NATIONAL BUREAU OF STANDARDS REPORT

10 483

FIELD MEASUREMENTS OF HC1 CONCENTRATIONS FROM PVC ELECTRICAL CONDUIT INVOLVED IN FIRE

University of Maryland Veterans Housing Fire Test
June 10, 1971

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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The Bureau comprises the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, the Center for Radiation Research, the Center for Computer Sciences and Technology, and the Office for Information Programs.

THE INSTITUTE FOR BASIC STANDARDS provides the central basis within the United States of a complete and consistent system of physical measurement; coordinates that system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. The Institute consists of an Office of Measurement Services and the following technical divisions:

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Office of Standard Reference Data—Clearinghouse for Federal Scientific and Technical Information [3]—Office of Technical Information and Publications—Library—Office of Public Information—Office of International Relations.

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Located at Boulder, Colorado 80302.
[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

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University of Maryland Veterans Housing Fire Test
June 10, 1971

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Field Measurements of HCl Concentrations from PVC Electrical Conduit Involved in Fire

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1.0 INTRODUCTION

To examine the potential development and spread of HCl from burning PVC electrical conduit, a fire test was conducted in a two-story apartment building at the University of Maryland. The facility, a recently vacated structure scheduled for demolition, was made available by and with the cooperation of the Fire Protection Curriculum of the University of Maryland. Due to limited time and availability of personnel, only an exploratory fire test was performed. Hence, the results from this test do not reflect the range of responses which could be obtained under other conditions of fire load, ventilation, PVC conduit type, size, location, etc.

The test room on the first floor was a former bedroom of 100 sq. feet floor area (800 $ft.^3$ volume) with a single window and door. The walls and ceiling were painted gypsum board and the floor was asphalt tile. A wood crib weighing 63 lbs. was placed along one wall to represent the combustible contents. It was ignited by a small quantity of flammable liquid placed in a tray under the crib. The PVC conduit was fastened to the wall next to the crib and extended along the ceiling and into the adjacent room and the room above. The object of the test was to determine to what extent a small fire in a room containing exposed PVC electrical conduit would generate and spread the primary combustion product, HCl, to adjoining rooms through the conduit system.

2.0 MATERIALS AND CONSTRUCTION

2.1 Experimental Rooms

Figure 1 shows the dimensions and location of rooms in the test building. The building was essentially a two-story, 90 x 20 foot wood frame structure with asbestos-cement shingle siding. The ground floor consisted of about 15 rooms divided into four apartments with four entrances. The floor plan of the second floor was identical to that of the ground floor. Three bedrooms, all 10 x 10 x 8 feet high in the middle of the structure were used in this study. Measurements were made in a ground floor bedroom used as a fire room, in a room adjacent to the fire room, and in the second-floor room above the adjacent room.

The walls and ceilings of all the rooms were painted 3/8 inch thick gypsum wall board. The flooring on all the first floor rooms consisted of asphalt tile on concrete slab. Each room had a double-hung wooden sash window. Except for the fire room whose window was completely open at the bottom (2.5 x 2.5 ft.), all other windows and doors were closed during the test.

Directly above the wood crib a sheet of 4 x 8 foot fire-rated gypsum board 5/8 inch thick was nailed to the ceiling, to protect it from direct flame impingement.

2.2 Conduit Layout (See Figure 2)

Empty conduit ran from an outlet box 18 inches above the floor at the middle of the south wall vertically to the ceiling where it turned via a 90° ell and proceeded along the ceiling to another 90° ell and outlet box mounted on the middle of the room ceiling. The conduit then continued along the ceiling penetrating the east wall into the adjacent room where it was connected into a covered outlet box mounted on the ceiling. From the outlet box, one branch proceeded downward at the wall to an outlet box near the floor of the adjacent first floor room, the other upward through the ceiling to an outlet box in the second floor room.

A total of 16 feet of conduit was used in the fire room. Though no wire was used inside the conduit, its installation and the use of receptacles and junction boxes followed usual industrial practice. Gas leakage between rooms was minimized by caulking the openings through which the conduit pierced the walls and floor with glass wool.

2.3 PVC Conduit

Rigid plastic piping, gray in color, schedule 40, 3/4 inch ID and 1-1/16 inch OD, weight 0.22 lb/ft, was used. Couplings and elbows of the same material were solvent-welded to the conduit as required.

2.4 Outlet Boxes

These consisted of 2-3/4 x 2-1/8 x 4-1/2 inch common residential boxes of aluminum construction. Duplex 3-prong receptacles were installed in each outlet box. There were two boxes in the fire room, two in adjacent room and one in the second-floor room.

2.5 Wood Crib

The only contents of the fire room was a 2 x 2 x 2 foot wooden crib constructed from symmetrical stacking of 1 x 1 inch x 2 feet white pine sticks (moisture 6-8%). The crib, representing combustible contents, weighed 63 pounds. It was supported 3 inches above the floor by three

common brick. The size of the wood crib was minimized and located in only one corner of the room since the building could not withstand a large fire.

2.6 Gas Sampling

Indications of the HCl concentration were obtained in the adjacent room and second-floor room by the use of Drager colorimetric indicator tubes, specific for HCl. These tubes indicate HCl concentration by a pre-calibrated length of color stain when a known volume of gas is drawn through the tube using a manually-operated hand pump. The indicator tubes were positioned near the center of each room. A hollow rigid horizontal tube passed through an opening in the exterior wall into the center of the room and provided support for remote pumping and easy retrieval and replacement of the indicator tubes. In the very early stages of the fire, an observer inside the rooms also performed gas sampling near the outlet boxes.

2.7 Temperature Measurements

Four thermocouples located within the room were used to monitor continuously the temperature profile of the fire. Figure 3 shows the thermocouple locations and the time-temperature profiles developed during the test.

3.0 OBSERVATIONS

Motion pictures of the fire room recorded graphic information on the deflection and melting of the conduit and behavior of the fire. Observers stationed outside the window took note of events in the fire room. Table 1 is the log of the entire fire test as recorded by Professor J. L. Bryan.

4.0 RESULTS AND DISCUSSION

The primary interest of this experiment was the behavior of the conduit and the possibility of the generation and spread of HCl through the conduit to other rooms. At about 5 minutes, the conduit along the ceiling directly over the fire began to soften and droop. It finally melted into two sections at 7.5 minutes and fell away from the area of the fire.

Some visible flaming appeared at 6.8 minutes at the melted region. Because of its high chloride concentration, the material burned slowly and emitted a large quantity of dark smoke.

All conduit sections not directly touched by flame showed blistering and charring at surfaces facing the fire. This undoubtedly was caused by radiative and convective heating from the fire. The conduit surface against the ceiling away from the burning crib showed no evidence of charring or melting when a typical section was examined after the fire.

The conduit that blistered did not ignite. Except for the section directly above the fire, there was no flaming. The conduit in the other rooms was intact and showed no sign of softening or charring.

The charred surface in the area of the fire showed partial collapse of about half of the inside surface of the conduit. The cross-sectional area of a typical section was about one-half of the original area. Recovered conduit was examined and weighed to estimate average weight loss. Weight loss of the charred section was about 12% of the initial weight. A 5 foot long piece and the cross-section of a typical piece is shown in Figure 4.

HCl was detected emanating from the receptacle at the outlet box of the adjacent room. Concentration at the vicinity was 8 ppm at 9 minutes. Figure 5 shows measured HCl concentration at the center of each room as a function of time. The maximum was 30 ppm in the adjacent room. The decay portion of the curve shows the relative ease with which HCl vapor in the room is lost (by absorption on solid surfaces) after 18 minutes when the fire was extinguished.

A theoretical calculation based on 16 feet of conduit (weighing 0.22 lb/ft) and a 12% loss in an 800 $ft.^3$ room yields a HCl concentration in the order of 2200 ppm assuming no air exchange or vapor loss in the fire room.

The maximum HCl monitored in the adjacent room was 30 ppm. The HCl problem in the adjacent room was not severe: due to low air temperature as a result of the air-limiting nature of the fire, and due to the fact that only a small section of conduit was actually involved in the fire.

Based on observation at the fire and laboratory tests, the smoke level associated with the HCl in the adjacent room would probably be of a level such that an experienced firefighter could not remain in the room longer than a couple minutes without a mask. At this level the smoke density rather than HCl would probably be the major factor.

Another experiment with better ventilation of the fire room and simultaneous measurements of smoke, CO and HCl both in the fire room and in adjacent rooms is needed to provide a more meaningful interpretation.

5.0 CONCLUSIONS

1. An experiment in which a 63 pound wood crib was burned in a 800 $ft.^3$ room with 6 $ft.^2$ window opening and 16 feet of 3/4 inch PVC electrical conduit installed along the ceiling and wall, shows that practically all the conduit remaining after test had partially collapsed and had undergone charring and blistering over half of its surface.

2. The conduit did not burn or self-ignite except when it came in direct contact with the flame from the wood crib. Weight loss of the recovered conduit was about 12% of the original weight. Due to the limited nature of the fire only a portion of the conduit was subject to direct flaming, since it dropped away from the fire.

3. The maximum indicated HCl concentration in the adjacent room was 30 ppm. The maximum HCl concentration in the fire room based on a simple theoretical calculation was estimated to be 2200 ppm with no ventilation.

4. In both the adjacent and second floor rooms, smoke density and CO may be considered major hazards along with HCl. Other experiments were smoke, CO and HCl are measured in all rooms, should provide more meaningful data.

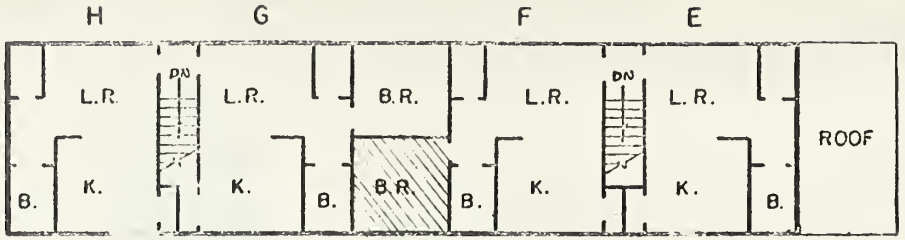
5. The presence of wiring in conduit may tend to support a conduit which softens and droops at elevated temperatures, thereby changing the exposure conditions by keeping the conduit in the fire.

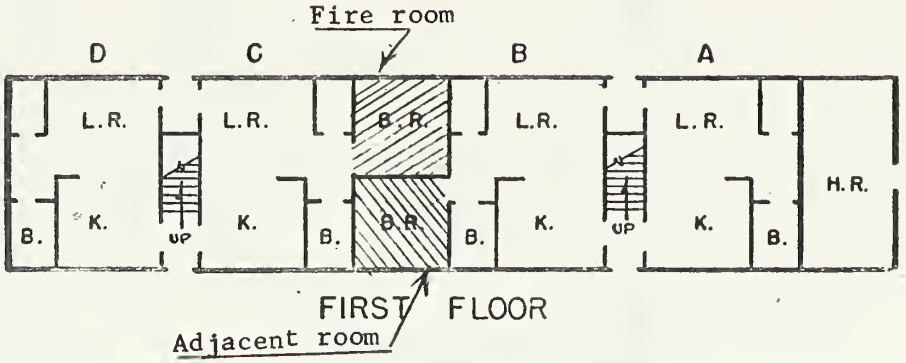
Table 1 Log of Observations

Approximate time of initiation of study: 4:45 pm Building: VF-6

Time	Observation
0:20	Crib beginning to burn, cracking.
0:55	First flame to top of the crib.
1:30	Flame about 12 inches above crib, 3 inches diameter at top of crib.
2:00	Flame about 18 inches above crib, 4 inches diameter at top of crib.
2:20	First light smoke out of window, light gray color.
2:40	Light haze of smoke in room, light gray smoke out window.
3:00	Flame about 24 inches above crib, 6 inches diameter at top of crib.
3:30	Flame about 24 inches above crib, 6 inches diameter at top of crib.
4:00	Flame about 24 inches above crib, 6 inches diameter at top of crib. Neutral plane now splits window opening in center, still light gray smoke.
4:30	Flame about 36 inches above crib, 6 inches diameter at top of crib.
5:00	Flame about 36 inches above crib, 10 inches diameter at top of crib.
5:20	Conduit deflecting from ceiling, about 6 inches.
5:50	Conduit deflecting from ceiling, about 24 inches.
6:15	Conduit deflecting from ceiling, about 36 inches.
6:25	Conduit deflecting from ceiling, about touching flames from crib.
6:35	Conduit charring, discoloration.
6:50	Conduit flaming.
7:00	Flame about 48 inches above crib.
7:30	Conduit broke in two pieces, continuing to burn. Sampling from receptacle.
8:00	Flames hit ceiling.
8:40	Observor leaving room upstairs.
9:00	Flames spreading in waves across ceiling.
9:40	Window glass cracked.
10:00	Smoke from top receptacle and room adjacent.
10:20	Smoke out of ventilators in adjacent room.
10:45	Neutral plane now down to 4 inches above window sill - smoke turning dark.
11:00	Smoke from adjacent room.
11:20	Smoke now very dark, neutral plane 4 inches above sill.
12:00	Smoke now very dark, neutral plane 4 inches above sill, room full of smoke.
12:30	Same as above, also now difficult to observe flame.
13:00	Same as above.
13:30	Same as above.
14:00	Same as above.
14:25	No flame visible, through smoke, can be heard however.
14:50	Flame again visible through smoke conditions as above.
15:40	Sampling from adjacent room upstairs.
16:00	Fire observed to have extended to adjacent room 1st floor.
16:40	Fire attacked in adjacent room, 1 1/2 inch line.
16:50	Air from attack in adjacent room caused flare up in room. Paint on walls flashed and window frame was ignited.
17:05	Fire appeared to have returned to previous steady state with neutral plane 4 inches from window sill, very dark smoke, and small flames around window frame.
17:40	Sampling adjacent room upstairs.
18:30	Fire attacked through window with 1 1/2 inch line.

Observor: J. L. Bryan





RM.	NET AREA	CAP.	REMARKS	RM.	NET AREA	CAP.	REMARKS
	200		HEATING ROOM	E	120		LIVING RM.
A	120		LIVING RM.		110		KITCHEN
	110		KITCHEN		35		BATH
	35		BATH	F	120		LIVING RM.
B	120		LIVING RM.		110		KITCHEN
	110		KITCHEN		100		BED RM.
	100		BED RM.		35		BATH
	35		BATH	G	120		LIVING RM.
C	120		LIVING RM.		110		KITCHEN
	110		KITCHEN		100		BED RM.
	100		BED RM.		35		BATH RM.

VETRANS FAMILIES BUILDINGS
SPACE DIAGRAM

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Fig. 1 Location of experimental rooms in test building

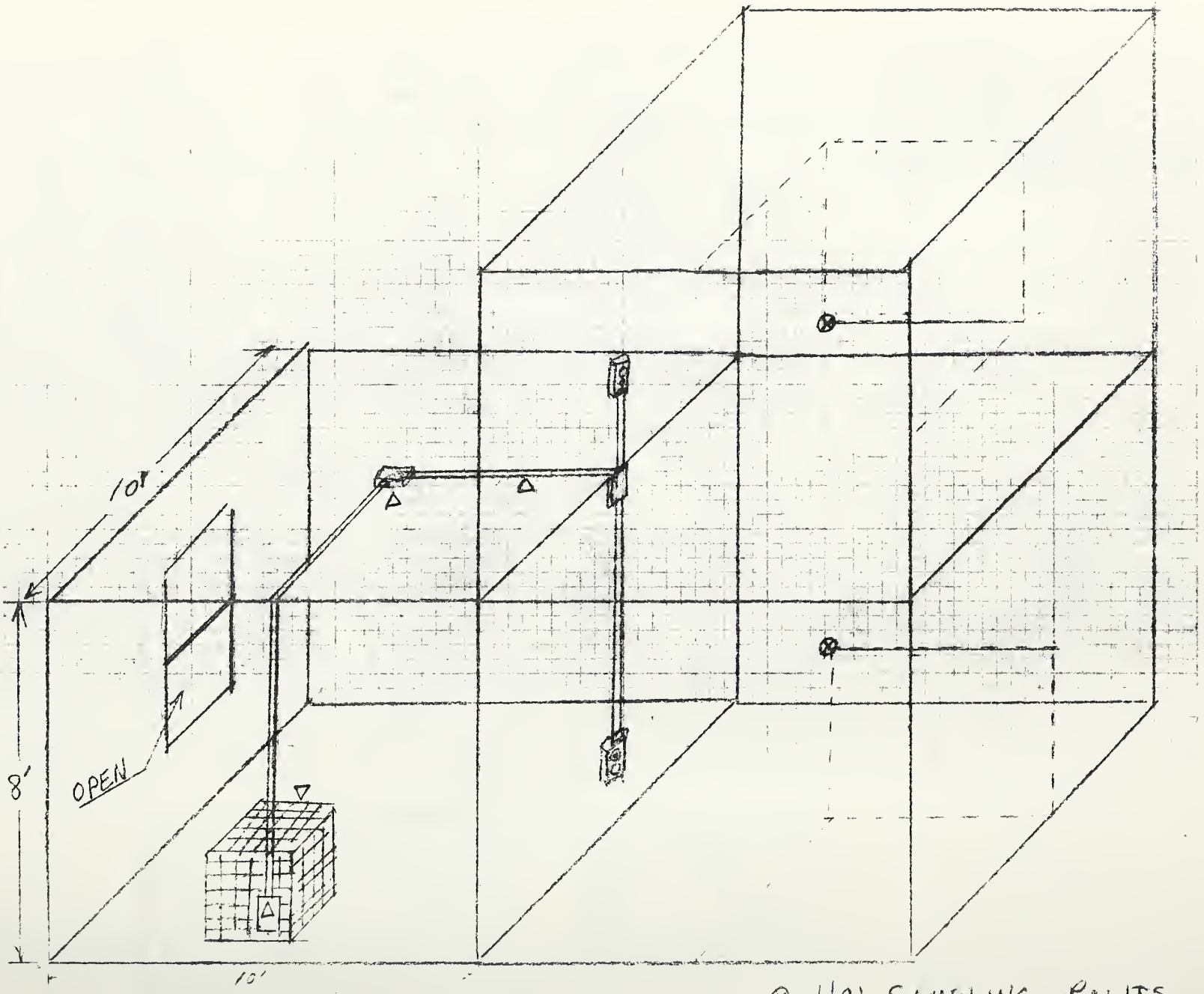

Fig. 2. PVC conduit layout in experimental rooms

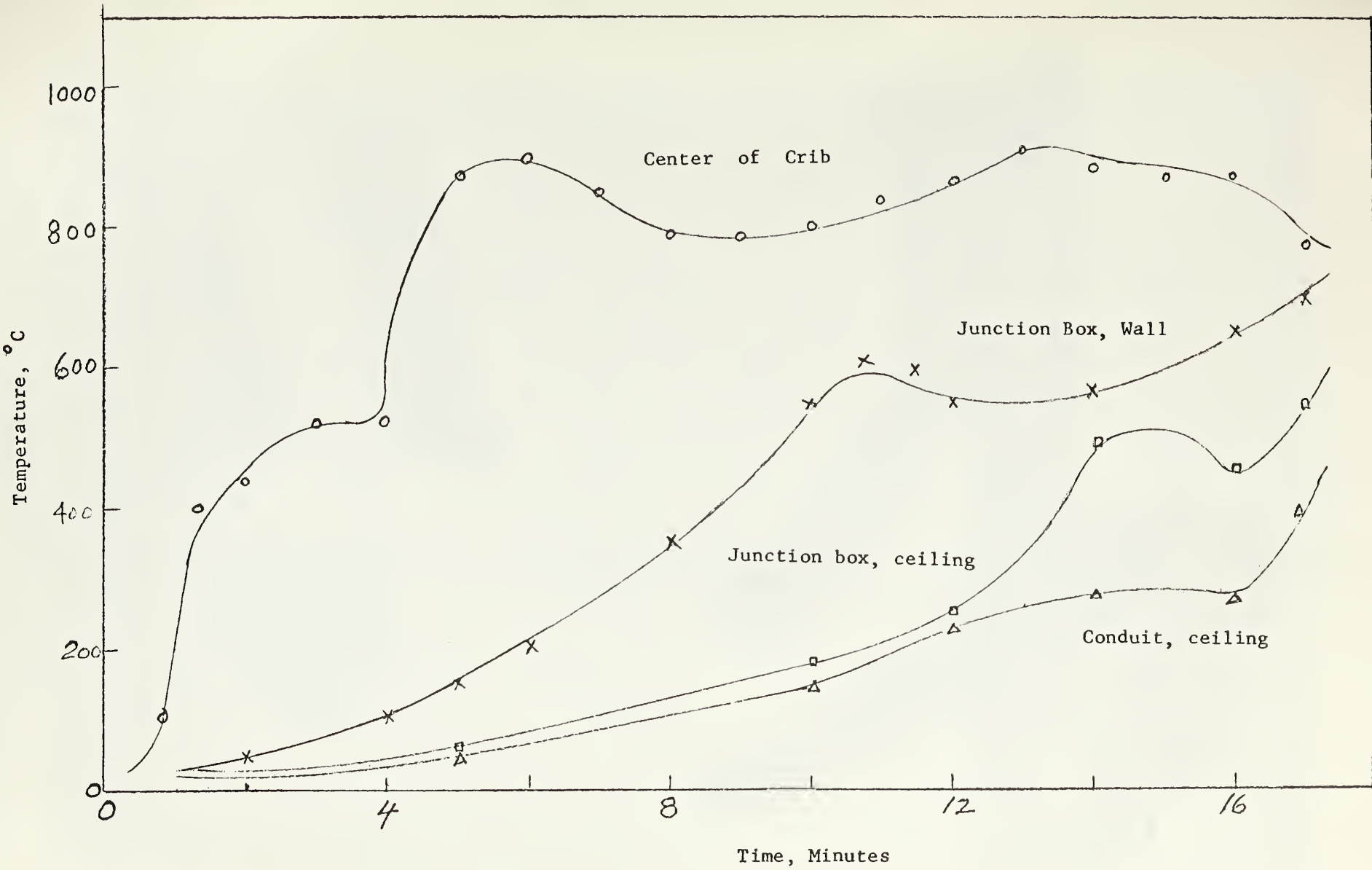

Figure 3 · Time-Temperature Profiles in the Fire Room

Figure 4 Typical Section of PVC Conduit Recovered from Fire Room

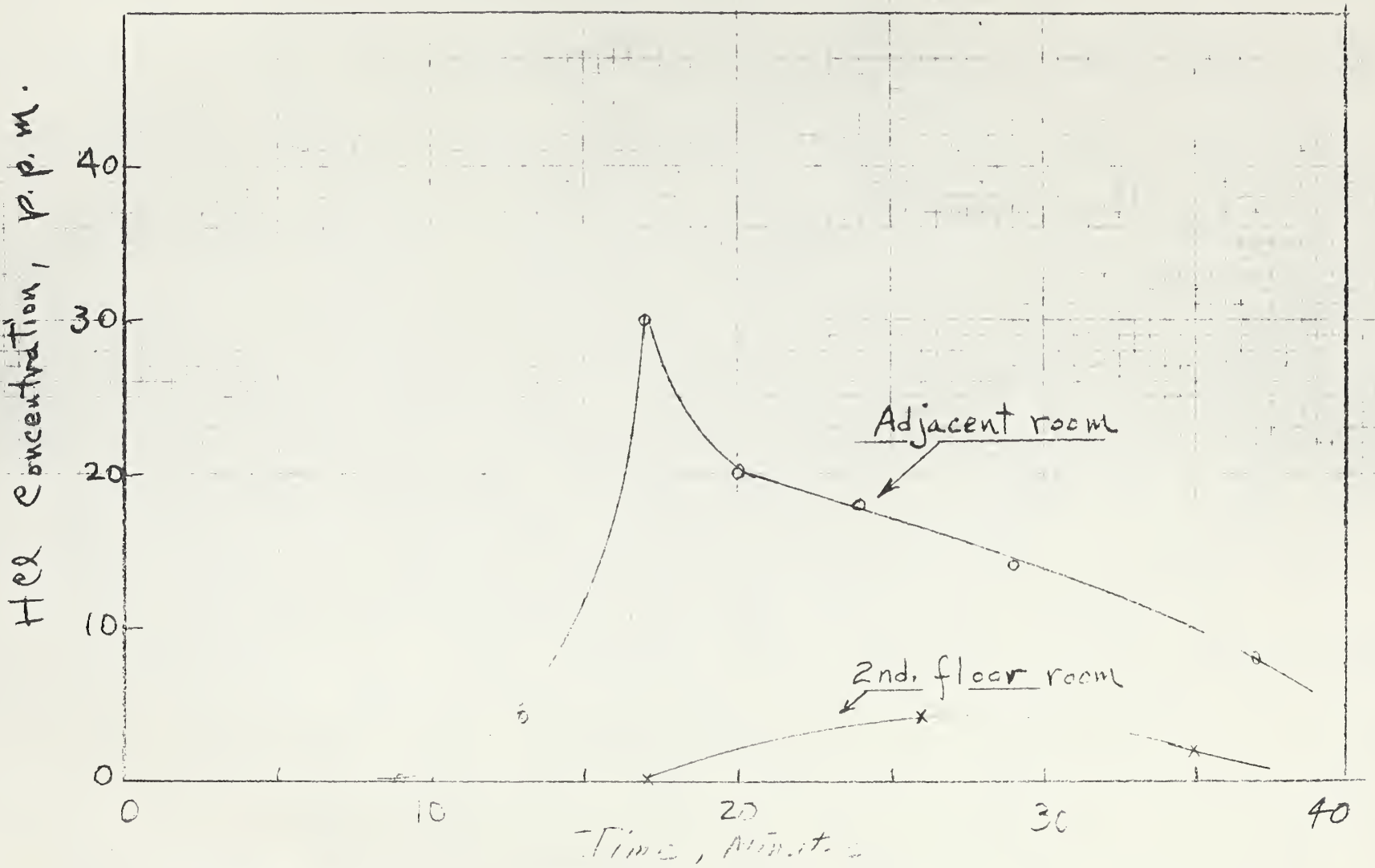

Figure 5 HCl Concentration in Center of Rooms