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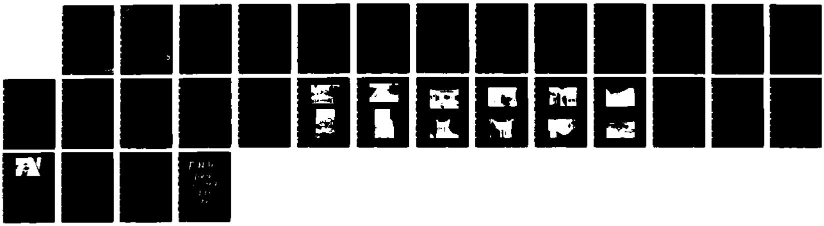

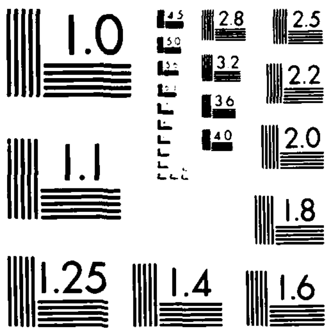

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Evaluation of Residential Sprinklers for Use in Military Housing

by
Robert A. Weber
Daniel T. Smith

This report documents the results of research conducted to test residential sprinkler systems under live fire conditions, to determine their potential for use in military family housing. The test results indicated that sprinkler systems, when used in conjunction with smoke detectors, significantly reduced fire losses and will greatly decrease the potential for injury and loss of life.

Since the sprinkler system reduces the temperature of the flame, it will reduce combustion, thereby increasing the smoke level. Since heavier smoke levels could cause panic among building occupants, it has been concluded that fire safety education programs that would teach residents proper fire safety procedures would be helpful.

Since the average cost of a fire is about $7900 and the estimated damages sustained in a fire contained by sprinklers are only $300 to $500, the costs of sprinkler systems could be recovered. Sprinkler system maintenance requirements are low and can be completed during quarters maintenance.

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FOREWORD

This research was conducted for the U.S. Army Fire Department, Training and Doctrine Command (TRADOC), under Reimbursable Order GEFAE43450M109, dated December 1984. The work was conducted by the Engineering and Materials Division (EM), U.S. Army Construction Engineering Research Laboratory (USA-CERL). The TRADOC Technical Monitor was Mr. George T. Wilder.

Dr. Robert Quattrone is Chief of USA-CERL-EM. COL Norman C. Hintz is Commander and Director of USA-CERL, and Dr. L.R. Shaffer is Technical Director.

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EVALUATION OF RESIDENTIAL SPRINKLERS FOR USE IN MILITARY HOUSING

1 INTRODUCTION

Background

From 1977 to 1981, 7175 civilians in the United States died as a result of fire, and 81 percent of this number died in residential structure fires. Residential structures are the primary concern of fire officials, not only because a large number of civilians die in home fires each year, but also because firefighters killed or injured in the line of duty are usually hurt in a residential fire.[1]

A report of the Presidential Commission on Fire Prevention and Control[2] has indicated that residences need a more active, built-in automatic suppression system to detect and attack fire in its earliest stages. Based on that information, several major research projects were funded to develop an effective means of dealing with the residential fire problem. One of the most promising developments of this research has been residential sprinkler systems that will protect a structure 24 hours a day, 7 days a week. The sprinkler systems are designed to prevent flashover and a large amount of fire extension. Sprinklers operate by absorbing heat from a fire and conducting it to an alloy that melts at a specified temperature. When the alloy melts, a plunger drops and allows water to discharge from the sprinkler in a prescribed flow pattern.

Sprinklers have a success rate of 97 percent, which means that 97 percent of the fires are held in check until professional firefighters arrive to extinguish the fire completely. An amazing statistic is that no multiple deaths (three or more) have ever resulted from a fire that occurred in a fully sprinkled building.[3]

U.S. Army Training and Doctrine Command (TRADOC) statistics show that the Army is not immune to the residential fire problem. In calendar year 1984, there were 254 fires that caused $2 million in damage, injured 35 people, and killed 6. These residences were not sprinkler-protected nor were smoke detectors always present and working. This loss of life and property could probably have been greatly reduced by installing residential-type sprinkler systems in military housing.

The military differs from civilian residential areas in that each installation has a large, transient population. Each change in personnel brings a different attitude toward fire safety; for example, cultural and social background impacts people's view of the fire problem and the need for fire safety.

The presence of combustible materials within military residences is also a problem. During a fire these combustibles add to the fire load, flame spread, and propagation of toxic gases. Residential furnishings are a primary source of combustibles. Many types of furnishings are produced from hydrocarbons which, when

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[1] Arthur E. Cole, "Update or Residential Sprinkler Protection," *Fire Journal* (November 1983).

[2] *America Burning* (Presidential Commission on Fire Control, 1973).

[3] "An Ounce of Prevention," *Federal Emergency Management Agency Brochure* (U. S. Fire Administration, 1985).

exposed to flame and heat, generate massive quantities of poisonous carbon monoxide gas. The gas generation also produces a large amount of heat. This compounds problems for the occupants because the interior becomes untenable in a short time. The longer the occupants are exposed to such an environment, the lower are their chances of survival.

Methods such as equipping each dwelling with portable fire extinguishers could be tried. However, the occupants would have to be equipped with the proper types of extinguishers to handle specific types of fire, and would have to have appropriate training to ensure adequate operation. Maintaining these extinguishers would be a monumental task, and just keeping an inventory of them would also be a very large job.

Installed dry chemical systems could provide protection only from specific hazards. They are useful for protecting the kitchen area; however, children's carelessness, arson, and smoking accounted for most of the fire incidents in quarters. Another drawback is that inspection, testing, replacement and recharging of installed dry chemical systems is a large maintenance item.

Other methods of protection may be available, but maintenance, installation cost, deterioration, and reliability make them questionable. Thus, when adequate fire protection alternatives are evaluated, the reasonable solution to protect family quarters seems to be residential sprinkler systems.

Objective

The objective of this research was to test residential sprinkler systems under live fire conditions to determine their potential for use in military family housing and to assess their costs and maintenance requirements.

Approach

Six live fire tests, each simulating different common fire situations, were conducted. Cost data were obtained from sprinkler manufacturers, and maintenance requirements were obtained from the National Fire Protection Association (NFPA). The information was analyzed, and the system's potential for use in military housing was evaluated.

Mode of Technology Transfer

It is recommended that the information in this report be used as the basis for retrofitting TRADOC residential housing and that the information be included in official guidance issued to residents from the TRADOC Fire Protection Group.

2 TEST EQUIPMENT AND PROCEDURES

The live fire tests were conducted at the University of Illinois Fire Services Institute--a nationally recognized training facility for firefighting personnel. A residential sprinkler system was installed in a mobile home 12-ft*-wide, 62-ft-long, with 8-ft-high ceilings.

All types of piping that can be used in a sprinkler system could not be adequately evaluated during the tests. Therefore, the B.F. Goodrich "Blaze-Master" piping system, manufactured by R & G Sloane, was chosen because it was easy to install. Shell Oil manufactures a polybutylene pipe which may also be used. Installation of the test system did not conform to NFPA Standard 13D, which required that chlorinated polyvinyl chloride (CPVC) pipe be protected. This was done to facilitate installation and to simulate a worst-case scenario. Design criteria for the system established by both the manufacturers and the NFPA were followed.

The sprinkler heads used consisted of six 160-degree Omega C/1 heads, six Omega ESC heads, and two Omega EC-20 heads, all manufactured by the Central Sprinkler Corporation, and three F991 heads, two F954 heads, and 1 F958 head, all manufactured by Grinnell Fire Protection Systems. To determine water distribution characteristics of the various heads, a 14-ft square grid was set up, in which graduated cups were placed in 1-ft squares. Water was discharged through an open head for 4 minutes, collected in the cups, and then measured.

Six tests were conducted in the mobile home: test 1 was a kitchen fire, tests 2 and 3 were living room fires, tests 4 and 5 were bedroom fires, and test 6 was an "arson" fire set in the hallway. Water flow and pressures were measured and the times of activation of both smoke detector and sprinkler head were recorded. Various toxic gases, oxygen levels, and ceiling temperatures were also measured. Data were obtained on six aspects of the sprinkler system: (1) performance during fire tests, (2) water supply requirements, (3) piping, (4) characteristics of fire gases, (5) system maintenance, and (6) cost of the system, Chapter 3 outlines the test results. The following equipment was used to collect data: Mine Safety Appliances (MSA) Model IV Carbon Monoxide Monitor; Model 245 RA Oxygen Monitor; sampling tubes and Model A Sampler; a fire research flow meter; a pyrometer; and a gas sampling device.

*Metric conversion factors are provided on page 15.

3 RESULTS AND DISCUSSION

Fire Test Results

Table 1 summarizes all test results.*

Test Fire 1

Test fire 1 was set in a 9¼- x 12-ft kitchen which had cabinets extending about 2 ft from the walls on three sides. The scenario was designed to simulate a grease fire on the stove. A small amount of gasoline and vegetable oil was used for fuel and was ingnited with a flare. The gasoline was used because the test mobile home had no gas supply.

In this test, the sprinkler activated before the smoke detector. During cooking, the ceiling temperature rises gradually. If a flash fire such as a grease fire occurs, the sprinkler system activates quickly. During the testing, the ceiling temperature did not rise more than 20 degrees because of the calibration of the pyrometer and the effectiveness of the sprinkler system.

Damage in the test area was limited and was estimated to be less than $300. Figure 1 shows that damage occurred only to the wall covering near the stove and to some of the undersides of the cabinets. Because of the sprinkler system's fast response, this house would be still livable and could be repaired easily. It should also be noted that even if this fire had occurred while the kitchen was unattended, the activation of both the smoke detector and the sprinkler system would have ensured the safe escape of the occupants.

Test Fire 2

Test fire 2 was conducted in the 23- x 12-ft combination living room and dining room. The living room portion was 16 x 12 ft. The scenario was designed to represent the most difficult situation, in which there is a vented fire that is not close to and protected by the sprinkler head. The fire was started on discarded paper in a trash can behind a television set (Figure 2). A hole was placed directly above the fire, so that the smoke and gases would be vented away from the sprinkler head and produce a larger fire. However, even with this scenario, the fire did not cause major damage (less than $800). Figure 3 shows the fire damage.

Again the sprinkler system performed well, although it activated 2 seconds after the smoke detector. After the system discharged for 1.5 minutes, a small amount of fire in the roof area had to be extinguished with a hose line. Even in this case, the occupants would have had ample time to escape the fire.

Test Fire 3

Test fire 3 was performed in the same area as test fire 2. The purpose of this test was to build a fire large enough to activate two sprinkler heads at the same time. A small amount of gasoline was put on the sofa and chair to serve as the ignition source. The furnishings, much like those found in any living room (Figure 4), were constructed of wood, covered with vinyl, and surrounded with polyester curtains. Again, damage was

*Tables and figures are listed at the end of the report.

confined mainly to the items of origin, with no structural damage occurring. Estimated structural damage was less than $250--the cost of removing smoke particles from the walls and ceilings.

In this test, the sprinkler system actually performed better than expected. The discharge pattern and the cooling effect of the first sprinkler made it very difficult to activate the second one. The system's performance in this type of fire will obviously depend on the type of furnishings, but it is felt that the occupants of this residence could have escaped unharmed (even if the fire had occurred when they were sleeping) and could have returned to live in the structure the same day.

Test Fires 4 and 5

Test fires 4 and 5 were conducted in the 12½-x 12-ft bedroom. The only difference between the two tests was that the manufacturers of the sprinkler heads were different. The sprinkler heads used were side-wall-mounted rather than pendent heads, which are installed on the ceiling. This fire simulated the ignition of bedding material. Each fire was extinguished within 30 seconds. In both cases (even though the door to the room was almost closed), the smoke detector activated before the sprinkler head and provided ample time for the occupants to escape from the area.

Test Fire 6

Test fire 6 simulated a large quantity of flammable liquids being spilled in a confined space and was similar to an arson fire. The area chosen was the 2 ft, 3-in. x 16 ft, 10-in. hallway (Figure 5). The sprinkler system did not extinguish the fire; however, it did hold it in check for 3 minutes, providing time for the fire department to arrive. The heat buildup was great enough to activate all seven sprinkler heads in the mobile home. Figures 6 and 7 show the extent of damage in the hallway only minutes after the fire was ignited. Note the pattern of the discharge and the lack of major structural damage under the flow of water.

Several lessons were learned in this test. Failure to extinguish the fire may have resulted from the positioning and type of sprinkler heads used, rather than from the system. A sidewall sprinkler directed down the hallway would probably have been more effective than a pendent-type sprinkler.

Another factor in the system's performance may have been the quantity of water on the floor from previous tests. When the sprinklers discharged, the water on the floor permitted the fuel to be pushed around rather than extinguished.

Water Supply Requirements

During the tests, the water flow rates varied from 25 to 28 gal per minute (gpm), with a residual pressure of about 50 to 55 psi. These values were within the limits recommended by both the manufacturer and NFPA Standard 13D.[4] Since there are many different sprinkler configurations, posts installing sprinkler systems should refer to the manufacturers' worksheets. Both Grinnell Fire Protection and Central Sprinkler Corporation provide excellent documentation.

[4] *Standard for the Installation of Sprinkler Systems and One-and Two-Family Dwellings and Mobile Homes* (National Fire Protection Association, 1980).

Piping, Fittings, and Heads

Figure 8 shows the damage to the sprinkler pipe after the arson-type fire. The pipe was still able to hold water and pressure after this test. Tables 2 through 7 show the results of the water distribution characteristics measurements. These tables show that the discharge patterns of the Central Sprinkler Corporation heads were somewhat irregular. Observation of these patterns indicated that the spray was coarser than that produced by the Grinnell heads. However, the Grinnell heads produced a relatively even pattern. The residual pressure for all the heads was about the same, but the Central heads allowed more water flow than the Grinnell heads. The increased water discharge may not be an advantage; results of the fire tests show that the pattern is as important, if not more important, than the volume, and both systems discharged at least the minimum quantity of water required.

Fire Gases

To determine the relative toxicity of the atmosphere within the structure, sampling for the presence of common fire gases was conducted at the time of sprinkler activation (Figure 9). The following gases were sampled: hydrogen cyanide, carbon monoxide, hydrogen sulfide, hydrogen chloride, vinyl chloride, aromatic hydrocarbons, and oxygen. Gases were tested at three levels within the structure that represented heights at which persons may breathe in toxic gasses. A height of 5 ft was chosen to represent a person standing. Three feet represented the height of a person crawling on hands and knees or lying on a bed. One foot was chosen to represent the height of a person on his/her back, unconscious, on the floor.

Hydrogen cyanide was measured using an MSA detector tube #93262 with a range of 0 to 80 ppm. Carbon monoxide was measured using an MSA detector tube #91229 calibrated for 10 to 3000 ppm and the Mini Indicator Model IV #468572 calibrated for 0 to 500 ppm. Hydrogen sulfide was measured using an MSA detector tube #460058 calibrated for 1 to 100 ppm. Hydrogen chloride was measured with an MSA detector tube #466612 calibrated for 1 to 100 ppm. Aromatic hydrocarbons were measured with the MSA detector tube #3074, and oxygen content was measured using the MSA model 245RA Oxygen Indicator. For each fire, measurements at the 3-ft level were made using a carbon monoxide meter and the electronic oxygen meter. The detector tubes were used to sample the 1-, 3-, and 5-ft levels simultaneously for each fire. Sampling started when water first began discharging from the sprinkler head.

The detector tubes required a specific volume of gas to be pulled through in 40 seconds. The following volumes were required for each sample:

Carbon monoxide:	100 cc
Vinyl chloride:	100 cc
Hydrogen chloride:	100 cc
Hydrogen sulfide:	200 cc
Hydrogen cyanide:	300 cc
Aromatic Hydrocarbons:	300 cc

The following method was used to calculate dead air space in each detector tube sample line. Given a 1/8-in.-diameter sample line, 5 ft long, the total dead air space for the line is 12.26 cc. This is divided by the number of tests using the dead air space (six), which gives a dead air space of 2.04 cc per test. This amount was then divided by the number of cubic centimeters in each test and multiplied by 100 to convert the value to a percentage. Following is the dead air space error for each test:

Carbon monoxide:	2.04%
Vinyl chloride:	2.04%
Hydrogen chloride:	2.04%
Hydrogen sulfide:	1.02%
Hydrogen cyanide:	0.68%
Aromatic hydrocarbons	0.68%

Table 8 presents the sampling results.

Although the carbon monoxide level was high, the gases measured did not pose an immediate threat to life. For the concentrations measured, a short exposure time should not affect the consciousness of healthy individuals. The oxygen content remained high through the test and therefore is not a factor that will affect occupants during a fire. The other measured gas concentrations would not threaten the lives of occupants near the fire.

When the sprinkler heads opened, the temperature of the flame was reduced, changing the combustion byproducts and producing more smoke. The spray pattern also pushed the fire gases and smoke down. This filled the room with white smoke that reduced visibility and which could cause panic among residents during an actual fire. With the sprinklers operating properly, there appears to be no way to alleviate the decreased visibility. However, it is felt that the adverse effects can be minimized by educating the occupants in fire safety procedures.

System Maintenance

The NFPA recommends inspecting the system monthly to ensure it is operating properly. If tamperproof valves are used and an occupant education program is incorporated, the frequency of inspections could probably be decreased to annual or semi-annual with only a flow test required. System maintenance would require only operation of the valves during the annual check and the removal of heads to check for sediment buildup, and could be done when other maintenance is performed in the quarters.

Costs

The basic sprinkler system for a residence costs about $250, which includes the cost of materials, but not labor or installation. The sprinkler industry estimates that the cost for installed systems in a single-family residence is between $900 and $2000 per unit, depending on the system design.[5] In the event of a fire, the system costs would be recovered easily, since the average cost of a fire is less than $7900 and the test results showed that the estimated cost of a fire contained by sprinklers is $300 to $500 or less. The sprinkler system has low maintenance requirements so the costs can be spread over the life of the building. Also, the system can be relocated to new quarters if desired.

[5] Robert Gorman, "Home Fire Sprinklers," *Popular Science* (January 1982).

4 CONCLUSIONS AND RECOMMENDATIONS

The results of the live fire tests show that use of residential sprinkler systems in conjunction with smoke detectors will reduce fire losses and help prevent injury to military housing occupants. Activation of the sprinkler system alerts the residents of the hazard and keeps the fire from spreading; in some cases, the fire was completely extinguished before the fire department could reasonably be expected to arrive. The smoke detectors, which are activated concurrently with the sprinklers, warn the residents of the smoke. The sprinkler system reduces the temperature of the flame, which in turn reduces combustion and increases the smoke level. This heavier smoke could cause panic among residents if they are not educated in fire safety procedures.

Costs of purchasing and installing sprinkler systems ($900 to $2000 per residence) would be recovered in the event of a fire, since the average cost of a fire is $7900 and the estimated damages from a fire contained by sprinklers is $300 to $500.

Maintenance requirements of the sprinkler system are low and could be conducted during other quarters maintenance.

METRIC CONVERSION FACTORS

1 ft	=	0.3048 m
1 psi	=	6.895 KPa
1 gal	=	3.785 L
1 in.	=	25.4 mm
1 sq ft	=	0.0929 m^2

Table 1

Fire Test Results Summary

Fire Test	1	2	3	4	5	6
Time: Smoke Detector Activated (sec)	46	50	20	20	20	7
Time: Sprinkler Activated (sec)	44	607	115	45	30	18
Flow Rate (gpm)	28	26	34	25	27	50
Static Pressure (psi)	60	60	60	60	60	60
Residual Pressure (psi)	50	55	50	55	55	10
Time: Fire Extinguished (sec)	394	700	125	64	68	
Time: Sprinkler Shutoff (sec)	395	705	130	65	72	325

Fire Test 1: Kitchen
Fire Test 2: Living Room (One Head)
Fire Test 3: Living Room (Two Heads)
Fire Test 4: Bedroom
Fire Test 5: Bedroom
Fire Test 6: Hallway (Sprinklers unable to extinguish fire)

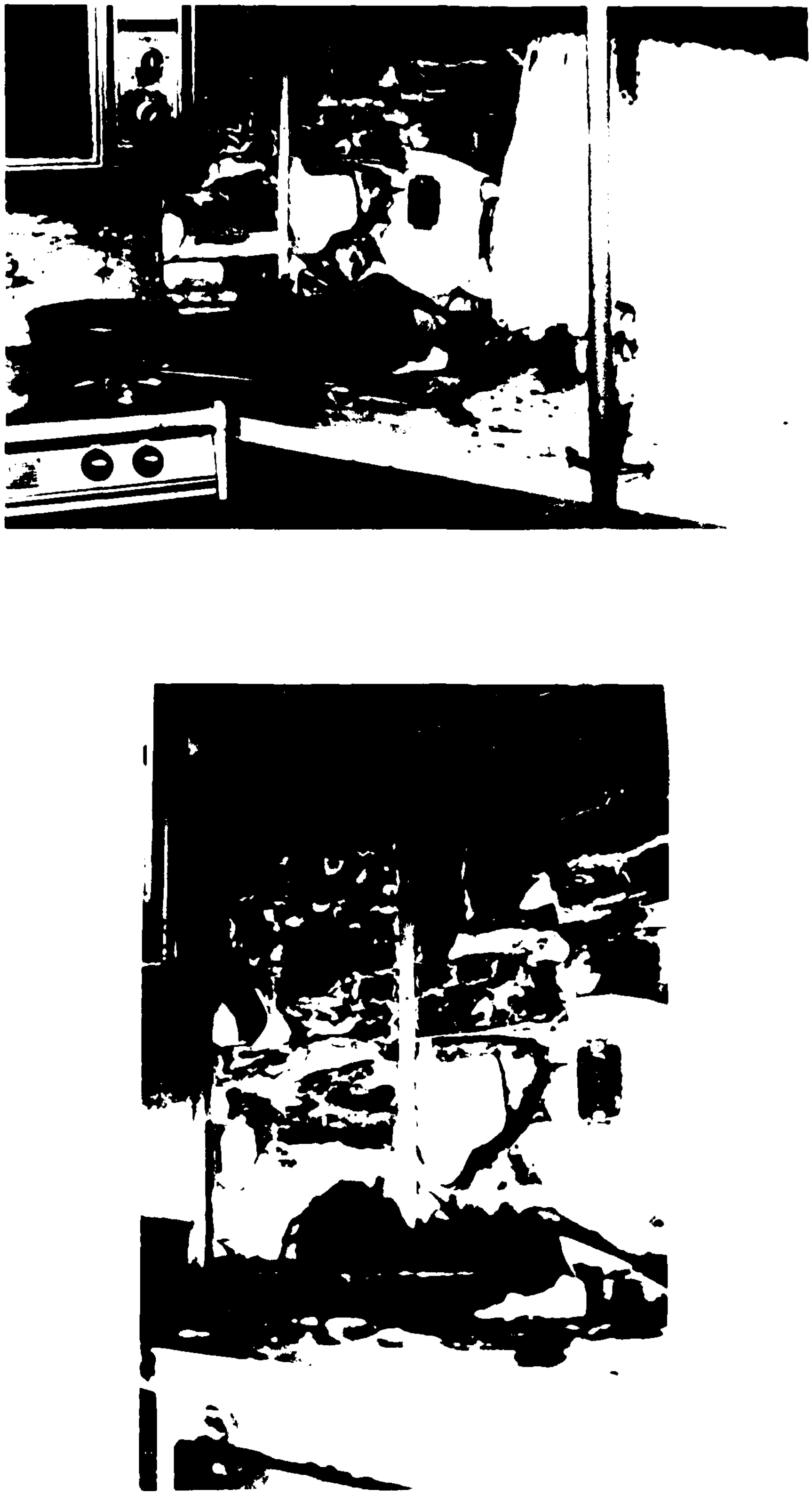

Figure 1. Fire damage in the kitchen.

Figure 2. Fire scene in the living room.

Figure 3. Fire damage in the living room.

Figure 4. Living room scene for fire test #3.

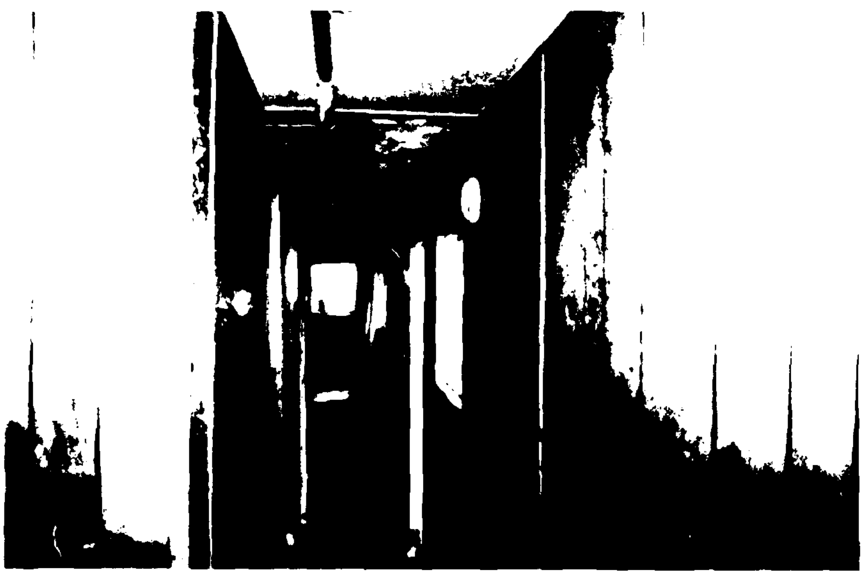

Figure 5. Hallway before fire simulating arson was set.

Figure 6. Fire damage in the hallway (looking toward the living room).

Figure 7. Hallway fire damage (looking toward the bedroom).

Figure 8. Fire damage on the CPVC pipe.

Table 2

Water Distribution Results for the Grinnell F991 Pendent Sprinkler (All values are in milliliters; flow = 27 gpm at 55 psi.)

6	5	0	0	0	0	8	0	0	0	0	11	12
16	9	5	7	8	7	8	9	8	13	18	12	14
19	20	14	8	9	9	8	10	8	14	14	30	27
13	18	20	20	13	9	10	10	10	11	16	25	35
23	20	22	22	18	11	9	10	11	20	29	28	30
15	18	18	12	16	13	10	10	16	32	31	25	25
16	29	16	14	13	11	11	12	21	39	62	43	28
18	16	11	12	12	13	12	15	22	34	35	18	21
19	16	12	10	12	11	15	24	31	39	52	32	26
17	15	13	10	12	11	12	20	31	33	25	25	35
15	12	10	10	9	8	7	5	12	25	27	13	10
14	10	8	9	10	11	7	4	6	9	21	25	15
11	8	7	8	10	16	10	7	7	8	14	23	18
12	10	10	8	10	10	11	10	16	24	37	31	28

Note: Sprinkler head mounted in center of pattern.

Table 3

Water Distribution Results for the Grinnell F954 Pendent Sprinkler (All values are in milliliters; flow = 19 gpm at 50 psi.)

9	31	0	0	0	0	12	0	0	0	0	2	2
18	28	50	38	40	25	10	3	3	4	3	4	4
36	38	37	28	32	19	5	4	10	6	4	4	5
22	24	36	40	28	14	10	17	13	7	7	4	5
12	8	14	35	41	17	18	20	11	7	5	3	3
4	5	9	19	40	28	20	15	10	7	5	14	3
2	4	12	36	37	29	25	21	21	33	35	8	0
1	3	18	59	57	55	35	27	34	14	9	4	6
1	2	5	11	24	40	44	30	27	8	8	23	12
1	3	6	12	21	37	33	28	23	15	11	21	27
3	9	10	12	25	28	23	17	20	19	29	12	12
6	7	14	5	15	15	20	19	27	20	14	0	0
7	7	5	5	15	15	26	30	35	32	19	0	0

Note: Sprinkler head mounted in center of pattern.

Table 4

Water Distribution Results for the Grinnell F958 Sidewall Sprinkler
(All values are in milliliters; flow = 28 gpm at 50 psi.)

15	21	0	0	0	0	29	0	0	0	0	25	26
17	24	27	24	22	24	23	22	22	22	24	25	25
20	24	23	19	20	19	18	16	16	18	20	12	23
20	19	17	15	14	13	13	13	15	17	15	22	22
13	12	11	11	11	10	10	10	10	11	13	19	18
20	12	10	7	7	7	7	7	8	0	11	17	25
25	18	10	7	6	5	7	7	7	0	5	11	17
33	26	11	10	7	7	8	8	7	7	7	10	14
29	25	16	12	7	8	7	10	10	10	10	8	13
26	23	21	12	10	9	7	10	10	11	12	12	15
25	22	13	14	10	8	8	9	10	13	13	13	16
25	22	12	14	11	9	10	10	12	14	8	14	15
24	29	26	18	13	10	10	13	10	16	21	18	20
17	27	25	21	21	18	15	14	16	22	26	25	22

Note: Sprinkler head mounted on left side of pattern.

Table 5

Water Distribution Results for the Central Omega C-1 Pendent Sprinkler
(All values are in milliliters; flow = 33 gpm at 50 psi.)

8	15	0	0	0	0	35	0	0	0	0	9	9
18	34	31	33	35	42	45	37	45	27	35	23	10
21	35	42	49	54	64	63	55	53	39	32	17	14
24	40	54	64	64	64	64	64	64	41	29	64	31
31	33	51	55	64	60	64	64	45	49	59	64	14
22	44	42	41	42	45	49	35	45	53	50	32	18
43	57	47	43	34	30	41	36	40	47	48	55	26
44	30	45	37	28	28	48	52	50	53	64	40	32
20	46	36	40	40	30	52	56	64	64	55	40	38
45	32	45	48	64	64	64	64	64	64	53	39	17
15	22	35	54	64	64	64	64	64	64	46	35	17
13	17	40	40	64	64	64	64	53	55	38	32	10
14	18	32	35	53	53	56	52	45	43	27	10	0
15	18	18	28	31	38	42	36	39	23	26	5	0

Note: Sprinkler head mounted in center of pattern.

Table 6

Water Distribution Results for the Central EC-20 Pendent Sprinkler
(All values are in milliliters; flow = 33 gpm at 50 psi.)

16	21	0	0	0	0	25	0	0	0	0	42	21
14	16	14	15	29	37	22	20	23	36	44	31	14
13	12	10	10	21	38	30	20	26	30	28	18	11
17	12	8	8	18	38	46	33	25	19	17	13	11
30	21	15	13	24	43	60	34	19	10	11	12	12
35	37	32	25	34	43	38	18	11	9	10	12	15
22	27	35	30	35	33	28	15	11	11	13	13	64
18	19	19	24	30	36	22	17	17	31	24	16	17
18	19	16	17	27	51	60	47	26	26	27	25	25
19	18	17	17	31	64	60	46	26	21	27	30	35
17	19	20	27	36	44	55	38	18	14	15	19	27
18	23	33	43	36	32	35	42	20	13	12	14	17
22	34	51	37	26	20	25	40	32	18	15	13	10
28	54	48	27	23	22	27	35	44	26	19	17	13

Note: Sprinkler head mounted in center of pattern.

Table 7

Water Distribution Results for the Central HEC-12 Sidewall Sprinkler
(All values are in milliliters; flow = 32 gpm at 50 psi.)

8	10	0	0	0	0	12	0	0	0	0	9	3
7	15	20	12	13	17	20	23	24	37	38	8	8
13	26	26	18	24	27	33	34	37	53	56	36	34
20	40	34	26	30	34	41	44	57	52	53	55	54
28	49	42	32	33	34	37	40	47	64	60	54	48
28	44	47	39	36	40	48	50	64	60	56	64	45
21	47	36	36	36	34	37	40	46	60	58	59	49
18	39	52	52	45	44	37	38	43	60	58	52	52
15	37	53	57	58	57	58	56	52	44	40	53	53
17	40	57	50	46	41	36	32	34	53	43	59	54
15	37	57	52	45	45	46	40	39	50	46	52	50
16	32	44	37	37	40	40	37	37	34	42	42	40
10	26	30	23	28	30	34	30	35	36	37	40	40
10	22	21	15	21	25	30	30	32	32	32	38	36

Note: Sprinkler head mounted on left side of pattern

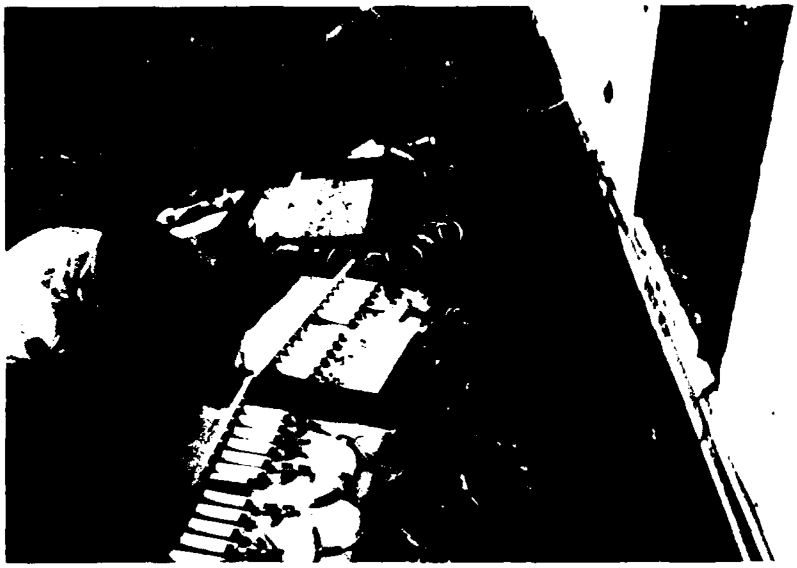

Figure 9. Gas sampling apparatus.

Table 8

Results of the Gas Sampling for Fire Tests 1 through 4

Fire Test Number	1			2			3			4		
Test Height (ft)	1	3	5	1	3	5	1	3	5	1	3	5
Hydrogen Cyanide (ppm)	0	0	0	0	0	0	0	0	TR	0	0	0
Carbon Monoxide (ppm)	200	150	250	150	100	100	100	100	150	200	200	200
Hydrogen Sulfide (ppm)	0	0	0	0	0	0	0	0	0	0	0	0
Hydrogen Chloride (ppm)	5	5	5	5	5	5	TR	TR	TR	TR	TR	TR
Aromatic Hydro-carbons (ppm)	25	25	25	TR	0	TR	50	25	25	25	TR	TR
Vinyl Chlorides (ppm)	0	14.5	14.5	14.5	14.5	14.5	0	TR	TR	TR	TR	TR
Oxygen (%)		19			20			19			19	
Carbon Monoxide Meter (ppm)		155			107			105			215	

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