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FIRE DETECTION, EXTINGUISHMENT, AND MATERIAL TESTS FOR AN AUTOM--ETC(U)
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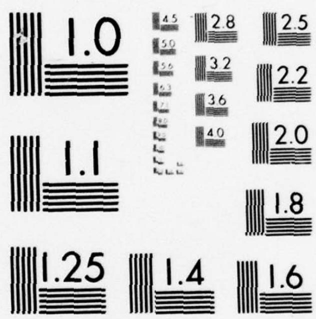

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FIRE DETECTION, EXTINGUISHMENT, AND MATERIAL TESTS FOR AN AUTOMATED GUIDEWAY TRANSIT VEHICLE

Richard G. Hill
George R. Johnson

MAY 1978

FINAL REPORT

Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

Prepared for

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16. Abstract

Tests were conducted in a simulated automated guideway transit vehicle to determine the effectivity of a Halon 1301 fire-extinguishing system during various types of fires, evaluate a photoelectric and an ionization fire detection system, and compare various materials under full-scale fire conditions. A portion of a school bus (770 cubic feet) supplied with an airflow system (300 cubic feet per minute--225 recirculated and 75 fresh air) was used as the test article. Smoke density, temperature, carbon monoxide, and Halon 1301 concentrations were monitored throughout the tests. Hydrogen fluoride (HF) samples were taken during the fire extinguishing tests. The noise level associated with the activation of the explosive charge and release of the compressed gas from the 1301 reservoir is high. In the experiment, levels of 120-132 decibel (Absolute) were recorded. There was no attempt to muffle this noise level to the passengers in an enclosed compartment, since this was beyond the scope of the report. A noise suppression system would most likely have to be designed for any practical applications. Halon 1301 is most effective if it is released within 1 to 2 seconds, to establish the 5 percent by volume concentration. If slower release occurs, or if the fire is deep-seated, the Halon 1301 can be decomposed to HF, a toxic gas. In the tests, when a release time of 7 seconds occurred, the HF concentration reached dangerous conditions. Test results showed that the photoelectric detector was faster responding than the ionization detector. Material tests indicated that underseat fires were more severe than fires on or in the seat for both neoprene and urethane cushions.

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METRIC CONVERSION FACTORS

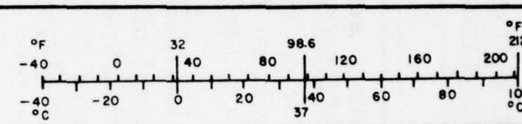
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



SUMMARY

This report describes 27 fire tests performed in a mockup (modified school bus) of an automated guideway transit vehicle. There were a number of significant findings relative to fire safety in this type of vehicle. First, Halon 1301 was found to be effective in extinguishing typical seat fires, but generated extremely high noise levels during discharge; however, significant reductions in noise were achieved by modifying the discharge nozzle. Another important finding was that in all tests fires, the photoelectric detector responded more quickly than did the ionization detector. Finally, by studying various seat fire ignition sources, it was concluded that the underseat fire was the most severe condition.

PREFACE

This report describes tests of a Halon 1301 fire extinguishing system for an Automated Guideway Transit System conducted by the Fire Protection Branch at the National Aviation Facilities Experimental Center (NAFEC). The project was funded by the Department of Transportation, Urban Mass Transportation Administration (UMTA) through its Office of New System and Automation (UTD-40), as part of UMTA's Advanced Group Rapid Transit (AGRT) program. The program was initiated and monitored by the Transportation Systems Center (TSC), Urban Systems Division. The work reported herein was performed between May 1976 and August 1976. It consisted of tests, measurements, and evaluation.

Special recognition and appreciation is made to James D. Leach, James Simpkins, Louise Speitel, and Ralph Russell of the Fire Protection Branch at NAFEC for their assistance during the test program. Acknowledgement is also made to Irving Litant and George Anagnostopoulos, the TSC technical monitors.

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INTRODUCTION

PURPOSE.

The purpose of this project is a threefold evaluation:

1. To determine the feasibility of using a Halon 1301 extinguishing system for transit vehicles,

2. To determine if photoelectric or ionization detectors can sense a fire quickly enough for the Halon 1301 to be safely and effectively deployed, and

3. To test the flammability behavior of certain materials proposed for use in these vehicles and how quickly extinguishment could be achieved with Halon 1301.

BACKGROUND.

The Advanced Group Rapid Transit (AGRT) Program of the Urban Mass Transportation Administration (UMTA) is developing a short (3 second) headway, 12-passenger vehicle automated urban transit system. One consideration under this program is the subject of fire safety.

Of the potential design configurations for the AGRT program, the worst case for fire safety is the suspended monorail concept where rapid evacuation would be difficult at best. Thus, the safety philosophy assumes that fires must be contained while passengers remain in a vehicle. Even in supported systems, it is the general philosophy to keep passengers (including children, the elderly, and the handicapped) inside a vehicle during most abnormal conditions until the vehicle can be moved to the nearest station.

Passengers can survive in a vehicle if a method of fire control is provided for surface fires that is both safe and rapid. Even the use of fire retardent materials does not account for combustible materials that may be carried on-board by the passengers.

After an investigation of numerous alternatives by the Transportation Systems Center (TSC), it was determined that the use of Halon 1301 in low (5 percent by volume) concentrations had the greatest potential in this area. Even though the nature of the Halon reaction in extinguishing fires is not completely understood, it has proven to be an effective process. This report assessed its use in transit vehicles, including a review of any hazards associated with undecomposed Halon 1301 and its decomposition products. Note, however, that this approach may be relatively expensive.

HALON 1301 CHARACTERISTICS AND HAZARDS.

Halon 1301 is a colorless, odorless gas, which is easily liquified under pressure. The vapor pressure at 70° Fahrenheit (F) is 200 pounds per square inch gauge (psig), the critical temperature and pressure being 152.6° F and 575 psig, respectively. Chemically, Halon 1301 is bromotrifluoromethane ($CBrF_3$) and has a molecular weight of 148.93 (reference 1).

The National Fire Protection Association (NFPA) guideline (reference 2) states that Halon 1301 can be safely used in occupied areas in concentrations up to 7 percent, but further recommends that occupant exposure to Halon 1301 concentrations of 7 percent or less not exceed 5 minutes. The volume of agent in all of tests described herein was 5 percent.

At elevated temperatures (approximately 900° F), Halon 1301 breaks down, with the decomposition products including hydrogen fluoride (HF), hydrogen bromide (HBr), free bromine, and carbonyl halides. The decomposition products of Halon 1301 pose much more of a threat to human habitation than does the agent itself. The reported approximate lethal concentration (ALC) using white rats for decomposed Halon 1301 ranges from 2,300 parts per million (p/m) (reference 3) to 14,000 p/m (reference 4). From previous data, it was determined that the major decomposition product of Halon 1301 was HF and that the ALC for decomposed Halon 1301 and for HF were close enough to assume that the toxicity of the decomposed Halon was due to the HF concentration (reference 3). Therefore, only HF concentrations were determined from the decomposing Halon 1301.

TEST VEHICLE DESCRIPTION.

The test vehicle used to simulate an automated guideway transit vehicle (AGTV) was a standard-size, Superior Coach® school bus, with an aluminum partition installed to divide the bus interior into two sections. The aft section was designated the test section, and all passenger seats were removed from this area. The dimensions of the test section were as follows:

Length: 17 feet, 11 inches (215 inches),
Height: 6 feet (72 inches) at centerline, and
Width: 7 feet, 6 inches (90 inches).

These dimensions provide an internal volume of 806.22 cubic feet (ft^3); however, due to the curvature of the bus structure and the presence of the bus aft wheel covers in the test section, the actual volume was reduced to 770 cubic feet, the approximate volume of an operational AGTV.

Entrance to the test vehicle was gained through the rear emergency door. The seven windows on each side of the test section were permanently closed and provided project personnel an excellent view of test occurrences. Both closed circuit television and color motion picture film of selected tests were taken through these windows and through the bus rear door.

To create an internal airflow that would be similar to that provided by the AGTV air-conditioning system, a system of external ducting, with a circulation fan and airflow regulating valve, was installed on the test article (figure 1). The flow through this system was maintained at 300 ft^3 per minute (225 ft^3 recirculated air and 75 ft^3 fresh) during all tests requiring air movement. The airflow generated by the circulation fan entered the test section through two 4-inch-diameter outlets in the upper portion of the separating partition. It exited the section through two 4-inch-diameter ducts in the lower rear wall. Fresh air was drawn in through a 2-inch-diameter regulating valve mounted on the fan-air distribution box atop the bus. To prevent inadvertently overpressurizing the test vehicle, a 7-inch by 5-inch flapper-type relief door was installed on the lower rear wall of the bus. A baffle was installed in front of each of the air outlets in the partition to prevent concentrated air blasts. Fire load ignition was provided by using a manually activated high-voltage transformer creating a spark across two electrodes. Two common book matches placed between these electrodes flamed, thereby igniting the fire load. The various fire loads are described in the "TEST DESCRIPTION" section of this report. Mounted atop the bus (figure 2), with the discharge tube exactly in the center of the test section ceiling, was a Halon 1301 extinguisher storage bottle, with a volume of approximately 770 cubic inches (in^3). This bottle was serviced with 15.4 pounds of Halon 1301 with a dry nitrogen charge of 360 pound per square inch gauge (psig) for all tests. This weight of agent was calculated to produce a 5-percent concentration in the test vehicle. The discharge tube directed agent to the discharge nozzle located 2 inches below the ceiling. Various discharge nozzles were used during the test program (figure 3). A high-volume carbon dioxide (CO_2) discharge horn was installed on the upper rear wall of the test vehicle to extinguish the test fire when Halon 1301 was not used.

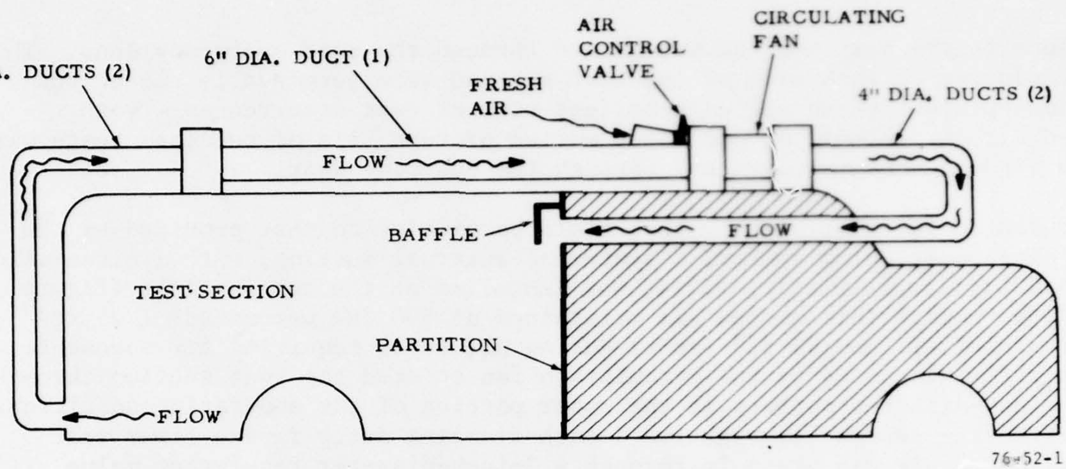

FIGURE 1. AIRFLOW-CIRCULATING SYSTEM

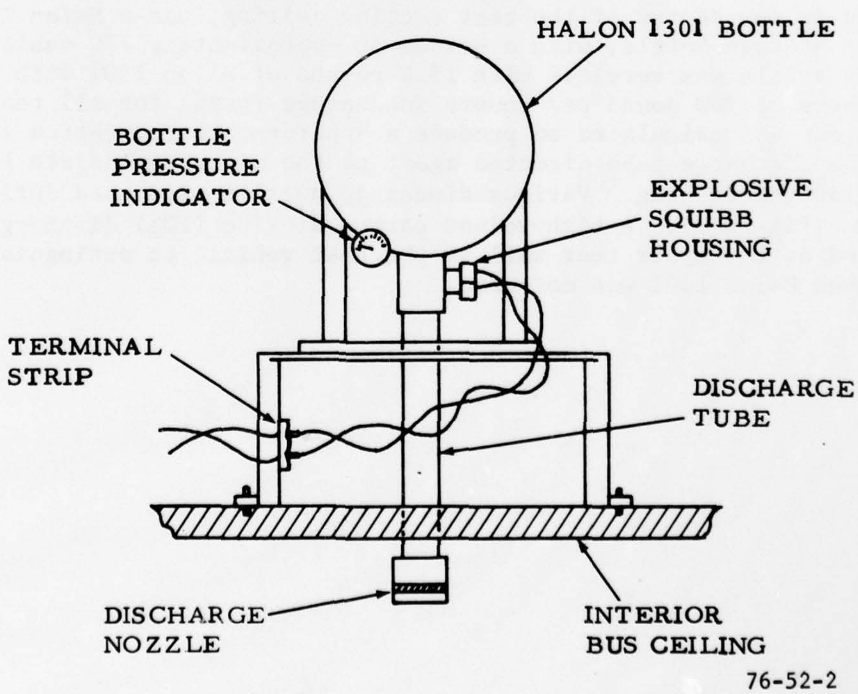

FIGURE 2. HALON 1301 BOTTLE INSTALLATION

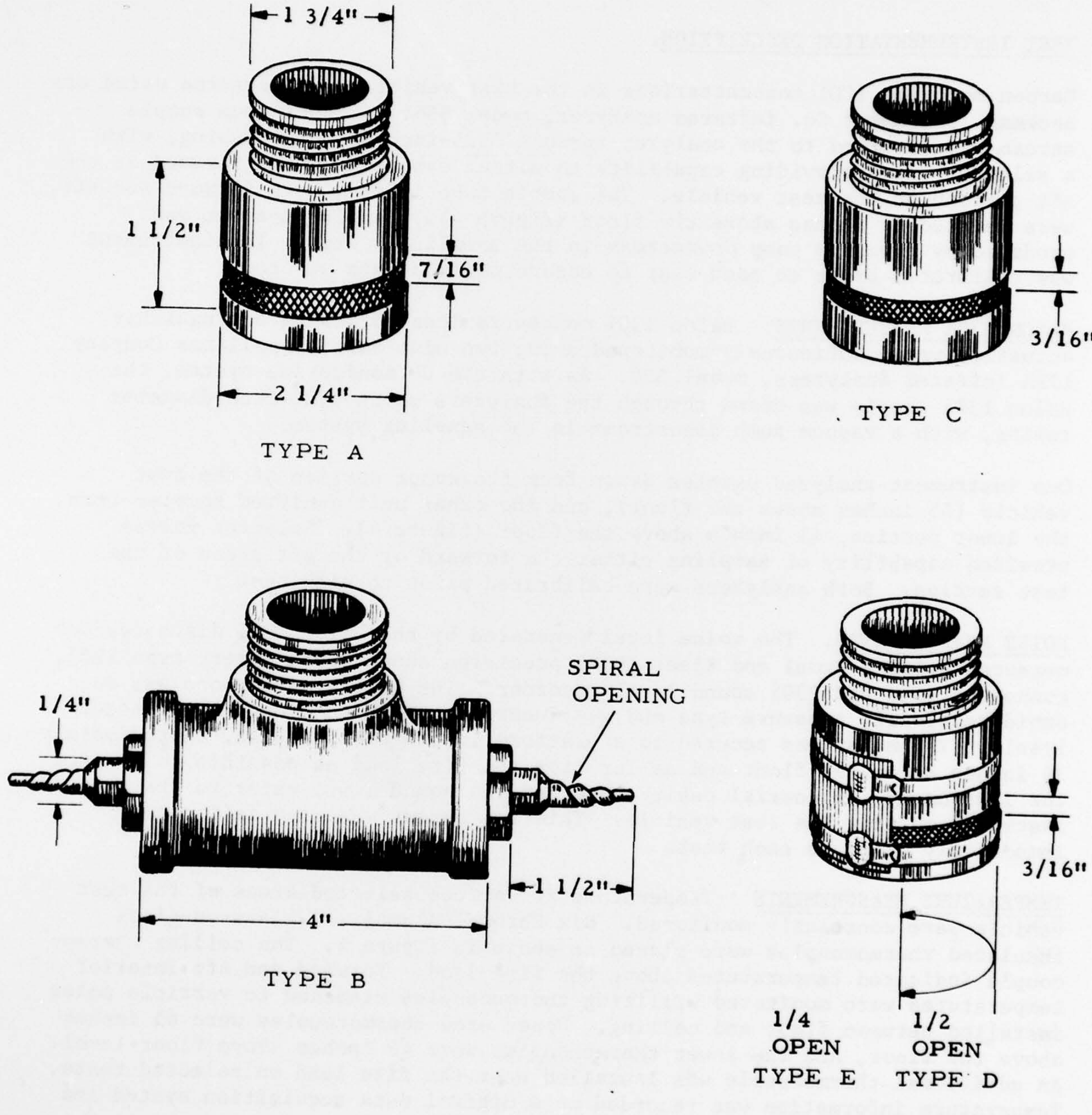

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FIGURE 3. DISCHARGE NOZZLE CONFIGURATIONS

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TEST INSTRUMENTATION DESCRIPTION.

Carbon monoxide (CO) concentrations in the test vehicle were measured using one Beckman Instrument Co. infrared analyzer, model 864. A continuous sample stream was directed to the analyzer through 0.25-inch-diameter tubing, with a selector valve providing capability to either sample from the forward or the aft portion of the test vehicle. The sample tube inlets, both forward and aft, were located 64 inches above the floor (figure 4). Sample movement was produced by a vacuum pump downstream in the sampling system. The instrument was calibrated prior to each test to ensure maximum data accuracy.

HALON 1301 MEASUREMENTS. Halon 1301 concentrations following extinguisher actuation were continuously monitored using two Mine Safety Appliance Company LIRA infrared analyzers, model 300. As with the CO monitoring system, the Halon 1301 sample was drawn through the analyzers using 0.25-inch-diameter tubing, with a vacuum pump downstream in the sampling system.

One instrument analyzed samples drawn from the upper portion of the test vehicle (65 inches above the floor), and the other unit analyzed samples from the lower portion, 41 inches above the floor (figure 4). Selector valves provided capability of sampling either the forward or the aft areas of the test section. Both analyzers were calibrated prior to each test.

NOISE MEASUREMENTS. The noise level generated by the Halon 1301 discharge was measured using a Bruel and Kjaer (B&K) precision sound level meter, type 2203, connected to a B&K 2305 sound level recorder. The unit's microphone was an omnidirectional, pressure type and was incorporated in the sound level meter itself. The meter was secured to a platform in the test section, approximately 36 inches above the floor and as far from the fire load as possible to protect the instrument. A coaxial cable connected the sound level meter to the recorder installed outside the test vehicle. This instrument was also calibrated immediately prior to each test.

TEMPERATURE MEASUREMENTS. Temperature at various selected areas of the test vehicle were constantly monitored. Six Chromel-Alumel (K) glass-on-glass insulated thermocouples were placed as shown in figure 4. The ceiling thermocouple indicated temperatures above the fire load. Forward and aft interior temperatures were monitored utilizing thermocouples attached to verticle poles installed between floor and ceiling. Upper area thermocouples were 65 inches above the floor, and the lower thermocouples were 42 inches above floor level. An additional thermocouple was installed near the fire load on selected tests. Temperature information was recorded on a digital data acquisition system and a strip chart recorder.

SMOKE DETECTION EQUIPMENT. Fire load smoke was observed by use of two smoke detectors secured to the ceiling in the aft area of the test vehicle (figure 4). One detector was a dual-chamber, ionization type (CPD-1212) and the other, a photoelectric, spot type (71-1X0000-000). Both detectors were manufactured by Fenwal, Incorporated. Normal smoke alarms on both units were steady red lights on the detector body. In addition to this signal, both detectors were connected

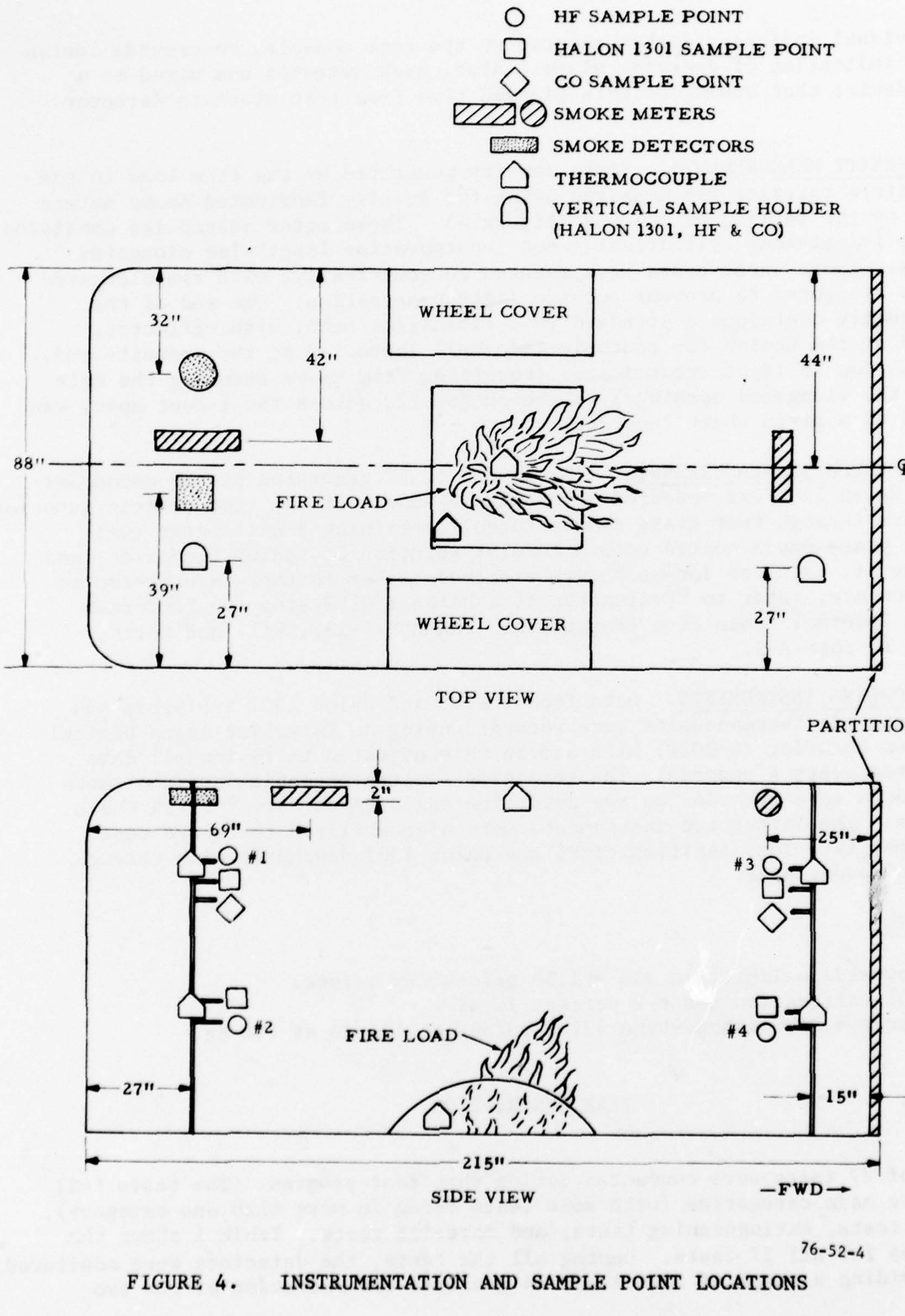


FIGURE 4. INSTRUMENTATION AND SAMPLE POINT LOCATIONS

to individual indicator lights mounted on the test console, to provide instantaneous indication of detector alarm. Also, each detector was wired to a timing device that would indicate elapsed time from test start to detector alarm.

SMOKE DENSITY MEASUREMENTS. Smoke density generated by the fire load in the test vehicle interior was measured using two locally fabricated smoke meters mounted on the ceiling of the bus (figure 4). These meter assemblies consisted of three 1-foot-long cylindrical tubes incorporating lengthwise elongated openings. These three tubes were mounted concentrically, with the elongated openings staggered to prevent outside light penetration. One end of the tube assembly contained a standard PR-3 flashlight bulb, with reflector, directed at the Weston 856 photoelectric cell installed at the opposite end. The reduction in light transmission (resulting from smoke entering the unit through the elongated openings) to the photocell, across the 1-foot span, was recorded on a strip chart recorder.

HYDROGEN FLUORIDE MEASUREMENTS. The amount of HF generated by the decomposition of Halon 1301 was measured by drawing a sample of the test vehicle interior atmosphere through four glass sample tubes, containing 3-millimeter (mm) diameter glass beads coated with a 1-molar solution of sodium hydroxide, and analyzing it, using an ion-selective electrode. For further information on this procedure, refer to "Evaluation of a Halon 1301 System for Postcrash Aircraft Internal Cabin Fire Protection," FAA-RD-76-132, Hill and Boris, appendix A, page A-1.

DATA RECORDING INSTRUMENTS. Data from the CO and Halon 1301 analyzers and four of the six thermocouples were recorded using an Esterline Angus Digital Aquisition Recorder (D-2020) with a scan rate adjusted to review all data points once every 4 seconds. The remaining two thermocouples and the smoke density data were recorded on two Esterline Angus Speed Servo® Strip Chart Recorders. The latter two instruments were also utilized to record test start time, fire load ignition time, and Halon 1301 discharge time through the use of event pens.

CALIBRATION.

Carbon monoxide calibration gas = 1.58 percent by volume.
Halon 1301 calibration gas = 7 percent in air.
Noise source = Pistonphone-type 4220, output of 124 dB at 250 Hz.

TEST DESCRIPTION

A total of 27 tests were conducted during this test program. The tests fell into three main categories (with some tests being in more than one category), detector tests, extinguishing tests, and material tests. Table 1 shows the categories for all 27 tests. During all the tests, the detectors were monitored, thus providing a range of fire loads to evaluate the operation of the two

TABLE 1. TEST PARAMETERS

Test No.	Detectors Monitored	Extinguishment Used	Fire Load
1	Yes	Yes	10 Sheets of Newspaper
2	Yes	Yes	10 Sheets of Newspaper
3	Yes	No	10 Sheets of Newspaper*1
4	Yes*	Yes	10 Sheets of Newspaper
5	Yes*	Yes	10 Sheets of Newspaper
6	Yes*	Yes	10 Sheets of Newspaper
7	Yes*	Yes	PVC Insulation on Hot Wire
8	Yes	Yes	PVC Insulation on Hot Wire
9	Yes	Yes	5 Sheets of Newspaper on School Bus Seat
10	Yes*	Yes	10 Sheets of Newspaper
11	Yes*	Yes	10 Sheets of Newspaper
12	Yes	No	10 Sheets of Newspaper on School Bus Seat
13	Yes	Yes	10 Sheets of Newspaper under Ambassador Seat
14	Yes	No	PVC Insulation on Hot Wire
15	Yes*	Yes	Bus Seat with 1/2-Pint Gasoline on and Under
16	Yes	No	10 Sheets of Newspaper
17	Yes*	Yes	10 Sheets of Newspaper
18	Yes*	Yes	10 Sheets of Newspapers
19	Yes*	Yes	10 Sheets of Newspapers
20	Yes	Yes	Ambassador Seat Slit--1/2 oz Gasoline
21	Yes	No	Neoprene Seat Slit--1/2 oz Gasoline
22	Yes	No	Neoprene Seat 10 Sheets of Newspaper Under Seat
23	Yes*	Yes	10 Sheets of Newspaper
24	Yes	No	Urethane PVC Covered Seat Slit--1/2 oz Gas
25	Yes	No	Urethane PVC Covered Seat Fiberglass Slit--1/2 oz Gas
26	Yes	No	Neoprene Seat with 10 Sheets of Newspaper under Seat
27	Yes	No	Urethane Seat with 10 Sheets of Newspaper under Seat

*Extinguishing agent discharge at photoelectric detector activation.

*1 Paper layed flat, not crumpled.

detectors used. During 17 of the 27 tests, Halon 1301 was used to extinguish the fire. Eight tests (test 13 and 20 through 27, excluding 23) were classified as material tests.

All tests were conducted with the fire load positioned near the center of the test vehicle. Fire load ignition for all tests except 7, 8, and 14 was accomplished with a match ignited by a spark ignitor. Tests 7, 8, and 14 used a standard barbecue lighter to overheat polyvinyl chloride (PVC) insulation, which was tied around the heating element of the lighter.

The standard fire load used in many of the tests was 10 full sheets of newspaper crumpled and placed in a pile. Other fire loads included the overheated PVC insulation, and various types of seats, with paper fires under or on them, gasoline on and under the seats, or a fire in the seat after the cover material was slit. Refer to table 1 for a description of the fire load used for each test.

The tests were conducted such that when the match was ignited, three timers would begin. One timer in the test vehicle would run for the entire length of the test, while the other two were individually hooked to the ionization detector and the photoelectric detector. The alarm of the detectors automatically stopped the timers, thus giving the time of detection.

The tests were set up such that the actuation of the photoelectric detector could automatically shut OFF the airflow and activate the discharge of the Halon 1301, or the agent discharge and/or airflow shutoff could be manually controlled.

Four hydrogen fluoride samples were taken, commencing with agent discharge, and at 15 second intervals, during all (except tests 1 and 7) the extinguishing tests. The noise level, resulting from the agent discharge, was monitored for tests 3, 5, 17, 18, and 23. The noise level was measured on the "A" scale.

DISCUSSION AND RESULTS

DETECTOR TESTS.

Both the photoelectric and ionization detectors were used in all 27 tests conducted during this program. Table 2 shows the overall results of those tests. In all 27 tests, the photoelectric detector alarmed before the ionization detector. The percent light reduction needed for detection varied with test conditions. The photoelectric detector activation varied from 2- to 7-percent light reduction, with the average light reduction needed for alarm being 4.26 percent. The ionization detector alarmed over a large range of smoke density, with the least light reduction being 6 percent and the largest being 88 percent. The four tests of seat fires started with paper under the seat brought the slowest response from the ionization detector. The average light transmission for those four tests was 23.75, as compared with an average of

TABLE 2. DETECTOR TESTS

Test No.	Time to Detection (Seconds) Photoelectric	Time to Detection (Seconds) Ionization	Percent Light Transmission (*1) (1 Foot) at Detection Photoelectric	Percent Light Transmission (*1) (1 Foot) at Detection Ionization	Temperature at (*1) Detection °F Photoelectric	Temperature at (*1) Detection °F Ionization	Fire Load
1	33	35	96	94	114	127	10 Sheets of Newspaper
2	35	39	96	93	102	108	10 Sheets of Newspaper
3	66	132	95	90	102	136	10 Sheets of Newspaper *2
4	24	*3	96	-	100	-	10 Sheets of Newspaper
5	18	*3	98	-	110	-	10 Sheets of Newspaper
6	18	*3	96	-	108	-	10 Sheets of Newspaper
7	142	*3	94	-	92	-	PVC Insulation on Hot Wire
8	118	No Detection at 148	95	-	93	-	PVC Insulation on Hot Wire
9	16	25	94	90	98	102	5 Sheets of Newspaper on School Bus Seat
10	28	*3	95	-	104	-	10 Sheets of Newspaper
11	21	*3	96	-	107	-	10 Sheets of Newspaper
12	18	22	95	90	104	106	10 Sheets of Newspaper on School Bus Seat
13	27	50	95	18	107	146	10 Sheets of Newspaper under Ambassador Seat
14	125	*3	97	-	114	-	PVC Insulation on Hot Wire
15	6	*3	95	-	115	-	Bus Seat with 1/2 Pint Gasoline on and under Seat
16	20	42	98	90	121	158	10 Sheets of Newspaper
17	18	*3	93	-	104	-	10 Sheets of Newspaper
18	25	*3	95	-	114	-	10 Sheets of Newspaper
19	24	*3	96	-	102	-	10 Sheets of Newspaper
20	63	130	95	92	103	107	Ambassador Seat Slit with 1/2 oz Gasoline
21	74	*3	97	-	99	-	Neoprene Seat Slit-1/2 oz Gasoline
22	10	19	97	50	105	116	Neoprene Seat 10 Sheets of Newspaper under Seat
23	15	*3	97	-	105	-	10 Sheets of Newspaper
24	68	230	97	88	103	107	Urethane PVC-Covered Seat Slit 1/2 oz Gas
25	97	*3	96	-	160	-	Urethane PVC-Covered Seat Fiberglass Slit 1/2 oz Gas
26	18	24	94	15	113	145	Neoprene Seat 10 Sheets of Newspaper under Seat
27	12	32	97	12	95	113	Urethane Seat 10 Sheets of Newspaper under Seat

*1 Measuring location near ceiling at aft end of vehicle.
*2 Paper layed flat, not crumpled.
*3 Extinguishment prior to ionization detector activation.

90.88-percent light transmission for the remainder of the tests where ionization detection occurred.

In order to determine the effectiveness of the smoke-type detectors versus thermal detection, the temperature in the vicinity of the detectors was measured. At the time of photoelectric detection, the average temperature was 105° F, and for ionization detection the average was 123° F (average starting temperature was in the mid 90°'s due to photographic lights).

Since the photoelectric detector proved to give the earliest alarm, it was used to provide the automatic agent discharge when that system was used. When that occurred, no detection time was obtained for the ionization detector. A false warning from the photoelectric detector was observed, which automatically actuated the Halon 1301 system prior to the start of a test. The cause of this false alarm was not determined, and no problem was observed during any subsequent tests.

EXTINGUISHMENT TESTS.

Seventeen tests were conducted using Halon 1301 as an extinguishing agent. Table 3 lists the extinguishing tests as well as pertinent data on each test. These tests were designed to answer a number of questions pertaining to the possible use of a Halon 1301 extinguishing system in a monorail-type vehicle. The system tests conducted showed the ability of 5 percent by volume of Halon 1301 to extinguish a variety of fire conditions.

Tests were conducted using newspaper as a fire load as well as seats with both urethane and neoprene foam, with and without PVC covering. Fires were started under the seats, on the seats, and in the seats (seat cushion was slit and 1/2 ounce of fuel was poured into slit, then ignited). A test was also conducted in which 1/2 pint of gasoline was poured on and under a seat and then ignited. In all cases, the fire was rapidly and totally extinguished with the use of 5 percent by volume, Halon 1301.

Two main areas of concern over the use of Halon 1301 investigated were the amount of toxic decomposition products and the sound level produced in the vehicle at discharge. In regard to toxic byproducts, table 4 lists the HF concentrations of all the samples taken during the extinguishment phase of the project. Samples were taken 15 seconds apart, commencing with location 1 at the time of agent discharge. The duration of each sample was approximately 30 seconds.

The amount of decomposition of the agent depended on the type and size of the fire and the length of agent discharge. A small, deep-seated fire in a seat produced very little HF when quickly extinguished. Larger fires of newspaper or seats extinguished in less than 1.8 seconds, produced HF levels ranging from 2.2. to 26.8 p/m. Although irritating to the eyes and nose, that level is not considered dangerous to life for short exposures. However, when the discharge time was increased to 7.3 seconds, the HF level jumped to a dangerously high level of 178 p/m.

TABLE 3. EXTINGUISHMENT TESTS

Test No.	Fire Load	Time of System Activation (Seconds)	Activation Reason	Time to Discharge Agent (Seconds)	Discharge Nozzle Type	Peak Hydrogen Fluoride (p/m)	Airflow	Remarks
1	10 Sheets of Newspaper	37	Ionization Detector Activation	0.60	A	NA	Yes	
2	10 Sheets of Newspaper	39	Ionization Detector Activation	.60	A	26.8	Shut off at Agent Discharge	
4	10 Sheets of Newspaper	24	Photoelectric Detector Activation	.60	A	21.9	Shut off at Agent Discharge	Peak Noise 132 dB(A)
5	10 Sheets of Newspaper	18	Photoelectric Detector Activation	.60	A	14.0	Shut off at Agent Discharge	
6	10 Sheets of Newspaper	18	Photoelectric Detector Activation	7.3	B	178	Shut off at Agent Discharge	Peak Noise 115 dB(A)
7	PVC Insulation on Hot Wire	142	Photoelectric Detector Activation	.60	A	NA	Shut off at Agent Discharge	
8	PVC Insulation on Hot Wire	148	Smoke Level Hot Wire-Red Hot	.60	A	0.75	Shut off at Agent Discharge	Smoke continued to come from PVC on hot wire after agent discharge.
9	5 Sheets of Newspaper on School Bus Seat	66	Seat Burning	.60	A	4.01	Yes	Small fire on seat completely extinguished.
10	10 Sheets of Newspaper	28	Photoelectric Detector Activation	.60	A	2.2	Yes	
11	10 Sheets of Newspaper	21	Photoelectric Detector Activation	7.3	B	71.68	Yes	
13	10 Sheets of Newspaper under Ambassador Seat	52	Major Seat Involvement	.60	A	18.3	Yes	Vinyl burned off bottom of seat. Completely extinguished.
15	Bus Seat with 1/2 pint of Gasoline on and under	6	Photoelectric Detector Activation	.60	A	15.77	Shut off at Agent Discharge	Large flaming area extinguished. No damage to seat.
17	10 Sheets of Newspaper	18	Photoelectric Detector Activation	.86	C	22.4	Shut off at Agent Discharge	Peak Noise 127 dB(A)
18	10 Sheets of Newspaper	25	Photoelectric Detector Activation	1.0	D	14.6	Shut off at Agent Discharge	Peak Noise 123 dB(A)
19	10 Sheets of Newspaper	24	Photoelectric Detector Activation	1.0	D	19.5	Yes	
20	Ambassador Seat Slit-1/2 oz Gas	276	Seat Involvement	.60	A	1.8	Yes	Seat fire totally extinguished.
23	10 Sheets of Newspaper	15	Photoelectric Detector Activation	1.8	E	18.4	Shut off at Discharge	Peak Noise 121 dB(A)

TABLE 4. HYDROGEN FLUORIDE CONCENTRATIONS

Test Number	Sample Location No.* 1 (p/m)	2 (p/m)	3 (p/m)	4 (p/m)
2	26.8	15.2	10.5	12.6
4	21.9	19.4	21.2	12.6
5	13.2	13.5	13.3	14.6
6	126	169	178	171
8	0.76	0.62	0.75	0.64
9	4.01	3.62	2.37	1.40
10	1.72	2.26	1.40	1.83
11	No Data	71.68	63.80	70.25
13	18.3	14.0	6.59	7.17
15	14.91	15.77	10.90	9.75
17	22.4	18.2	18.2	19.6
18	14.6	13.2	10.6	7.6
19	19.5	16.0	10.3	8.9
20	1.8	1.6	1.7	0.6
23	18.37	17.75	13.31	10.39

* Refer to figure 4 for sampling number locations.

Figure 5 shows a comparison of HF levels for the various discharge times tested when airflow was halted at the time of agent discharge. The HF levels remained fairly constant with discharge times of less than 1.8 seconds; however, when the discharge time increased to 7.3 seconds, a large increase in HF was noted. Figure 6 shows a comparison of HF concentrations between tests 6 and 11 and between 10 and 4. Tests 6 and 11 were similar tests, with 10 sheets of newspaper as the fire load and a long discharge time of 7.3 seconds. Tests 4 and 10 were of the same fire load, except a fast discharge of 0.6 seconds was used. Tests 4 and 6 were with airflow shut OFF at discharge; whereas for tests 10 and 11, the airflow continued after discharge. A marked reduction in HF concentrations occurred when the airflow continued after agent discharge.

The sound level was shown to be dependent on the rate of agent discharge. The faster the discharge, the greater the sound level. Figure 7 shows the sound level for the five discharge configurations used. The increase in discharge time from 0.6 seconds to 1.8 seconds lowered the peak decibel (dB) absolute (A) level from 132 to 121 dB(A), while no noticeable increase in HF was detected. However, when the discharge time was increased to 7.3 seconds, a large increase (7 to 10 times) in HF was recorded, while the peak noise level was reduced to 115 dB (A).

When the extinguishing tests were conducted simulating a PVC-covered electrical wire overheat, very small quantities of HF were recorded (0.75 p/m maximum). The PVC continued to smoke after agent discharge; however, no flaming occurred.

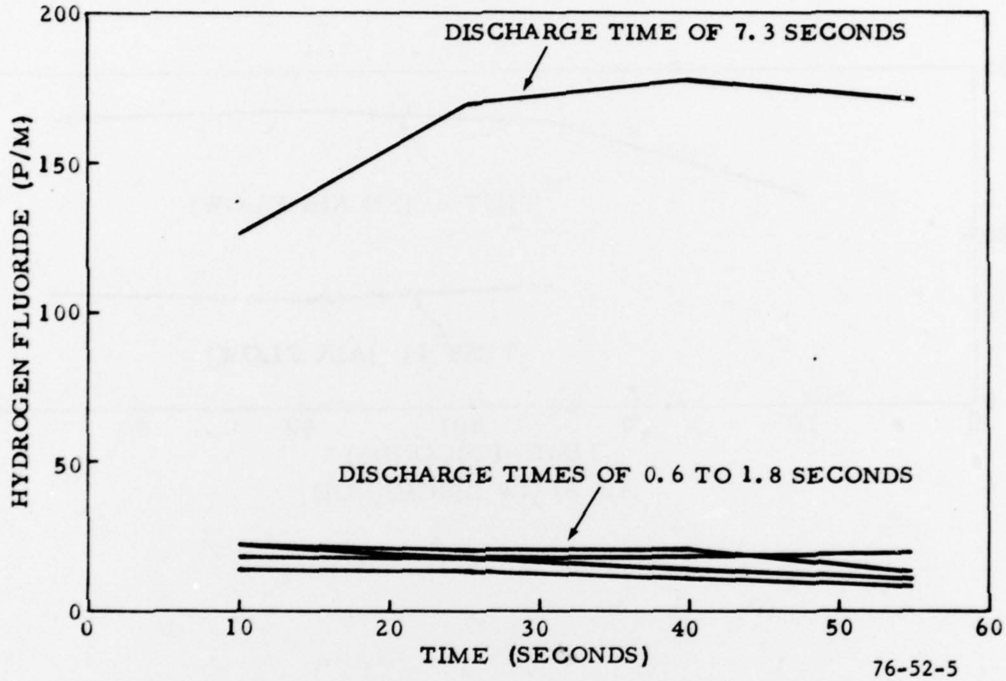


FIGURE 5. HYDROGEN FLUORIDE CONCENTRATIONS FOR VARIOUS HALON 1301 DISCHARGE TIMES

Figure 8 represents the smoke and temperature levels at the upper aft end of the vehicle for test number 15. One-half pint of gasoline was ignited on and under a school bus seat with 5-percent Halon 1301 being automatically discharged by the activation of the photoelectric detector. Activation of the detector and discharge of the agent occurred 6 seconds into the test. The temperature immediately dropped at discharge. Visability decreased at agent discharge, increased slightly a few seconds later, and then leveled off for the remainder of the test. HF levels were similar to those for a paper fire (less than 20 p/m).

Two other extinguishing tests were conducted using seats as a fire load. In both tests, the agent was manually discharged after the seat had become fully enveloped in fire. Test number 13 was a PVC-covered urethane foam seat ignited by 10 sheets of newspaper under the seat. When the seat was fully involved in the fire, the agent was discharged. The fire was fully extinguished, and HF levels were less than 20 p/m. Test 20 involved a deep-seated fire in a PVC-covered urethane foam seat. A slit was cut in the PVC covering, and

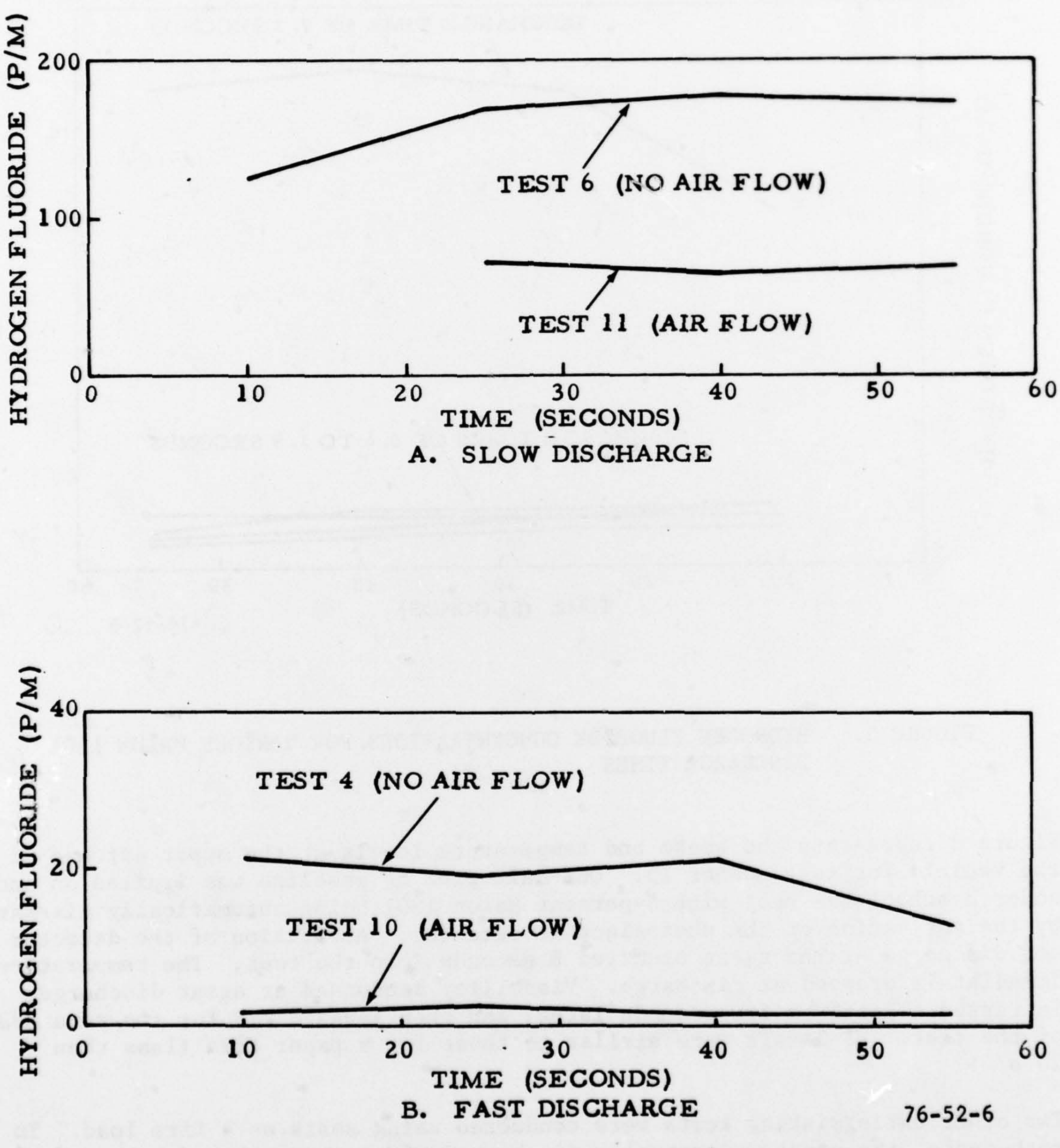


FIGURE 6. HYDROGEN FLUORIDE DEPENDENCE ON AIRFLOW

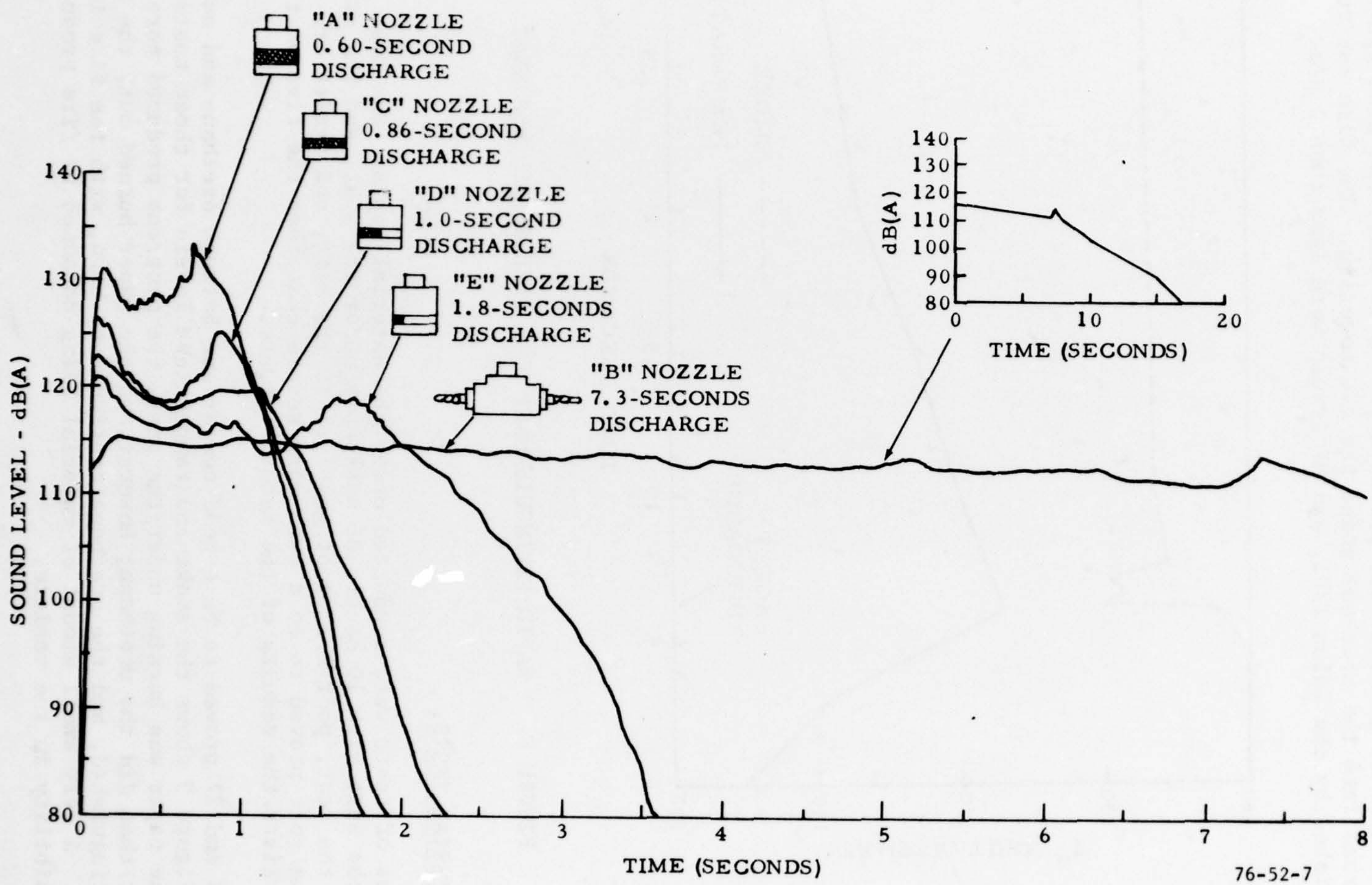


FIGURE 7. SOUND LEVELS FOR VARIOUS HALON 1301 DISCHARGE RATES

1/2 ounce (oz) of gasoline was poured into the urethane and then ignited. The fire burned into the urethane under the PVC covering. The fire was fully extinguished by the Halon 1301, and HF levels were less than 2 p/m.

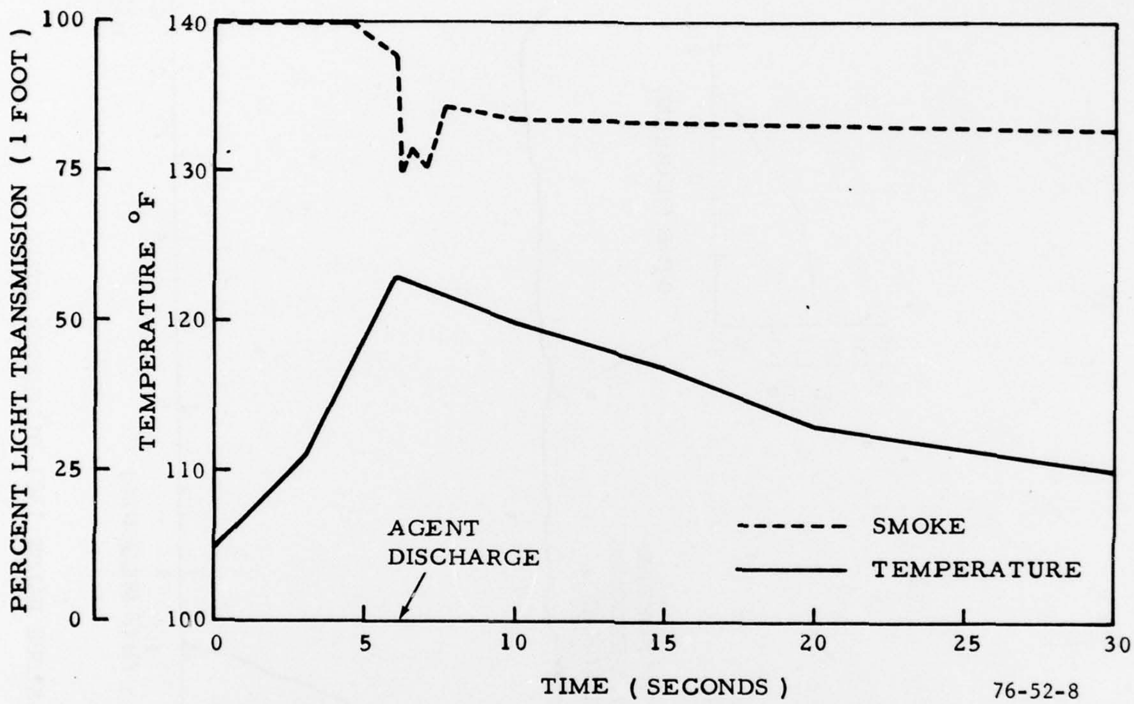


FIGURE 8. RAPID EXTINGUISHMENT OF A FUEL-SOAKED BUS SEAT

SEAT MATERIAL TESTS.

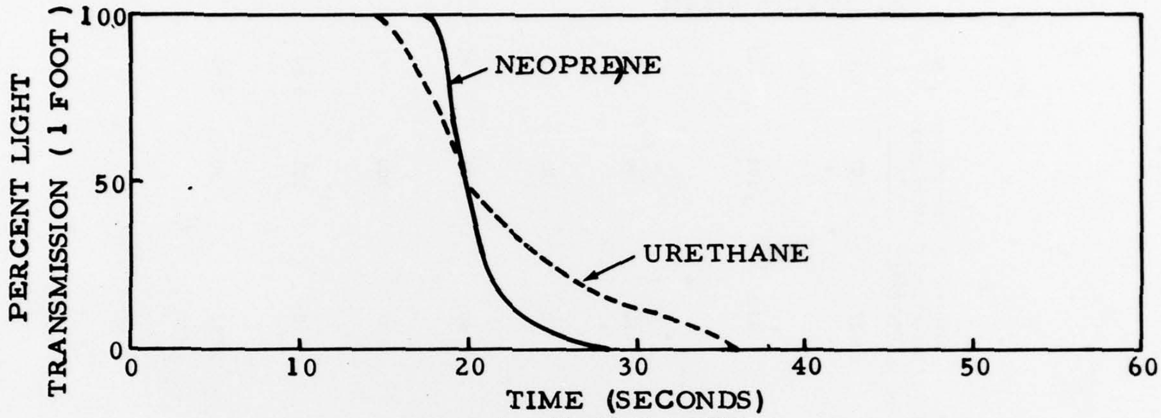
Two types of tests were conducted under the material tests. One test was to ignite the seat with 10 sheets of newspaper under the seat, and the other was to slit the seat, pour 1/2 oz of gasoline in the slit, and ignite it. The fire under the seat proved to be a much more severe case than the fire on the seat. Table 5 lists the results of the material tests.

Tests 26 and 27 proved to be a good comparison between urethane and neoprene foam. Figure 9 shows the smoke and temperature levels for those tests. While the paper was burning under the seat, the neoprene produced more smoke and heat than did the urethane; however, as the paper burned out, the neoprene self-extinguished, and the urethane continued to burn, with the fire increasing in size. A very small amount of material being consumed by fire produced zero visibility in the vehicle.

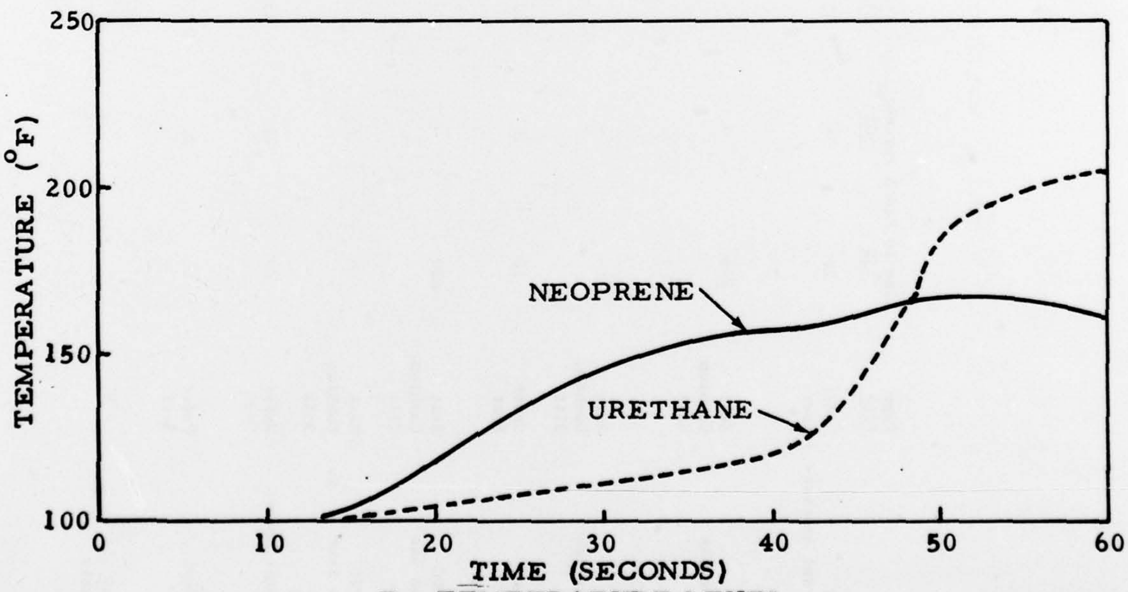
TABLE 5. SEAT MATERIAL TESTS

Test Number	Type Material	Type Fire	Time to Reach Percent Light Transmission (Seconds) 75%	50%	25%	0%	Time to Detection (Seconds)	Temperature At Detection °F	Peak CO %	Remarks
13	10 Sheets of Newspaper-and Ambassador Seat	Under Seat	28	34	41	52	27	107	0.87	Fire extinguished with 1301 at 52 sec.
20	Ambassador Seat-1/2 oz Gas	Seat Cushion Slit	276	-	-	-	63	103	.05	Fire extinguished with Halon 1301.
21	Neoprene Seat-1/2 oz Gas	Seat Cushion Slit	-	-	-	-	74	99	*1	
22	10 Sheets of Newspaper Neoprene Seat	Under Seat	18	19	22	-	10	105	0.2	
24	Urethane PVC Seat-1/2 oz Gas	Seat Cushion Slit	330	-	-	-	68	103	*1	
25	Urethane PVC Fiberglass Seat 1/2 oz Gas	Seat Cushion Slit	-	-	-	-	97	100	*1	
26	Neoprene Seat Under 10 Sheets Newspaper	Under Seat	20	21	23	28	18	113	0.60	
27	Urethane Seat 10 Sheets Newspaper	Under Seat	18	20	25	36	12	95	2.55	

- = Not attained
*1 = Not detectable



A. SMOKE LEVEL



B. TEMPERATURE LEVEL

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FIGURE 9. A COMPARISON OF NEOPRENE AND URETHANE FOAM SEAT FIRES

SUMMARY OF RESULTS

1. The photoelectric detector responded more quickly to all test fires than did the ionization detector.

2. All test fires were rapidly extinguished using 5-percent Halon 1301.

3. The decomposition of the Halon 1301 was dependent on agent discharge time, with discharge times from 0.6 to 1.8 seconds producing HF levels in the 20-p/m range and a discharge time of 7.3 seconds producing an HF level of 178 p/m.

4. The use of airflow after agent discharge tended to decrease HF levels.

5. The sound level from agent discharge also depended on the length of agent discharge, with a 0.6-second discharge producing a sound level of 132 dB(A) and a 7.3-second discharge producing a sound level of 115 dB(A).

6. Fire ignited under a seat produced a more severe condition than did fire ignited on a seat.

7. While exposed to a newspaper fire, neoprene produced more smoke and heat than did urethane; however, the neoprene self-extinguished, whereas the urethane continued to burn after the newspaper was consumed.

CONCLUSIONS AND RECOMMENDATIONS

1. A 5-percent Halon 1301 system, using an early-warning detection system, can safely extinguish fires in a passenger vehicle without producing intolerable levels of decomposition products.

2. The discharge time of the Halon 1301 system should be the fastest time possible that produces a tolerable noise level.

3. In order to minimize the severity of a seat fire ignited from beneath, noncombustible material should be used on seat bottoms, even if the seat material is self-extinguishing.

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4. Chambers, W.H., and Krackow, E. H., An Investigation of the Toxicity of Proposed Fire Extinguishing Fluids, Part I, Medical Division Research Report No. 23, U.S. Army Chemical Center, October 1950.