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FIRE-EXTINGUISHING METHODS FOR NEW PASSENGER/ CARGO AIRCRAFT

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16. Abstract

Full-scale fire tests were conducted to determine the degree to which fire in large cargo compartments may be controlled by the use of bromotrifluoromethane as an extinguishing method in conjunction with ventilation shutoff. Results of the tests, using a 10-percent load, indicated that temperature can be kept below 500°F and that a flash fire can be averted for at least 2 hours by the use of as little as 3 percent by volume of bromotrifluoromethane. The rate of agent application was about 3 1/2 pounds per second. During these tests, the normal leakage that occurs while in flight configuration was simulated by providing an airflow of 75 cubic feet per minute. Two tests were conducted to determine the effectiveness of liquid nitrogen as an extinguishing agent. The weights of agent used were 175 pounds and 284 pounds, respectively. The use of liquid nitrogen proved very effective in extinguishing the initial flames, but with the 75 CFM simulated leakage, when the oxygen concentration rose to 12 percent, a flash fire occurred. In both cases the protection lasted just over 30 minutes. The rate of application of the liquid nitrogen was as high as 10 pounds per second.

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INTRODUCTION

Purpose

The purpose of this project was to determine the effectiveness of bromotrifluoromethane (Freon 1301) and liquid nitrogen (LN_2) as extinguishing agents, when used in conjunction with airflow shutoff, for controlling cargo fires in large (5,000 cubic feet) cargo compartments.

Background

The current requirements, as expressed in the Federal Aviation Regulations, Parts 25.855 and 25.857, were formulated in part from information available as a result of baggage compartment fire tests conducted at the CAA Technical Development and Evaluation Center (TDEC), Indianapolis, Indiana, in 1950 and reported in Reference 1. This work was aimed at providing safety from fires originating in personal luggage or cargo of the type normally carried in the belly compartments of passenger aircraft. The largest compartment used in that investigation had a volume of 270 cubic feet.

Since the introduction of all-cargo air transports, compartment volumes as great as 8,000 cubic feet have been in use, and the same regulations applied to these large compartments which are 30 times as large as those used in the previous investigation.

In addition to the above mentioned CAA tests, fire investigations were made by the following:

1. American Airlines, Inc., on a simulated DC-6 all-cargo configuration at Norfolk, Virginia, during the winter of 1952-1953 (Reference 2). These tests indicated that relatively large fires and high temperatures could develop; that such fires are difficult to extinguish but could be controlled by stopping the airflow (oxygen starvation); that the fires could be confined under these conditions if good thermal insulation was provided; and that heat detectors provided satisfactory early alarms and remained operational.

2. The Federal Aviation Administration (FAA) on a 41-foot-long section of a C-130 cargo aircraft at the National Aviation Facilities Experimental Center (NAFEC), Atlantic City,

New Jersey, and reported in References 3 and 4. These tests indicated that in large cargo compartments involving currently used packaging materials, fires can readily reach damaging proportions even though detection and airflow shutoff occur immediately, and that the use of bromotrifluoromethane, as an extinguishing agent, can reduce the severity of a fire.

Description of Test Article and Equipment

The test article used in this project was a 41-foot section of a Lockheed C-130 airplane fuselage (Figure 1), the section that lies between Stations 245 and 737. Aluminum bulkheads were fabricated and attached to the ends of the fuselage section. This provided a compartment with a volume of 5,000 cubic feet.

Two observation windows, each 1 foot square, were provided in each of the bulkheads. These were located just above the floor line. An air inlet, 14 inches in diameter, was located in the forward bulkhead 5 feet above the floor and a baffle was provided to reduce inlet air velocities and localized effects, such as dead air spaces within the compartment. The 14-inch-diameter duct attached to the inlet contained an axial flow fan which was capable of moving air at the desired 2,000 cubic feet per minute, a set of straightener vanes, and a calibrated orifice for measuring the airflow. An air outlet was provided in the aft bulkhead. This outlet was 14 inches in diameter, fitted with a check damper for controlling airflow, and located 1 1/2 feet from the top of the bulkhead. An aluminum flap was fabricated, to be interchangeable with the observation windows, to provide an outlet near the floor.

The same compartment insulation used in a previous test program was used in this program. The insulation was quite inert, since it had been exposed to a large number of relatively severe fires during the previous program. The compartment was instrumented with chromel-alumel thermocouples for measuring air temperatures at locations shown in Figure 2.

Ignition of the fire load was effected by an electric heating element. The element used was a Chromalox Electric Barbeque Lighter, Catalog No. CL-5, 500 watts, 120 volt ac service.

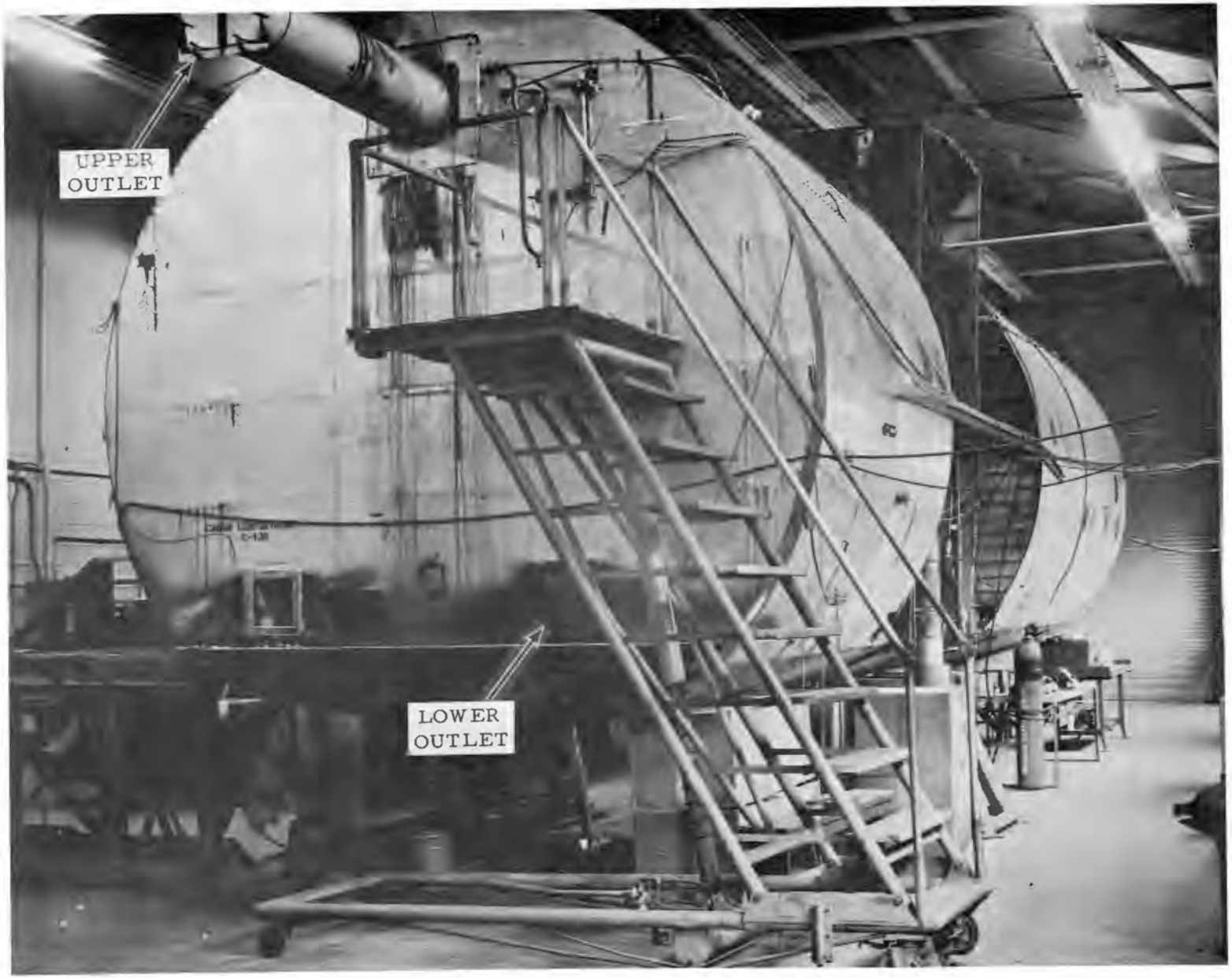
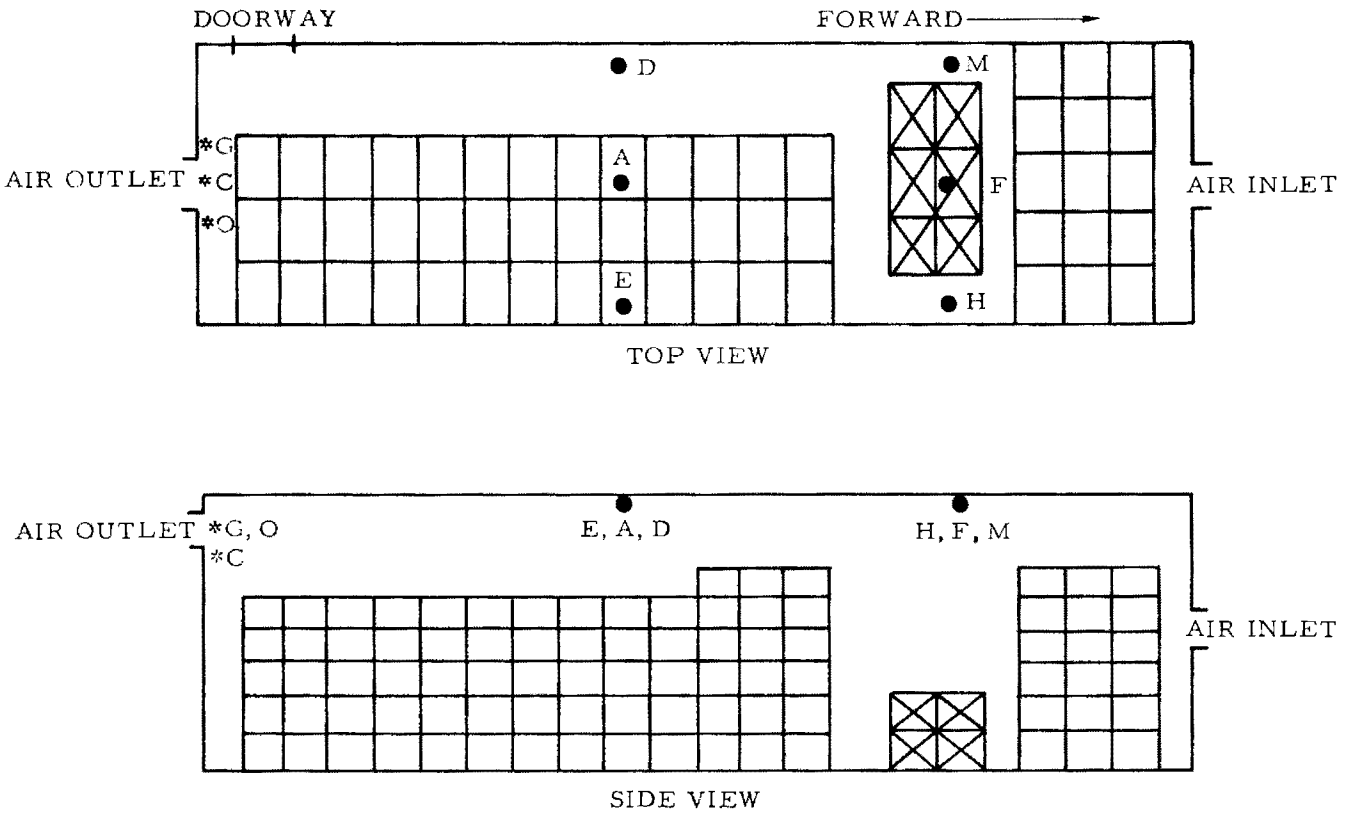


FIGURE 1 - TEST ARTICLE - THE CARGO SECTION OF A C-130 FUSELAGE



LEGEND

* OUTLET THERMOCOUPLE LOCATIONS.

● CIELING THERMOCOUPLE LOCATIONS.

▭ LOCATION OF EACH OF 292 CARTONS REPRESENTING THE CARGO LOAD.

⊠ LOCATION OF EACH OF 12 CARTONS REPRESENTING THE FIRE LOAD.

NOTE:

THE TOTAL CARGO, INCLUDING THE FIRE LOAD, WAS 47.2% OF THE COMPARTMENT VOLUME, AND WAS CONSIDERED A NOMINAL 50% LOAD.

FIGURE 2 - PLAN VIEW OF THE 5,000-CUBIC-FOOT COMPARTMENT (50-PERCENT-LOAD CONFIGURATION)

Instrumentation: Air temperatures at nine locations were recorded on five Honeywell Electronik strip-chart-duplex recorders. These were the two-pen continuous recording-type instruments with an event-indicating pen on the right hand margin of each. A sixth Honeywell Electronik strip-chart-duplex recorder was used to record the output of two pressure transducers located near the compartment floor on the starboard side as indicated in Figure 3.

The oxygen content of the atmosphere within the compartment was monitored by two Davis Gas Analyzers. These instruments had a range from 0 to 25 percent (by volume) and recorded the information on a Honeywell Electronik strip-chart-recorder and a Bristol duplex recorder.

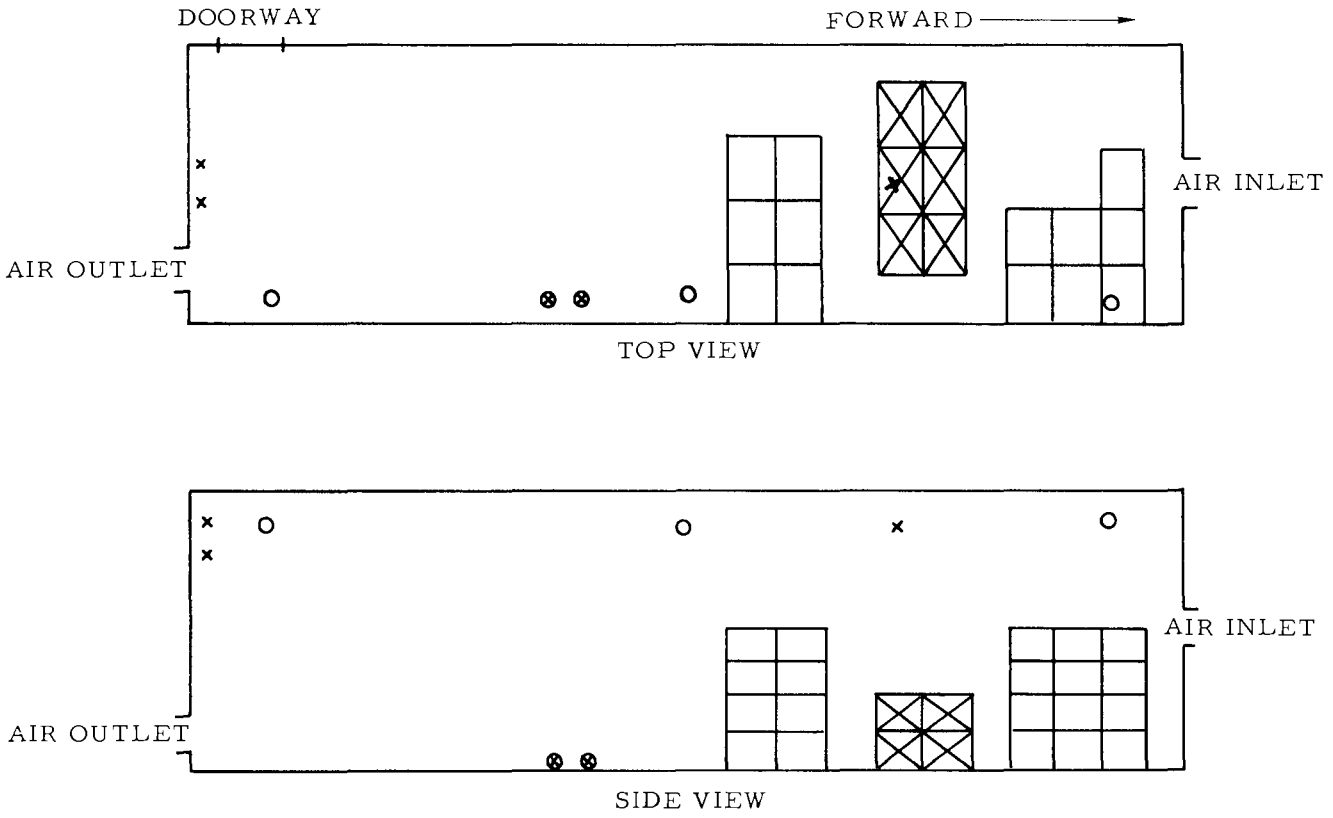
The airflow through the compartment was determined by use of calibrated orifices. These were introduced into the 14-inch-diameter air duct between the straightener vanes and the compartment itself. A suitable slide damper arrangement was incorporated in order to facilitate rapid removal and replacement of the calibrated orifices as the test conditions demanded.

DISCUSSION

Procedure

Throughout this program, standard pieces of cargo were used, both for the fire load and for the cargo load. This standard parcel consisted of a corrugated cardboard carton measuring 28 by 24 by 20 inches, weighing 4 pounds and filled with 16 pounds of excelsior. Thus, each parcel weighed a total of 20 pounds. Figure 4 shows a stack of 144 cargo-parcels and one open parcel on the scale showing its contents. This stack represents abount one-half the load used in the C-130 fuselage compartment when the 50-percent-load test was conducted. Figures 5 and 6 show the compartment loaded prior to a 10-percent-load test.

In order to avoid inconsistencies in test results due to high humidity, as discussed in Reference 3, the conduct of tests during or immediately following a damp spell was avoided. To assure that consistently dry fire loads were used in the tests, the compartment was loaded at least 3 days prior to testing and electric heaters were installed in the compartment to reduce the moisture. Humidity readings were taken inside the compartment and inside the building with a Bacharach sling-type psychrometer.



LEGEND

- LOCATION OF EACH OF THE 52 CARTONS REPRESENTING THE CARGO LOAD
- LOCATION OF EACH OF THE 12 CARTONS REPRESENTING THE FIRE LOAD
- × LOCATION OF OXYGEN PICKUPS
- ⊗ LOCATION OF PRESSURE PICKUPS
- O EXTINGUISHING AGENT DISCHARGE TUBES

NOTE:

THE TOTAL CARGO, INCLUDING THE FIRE LOAD WAS 10.1% OF THE COMPARTMENT VOLUME AND WAS CONSIDERED A NOMINAL 10% LOAD

FIGURE 3 - PLAN VIEW OF THE 5,000-CUBIC-FOOT COMPARTMENT (10-PERCENT-LOAD CONFIGURATION)

FIGURE 4 - CARGO PRIOR TO LOADING INTO COMPARTMENT

FIGURE 5 - CARGO LOADED IN CARGO COMPARTMENT IN THE 10-PERCENT CONFIGURATION LOOKING FROM THE AIR-INLET END

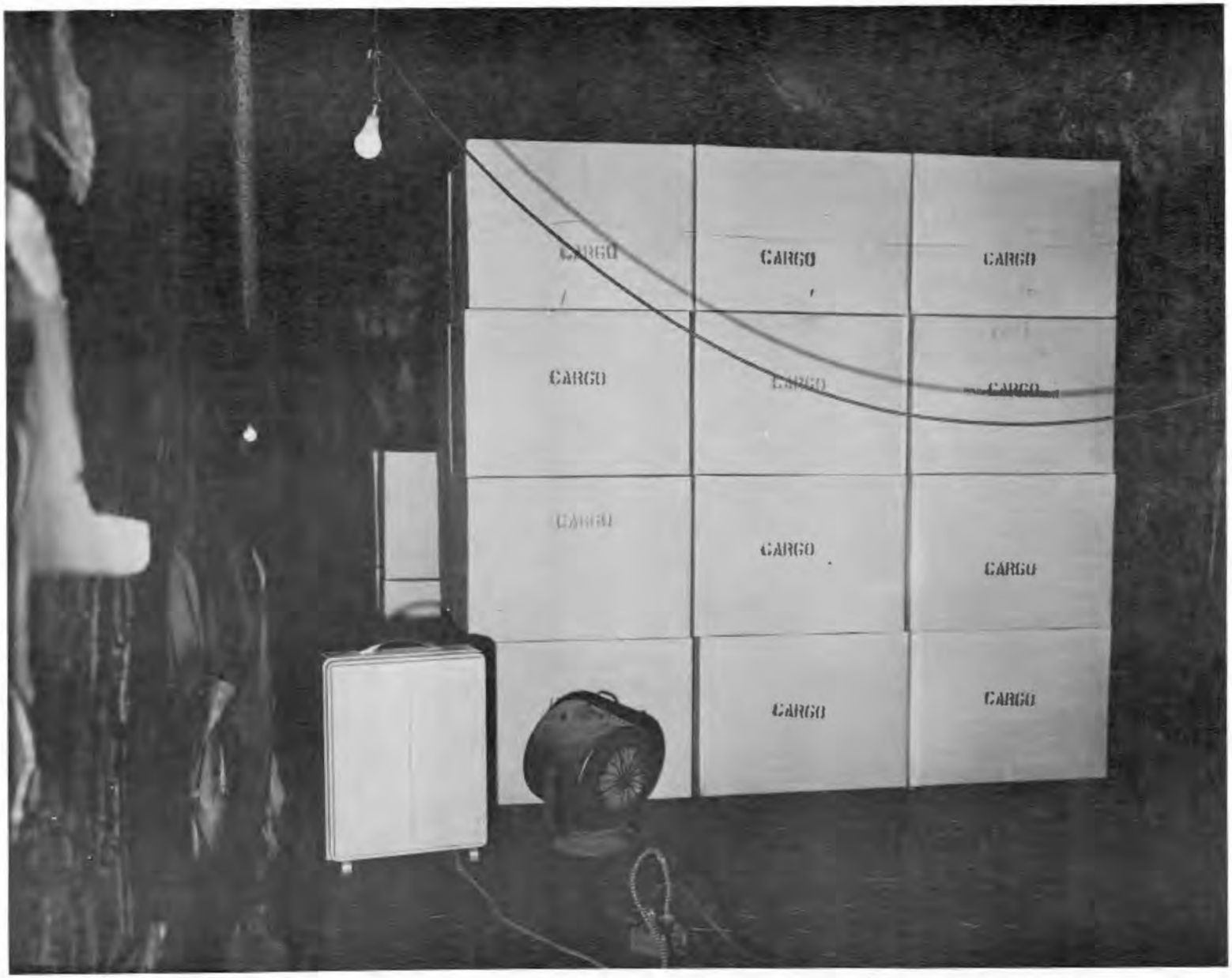


FIGURE 6 - CARGO LOADED IN CARGO COMPARTMENT IN THE 10-PERCENT CONFIGURATION LOOKING FROM THE AIR-OUTLET END

Tests were conducted in the 5,000-cubic-foot C-130 fuselage compartment using a loading of 10 percent by volume and a loading of 50 percent (for all practical purposes, nearly full). Three methods of extinguishment or fire control were used: (1) airflow shutoff; (2) airflow shutoff plus bromotrifluoromethane; and (3) airflow shutoff plus liquid nitrogen (LN_2). Table 1 shows the test run and the type of extinguishment used.

Four tests were run using airflow shutoff as a means of fire control. In these tests, as in all tests in this program, ignition was achieved by placing an electric barbecue lighter in the bottom center standard parcel of the fire load. Ignition (visible flames external to the cardboard container) usually occurred about 3 minutes after voltage was applied to the lighter. Twenty seconds after ignition, application of the voltage to the igniter was discontinued. During the ignition period and until detection occurred, airflow through the compartment was maintained at 2,000 cubic-feet-per-minute or about one air change every 2.5 minutes. At the time of detection (when 300°F was recorded by any one of the thermocouples), the airflow was either reduced to 75 cubic feet per hour or to near zero, as indicated in Table 1.

Although temperatures at nine different locations were recorded, only the highest temperature trace was used in evaluating the data, because the lower temperatures were of less significance. The convection currents due to the heat generated by the fires had more effect on temperature distribution than the airflow through the compartment so the highest temperature, even before detection and airflow shutoff, invariably occurred at the thermocouples located above the fire location rather than downstream or at the air outlet. Therefore, only the highest temperature recorded was used to determine detection, fire severity, and for plotting the time-temperature curves.

Seven tests were run using Freon 1301 (bromotrifluoromethane) as an extinguishing agent. The location of the air outlet was changed after four tests, from near the ceiling (Figure 2) to near the floor (Figure 3). This was done to determine the effect of the lower air outlet on the effectiveness of the extinguishing agent. The agent was discharged from three Walter Kidde and Company Fire-Extinguishing Containers (Figure 7) about 10 seconds after the airflow was reduced from 2,000 cubic feet per minute to 75 cubic feet per minute. The agent was discharged through three 5/8-inch copper tubes, the ends of which were located as shown in Figure 3.

TABLE I

CARGO COMPARTMENT FIRE EXTINGUISHING TESTS

ALL RUNS WERE MADE USING AN INITIAL AIRFLOW OF 2000 CFM AND DETECTION AT 300°F

RUN NO.	TYPE AND AMOUNT OF AGENT USED	PERCENT LOAD	AIRFLOW AFTER DETECTION	LOCATION OF AIR OUTLET	REMARKS
236	NONE	10	ZERO	TOP	
237	NONE	10	ZERO	TOP	
238	NONE	10	ZERO	TOP	
239	100 LB. FREON 1301	10	75 CFM	TOP	
240	100 LB. FREON 1301	10	75 CFM	TOP	
241	66 LB. FREON 1301	10	75 CFM	TOP	
242	60 LB. FREON 1301	10	75 CFM	TOP	
243	100 LB. FREON 1301	10	75 CFM	BOTTOM	
244	60 LB. FREON 1301	10	75 CFM	BOTTOM	
245	NONE	10	75 CFM	BOTTOM	
246	60 LB. FREON 1301	50	75 CFM	BOTTOM	
247	173 LB. LN_2	10	75 CFM	BOTTOM	240 LB. LN_2 (ADDED)
248	284 LB. LN_2	10	75 CFM	BOTTOM	

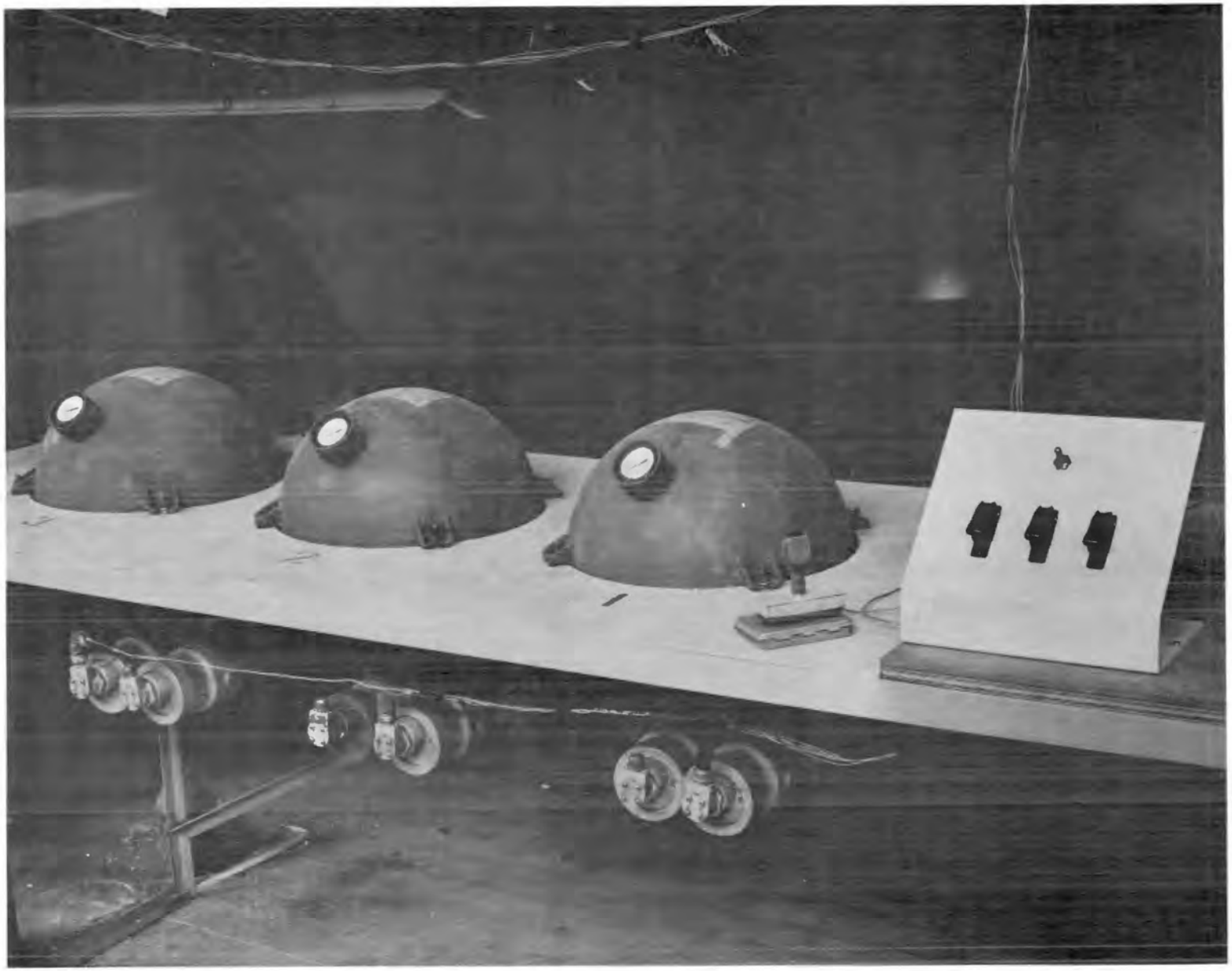


FIGURE 7 - FIRE-EXTINGUISHING CONTAINERS USED IN THE BROMOTRIFLUOROMETHANE EXTINGUISHING TESTS

Two fire-extinguishing tests were run using LN_2 as the extinguishing agent. These tests were conducted as were the Freon 1301 tests; except the LN_2 had to be discharged from a Dewar container and a trailer tank. The trailer was used to fill the Dewar and also to discharge agent into the compartment. The Dewar's capacity was limited to approximately 100 pounds, while the trailer could hold over 3,500 pounds (see Figures 8 and 9).

In every cargo-fire extinguishing test conducted in this program, data were taken for 2 hours after the start of the tests. This permitted a determination to be made of the effectiveness of the control or extinguishing method employed in each particular test. At the end of this 2-hour test period, since visual flames were extinguished but smoldering continued in every case, the fire was extinguished completely by introducing approximately 1,200 pounds of CO_2 from a Cardox system. The compartment was kept closed, with zero airflow, until the next day. With the possible exception of two occasions, the fire was out by then and after airing out the compartment for an additional day, it could be emptied and cleaned in preparation for loading for the next test.

FIGURE 8 - DEWAR USED IN THE LIQUID NITROGEN EXTINGUISHING TESTS

FIGURE 9 - TRAILER CONTAINING LIQUID NITROGEN

ANALYSIS OF RESULTS

As mentioned in the description of the test article, the insulation and lining materials on the interior surface of the fuselage compartment were inert as a result of the many fire tests conducted during the previous programs. Thus, the flash fires obtained during this program were due to the combustible volatiles produced by the cargo and the results were not affected by any of the volatiles that would normally come from the interior lining materials. However, from tests conducted in previous cargo-compartment test programs, it was noted that volatiles from these lining materials contributed little to the severity of the flash fire which resulted from the cargo volatiles.

In general, the results of the tests conducted indicate that the relocating of the compartment outlet from the top to the bottom location had no noticeable effect on the control afforded by either the airflow shutoff or the Freon 1301 extinguishant method for combating the compartment fire.

Figures 10 and 11 show a typical cargo-compartment fire in progress. Figures 12 and 13 show the remains of a cargo fire of the 10-percent-load configuration after a fire test in which airflow shutoff was used as the method of effecting control of the fire.

The results of a typical cargo-compartment fire test, 10-percent-load configuration, in which airflow shutoff was used to effect control, are shown in Figure 14. In this test, detection was assumed when a temperature of 300°F was indicated, at which time the airflow was shut off. Shortly thereafter, a flash fire occurred as evidenced by the rapid rise in pressure and temperature followed by a reduction in the percent oxygen reading which usually dropped to near zero percent and remained there for several minutes. During the flash fire a maximum temperature of 1,800°F and a pressure of 0.10 pound per square inch were recorded. In other similar tests, temperatures of over 2,000°F and pressures up to 0.175 pound per square inch were recorded.

Results of the tests conducted using bromotrifluoromethane in addition to airflow shutoff(with simulated leakage) are shown in Figure 15. These results show that in all cases where an extinguishant is used in addition to airflow shutoff the flash fire was eliminated. They also indicated that both 100 pounds of agent (5 percent by volume) and 60 pounds of

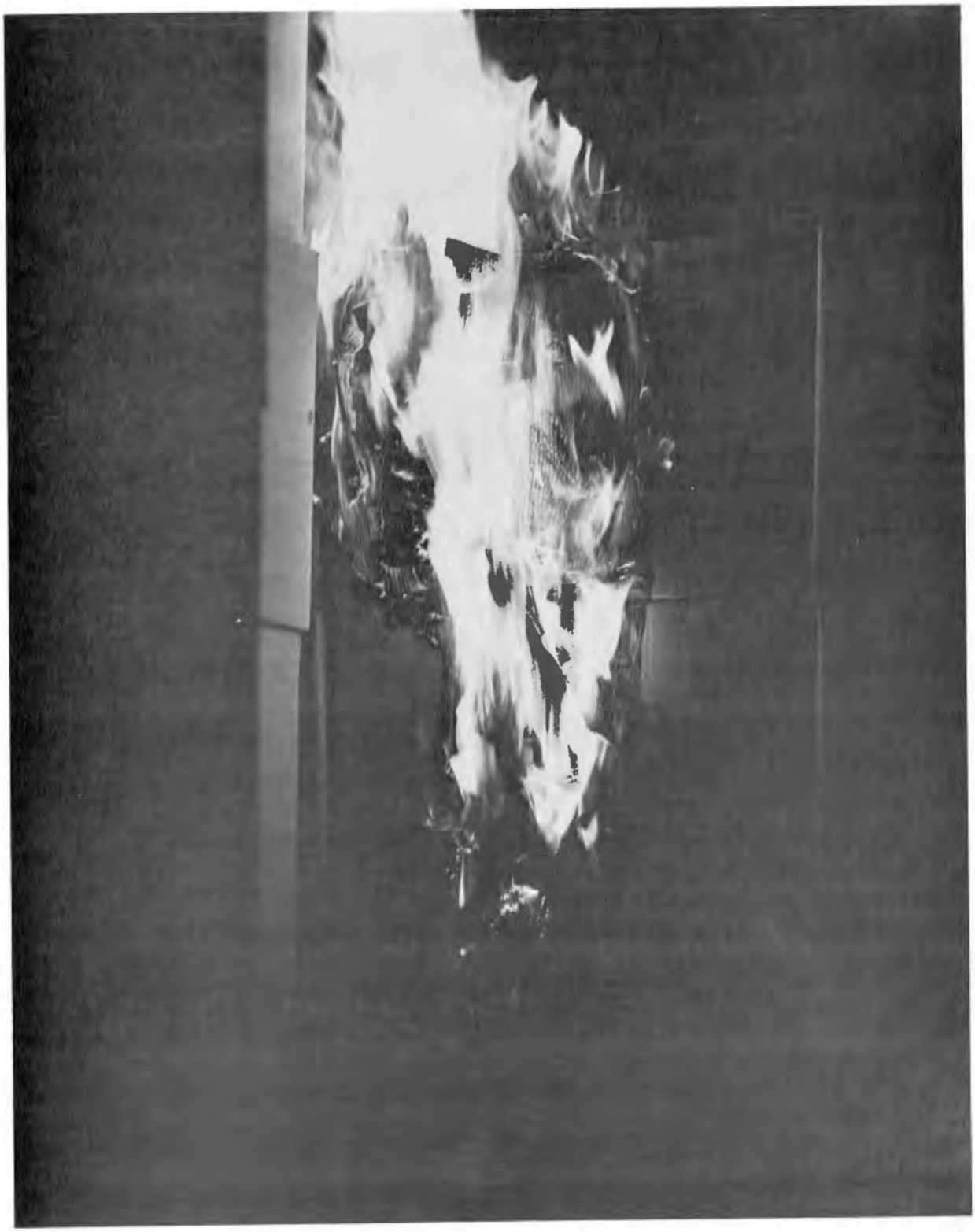


FIGURE 10 - CARGO FIRE PRIOR TO DETECTION

FIGURE 11 - CARGO FIRE AT TIME OF DETECTION

FIGURE 12 - CARGO LOADED IN CARGO COMPARTMENT IN THE 10-PERCENT CONFIGURATION AFTER AN AIRFLOW-SHUTOFF TEST, LOOKING FROM THE INLET END

FIGURE 13 - CARGO LOADED IN CARGO COMPARTMENT IN THE 10-PERCENT CONFIGURATION AFTER AN AIRFLOW-SHUTOFF TEST, LOOKING FROM THE OULET END

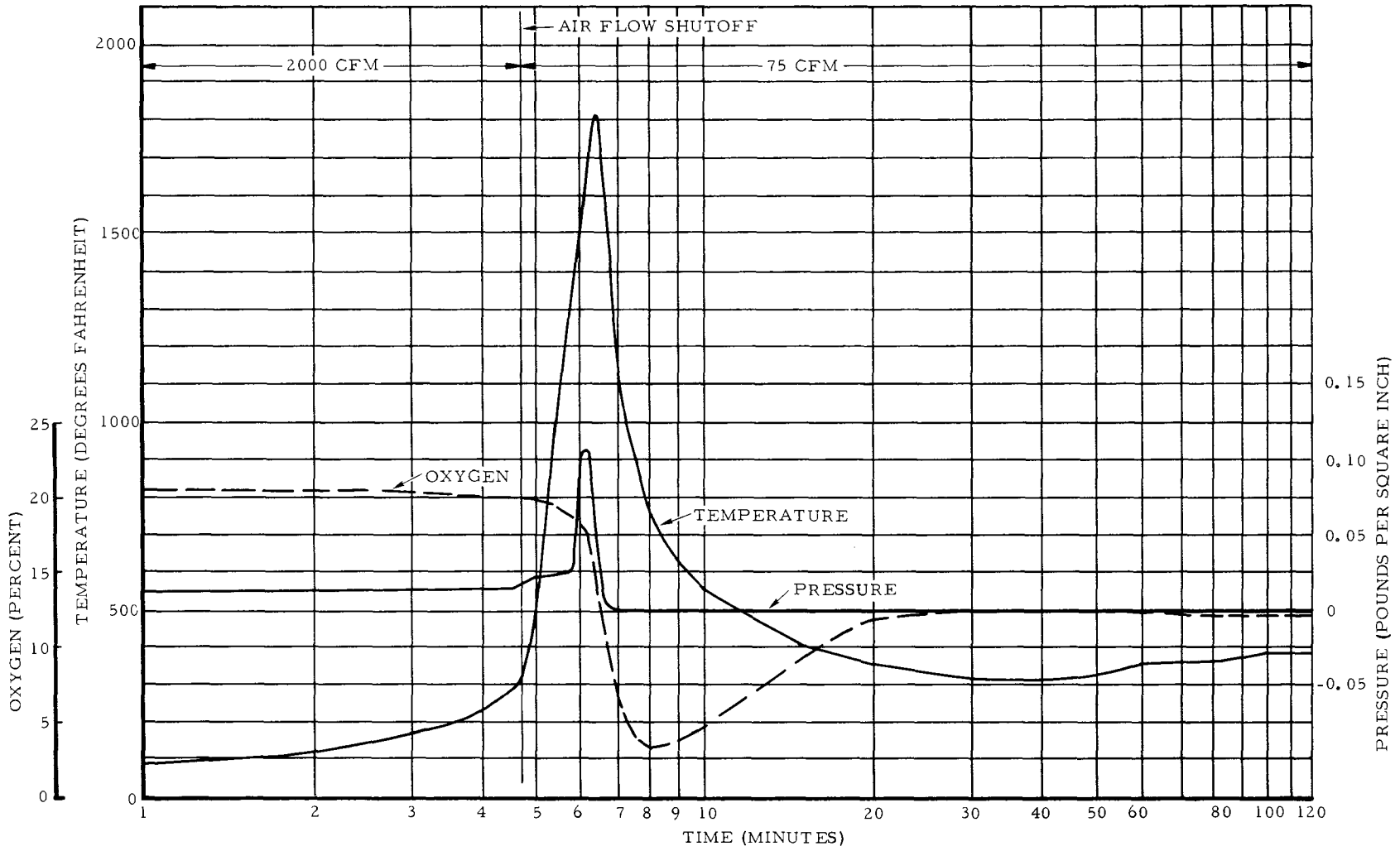


FIGURE 14 - TEMPERATURE, PRESSURE, AND OXYGEN RECORDINGS OF AN AIRFLOW-SHUTOFF FIRE-EXTINGUISHING TEST IN THE 10-PERCENT-LOAD CONFIGURATION

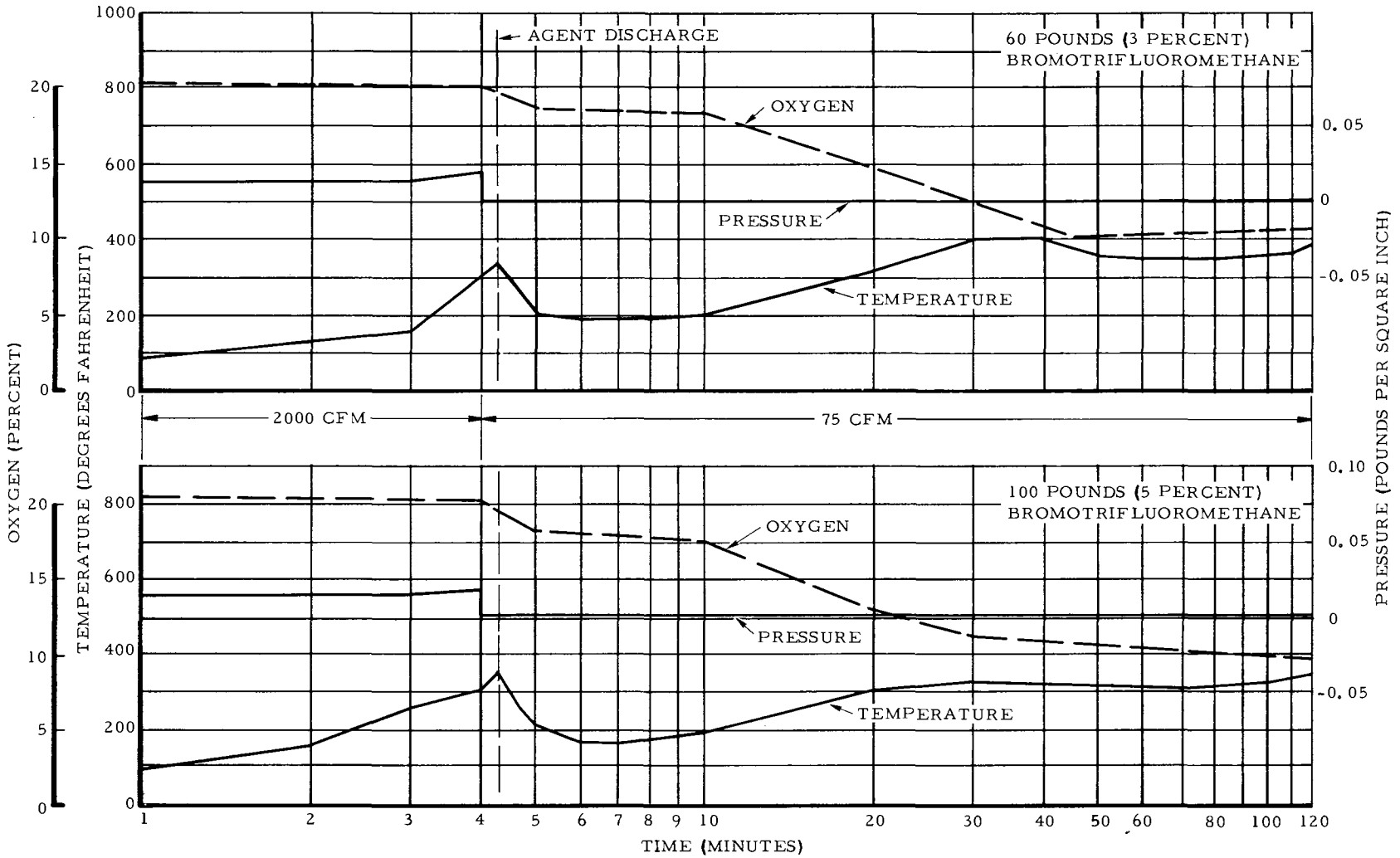


FIGURE 15 - TEMPERATURE, PRESSURE, AND OXYGEN RECORDINGS OF BROMOTRIFLUOROMETHANE FIRE-EXTINGUISHING TESTS IN THE 10-PERCENT-LOAD CONFIGURATION

agent (3 percent by volume) were effective in extinguishing the flames and controlling the continuing smoldering condition for a 2-hour period. The only noticeable difference between the 3- and 5-percent agent tests was that the compartment temperature, due to the smoldering cargo, remained between 50° and 100°F higher throughout the 2-hour period when the lower agent concentration was used. Figures 16 and 17 show the remains of a 10-percent-loaded test in which bromotrifluoromethane was used as the extinguishing agent.

In order to simulate a fire condition in a compartment filled to its usable capacity, a fire-extinguishing test was conducted in the 50-percent-loaded configuration. In this test, 60 pounds of bromotrifluoromethane (3 percent by volume-gross) were used in addition to airflow shutoff. The results of this test are shown in Figure 18. Figure 19 shows these results compared with the results of a test conducted during the test program reported on in Reference 4 in which only airflow shutoff was used to effect control. It should be noted that even though the temperature of 1,300°F is generally indicative of the occurrence of a flash fire, this was not the case. The feasibility tests conducted during the program reported on in Reference 4 were conducted under conditions favorable to extinguishment by not simulating leakage after airflow shutoff and by introducing the extinguishing agent in the vicinity of the fire. In those tests, the temperature rise was stopped at the introduction of the agent, 350°F and remained below this figure throughout the 2-hour test period, leveling off at 220°F at the end of the test. Conversely, the test conditions used during the present program were selected to be most adverse. When the airflow was shut off, a flow of 75 cubic feet per minute was permitted to simulate leakage and the agent was discharged in locations other than the fire area. Thus, the fire at the time of agent discharge, continued to burn and was driven upward in the vicinity of the three thermocouples in the fire area location until the agent became diffused and reached the fire area by the agitation of the agent introduction and by the convection due to the fire. During this short time these thermocouples sensed temperatures between 800° and 1,300°F while thermocouples in other locations throughout the compartment gave no indication of a fire at all until a half hour later when temperatures had leveled off through the compartment. At the end of the 2-hour test, all the ceiling thermocouples indicated between 300° and 400°F. These somewhat elevated temperatures were attributed to the fact that air leakage was simulated and possibly that the air outlet was located near the floor level.

FIGURE 16 - CARGO LOADED IN CARGO COMPARTMENT IN THE 10-PERCENT CONFIGURATION AFTER A BROMOTRIFLUOROMETHANE-EXTINGUISHING TEST, LOOKING FROM THE INLET END

FIGURE 17 - CARGO LOADED IN CARGO COMPARTMENT IN THE 10-PERCENT CONFIGURATION AFTER A BROMOTRIFLUOROMETHANE-EXTINGUISHING TEST, LOOKING FROM THE OUTLET END

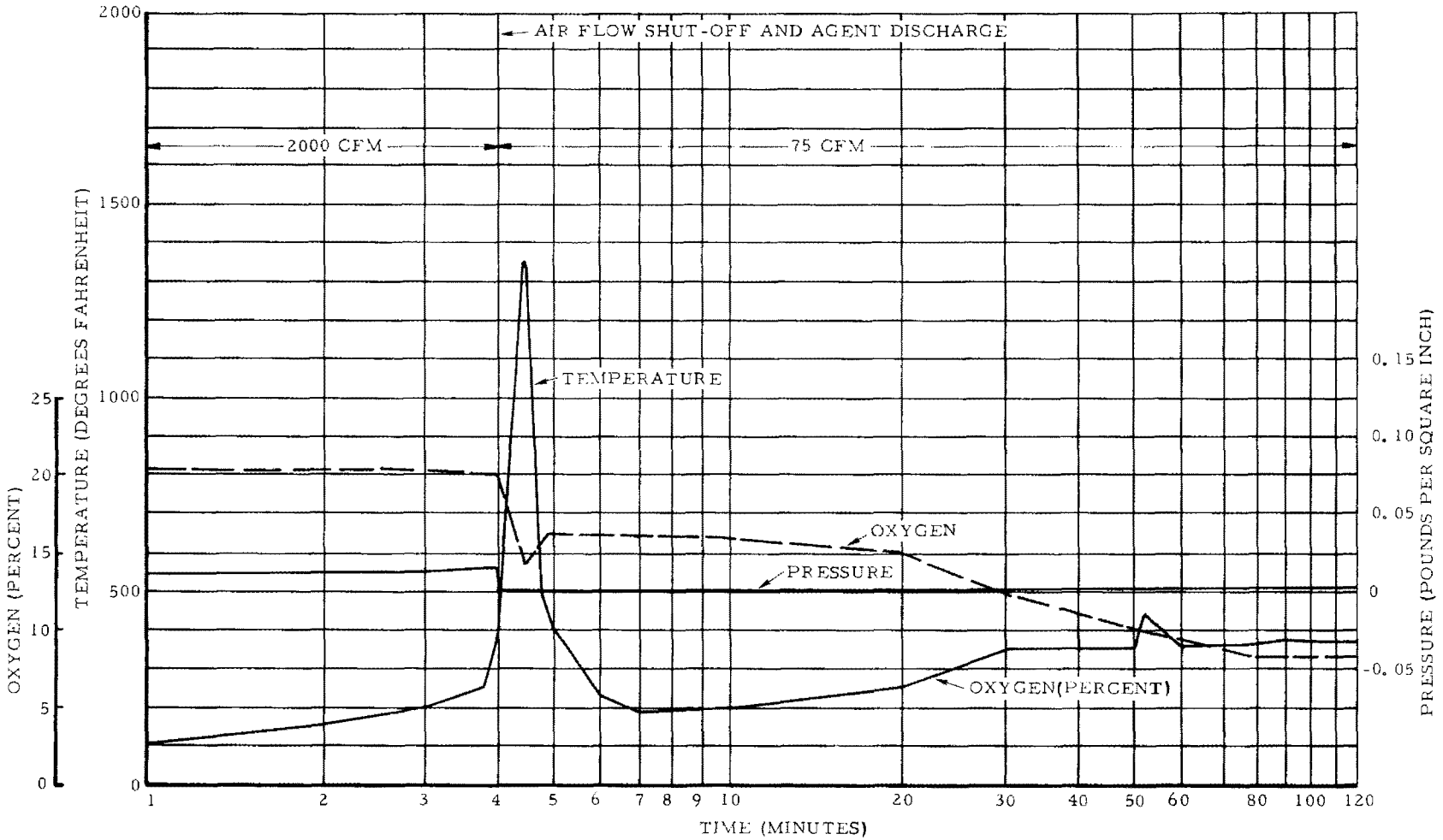


FIGURE 18 - TEMPERATURE, PRESSURE, AND OXYGEN RECORDINGS OF A FIRE-EXTINGUISHING TEST USING 60 POUNDS OF BROMOTRIFLUOROMETHANE ON A 50-PERCENT-LOAD CONFIGURATION

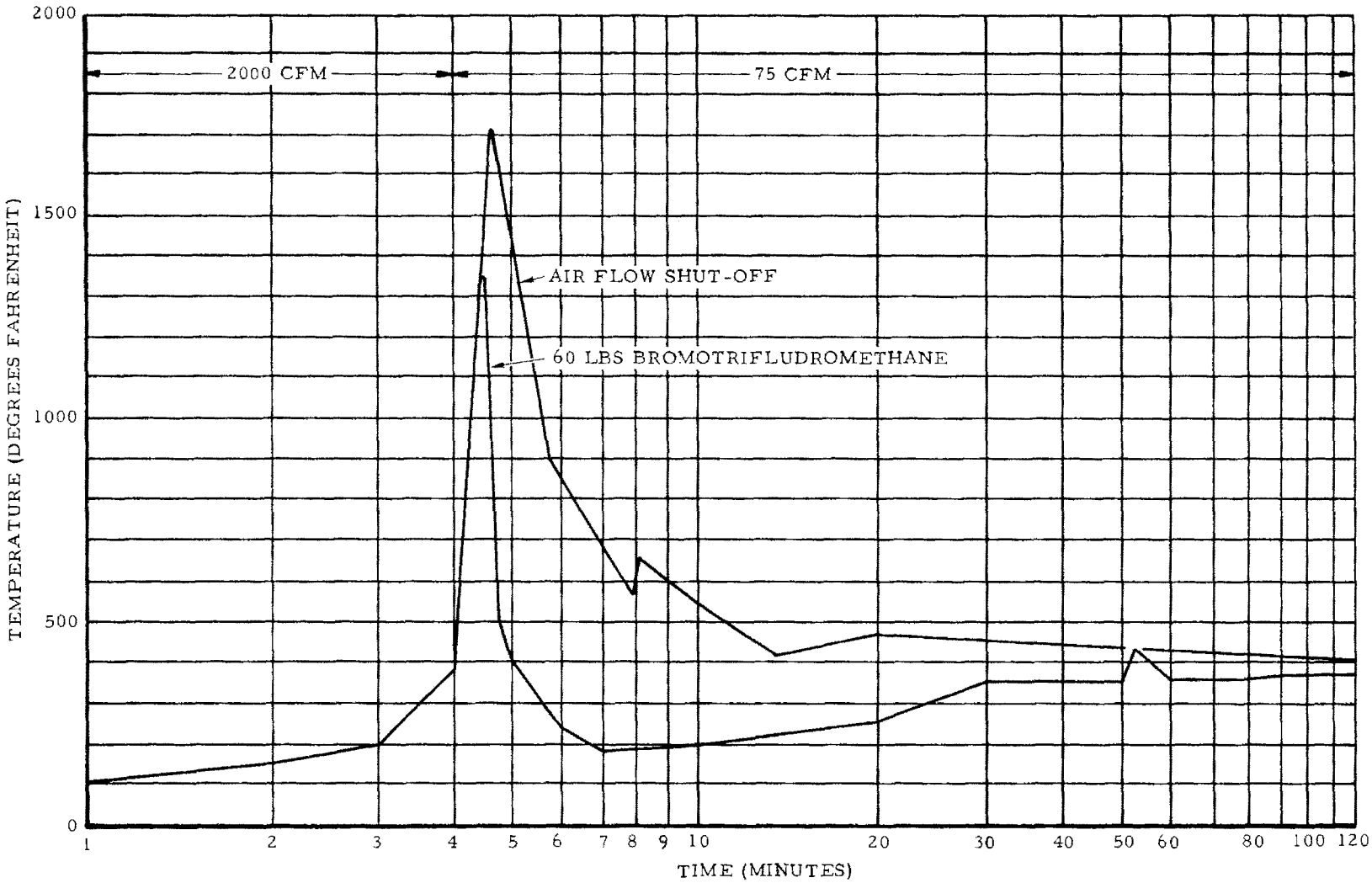


FIGURE 19 - COMPARISON OF EXTINGUISHMENT BY THE USE OF 60 POUNDS OF BROMOTRIFLUOROMETHANE AND AIRFLOW-SHUTOFF ON A 50-PERCENT-LOAD CONFIGURATION

Results of tests conducted using LN_2 in addition to airflow shutoff (with simulated leakage) are shown in Figures 20 and 21. In these tests a 10-percent cargo-load compartment was used and leakage was simulated after airflow shutoff by providing a 75-cubic-feet-per-minute airflow. In the first of these tests, 173 pounds of LN_2 were discharged at the time of detection. This amount extinguished the flames and reduced the oxygen concentration to 9 1/2 percent. About 33 minutes after the start of the test, when the oxygen concentration reading reached 12 percent, a flash fire occurred. An additional 240 pounds of LN_2 were immediately added; however, since there was no prior warning of the flash fire this addition of agent did not take place until the flash fire had consumed most of the oxygen and temperatures were already on the way down. During this flash fire, temperatures as high as 1,300°F were recorded. This was not as severe as when control by oxygen depletion only was employed, but was considerably higher than is considered acceptable when an extinguishing agent is used for fire control. The pressure of 0.10 pound per square inch generated during this flash fire was as high as that resulting from a flash fire during a typical fire controlled by the oxygen depletion method.

In the second LN_2 extinguishing test, 284 pounds of agent were discharged at the time of detection. The flames were extinguished and the oxygen concentration was reduced to 8 1/2 percent. Approximately 37 minutes after the start of the test, when the oxygen concentration had increased to 12 percent, a flash fire occurred, which was considerably less severe than that of the first LN_2 extinguishing test. In this test the temperature was very well controlled throughout the 2-hour test. However, the pressure at the time of agent discharge was as high as was normally experienced during a flash fire when no extinguishant was used.

The use of LN_2 in addition to airflow shutoff was very effective in extinguishing the flames and in maintaining relatively low temperatures, except during the ensuing flash fires which occurred approximately a half-hour after agent discharge. These two tests indicated that an amount of LN_2, which when in the gaseous state, would equal 75 percent of the gross volume of the compartment was required to provide adequate protection for a 2-hour period.

The time-pressure curves shown in Figure 22 give a comparison of the pressure generated during the extinguishing phase of a fire by each of the three methods used in this program.

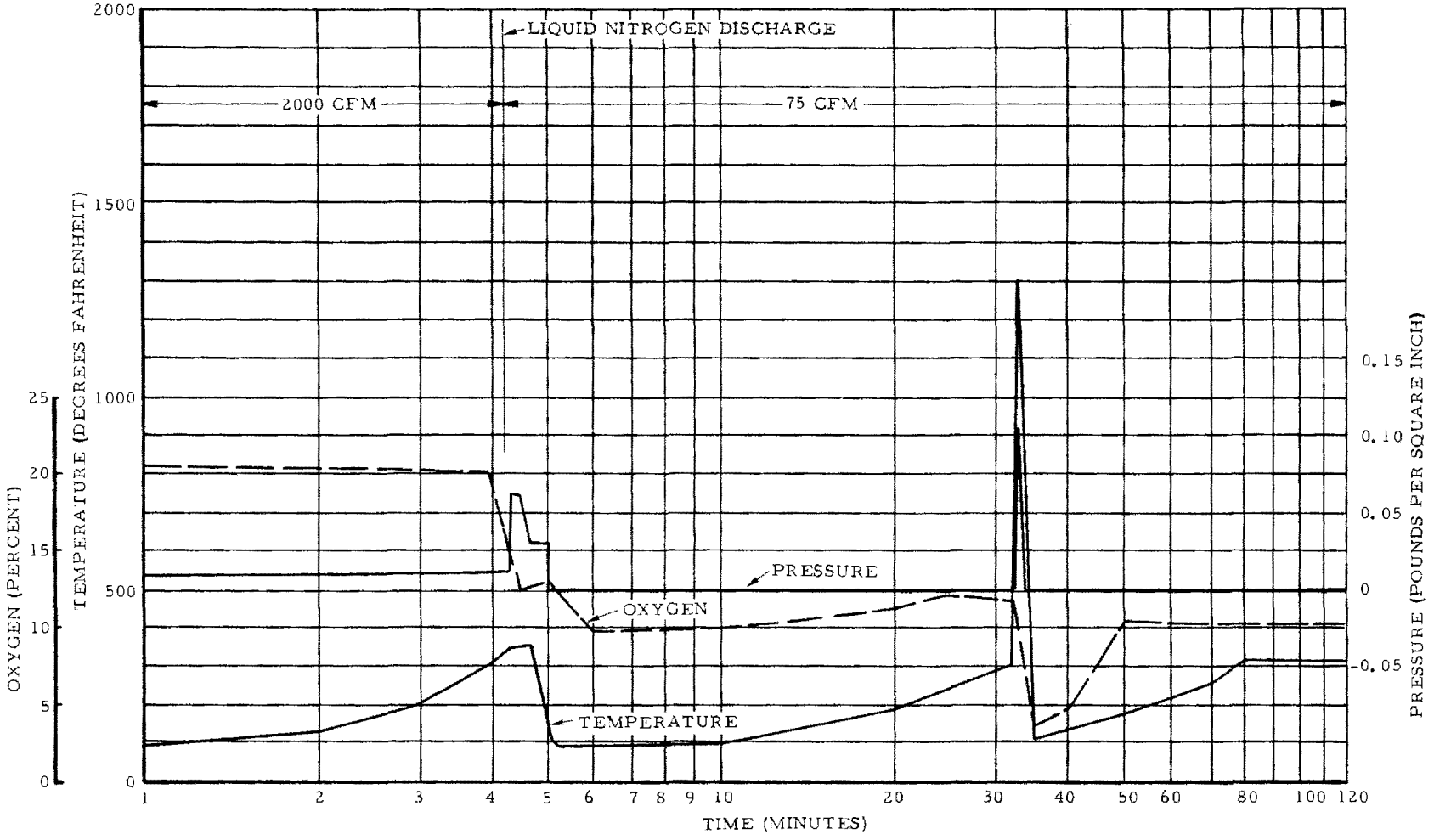


FIGURE 20- TEMPERATURE, OXYGEN, AND PRESSURE RECORDINGS OF A FIRE-EXTINGUISHING TEST USING 173 POUNDS OF LIQUID NITROGEN ON A 10-PERCENT-LOAD CONFIGURATION

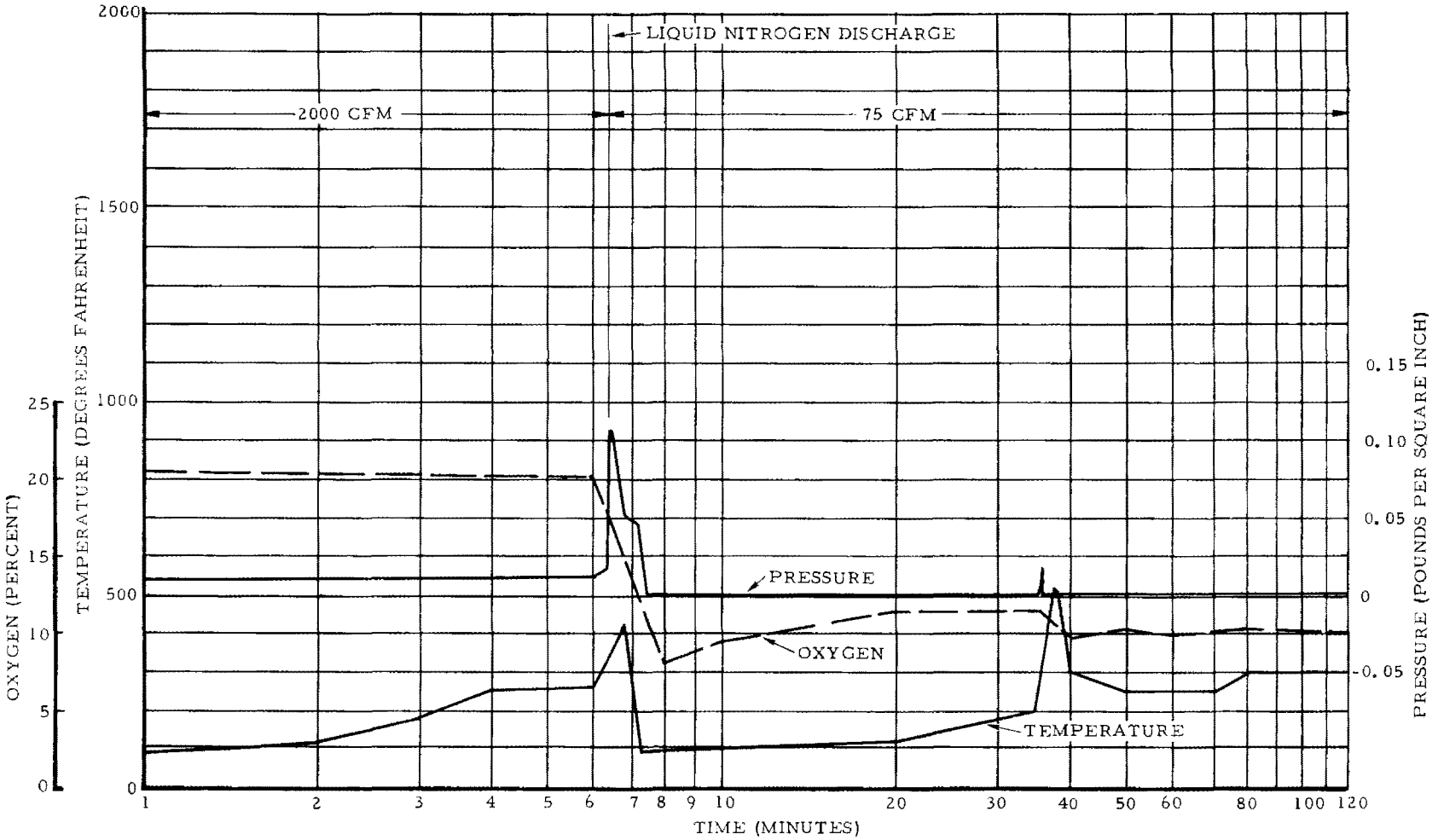


FIGURE 21 - TEMPERATURE, OXYGEN, AND PRESSURE RECORDINGS OF A FIRE-EXTINGUISHING TEST USING 284 POUNDS OF LIQUID NITROGEN ON A 10-PERCENT-LOAD CONFIGURATION

Taking both temperature and pressure into consideration, the most efficient and desirable means for extinguishing and controlling fires in large cargo compartments appears to be the use of a 3 to 5 percent concentration of bromotrifluoromethane in addition to airflow shutoff, since a significant increase in pressure in the cargo compartment is a constant threat for causing smoke and high-temperature contaminants to enter the crew or passenger compartments of the aircraft.

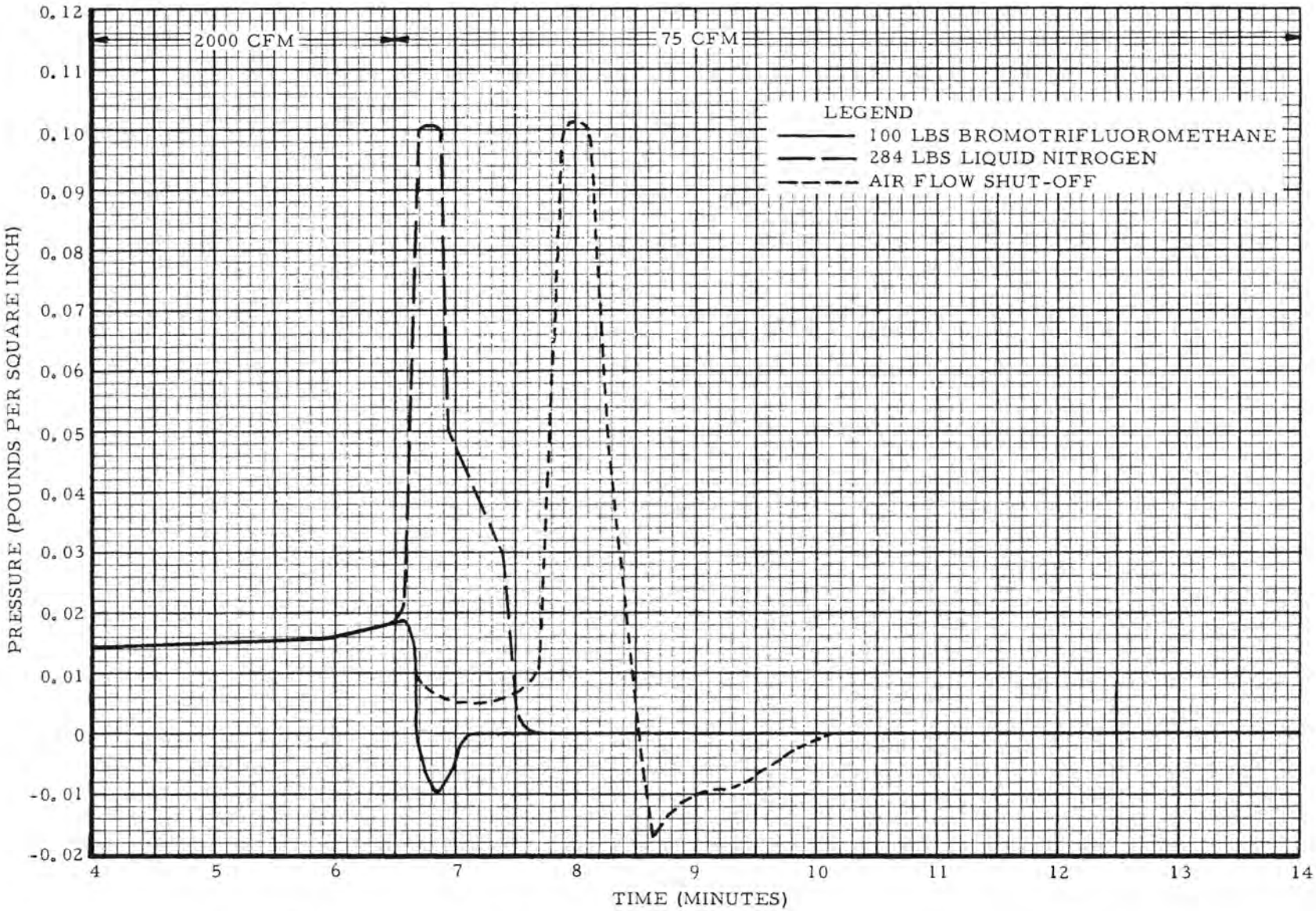


FIGURE 22 - COMPARISON OF THE PRESSURES OBTAINED DURING EXTINGUISHMENT BY EACH OF THE THREE METHODS USED

CONCLUSIONS

Based on the results of the tests conducted, it is concluded that in compartments with a volume of up to 10,000 cubic feet:

1. The use of bromotrifluoromethane extinguishing agent released at the time of detection of a cargo fire can prevent the occurrence of flash fire, greatly reduce the maximum temperatures, and provide effective fire control for periods of at least 2 hours.

2. The use of as little as 3 percent by volume of bromotrifluoromethane can effectively control cargo fires in a compartment with a 10-percent and a 50-percent load configuration.

3. An amount of LN_2, which when in a gaseous state would equal 75 percent of the gross volume of the compartment, is required to provide adequate control.

4. The use of liquid nitrogen as an extinguishant is effective for extinguishing flames, but unless a large quantity of agent is used, adequate control is not ascertained.

5. The introduction of a large amount of LN_2 creates an overpressure similar to that of a flash fire.

APPENDIX

REFERENCES

1. Asadurian, L.A., "Evaluation of Flight Fire Protection Means for Inaccessible Aircraft Baggage Compartment," CAA Technical Development Report No. 146, June 1951.

2. Smith, Mark H., "Simulated DC-6A Fire Test Program," (Preliminary Report)(Supplement #2 and Supplement #3), American Airlines, Inc., Engineering Department Report No. LDC-6A-9920-X1R, September 1952 and March 1953.

3. Gassmann, Julius J., "Characteristics of Fire in Large Cargo Aircraft, " Federal Aviation Agency Technical Report No. FAA-ADS-73, March 1966.

4. Gassmann, Julius J., "Characteristics of Fire In Large Cargo Aircraft (Phase II), "Federal Aviation Administration Technical Report No. FAA-RD-70-42, September 1970.