SESSION III

FIRE PROTECTION

Monday, August 28, 1972
CHAIRMAN: R. B. Smith

FIRE PROTECTION OF HEPA FILTERS BY USING WATER SPRAYS*

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Abstract

In experiments with a full-size section of an exhaust-ventilation system at the Lawrence Livermore Laboratory, fine water sprays used in conjunction with metal screen scrubbers and demisters successfully protected HEPA filters against hot fire gases. When a single HEPA filter was used, at an air-flow rate of 1000 cfm, temperature was reduced from 1500°F to ~300°F, with 4 gpm of water distributed through three nozzles. Variations in the heat and flow parameters, and in the spray and scrubber systems used, are described in this paper, and results are given.

I. Introduction

Where radioactive or toxic materials are handled, safe practice dictates that such materials be used in partial or total enclosures, e.g., hoods or glove boxes. Furthermore, the air pressure in such enclosures is maintained negative to that in the workroom, that in the workroom negative relative to that in the halls and offices, and that in the building negative with respect to the outside. The theory of these sequential pressure differentials is that all air leakages shall be inward from the cleanest to the most ''contaminated'' areas.

At LLL the workrooms are maintained at a negative air pressure by separate air-exhaust systems, equipped with HEPA (high-efficiency particulate air) filters, which serve to remove fine airborne particles that may escape from the enclosures. Each such workroom has individual exhaust systems leading to a common exhaust duct and blower. A prefilter followed by a HEPA filter is installed in the opening of the exhaust duct in the room. The general scheme is shown in Fig. 1.

Although elaborate precautions are taken to prevent and to suppress an unwanted fire, it is possible that one can occur in a radioactive-material enclosure or even in a workroom outside the enclosure. In either case, it must be assumed that containment of the radioactivity could be compromised; thus it is necessary to keep the fire and contamination from spreading to other areas, particularly to the outside environment.

The use of a fire damper – a metal plate that swings shut in the exhaust ductwork – will prevent hot gases from reaching the filters; but the resulting pressure buildup in the workroom will force heat, smoke, and contamination into other areas in the building. Hence, it is necessary to maintain exhaust ventilation to minimize this effect and to clear the room of heat and smoke as an aid to firefighting.

However, HEPA filters are subject to heat degradation as follows:[1]

Temperature	Service Time
750°F	Less than 10 min
325°F	Up to 2 hrs
276°F	48 hrs

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

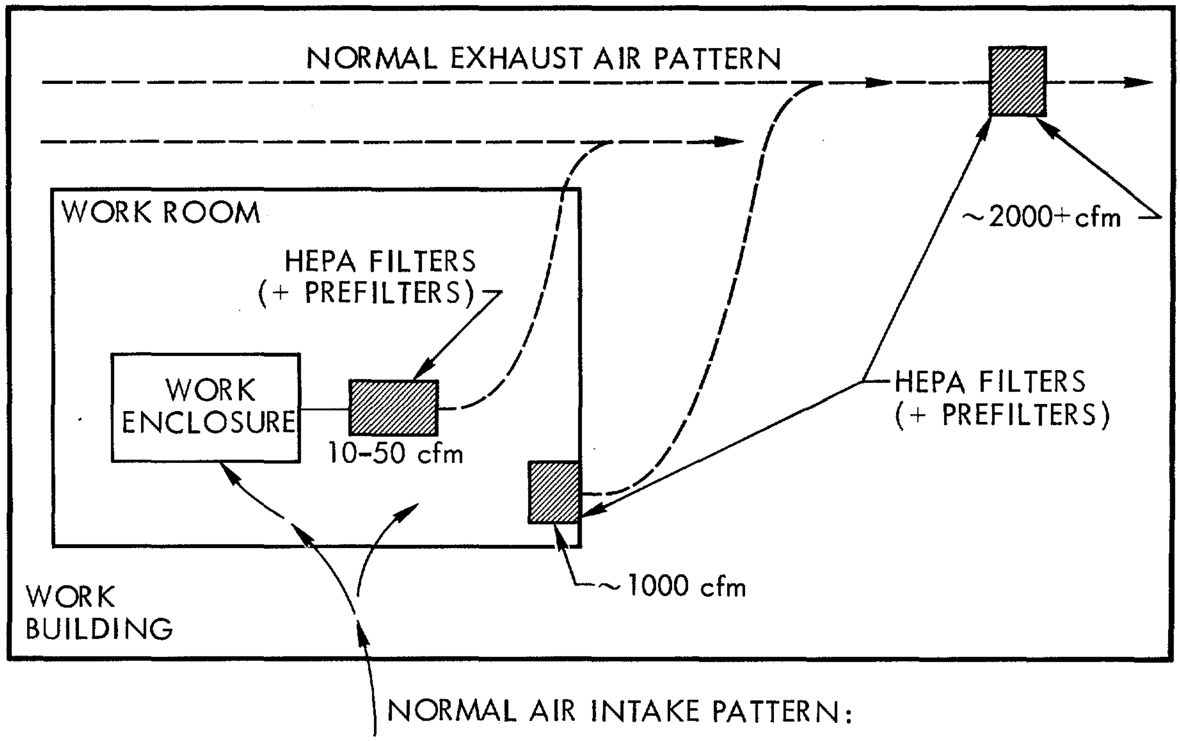


Fig. 1. Schematic diagram of one type of airflow system in a building where radioisotopes are used.

To protect our HEPA filters from heat damage, we carried out an experimental program at LLL, using combinations of water sprays, scrubbers and demisters. The results of this experimental program are the subject of this report. A current study aimed at preventing smoke from plugging the filters and thus pressurizing the fire room will be reported at a later date.

II. Experimental Critera

The basis for the experimental setup was as follows:

1. The ductwork system was to be full-size, i.e., 26 × 26 in. in cross section.
2. It was to be operated at rated flow for a 24 × 24-in. HEPA filter, i.e., 1000 cfm, although means were to be provided for varying the flow rate.
3. The experimental portion of the ductwork was to be modular; it should be capable of being rearranged easily, to vary the experimental conditions.
4. The system should be well-instrumented, to provide adequate data.
5. The ''fire'' temperature should be a ''worst case,'' i.e., 1500°F; this is about a 1/2-hr fire on the standard time-temperature curve.[2]

III. Experimental Setup

The experimental setup, shown schematically in Fig. 2 and pictorially in Figs. 3 through 8, consists of three sections, as follows:

1. A gas-fired heater section consisting of insulated and baffled ductwork. In this section outside air is heated and mixed uniformly to provide the desired ''fire gas'' inlet temperature.
2. An experimental section consisting of square, flanged pieces of ductwork 6, 12, and 24 in. long. The 12- and 24-in. sections contain viewports; all

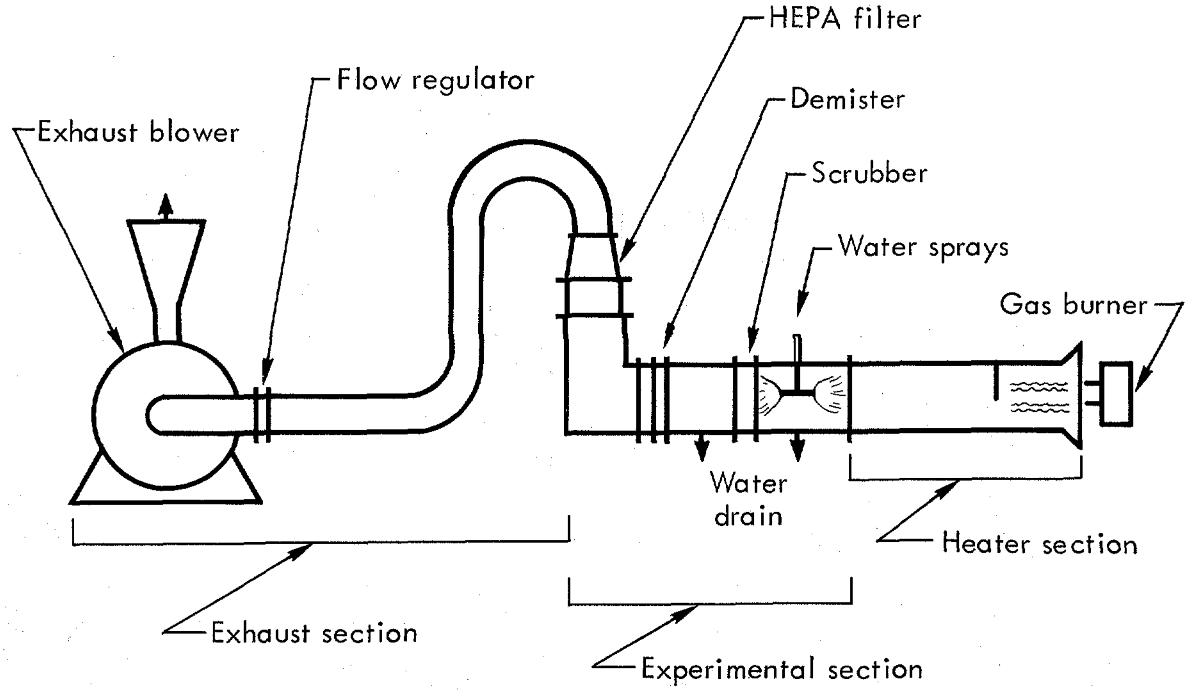


Fig. 2. Schematic diagram of LLL experimental spray damper setup.

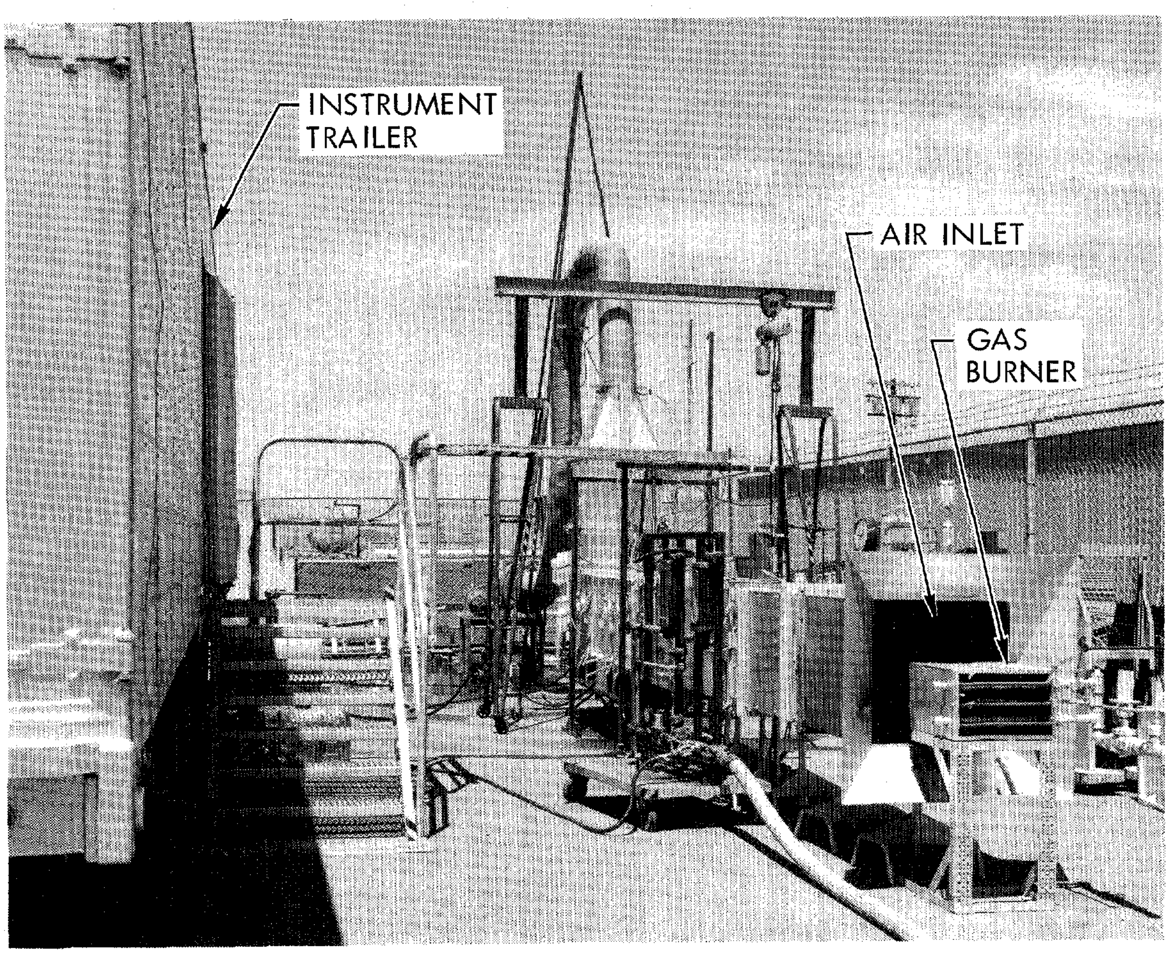


Fig. 3. View of spray damper experimental setup from fire end.

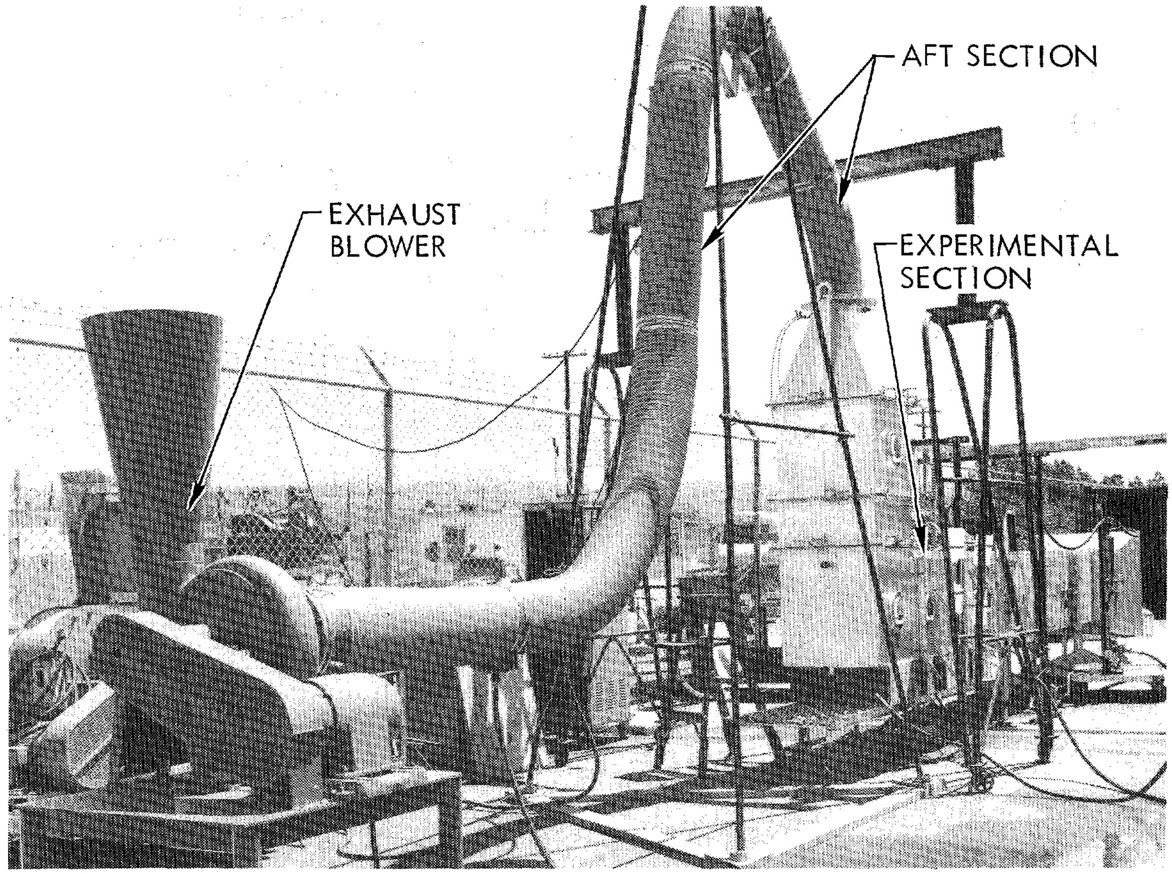


Fig. 4. View of spray damper experimental setup from exhaust end.

sections contain 1-in. pipe couplings, to permit the introduction of pressure taps, thermocouples, and water-spray piping, or to act as drains. Figures 9 through 12 show typical sections.

3. An exhaust section consisting of a square-to-round transition piece, 12-in.-diam flexible and rigid tubing, and an exhaust blower equipped with an adjustable gate damper.

Filters, scrubbers, and demisters used in this work were fastened to 1/4-in.-thick steel ''picture frames'' of the same extermal dimensions as the flanges of the duct sections. These frames holding the filter, scrubber, etc., were clamped in place between duct sections, according to the experiment. Figures 13 through 17 show these picture frames and the scrubbers, demisters, and filters used.

A variety of spray nozzles were tried external to the system and in preliminary fire and gas-cooling experiments. However, the more successful tests were conducted with the types shown in Fig. 18: pin-type hollow cone, modified hollow cone, and square-pattern solid spray. The sprays were operated at total water flows of 2 to 4 gpm. Excess water was drained from the duct through water seals and measured. By knowing the incoming and outgoing water flow rates and respective water temperatures, we could calculate sensible heats of absorption. ''Lost'' water was assumed to be evaporated; hence, we could compute latent heats of absorption.

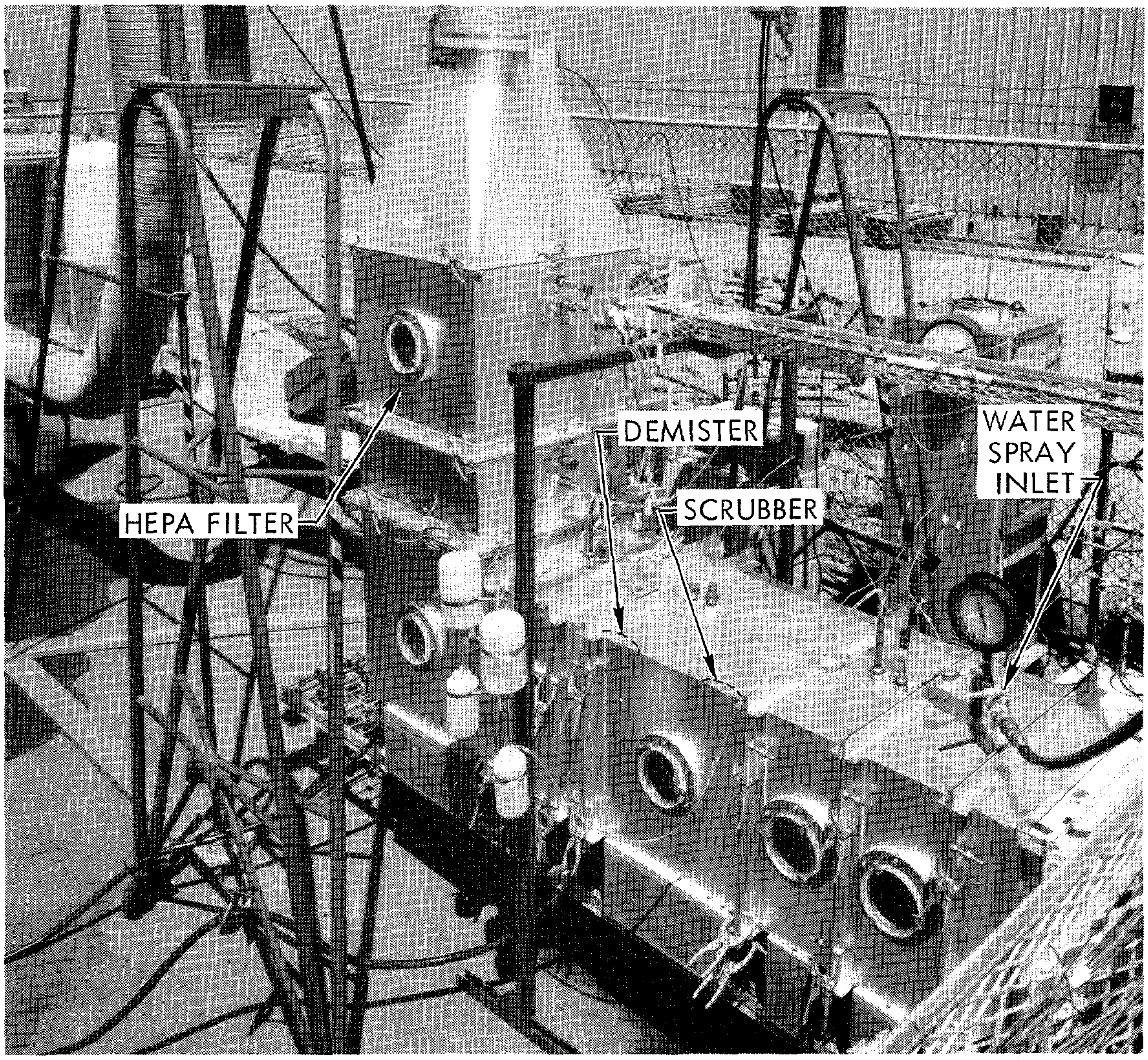


Fig. 5. View of one arrangement of experimental section of LLL spray damper.

IV. Operating Procedure

For a given experimental setup, the system was checked under ambient flow conditions, and the gas fire was lit. When the inlet temperature (to the experimental section) reached 250°F, the sprays were turned on to a predetermined constant flowrate. Heating was continued to an inlet temperature of 500°F. This temperature was maintained at a steady state for 10 min, and typical readings of temperatures, pressure differences, and water flows were obtained. The inlet temperature was raised to 1000°F, and a 10-min set of steady-state readings was obtained. The temperature was then raised to 1500°F, and the process was repeated. The results (air temperature reduction, water usage, heat absorption, and pressure drops across scrubber, demister, and filter) were calculated from the data, and the next experiment was arranged in a manner intended to improve the situation. Successful experiments were repeated as a check. In later runs, the 500°F inlet-temperature portion of the test was omitted, and a test at 1250°F was substituted.

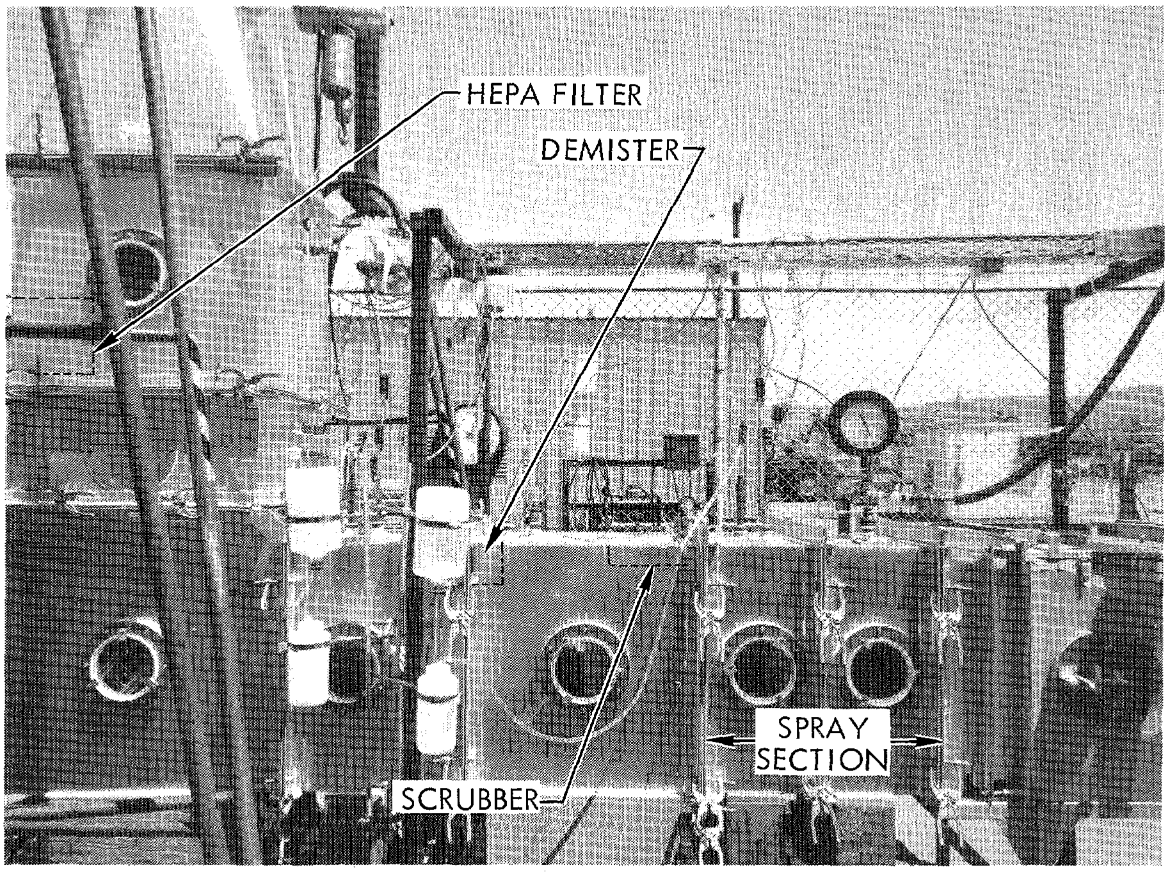


Fig. 6. View of one arrangement of experimental section of LLL spray damper.

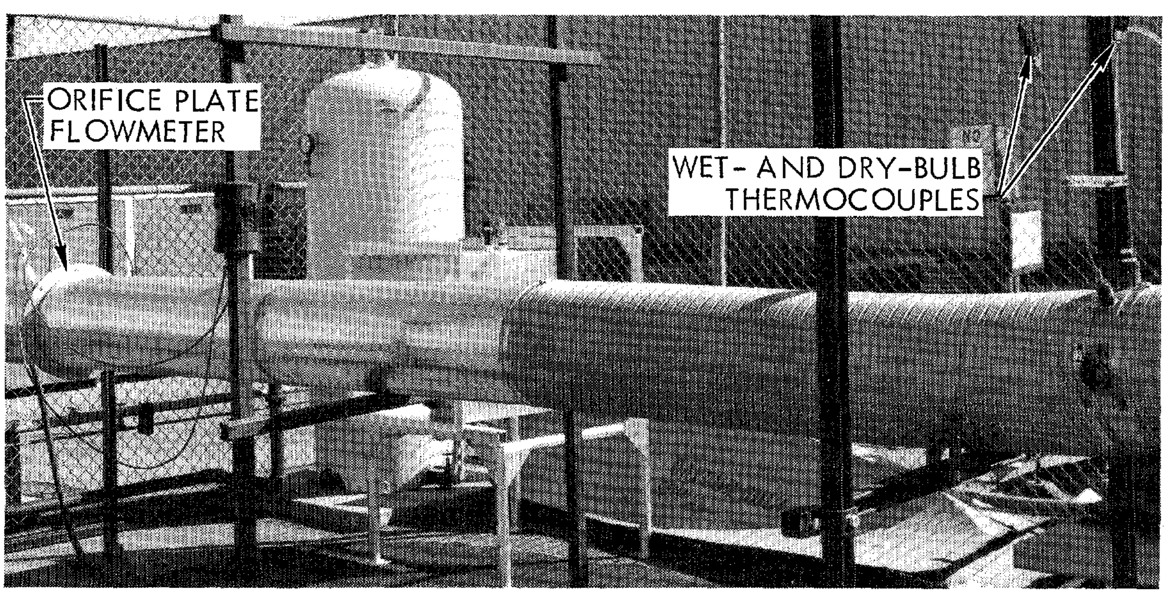


Fig. 7. View of modified aft section of LLL spray damper setup.

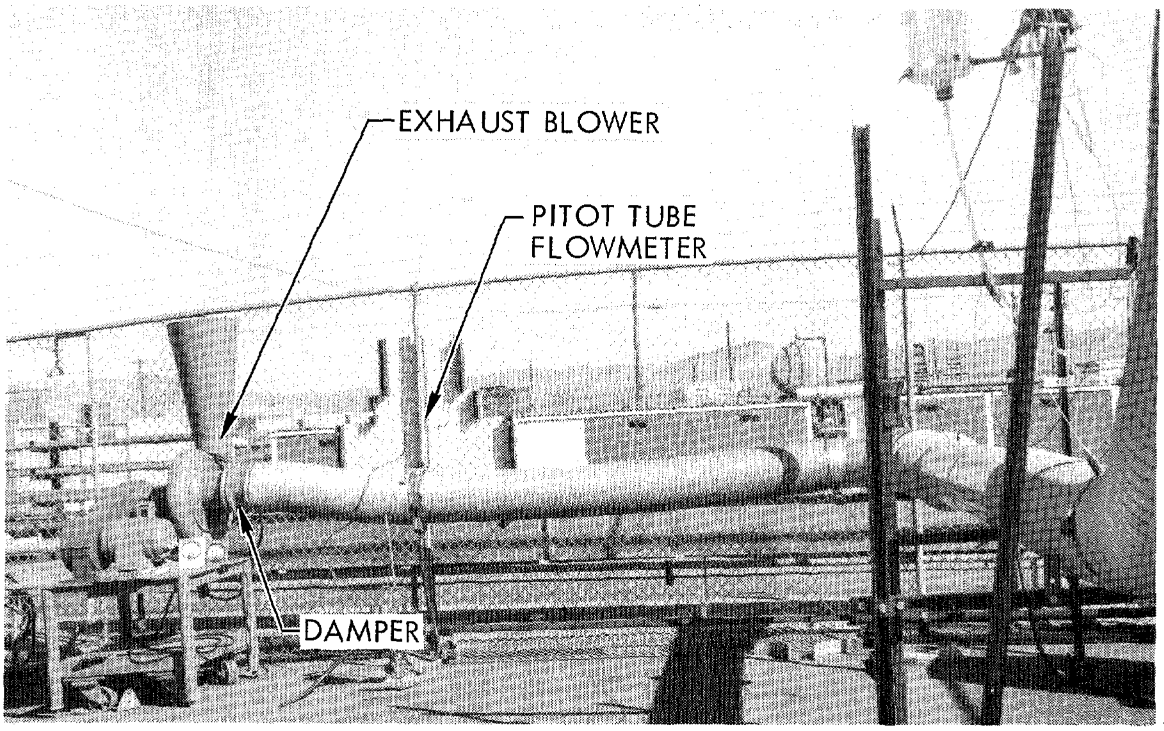


Fig. 8. View of modified exhaust section of LLL experimental spray damper setup.

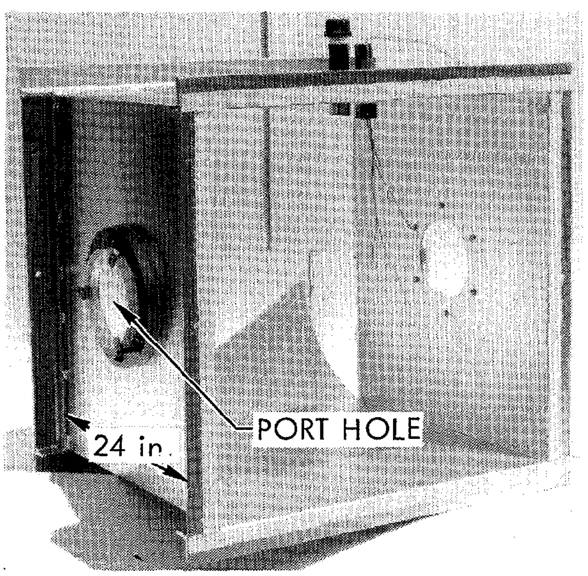


Fig. 9. Twenty-four-in. experimental duct section, showing means for intorducing thermocouples.

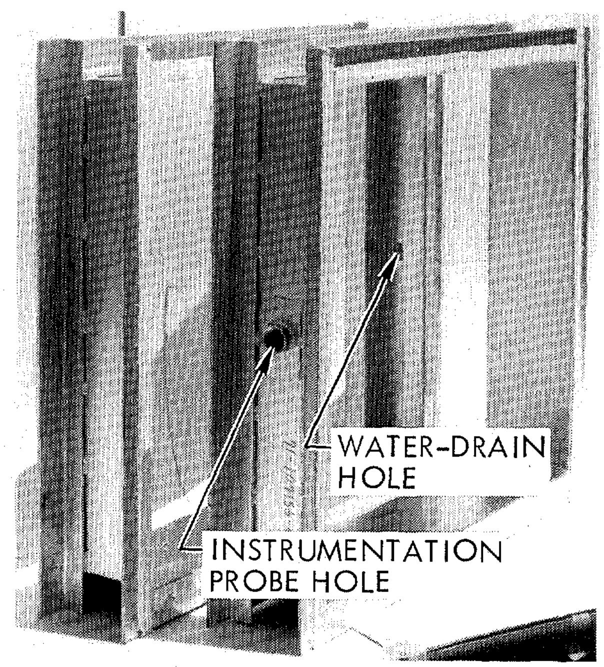


Fig. 10. Six-in. duct sections.

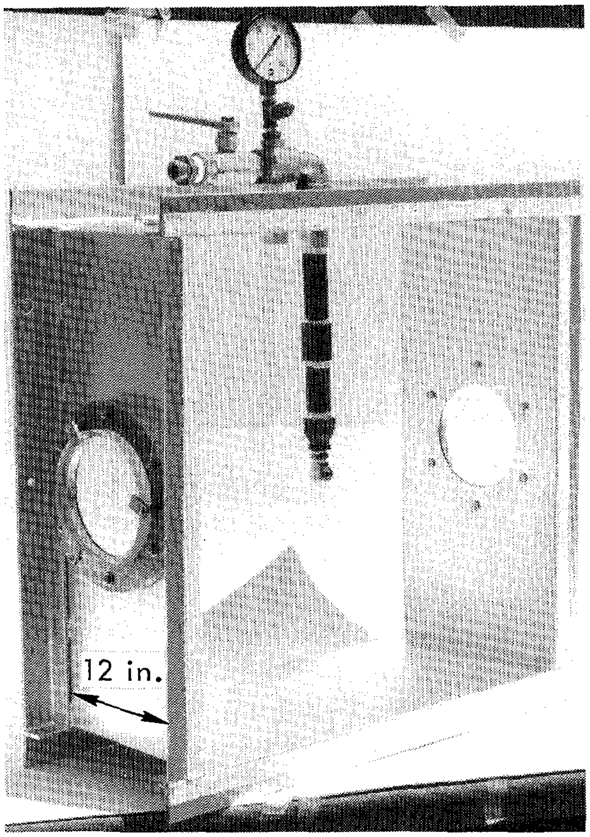


Fig. 11. Twelve-in. duct section, showing one spray system.

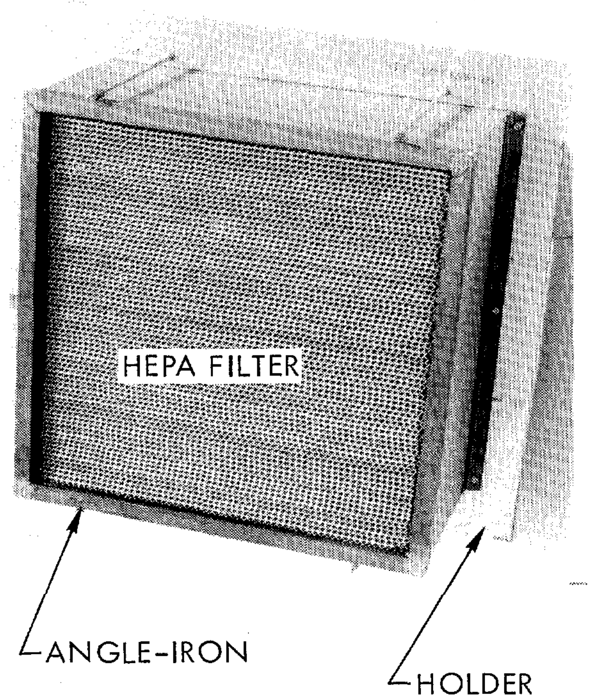


Fig. 13. Mounting of HEPA filter in picture-frame holder.

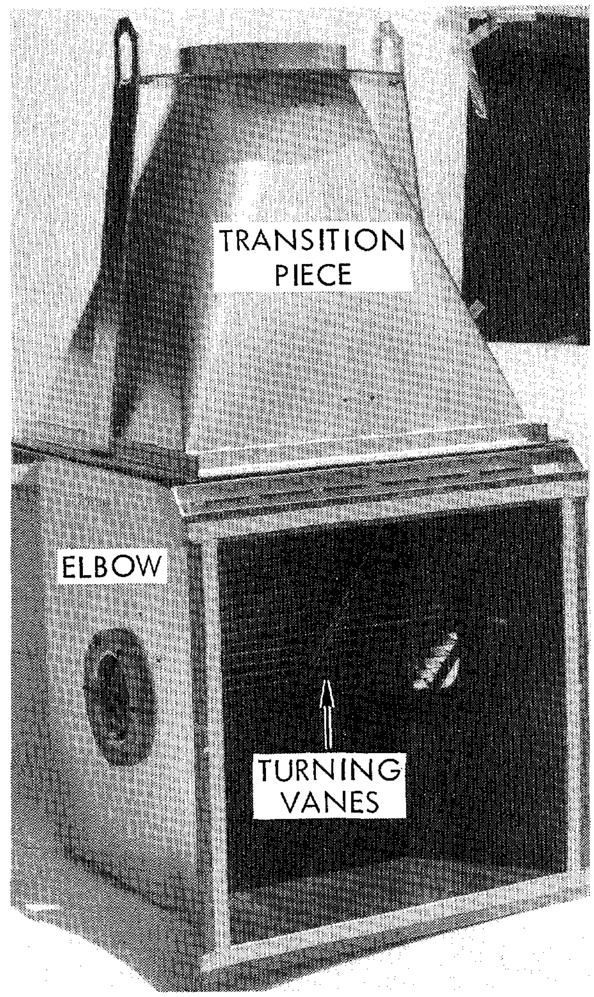


Fig. 12. Elbow and transition piece.

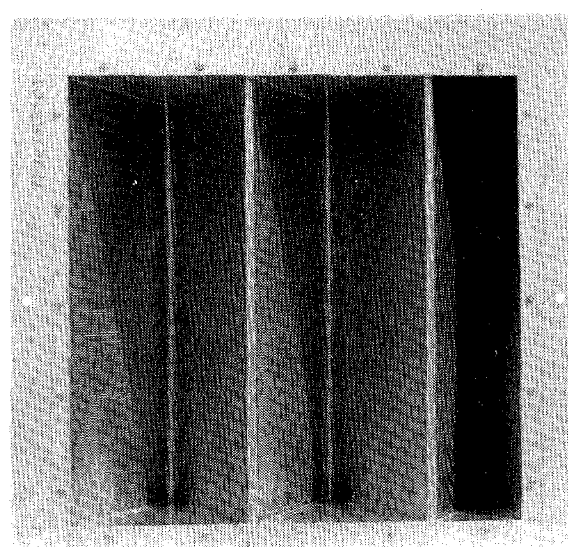


Fig. 14. Perforated metal-sheet scrubber mounted in picture-frame holder.

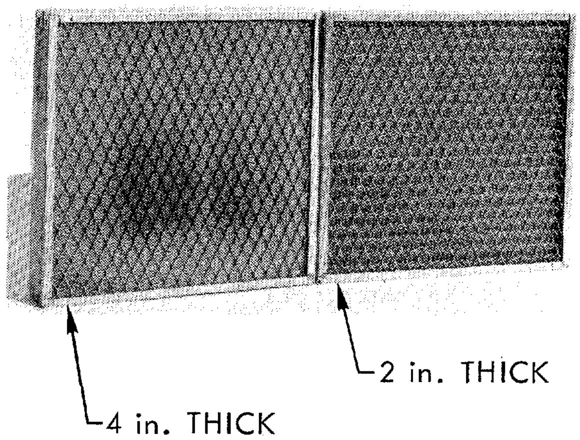


Fig. 15. Graded metal mesh scrubbers.

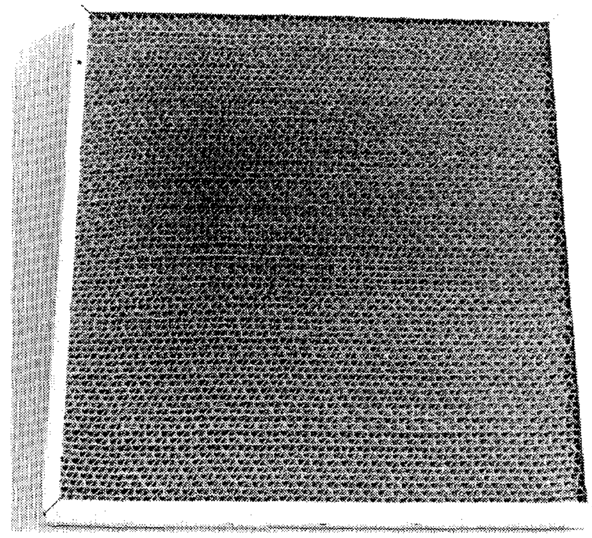


Fig. 16. Demister herringbone crimped steel mesh, 2 in. thick.

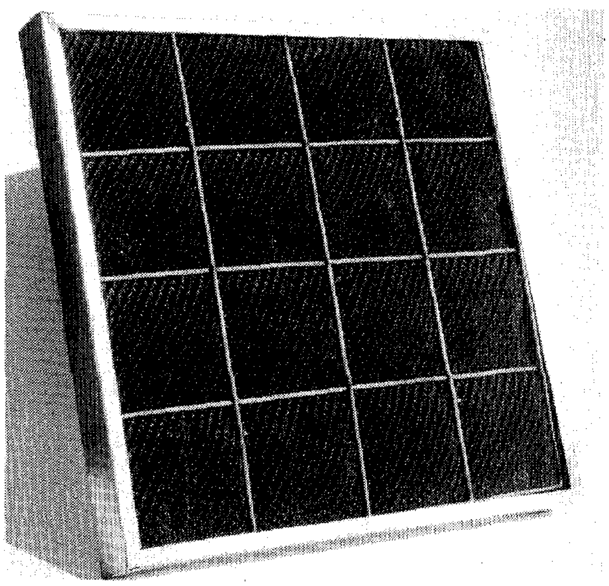


Fig. 17. Demister: stainless steel wire and halogenated plastic filaments, 2 in. thick.

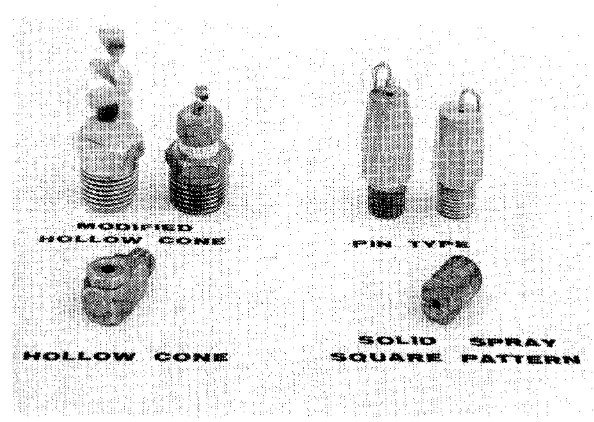


Fig. 18. Spray nozzles used in spray damper experiments.

V. Results

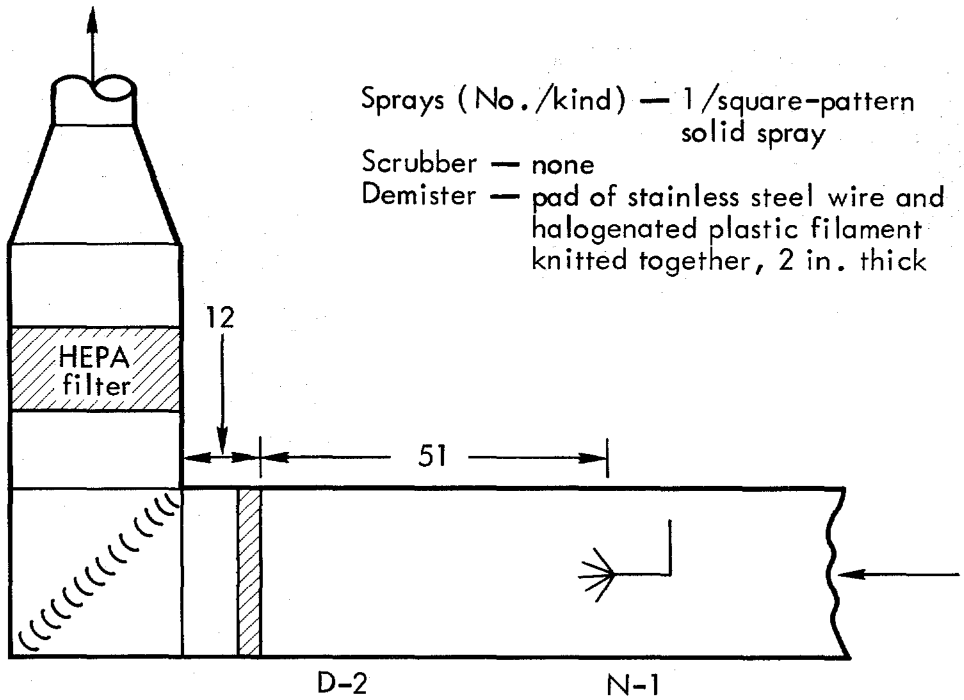
Some thirty tests were carried out, of which only the more interesting and successful are reported (Figs. 19-26). These are discussed briefly, below.

Test S-6.5 (Fig. 19)

A square-pattern, solid spray was aimed downstream at a stainless steel/fluorocarbon demister 4 ft away. At a 1000°F feed temperature, the air temperature ahead of the HEPA filter was over 400°F. This was unsatisfactory.

Test S-6.7 (Fig. 20)

The same square-pattern solid spray was aimed downstream at a folded scrubber consisting of a double layer of perforated stainless steel sheet with offset holes.

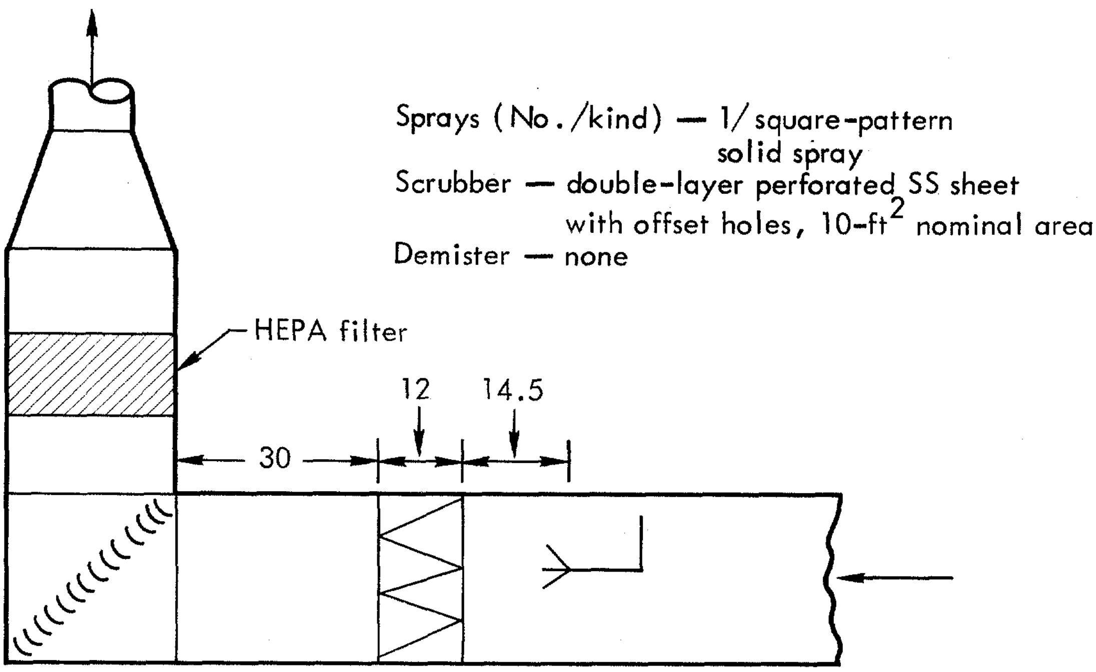


Results

Water flow	gpm	
	2.0	2.5
Temperatures	°F	
Feed	500	1000
In spray	110	140
After scrubber	-	-
After demister	270	410
After HEPA	265	385
ΔP's	in. H_2O	
Scrubber	-	-
Demister	1.0	0.70
HEPA	1.5	1.50
Total	2.5	2.2
Heat (absolute)	Btu/min	
Sensible	85	435
Latent	1740	5230
Total	1825	5665

Fig. 19. Data experiment S-6.5.

Although the air temperature ahead of the filter was less than 400°F for a feed temperature of 1000°F, the pressure drop across the scrubber was over 1.7 in. of water, yielding a total pressure drop of 3 in. of water for the system.



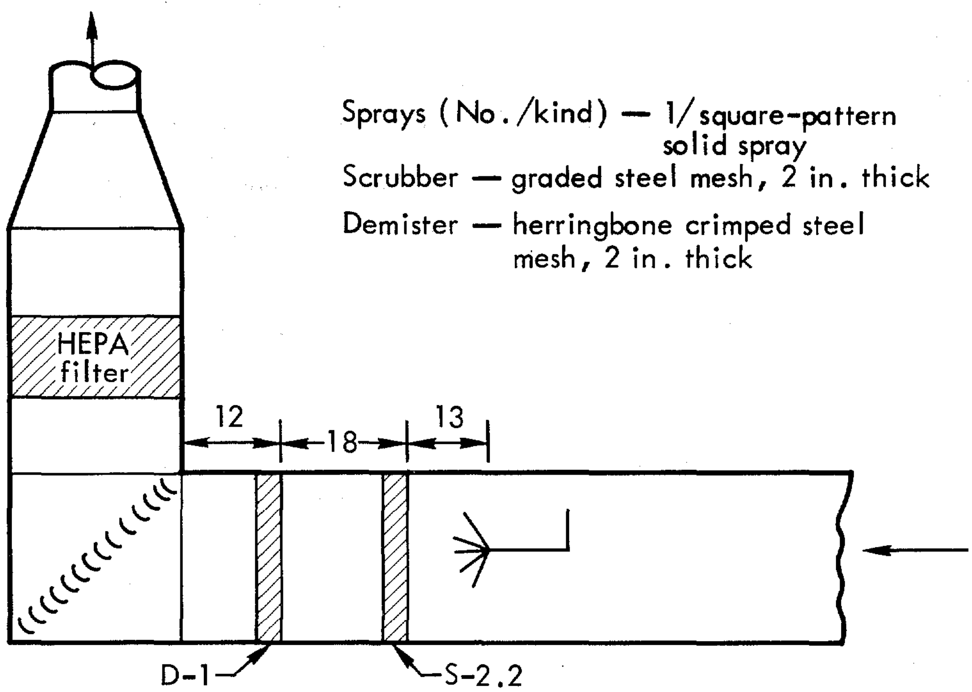
Results

Water flow	gpm	
	2.0	2.5
Temperatures	°F	
Feed	490	1005
In spray	100	130
After scrubber	235	>350
After demister	-	-
After HEPA	260	380
ΔP's	in. H_2O	
Scrubber	1.92	1.73
Demister	-	-
HEPA	1.26	1.28
Total	3.18	3.01
Heat (absolute)	Btu/min	
Sensible	90	395
Latent	1740	4650
Total	1830	5065

Fig. 20. Data experiment S-6.7.

Test S-6.9 (Fig. 21)

A square-pattern solid spray at 2.5 gpm aimed downstream a foot away from a 2-in.-thick graded steel-mesh scrubber followed by a 2-in.-thick demister produced a temperature ahead of the filter of 240°F with a feed temperature of ~1200°F. The



Results

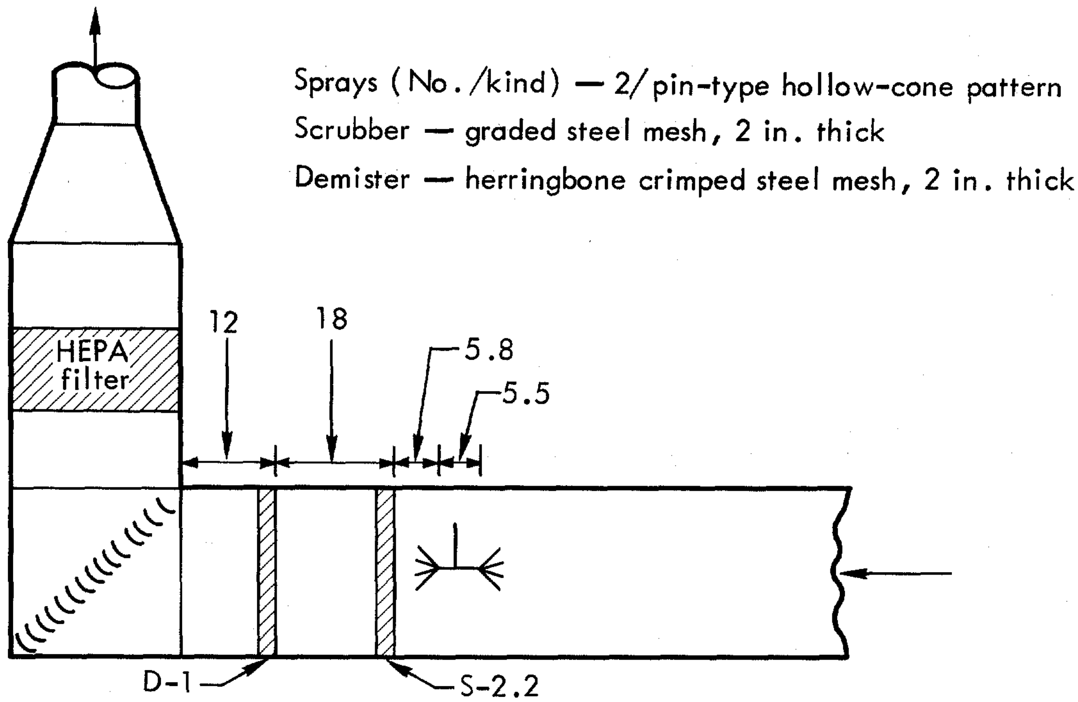
Water flow	gpm		
	2.0	2.0	2.5
Temperatures	°F		
Feed	520	1005	1180
In spray	120	150	155
After scrubber	-	-	-
After demister	230	345	340
After HEPA	230	345	335
ΔP's	in. H_2O		
Scrubber	0.10	0.10	0.10
Demister	0.05	0.07	0.07
HEPA	1.02	1.16	1.30
Total	1.17	1.33	1.47
Heat (absolute)	Btu/min		
Sensible	785	810	1155
Latent	2660	6750	8300
Total	3445	8560	9455

Fig. 21. Data experiment S-6.9.

pressure drop through the scrubber-demister combination was less than 1/4 in. of water.

Tests S-6.13/6.14 (Fig. 22)

Two pin-type hollow-cone sprays (one aimed upstream and one downstream, for a total flow of 2 gpm) with the same scrubber/demister combination as in S-6.9,



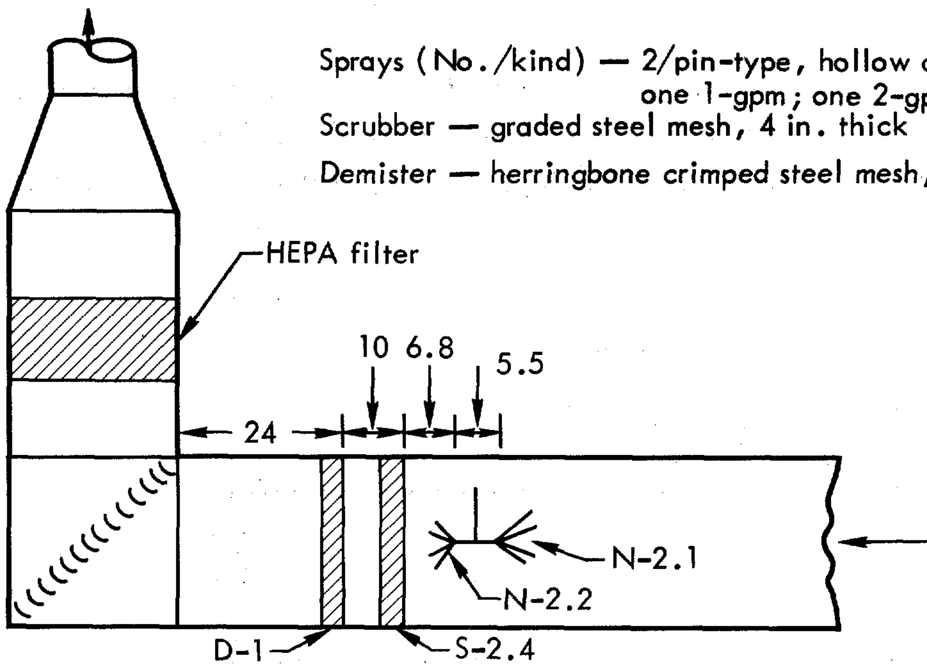
Results

Water flow	gpm		
	2.0	2.0	2.0
Temperatures	°F		
Feed	1000	1260	1495
In spray	260	310	340
After scrubber	-	-	-
After demister	335	410	445
After HEPA	300	355	400
ΔP's	in. H_2O		
Scrubber	0.12	0.12	0.12
Demister	0.07	0.07	0.07
HEPA	1.35	1.47	1.95
Total	1.54	1.66	2.14
Heat (absolute)	Btu/min		
Sensible	875	810	765
Latent	7015	8520	9350
Total	7890	9330	10115

Fig. 22. Data experiment S-6.13, 6.14.

yielded a temperature of 450°F ahead of the filter, with a feed temperature of 1500°F and with the same low pressure drop.

Sprays (No./kind) — 2/pin-type, hollow cone
one 1-gpm; one 2-gpm
Scrubber — graded steel mesh, 4 in. thick
Demister — herringbone crimped steel mesh, 2 in. thick



Results

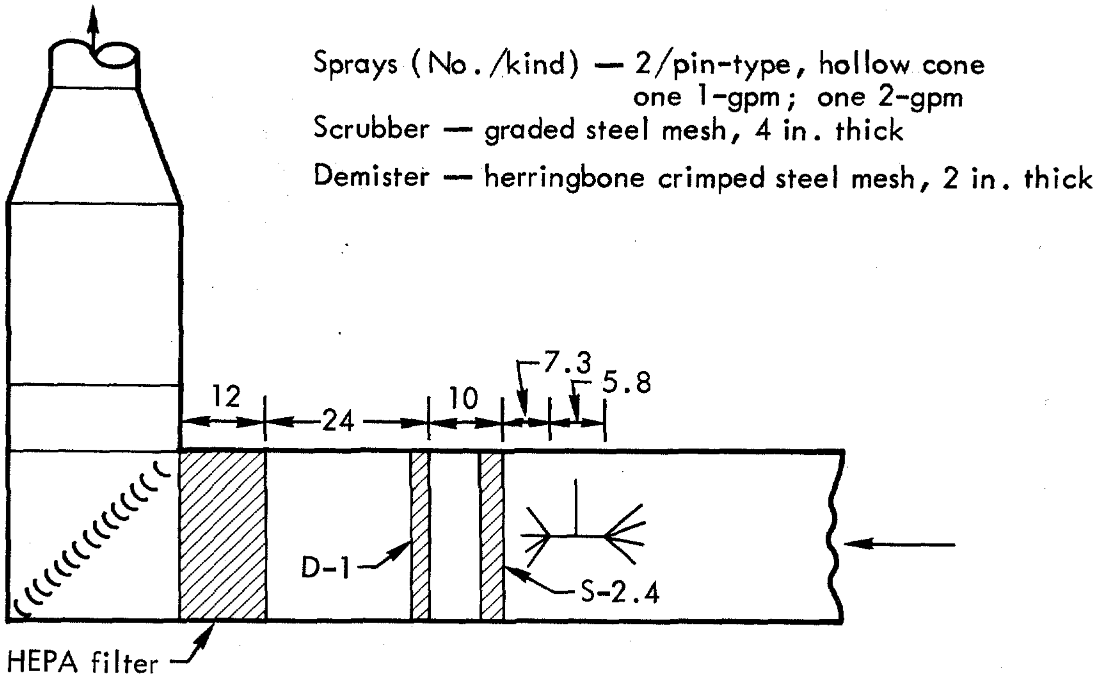
Water flow	gpm		
	3.0	3.0	3.0
Temperatures	°F		
Feed	1005	1250	1505
In spray	690*	885*	615*
After scrubber	-	-	-
After demister	265	300	360
After HEPA	270	300	350
ΔP's	in. H_2O		
Scrubber	0.13	0.13	0.13
Demister	0.04	0.04	0.04
HEPA	0.83	0.84	0.86
Total	1.00	1.01	1.03
Heat (absolute)	Btu/min		
Sensible	1740	1800	1815
Latent	6550	8200	9920
Total	8290	10000	11735

* Thermocouples not wet by sprays

Fig. 23. Data experiment S-6.19, 6.20.

Tests S-6.19/6.20 (Fig. 23)

With an arrangement similar to S-6.13, but with a larger pin-type nozzle aimed downstream, a temperature of 360°F ahead of the filter was achieved. In this case, the water flow was 3 gpm.



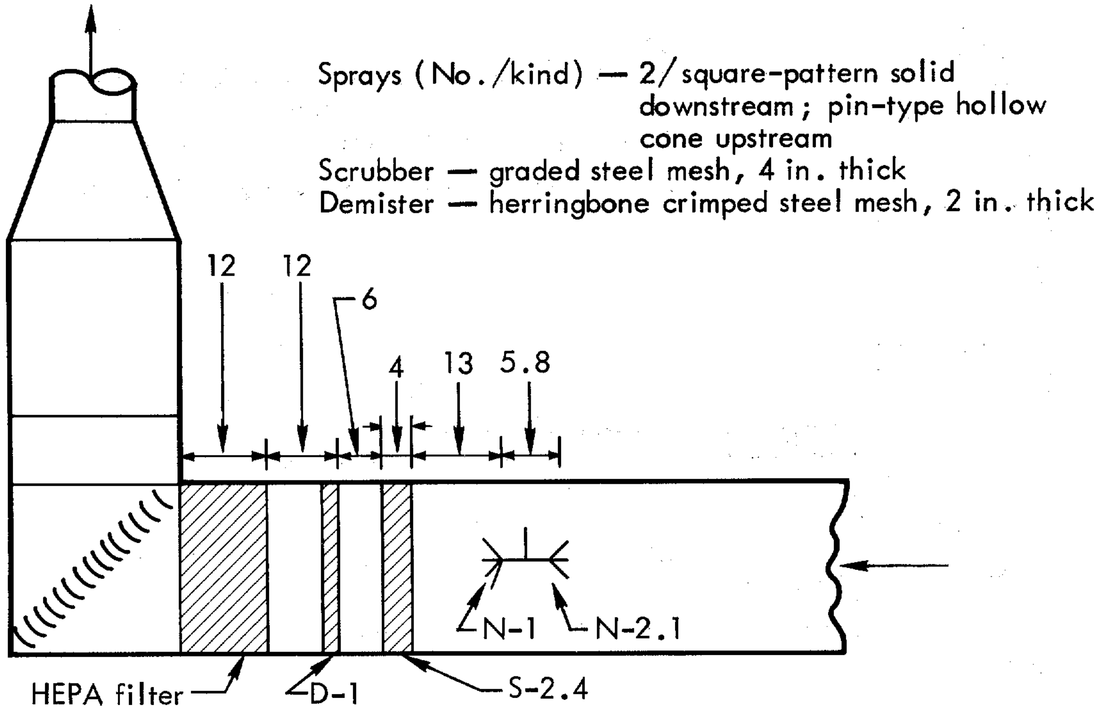
Results

Water flow	gpm			
	3.0	3.0	3.0	4.0
Temperatures	°F			
Feed	970	1250	1495	1495
In spray	600	745	770	840
After scrubber	-	-	-	-
After demister	275	340	375	315
After HEPA	245	285	330	285
ΔP's	in. H_2O			
Scrubber	.15	.14	.14	.15
Demister	.06	.06	.06	.08
HEPA	.97	.99	1.00	.98
Total	1.18	1.19	1.20	1.21
Heat (absolute)	Btu/min			
Sensible	1785	1850	1850	2260
Latent	7050	7600	9720	14000
Total	8835	9450	11570	16260

Fig. 24. Data experiment H-1.0.

Test H-1.0 (Fig. 24)

With the same arrangement but a higher water flow (4 gpm), the temperature of the filter was further reduced to 315°F, again with a pressure drop of less than 1/4 in. of water.



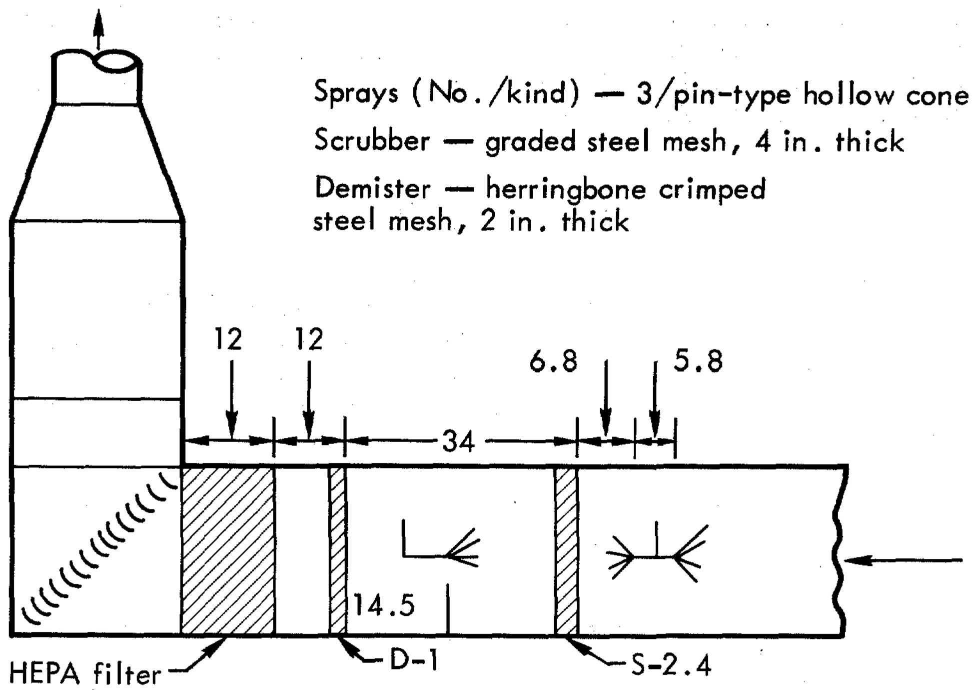
Results

Water flow	gpm	
	4.0	4.0
Temperatures	°F	
Feed	1010	1550
In spray	139	148
After scrubber	220	298
After demister	204	272
After HEPA	178	235
ΔP's	in. H_2O	
Scrubber	.18	.18
Demister	.11	.11
HEPA	1.21	1.29
Total	1.50	1.58
Heat (absolute)	Btu/min	
Sensible	2030	2120
Latent	10400	14200
Total	12430	16320

Fig. 25. Data experiment H-3.1.

Test H-3.1 (Fig. 25)

With the same arrangement and water flow as in H-1.0, but with a 4-in.-thick scrubber, the temperature to the filter was just under 300°F, but the pressure drop through the heat exchange was increased slightly.



Results

Water flow	gpm		
	3.5	3.5	3.5
Temperatures	°F		
Feed	970	1230	1450
In spray	595	780	980
After scrubber	-	-	-
After demister	315	390	460
After HEPA	275	350	395
ΔP's	in. H_2O		
Scrubber	.44	.43	.41
Demister	.15	.14	.14
HEPA	1.98	2.16	2.24
Total	2.57	2.73	2.79
Heat (absolute)	Btu/min		
Sensible	1390	1460	1420
Latent	13600	14690	16400
Total	14990	16150	17820

Fig. 26. Data experiment V-1.0, at 2000 cfm.

Test V-1.0 (Fig. 26)

In this test the air flow rate was increased to 2000 cfm under ambient conditions. To compensate for the greater heat load, a third (pin-type hollow cone) spray was added, facing upstream between the scrubber and the demister. The water-flow rate was adjusted to 3.5 gpm, on the theory that three separate spray zones might be more efficient than two. In this case, the temperature to the filter was 460°F for a feed temperature of 1450°F. Note that the pressure drop through the HEPA filter increased to 2.2 in. of water, and that through the heat exchanger system it increased to over 1/2 in. of water.

VI. Discussion

It will be noted that one difference between the S and H series of tests is the position of the HEPA filter. In the S series it was in the vertical run, and in the H series it was in the horizontal run, of the ductwork. The reason for these differences was the possible need for two different configurations at LLL. However, comparison of the results of Tests S-6.19/6.20 with those of the H series show no essential differences in the performance of the spray damper system.

The data indicate a progressive improvement in temperature reduction of the airstream ahead of the HEPA filter, coupled with a small pressure drop through the spray damper heat exchanger.

The arrangement shown for Test H-1.0 (Fig. 24) and operated at a water-flow rate of 4 gpm seems to be an optimum, based on our tests. We repeated this test for an hour at a feed temperature of 1500°F, with results essentially the same as shown in the original test.

As to the choice of spray nozzles, we believe that the pin-type hollow cone is more reliable than a solid cone, since, because of its construction, the pin-type hollow cone is less likely to become plugged with a small piece of rust or other debris.

The air temperature to the HEPA filter and the heat-absorption data for the tests made during the latter part of our work were plotted against the spray flow rate, by means of a least-squares fit (Fig. 27). It is clear that the air-temperature reduction is proportional to the water used, as is the heat absorbed.

At present we have added a subsystem for generating duplicable cool, warm, and hot smokes to the air stream, which in turn will be heated to various temperatures. We are also including the capability of adding various kinds of wetting agents to the spray system. By these means, we hope to be able to determine which of the smokes likely to be generated in a fire can cause the most trouble in plugging the HEPA filter, and what can be done about scrubbing them out. Thus, we hope to develop a system to protect the filters against the effects of a variety of fire conditions.

References

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2. ''Fire Tests of Building Construction and Materials,'' American Society for Testing and Materials, ASTM E-119-69, Part 14 (1970).

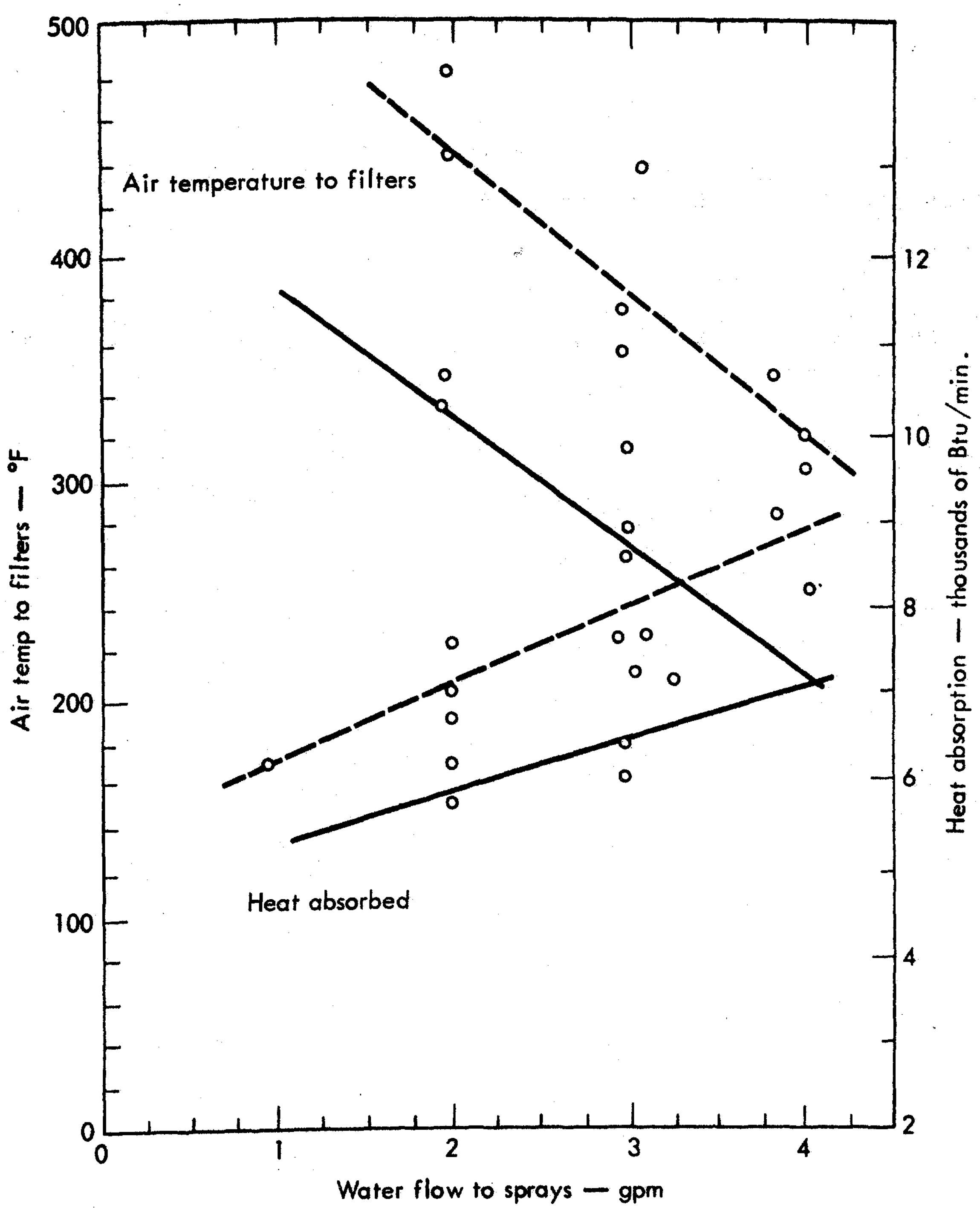

Fig. 27. Cooling of heated air (1000 cfm) with hollow-cone water sprays and various scrubber/demister combinations. Dotted lines represent a feed temperature of 1500°F; solid lines represent 1000°F feed temperature.

DISCUSSION

FISHER, J: How do you propose to protect these filters from all that water if you run it all the time? Do you not expect the filters to be degraded?

GASKILL: Let me answer that by saying that we have run the filter system using the best arrangements we had for about two hours at a temperature of about 1,500°F with the water flowing all the time, and we found no change in the pressure drop. We also ran an experiment where we purposely reduced the temperature and let the water run. The temperature in front of the filter was 200 to 205°F (i.e., below the boiling point of water) and we found no difficulty whatsoever with the filter. We took it out immediately afterwards and it was dry. Don't ask me why; it is merely submitted as a fact. Water runs only in the event of a fire. We are also doing triggering experiments to tell the water when to turn on, and, hopefully, it will do so automatically.

FIRE PROTECTION IN CAVES, CANYONS AND HOT CELLS

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Richland, Washington

Abstract

The Atlantic Richfield Hanford Company in Richland, Washington, under contract by the Atomic Energy Commission, is conducting a study on fire characteristics in caves, canyons, and hot cells, and methods of detecting and extinguishing these fires. This paper presents results that have been obtained and outlines the direction the program will take in the future.

Tests have been made of various methods for detecting and extinguishing fires in a full-size simulated process cell. Information is presented on fire development, detection, and extinguishing times for fires in typical hot cells. Data are presented on smoke density and particulate size from fires of typical hot cell combustibles. Attempts were made to cool and remove the particulate matter from the gaseous effluents from these fires. Data were taken on temperature patterns and their effect on the optimum location of fire detectors. Results are presented on the effect of a fire on the ventilation system, such as turbulence within the hot cells, pressure, gas volumes, and mixing of the hot gaseous effluents with effluents from adjacent hot cells.

Future efforts will be directed toward studying problems of detecting and extinguishing fires in heavily shielded cells using a wider variety of combustibles, as well as studying the role radioactivity plays in hot cell fires.

I. Introduction

The problem of fires in caves, canyons, and hot cells has not received a great deal of attention in the past. At first glance, a fire that involves a relatively small amount of combustible and is enclosed almost entirely by heavy concrete walls does not appear to pose much of a threat. But because of the quantities of radioactive contamination usually present and its potential for damage if released to the atmosphere, it is well to know as much about the fire potential as possible.

The Division of Operational Safety of the Atomic Energy Commission requested that the Atlantic Richfield Hanford Company undertake to study the subject of fires in caves, canyons, and hot cells with the intent of learning as much about such fires as possible and how to deal with them.

The first step was to define the problem. A questionnaire was sent to AEC installations that include caves, canyons, and hot cells to determine the characteristics of these existing facilities, including their fire potential and fire protection capabilities. Briefly, we found the size to vary from the Hanford Purex canyon, which is over 1,000 feet long over 50 feet wide and 54 feet high, to some of only a few cubic feet. The combustibles varied from none at all to a large quantity of kerosene-like solvent. The exhaust system may be unfiltered or have as much as twelve high efficiency particulate air (HEPA) filters in series.

The fire detection and extinguishing provided for those caves and hot cells varied as much as the cells themselves. Detectors, where provided, were of every type available. Thermocouples were the most prevalent with rate-of-rise detectors second.

Extinguishing methods for the cells were of all types. The three favorites were dry chemicals, water and Halon 1301, in that order.

These facilities do have a few features in common. They are all shielded, although the thickness varies widely, and they all have a form of ventilation planned to contain radioactive contamination. It is obvious that it is at least unwise to seek to prescribe a single fire protection plan for all such enclosures.

A literature search [1] was undertaken to determine the present state-of-the-art of fire protection for caves, canyons and hot cells. It was at once apparent that fire protection is an old and well-developed subject and far from a stagnant one. Veritable libraries of information are available including codes, standards, guides, reports, and other references on all phases of fire protection. In addition, many people in code committees, insurance groups, and investigative bodies are constantly adding to this accumulation. Much of this information can be used in planning the fire protection for caves, canyons, and hot cells. At the same time, manufacturers are adding new products and improving old ones to add to the tools available to the fire protection engineers.

A test facility was built to test detection and extinguishing materials, equipment, and methods as well as to collect information on how fire develops in various fuels and under varying conditions in a hot cell. A program of testing is underway and will continue in conjunction with other phases of the program. The facility, which is described in CONF-710401[2] and shown on Figure 1, consists of a 12 by 12 cell (inside dimensions) with an adjustable ceiling. It has an exhaust system in which washers, filters, demisters, and instrumentation is installed as needed (see Figure 2).

The fire that can be expected in a hot cell depends, of course, on the fuel type, quantity, and arrangement; on the ventilation of the cell, quantity and distribution of the air; and on the heat absorbing and reflecting surfaces in the cell.

It is understood that these fires can be of an infinite variety, but Figure 3 shows one type fire that may occur. This one was in 1 gpm of 70 percent normal paraffin hydrocarbon (NPH) - 30 percent tributyl phosphate (TBP) fuel spilled on the floor of the 12 by 12 cell with 2,000 cfm of air drawn from the cell by the exhaust system.

Note that the fire is slow to develop in the high flash point (158° F.) solvent. When the solvent and the cell become sufficiently heated, the fire develops rapidly to a maximum and then begins to recede. This corresponds to a point where the cell pressure approaches zero and the inflow of air is at a minimum. Near this point, the smoke release hits a high point and then reduces.

After the initial surge and reduction, the cell temperature continues to rise slowly and the smoke density decreases. The static pressure at the bottom of the 40 foot deep cell is lower than at the top because of the chimney effect of the hot gases. The oxygen content of the air gradually reduces as the temperature of the cell increases.

The program undertaken to study fires in caves, canyons and hot cells is divided into several categories:

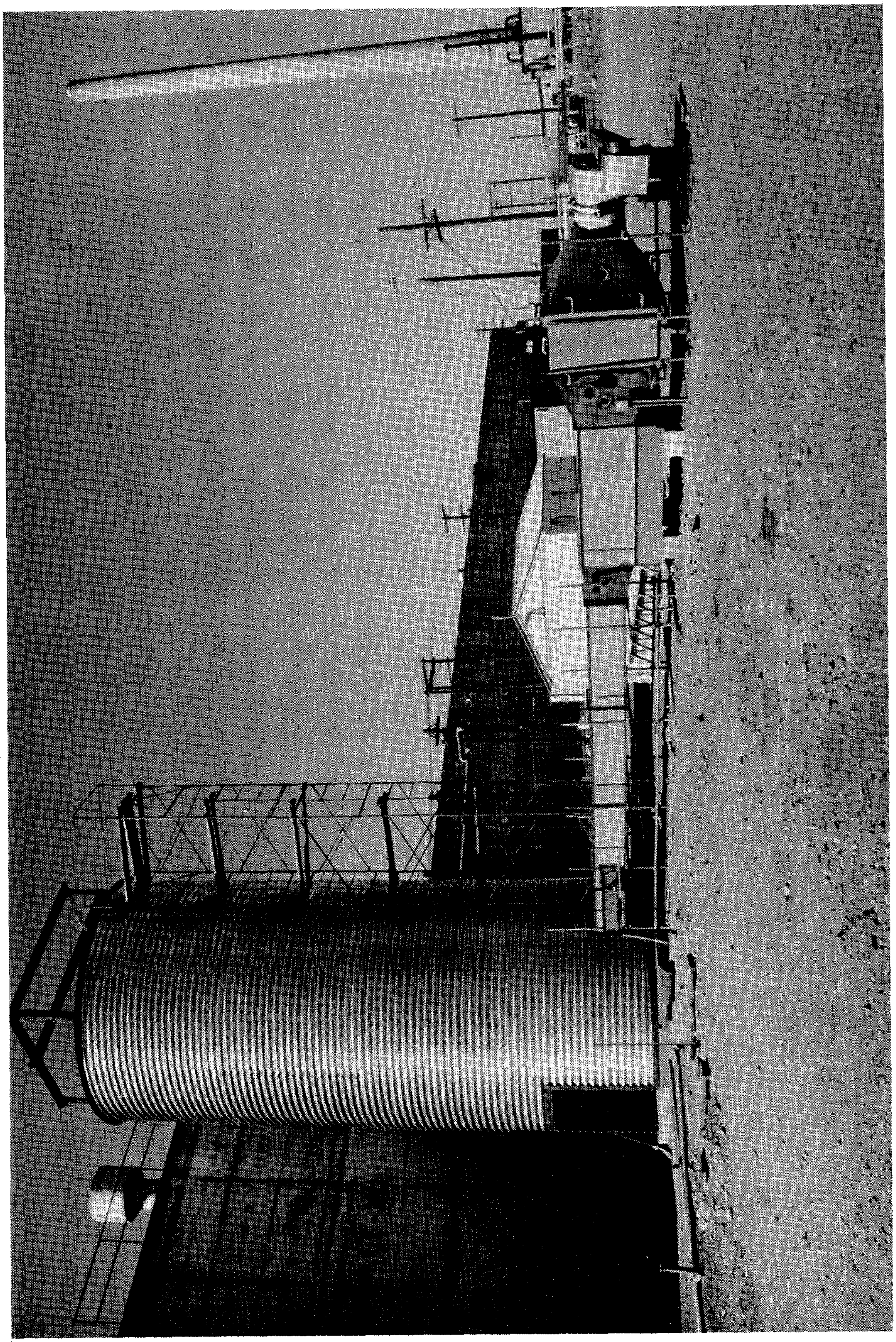


Figure 1. Fire Test Facility

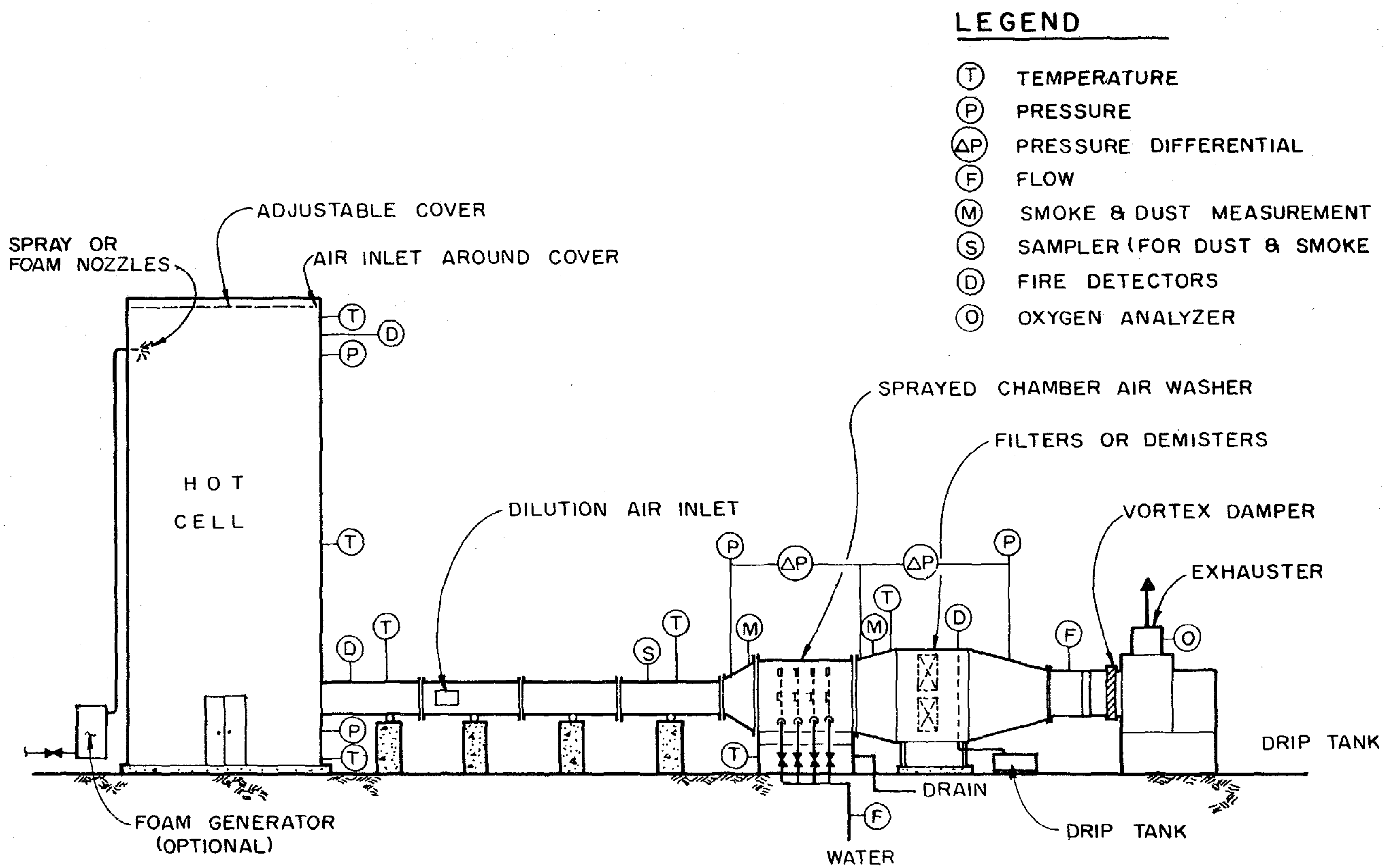
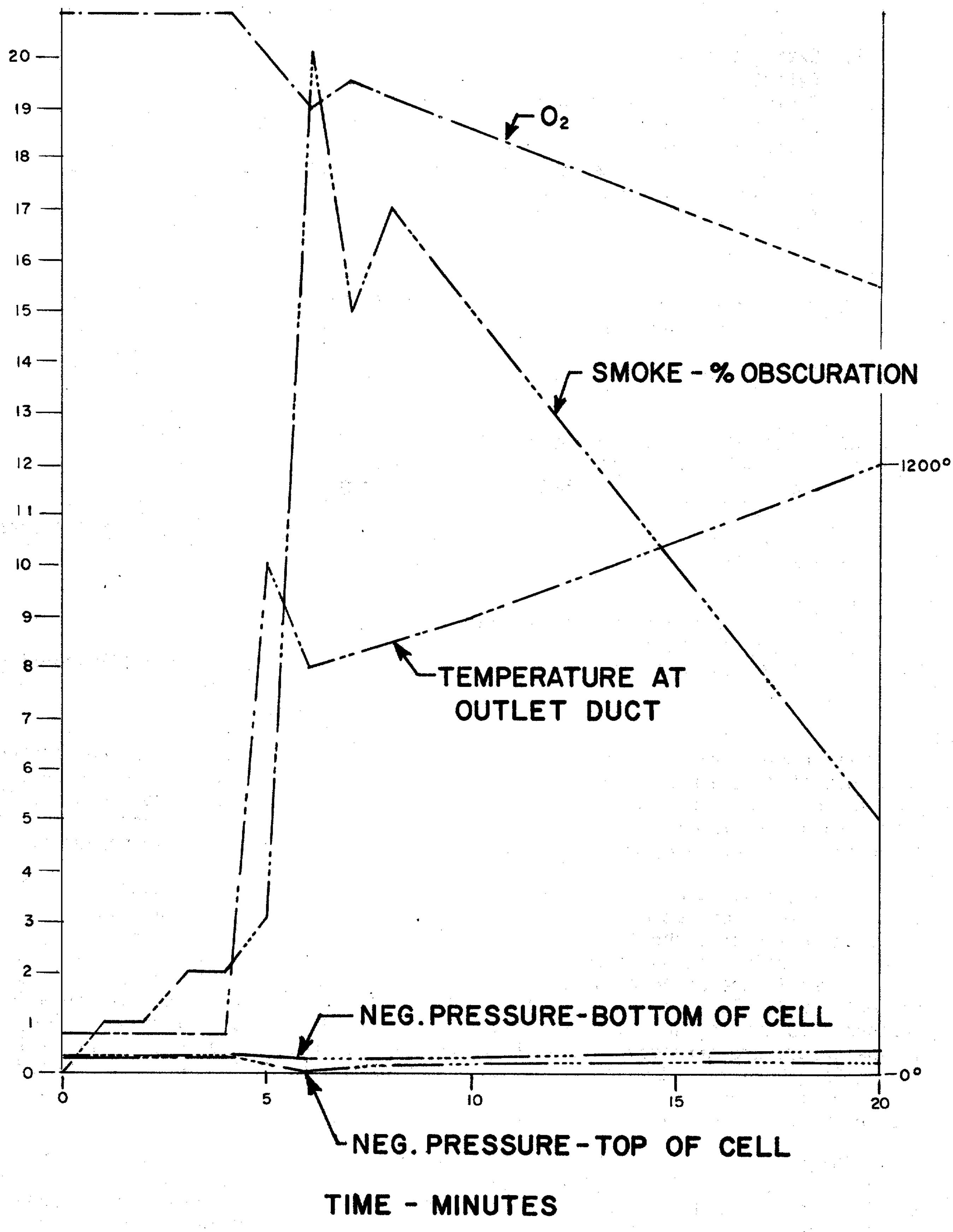


DIAGRAM OF FIRE TEST FACILITY

FIGURE 2



20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
5
10
15
20
1200°
0°
O_2
SMOKE - % OBSCURATION
TEMPERATURE AT OUTLET DUCT
NEG. PRESSURE-BOTTOM OF CELL
NEG. PRESSURE-TOP OF CELL
TIME - MINUTES

FIGURE 3

1. Extinguishing.
2. Detection.
3. Protection of filters during fires.
4. Effect of ventilation control on fire suppression.
5. Effect of radiation on combustion.
6. Effect of solvent temperature on the ignition and burning process.
7. Release of airborne contamination from burning radioactive solvents.
8. Protection of miscellaneous cell openings.

II. Extinguishing

It is desirable that the extinguishing media for use in caves, canyons, and hot cells meet several criteria.

1. The supply should be inexhaustible to cope with a fire of any size or duration.
2. It should leave no mess to clean up.
3. It should be simple and reliable to apply.
4. It should not damage equipment or process.
5. It should be completely effective.

It is apparent that no agent meets all of these requirements. Of the several types of agents available are:

1. Water
2. Inert gases, including CO_2 and Halon
3. Dry chemicals
4. Foams, including high expansion, low expansion, and aqueous film-forming foams
5. Steam

Water meets the first requirements if the plant water system has been designed to withstand the maximum credible accident. However, it does have a clean-up problem, especially now that all contaminated wastes are concentrated and stored. It can damage equipment, especially electrical equipment; and it is not 100 percent effective, for instance, when dealing with metal fire or with organic solvents.

Extinguishment with water was tested on the organic solvent most frequently used in nuclear separations processes. A variety of nozzles were used including standard sprinklers, three types of fog nozzles, water foam nozzles, and a spray wash-down nozzle. It was found that under certain conditions the water will extinguish fires in the organic solvent. If the fire has been allowed to get very hot, the water will flash to steam on the hot surfaces and extinguish the fire in a few seconds. Continuing the spray will cool the cell and prevent rekindling. Also, if the sprays are arranged so that they cover all of the fire directly, they will extinguish the fire. When the nozzles were located high in the cell and some of the solvent was under the tank, the fire resisted prolonged application of water whether by fog or spray.

The inert gases have the advantage of leaving the least mess but have the serious disadvantage of a limited reserve. We have done no testing of gases in the large cell because of this. Information is available for the design of such systems, and they will extinguish the fire. However, the problem of rekindling, especially in Class A materials, must be dealt with. Small caves or hot cells, where the ventilation is low, present much the same fire protection problems as glove boxes. Halon-1301 is being adapted to many glove boxes as well as small hot cells at the Savannah River Laboratory. These compact systems should be highly effective when connected to an alarm system and supplemented as necessary with water.

Dry chemicals have the disadvantages of creating a mess in the cell, having a limited capacity, and allowing rekindling of the Class A fires. They also tend to plug the exhaust filters. Their use should be limited to places where their rapid action is needed and can be effective as a supplement to another system.

The foams, as a group, are very effective agents for dealing with most cell fires, especially in Class A and Class B materials.

Many kinds of foams were tested on organic solvent fires and all were effective. They do not meet the criteria of having an inexhaustible supply, but it is easy to provide a supply sufficient to cope with any credible fire. It has the advantage of being backed with water without any addition to the system.

The high-expansion foam was tested on organic solvent fires, and while not as effective as the other foams, it did an adequate job of extinguishing the fire. The main problem is finding a suitable means to apply it. Because it cannot be depended upon to produce a good foam when using air containing smoke from a cell fire, large openings must be provided in the shielding walls for application. Smoke or air must also be exhausted from the cell rapidly enough to prevent pressurization.

Tests of high-expansion foam showed that 2,000 cfm of foam did not extinguish an organic fire nearly as rapidly as 40 gpm of low-expansion foam or aqueous film-forming foam. In addition, the light foam was carried into the exhaust system where it would have plugged the filters. Efforts to stop it with screens, sprays, and air washers were largely ineffective. Figure 4 shows the foam used to extinguish an organic fire in the test cell. Figure 5 is a view looking into the filter housing showing it almost half full of foam in spite of efforts to remove it from the exhaust stream.

The low-expansion foams tested were very effective in extinguishing the fires (figure 6). The foams were persistent (figure 7) and would resist rekindling and burnback. They also were difficult to clean up requiring direct and forceful water spray. When applied through any other than a water-foam nozzle, the foam was very poor and ineffective. These materials could well be considered for hot cell use if their chemical makeup is compatible with the waste system and means can be provided for cleanup.

Aqueous film-forming foams (figure 8) are relative newcomers to the fire-fighting scene. When mixed in the proper proportions with water, they form a highly mobile foam that floats on organic solvents (figure 9). They are also strong wetting agents making them effective on both Class A and Class B materials. Several kinds of these foams were tested and found to be especially effective on organic solvent fires. Their main drawback is their chemical stability and adverse effect on the waste concentration process. A method has been developed to cope with this in the Hanford waste streams. This and the fact that it is very effective when applied through existing sprinkler heads has allowed this material to be included in the fire extinguishing plans of two existing processing plants.

Steam has been used in the past in many fire extinguishing systems such as on naval vessels and factories where large quantities of steam are available. Lately this has fallen into disuse. For application to caves, canyons, and hot cells, it

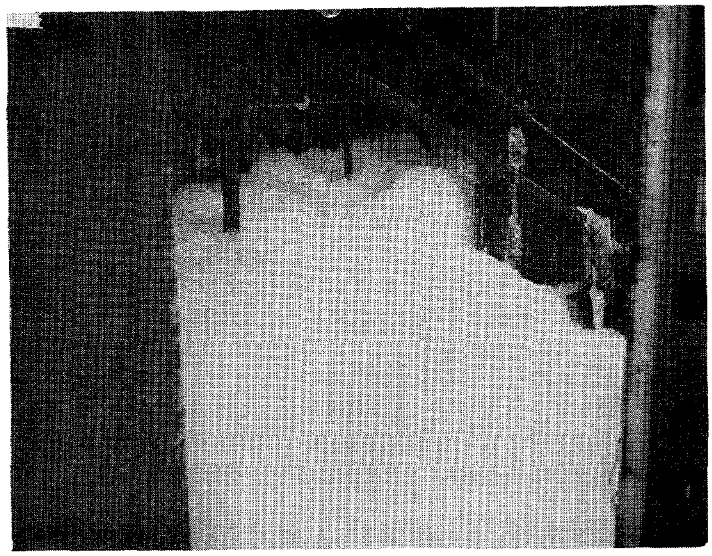


Figure 4. High-expansion foam extinguished the fire when its depth reached eight inches above the tank bottom.

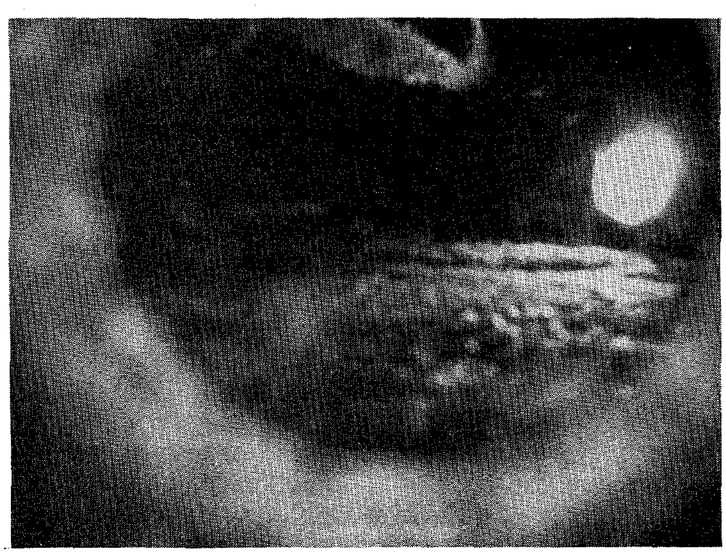


Figure 5. High-expansion foam was carried down the exhaust duct through the washer and half filled the filter housing.

Figure 6. Low-expansion foam at 40 gpm gives an effective extinguishing blanket.

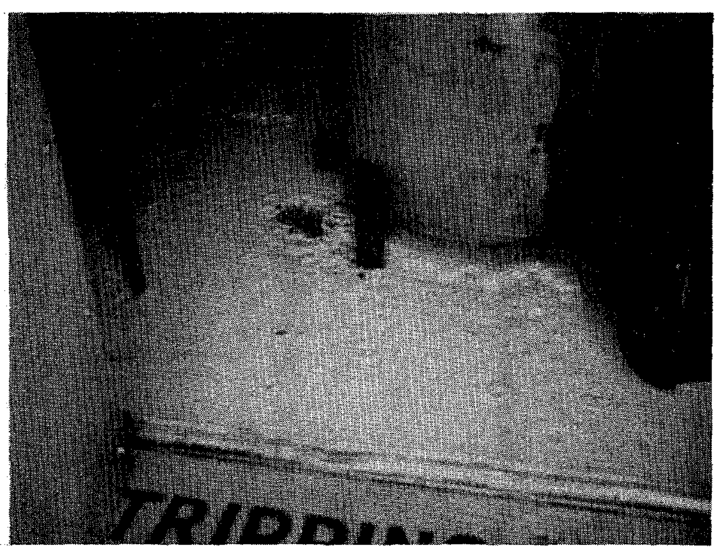


Figure 7. Low-expansion foam resists a 40 gpm wash-down for several minutes. Three days later, it had dried with little volume reduction.

Figure 8. Several types of aqueous film-forming foam concentrates were tested.

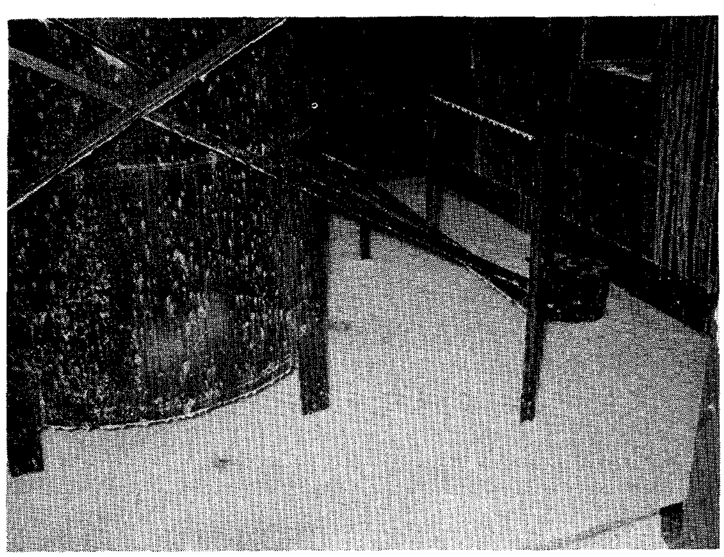


Figure 9. One gallon of six percent film-forming foam made an effective blanket over a layer of organic solvent.

might be considered in special cases where the steam supply is large enough and danger to equipment and exhaust filters is not a problem.

III. Fire Detection

The matter of fire detection in shielded cells is a subject that has been covered by Arthur J. Hill, Jr. of Savannah River Laboratory in his documents DP-1242[3] and DP-1261[4]. The information contained therein was used as a starting point for testing of detectors in the simulated hot cell.

The problems of detecting hot cell fires is unique in some respects:

1. Radioactivity is usually present in sufficient intensity to interfere with the operation of some types of detectors and to limit the life of others.

2. Hot cells are usually arranged so that maintenance of detectors is difficult because of the necessity of penetrating the shielding with electrical or pneumatic leads and because of the limited access to personnel.

Examples of several types of detectors that may be considered for hot cells are shown on Figure 10. From left to right they are Fenwall ultraviolet light detector, Pyrotronics infrared light detector, Infrared Industries infrared detector, and Fenwal continuous fire detector. Fenwal rate-compensated thermal detector is shown on the right with a stainless steel sheathed heater for remote testing and an insulating coupling. A stainless steel sheathed thermocouple is in the foreground.

Figure 11 shows how the heater can be used with the rate-compensated thermal detector for remote testing and supervision. The sensitivity of this model is not as high as the others, but its simplicity and ruggedness make it a good choice for hot cells.

The stainless steel sheathed thermocouple is a simple rugged device and is in use in many hot cells.

The reliability of the detection system for caves, canyons, and hot cells is of vital importance. It is desirable that it be sensitive and rapid acting; but if necessary, these characteristics can be sacrificed for greater reliability. Above all, the detectors must survive radiation, corrosive fumes, mechanical abuse, and often neglect and still detect a dangerous fire without fail in time to control and contain it. Remember that there really is no typical cave, canyon, or hot cell. Each is unique to some extent. Consider carefully the needs and characteristics of each installation, before selecting a fire detection system. Perhaps in some cells, two types of detectors should be used.

Some of the characteristics of the available detectors of interest to hot cell application are:

1. Heat detectors are generally slower to react if encased so that they are protected from corrosion or mechanical damage. Models available present some problems of supervision and testing. The rate-compensated thermal detector has good reliability because it can be protected and is of simple sturdy design. Sensitivity is adequate if well located and the activating temperature setting is low. In some hot cells they may be installed in

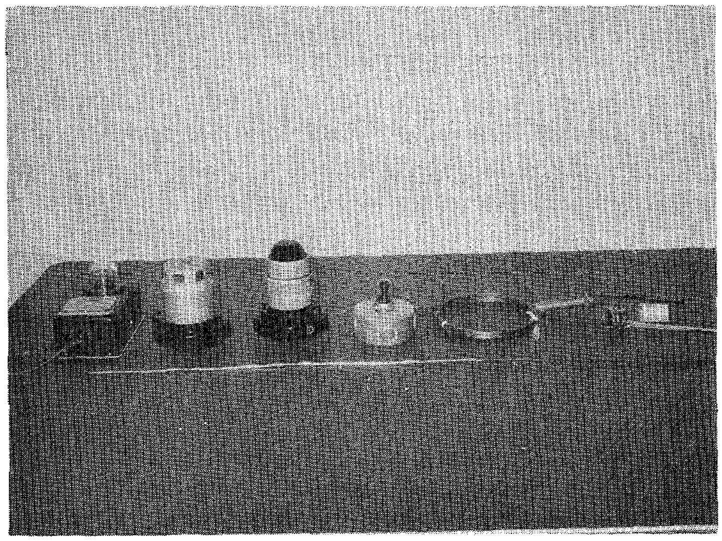


Figure 10. Types of Fire Detectors

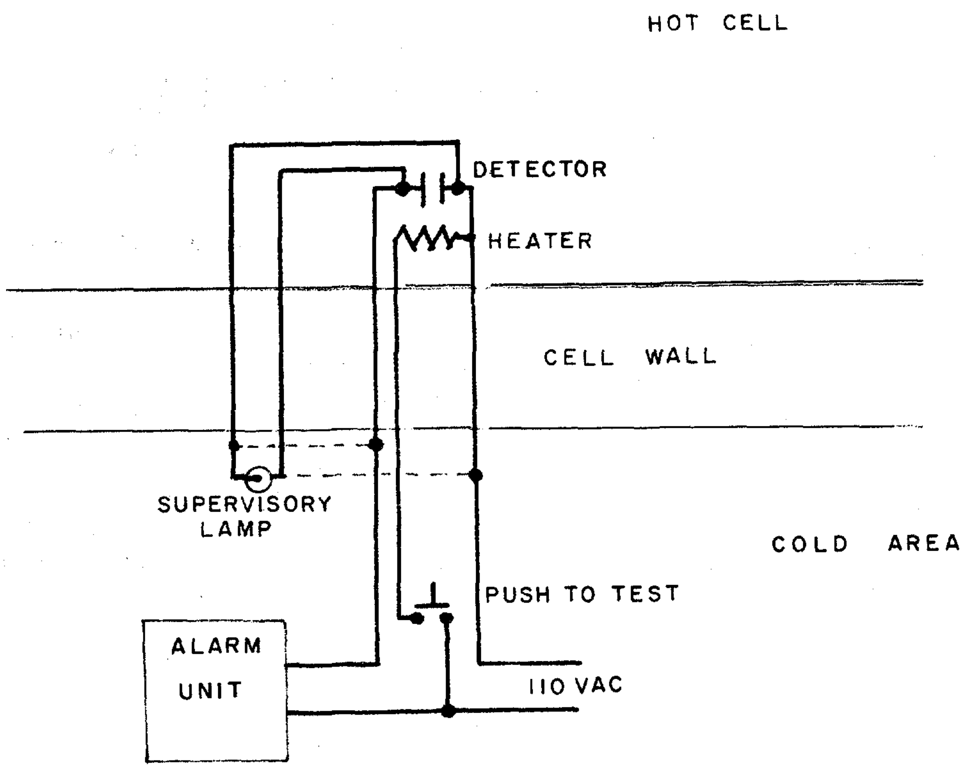


Figure 11. Diagram for installation of thermal switch in a hot cell.

wells from the clean side as has been suggested for glove boxes[2].

2. Products of combustion detectors are sensitive and are capable of detecting fires even before they become visible. However, they are not adaptable to the intense radiation or corrosion fumes found in hot cells. In the exhaust ducts, they were found to be less sensitive than other detectors[3]. They are sensitive to dust and vapors and require excessive care and maintenance in hot-cell use.

3. Smoke detectors that are a light source and a light detector are subject to false alarm from dust or chemical fumes and are somewhat difficult to incorporate into hot-cell design to allow for maintenance.

4. The surveillance detectors which include ultraviolet, infrared, and other light detectors are fast acting but are subject to false alarm and failure in the hostile environment usually found in hot cells.

The best location for the detector is closely related to the convection currents that will be caused by the fire and the ventilation system. The tests indicated that both temperature and products of combustion can be detected early during the fire at the top of the cell directly above the fire even for the tallest cell. However, the hottest temperatures were nearly always found at the exhaust port.

IV. Protection of Filter During a Fire

This phase of the program has been curtailed because of the work in progress at Lawrence Livermore Laboratory on the same subject. Smoke data was taken while conducting other experiments and data on cooling exhaust gases while protecting the fan and duct work. Conclusions are that the smoke from the organic solvent fires is hard to remove in a sufficient quantity to add significantly to the life of the exhaust filters. Typical smoke from an organic solvent fire is shown on the electron microphotograph, Figure 12. It is of a size and character that resists removal by simple water washes. The quantity of smoke varies widely with the character of the fire. The average fire in the test cell appeared to produce about one milligram per cubic foot, but some fires contained as much as three milligrams per cubic foot. A single 1,000 cfm-rated HEPA filter was loaded with soot from a solvent fire. Five gallons of solvent burned in a cut-off steel drum increased its pressure drop from one inch to four inches at rated flow.

V. Effect of Ventilation on Fire Suppression

Down-draft ventilation is more common in the large chemical processing cells than up-draft. The superficial down-draft velocity is only a few feet per minute. Thermals from a fire are many times this velocity. Figure 13 shows one gas-flow pattern that was calculated from a computer program prepared by Battelle-Northwest. The streamlines show direction of flow but give no value for their velocity. The highest velocity is where the lines are closest together.

Figure 14 shows the temperature patterns from the same fire. Note that the high temperatures are near the exhaust point of the cell, drawn there no doubt by the high velocity air patterns. Figure 15 is a photograph of a fire in the cell that shows much the same pattern. The program that produced these plots is being improved and included in a computer modeling program for hot cell fires at Battelle-Northwest at this time. It is hoped that it will be possible to predict the action of a fire in a cave, canyon, or hot cell with reasonable accuracy using the program they develop.

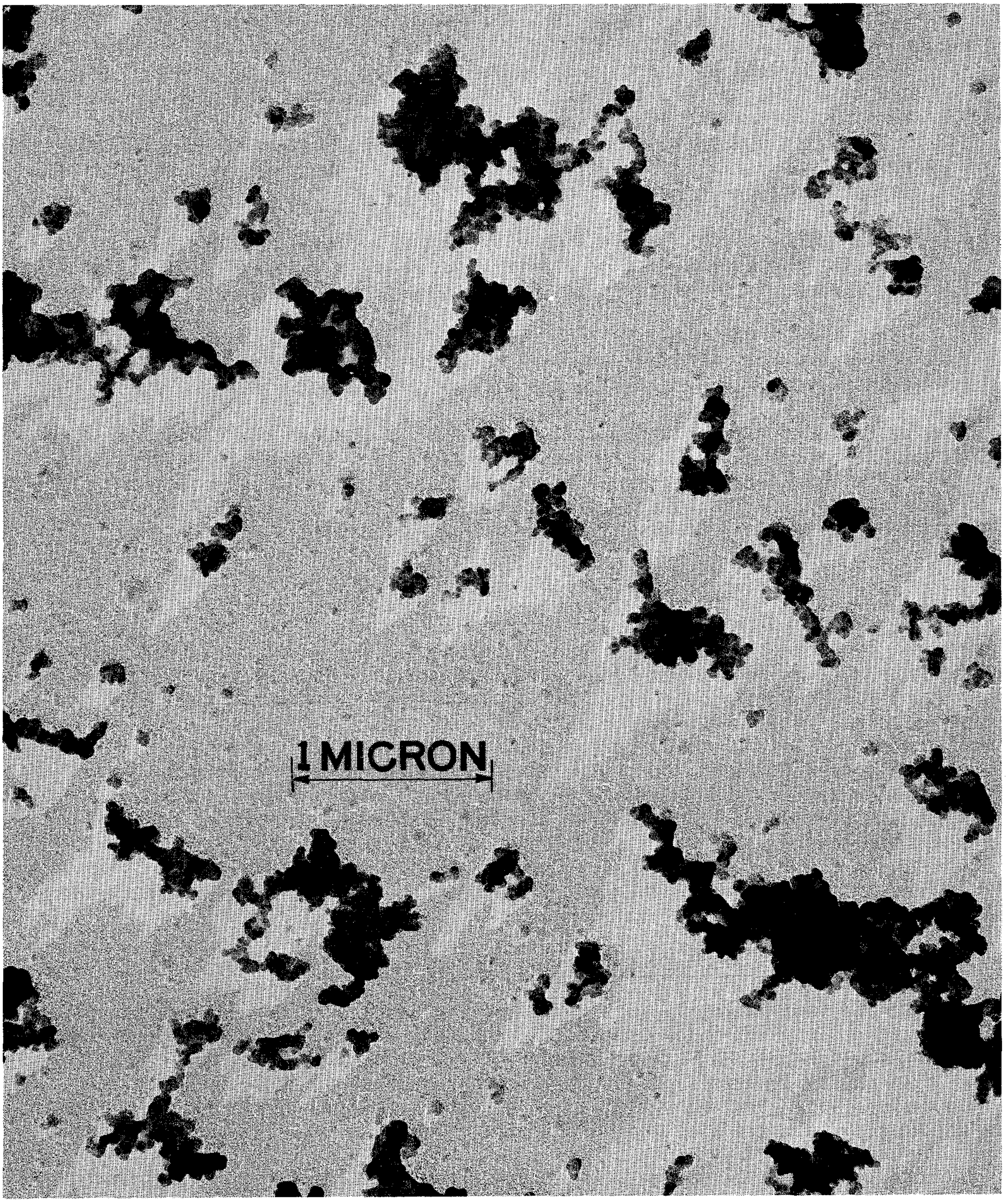


Figure 12. Smoke particles from 70 percent normal parafin hydrocarbon, 30 percent tributyl phosphate fire

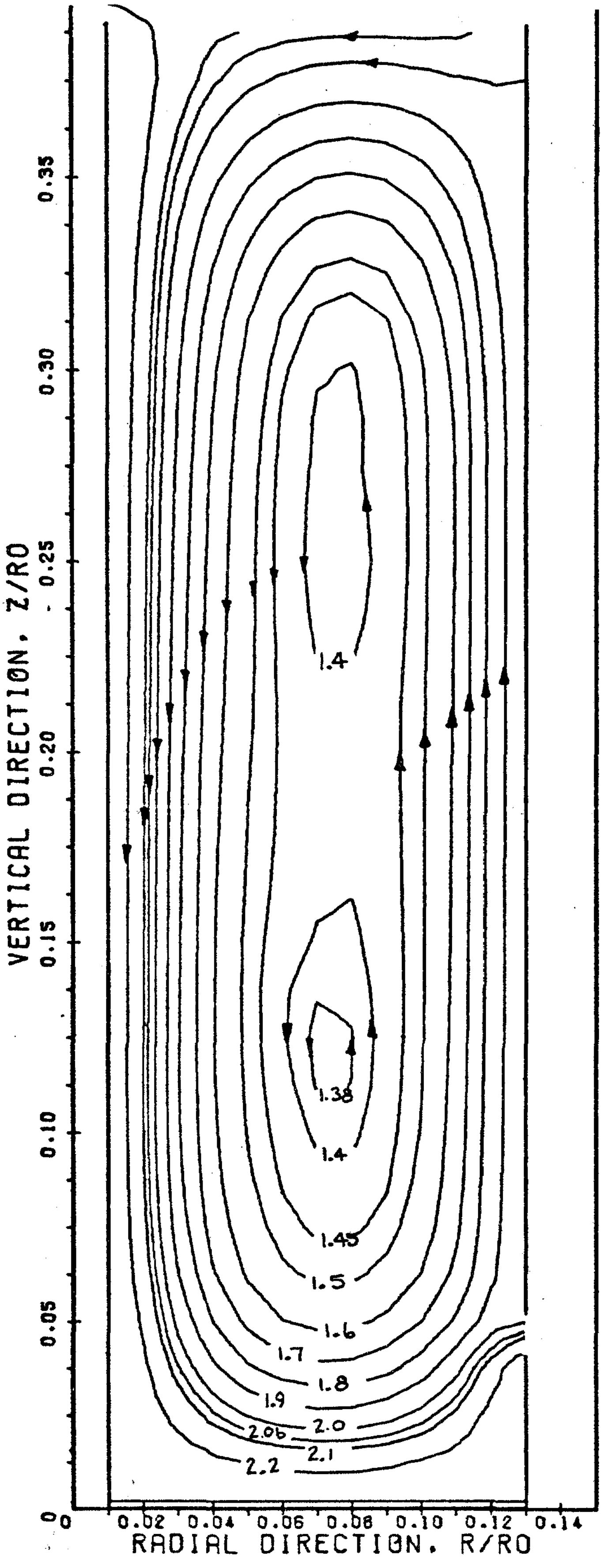


FIGURE 13. STREAMLINES FOR HOT CELL FIRE

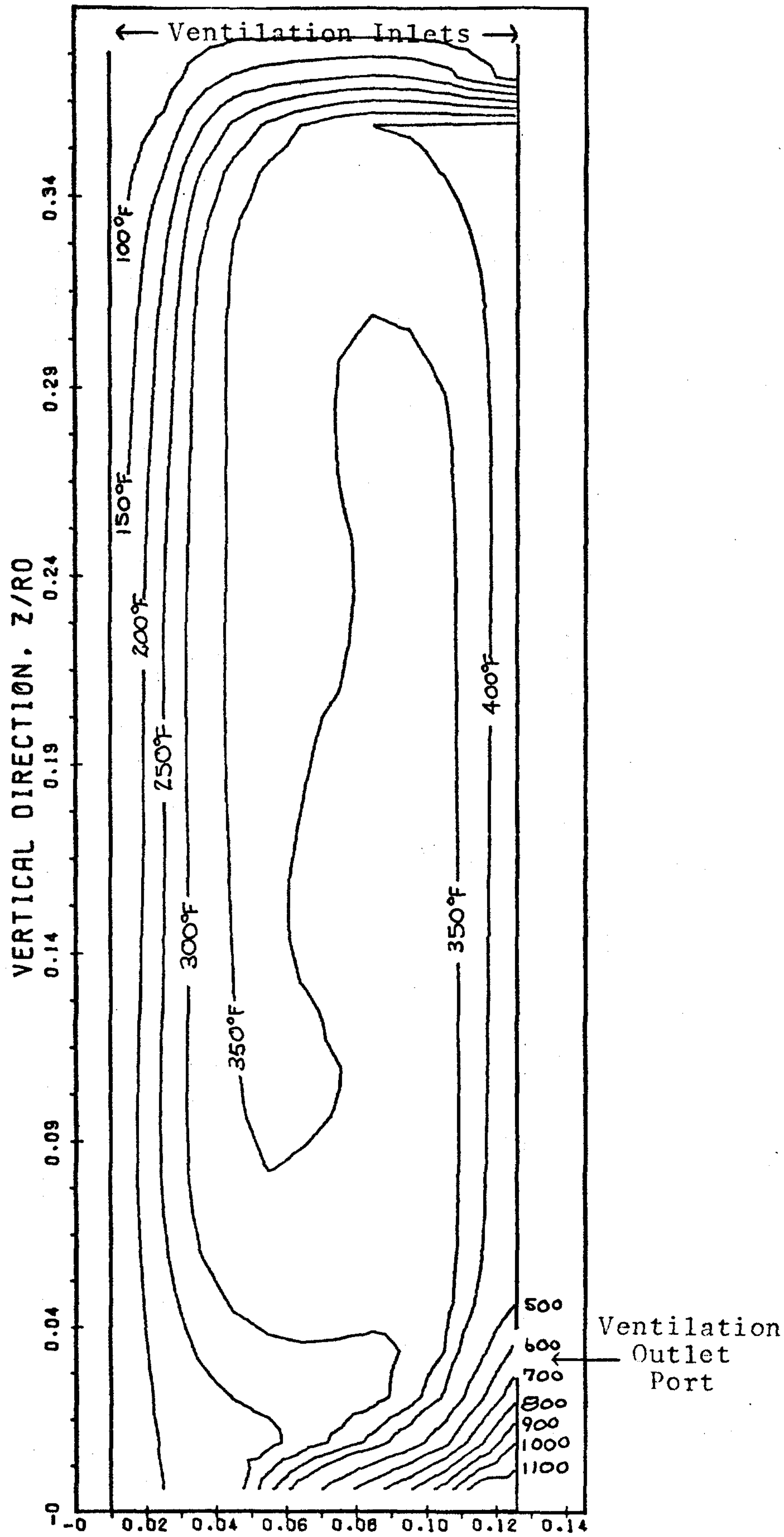


Figure 14. Isotherms for Hot Cell Fire

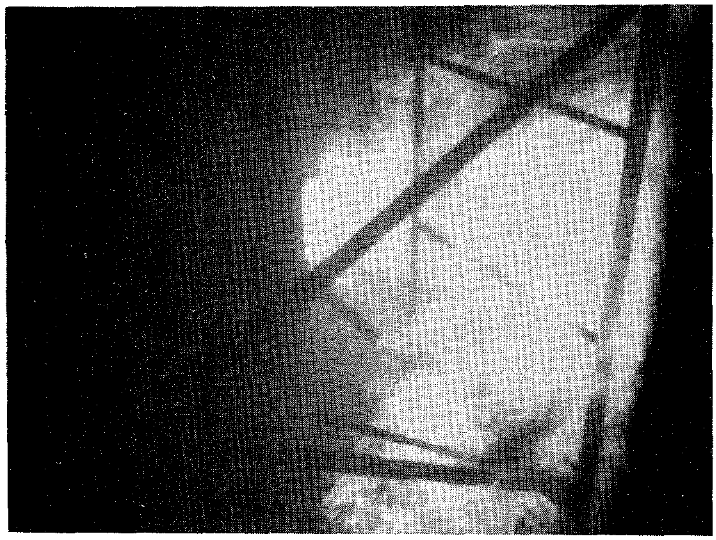


Figure 15. Fire is drawn to ventilation outlet.

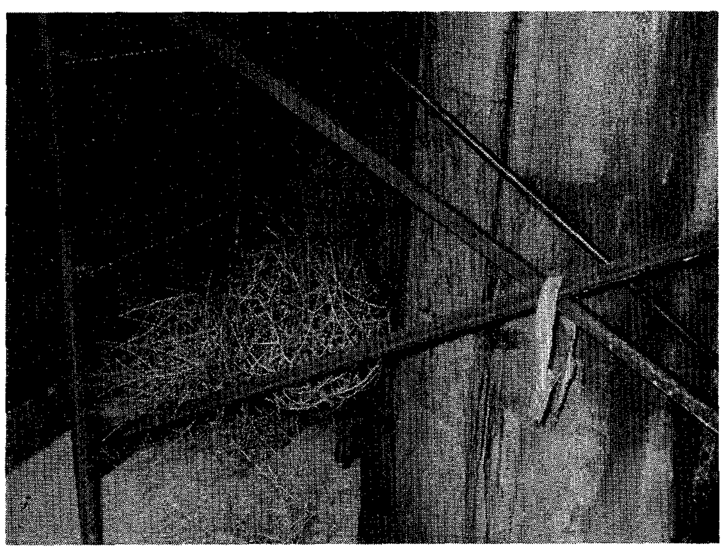


Figure 16. Dry weeds did not burn one side of tank when fire reached 1300°F on the other.

From the test data thus far, it appears that restricting the air to a hot cell fire can severely limit the fire and thus expedite its extinguishment and limit the damage. This has not been thoroughly tested in the test facility because of some chance of an explosion. It is hoped the modeling program will show the way to avoid this problem or if it really exists.

VI. The Effect of Radiation on Combustion

It is known that some work has been done that suggests that the presence of radiation may have a significant effect on the burning process.

A literature search revealed studies which showed the effects of nuclear radiation on the combustion of hydrocarbon-air mixtures. The combustion efficiency is increased and flame speed is increased when flames and fuel-air mixtures are irradiated with very intense beta sources. The minimum amount of radiation necessary to show any noticeable effect on combustion is very high (about 2,000 curies of beta per cubic inch). Organic solvents in a radiation field this high would probably not be encountered in caves, canyons, and hot cells.

VII. The Effect of Solvent Temperature on the Ignition and Burning Process

Organic solvents are sometimes used at elevated temperatures in caves, canyons, and hot cells. The additional danger from easier ignition and greater rapidity of fire development is suspected but not quantitatively known.

The ARHCO Separations Chemistry Laboratory is preparing to conduct experiments into the effect of initial temperature of the organic solvent on the ease of ignition, rate of combustion, and the rate of cell pressure increase.

Current efforts are confined to preparing laboratory facilities, gathering information on solvents, and reviewing methods of obtaining the required data.

VIII. The Release of Radioactive Contamination from Burning Radioactive Solvents

It is known that airborne radioactive contamination is released from a fire in a radioactively contaminated organic solvent. The quantities released and the factors affecting this release are not quantitatively known. This information is needed by the industry to evaluate the hazards of release of radioactive contamination from a fire in a cave, canyon, or hot cell. This will influence the design of safety measures to cope with such fires.

The assistance of Battelle-Northwest has been engaged to carry out this investigation. They will also investigate the possible influence of the presence of water on the release of contaminants. They plan to investigate the release of a variety of radioactive contaminants from fires in five of the organic solvents most commonly used in caves, canyons, and hot cells.

IX. Protection of Miscellaneous Cell Openings

It is recognized that cave, canyon, and hot cell openings such as doors, windows, coverblocks, manipulator sleeves, ventilation inlets and various service ports are the only exit points for radioactive contamination other than the ventilation exhaust system. Existing designs for these openings may not be adequate to cope with a fire. Careful design from existing information on fire hazards may be adequate in many cases. However, improved means of assuring the integrity of some types of openings during a fire are needed. Plans are being made to test some hot cell opening designs for resistance to fire.

References

1. H. A. Lee, "A Literature Search and Analysis of Fire Protection in Nuclear Hot Cells and Filtered Exhaust Systems", ARH-1918, Atlantic Richfield Hanford Company, Richland, Washington, June 15, 1971.

2. CONF-710401, "Proceedings of the Rocky Flats Symposium on Safety in Plutonium Handling Facilities", USAEC DTI, pp. 237-247, (April 14, 1971).

3. A. J. Hill, "Fire Prevention and Protection in Hot Cells and Canyons", DP-1242, Savannah River Laboratory, Aiken, South Carolina, April 1971.

4. A. J. Hill, "Automatic Fire Extinguishing Systems for Glove Boxes and Shielded Cells at the Savannah River Laboratory", DP-1261, Savannah River Laboratory, Aiken, South Carolina, June 1971.

DISCUSSION

BURLOW: Perhaps I shouldn't broach this at the present time but everybody seems to have avoided the subject of charcoal filters in one aspect. I realize this is a can of worms, but one aspect particularly is the prevention of self-ignition due to radioactive iodine on unactivated charcoal filters, and I wonder if you or Mr. Gaskill would have any words of wisdom on that particular subject. I realize it is an important one and is one that I had rather hoped I would hear here today.

LEE: We haven't done anything with that at our facility. I doubt that Jim Gaskill has. I think that question should probably be referred to Jack Morrow, since he has done the only work on that subject that I am aware of.

MORROW: I guess most of you recall that after the Air Cleaning Conference two years ago we did some work on the extinguishment of "carbon fires" but that was on one kind of cell, the kind used at Savannah River. I did not take into consideration what started the fire, but only that a fire had started, and then tried to extinguish it, once it was started. There is some literature on heat transfer in carbon although I can't give you the references off the top of my head, but there is some on that. As long as the loading is in the neighborhood of 5 to 25 micrograms per gram of carbon (I hope I am right) and the flow is at designated value there is little chance of ignition. If the loading goes higher, or if the flow is reduced or is cut off, then there is a chance for fire. I don't think that answers your question, but that is about all I know about the subject.

BARLOW: I realize these fires are very difficult to put out once they get started.

MORROW: Two years ago I tried to extinguish a carbon fire with water rates of 115 gallons a minute at 150 PSI on a single adsorber cell with 1,000 CFM going through it. As long as the air was flowing, the fire continued. I was able to extinguish it with an application of 20 liters a minute of liquid nitrogen for a period of seven minutes.

LORENZ: ORNL has a small scale program in progress which will use the decay heat from radioactive iodine to ignite, or attempt to ignite, charcoal. We do not have experimental results to present yet, but we hope to be able to do so within a few months. We will publish results in the Oak Ridge National Laboratory Nuclear Safety Program Bi-monthly Progress Report and a similar annual progress report.