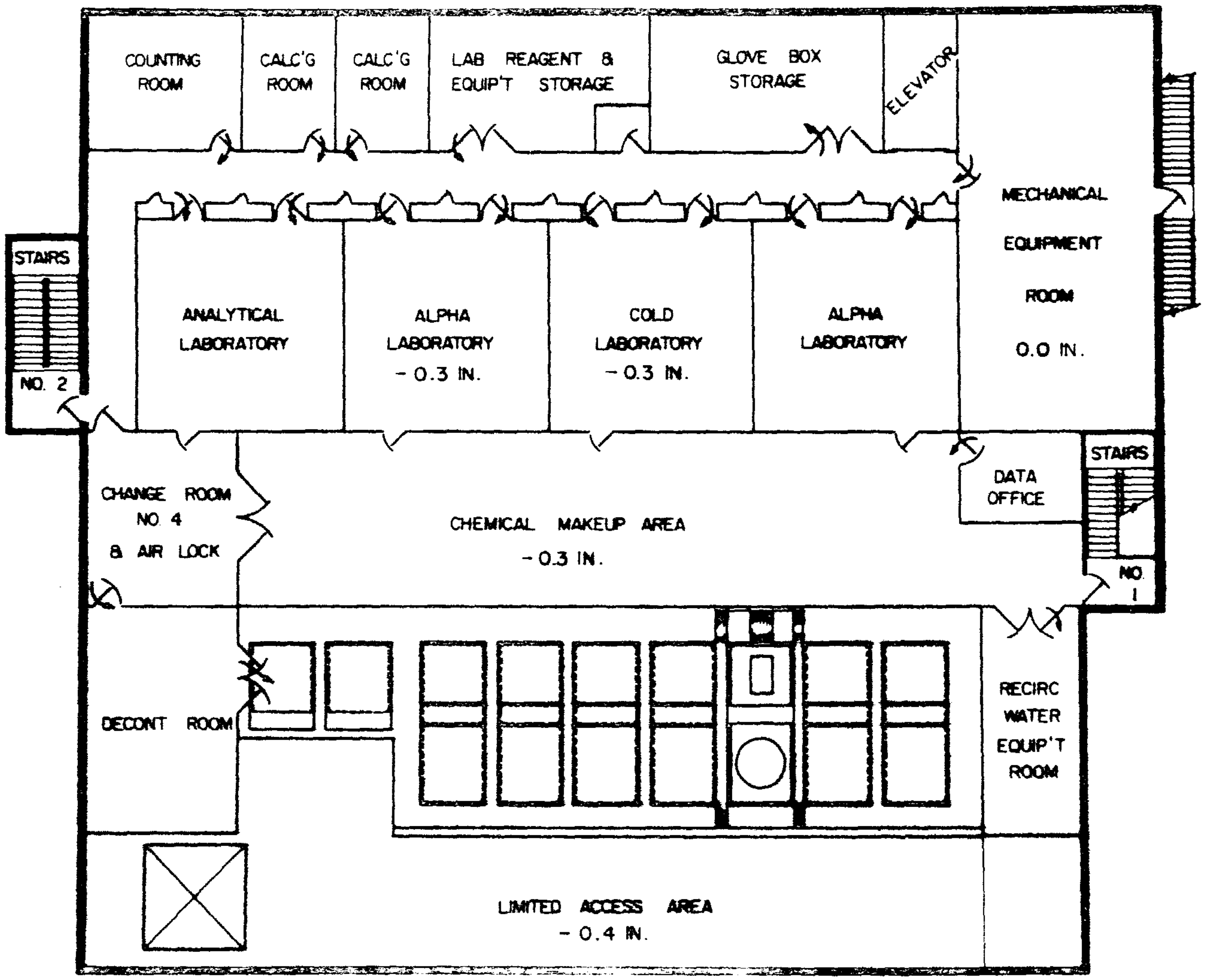


Figure 3 TRU SECOND FLOOR PLAN--VENTILATION FLOWS AND PRESSURES

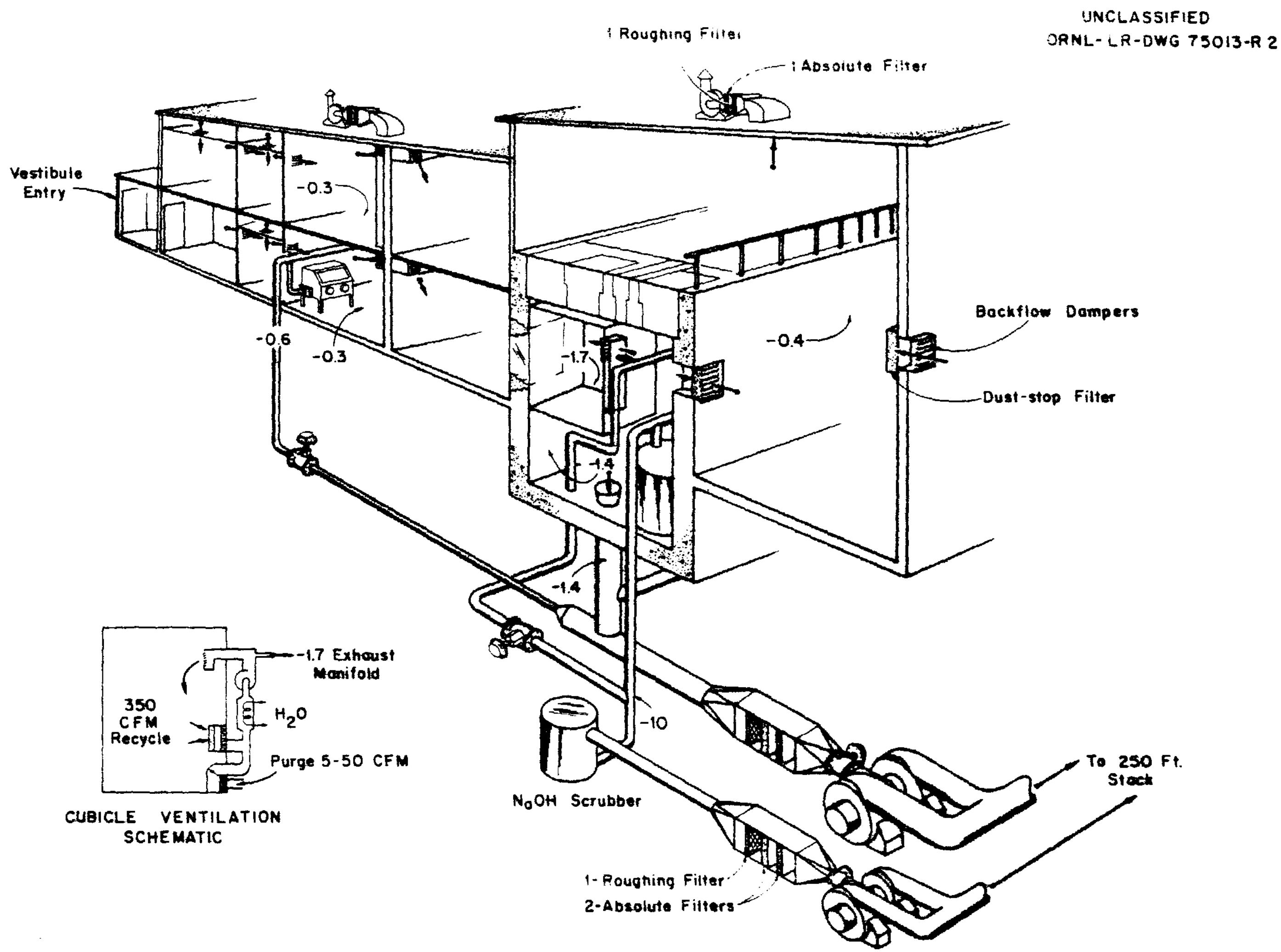


Figure 4 TRU PLANT VENTILATION SCHEMATIC

blower systems which circulate 350 CFM of air within the cubicle through absolute filters for cleaning, an external cooling coil and back into the cubicle. The major source of heat with the cubicles is from the lighting system. Purge air through the cubicles is manually set in the range of 5 to 50 CFM. Cubicle pressure is controlled through a pressure control valve in the exhaust manifold. Thus all cubicles are tied together, but contamination spread from one cubicle to another is eliminated by back flow preventers in addition to the positive air flow into the manifold. One roughing and two absolute filters are provided in the air stream down stream of the caustic scrubber.

Cell Ventilation System: Flows from 300-1000 CFM are maintained through each cell, depending on heat removal requirements, which are in turn governed chiefly by the number and size of evaporator vessels within the cell. Air is admitted through roughing filters and back flow preventers at the top rear face of the cell and exhausted into the cell ventilation duct which runs beneath the cubicles. The total stream of approximately 6000 CFM is exhausted through an absolute and two roughing filters, thence to the 250 foot stack. Pressure is controlled in the main header at - 1.4 in. by means of dampers in the blower suctions. During maintenance operations in which one cell is opened up, the system is so designed to provide an extra 6000 CFM flow into this cell while maintaining normal flows and pressures in the others. Fire protection is provided in the cells by dual detection devices which first alarm on signal from a rate-of-rise detector, then provide an automatic deluge upon fusion of a Quartzoid element. A similar system in the cubicles detects and alarms from a rate-of-rise detector, but water spray is actuated manually. Each cell is protected separately to minimize the quantity of water used.

Up to 100 alpha glove boxes in the laboratory wing are also exhausted through the cell ventilation system.

Filter Housings: Filters for both the cubicle vent system and the cell vent system are installed in parallel with shut off valves for isolation during replacement. In each system (Fig. 5) the roughing and absolute filters are installed together in a single housing. This reduces the cost of the original installation by minimizing the number of the special joints required between filters, but results in some additional operating costs for changing filters. The filter housing installation is designed for safe filter changing even with gross quantities of contamination on the filters. After isolating a filter unit, a slide guillotine valve is lowered into place to close off each end of the filter housing, and the housing, containing the dirty filters, is removed into a specially built disposal box. If gross contamination is

UNCLASSIFIED
ORNL-DWG 63-5478R1

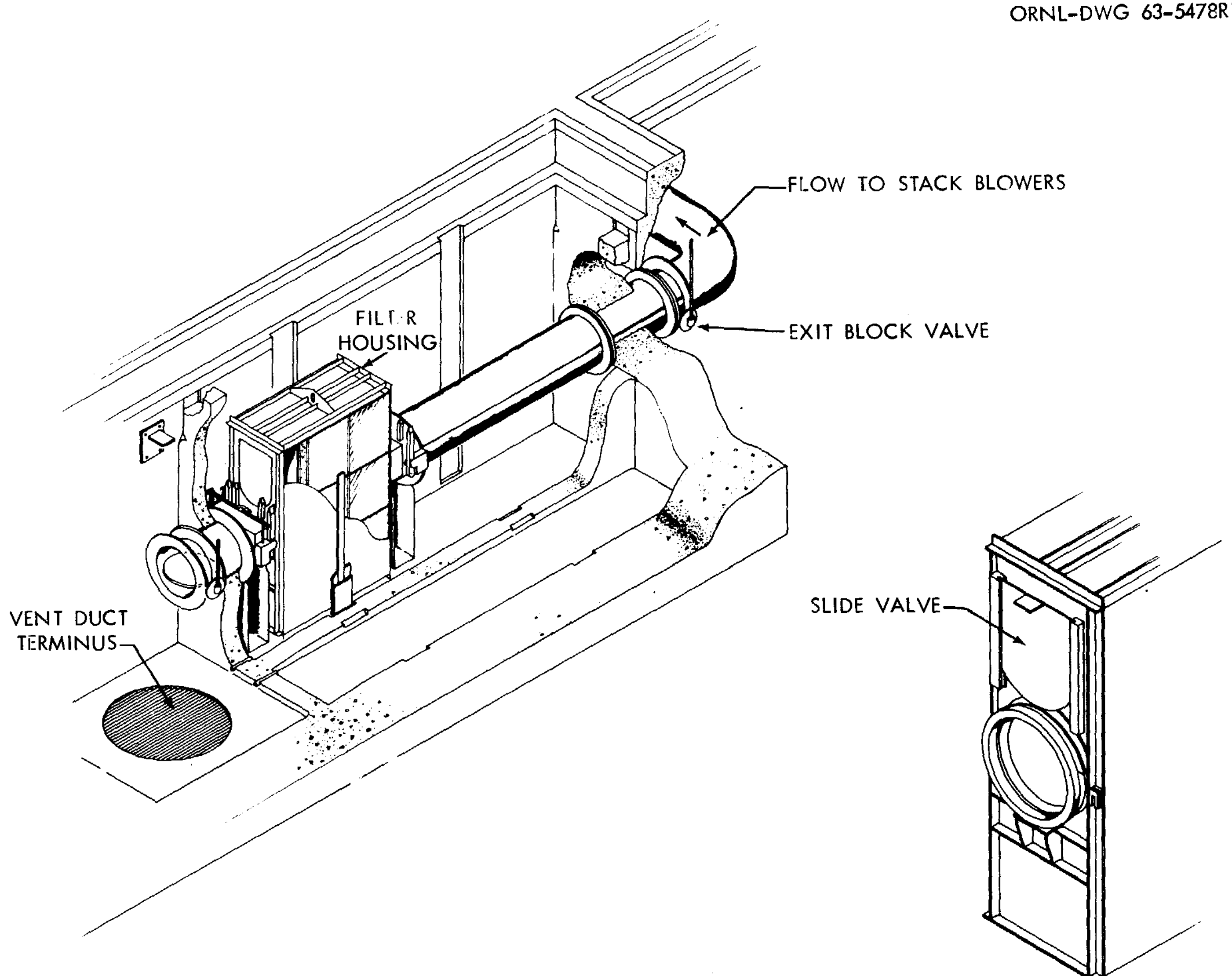


Figure 5 TRU CELL VENTILATION FILTER ARRANGEMENT

present, the disposal box is handled in a one-foot thick concrete shield. The filters are located below floor level in the limited access area, thus insuring against activity release from the building during filter changes. Filters are sealed by a spring-loaded flange operated by a lever extending up to the operating floor.

HAZARD ANALYSES - FILTER EFFICIENCY REQUIREMENTS

Routine Operational Activity Releases: During routine operation of the plant, small quantities of radioactive rare gases, halogens, and aerosols will be released through absolute filters and scrubbers in the vessel and glove box ventilation systems to the 250 foot stack (Table I).

Dissolution of HFIR targets will result in release of < 40 curies Xe^{133} and < 1 curie I^{131} (18 curies released, assume 1 curie through scrubber) over a several-minute period about every two weeks. The xenon release will cause maximum downwind ground concentrations averaged over the time of release of only 10% of the maximum permissible concentrations in air for occupational exposure. The average annual concentration and deposition resulting from the xenon release is negligible. Release of one curie of I^{131} will cause maximum downwind concentrations over the time of the release of 2.5 times MPC. This concentration averaged over a year will be negligible. Maximum deposition of I^{131} on the ground will be 4400 d/min-dm^2 and the maximum levels of deposition averaged over yearly weather conditions will be 50 d/min-dm^2, both levels tolerable in the area surrounding the Transuranium Processing Plant.

The continuous release of radioactive rare gases from spontaneous fission of californium in storage in the facility and the release of aerosols of alpha-emitting actinides and fission products from handling operations in the facility will result in acceptably low air concentrations and deposition rates.

Accidental Releases: The worst accidents that may credibly occur in TRU (Table II) would result from dispersal of the maximum quantity of radioactive material in a cell or glove box by a fire or explosion.

Our studies have shown that, in the event of credible (contained) accidents, the activity released from successive leaks through the primary and secondary containment walls is insignificant as compared to the credible release through the ventilation filters. In a credible accident, the blast effects of an explosion are confined to the region of primary containment (glove box, lab, or cell). Although a radioactive aerosol may leak through the primary containment wall and become mixed with the air in the secondary

Table I

UNCLASSIFED
ORNL-LR-DWG 75000

OPERATIONAL RELEASE OF RADIOACTIVE GAS AND AEROSOL FROM TRU

SOURCE OF RELEASE	TYPE ACTIVITY	DOWNWIND GROUND CONCENTRATION % MPCa-40		GROUND DEPOSITION d/min.-100 cm^2	
		MAX. AVG.	MAX. AVG. ANNUAL	MAX. AVG.	MAX. AVG. ANNUAL
HFIR TARGET DISSOLUTION 40 CURIES Xe^{133} AND <1 CURIE I^{131} RELEASED IN SEVERAL MINUTES EVERY TWO WEEKS	Xe-133 I-131	10 250	0.0001 0.01	— 4400	— 50
CONTINUOUS RELEASE RARE GAS F.P.'S 100 WATTS SF IN Cf	Xe & Kr	2	0.04	5000 (Cs 138)	8 (Cs-137, Sr-89)
CONTINUOUS ESCAPE OF AEROSOLS OF ACTINIDES (10 μc/day) & NONVOLATILE F.P.'S (1000 μc/day) FOR 10 YRS.	ACTINIDES F.P.'S	0.2 0.002	0.005 0.00001	— 270	5 80

Table II

UNCLASSIFIED
ORNL-DWG 63-5787

EFFECTS OF MAXIMUM CREDIBLE ACCIDENTS IN TRU

TYPE OF ACCIDENT	EFFECTS OF ACCIDENT
RUPTURE OF GLOVE BOX CONTAINING 1 g. Cm^{244} BY EXPLOSION AND FIRE	(a) < 1 g Cm^{244} DISPERSED TO LABORATORY GLOVE BOX. OPERATOR MUST EVACUATE IMMEDIATELY TO PREVENT INGESTION OF A LETHAL DOSE (b) 2 mg Cm^{244} ESCAPES THROUGH FILTERED VENTILATION SYSTEM; MAXIMUM DOWN-WIND DOSE, 2 rems; 8.5 sq. mi. CON-TAMINATED ABOVE 30 dis/min-dm^2
RUPTURE OF CELL CUBICLE CONTAINING 1 g Cf POWDER BY EXPLOSION	(a) <1 g Cf RELEASED TO CELL (b) $\sim 5 \times 10^{-8}$ g Cf RELEASED TO BUILDING CAUSING PERSONNEL EXPOSURES OF ~1 rem BEFORE EVACUATION (c) 0.2 mg Cf ESCAPES FROM STACK THROUGH FILTERED VENTILATION SYSTEM; MAXIMUM DOWNWIND DOSE 0.2 rems; 6.5 sq. mi. CONTAMINATED ABOVE 30 dis/min-dn^2

containment zone (building) during the period when the primary containment zone is pressurized, the leaked air is ordinarily not sufficient to raise the secondary containment pressure above atmospheric.

The so-called "AEC absolute" filters that are widely used in radiochemical plants are the weakest link in the containment of credible accidents. The susceptibility of the filters to both physical and chemical degradation necessitates that their integrity and efficiency be assured by routine in-situ testing or by preplacement testing plus careful installation and operation. The filters must be protected from excessive corrosion and excessive loadings of dust or water, and must be located such that they can withstand the blast wave from credible explosions without rupture. In typical facilities the tortuous path and expansions and contractions of the ventilation duct are sufficient to reduce the blast wave from credible explosions to a tolerable level at the filters.

In the evaluation of the credible accidents in TRU, it is assumed that no more than 20% of the radioactive aerosol that is dispersed in the primary containment zone passes to the filters and that the remainder is deposited on the walls and ventilation ducts. The fraction of aerosal penetrating the filters is estimated from the assumed particle size distribution in the aerosol and efficiency of the filters as a function of particle size.

Experience with AEC absolute filters operating at the rated flow indicates that they have greater than 99.95% efficiency for removing particles of size greater than 0.3 microns, that the efficiency decreases to a minimum of approximately 87% for particles of 0.05 to 0.1 μ size and that the efficiency is greater than 87% for particles of smaller size.[1] Cheever has shown that these filters are approximately 99.5% efficient in removing smoke from a plutonium metal fire, varying in size from 0.004 to 0.03 μ, and that the addition of one to six backup filters in series did not significantly improve the efficiency.[2]

In these studies it is assumed that filters have removal efficiencies of 99% for particles smaller than 0.05 μ, 87% for particles 0.05 to 0.1 μ, 95% for particles 0.1 to 0.3 μ, 99.95% for particles 0.3-5 μ, and 100% for particles larger that 5 μ. Smokes from fires of metal, solid carbonaceous materials, or organic liquids which would be predominantly 0.01 to 0.1 μ in size are assumed to be 99% removed in filters. This slightly enchanced

[1] L. Silverman, Harvard Air Cleaning Laboratory, personal communication with J. P. Nichols, ORNL, February 1960.

[2] C. L. Cheever, "Recent Air Cleaning Developments at Argonne National Laboratory," p 308-326, TID-7627 (March 1962).

efficiency, as compared to 87%, partially compensates for the effects of agglomeration in the duct and improved efficiency because of filter loading in moderately large fires involving carbonaceous solids or organic liquids.

The maximum credible accident in the glove box laboratories of TRU would result from an explosion and fire in a glove box that contains 1 g of Cm-244, the maximum quantity anticipated to be used in glove boxes. Such an accident could result in dispersal of < 1 g Cm-244 into the laboratory requiring that glove box operators evacuate immediately to prevent ingestion of a lethal dose. Allowing for 80% deposition of the smoke in the glove box and laboratory and assuming that the filters are only 99% efficient in removing the smoke approximately 2 mg of Cm-244 would be released from the roof of the building through the filtered ventilation systems. This release could cause maximum downwind ingestion doses (accumulated over a lifetime) of approximately 2 rem and contamination of approximately 8.5 square miles downwind to levels greater than 30 $d/min\text{-}dm^2$ of alpha.

While absolute prevention of such glove box ruptures is impractical, the probability of such accidents is to be maintained at an acceptably low value by inclusion of multiple safe-guards. The effects of fires in glove boxes are to be minimized by heat-activated water fog nozzles in the boxes as well as through the use of ventilation systems designed to maintain the differential pressure resulting from credible glove box fires below ~ 6 in. w.g., which is required to break gasket seals. Those boxes to be operated at temperatures above the flash point of the process solvents will be supplied with an inert gas atmosphere to prevent explosions.

The maximum credible accident in the cell area would be an explosion (of Al-air, H_2-air, or organic-air) in a cell cubicle containing 1 g of californium as fine powder. The explosion could have sufficient violence to shatter the vessel or cubicle and scatter its contents within the cell but would not rupture the cell wall or ventilation filters. The californium released through broken "alpha" seals in the cell wall into the building might cause lifetime doses to operating personnel of approximately 1 rem. Assuming a conservative particle size distribution (98.8% = 0.3 μ, 1.1% between 0.1 and 0.3 μ, and 0.1% less than 0.1 μ) and assuming 80% removal by deposition before the filters 0.2 mg of Cf could be released through the cell ventilation system to the 250-foot stack. This could cause maximum downwind doses (accumulated over a lifetime) of approximately 0.2 rem and contamination of approximately 6.5 square miles downwind to levels greater than 30 $d/min\text{-}dm^2$ of alpha.

The possibility of such dispersive accidents will be minimized through inclusion of multiple safeguards.

It is not credible that an explosive mixture could occur in a significant portion of an entire cell since the ventilation rate is sufficient to dilute the maximum credible formation rates of organic vapor or hydrogen below its explosive limit.

DISCUSSION AND COMMENT

The filter efficiency was based on experimental data, much of which was presented at the last Conference. For example, the efficiency in absolute filters for smoke was of the order of 99%. The smoke has a particle size of .01 to .05 μ when it is formed assuming the particle size distribution.

The only rationale for two-in-series filter is that we consider the second filter as a safety factor.

The presumption for shielding was based on a full gram of californium, which is estimated to contain a quantity of californium-254, and thus was shielded down with four feet of high-density concrete to a quarter mr per hour.

A water spray fire-protection system is provided within the cubicle.

Session Chairman: My appreciation and thanks to all four speakers for the excellent papers presented during Session II.

SESSION III - CLEANING METHODS FOR RADIOACTIVE PARTICULATES

Afternoon - 22 October 1963

W. E. Browning, Jr., Chairman

Session Chairman: Will the meeting come to order? Mr. D. D. Cowen, of the Oak Ridge National Laboratory, which plays host to meetings such as this, has an announcement.

MR. COWEN: Good afternoon, gentlemen. I had a feeling this morning you had three or four welcomes, but I, too, would like to welcome you on behalf of the AEC-Oak Ridge National Laboratory, and the prime operating contractor, Union Carbide.

I am sure you have heard by now that we have a little trouble, trying to struggle along with it, and this meeting is further complicated by the fact that we are doing an international conference on approximations in Gatlinburg at the same time.

We are happy to have you, again, as our guests at Oak Ridge, under rather adverse circumstances. If we can do anything here--within reason, of course--to make your visit more informative, more profitable, more pleasant, please see us and we will try to see what we can arrange. Thank you very much, gentlemen.

Session Chairman: We are pleased in Session III to have a UKAEA contribution, "Experience in Trapping Iodine-131 and Other Fission Products Released from Irradiated AGR-Type Fuel Elements," by D. A. Collins, R. Taylor, and W. D. Yuille. The paper will be delivered by Mr. Collins.