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STOVE-TOP AUTOMATIC FIRE-EXTINGUISHING DEVICE FOR
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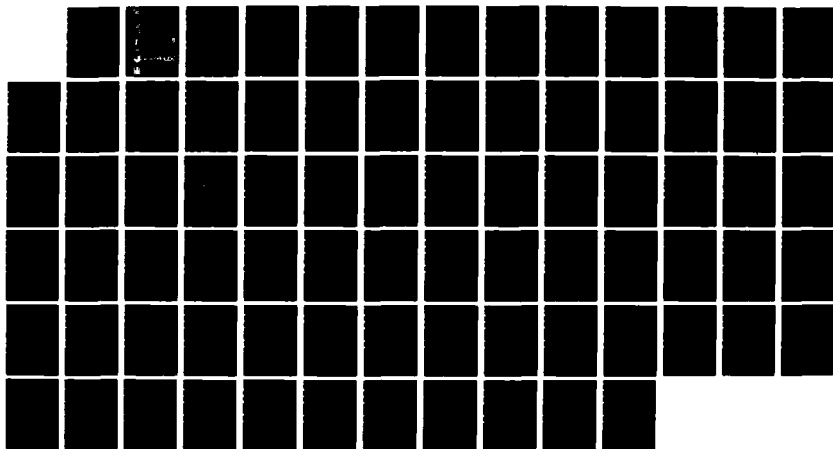
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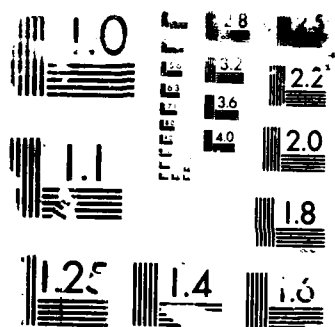
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STOVE-TOP AUTOMATIC FIRE-EXTINGUISHING DEVICE FOR RESIDENTIAL USE

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OCTOBER 1987

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JANUARY 1986 - JUNE 1986

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) Statistics show that cooking stoves are a significant cause of fires in the Air Force Community. Commercially available, self-contained automatic fire extinguishers for cooking stove areas were evaluated, using a standard kitchen arrangement for military housing. Units tested failed the established criteria, but have potential for successful development. The effect of operating the hood exhaust was negligible. It is recommended that units with automatic gas/electric shutoff be developed to respond more quickly with improved securing capabilities. This report contains four sections and three appendices. Section I contains a description of scope and how the test series was approached. Section II describes the test units and modes of operation and the general conditions for each test. Section III provides					
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19. ABSTRACT (continued)

the quantitative data collected from each test series. Section IV contains the conclusions and recommendations. Appendix A contains the military purchase description and Appendices B and C contain the Air Force and Underwriters Laboratories test plans for testing stove-top extinguishing devices.

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Fire

PREFACE

This final report was prepared by the New Mexico Engineering Research Institute (NMERI), University of New Mexico, under Contract F29601-84-C-0080, with the Engineering and Services Laboratory, Headquarters Air Force Engineering and Services Center, Tyndall Air Force Base, Florida.

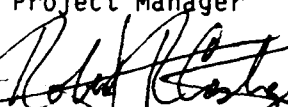
This report summarizes the work done between 7 January 1986 and 30 June 1986. HQ AFESC/RDCF program manager was Mr. Joseph Walker; project officers were Mr Richard Vickers and CWO-4 Bob Barrow.

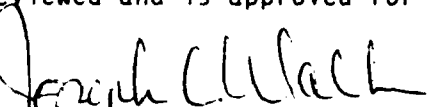
The authors would like to acknowledge the support and assistance provided by Chief John C. Stokes and personnel from the Tyndall Air Force Base, Fire Department.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.


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SECTION I

INTRODUCTION

A. OBJECTIVE

The objective of this effort was to evaluate and test commercially available automatic kitchen range fire-extinguishing devices to determine their effectiveness to detect and extinguish residential unattended cooking oil fires, and to draft a performance purchase description.

B. BACKGROUND

Government records indicate that 45 percent of military family housing (MFH) fires occurred in the kitchen with cooking equipment involved in the ignition. In response to this threat, the U.S. Air Force began studies to determine requirements for installing an extinguishing device in stove exhaust hoods for MFH. In an attempt to better define the design concepts, the Air Force has pursued the development of a localized fire protection device used for computer facilities. These concepts involve capsulized and independent fire-extinguishing devices to cost effectively prevent large-scale damage. These small capsulized devices can be located near ignition sources so that fires are quickly detected and suppressed.

As a result of the research, the Air Force decided to evaluate a new concept in an automatic, independent, self-contained fire extinguisher to prevent large-scale damage to MFH kitchens and associated areas. The self-contained device would be located in the range hood, near the ignition source, to detect and suppress stove-top fires quickly, and minimize heat and smoke damage to kitchen and surrounding areas.

The device should detect and suppress fires and send a signal that will electrically or mechanically shut off the range and hood power sources.

C. APPROACH

All known commercial manufacturers of automatic kitchen range fire-extinguishing devices were contacted and invited to participate in the test program. Of five companies responding, three accepted invitations to participate in the test program. For the purpose of this report, the companies participating in the test program will be referred to as Company A, Company B, and Company C. The Company A unit had Underwriters Laboratory (UL) listing. The other companies did not have UL certification; however, Company C was in the certification process. The mechanisms, fire suppression agents, and several other test parameters were evaluated. Testing was done, using the manufacturer-recommended installation of the extinguishers in a typical size kitchen using typical ancillary equipment such as cabinets.

D. SCOPE

The scope of this project was to evaluate and test commercially available automatic kitchen range extinguishers and develop a military purchase description. The testing was sufficient to determine the limits of protection for various cooking stove fire types, sizes, and configurations.

A series of tests was conducted at Tyndall Air Force Base, Florida, to determine the suppressive abilities of these extinguishing devices on kitchen range fires. The test platform for the tests was a standard 30-inch wide electric range (Figure 1), with a standard 30-inch wide internal and external exhaust hood (Figure 2). The range, exhaust hood, and kitchen cabinets were installed in accordance with standard Building Code Requirements (Figure 3), and modeled after existing USAF MFH kitchen configurations.

The scope of this research project included evaluation of the specification requirements for an efficient, effective stove-top fire detection/suppression device. Test procedures were planned for evaluating commercial devices in situations which represented actual household cooking environments.

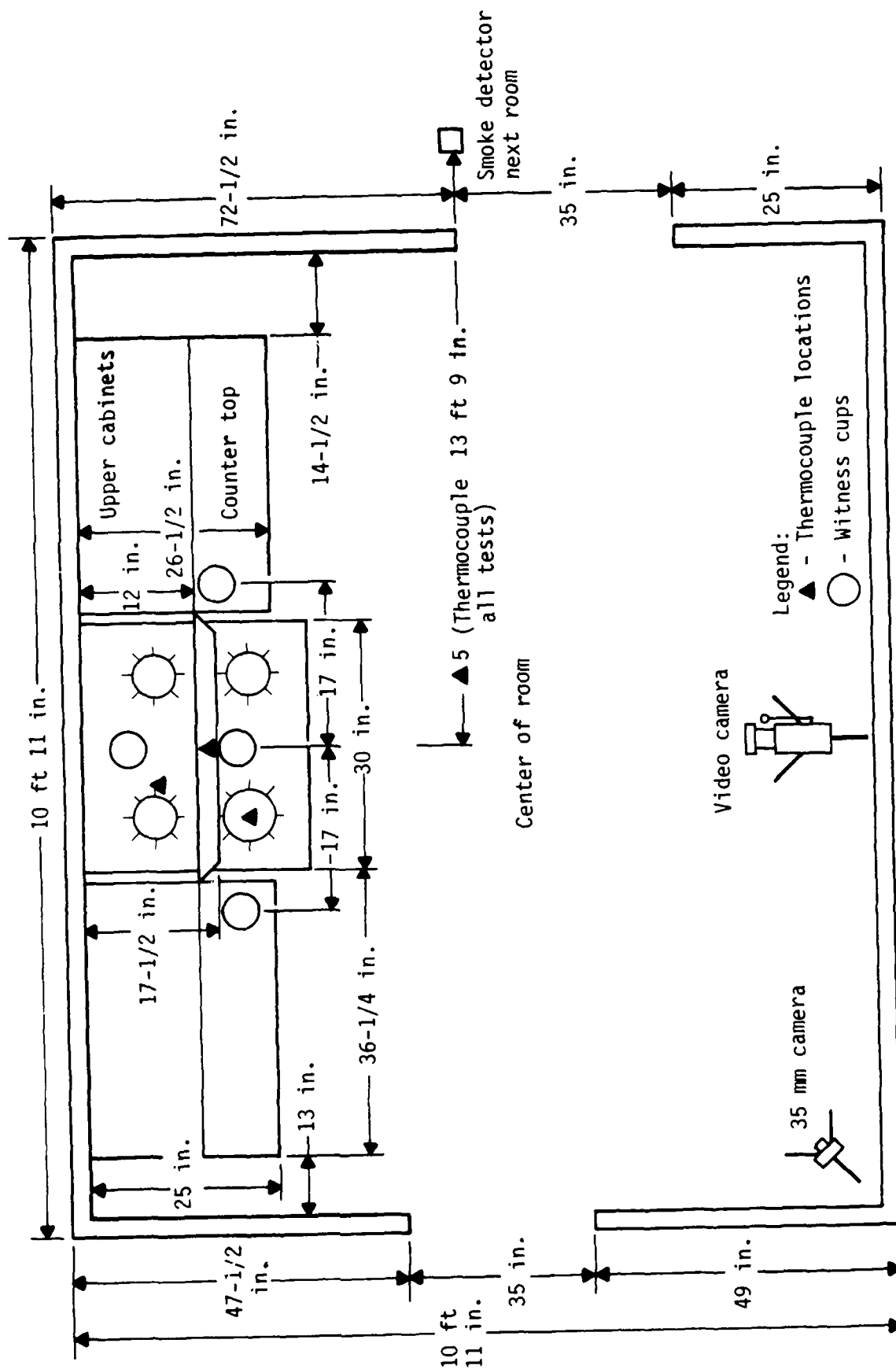


Figure 2. Typical Layout for Test Platform, Plan View.

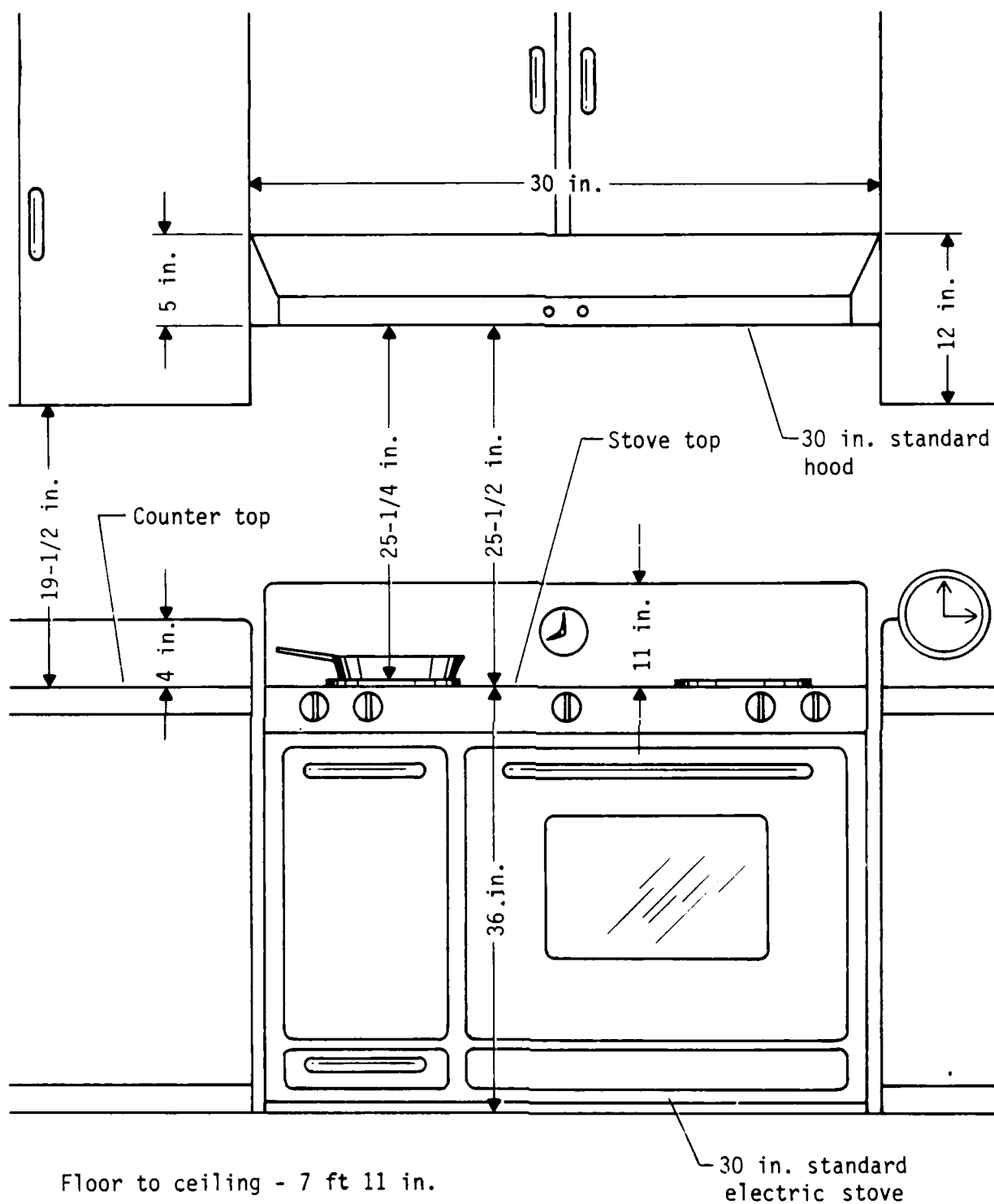


Figure 3. Typical Layout for Test Platform, Elevation View.

This project was not intended to confirm, evaluate, or recreate any testing conducted by UL. However, the basic procedures used by UL in testing prototype (production model) residential stove extinguishing devices are contained in Appendix C for comparison.

SECTION II

GENERAL DESCRIPTION OF TESTS CONDUCTED

A. TEST UNITS

The extinguishers tested were automatic systems designed for installation in or near a kitchen range hood to control and extinguish range-top fires. The systems were either flame-activated, using a precious metal sensor, or heat-activated, using a fusible link (solder type or resettable) that activated when heated to its design temperature. The extinguishers were designed to automatically blanket the stove top with either a dry chemical or a liquid fire-extinguishing agent (depending on manufacturer) and automatically turn off the exhaust hood fan and the power or gas to the range following activation.

B. INSTRUMENTATION AND PHOTOGRAPHING

Thermal, agent distribution, and photographic data were collected during each test. Thermocouples were used to monitor and record temperatures at various locations during testing (Figures 2 and 4). Agent dispensing and concentration patterns were monitored by placement of witness cups on the stove and on nearby horizontal surfaces. The data recorder was set at zero time when the cooking oil/fuel source ignited. The video coverage used was normal speed VCR synchronized with the data collection computer. Color slides were taken to document the pretest setup and posttest damage to the range and surrounding area.

C. TEST PREPARATION AND PROCEDURES

Preparations for each individual test series were performed as follows:

1. Install the extinguishing device.
2. Install thermocouple gages and agent concentration monitors. Hook up gages and test for functioning.
3. Position cameras.
4. Take pretest still photographs.
5. Place cooking oil into appropriate pan for test.

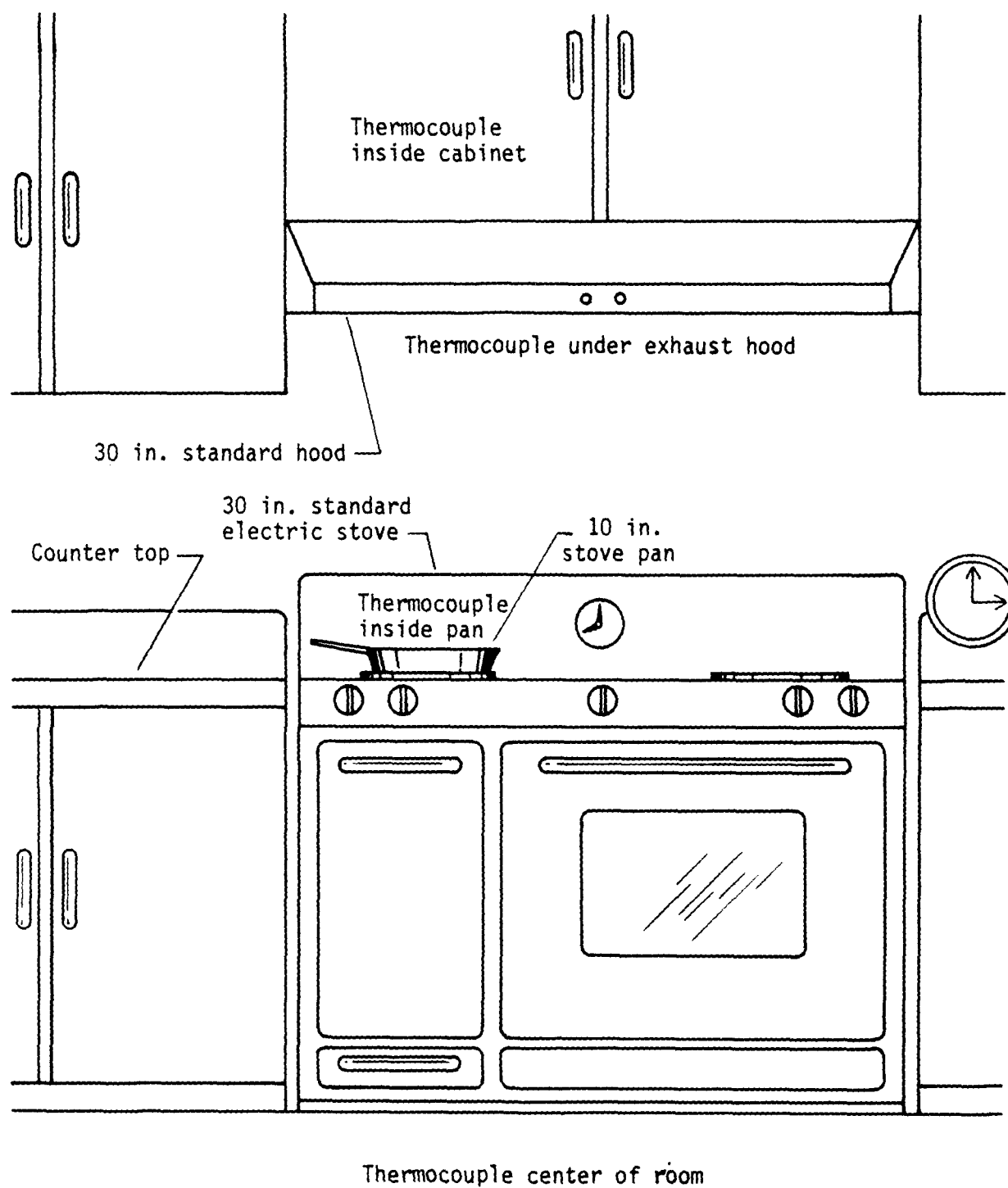


Figure 4. Typical Locations for Temperature Measurements.

6. Position pan on selected burner.
7. Evacuate nonessential personnel.
8. Perform final check of cameras and instrumentation.
9. Apply power/gas to the range burner and allow the heat from the burner to autoignite the cooking oil contained in the fry pan.
10. Collect data on fire and extinguisher behaviors.
11. Ensure that the power/gas was automatically or manually disconnected from the range and that the fire was extinguished and controlled.

D. POSTTEST PROCEDURES

Immediately following each test event, the following actions were taken:

1. Evacuate smoke from inside the test area.
2. Take still photographs of damage in undisturbed situation.
3. Check instrumentation readings.

E. CHEMICAL ANALYSIS OF AGENTS

Company A and B fire extinguishants used in stove-top-type extinguishing systems were analyzed. The Company C extinguishant used a standard Ansul dry chemical called Purple K® (potassium bicarbonate, KHCO_3).

The Company A extinguishing agent was obtained by setting off the sealed unit with a propane torch and collecting the extinguishant in a large plastic bag. The solid material did not completely dissolve in water; some insolubles were present. The material effervesced strongly upon treatment with an acid, indicating that the principal active ingredient was a carbonate. Addition of several milliliters of a concentrated sodium hydroxide solution to the solid did not liberate ammonia gas, which is detectable with moist litmus paper. Flame tests indicated the presence of a large amount of sodium. Atomic absorption spectroscopy of the solid showed the presence of 47 percent sodium with very little potassium. The water-insoluble material was dissolved with a solution of HF and perchlorate. This is indicative of silicates, which are often used to prevent clumping and improve the fluidics of powders. It was deduced that the Company A extinguishant was sodium carbonate (Na_2CO_3) and/or sodium bicarbonate (NaHCO_3) with a silicate filler.

The Company B extinguishing agent was a colorless liquid with a small number of crystals at the bottom of the container. The liquid had no odor and was assumed to be an aqueous solution. Treatment with strong acid (H_2SO_4) resulted in violent effervescence of gas (presumably CO_2) and formation of a white solid (sulfate salt). This action indicated the presence of carbonates. The carbonate was most likely to be a salt of Na^+ , K^+ , or NH_4^+ . A small amount of the liquid was made basic with NaOH , boiled, and the vapor tested for pH. If NH_4^+ were present, the basic solution would liberate NH_3 vapors, indicated by a high pH. No ammonia was detected. In the absence of a large amount of sodium, a flame test can detect potassium. Sodium ion burns bright yellow and potassium ion, a pale pink. The water was driven out of a portion of the material and the remaining crystal was heated in a Bunsen flame. Other salts containing sodium and potassium were flame tested for comparison. Although the test was not conclusive, the Company B agent appeared to be potassium carbonate (K_2CO_3). A sample of the liquid was analyzed by atomic absorption spectroscopy. The results indicated that the solution was 53 percent K_2CO_3 in water (113 grams of K_2CO_3 in 100 grams of H_2O). This value is in excellent agreement with the solubility reported for K_2CO_3 (112 grams of K_2CO_3 in 100 grams of H_2O at 20 °C, Reference 1). It was concluded that the Company B extinguishant was a saturated aqueous solution of potassium carbonate.

F. SUMMARY

Carbonates of alkali metals are often used as extinguishing agents; however, the mechanism of their action in a fire is not well defined. The surface of the solid salt particles (solid carbonates) may provide a support for recombination of radicals generated in flames (Reference 2). Another proposed reaction mechanism is that of M_2O ($\text{M} = \text{Na}, \text{K}$) with hydrogen atoms in the fire (Reference 3), a chemical action similar to that of halons. The amount of CO_2 released from carbonates as diluent in flames does not account for the degree of fire suppression observed.

Further testing is required to understand the total interaction of the agent ingredients in the presence of flame. Any future development which is undertaken for stove-top extinguishing devices will require additional chemical analyses of the fire suppression agents.

SECTION III

TESTING AND DATA

A. TEST EVENTS

All test events, unless otherwise noted, occurred in accordance with the approved Air Force Test Plan (see Appendix B). All but one test (noted) were conducted using a 10-inch diameter cast iron frying pan with 30 ounces of either vegetable, olive, or lard cooking oil. In each test, the cooking oil was heated to autoignition, at varying temperatures, depending upon environmental conditions and the type of oil. All tests were conducted on the high setting of the largest burner of an electric stove, Type SUNRAY, Model SSE26PH-030, with three 700-watt burners and one 1200-watt burner. Each system displayed the ability to shut off either gas or electric current to the stove when the presence of flame was detected. The instrumentation and procedures for all events were as stated in Section II, unless otherwise noted. All temperatures were collected by a Model CASS-116U-36 thermocouple, temperature range -350 to +2300 °F (Type K). Either the manufacturer or his designated representative was present during testing of each device.

B. COMPANY A GENERAL TEST SETUP

During each of the four tests conducted with the Company A system, the same type of unit, containing 1000 grams of dry chemical agent, was used. Each unit was installed in accordance with the manufacturer's installation instructions (Figure 5). The unit was activated during each test by a flame-sensitive wire, and the agent was discharged by pressure from a CO₂ cylinder. The unit contained four orifices, each directed toward a separate burner. In each test, the oil used was allowed to autoignite. Four 3-ounce witness cups were strategically placed for collecting the discharged agent to calculate the agent coverage over the entire stove surface. The locations of these cups are shown in each test description. If the entire 1000 grams of agent were discharged with a uniform distribution over the stove surface, the pan would receive 110 grams of agent.

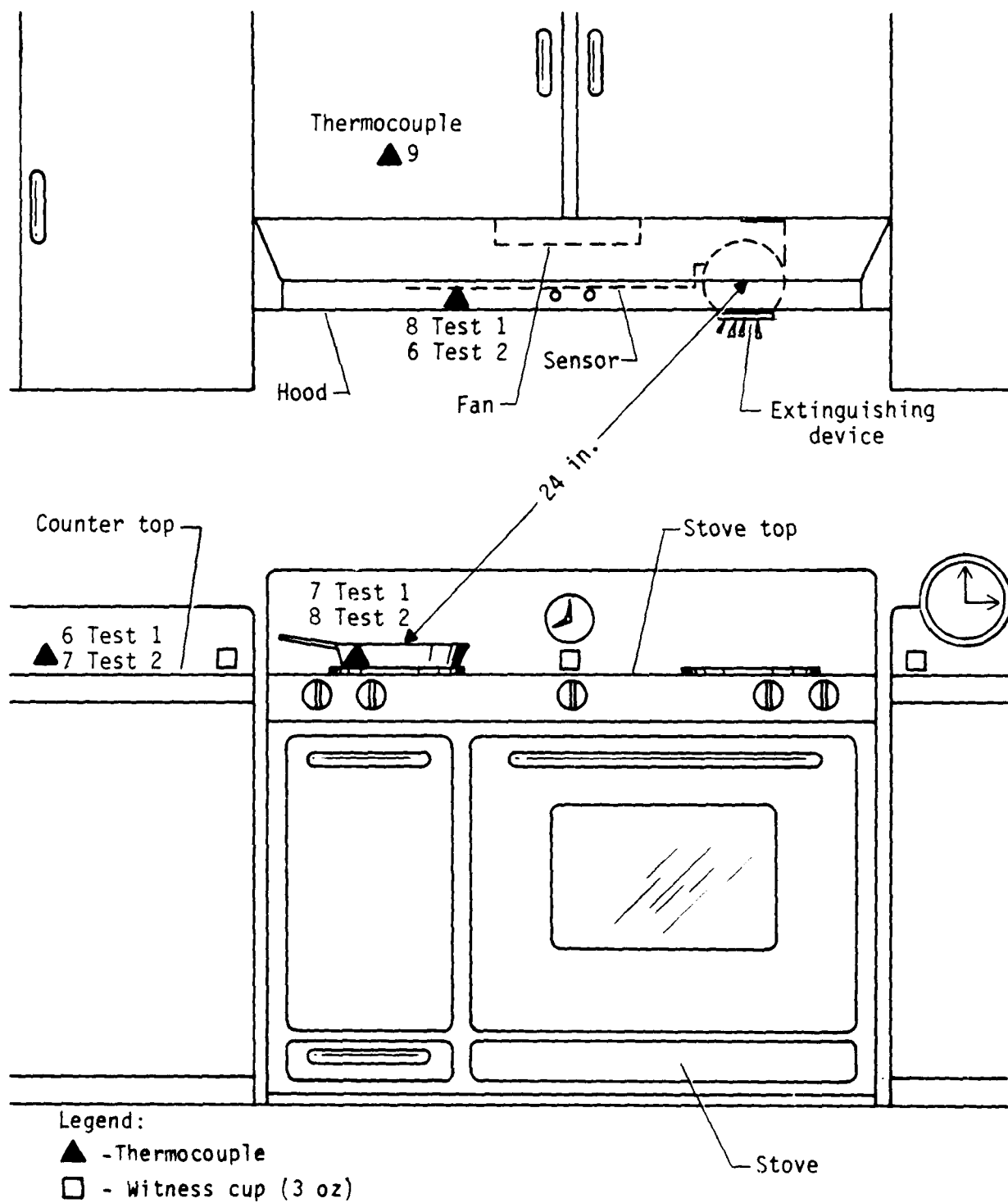


Figure 5. Test Platform for Company A Tests.

C. COMPANY A TEST 1

The test platform for this test is shown in Figures 5 and 6. In this test, the exhaust hood was operating and the frying pan contained vegetable oil. The autoignition temperature, indicated by a thermocouple to be 711 °F, was attained in approximately 18 minutes. The time from autoignition to flame detection was 61 seconds. The temperatures at the time of flame detection were 791 °F in the frying pan and 406 °F in the center of the exhaust hood. During the heating and flame processes, the room became filled with a light concentration of smoke. The test platform was always visible to the camera. Upon detection of the flame, 4 seconds were required for the extinguishing device to activate the discharge of approximately 690 grams of dry chemical agent. The temperatures reached during this test are shown in Figure 7. The thermocouple positions are shown in Figure 5.

The pattern of agent discharge, as determined from the amounts collected in the witness cups (Figure 8), was not uniform across the width of the front two burners. A larger quantity of agent was dispensed on the right rear quadrant of the stove surface. That area was directly under the extinguishing device. The agent effectively extinguished the flame, but could only prevent reignition for 7 seconds. The second flame was manually extinguished by test personnel.

The agent amounts collected in the witness cups were as follows:

Location	Amount, grams
1	13.04
2	3.79
3	5.64
4	0.00

An area proportional analysis estimated that the surface of the frying pan received 27 grams of dry chemical agent during this test. If uniform distribution of the 690 grams of agent had occurred, the pan should have received approximately 76 grams.

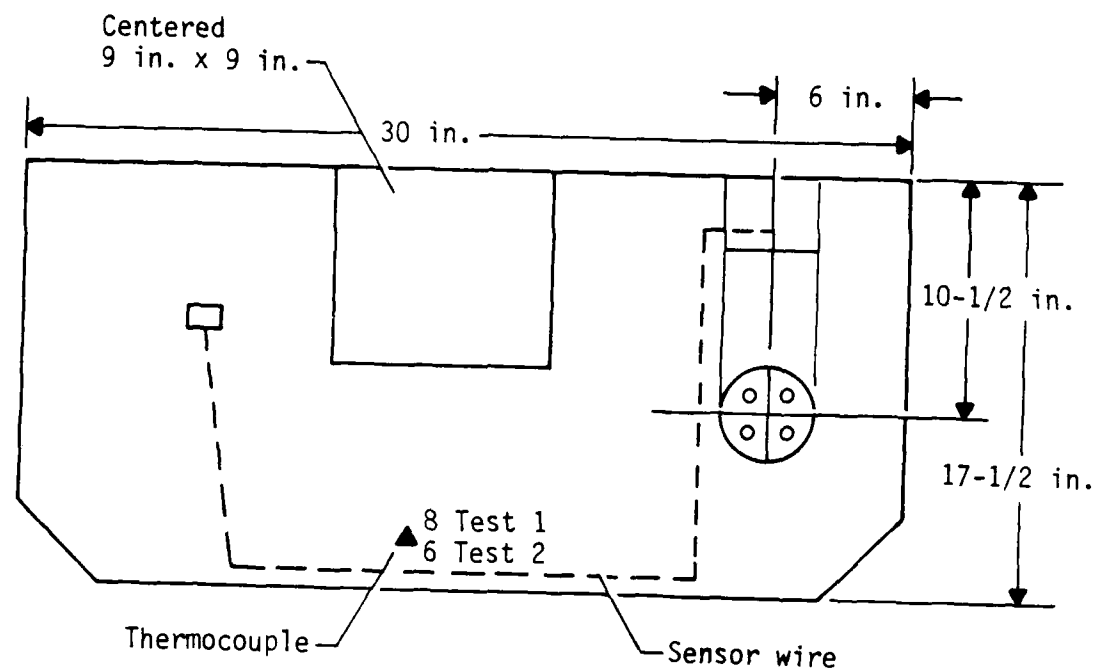


Figure 6. Exhaust Hood Layout for Company A Tests 1 and 2.

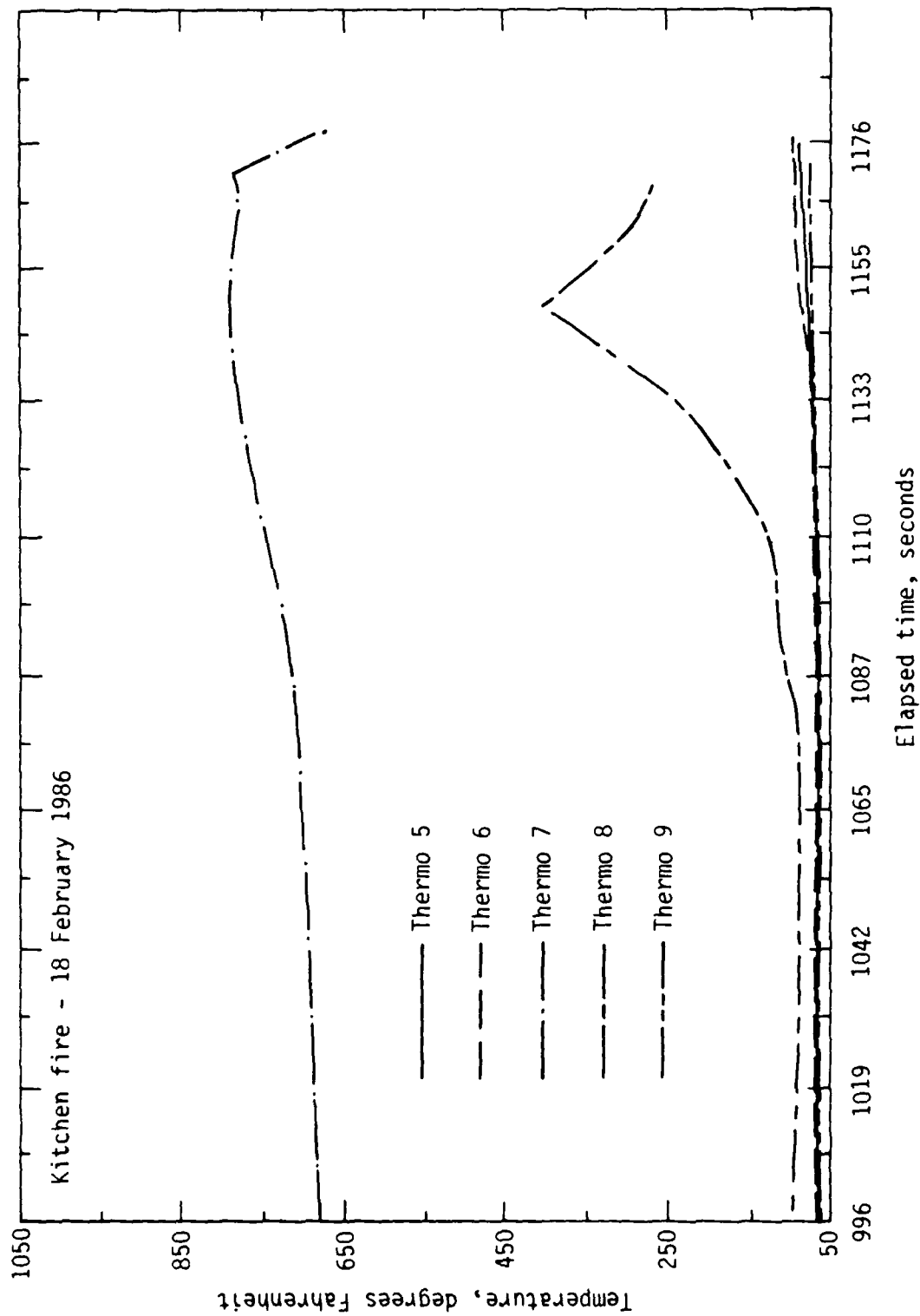
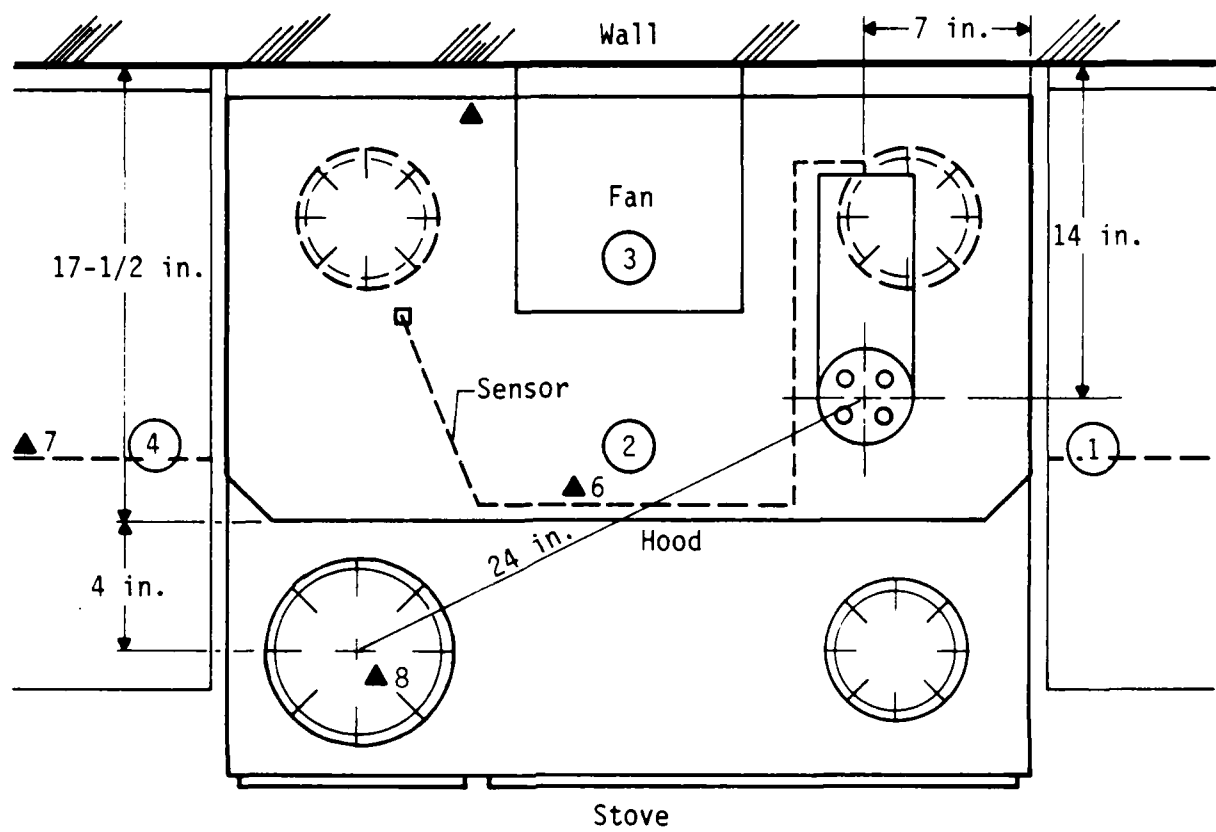


Figure 7. Thermal Performance of Test A-1.



Legend:

- ▲ - Thermocouple
- ① - Witness cup (3 oz)

Figure 8. Layout for Company A Test 3.

The following damage occurred between initial flame and manual extinguishment after reignition:

1. The stove surface was severely burned by the hot metal (estimated between 1500 and 2000 °F) from the detector sensor wire which activated the agent discharge (estimation).
2. Before extinguishment, the exhaust hood and overhead cabinet were slightly burned by the flame, which reached a height of approximately 3 feet.
3. The adjoining left-side cabinet counter top was severely scorched during attempts to manually extinguish the flashback flame.

D. COMPANY A TEST 2

The test platform for this test is shown in Figures 5 and 6. In this test the exhaust hood was operating and the frying pan contained olive oil. The autoignition temperature, indicated by a thermocouple to be 689 °F, was attained in approximately 13 minutes. The device detected the presence of flame 91 seconds after autoignition. The temperatures at this time were 788 °F in the frying pan and 408 °F in the center of the exhaust hood. During the heating and flame processes, the room became moderately filled with smoke. The smoke concentration never obscured the stove or the exhaust hood from the camera; however, the density was slightly greater than that which occurred in Test 1. Upon detection of the flame, 2 seconds were required for the extinguishing device to activate the discharge of approximately 925 grams of dry chemical agent. The discharge continued for about 5 seconds. The temperatures reached during this test are shown in Figure 8. The thermocouple positions are shown in Figure 5.

The pattern of discharge, as determined from the amounts collected in the witness cups (Figure 8), was again heavier toward the rear of the stove. During this test, however, the left side of the stove received more agent than the right side. The agent effectively extinguished the flame, but could prevent reignition for only 33 seconds. The second flame was manually extinguished by test personnel.

The agent amounts collected in the witness cups were as follows:

Location	Amount, grams
1	3.45
2	12.74
3	7.53
4	4.58

Area proportional analysis revealed that the surface of the frying pan received an estimated 79 grams of dry chemical agent during this test. If uniform distribution of the 925 grams of agent had occurred, the pan should have received approximately 102 grams.

Between initial flame and manual extinguishment, after reignition, the following damage occurred:

1. The stove surface again sustained severe damage due to the hot metal from the burned sensor wire. The porcelain surface was burned away wherever the metal particles fell.
2. The exhaust hood again received severe damage from the initial flame, which reached a height of over 3 feet.
3. The adjoining cabinets and/or ceiling did not receive any noticeable damage.

E. COMPANY A TEST 3

The test platform for this test is shown in Figures 5 and 9. In this test, the exhaust hood was operating and the frying pan contained lard cooking oil. The autoignition temperature, indicated by a thermocouple to be 734 °F, was attained in approximately 16.6 minutes. Seventy-five seconds elapsed from the time of autoignition until the device detected the flame. The temperatures at this time were 796 °F in the frying pan and 708 °F in the center of the exhaust hood. During the heating stage, the room became filled with smoke so dense as to obscure the stove and exhaust hood just before autoignition. Upon detection of the flame, 6 seconds were required for the extinguishing device

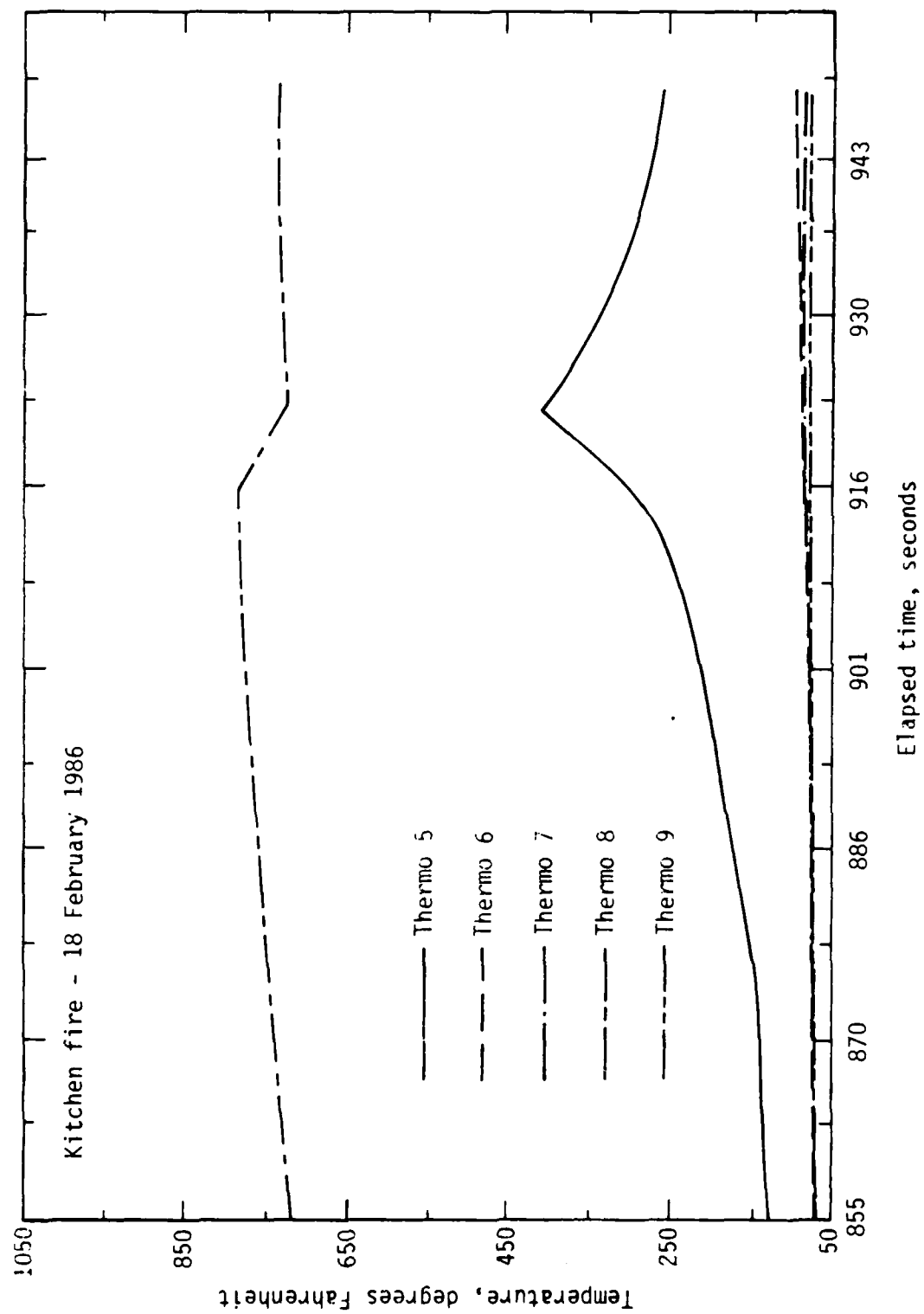


Figure 9. Thermal Performance of Test A-2.

to activate the discharge of only 502 grams of dry chemical agent. The agent discharged for approximately 3 seconds. The temperatures reached during this test are shown in Figure 10. The thermocouples were placed in accordance with Figures 5 and 9.

The pattern of discharge, as determined from the amounts collected in the witness cups (Figure 8), was not uniform around the perimeter of the stove. A proportionately higher quantity of agent occurred at the center of the stove surface, as should be expected. The agent effectively extinguished the flame, but could only prevent reignition for 3 seconds. The second flame was manually extinguished by test personnel.

The agent amounts collected in the witness cups were as follows:

Location	Amount, grams
1	3.56
2	5.68
3	3.79
4	3.56

Area proportional analysis revealed that the surface of the frying pan received an estimated 31 grams of dry chemical agent during this test. A uniform distribution over the stove surface would have deposited approximately 55 grams of agent in the pan.

Between initial flame and manual extinguishment after reignition, the same degree of damage occurred as in Test 2.

F. COMPANY A TEST 4

The test platform for this test is shown in Figures 5 and 11. Based on the manufacturer's request, the test platform was modified (Figure 11) to position the sensor wire over the center of the front burner. During this test, the exhaust hood was not operated and the frying pan contained vegetable oil. The autoignition temperature, indicated by a thermocouple to be 715 °F, was attained in approximately 17.3 minutes. Sixty-two seconds elapsed from the point of autoignition until the device detected the presence of flame. The

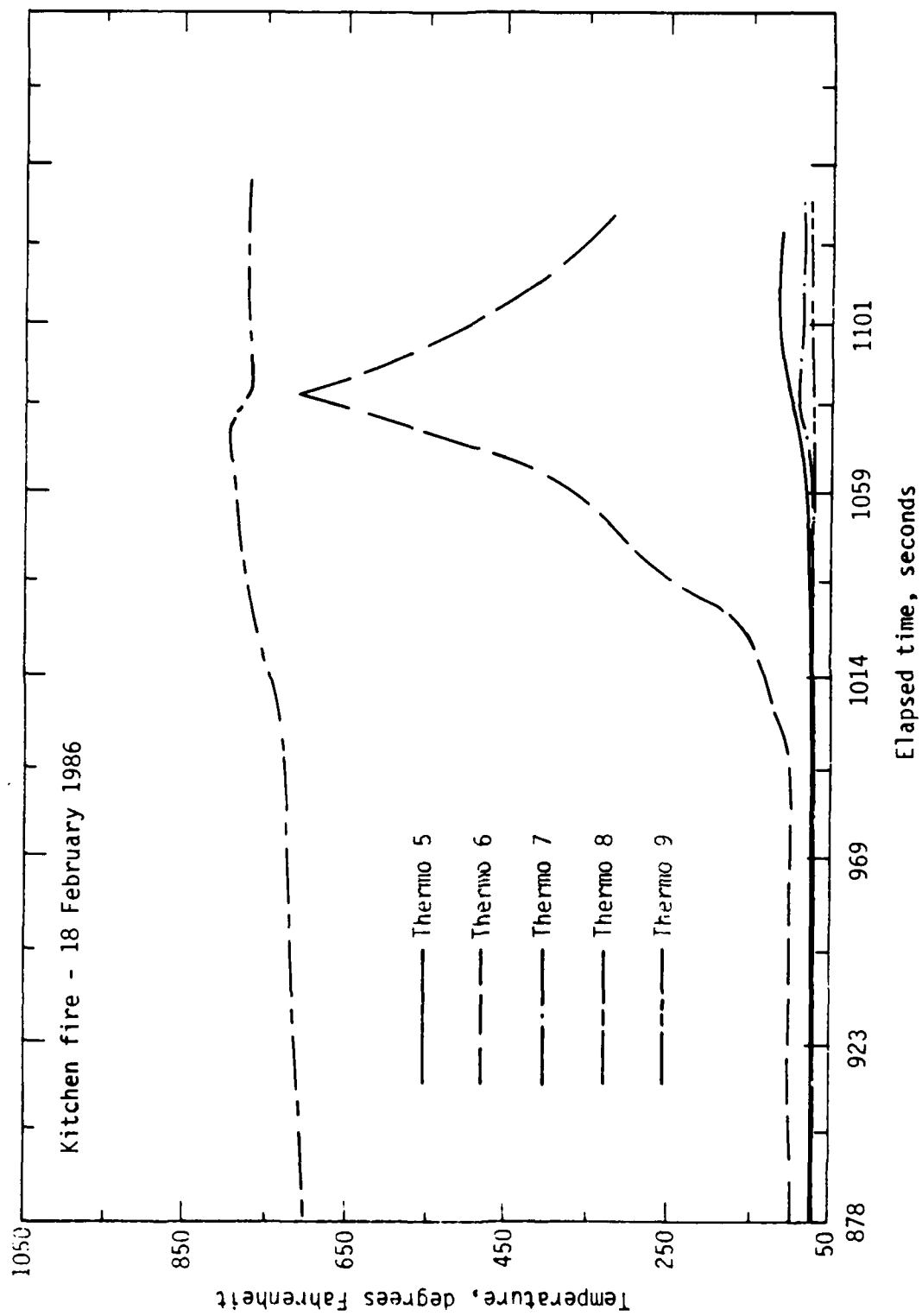
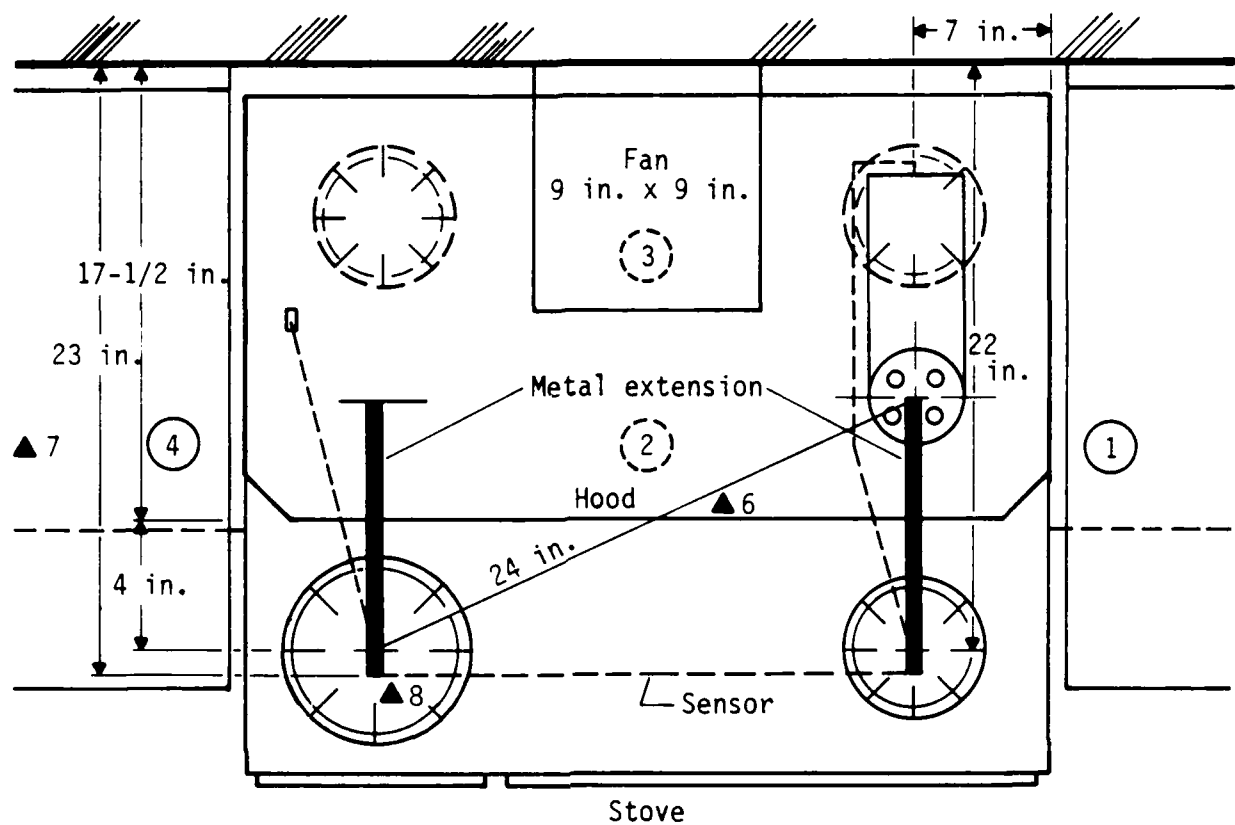


Figure 10. Thermal Performance of Test A-3.



Legend:

- ▲ - Thermocouple
- - Witness cup (3 oz)

Figure 11. Layout for Company A Test 4.

temperatures at this time were 788 °F in the frying pan and 466 °F in the center of the exhaust hood. During the heating and flame processes, the room became lightly filled with smoke. The smoke concentration was identical to that which occurred in Test 1. Upon detection of the flame, 5 seconds were required for the extinguishing device to activate the discharge of approximately 940 grams of dry chemical agent. The agent discharged for approximately 4 seconds. The thermocouple placement is shown in Figure 11. The temperatures reached during this test are shown in Figure 12.

The pattern of discharge, as determined by the amounts collected in the witness cups (Figure 11), was relatively the same as in Test 3, except that the unit discharged 87 percent more agent than in Test 3. The agent effectively extinguished the flame, but could only prevent reignition for 12 seconds. The second flame was manually extinguished by test personnel.

The agent amounts collected in the witness cups were as follows:

Location	Amount, grams
1	4.44
2	5.16
3	3.87
4	3.51

It is estimated by area proportional analysis that the surface of the frying pan received approximately 57 grams of dry chemical agent during this test. If there had been uniform distribution of the 103 grams of agent over the stove surface, the pan should have received approximately 103 grams of agent.

Between the period from initial flame and manual extinguishment after reignition, the damage was approximately the same as in previous tests.

G. SUMMARY OF COMPANY A TESTS

The Company A system was able to detect the presence of flame in each test; however, it was unable to prevent reignition. The dry chemical agent (see Section II for chemical analysis) suppressed the flame from 3 to 33

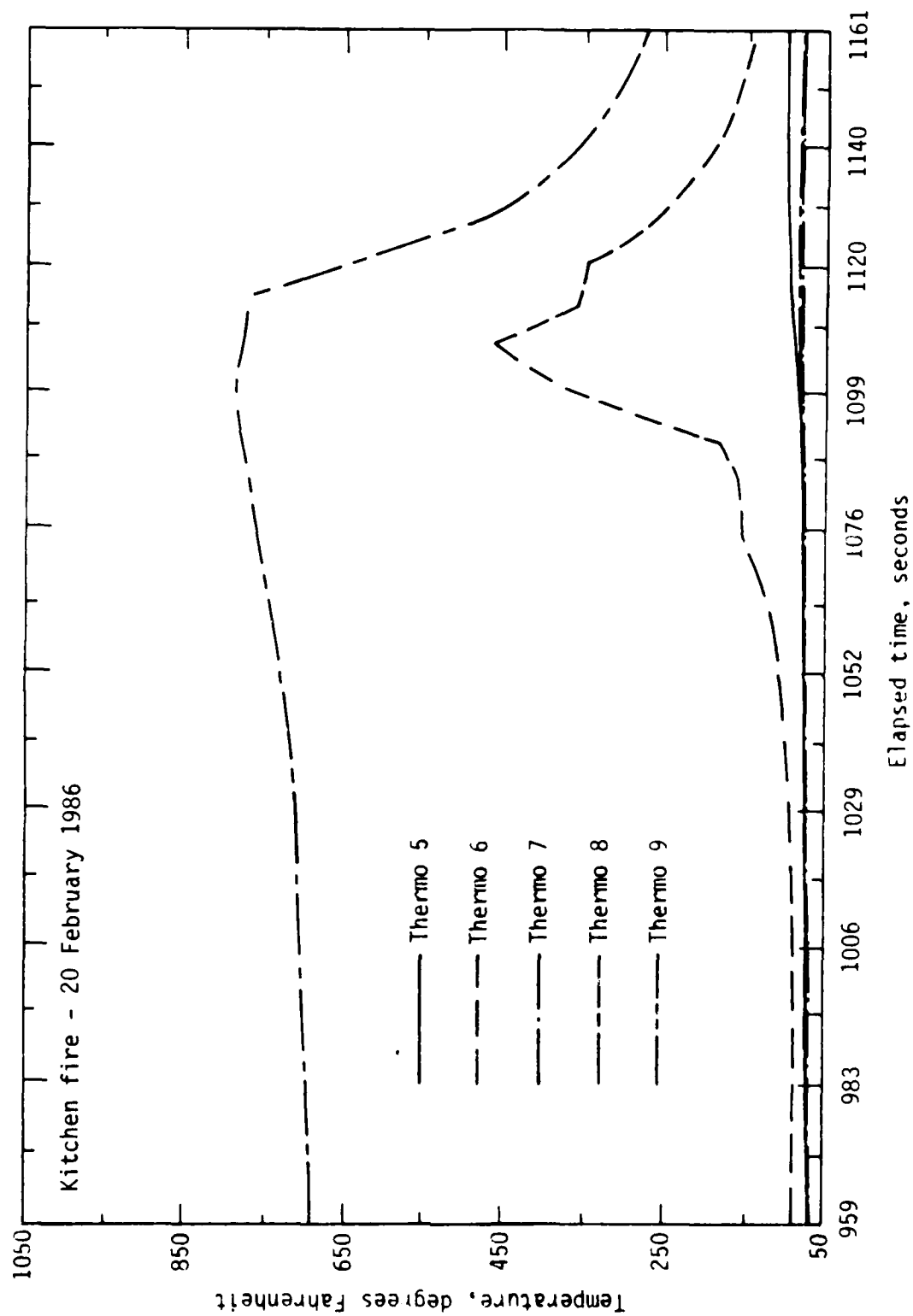


Figure 12. Thermal Performance of Test A-4.

seconds before reignition occurred. The amount of agent discharge was highly variable, ranging from 502 to 940 grams. The sensor wire burn temperature was determined with a thermocouple. The burning of this wire presents a separate ignition hazard because it reaches temperatures between 1500 and 2000 °F, and small particles are discharged during the burn. During the testing of the Company A unit, the stove surface was severely burned by the particles from the sensor wire. Mounting this unit was relatively simple; no special tools or specialized skills were necessary.

H. COMPANY B GENERAL TEST SETUP

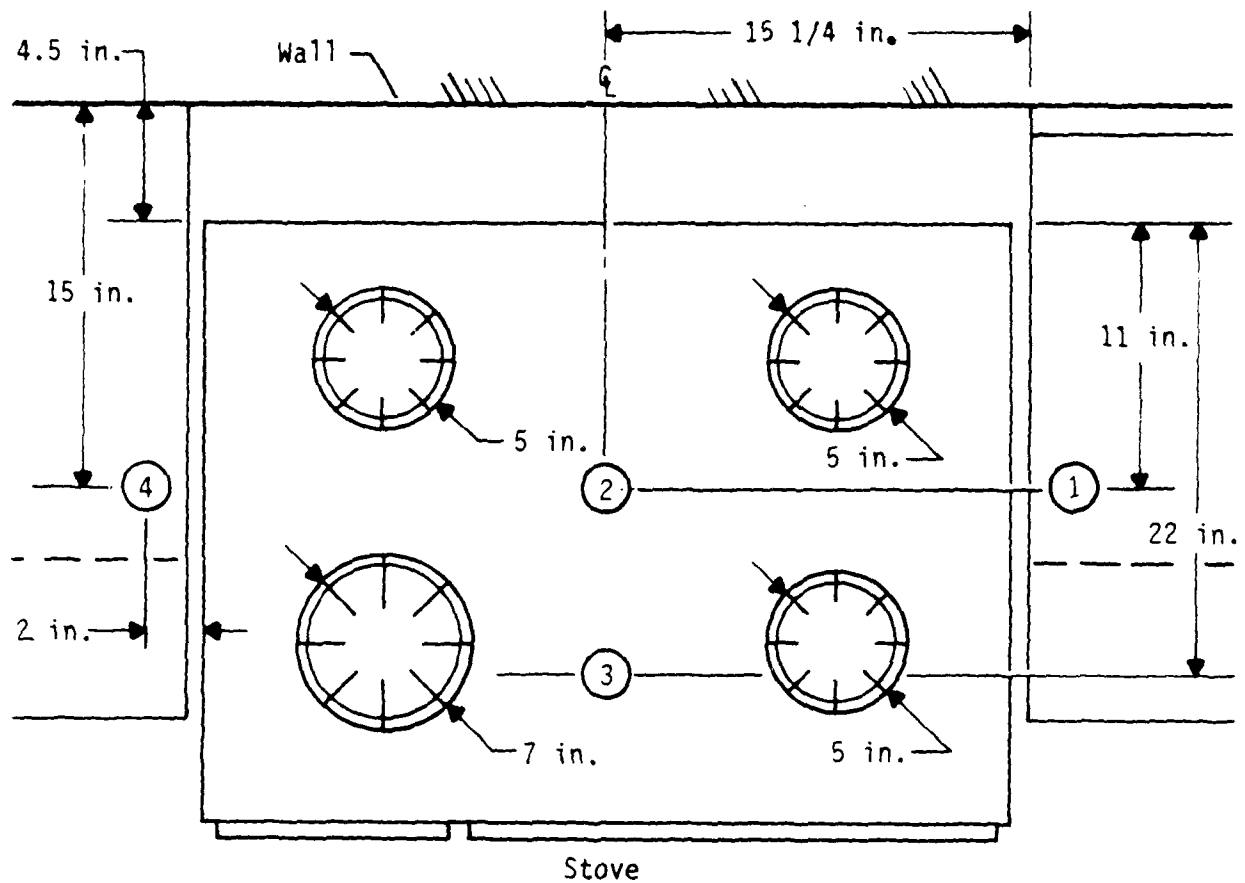
The testing of this unit involved several different mounting configurations and system sizes because the unit was unsuccessful in detecting the flame in the original configuration. In each test, the system used a liquid agent (see Section II for analysis), which was delivered by gravity force. The standard unit contained 32 ounces of agent and had four orifices, each directed toward a separate burner. The system was activated by a solder thermal link. The unit was designed for vertical wall mounting inside an exhaust hood. The design tested could only be used for stove installations where a vertical wall surface was nearby. In all tests for this system, witness cups were placed as shown in Figure 13.

I. COMPANY B TEST 1

The test platform for this test is shown in Figure 14. The exhaust hood was operating and the frying pan contained vegetable oil. The oil autoignited during this test at 720 °F. The system could not detect the presence of flame; therefore, after the frying pan temperature reached 793 °F, the test was terminated and the flame was extinguished by test personnel. During the heating and flame processes, the room became lightly filled with smoke. Due to termination of the test, no agent was discharged.

The temperatures reached during this test are shown in Figure 15. The thermocouples were placed in accordance with Figure 13.

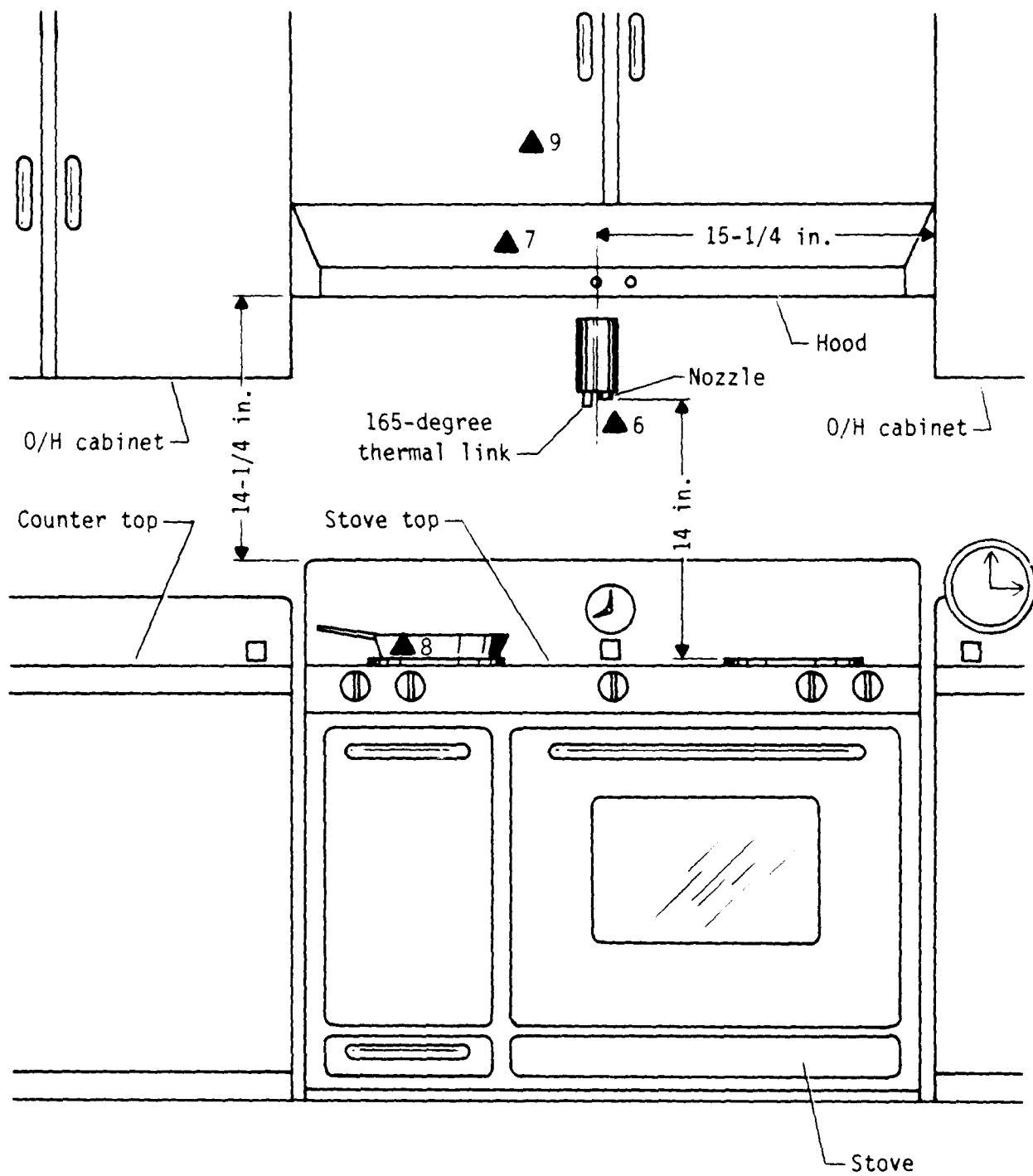
During the period from initial flame to manual extinguishment, the stove surface, exhaust hood, and overhead cabinet received minor damage. If the tests had not been stopped, the entire test platform would probably have been lost to fire.



Legend:

① - Witness cup (3 oz)

Figure 13. Witness Cup Layout for Company B - All Tests.



Legend:

▲ - Thermocouple

□ - Witness cup (3 oz)

Figure 14. Test Platform for Company B Test 1.

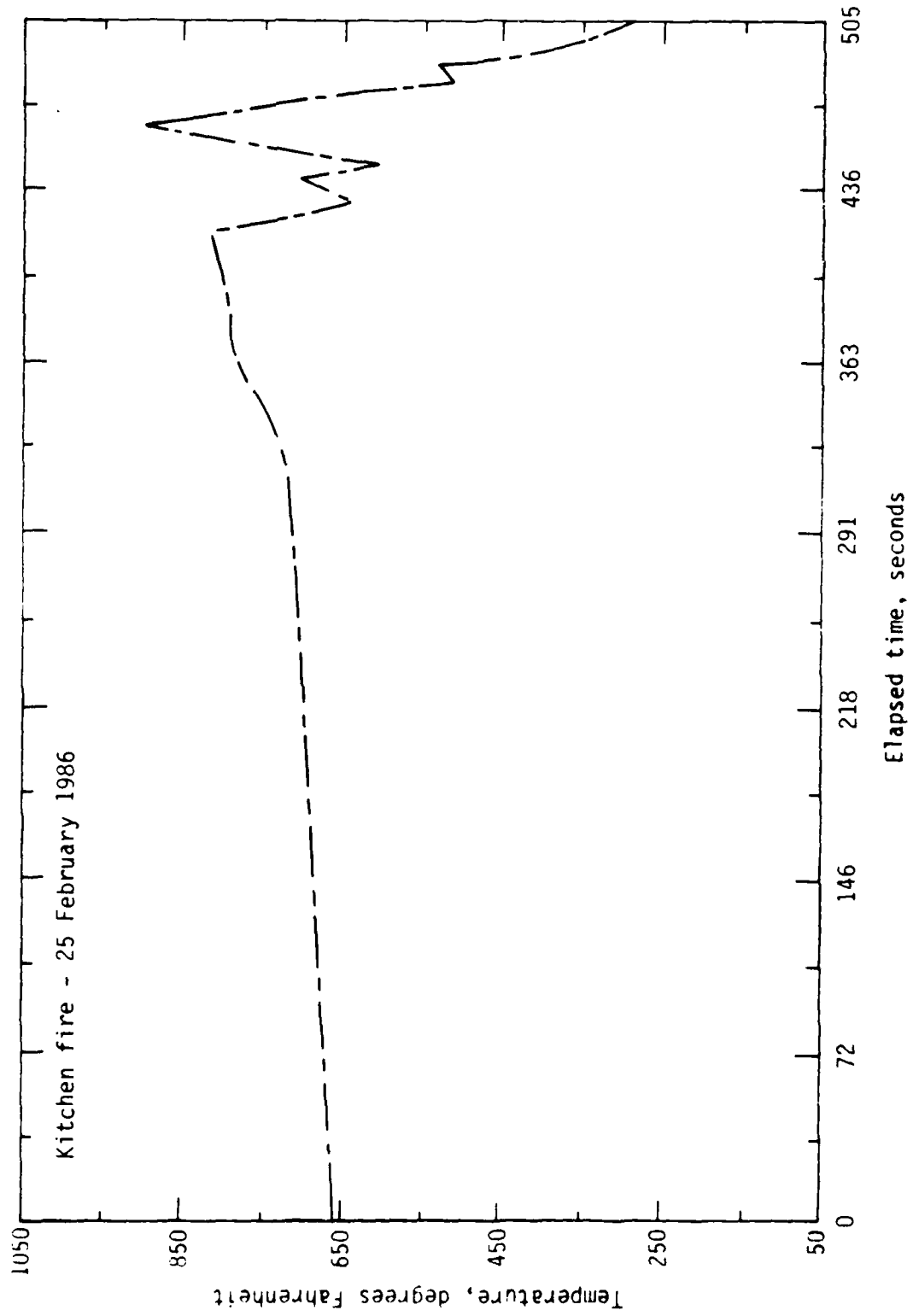


Figure 15. Thermal Performance of Test B-1.

J. COMPANY B TEST 2

The test platform for this test is shown in Figure 16. During this test, the exhaust hood was operating and the frying pan contained olive oil. The oil autoignited at 709 °F, which took approximately 24.4 minutes. Again, the device was unable to detect the presence of flame; therefore, the thermolink on the device was activated by a butane torch after the frying pan temperatures reached 778 °F, 63 seconds after autoignition. Following activation of the extinguishing device, approximately 8 seconds were required for total agent discharge. Because the agent did not effectively extinguish the fire, the flame was manually extinguished by test personnel. During the heating and flame processes, the room became moderately filled with dense smoke. The temperatures reached during this test are shown in Figure 17. The thermocouples were placed in accordance with Figure 16.

Because the streams of liquid agent were aimed at the centers of the stove burners, the witness cups collected no discharged agent and the amount of agent discharged into the frying pan could not be estimated.

Between autoignition and manual extinguishment of the flame, the exhaust hood and overhead cabinet were severely burned, and the fan inside the exhaust hood was melted. In addition, a ceiling light panel was badly warped by the heat in the room.

K. COMPANY B TEST 3

Testing was not performed in accordance with the approved Air Force Test Plan: two extinguishing devices, each containing 32 ounces of agent, were installed on the wall behind the stove (Figure 18). These units were placed in this configuration to determine if the system could better detect the presence of flame.

During this test, the exhaust hood was operating and the frying pan contained vegetable oil. The oil autoignited at 702 °F, which took approximately 27.15 minutes. The device was not able to detect the presence of flame; therefore, both devices were activated by butane torch. Upon activation of the device, 7 seconds were required for discharge of all the liquid agent. Because the agent did not effectively extinguish the flame, when the pan temperature

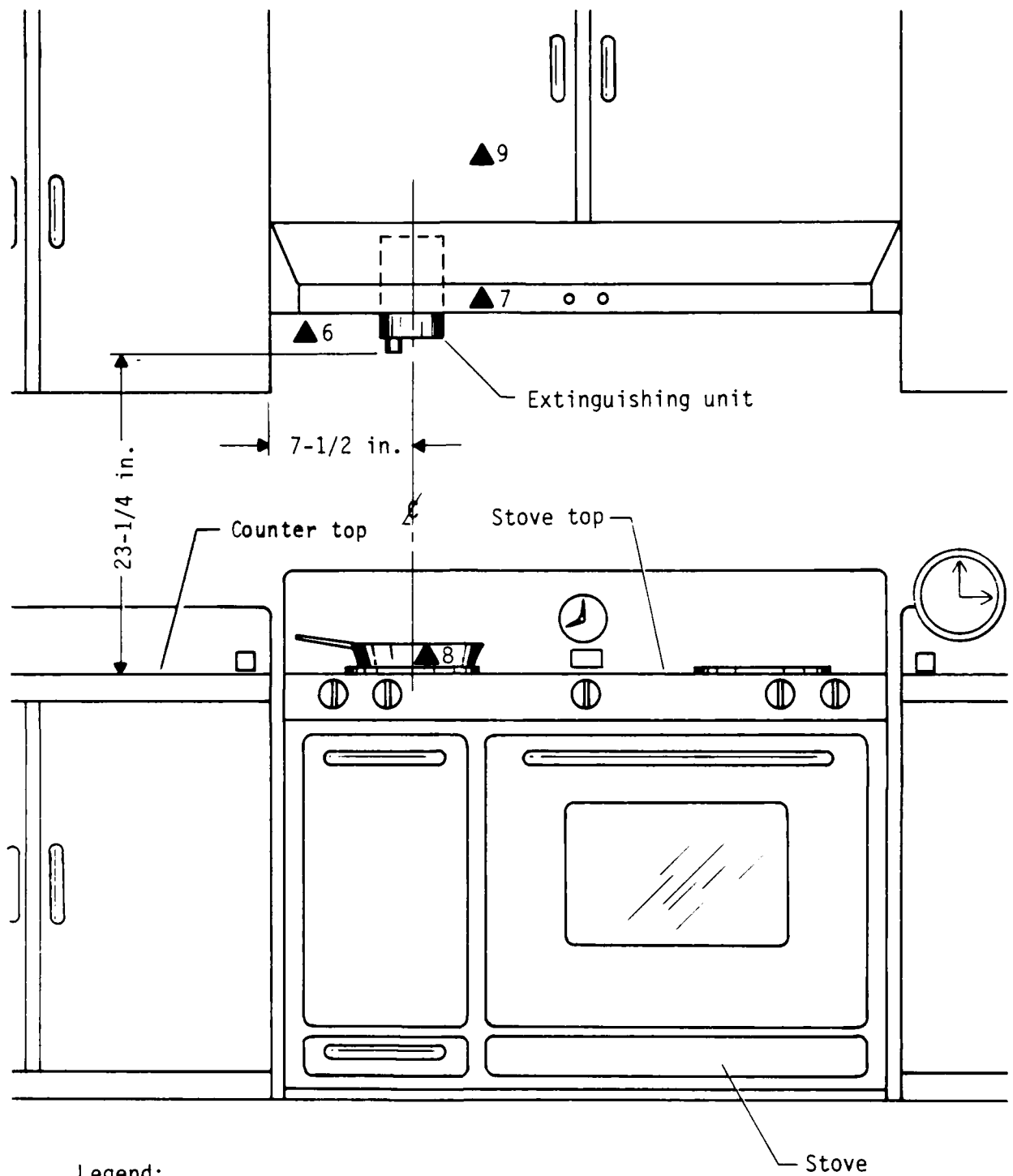


Figure 16. Test Platform for Company B Test 2.

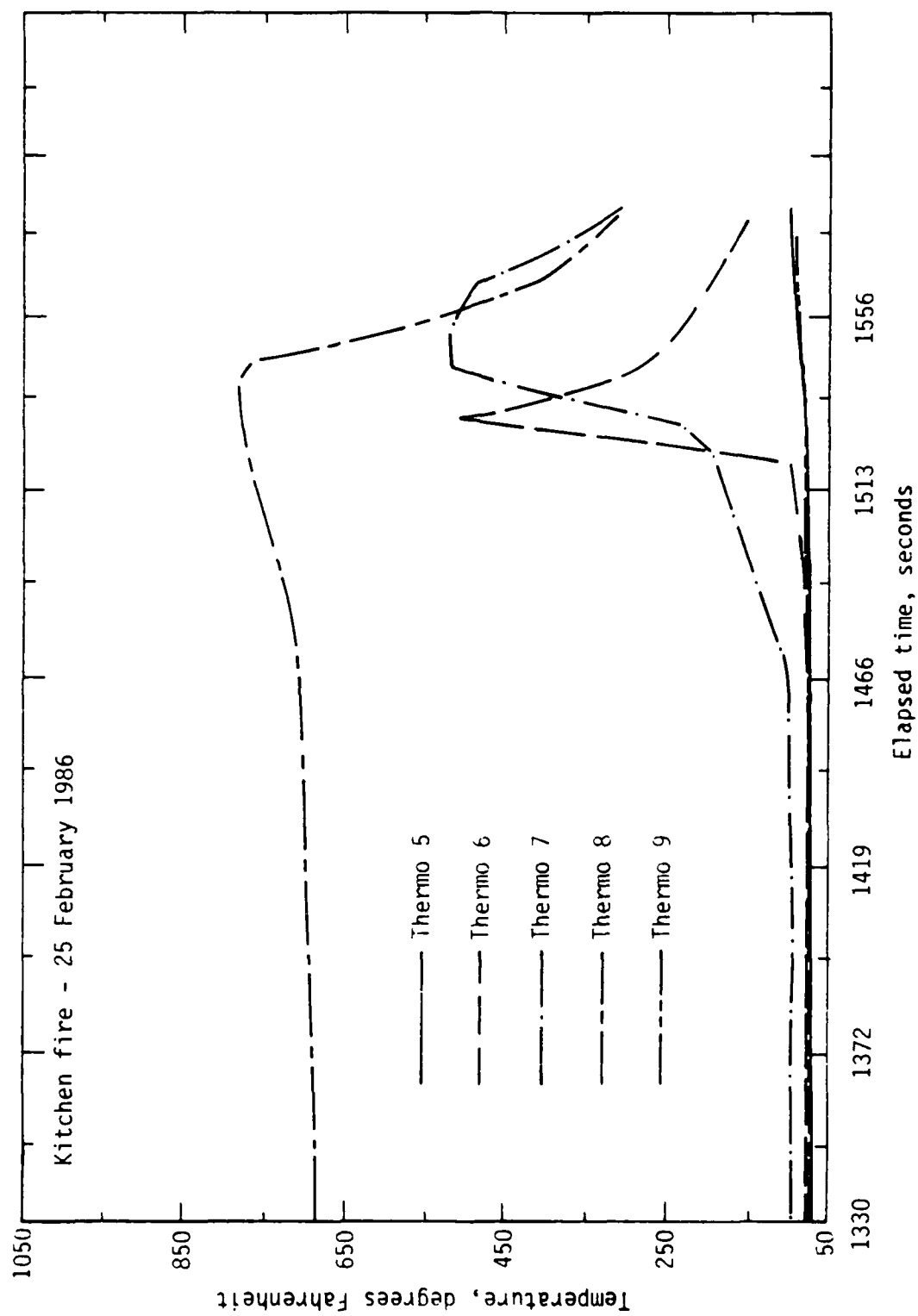


Figure 17. Thermal Performance of Test B-2.

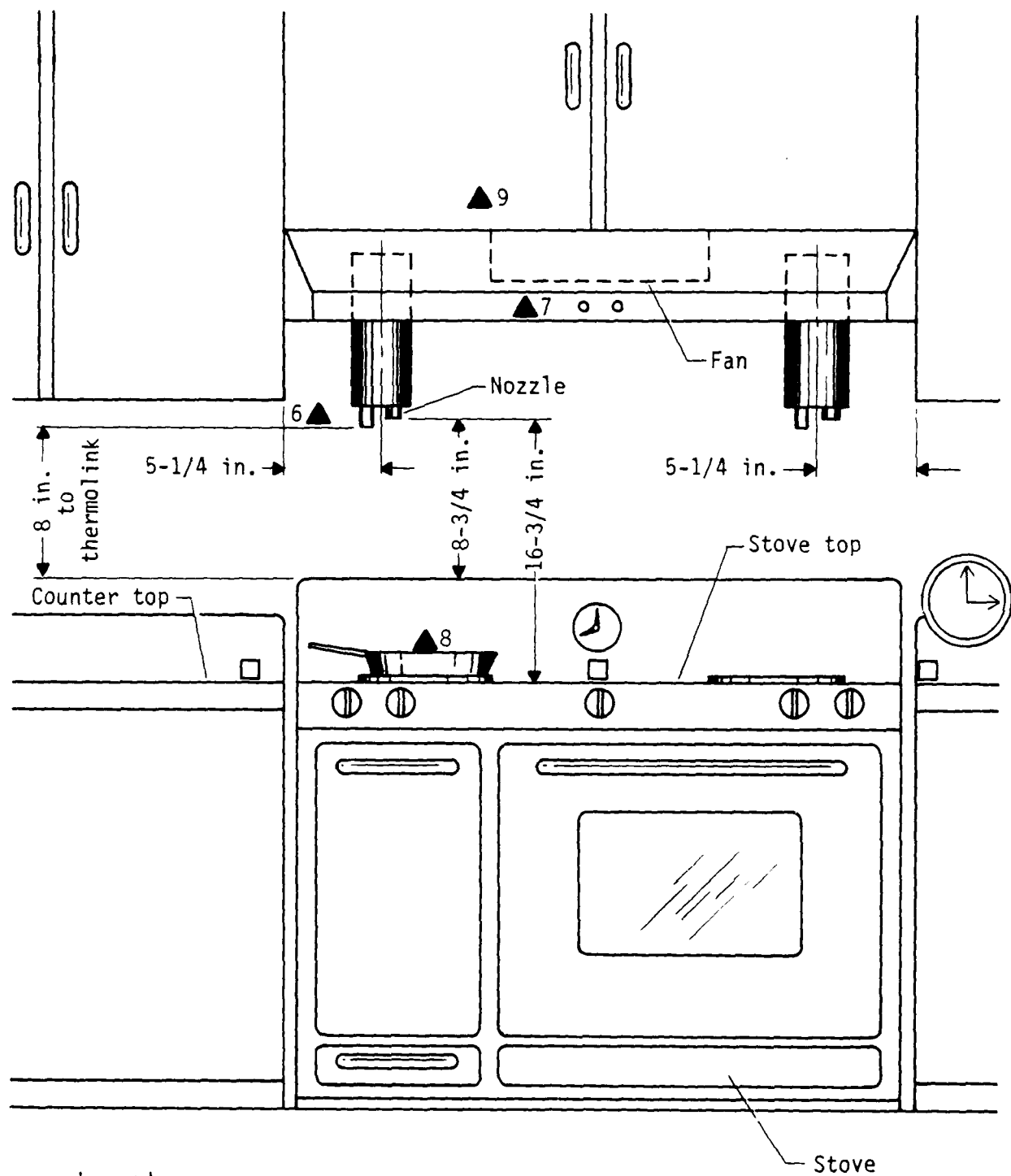


Figure 18. Test Platform for Company B Tests.

reached 799 °F, the flame was manually extinguished by test personnel. During the heating and flame processes, the room became moderately filled with smoke. The temperatures reached during this test are shown in Figure 19. The thermocouples were placed in accordance with Figure 18.

The cups again did not collect any of the discharged agent; therefore, it was not possible to estimate the agent coverage.

Between autoignition and manual extinguishment of the flame, the stove surface, exhaust hood, and overhead cabinet received extensive damage. The highest temperature reached in the exhaust hood was 1066 °F. At this temperature, a ceiling light fixture panel became warped and fell to the floor. Had the fire not been extinguished manually, the entire test platform would probably have been destroyed.

L. COMPANY B TEST 4

At the request of the company representative, this test was not performed in accordance with the approved Air Force Test Plan. A highly modified unit with a lower activating thermolink was affixed to the exhaust hood over the center of the large burner (Figure 20). This unit only contained 7.5 ounces of agent per manufacturer's design.

During this test, the exhaust hood was not operating and the frying pan contained vegetable oil. The oil temperature was allowed to rise to autoignition temperature, indicated by a thermocouple to be approximately 700 °F. In 16 seconds from the point of autoignition, the device detected the presence of flame and discharged all the agent in 8 seconds. The modified unit was not pressurized; the discharge occurred by gravity. The agent effectively extinguished the flame and prevented any reignition. During the heating and flame processes, the room became lightly filled with smoke. The temperatures reached during this test are shown in Figure 21. The thermocouples were placed as shown in Figure 20.

The modified unit contained only one discharge orifice, and an attempt was made to collect the discharged agent. Witness cups were placed in accordance with the layout shown in Figure 22; however, no agent was collected.

During the test period, no damage occurred to any part of the platform.

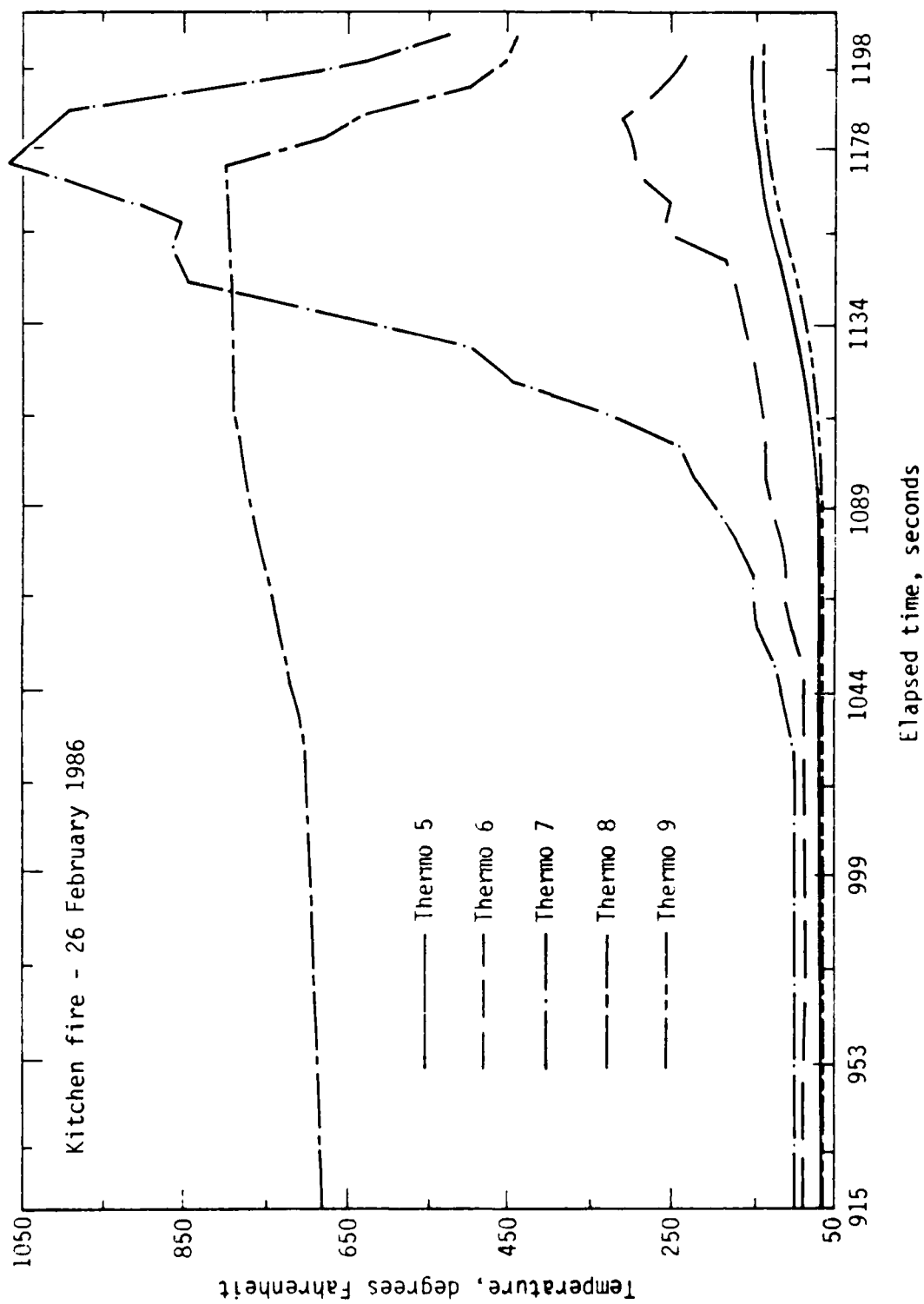
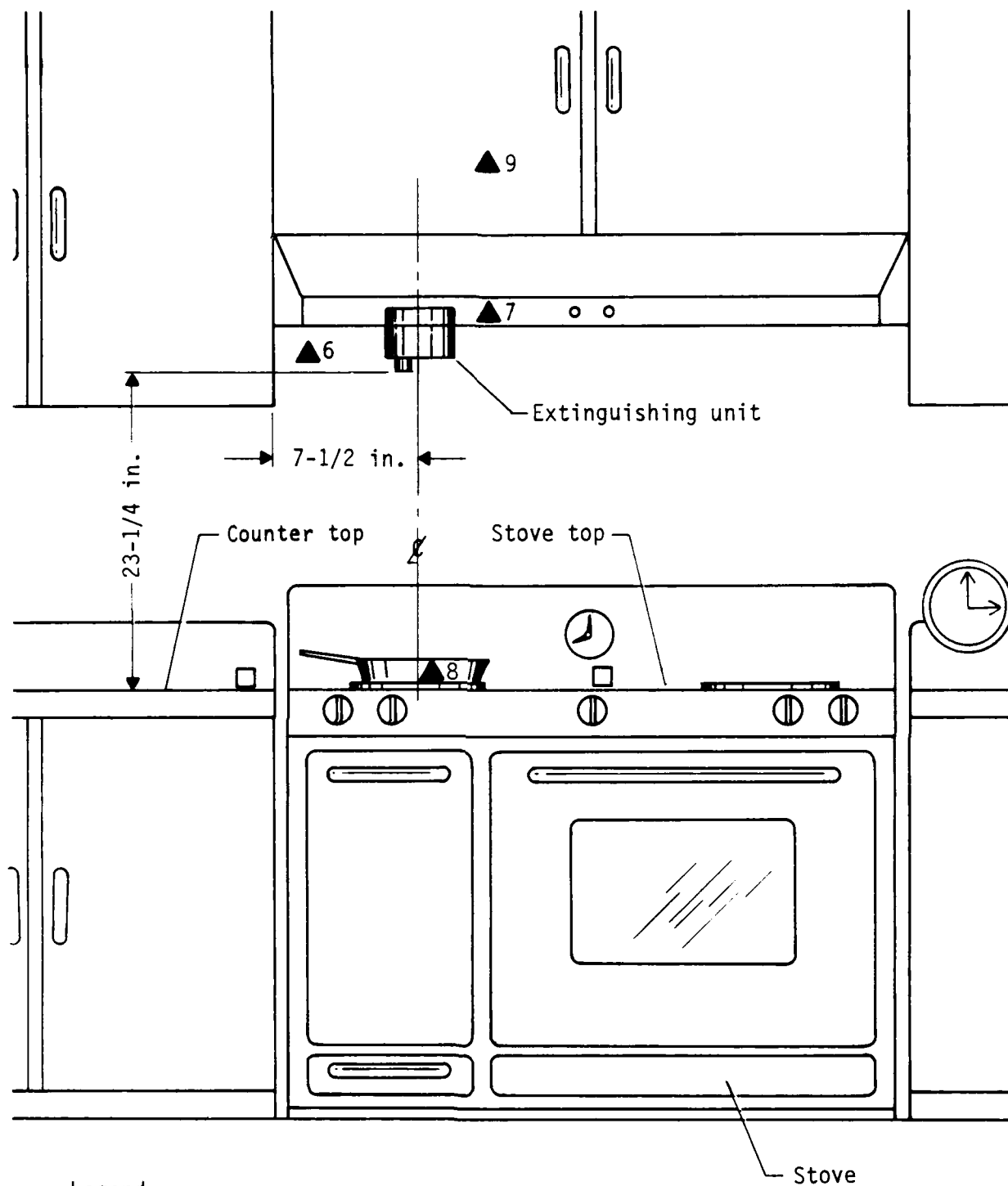


Figure 19. Thermal Performance of Test B-3.



Legend:

- ▲ - Thermocouple
- - Witness cup (3 oz)

Figure 20. Test Platform for Company B Test 4.

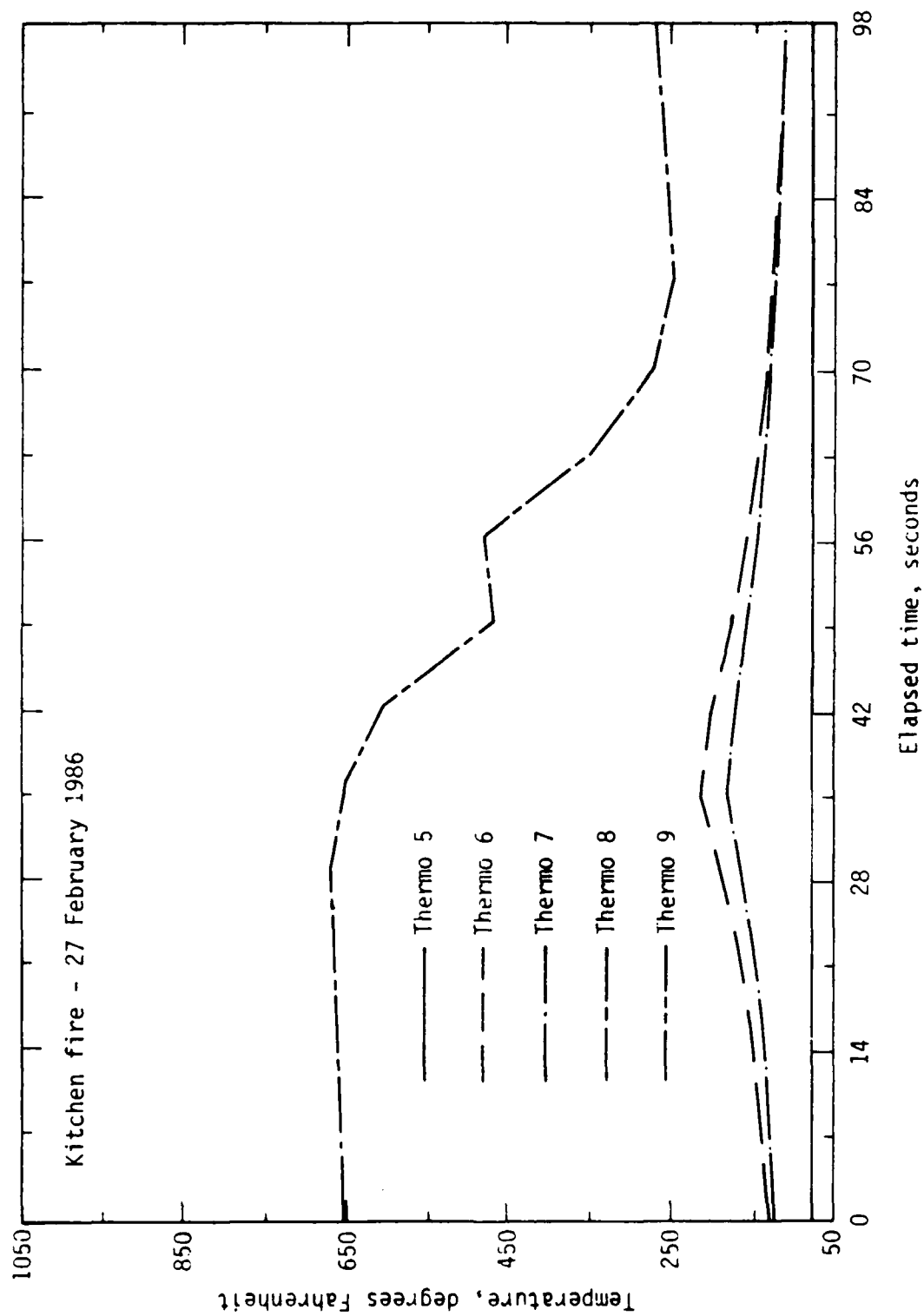
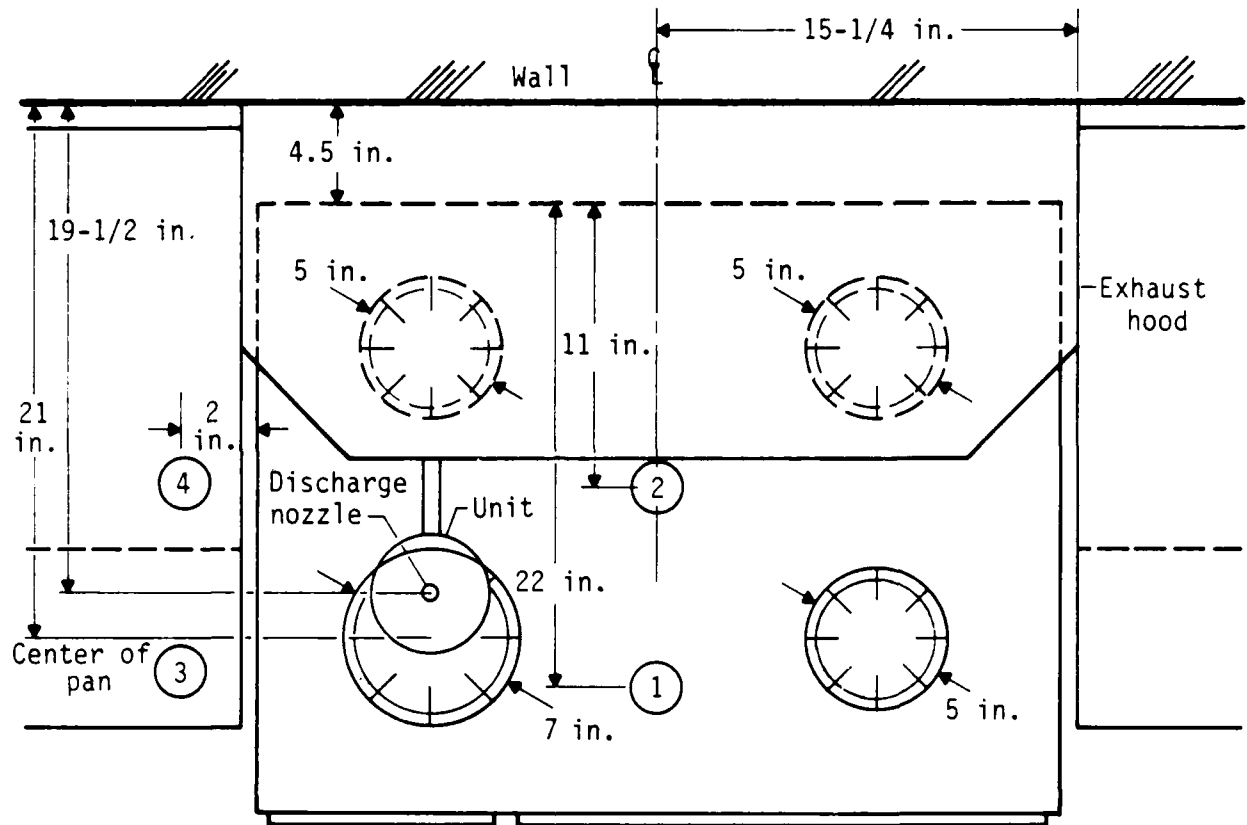


Figure 21. Thermal Performance of Test B-4.



Legend:

① - Witness cup (3 oz)

Figure 22. Plan View Company B Test 4.

M. SUMMARY OF COMPANY B TESTS

These tests indicated a wide variance in system operation. Because only data that would evaluate the system performance were collected, it is not possible to summarize the effectiveness of the total system operation. The system could not reliably detect the presence of flame. This inability appeared to occur due to the placement of the unit in relationship to source of the fire. When effectively applied, the liquid agent will extinguish fires and prevent reignition.

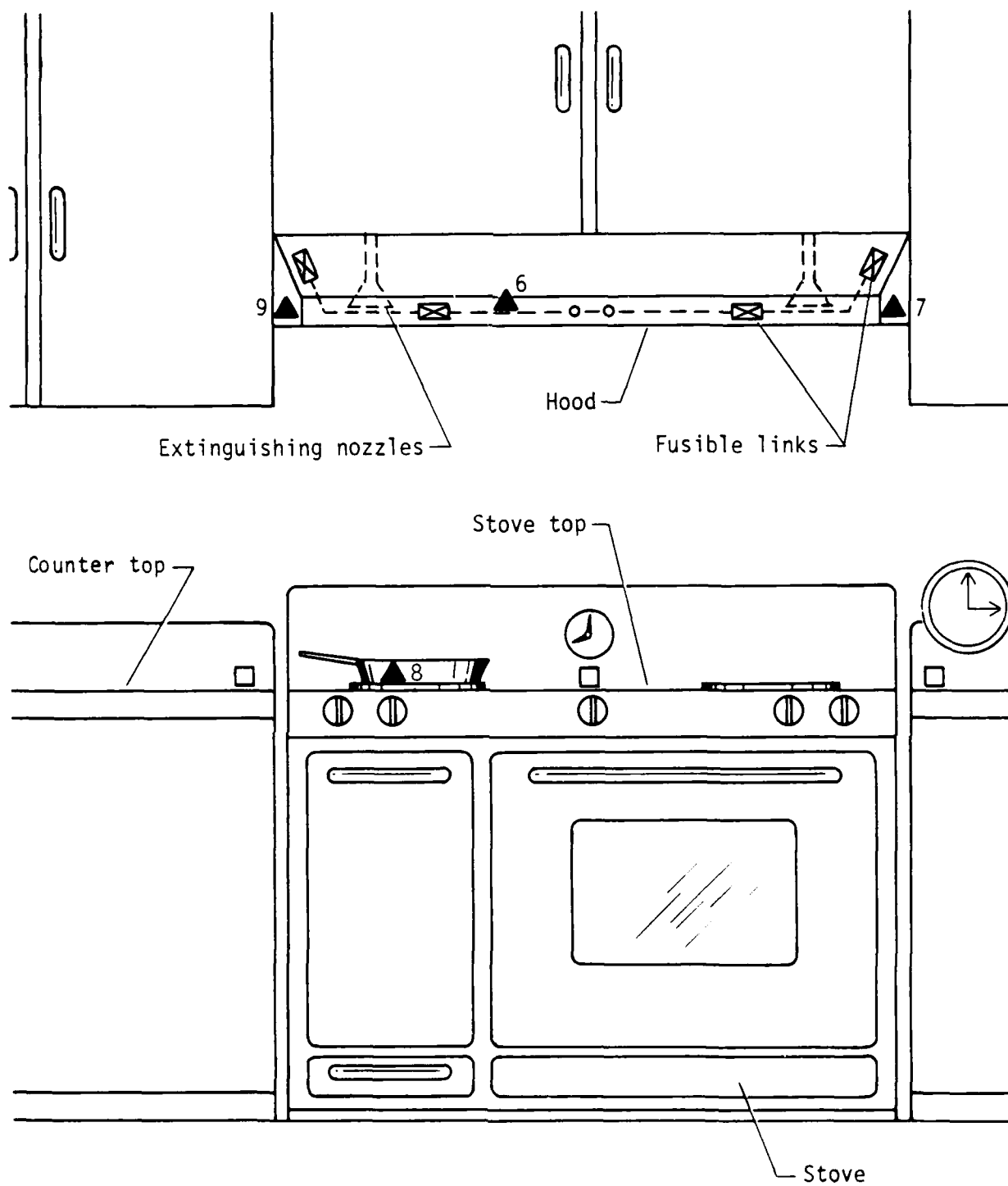
N. COMPANY C GENERAL TEST SETUP

This unit was a scaled-down version of a commercial deep fat/grill extinguisher system. It used a standard 4.5-pound fire extinguisher bottle with 4.5 pounds of dry chemical made by Ansul Corporation. The unit was activated by resettable fusible links. The activation of one of the links released a spring, which allowed agent to discharge through two standard conical nozzles. Installation of the unit required the use of an entire cabinet above the exhaust hood and was sufficiently complicated that a trained person was needed for installation. The system was rechargeable; however, bottle removal and reinstallation probably could not be accomplished by the average homeowner.

O. COMPANY C TEST 1

The test platform for this test is shown in Figures 23 and 24. In this test, the exhaust hood was operating and the frying pan contained vegetable oil. Autoignition occurred at 705 °F. It took 73 seconds from the point of autoignition until the device detected the presence of flame. During the heating and flame processes, the same level of smoke occurred as in previous vegetable oil tests. Upon detection of the flame, it took 1 second for the extinguishing device to activate the discharge of 4 1/2 pounds of dry chemical agent. The agent discharged for approximately 7 seconds. The temperatures reached during this test are shown in Figure 25. The thermocouples were placed in accordance with Figure 23.

The discharged agent blanketed the stove surface, nearby cabinets, and half of the floor area to a uniform depth of approximately 1/8 inch. However, the witness cups (Figure 23) collected no measureable amount of agent. The



- Legend:
- ▲ - Thermocouple
 - - Witness cup (3 oz)

Figure 23. Typical Test Platform for Company C - All Tests.

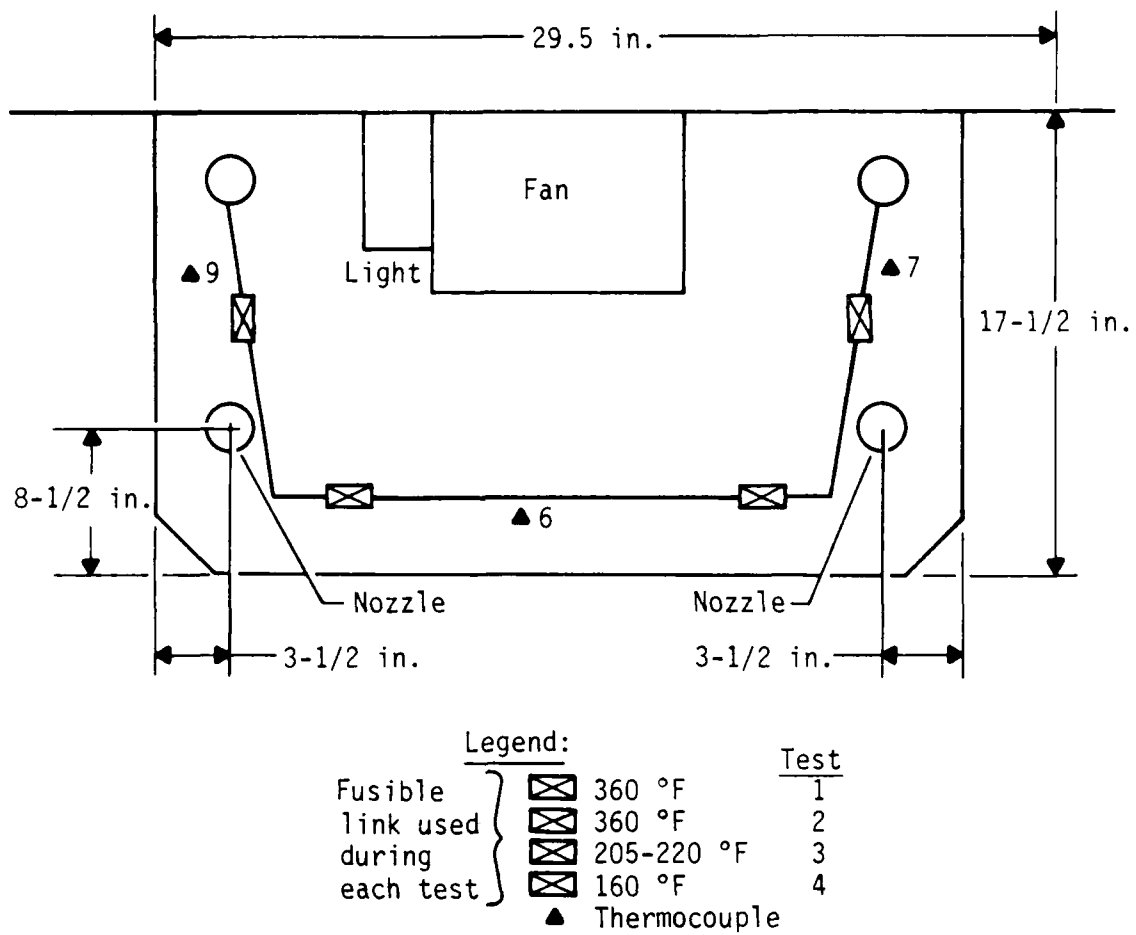


Figure 24. Typical Hood Configuration for Company C Tests 1 through 4.

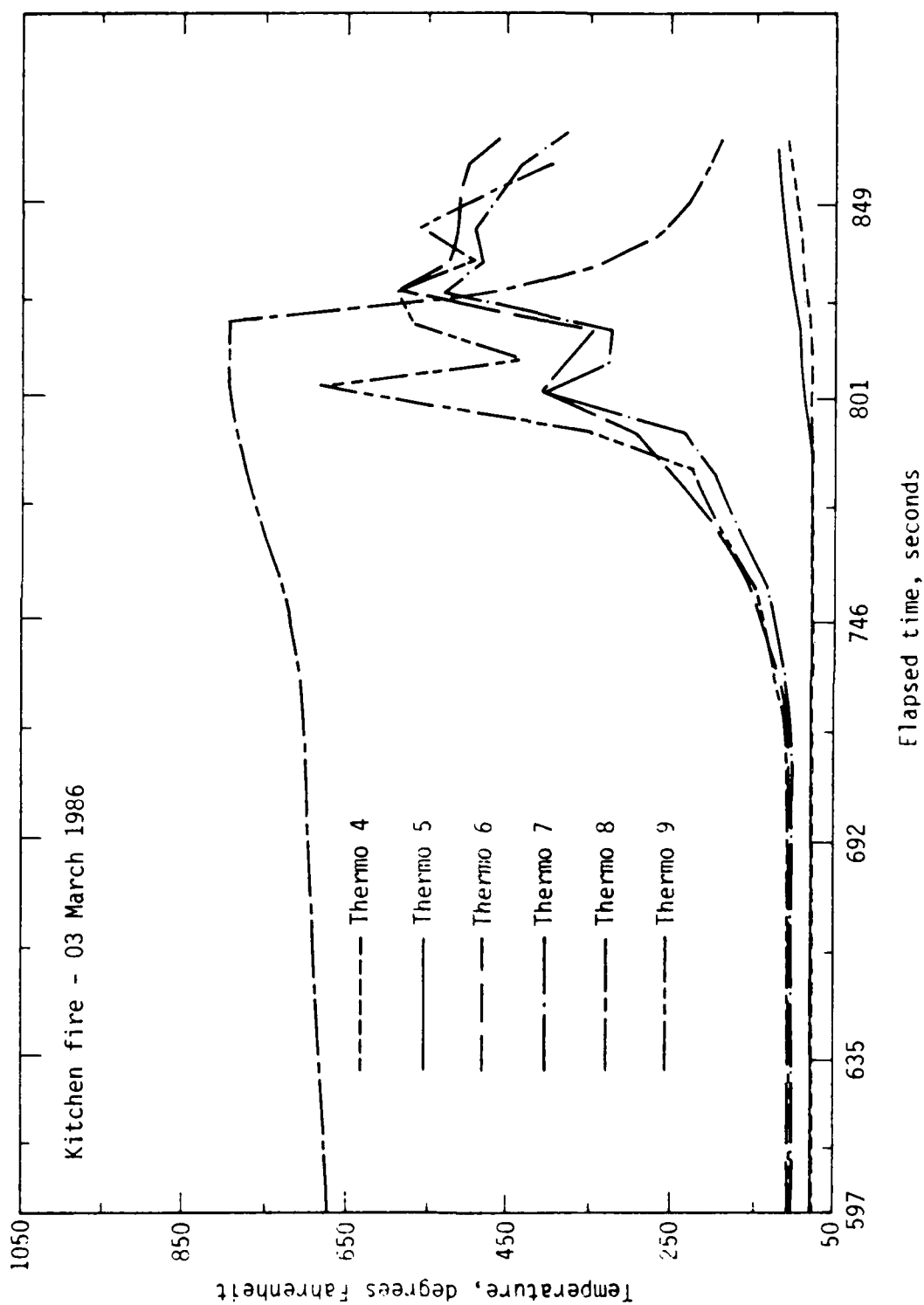


Figure 25. Thermal Performance of Test C-1.

bottoms of the cups contained only a very light trace of material. The discharge stream from the two nozzles was more straight than conical, and as such impacted the stove surface and bounced fine agent particles below the height of the witness cups. Therefore, little agent was collected in the cups even though the surrounding area received a uniform blanket. The amount of agent which reached the pan was sufficient to effectively extinguish the flame, but it could only prevent reignition for 12.5 seconds. The second flame was manually extinguished by test personnel.

During this test, no damage occurred to any part of the test platform except the exhaust hood, which was scorched by flames from the pan.

P. COMPANY C TEST 2

The test platform for this test is shown in Figures 23 and 24. During this test, the exhaust hood was operating and the frying pan contained olive oil. Autoignition occurred at 716 °F. It took 95 seconds from the point of autoignition until the device detected the presence of flame. The smoke concentration during this period was similar to that found in other tests conducted with olive oil. Upon detection of the flame, it took 1 second for the extinguishing device to activate the discharge of 4 1/2 pounds of dry chemical agent. Total agent discharge required approximately 13 seconds. The temperatures reached during this test are shown in Figure 26. The thermocouples were placed in accordance with Figure 23.

The pattern of agent discharge was identical to that in Test 1. Again, only traces of agent were collected in the witness cups. The agent effectively extinguished the flame, but could only prevent reignition for 20.8 seconds. The second flame was manually extinguished by test personnel.

No damage occurred during this test to any part of the test platform.

Q. COMPANY C TEST 3

At the request of the company representative, this test was not performed according to the approved Air Force Test Plan: the manufacturer modified the unit by lowering the activation temperature of the fusible links as shown in Figure 24.

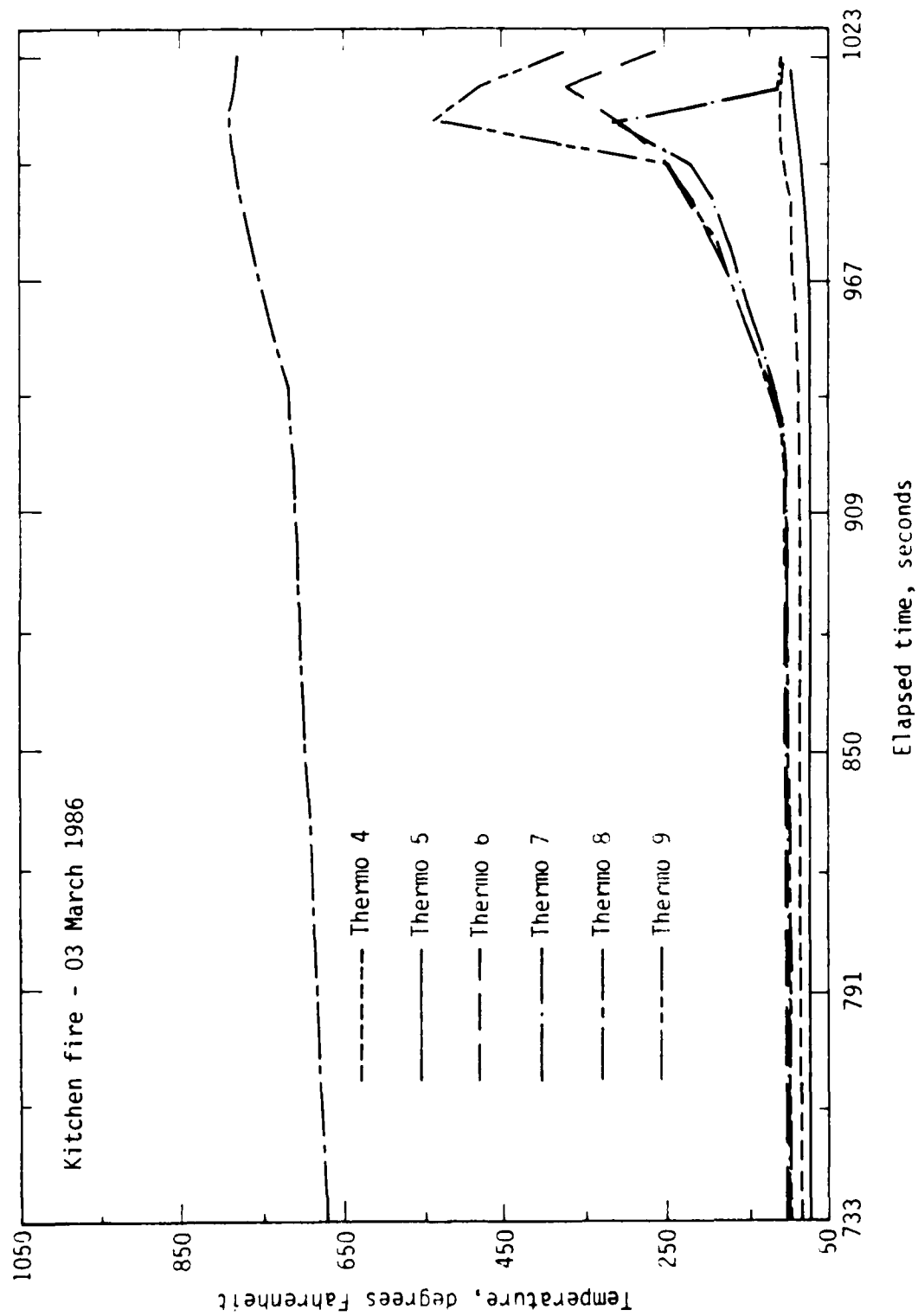


Figure 26. Thermal Performance of Test C-2.

The test platform for this test is shown in Figures 23 and 24. This test was performed with the exhaust hood off to evaluate the effect of hood action on the agent-dispensing pattern. The frying pan contained lard cooking oil. Autoignition occurred at 745 °F. It took 34 seconds from the point of autoignition until the device detected the presence of flame. During the heating and flame processes, the room became densely filled with smoke.

Upon detection of the flame, it took less than 1 second for the extinguishing device to activate the discharge of 4 1/2 pounds of dry chemical agent. The agent discharged for approximately 9 seconds. The temperatures reached during this test are shown in Figure 27. The thermocouples were placed in accordance with Figure 23.

There was no noticeable change in discharge pattern in this test from those found in Tests 1 and 2. The agent extinguished the flame and prevented reignition.

No noticeable damage occurred to any part of the stove surface, exhaust hood, cabinets, or ceiling.

R. COMPANY C TEST 4

At the request of the company representative, this test was not performed in accordance with the approved Air Force Test Plan. A 10-inch diameter aluminum frying pan was used and the fusible link activation temperature was lowered by 44 percent from the those used in Test 1.

The test platform for this test is shown in Figures 23 and 24. During this test, the exhaust hood was not operating and the frying pan contained olive oil. Autoignition occurred at 726 °F. It took 48 seconds from the point of autoignition until the device detected the presence of flame. During the heating and flame processes, the room became densely filled with smoke. Following flame detection, 4.9 seconds were required for the extinguishing device to activate the discharge of 4 1/2 pounds of dry chemical agent. The agent discharged for approximately 9 seconds. The temperatures reached during this test were as shown in Figure 28. The thermocouples were placed in accordance with Figure 23.

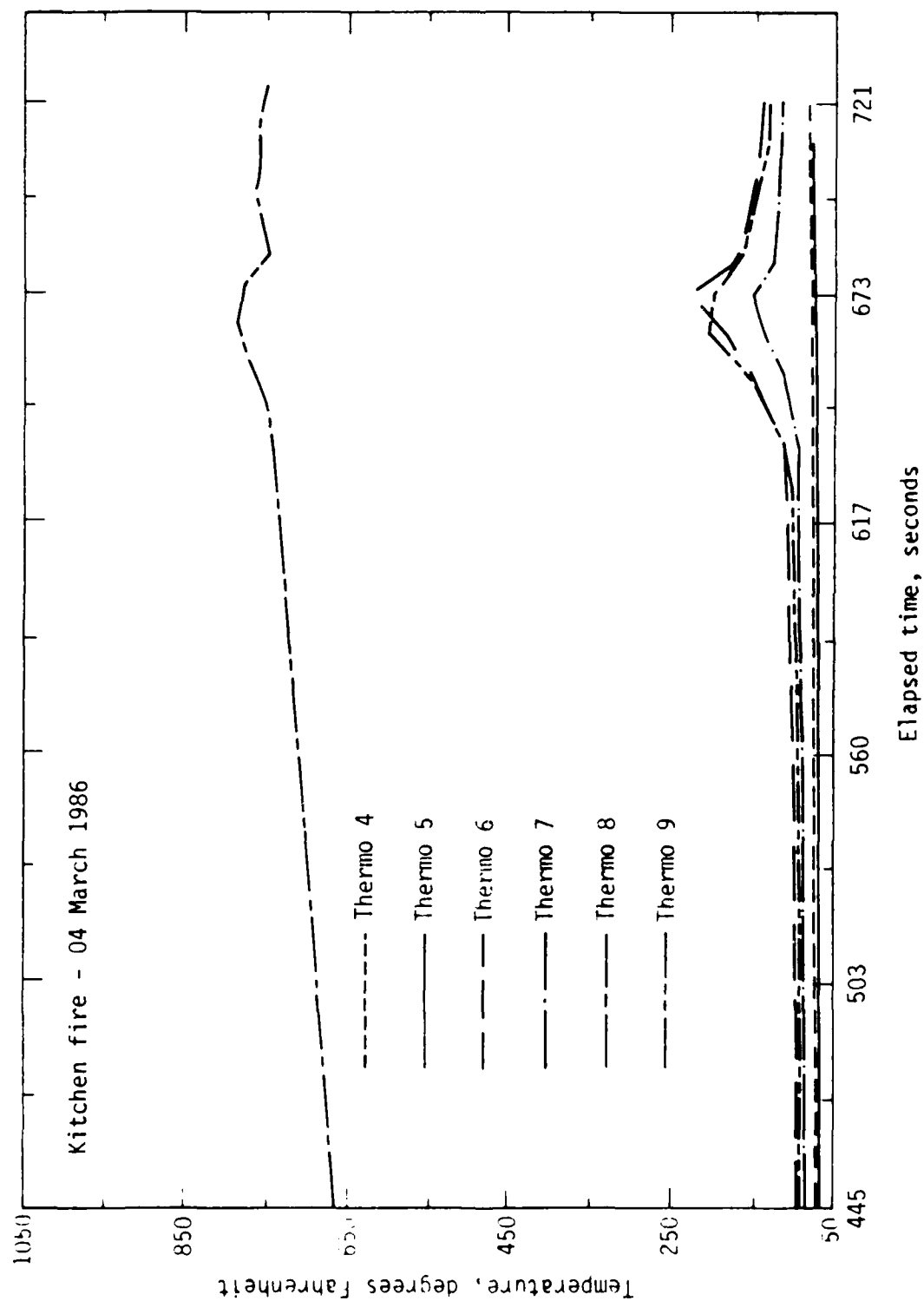


Figure 27. Thermal Performance of Test C-3.

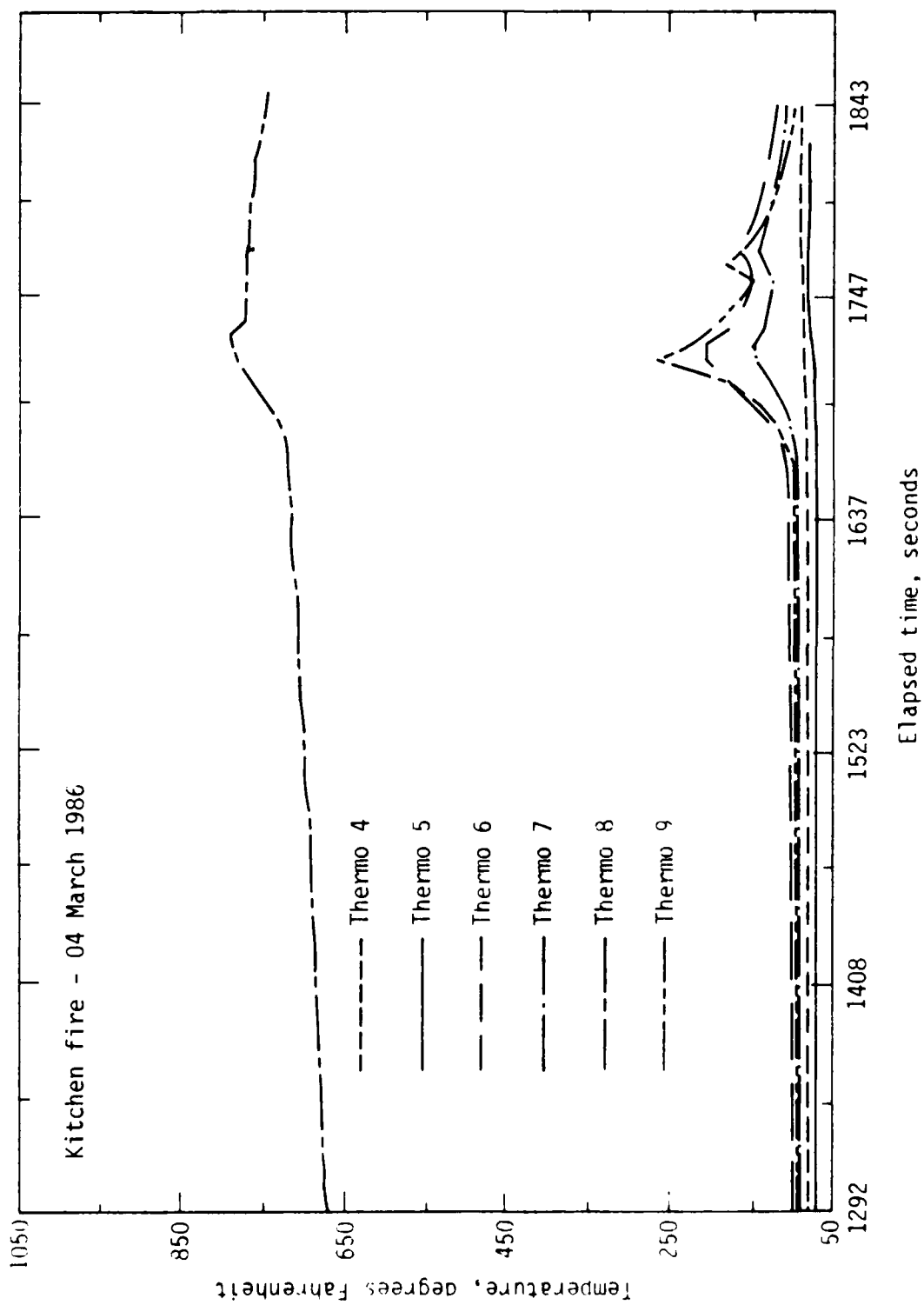


Figure 28. Thermal Performance of Test C-4.

The pattern of discharge was again uniform; approximately 1/8 inch of agent covered the stove and nearby cabinets. Again, no agent was collected. The agent effectively extinguished the flame, but could only prevent reignition for 40 seconds. The second flame was manually extinguished by test personnel.

The only damage to the test platform was scorching of the exhaust hood.

S. SUMMARY OF COMPANY C TESTS

This single test series indicated that scaling down a commercial system probably does not give the same level of reliability present in the larger unit. The quantity of agent used in this series was much greater than that in either of the other test series, but the results were basically the same. The system could only prevent reignition in one of the four tests, and that unit was modified from the original system design submitted. In each test, the cleanup of the area after agent discharge was tedious and time consuming. One highly advantageous aspect of this system is the fact that the unit can be recharged. All system components are reusable.

SECTION IV

SUMMARY OF RESULTS

A. CONCLUSIONS

Three commercially available stove-top fire-extinguishing devices were tested. Two used a dry chemical and one used a liquid product as extinguishing agents.

Twelve tests were conducted to evaluate the three systems (Table 1). In only 2 of these 12 tests did the systems successfully extinguish and prevent reignition. The systems used during these two tests contained modifications not found on the original systems submitted for testing. In only 9 of the 12 tests was the fire detected by the system. The time to detect the fire in these 9 tests ranged from 16 seconds to 95 seconds. The temperature in the frying pan at the time of detection ranged from 700 °F to 796 °F. In 7 of the 9 tests in which the agent was discharged and extinguishment was attained, the fire reignited. The reignition time ranged from 3 seconds to 40 seconds.

The data contained in Table 1 indicate that detection time is critical in extinguishing fires and preventing reignition. In the two tests in which fires were successfully extinguished and held, the detection times were less than 35 seconds after autoignition. With high temperatures resulting from a long-burning fire, the agent cannot encrust the surface of the oil for a long enough time to allow the liquid and pan temperatures to decrease below the autoignition level.

Because of the very limited success in extinguishing and preventing reignition, no attempt was made to determine the length of time that various amounts of each agent would prevent reignition. The minimum reignition time required by UL is 10 minutes.

All systems were tested both with the hood exhaust fan operating and with it shut off, and no noticeable differences could be detected between either operation. The flame characteristics and the temperatures at all thermocouples followed a consistent pattern for all 12 tests.

TABLE 1. TEST RESULTS.

Test event	Type oil	Type pan	Type agent	Amount agent discharge	Exhaust temp. max., °F	Ignition temp., °F	Time to detect, s	Reignition time, s	Maximum pan temp., °F
A-1	Veg	Cast	Dry chem	690 gr	406	711	61	7	791
A-2	Oil	Cast	Dry chem	925 gr	408	689	91	33	788
A-3	Lard	Cast	Dry chem	502 gr	708	734	75	3	796
A-4	Veg	Cast	Dry chem	940 gr	466	715	62	12	788
B-1	Veg	Cast	Liquid	0 oz	N/A ^a	720	^b	N/A	793
B-2	Oil	Cast	Liquid	32 oz	521	709	^b	N/A	778
B-3	Lard	Cast	Liquid	64 oz	1066	702	^b	N/A	799
B-4	Veg	Cast	Liquid	7.5 oz	165	700	16	no	700
C-1	Veg	Cast	Dry chem	4.5 lb	585	705	73	12.5	796
C-2	Oil	Cast	Dry chem	4.5 lb	373	716	95	20.8	789
C-3	Lard	Cast	Dry chem	4.5 lb	229	745	34	no	787
C-4	Veg	Alum	Dry chem	4.5 lb	207	726	48	40.0	792

^aN/A = Not applicable.^bNo detection.

The test method used was intended to realistically recreate actual reported, unattended stove-top fires. The results of these tests indicate a variance in the degree of serviceability and reliability expected from UL certification. These tests were not intended to duplicate, replace, or contest any tests previously conducted by UL. The basic test plan scenario was developed to realistically represent the conditions normally found in MFH, where kitchen range-top fires have occurred with alarming regularity. All units tested have potential but have not been developed and sufficiently tested to ensure the degree of dependability/reliability required for installation and use in MFH.

B. RECOMMENDATIONS

A performance specification should be developed and distributed to industry. The specification should describe an extinguishing system which will prevent or automatically detect, extinguish, and prevent reignition of stove-top fires in MFH. Successful development of a specification can produce a low-cost effective system that will ensure a significant reduction in damages caused by unattended residential stove-top fires.

Because of the limited success shown by the systems tested, it is not recommended that the Air Force install commercially available automatic fire detection/extinguishing systems in residential stove exhaust hoods until system performance can be validated.

REFERENCES

1. **Handbook of Chemistry and Physics**, 51st edition, R. C. Weast, Editor, The Chemical Rubber Co., Cleveland, Ohio, 1970, p. B-121.
2. Dodding, R. A., Simmons, R. F., and Stephens, A., "The Extinction of Methane-Air Diffusion Flames by Sodium Bicarbonate Powders," **Combustion and Flame**, Vol. 15, pp. 313-315, 1970.
3. Birchall, J. D., "On the Mechanism of Flame Inhibition by Alkali Metal Salts," **Combustion and Flame**, Vol. 14, pp. 85-96, 1970.

APPENDIX A

PURCHASE DESCRIPTION FOR

AUTOMATIC KITCHEN RANGE FIRE-EXTINGUISHING DEVICE

1.0 SCOPE

1.1 Scope General

1.1.1 This purchase description covers the details of an automatic, kitchen range, fire extinguishing system, and the components needed for installation.

1.2 Scope System Requirements

1.2.1 System requirements are the following. The device shall:

- a. Be a self-contained agent and detection system.
- b. Dispense agent on each burner equally.
- c. Be mountable within underside of stove exhaust hood.
- d. Be capable of detecting fire at any area of the stove surface.
- e. Be a rechargeable agent system and have resettable detector.

1.3 Scope Design Requirements

1.3.1 System design requirements are the following:

- a. System and components to be designed for a temperature environment of -20 °F to +150 °F.
- b. System and components to be designed for use with standard internal or external kitchen range exhaust hoods.
- c. System and components to be designed for owner/occupant installation.
- d. System and components to be designed so as not to create safety hazard within the kitchen area.
- e. System and components to be designed to all National Fire Protection Association (NFPA) standards for wet or dry chemical agents used to extinguish cooking oil fires.

2.0 APPLICABLE DOCUMENTS

2.1 Government Documents

2.1.1 Specifications and Standards

The following documents, of issue, in effect on the date of invitation for bid or Request for Proposal, form a part of the specification to the extent specified herein:

SPECIFICATIONS

Military MIL-S-901

STANDARDS

MIL-STD-210 Climate Extremes for Military Equipment

MIL-STD-781 Reliability Testing for Engineering Development Qualification and Production

MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-810D Environmental Test Methods

MIL-STD-1472C Human Engineering Design Criteria for Military System, Equipment, and Facilities

MIL-STD-1516A Unified Code for Coatings and Finishes for DOD Material

(Copies of Military Specifications and Standards required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3.0 REQUIREMENTS

3.1 Preproduction Article(s)

The supplier will furnish, within the time period specified, six automatic kitchen range extinguishing devices to demonstrate, prior to starting production, that his production methods and choice of design criteria will produce an extinguishing system which complies with the requirements of this purchase description. Examination and test of components and system shall be those specified herein. Any changes or directions subsequent to the tested preproduction model by the contracting agency shall not relieve the supplier of his contractual obligation to furnish extinguishing systems conforming to the details of this purchase description or the accepted standard of quality provided in the First Article Test.

3.2 Automatic Kitchen Range Fire-Extinguishing System

3.2.1 Automatic Extinguishing Device

Fire-extinguishing device is to detect and extinguish kitchen stove-top fires in military family housing (MFH). The device shall:

3.2.1.1 Be self-contained and designed for installation in the kitchen range hood.

3.2.1.2 Be flame activated.

3.2.1.3 Be designed to automatically blanket the range top with chemical compound to extinguish the fire and prevent reignition for at least 10 minutes with the heat source on.

3.2.1.4 Automatically turn off the electrical power or gas to the range.

3.2.1.5 Be easily installable by homeowner using common hand tools.

3.2.1.6 Be designed so that the agent will not be released unless there is actual flame on the stove surface other than that produced by the gas burner.

3.3 Design and manufacturing

The extinguishing system shall be designed and manufactured to permit ease of installation, inspection, repair, maintenance, and storage. All components of the extinguishing system will be designed to permit easy installation by semiskilled personnel.

3.4 Materials and Construction

For construction, materials for the system and components will be selected on the basis of weight, cold and heat temperature directly, functional service, corrosion-resistance, environmental factors, extinguishing agent compatibility, and service factors. All alloy parts will be provided with corrosion resistant plating protection in accordance with MIL-STD-1516A. Where plating protection is not practical, protective coating of paint will be specified.

3.5 Human Engineering

Human engineering design criteria and principles shall be applied in accordance with MIL-STD-1476C to achieve effective integration of personnel into the design of the system. The human engineering effort shall be provided to develop or improve the system interface during operation installation and maintenance to make effective, economical demand upon personnel resources, skills, training, and cost.

3.6 Durability

The extinguishing device shall perform as required after exposure the following environmental tests.

3.6.1 High Temperature

According to Method 501.2, MIL-STD-801D.

3.6.2 Temperature Shock

According to Method 503.2, MIL-STD 810D.

3.6.3 Humidity

According to Method 507.2, MIL-STD-810D.

3.6.4 Leakage

According to Method 512.2, MIL-STD-810D.

3.6.5 Vibration

According to Method 514.3, MIL-STD-810D.

3.7 Identification and Marking

The Contractor shall provide identification and marking of all items of the extinguishing device in accordance with MIL-STD-130.

3.8 Workmanship

The extinguishing device shall be manufactured according to the specifications and standards contained in this document and to accepted commercial practices.

3.9 Acceptance Test

Each prototype, batch, or other extinguishing device built shall be subjected to an operational acceptance test. The procedure for this test shall be prepared by the contractor and approved by the contracting officer, using current Government criteria, before delivery of production units.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspections

Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier will use a commercial laboratory acceptable to the Government. The Government reserves the right to perform any of the inspections set forth in the specifications where such inspections are needed.

4.2 Classification of Inspection

Preproduction Inspection (see 4.3).
Acceptance Inspection (see 4.6).

4.3 Preproduction Inspection

Six test articles of the extinguishing device shall be examined and tested as specified in paragraph 3. Presence of one or more defects shall be cause for rejection.

4.4 Lot

For inspection purposes, a lot shall consist of all extinguishing devices submitted for inspection at the same time and place.

4.5 Sampling

For acceptance, sampling shall be in accordance with inspection level II of MIL-STD-781, with an Acceptance Quality Level (AQL) of 95 percent.

4.6 Acceptance Inspection

Each extinguishing device shall be examined as specified in 4.6.1 and 4.6.2. The presence of one or more defects shall be cause for rejection.

4.6.1 Examination

Each extinguishing device shall be examined for the following or similar defects:

- Missing parts

- Nonconformance to approved drawings

- Nonspecified materials of construction

- Damaged components or parts

- Noncompliance with purchase description

- Void area of primer, paint, or plating

4.6.2 Operation

Each extinguishing device shall be checked to ensure proper assembly and performance.

4.7 Preproduction Tests

Extinguishing devices shall be tested at the Air Force Engineering and Services Center, Tyndall Air Force Base, Florida, as follows:

4.7.1 Demonstrate capability to detect and suppress kitchen range-top unattended grease fires.

4.7.2 Demonstrate capability to electrically or mechanically shut off the power or gas to the range.

4.7.3 Demonstrate capability of the extinguishing agent to prevent flashback or restarting of the fire after initial extinguishment for a minimum of 10 minutes.

- 4.7.4 Demonstrate simplicity of maintenance while installed.
- 4.7.5 Demonstrate simplicity of maintenance and storage when not installed.
- 4.7.6 Demonstrate capability of the extinguishing device to perform operationally and to extinguish range-top fires as specified above after completion of the environmental tests.

5.0 PREPARATION FOR DELIVERY

5.1 Packaging and Packing

Each extinguishing device will be packaged in individual containers to afford adequate protection against damage during shipment from the supplier to the destination (see 6.2). Containers and packing shall comply with uniform freight classification for National Motor Freight Classification.

5.2 Marking

In addition to any other marking required by the order of contract (see 6.2), the interior package and exterior shipping container shall be marked in accordance with MIL-STD-129, as applicable.

6.0 NOTES

6.1 Intended Use

The self-contained automatic extinguishing device will be located/installed in the range exhaust hood, near the ignition source, so the range-top fires are sensed quickly and suppressed.

6.2 Contract Data Requirements

Any data item to be delivered under contract for items should be specifically called for in the contract in accordance with the applicable regulation of the procuring activity using Form DD 1423.

APPENDIX B

TEST PLAN FOR AUTOMATIC KITCHEN
RANGE FIRE EXTINGUISHER

(This test plan is printed in its original format, as prepared.)

1.0 INTRODUCTION

1.1 Objective

A series of tests will be conducted at Tyndall AFB to determine effectiveness of an extinguishing device to detect and extinguish cooking oil fires in kitchens. The device will be tested with a gas and electric range. The tests will be conducted in Building 21 (hardened fire test facility).

1.2 Background

The Air Force is evaluating a new concept in fire protection. This concept is an automatic, independent fire extinguisher. The purpose of this concept is to prevent large-scale damage to military family housing (MFH) kitchens and associated areas. The self-contained device will be located in the range hood, near the ignition source, so that range-top fires are sensed quickly and suppressed. Therefore, minimal heat and smoke is generated that can damage the kitchen and surrounding areas. The device also generates an audible signal to warn occupants who may be present and a signal that will electrically or manually actuate the gas/electric shutoff valve to the range and range hood. These extinguisher devices that will be tested have desirable features for suppressing cooking oil fires where major losses should be avoided.

1.3 Scope

A series of tests will be conducted to determine the suppressive abilities of the extinguishing agent on kitchen range fires. The first series of tests will use an electric kitchen range with an internal hood. The second series of tests will use a gas range with external exhaust hood.

2.0 DESCRIPTION OF TESTS

2.1 Test Specimens

The units are automatic extinguishing systems designed for installation in or near the kitchen range hood to extinguish and control range-top fires. The systems are flame actuated, using a precious metal sensor link/wire, which ignites/melts and disintegrates when touched by flame. When the system activates, it automatically blankets the range top with a dry chemical compound, which will extinguish the fire and automatically turn off the power (gas) to the range and the power to the exhaust fan located in the range hood.

2.2 Test Facility

The device will be tested at Tyndall Air Force Base, Florida. Electric and gas ranges will be used for the testing. Internal exhaust hoods will be used during the tests. The device will be tested using six different applications for each range tested. (See paragraph 2.6 for details.)

2.3 Instrumentation and Photographing

Each test will have still and video photographic coverage. Thermocouples will be used to monitor and record temperatures at various locations during testing. (See paragraph 2.6 for details.) Agent dispensing and concentration patterns will also be monitored. The data recorder will be set at zero when the cooking oil/fuel source is ignited. The photo coverage will be normal speed VCR. The photography will be synchronized with the other data collection. Still photography will be required in the form of color slides and black and white negatives to document the pretest setup and posttest damage to the range and surrounding area.

2.4 Test Preparation

Preparation for the individual test series will proceed as follows:

- a. Install the extinguishing device.
- b. Install thermocouple gages and agent concentration monitor.
Hook up gages and test for functioning.
- c. Position cameras.
- d. Take pretest still photographs.
- e. Place cooking oil into appropriate pan for test.
- f. Position pan on selected burner.
- g. Evacuate nonessential personnel.
- h. Conduct final check of cameras and instrumentation.
- i. Apply power/gas to the range burner; allow the heat from the burner to ignite the cooking oil contained in the pan located on the burner.
- j. Ensure that the power/gas is automatically or manually disconnected to the range and that the fire is extinguished.

2.5 Posttest Procedures

Immediately following each test event, the following actions shall be taken:

- a. Evacuate smoke from inside the test area.
- b. Take still photographs of damage in undisturbed situation.
- c. Check instrumentation readings.

2.6 Testing

2.6.1 Test No. 1

In the first test, the extinguishing device will be securely mounted to the range hood. A cooking container partly filled (predetermined line) with cooking oil will be placed on the right front burner of the range, and a maximum heat setting will be selected on the burner control. This will cause the cooking oil to overheat, smoke, and eventually burst into flames. Once the heat and smoke are detected, the detector will sound an alarm and dispense the extinguishing agent. Eight Type K thermocouples connected to the Air Force instrumentation system will be used to record the temperatures at selected points. The thermocouples will be labeled 00 to 07. (See instrumentation plan for thermocouple locations.) Thermocouple 00 will be placed 2 inches to the side of the burner. Thermocouple 02 will be placed 6 inches directly above

the cooking container. Thermocouple 03 will be placed 12 inches above 02. Thermocouple 04 will be placed at the bottom center of the range hood. Thermocouple 05 will be placed in line with 04 and 12 inches to the right. Thermocouple 06 will be placed in line with 04 and 12 inches to the left. Thermocouple 07 will be at the detector.

2.6.2 Procedures for Remaining Tests

In the next five tests, the same setup procedure will be used for the thermocouple placement, video equipment placement, and instrumentation. The burner selection and the amount and type of cooking oils will be different than test No. 1. The source for the smoke and flame will be a type of cooking oil in all of the tests.

2.6.3 Chemical concentration samples will be taken from:

- a. The stove.
- b. One foot away from stove front.
- c. Three feet away from stove on kitchen cabinet top.

3.0 RESPONSIBILITIES

The overall responsibility for the entire test program rests with the Test Director. In addition, the Test Director will be responsible for performance of the test event's countdown coordination and procedures, and any extraordinary safety and security precautions during test days. The Test Director will delegate authority as necessary. Specific responsibilities relative to safety and instrumentation are contained in the Attachment 1 and Appendix C.

ATTACHMENT 1

SAFETY PLAN

1.0 PURPOSE

This safety plan establishes the safety areas for the testing site and a related functions thereto, to be conducted at Tyndall Air Force Base, Florida, and identifies the agency responsible for each of these areas. All references to the test throughout this safety plan will pertain to the tests to be conducted at Tyndall Air Force Base, Florida. The detailed safety rules which are applicable to this project are documented herein. Before any fire testing can be conducted at Tyndall Air Force Base, Florida, the Base Fire Chief must be notified. The following safety documents are applicable to this test:

AFOSH Standards
AFR 127-4

2.0 OVERALL SAFETY RESPONSIBILITY

HQ AFESC/RDCF, as Test Director, is responsible for enforcing the overall safety program for the test. The Base Fire Chief or a designated representative will act as the safety officer during all actual fire tests. The Test Director is the safety officer for all other events at the test site. The Test Director will maintain close coordination with the Air Defense Weapons Center Ground Safety Officer on all safety matters.

3.0 SAFETY AREAS

The safety requirements of the test have been divided into three separate and distinct areas to facilitate the establishment of specific requirements for the different areas of operation. The areas of safety requirements are divided into three areas as follows:

- a. General Safety
- b. Construction Safety
- c. Fire Safety

4.0 GENERAL SAFETY

The responsibility for general site safety resides with AFESC. The authority to execute specific safety directives is delegated to the Test Director. The Public Affairs Office (HQ AFESC/PA) is responsible for notification and publicizing the test (when applicable).

a. Safety Briefing. The Test Director will brief all AFESC personnel and/or supervisors of construction crews on the safety hazards existing within the test site. Supervisors will, in turn, brief their personnel on these hazards.

b. Visitors. Visitors shall not be allowed at the test site without approval of the Test Director or authorized delegates of the Director. Visitors will be instructed on applicable safety regulations.

c. Individual Safety Responsibility. Careful attention to potential hazards involved in work dealing with fire must be stressed in all levels of responsibility. The purpose of the safety rules outlined herein is to present the most important elements in setting controlled fires. These rules do not cover all the possible hazards or safety precautions necessary at the site. As new problems arise, new safety measures will be established to cope with them. In the interim, common sense must be applied to ensure that safety prevails. This entire safety plan must be closely followed by all personnel and enforced by all supervisors. The procedures contained herein shall be accepted as minimum standards until such time as the Test Director, with the concurrence of the AFESC Safety Officer, authorizes deviation therefrom.

d. Vehicles. Speeds shall not exceed 20 mph when driving on unpaved roads. Seat belts will be used at all times while vehicles are in motion. When a vehicle is parked, the hand brake will be set and the transmission put in park or reverse.

e. Accident Reporting (Emergency)

(1) Scope. This standard procedure is intended as a guide to ensure expedient handling and care of personnel injured in an accident or disaster. All postemergency reporting and investigation of an accident will be performed in accordance with applicable Air Force regulations and are not considered to be within the scope of this standard procedures.

(2) Responsibility. Every person involved in this program must be completely familiar with the emergency reporting procedures established by this plan and must implement these procedures immediately in the event of an accident. The Test Director must familiarize all supervisors with this standard procedure. The supervisor must familiarize subordinate personnel with the procedures established by this plan.

(3) Emergency Reporting Procedures. In the event of an accident at the test site, the following procedures will be followed:

(a) The senior supervisor at the scene of an accident direct appropriate first aid. Caution will be exercised to prevent aggravation of an accident-related injury.

(b) Tyndall AFB Hospital Ambulance Service will be immediately notified by calling Extension 2333. The nature of the accident, including apparent condition of injured personnel and the location of the test site, will be reported to the medical personnel. The Test Director (or if absent, the Senior Supervisor) shall determine whether to attempt transfer of the injured to a hospital or to request emergency ambulance support.

(c) The Test Director (or if absent, the Senior Supervisor) shall determine the seriousness of the accident. If the accident is not serious enough to require emergency hospitalization or ambulance service, the injured person will be taken to a doctor or hospital by normal means of transportation.

(d) First Aid. An adequate supply of first aid items will be maintained at the site. These items will be properly stored and periodically inspected to ensure their availability in case of an emergency.

(e) Fire Prevention Reporting and Emergency Procedures. This paragraph defines the responsibility for fire prevention and reporting procedures related to the test.

1. Responsibility. The Test Director will be responsible for the implementation of the procedures established by this plan. All onsite personnel must be completely familiar with these procedures to ensure proper response to an emergency.

2. Fire Prevention Procedures. The procedures listed below are to be followed in an effort to reduce chances of an uncontrolled fire.

- a. Three portable fire extinguishers will be at the test site.
- b. The Test Director shall instruct all personnel on the procedures to follow in case of fire, and the location and use of the available fire extinguishers.

APPENDIX C

UNDERWRITERS LABORATORIES OUTLINE OF PROPOSED INVESTIGATION FOR EXTINGUISHING SYSTEM UNITS FOR RESIDENTIAL RANGE-TOP COOKING SURFACES

The following tentative requirements will be employed by Underwriters Laboratories Inc. (UL) as a guide in the investigation of a product of this type. However, it should be understood that these requirements are not to be considered complete or final in the determination of either UL's judgment or the manufacturer's development of his product. Additional tests or requirements may be necessary if features of construction or use are present which have not been anticipated by these requirements. Certain tests included in these requirements may be omitted on the basis of previous recognition for particular materials.

This appendix is printed as submitted by Underwriters Laboratories.

GENERAL

1.0 SCOPE

1.1 Extinguishing system units for residential range-top cooking surfaces are intended for installation in single family dwellings, mobile homes, and apartment units when installed in accordance with the manufacturer's installation instructions.

PERFORMANCE REQUIREMENTS

2.0 FIRE TESTS

2.1 The test setup shall consist of a four-burner gas cooking surface unit having outside dimensions of approximately 21 by 30 inches, or 21 by 36 inches. A ventless range hood shall be located either 20 or 30 inches above the cooking surface, centered over it. The extinguisher unit shall be mounted, after conditioning, on the underside of the hood. The sensor shall be coated with used grease. The nozzles shall be aimed in accordance with the manufacturer's instructions.

2.2 Extinguisher units, charged with their exact rated capacity, shall be used.

2.3 Each test shall begin by installing the extinguisher unit, placing the test vessel on the cooking surface, adding fuel, securing the thermocouples, and lighting the burner. The flame height shall be adjusted so that the underside of the vessel is completely covered by flames, or the burner on full. To evaluate the hold-out characteristics of the extinguishment, the test shall be continued until at least 10 minutes after extinguishment has been achieved. Observations shall be made during the test for the times of actuation and extinguishment, using autoignition as time zero. Observations shall be made to determine that the test burners remain lit or automatically relit by the pilot after the discharge and that no reignition of the test fuel occurs.

2.4 Some of the tests shall be conducted using units previously conditioned at 32 °F. In these tests, the unit shall also be examined for maximum discharge range. Units shall be located at the maximum height under the minimum temperature conditions. In some tests, the unit shall be examined for splash characteristics with the unit being located at the minimum height under maximum temperature conditions. Various size vessels and fuels shall be used.

2.5 Tests shall be conducted both with and without the blower in the range hood operating. Observations shall be made of the influence of the blower operation on the discharge characteristics of the extinguisher.

2.6 Tests shall be conducted both with and without the blower in the range hood operating. Observations shall be made of the influence of the blower operation on the discharge characteristics of the extinguisher.

3.0 DISCHARGE TEST

3.1 Extinguisher units shall be conditioned at 32, 70, and 120 °F. The units fitted with pressure gages shall be operated by exposing the sensor to flame. Bags shall be laid over the nozzles to collect the dry chemical discharged. Observations shall be made for maximum pressure developed and amounts of extinguishent discharged.

3.2 The results of this test shall be used in determining conditions for comparison purposes with results of other tests.

4.0 TEMPERATURE CYCLING TEST

4.1 Two extinguishers shall be conditioned at 32 °F for 24 hours at 120 °F for 24 hours, at 32 °F for 24 hours, and then at 70 °F for 24 hours. After this conditioning, they shall be discharged. The amount of discharge shall be compared to the amount of extinguishent in the units and to the amount discharged by unconditioned units.

5.0 ACCELERATED AIR-OVEN AGING TESTS

5.1 Empty samples of the extinguisher are to be air-oven aged for 17 days at 121 °C (250 °F) and 75 days at 100 °C (212 °F). After the aging periods, the samples are to be examined for cracking, pitting, deformation, and other signs of deterioration. One-inch wide rings are to be cut from unaged and aged samples and subjected to a crush test. A crosshead speed of 0.5 in./min shall be used on the Instron testing machine.

5.2 The housing shall show no signs of cracking, pitting, deformation or other signs of deterioration.

6.0 ULTRAVIOLET LIGHT AND WATER EXPOSURE TESTS

6.1 Half-sections of the extinguisher are to be exposed to ultraviolet light from two single enclosed carbon arc lamps, using the apparatus described below. Water shall be automatically sprayed into the specimens at predetermined intervals.

6.2 The arc shall be formed between one upper electrode and two lower vertical electrodes held in a solenoid-actuated speed mechanism. All electrodes shall be of carbon, 1/2-inch diameter, the upper electrode being of the solid type and the lower electrodes being of the neutral-core type, or vice versa. The potential across the arc shall be 120 to 145 VAC and the operating current shall be 15 to 17 A. The arc shall be enclosed by a clear globe of Pyrex No. 9200PX glass.

6.3 Water at room temperature and about 12 lb/in.²g shall be sprayed horizontal onto the samples through an assembly of nozzles, the flow of

water and duration of spraying being controlled by a solenoid valve operating in conjunction with the motor driven timer. A chamber having partially recirculated mechanical ventilation and temperature control shall surround the arc, the revolving cylinder in which the test samples are mounted, and the water spray nozzles. The temperature of the test samples shall be measured by a black panel assembly consisting of a dial-type thermometer with the sensing element fastened to a sheet of stainless steel, both the sheet and the thermal metal element being coated with black enamel. This black panel shall be mounted on the interior of the revolving drum, at the same distance from the arc as the test samples.

6.4 During each operating cycle of the apparatus (120 minutes), each specimen shall be exposed to ultraviolet light from the carbon arc for 120 minutes, and to ultraviolet light and water for 18 minutes. The test shall be continued until the samples are exposed to ultraviolet light for a total of 612 hours, and the ultraviolet light and water for a total of 108 hours. The temperature within the apparatus, as measured by the black panel assembly, shall be of the order of 60 °C (140 °F).

6.5 The samples shall show no cracking, crazing, distortion, or other signs of deterioration as a result of the exposure to ultraviolet light and water.

7.0 IDENTIFICATION TESTS

7.1 Samples of the extinguisher shall be subjected to specific gravity and infrared analysis tests for identification purposes.

8.0 HYDROSTATIC PRESSURE TEST

8.1 Sample extinguishers, less piston actuator plate and nozzles, if used, shall be fitted with an adapter, filled with water, and connected to a source of hydrostatic pressure in a manner which shall exclude all air from the enclosed volume. The pressure shall gradually be increased at rate of approximately 300 lb/in.²/min until failure occurs. Note shall be made of the burst pressure and location of failure. It is required that the samples be able to withstand a minimum of four times the average working pressure without rupture, based on the units being of the complete discharge type. Fifteen samples shall be tested.

9.0 ONE-YEAR LEAKAGE TEST

9.1 Twelve samples of pressure holding container, such as CO₂ cartridges, shall be weighted to the nearest 0.1 and stored at room temperature. Weight checks shall be made after 1, 3, 6, and 12 months. Any loss in weight shall be noted as evidence of leakage. The extinguishers shall show no sign of leakage.

10.0 VIBRATION TEST

10.1 The extinguisher shall be mounted as described in the manufacturer's installation instructions and subjected to vibration as described in the following table.

Frequency of vibration, Hz	Displacement, inch	Amplitude
10-19	0.060 + 0.006	0.030 + 0.003
20-39	0.040 + 0.004	0.020 + 0.002
40-60	0.020 + 0.002	0.010 + 0.001

10.2 The test specimen shall be subjected to tests in each of the three rectilinear planes--horizontal, lateral, and vertical. The specimen shall be vibrated from 10 to 60 Hz in discrete frequency intervals of 2 Hz at the displacement indicated. The vibration at each frequency shall be maintained for 5 minutes. The sample shall then be vibrated for 2 hours at the frequency which produced maximum resonance. If no resonance is found, 60 Hz shall be used.

10.3 Observations shall be made for failure of any of the components.

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