GE-MTSD-R-061

PYROTECHNIC HAZARDS CLASSIFICATION AND EVALUATION PROGRAM TEST REPORT HEAT FLUX STUDY OF DEFLAGRATING PYROTECHNIC MUNITIONS

APRIL 16, 1971

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PYROTECHNIC HAZARDS CLASSIFICATION AND EVALUATION PROGRAM TEST REPORT HEAT FLUX STUDY OF DEFLAGRATING PYROTECHNIC MUNITIONS

Details of illustrations in this document may be better studied on microfiche

APRIL 16, 1971

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ABSTRACT

The heat flux studies described in this report were performed under a National Aeronautics and Space Administration Contract NAS8-23524, Modification 8, Item No. 8. Three tests had been authorized to investigate whether heat flux measurements may be used as effective hazards evaluation criteria to determine safe quantity distances for pyrotechnics. A "Passive Sensor Study" was conducted simultaneously to investigate their usefulness recording certain events and conditions, e. g., heat attenuation, temperature ranges in the vicinity of a deflagrating pyrotechnic stack, etc.

The tests have shown that heat flux measurements can effectively be used to evaluate hazards criteria and that passive sensors are an inexpensive tool to record certain events in the vicinity of deflagrating pyrotechnic stacks.

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INTRODUCTION

1.1 OBJECTIVES

The objectives of the heat flux study of pyrotechnic munitions are as follows:

a. To measure the heat flux incident at discrete distances from a deflagrating pyrotechnic stack.

b. To determine whether heat flux is significantly affected by wind direction and velocity.

c. To investigate whether heat flux measurements may be used as effective hazards evaluation criteria to determine safe quantity distances for pyrotechnics.

1.2 AUTHORITY

Three tests were authorized for this study under a National Aeronautics and Space Administration Contract NAS8-23524, Modification No. 8, Item No. 8, dated 22 February 1971.

1.3 TEST RATIONALE

The Department of Defense's (DOD) Quantity-Distance Tables regulate the placement of manufacturing facilities and storage areas for ammunition and pyrotechnics relative to inhabited structures, adjacent ammunition manufacturing and/or storage areas, roads, etc. These tables have been established in accordance with the hazards classifications for the materials and end items to be manufactured or stored.

The majority of pyrotechnics have been classified as Class 2 materials (deflagration only). The Quantity-Distance Tables for this class are based mainly on estimates and comparisons to other more hazardous materials for which data on overpressure, fragmentation, etc. have been collected during test detonations. Since the prime source for major damages from pyrotechnics is fire, it has been proposed to measure the heat flux incident on materials at discrete distances from a burning pyrotechnic stack.

There are basically three types of heat transfer between volume elements that are at different temperatures: Heat conduction, heat convection, and radiation.

Heat conduction is the transport of energy (heat) between two neighboring volume elements that are separated by an infinitesimal slab of material.

Heat convection is the transport of energy (heat) by a current of liquid or gas. If the motion of the fluid is caused by a difference in density that accompanies a temperature difference, the phenomenon is called natural convection. If the motion is caused by an external force, e.g., a pump or a fan, it is called forced convection.

Radiation is the transport of energy (heat) by the infrared portion of the magnetic spectrum.

The amount of energy (heat) that is flowing between volume elements of different temperatures is called heat flux and is measured in calories per unit area per unit time $\frac{cal}{cm^2 . s}$. If applied to pyrotechnics, the above volume elements are stacks of pyrotechnic materials or end items, buildings, magazines, etc.

Since the purpose of this study is to determine the heat flux incident from a stack of burning pyrotechnic end items at discrete distances, it is apparent that heat transfer is by heat convection and radiation. Heat conduction may occur within the burning stack, but only if the containers are closely stacked (touching each other).

The criterion to correctly determine safe distances is a function of the maximum temperatures a stack of pyrotechnic materials or end items can assume during a maximum deflagration accident and the minimum ignition temperature of an adjacent building, pyrotechnic stack, or other flammable materials. The induced temperature at the reception is a function of the heat flux incident on the material, the absorptivity of the surface, and the thermal conductivity of the packaging/container.

For sympathetic ignition, the only requirement is that somewhere and sometime in a pyrotechnic, the temperature must equal or exceed its characteristic minimum ignition temperature.

Heat flux by radiation can be affected by varying the size of a stack, the type of pyrotechnic material, and the interstack distance. Fog, rain, and smoke, as well as the insertion of a heat shield, will have an attenuating effect.

The above is also true for heat flux by convection. However, consideration must be given to many additional environmental and physical variables; e.g., air temperature, wind velocity, humidity, temperature inversion, ground condition, etc.. It is apparent that a detailed investigation of the individual effect of each of these variables on convective heat flux is too great a task to be performed within this study. However, the three tests to be performed for this study have been designed to investigate:

- Whether it is feasible to use heat flux sensors to determine safe quantity distances for class 2 pyrotechnic munitions, and,
- Whether the above-mentioned environmental variables combined have a significant influence on heat flux.

Since materials and sensors were available, it was decided to perform a second test series simultaneously with the tests for the heat flux study. This study series, called the "Passive Sensor Study", is discussed in Section 3 of this report.

SECTION 2

HEAT FLUX TEST PERFORMANCE AND RESULTS

2.1 TECHNICAL APPROACH

Four Model 860 Heat-Flow meter systems, manufactured by Keithly Instruments, Inc., were used to measure heat flux at discrete distances from burning pyrotechnic stacks. The Model 860 consists of a heat-flow sensor mated with a microvolt meter calibrated to read Btu/ft$^2 \cdot$ h directly. The meter has a range from 0.5 to 10,000 btu/ft$^2 \cdot$ h in seven steps with an accuracy of $\pm$ 10 percent of full scale and a resolution of approximately $\pm$ 1 percent of full scale.

The heat flow sensors are represented electrically and schematically as a multi-junction thermopile (shown in Figure 2-1). The electrical output (E_o) from the thermopile generated by the temperature difference across a thin insulating film of known thermal conductivity is a measure of heat flow through the sensor. In order to prevent an appreciable temperature build-up on the mounting surface, the sensors were applied to heat sinks. Two of four assemblies fabricated in this manner were mounted in cardboard shields to minimize the effect of convective heat flux. They will be referred to as "shielded sensors" throughout this report. A thermocouple was attached to at least one heat sink in each test to determine the magnitude of a possible temperature rise in the heat sink.

Heat flow sensors were also mounted on pieces of lumber together with thermocouples. This made it possible to measure the total heat flux incident (convective and radiant heat combined) on the lumber and simultaneously determine the actual temperature rise at this location. However, since the sensor measures temperature differentials, any temperature change of the mounting surface will affect its output; in other words, an increase in surface temperature at the same heat flux incident will be recorded as a decrease in heat flux.

Since only four heat flow meter systems were available, the sensor placement was different for each test in order to collect data for as many azimuths as possible.

The pyrotechnic end items used in this test series were those available from the Edgewood Arsenal Phase I - Hazards Evaluation Program and were, of necessity, different for each test. They were stacked as closely as possible in a cube configuration and the stack simultaneously ignited in several places to reach maximum deflagration in minimum time.

2.2 TEST PLAN

2.2.1 MATERIALS

Materials used for the testing were as follows:

- Test 1 - Approximately 500 lb. (material weight) of HC white smoke in 105 mm canisters were used.

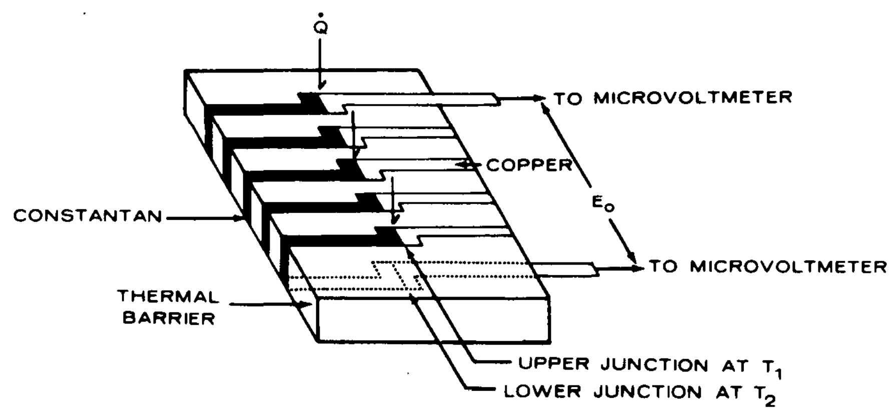

Figure 2-1. Sensor Construction

- Test 2 - Approximately 500 lb. (material weight) of colored smoke in M-18 grenades, from which the initiators have been removed, were used in the following combinations:
  - 16 grenades HC White
  - 160 grenades Sulphur Green
  - 160 grenades Sulphur Red
  - 160 grenades Sulphur Violet
  - 128 grenades Sulphur Yellow
- Test 3 - Approximately 380 lb. (material weight) of XM-9 CS 4.2-inch canisters were used.

2.2.2 TEST SETUP

2.2.2.1 Test 1

The canisters were stacked four layers high and strapped together as shown in Figure 2-2. A small amount of smokeless powder (approximately 20g) was dispersed between the canisters to accelerate the propagation of ignition by the ten S-94 squibs placed optimally throughout the stack.

Two heat flux sensing stations (station 1 and 2) with one shielded and one unshielded sensor and a thermocouple attached to each heat sink were set up fifty feet from the stack and at 90° to each other. A panel, which was developed and built for the "WP Operational Shielding" study, covered with screening on both sides was placed between the stack and sensing station 1. This panel is shown in Figure 2-2 and is cross-sectioned in Figure 2-3. Its purpose was to act as a heat shield.

Figure 2-4 shows one of the heat flux sensing stations with the microvoltmeters. Figure 2-5 presents a total view. Figure 2-6 displays the layout of the test set-up.

2.2.2.2 Test 2

The M-18 grenades were stacked four layers high and strapped together as shown in Figure 2-7. A small amount of smokeless powder (approximately 20g) was dispersed between the canisters to accelerate the propagation of ignition by the nine match head igniters placed optimally throughout the stack.

One shielded heat flux sensor (station 1) was located 50 feet upwind from the stack. The other three sensors were positioned 50 feet downwind as follows:

- One shielded sensor (station 2) 180° from the one at the upwind position with a thermocouple attached to its heat sink.
- Two sensors, (stations 3 and 4) were each attached to the wide side of a 1 x 4 length of lumber with a thermocouple a few inches below (see figure 2-8) and placed 30° to either side of station 2.

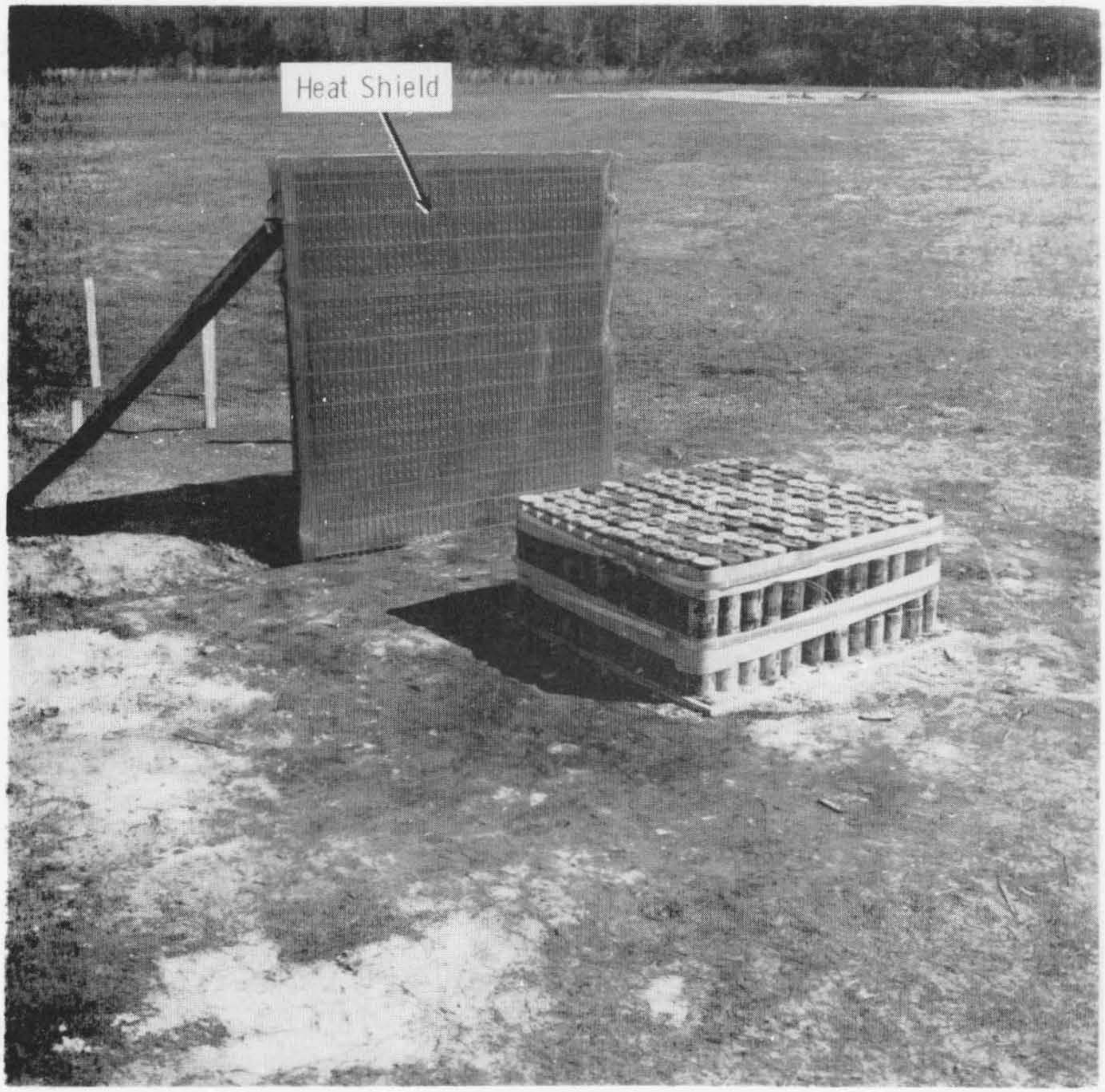

Figure 2-2. Stack of HC White Smoke 105 MM Canisters and WP Operational Shielding Panel Used as Heat Shield

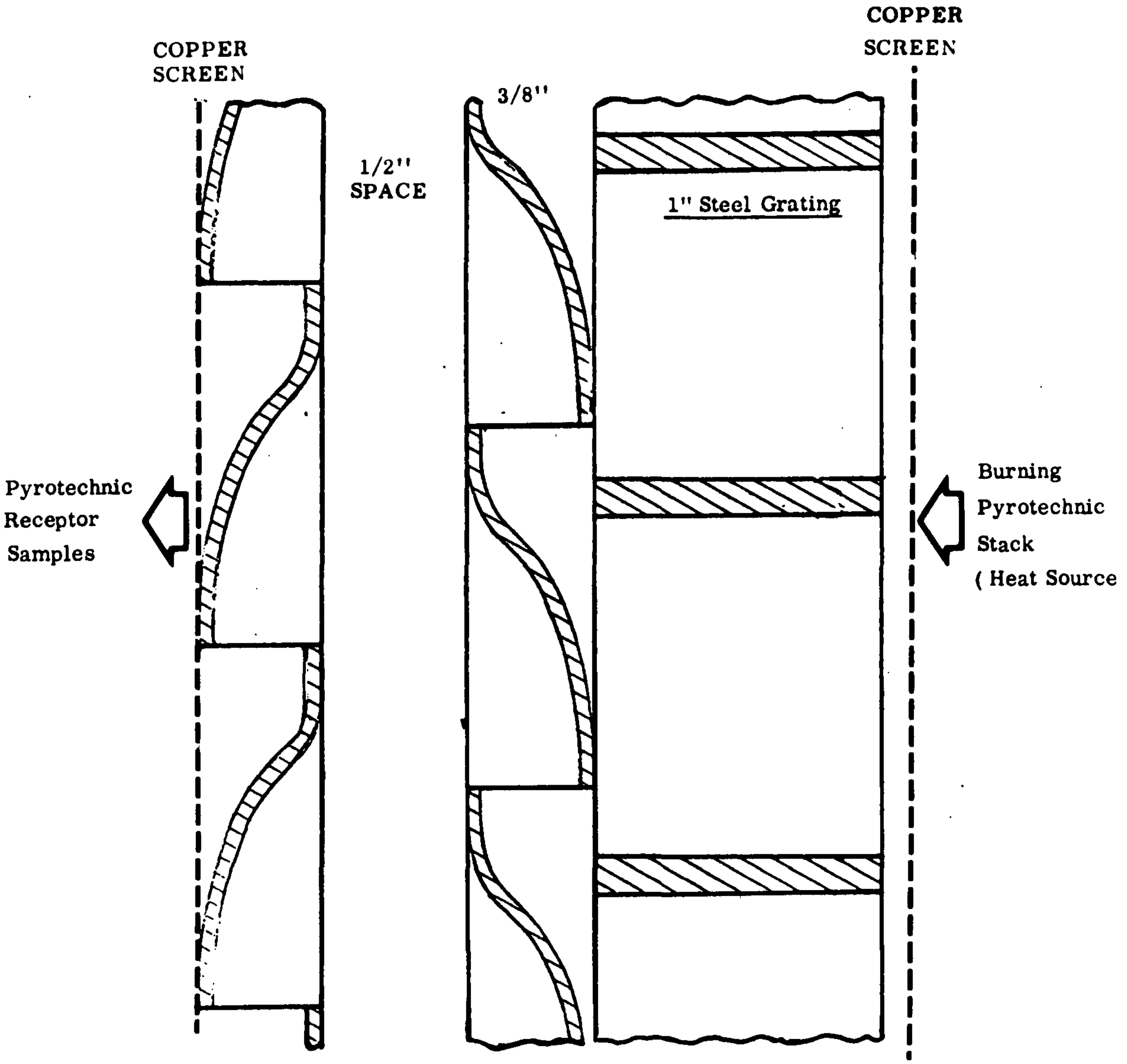

Figure 2-3. Cross-Section of Operational Shielding Panel Used as Heat Shield

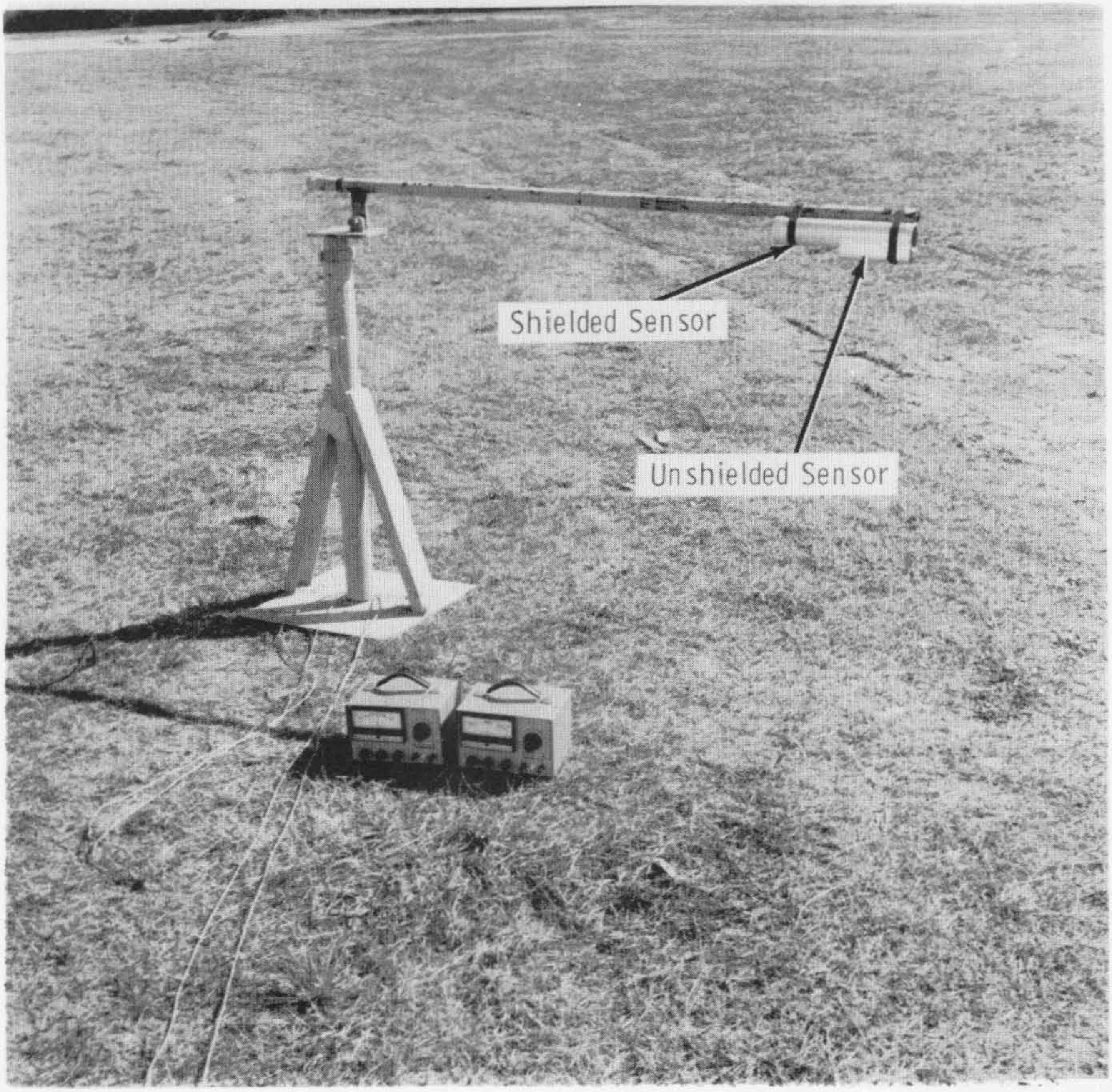

Figure 2-4. Heat Flux Sensing Station With Microvoltmeters

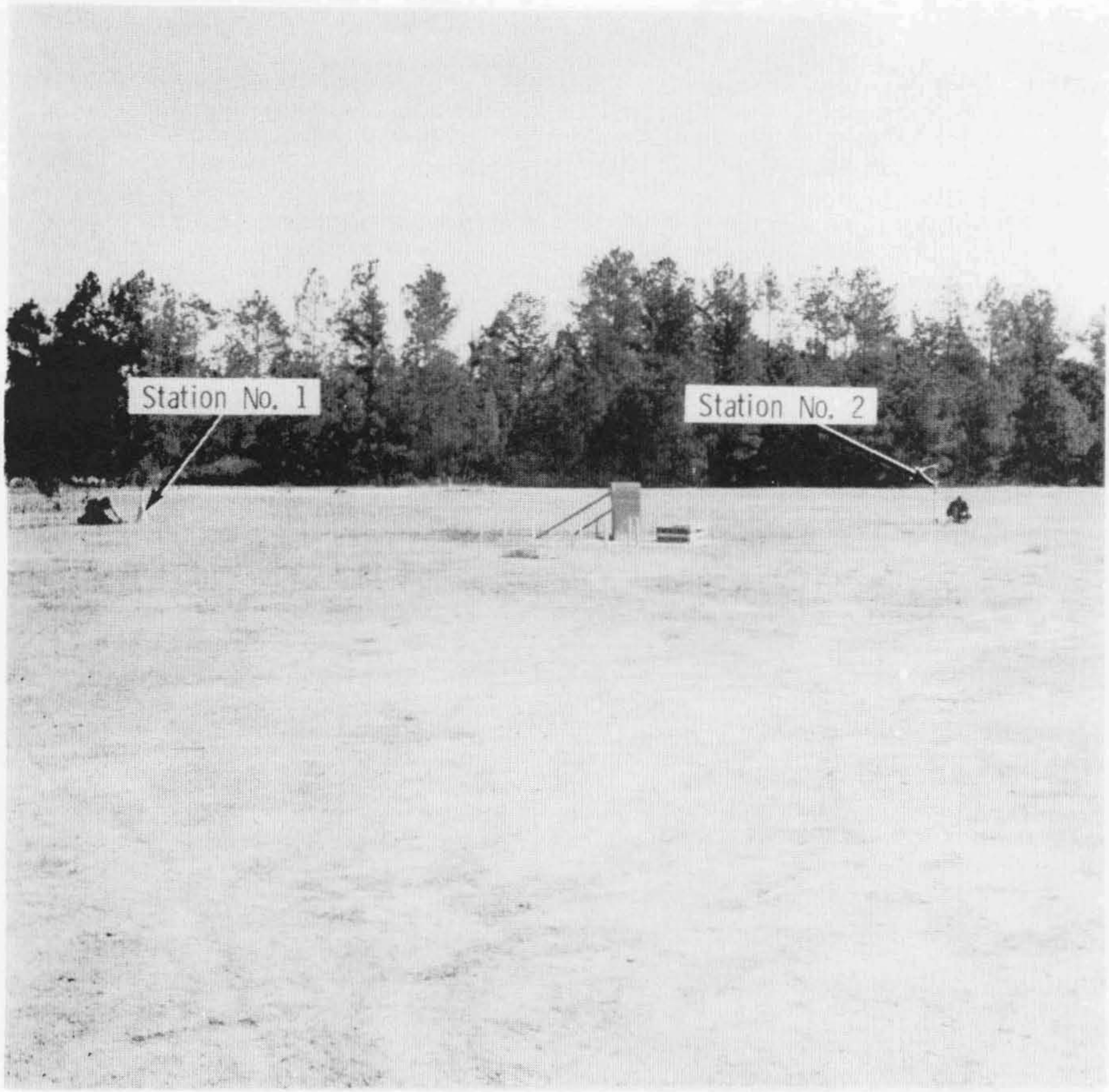

Figure 2-5. Setup for Test 1

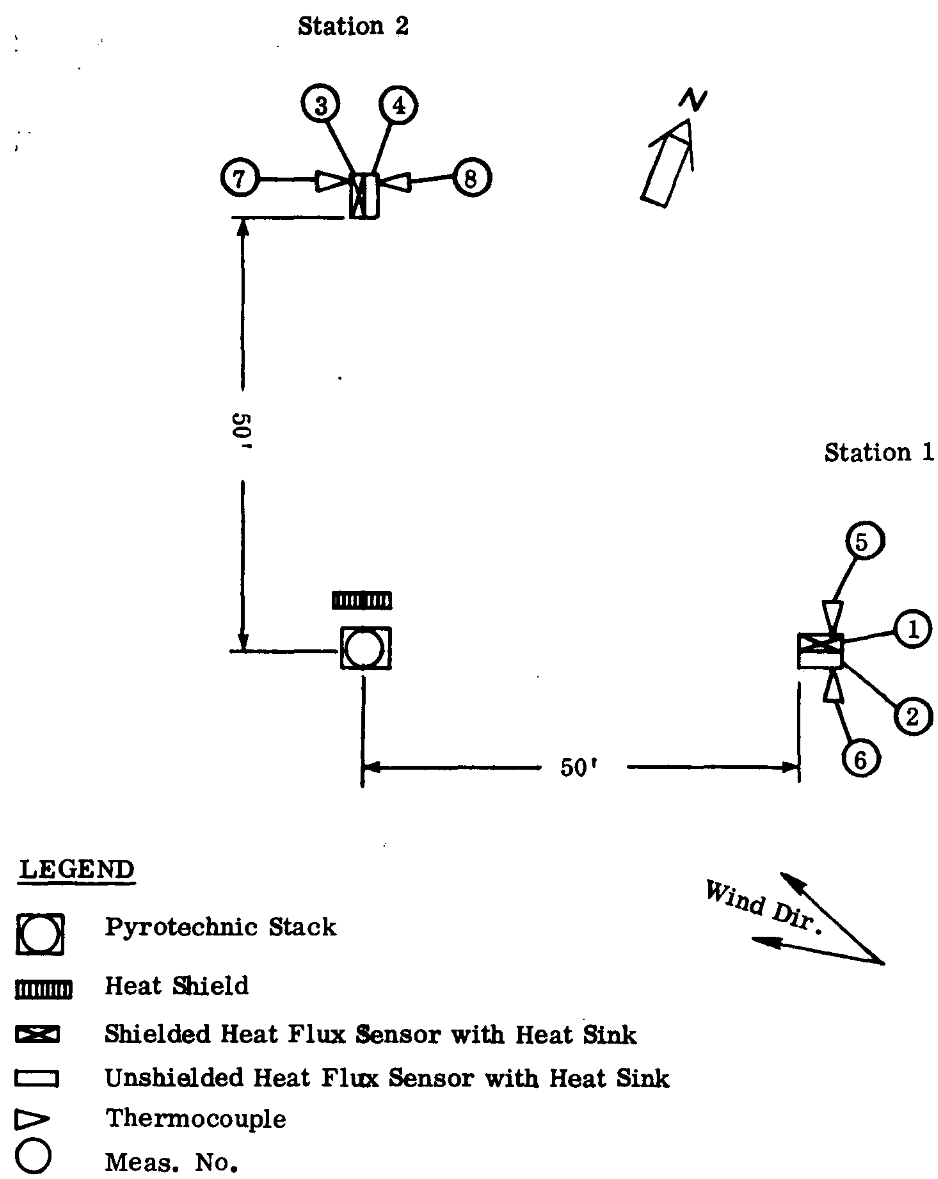

Figure 2-6. Heat Flux Test 1 Layout

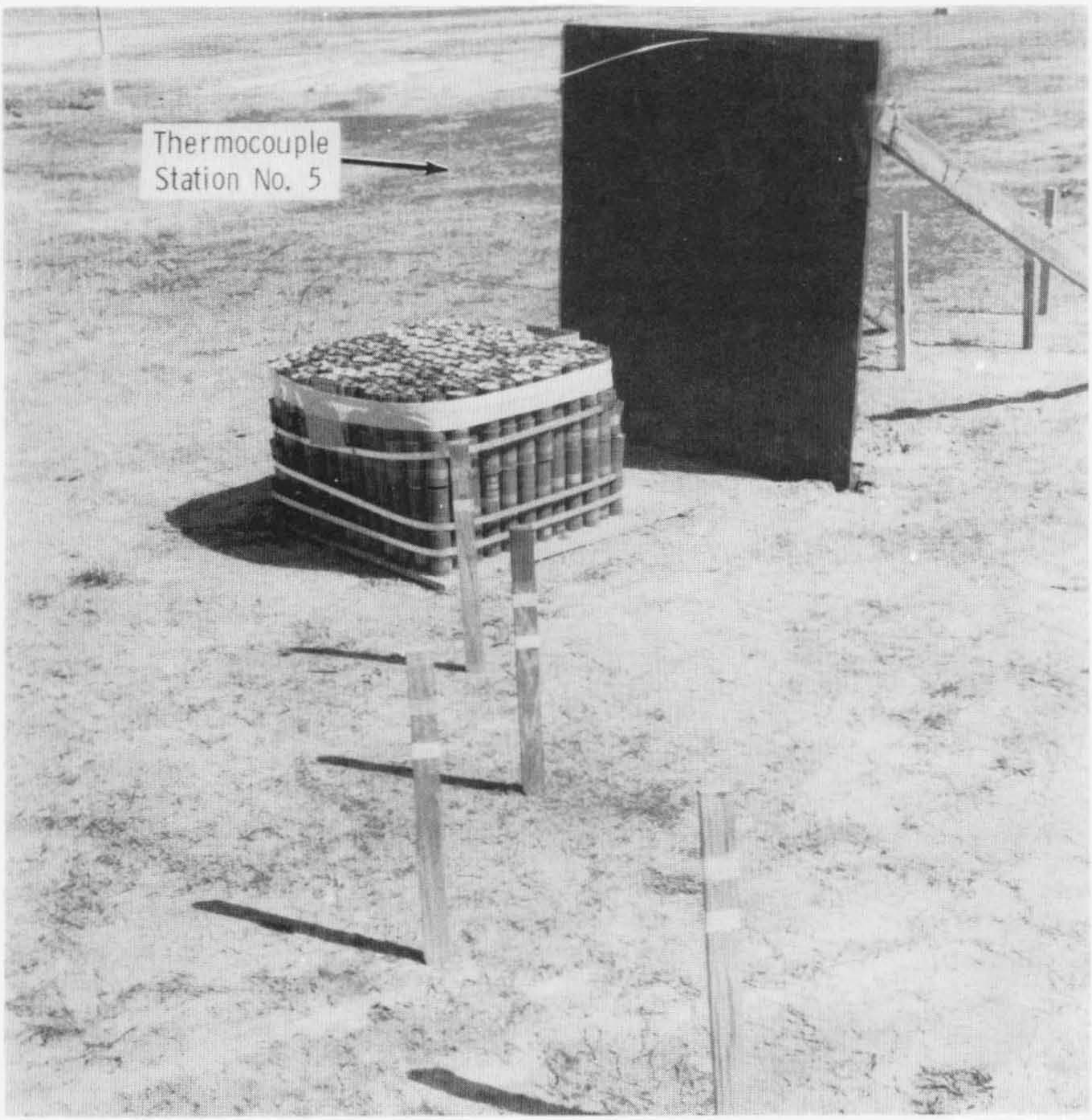

Figure 2-7. Stack of M-18 Color Smoke Grenades

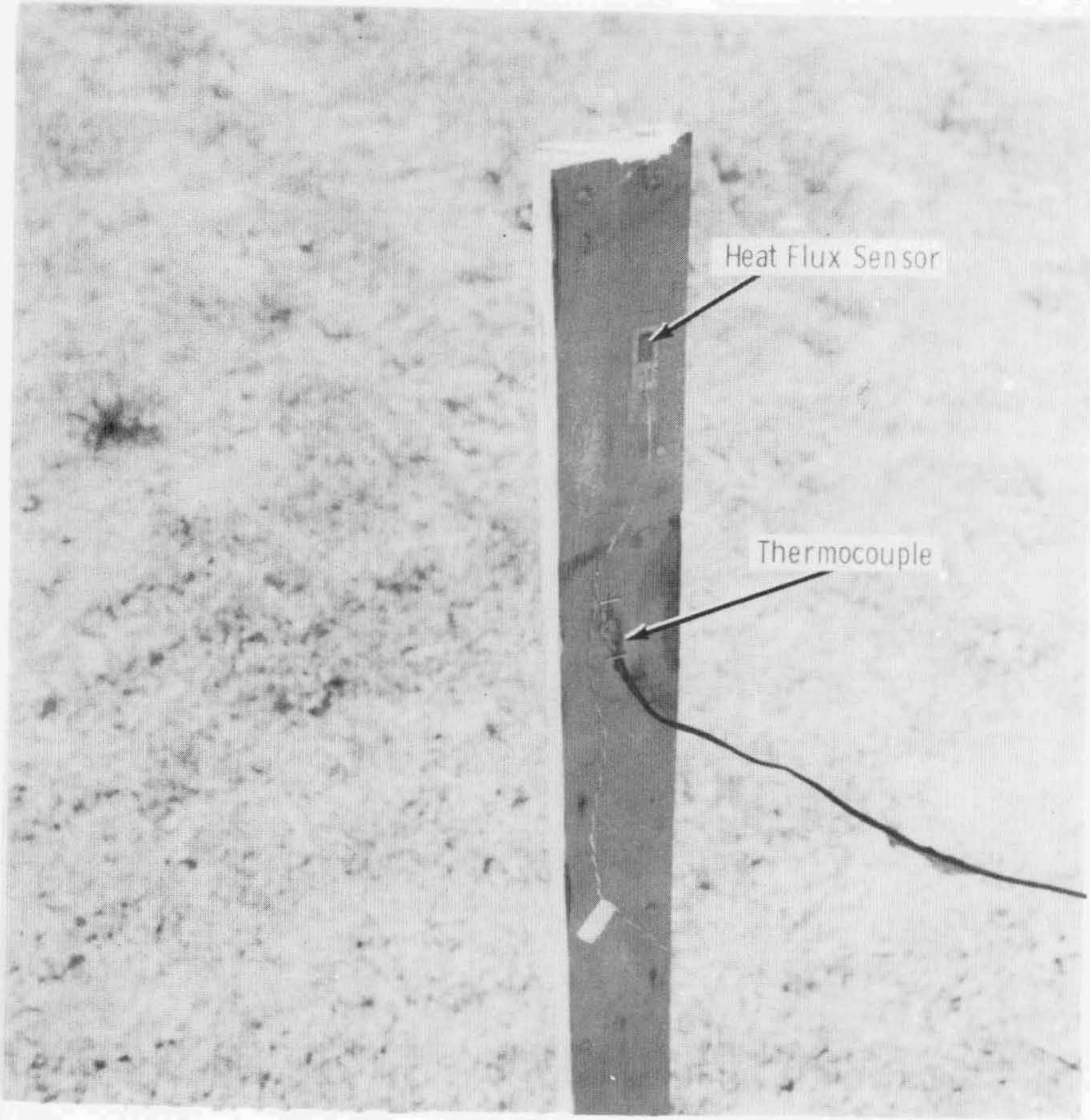

Figure 2-8. Heat Flux Sensor and Thermocouple Attached to 1 x 4 Length of Lumber

One thermocouple (station 5) was placed approximately 30 inches above the stack (see Figure 2-7) to measure the deflagration temperature. Figure 2-9 shows the two shielded sensors (station 2 in foreground) and Figure 2-10 the layout of the test setup. It should be noted that the panel that served as a heat shield in test 1 is positioned in such a manner as not to attenuate the heat flow in the direction of the sensors.

2.2.2.3 Test 3

The XM-9 CS 4.2-inch canisters were stacked seven layers high as shown in Figure 2-11. A small amount of smokeless powder (approximately 5-g) was dispersed between the canisters to accelerate the propagation of ignition by the six, S-94 squibs placed optimally throughout the stack.

One shielded heat flux sensor (station 1) with a thermocouple attached to its heat sink was placed downwind from the stack. A second shielded heat flux sensor (station 2) was placed 90° to station 1 and behind the "WP Operational Shielding" panel which was again used as a heat shield. Two more heat flux sensing stations (stations 3 and 4) as shown in Figure 2-8 were placed opposite the shielded sensors as shown in Figure 2-12 and the layout of the test setup (Figure 2-13). A thermocouple (station 5) was mounted on the heat shield next to the stack to measure the deflagration temperature.

2.2.3 INSTRUMENTATION

The instrumentation used for collecting and evaluating of data is described in Appendix A.

2.2.4 PHOTOGRAPHIC COVERAGE

Black and white still photos were taken before and after each test. All events were also covered by color motion picture as follows:

a. Test 1 - One actual time (24 fps) camera.

b. Test 2 - Two actual time (24 fps) cameras at 90° angles to each other. Both cameras were equipped with a timing device which superimposed on the film the elapsed time in milliseconds. Unfortunately, the camera positioned upwind from the stack failed to operate. Another camera was used which was loaded with infrared color film and set to make an exposure every ten seconds. This was an experimental set-up to determine whether infrared film would be able to penetrate the smoke so that the actual size of the flames could be better determined. However, the pictures showed that the smoke could not be penetrated and the experiment was not repeated in test 3.

c. Test 3 - One actual time (24 fps) camera and two cameras set for 100 fps and positioned 90° to each other. These two cameras were again equipped with the timing device described in (b). In addition, a Hulcher camera, set for 5 fps, was used.

Figure 2-9. Setup for Test 2

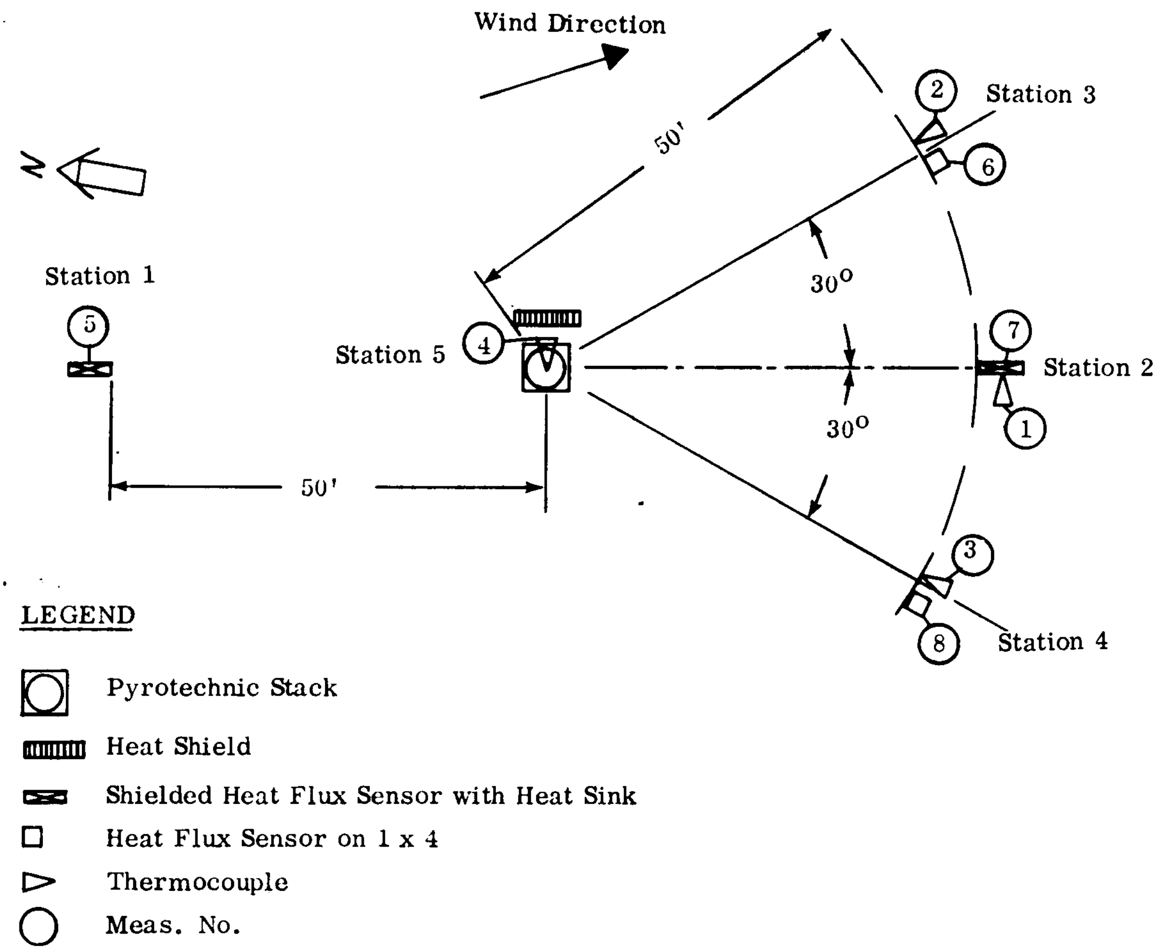

Figure 2-10. Heat Flux Test 2 Layout

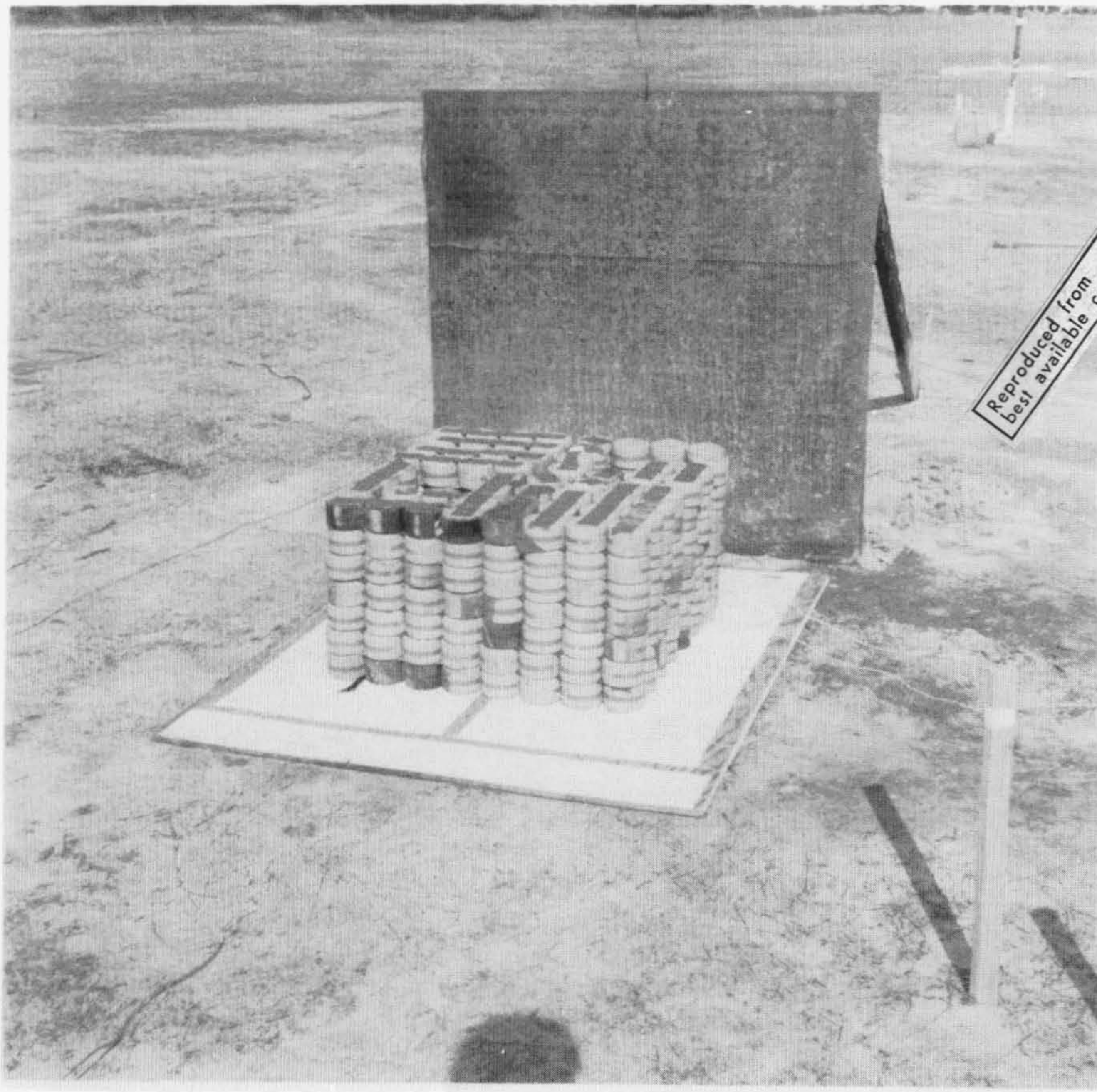

Figure 2-11. Stack of XM-9 CS 4.2-Inch Canisters

Figure 2-12. Setup for Test 3

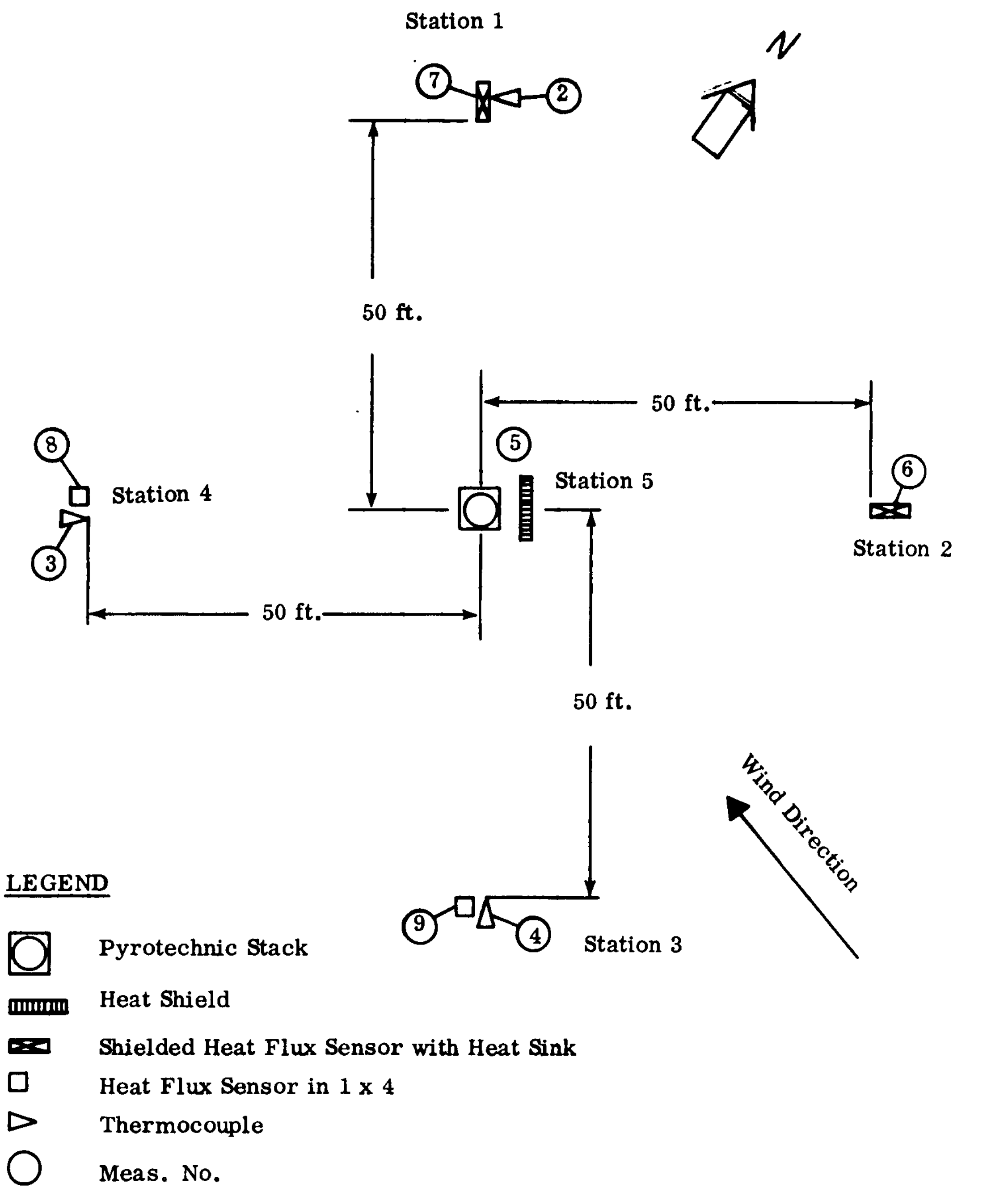

Figure 2-13. Heat Flux Test 3 Layout

2.3 TEST RESULTS

The diagrams used in the following discussion have been plotted from data recorded on computer tab runs. They start at time 0 (ignition) and, except for test 3 which had a duration of less than two minutes, show only the most significant burning phases to a time where the intensity of the fire has decreased to the point of no further heat build-up due to heat flux.

2.3.1 TEST 1

Station 1 was intended to be directly upwind from the pyrotechnic stack. However, the wind shifted during count-down and varied during the test as shown on Figure 2-6. Figures 2-14 and 2-15 show the heat flux ($Btu/ft^2 \cdot h$) versus time (seconds) as measured at stations 1 and 2 respectively. In analyzing the plotted and mopic data, the following observations and assumptions can be made.

a. The amount of heat flux recorded by the shielded sensor (solid line) at station 1 is generally lower than that recorded by the unshielded sensor (dotted line). The opposite is true at station 2. It can be assumed that the reason for this was that the unshielded sensor at station 2 was more exposed to the wind.

b. The maximum heat flux incident at station 2 was considerably lower than at station 1, which in addition to the wind, may have been caused by the effect of the heat shield.

c. At about 300 seconds, the heat flux at station 1 started to level off, while station 2 showed an increase. This was undoubtedly caused by radiation from the heat shield which was located only five feet from the stack and had been sufficiently heated by that time to become a second heat source creating more heat than the almost extinguished fire.

d. The curve of the unshielded sensor at station 2 shows several negative values. During these periods of time the heat flow was reversed because the mounting surface on the sensor was warmer than the surface facing the open air. Wind may have been the cause of this.

e. All curves show an erratic heat flux incident, especially for the unshielded sensors. Changing deflagration of the pyrotechnic stack, smoke, and wind can be assumed to be the main causes.

f. The mopic footage of this test did not have superimposed timing. However, observed with a special projector, the following events are occurring at the approximate times indicated:

- First flames at 92 seconds.
- Most intense fire from 150 to 220 seconds.
- Height of flames approximately 8 feet

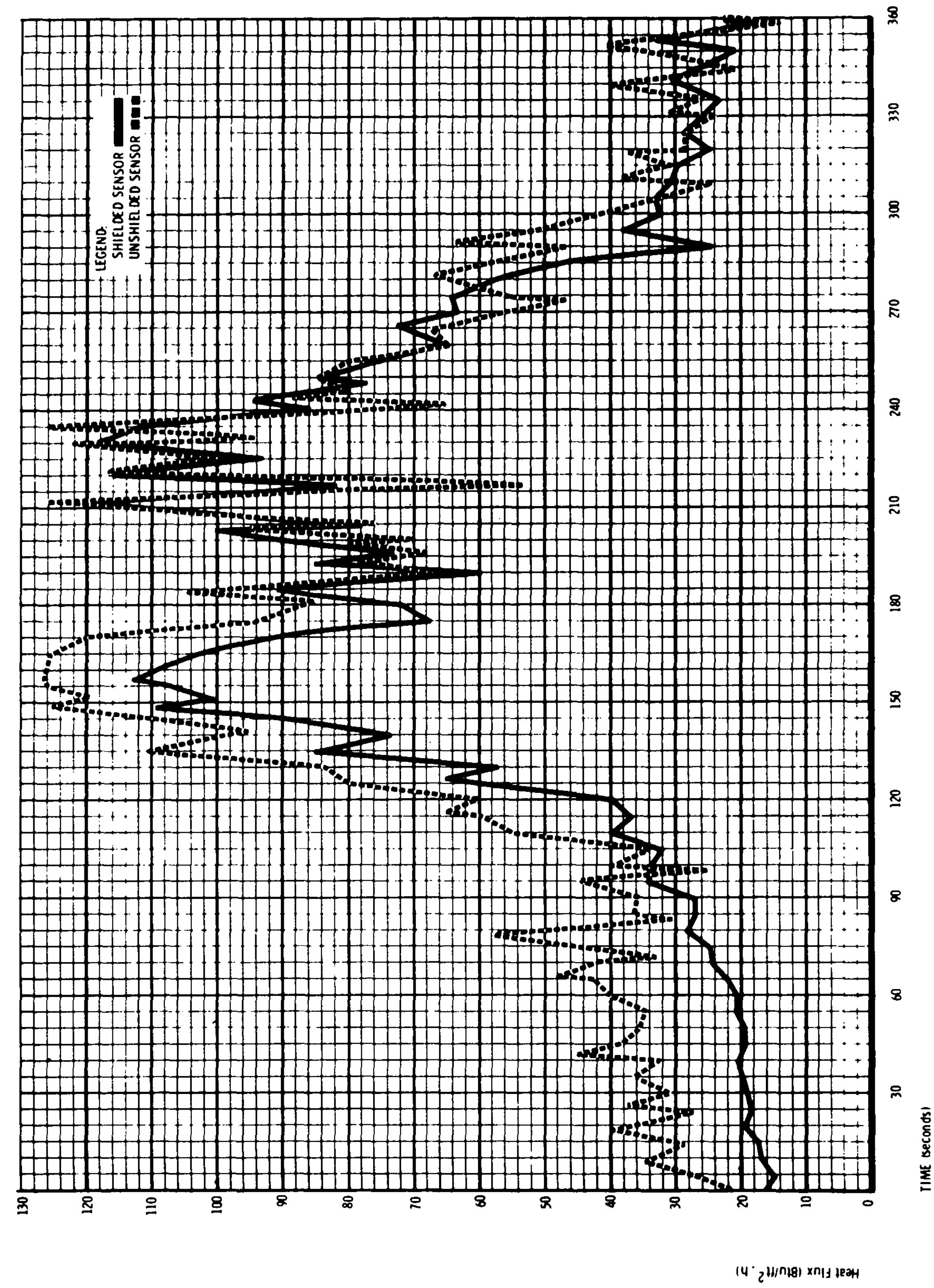

Figure 2-14. Heat Flux Versus Time at Station 1 - Test 1

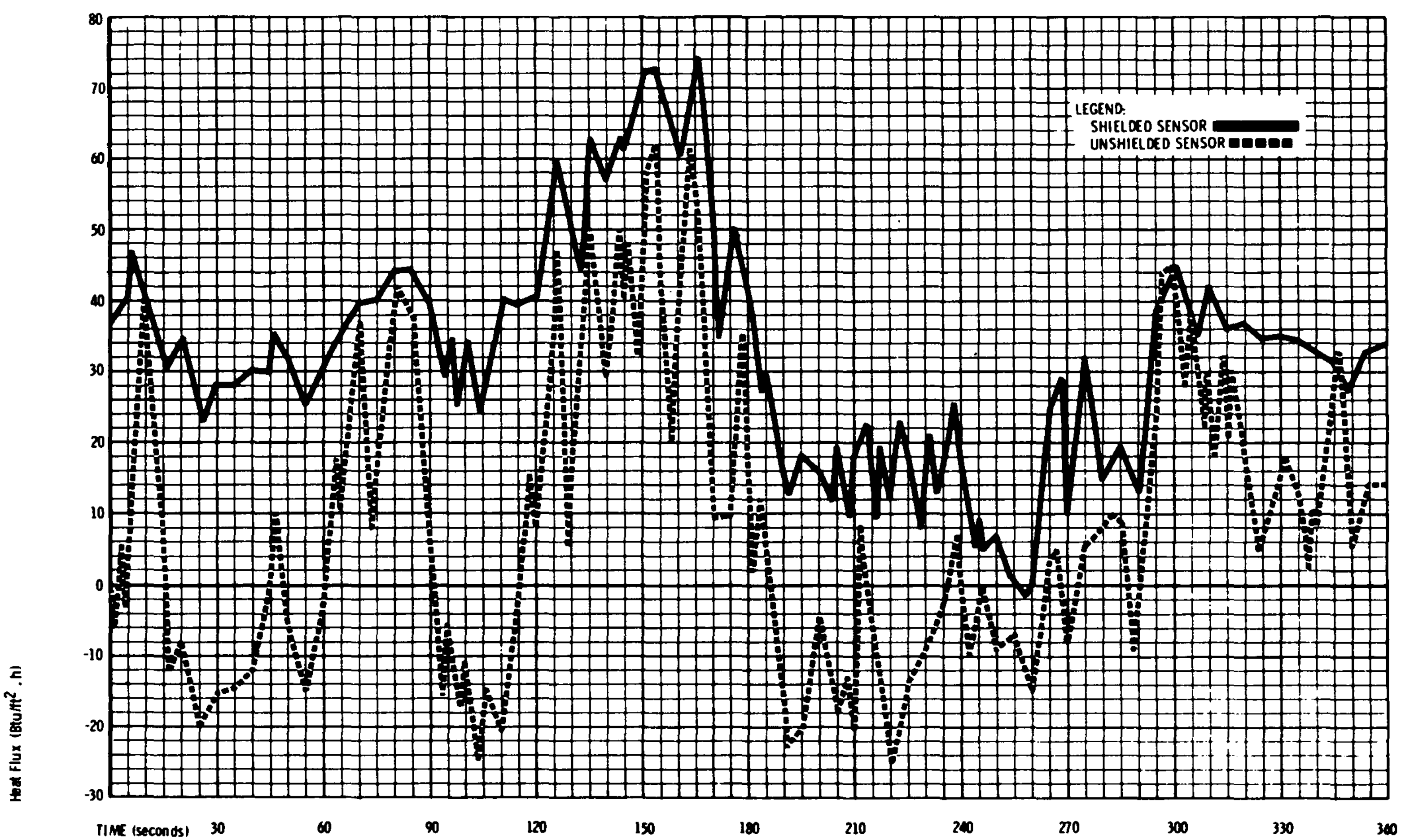

Figure 2-15. Heat Flux Versus Time at Station 2 - Test 1

- No visible flames after 380 seconds, but heavy smoke for approximately three more minutes.
- Light smoke continued for 14 to 15 minutes after ignition.

Figure 2-16 shows the burned out HC canisters.

2.3.2 TEST 2

Station 2 was intended to be directly downwind of the pyrotechnic stack. However, after the test was set up, the wind shifted slightly toward station 3 as shown in Figure 2-10. Figures 2-17, 2-18, and 2-19 show the heat flux ($Btu/ft^2 \cdot h$) versus time (seconds) for station 1, 3, and 4, respectively. The heat flux curve for station 1 (Figure 2-17) is shown on an overlay for easy comparison. Furthermore, Figures 2-18 and 2-19 show also the actual temperature versus time (dotted line) at their respective stations.

The data from the thermocouple at station 5 and the shielded heat flux sensor at station 2 could not be recorded because of a malfunction of their transmission channels. However, the thermocouple attached to the heat sink at station 2 and its read-out system were in proper working order and showed one degree temperature increase over a five minute period.

In analyzing the plotted date (Figures 2-17, 2-18, and 2-19) and the mopic data, the following observations are made:

a. Station 1 (shielded heat flux sensor with heat sink) showed the highest heat flux incident. It should be noted that during the period of 59 and 78 seconds, the heat flux remained almost constant at its maximum value of slightly above 380 $Btu/ft^2 \cdot hr$.

b. The next highest amount of heat flux was registered at station 3 followed by station 4. Both curves peak at the same time. While station 3 records one peak at 63 seconds, station 4 records two at 62 and 65 seconds, respectively. The peak values of both stations coincide with that of station 1.

c. The heat flux at station 3 decreased very abruptly from its peak and went negative within 13 seconds. A slower but more erratic decrease occurred at station 4 where the heat flux went negative within 26 seconds.

d. Upon comparison of the actual temperature at stations 3 and 4, there was a gradual increase of approximately two degrees during the first 45 seconds. From that time, the temperature at station 3 increased rapidly up to its peak of 116^{o}F at 80 seconds. At station 4, the increase was slower and reached its first peak of 108^{o}F at 85 seconds and, after remaining steady at 107^{o}F recorded a second peak of 108^{o}F at 102 seconds. Since station 3 was further downwind than station 4, it was, therefore, more exposed to convective heat transfer by the wind which may explain the 8^{o} F higher temperature and more rapid rise in temperature.

Figure 2-16. Burned-out HC White Smoke Canisters

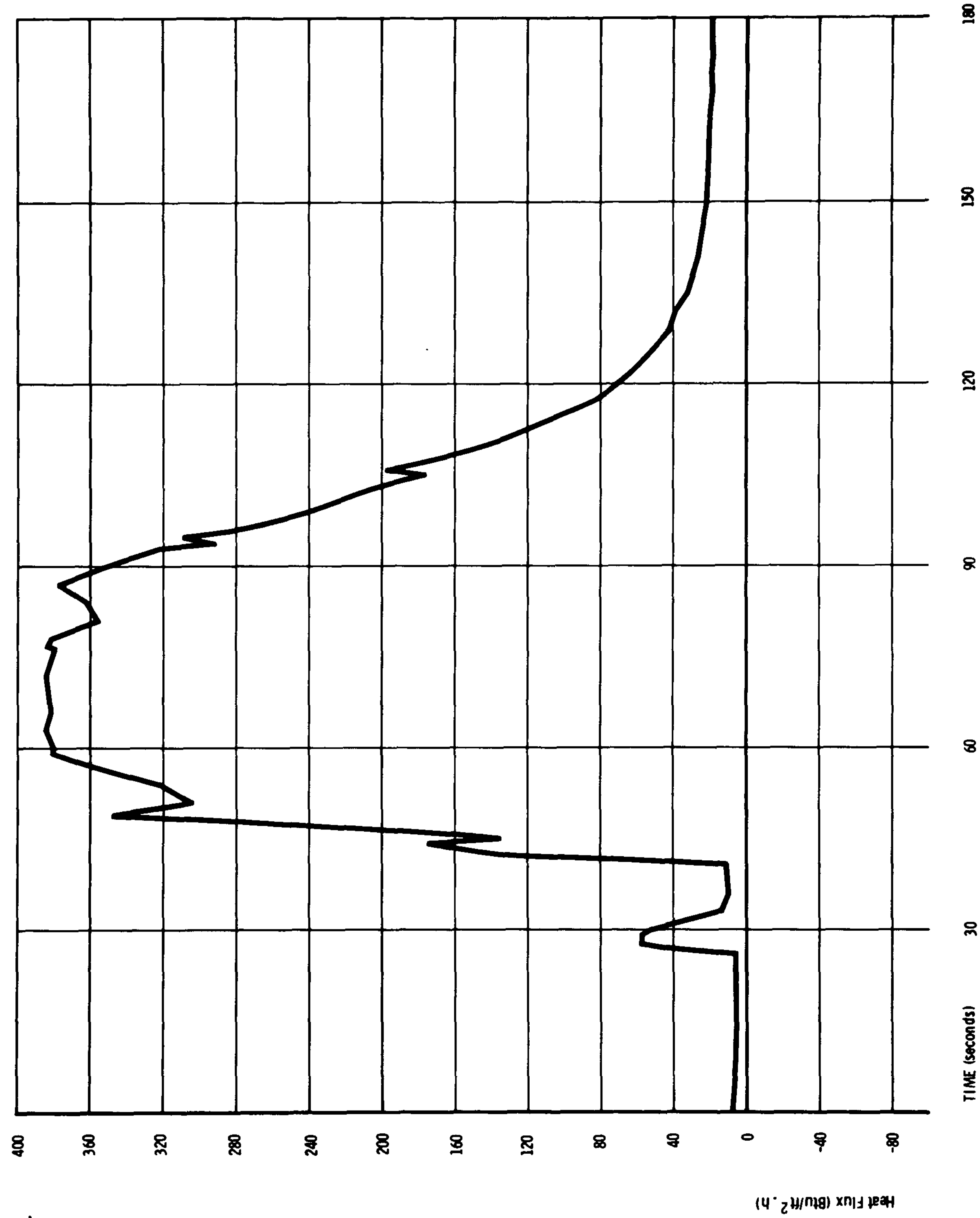

Figure 2-17. Heat Flux Versus Time at Station 1 - Test 2

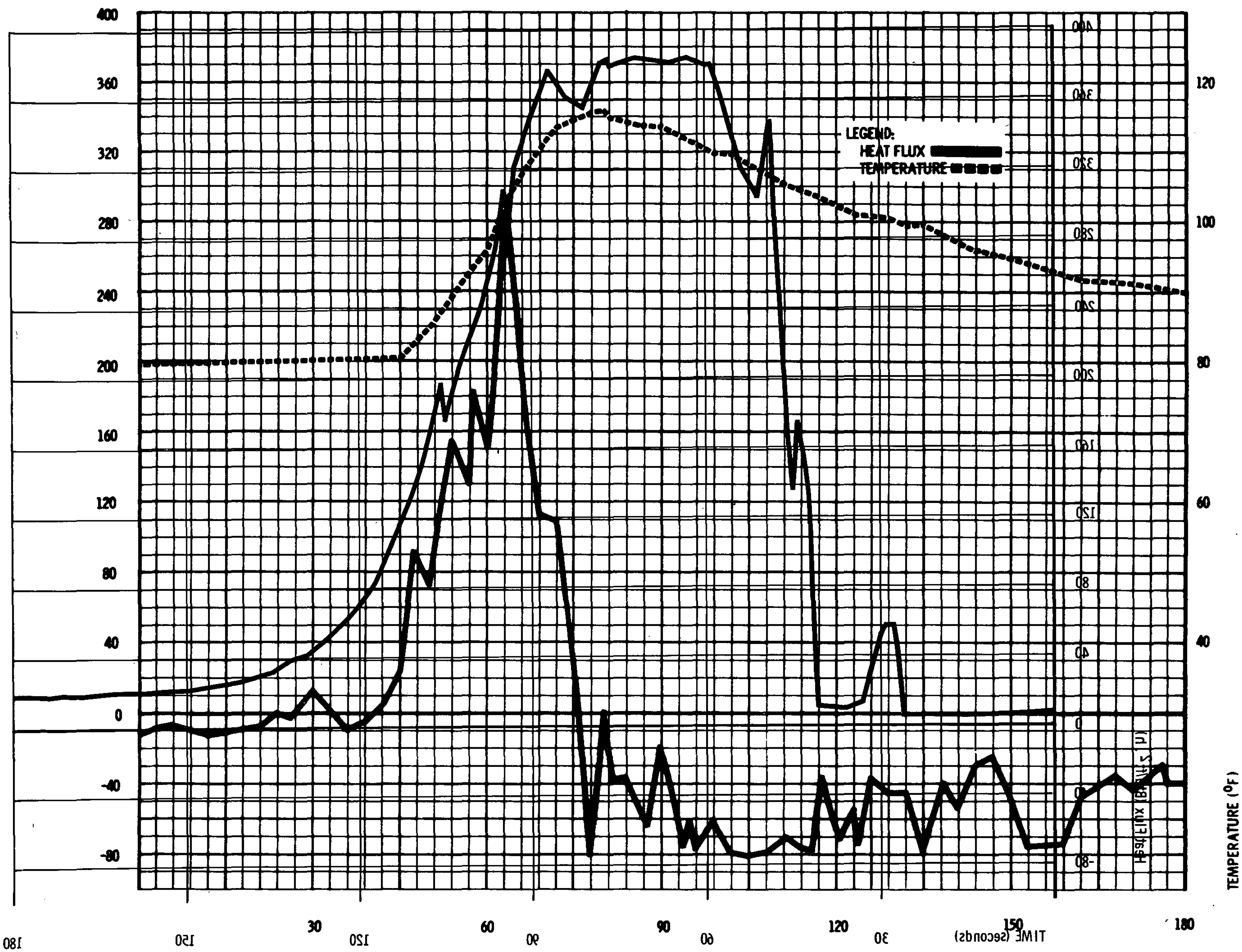

Figure 2-18. Heat Flux/Temperature Versus Time at Station 3 - Test 2

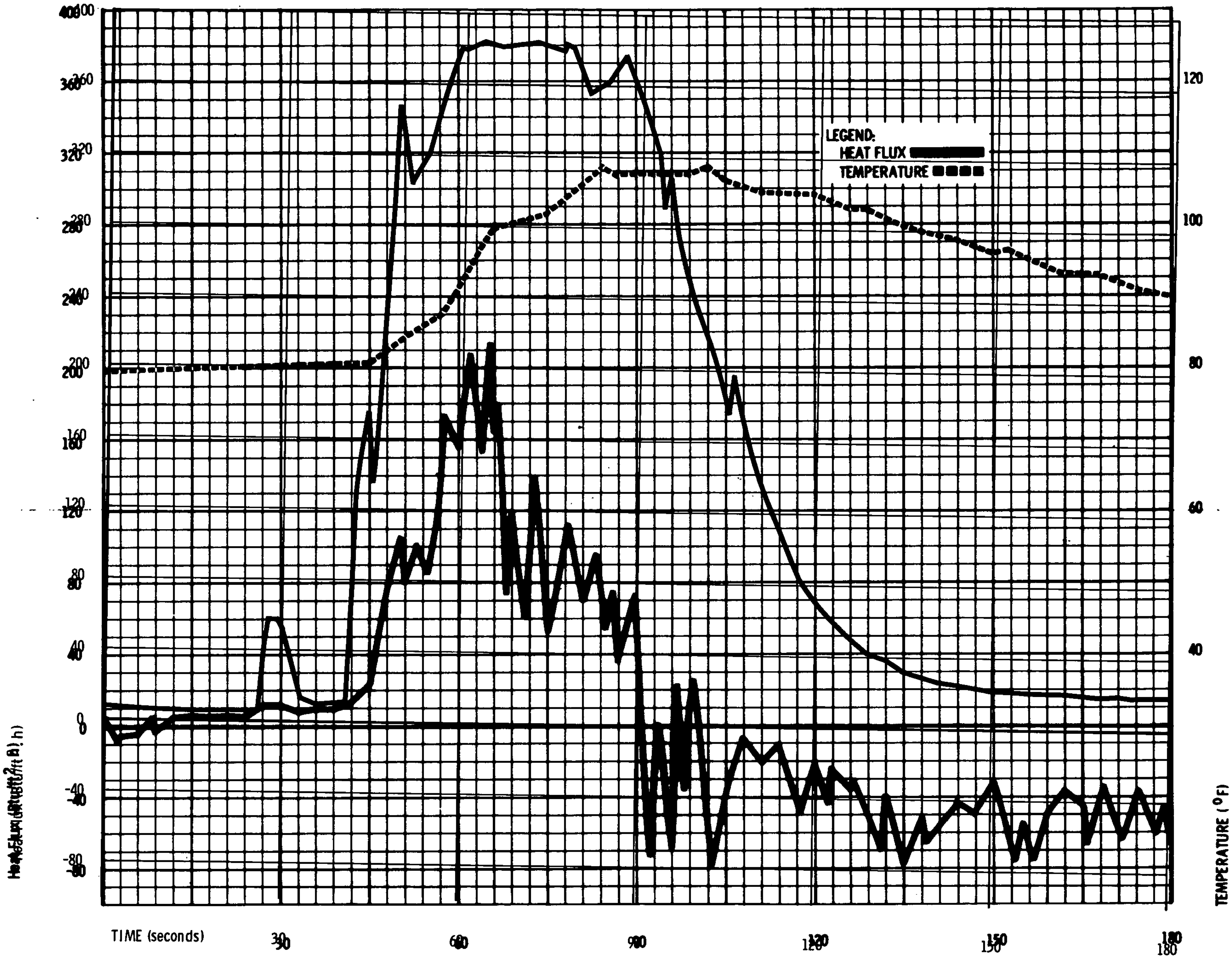

Figure 2-19. Heat Flux/Temperature Versus Time at Station 4 - Test 2

e. The mopic data of this test show the following events:

- First visible flames at 40 seconds
- Intense fire from 48 to 88 seconds
- Height of flames in excess of 20 feet
- From 56 to 67 seconds, smoke and flames were blown toward station 3
- Last visible flame at 148 seconds.

The above events coincide within a few seconds with the heat flux data recorded at station 1 (see Figure 2-17). They also coincide with those recorded at stations 3 and 4, but only up to their peak values (See Figures 2-18 and 2-19).

f. The abrupt decrease and negative values of the heat flux recorded at stations 3 and 4 reflect the large effect that a temperature change of the sensor mounting surface has on the sensor's output.

Figure 2-20 shows the burned-out M-18 smoke grenades.

2.3.3 TEST 3

Station 1 was intended to be directly downwind of the pyrotechnic stack. However, after the setup was completed, the wind shifted towards station 2 as shown in Figure 2-13. Figures 2-21 through 2-24 show the heat flux ($Btu/ft^2 \cdot h$) versus time (seconds) for stations 1, 2, 3, and 4, respectively. In addition, Figures 2-23 and 2-24 show the actual temperature versus time (dotted line) at their respective stations.

The thermocouple attached to the heat sink of the shielded sensor at station 1 did not show any appreciable temperature rise of the heat sink. For reasons unknown, the thermocouple at station 5 malfunctioned.

In analyzing the plotted and mopic data, the following observations are made:

a. Station 1 recorded the maximum heat flux incident with 1097 $Btu/ft^2 \cdot h$ at 34 seconds. Station 2 recorded its maximum with 999 $Btu/ft^2 \cdot h$ at the same time. The 10 percent difference in the two peak values may be due to the wind which carried flames and smoke in a direction between stations 1 and 4, but closer to station 1. The operational shielding panel used as a heat shield did not seem to have any effect, since bwtween 14 and 29 seconds, the heat flux curve of station 1 is lagging considerably behind that of station 2. Both stations recorded a second, slightly lower peak, four to five seconds after the maximum. This may be attributed to heavy smoke or erratic burning.

Figure 2-20. Burned-out M-18 Color Smoke Grenades

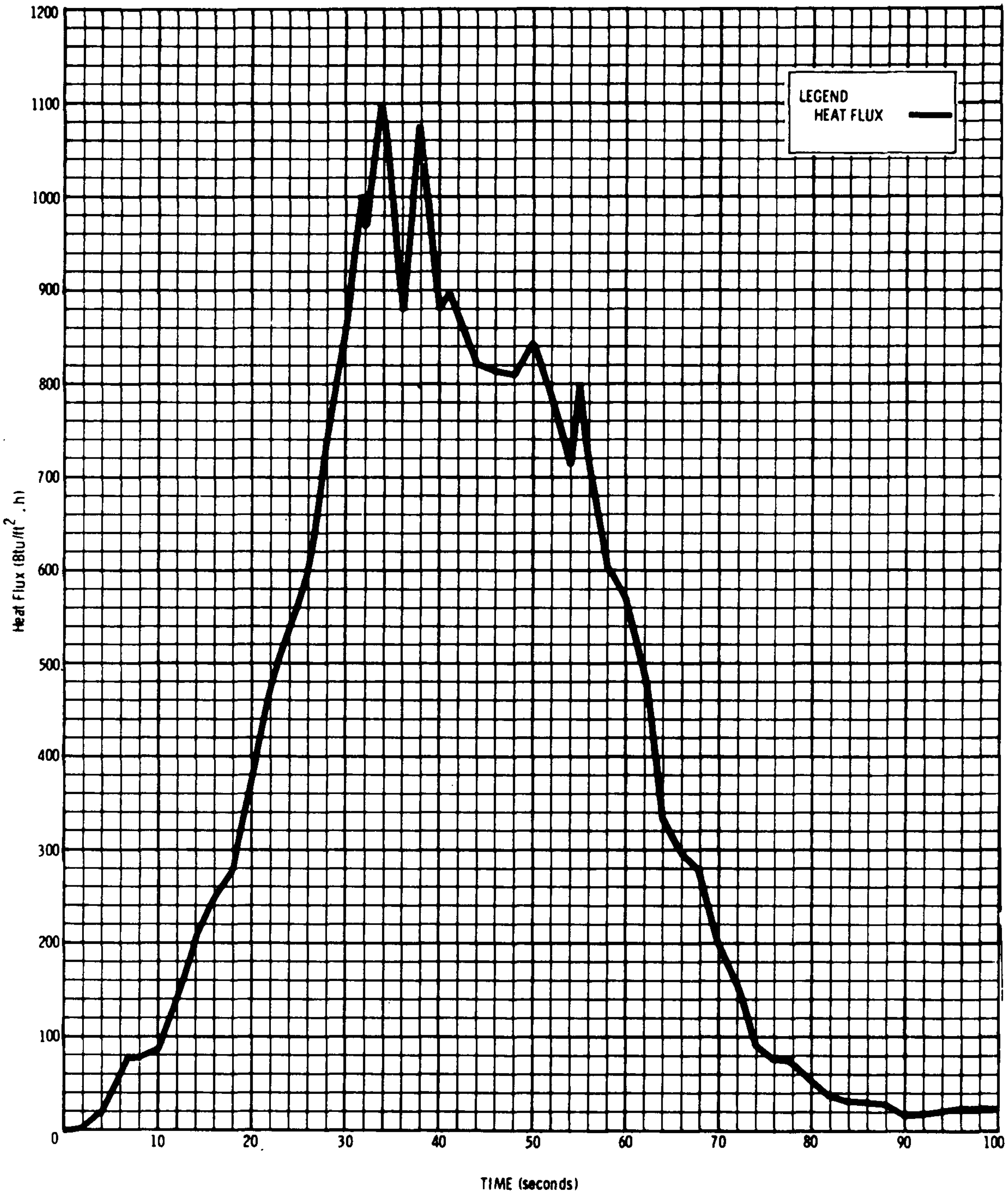

Figure 2-21. Heat Flux Versus Time at Station 1 - Test 3

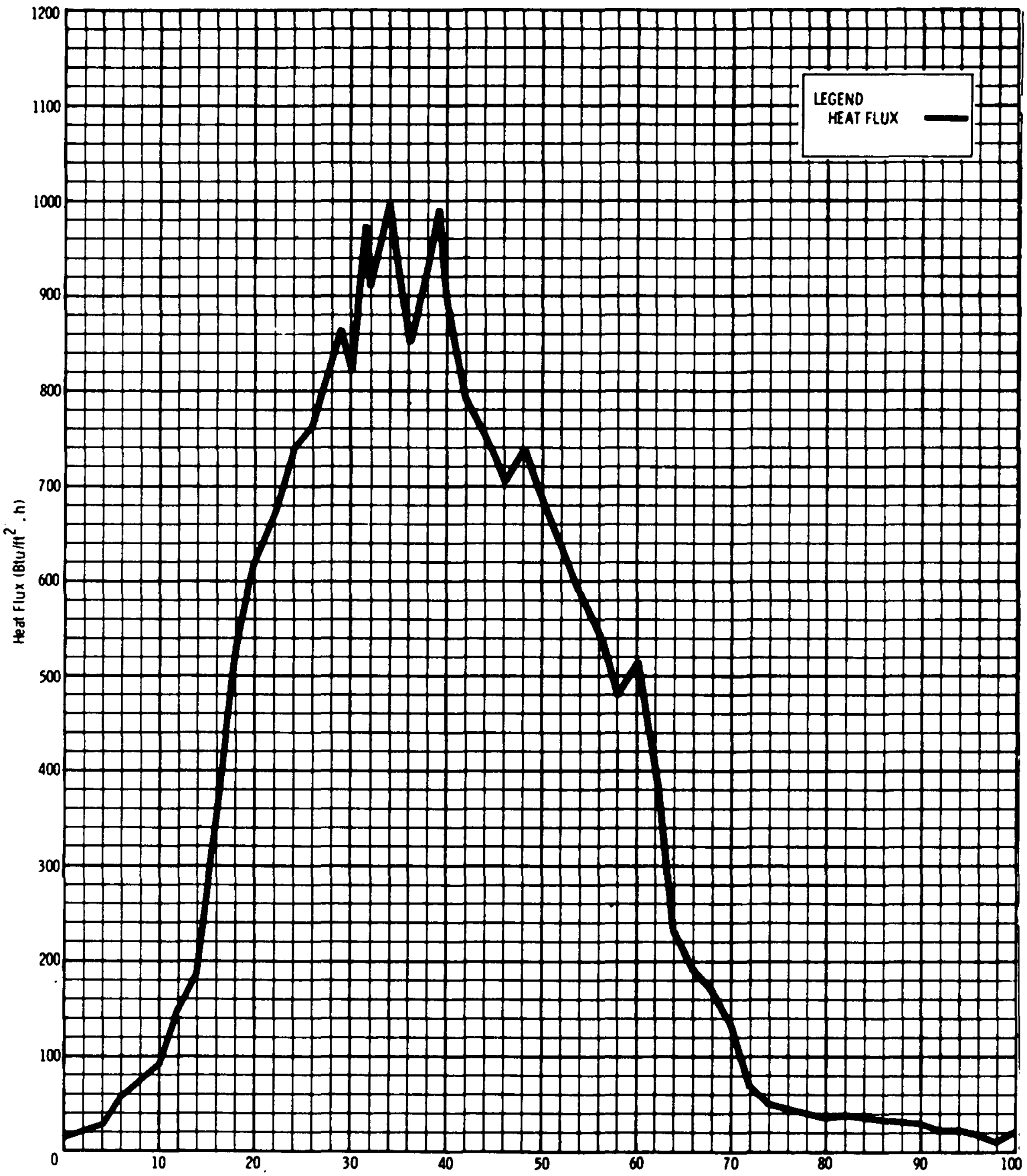

Figure 2-22. Heat Flux Versus Time at Station 2 - Test 3

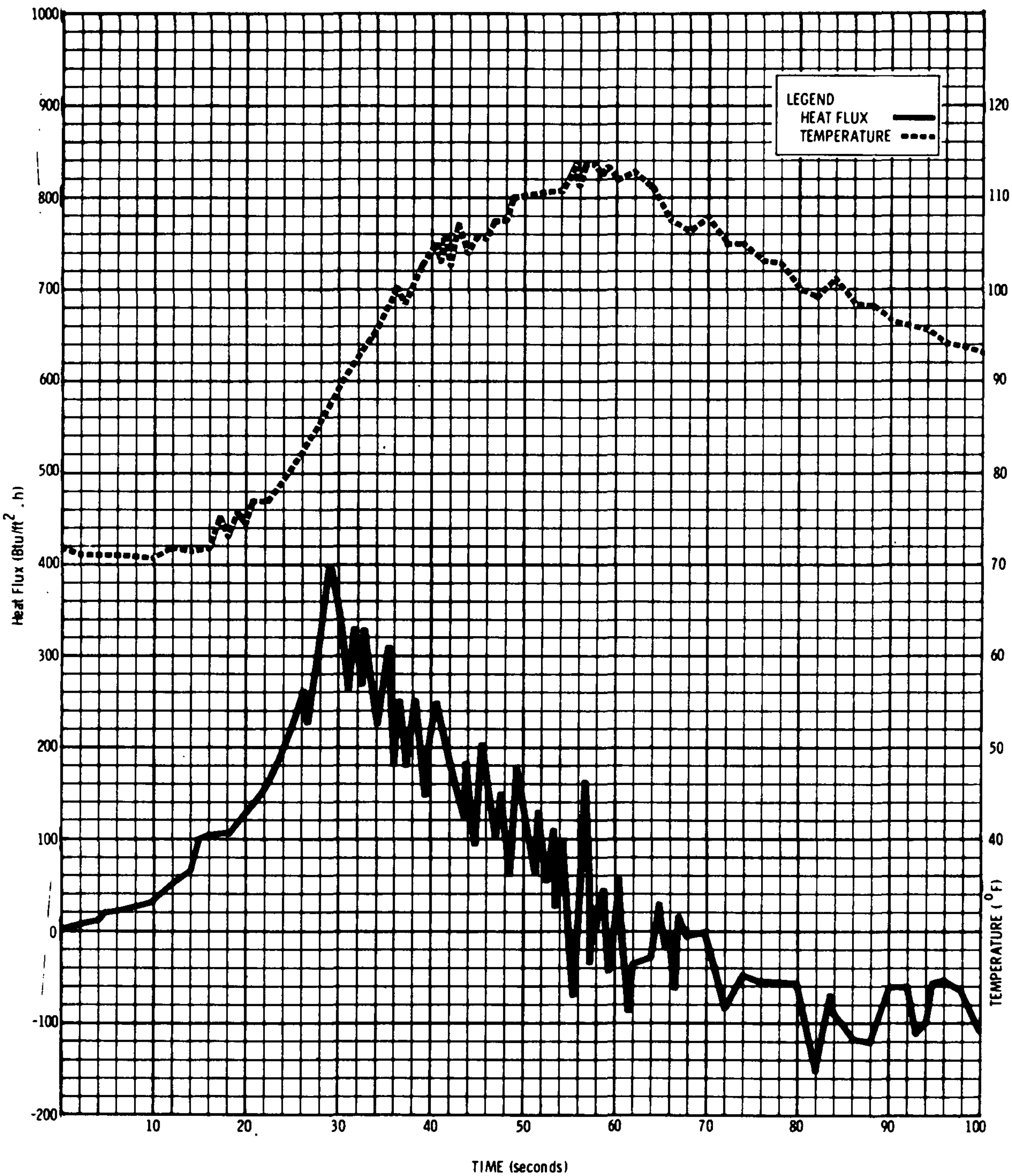

Figure 2-23. Heat Flux/Temperature Versus Time at Station 3 - Test 3

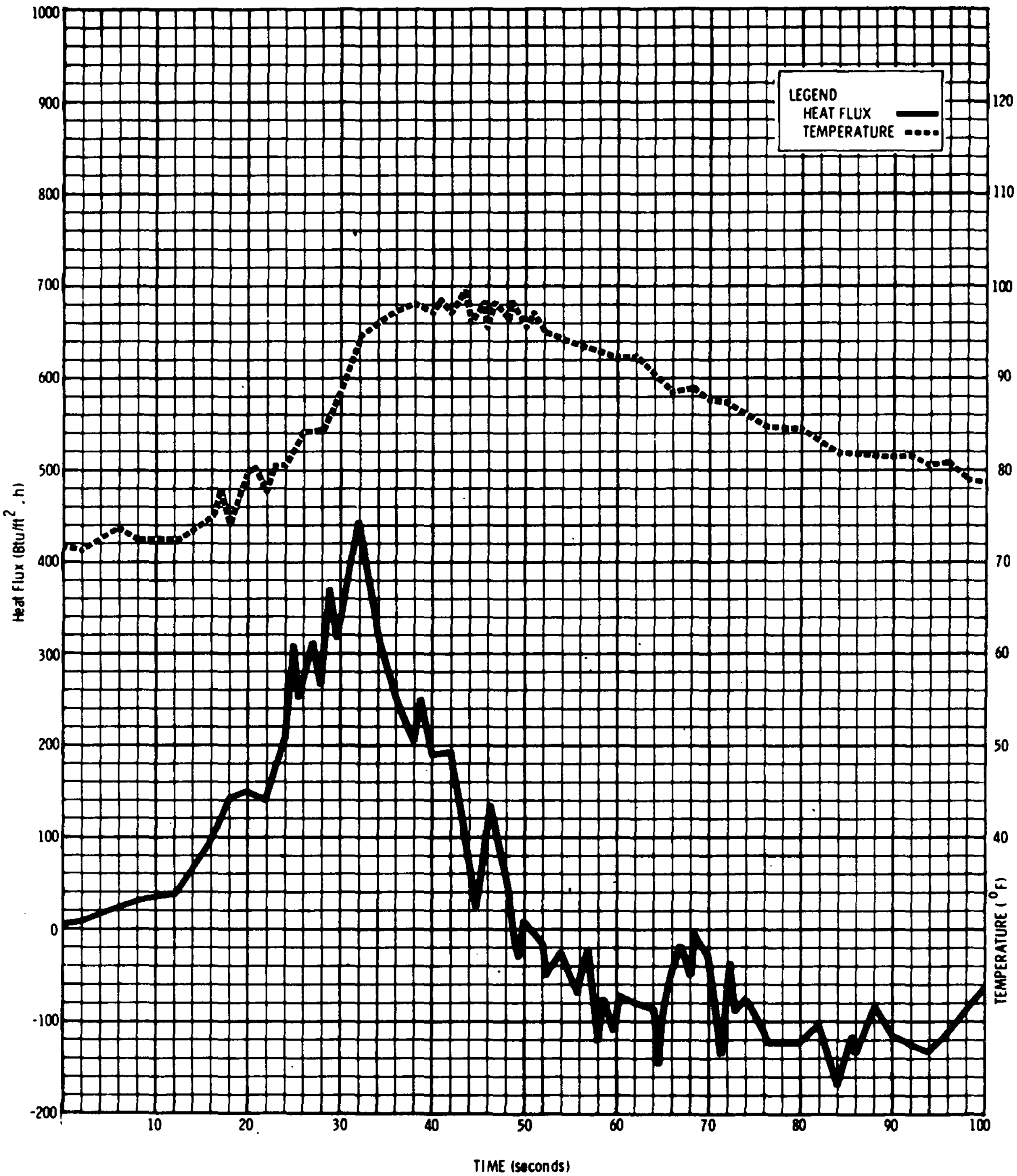

Figure 2-24. Heat Flux/Temperature Versus Time at Station 4 - Test 3

b. Station 3 showed the maximum heat flux with 396 Btu/ft^2 · h at 29 seconds, while station 4 recorded its maximum of 443 Btu/ft^2 · h at 32 seconds. Both stations showed only one distinct maximum peak a few seconds ahead of those at stations 1 and 2. Station 4 went negative at 49 seconds and stayed negative after 51 seconds. On the other hand, station 3 went negative at 55 seconds and after several changes between positive and negative values, remained negative after 70 seconds. It also showed a much more erratic behavior during its descent stage.

c. Comparison of the actual temperatures at stations 3 and 4 shows an almost identical rise between 22 and 33 seconds. However, station 4 started to level off at 33 seconds to reach its maximum of 99°F at 44 seconds, while station 3 started to level off at 50 seconds to reach its peak of 113°F at 57 seconds where it remained for two seconds.

d. The two mopic cameras with 100 fps exposures were placed behind stations 3 and 4. Since the view from the camera at Station 3 was much less obscured by smoke, only the events observed on the movie taken at that station will be discussed here. The time for each event is the elapsed time after Time 0 (ignition):

- First visible flames at 0.9 seconds
- Deflagration (black smoke) starts at 3 seconds
- Intense fire from 11 to 65 seconds
- Flame heights estimated in excess of 25 feet
- Last visible flame at 82 seconds
- Several canisters were thrown out of the burning stack. One (CS already smoking) fell within three feet of station 3 at 29 seconds. It stopped smoking at 78 seconds. At no time did the CS in this canister burn with an open flame. However, there is a possibility that this canister may have caused the erratic behavior of the sensors at station 3. Figure 2-25 shows the burned out canister in front of station 3. The sensors have already been removed.

e. Figure 2-26 shows the burned out stack of XM-9 CS canisters. It should be noted that the screening on this side of the panel has been completely destroyed.

Tables 2-1 and 2-2 display a summary of events as recorded on the graphs and through the motion pictures.

Figure 2-25. Burned-out XM-9 CS Canister which Fell in Front of Station 3

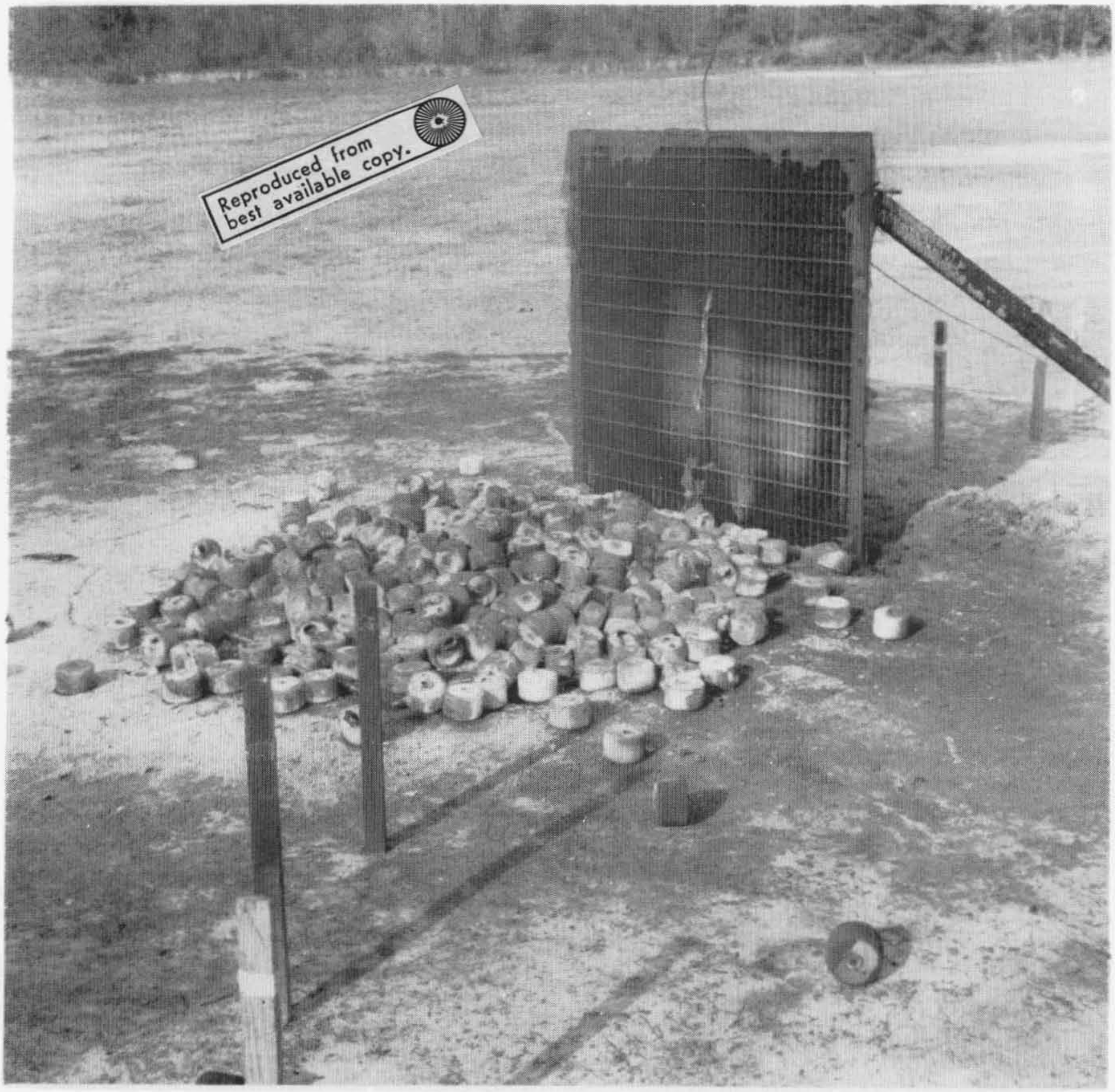

Figure 2-26. Burned-out Stack of XM-9 CS Canisters

Table 2-1. Summary of Events as Observed on Graphs: Heat Flux/Temperature Versus Time

TEST NO.	END ITEMS TESTED	STATION NO.	TYPE SENSOR *	HEAT FLUX: TIME HEAT FLUX STARTS RISING (seconds)	HEAT FLUX: ERRATIC RISE	HEAT FLUX: FIRST PEAK ($\frac{Btu}{ft^2.h}$)	HEAT FLUX: FIRST PEAK (seconds)	HEAT FLUX: SECOND PEAK ($\frac{Btu}{ft^2.h}$)	HEAT FLUX: SECOND PEAK (seconds)	HEAT FLUX: ERRATIC DOWN SLOPE	HEAT FLUX: END OF DOWN SLOPE (seconds)	HEAT FLUX: FIRST NEGATIVE VALUE AT (seconds)	TEMPERATURE: TIME TEMP. STARTS RISING (seconds)	TEMPERATURE: MAXIMUM (^{o}F)	TEMPERATURE: MAXIMUM (seconds)	TOTAL DURATION OF TEST (approx. seconds)
1	HC White Smoke 105 mm canisters	1	A	90	No	113	157	118	230	No	290	358	-	-	-	900
		1	B	105	No	127	157	126	236	Yes	309	357	-	-	-	
		2	A	104	Yes	73	154	74	166	No	193	256	-	-	-	
		2	B	110	Yes	62	154	62	164	Yes	191	187	-	-	-	
2	M-18 Grenades Colored Smoke	1	A	41	No	382	59	384	78	No	135	None	N/A	N/A	N/A	600
		2	A	M A L F U N C T I O N E D												
		3	C	36	No	288	63	-	-	No	78	76	45	116	80	
		4	C	39	No	208	62	213	65	Yes	92	91	45	108 108	85 102	
3	XM-9 CS 4.2 inch canisters	1	A	2	No	1097	34	1072	38	No	82	None	N/A	N/A	N/A	90
		2	A	4	No	999	34	988	38	No	74	None	N/A	N/A	N/A	
		3	C	10	No	396	29	-	-	Yes	72	55	16	113	57	
		4	C	12	No	443	32	-	-	No	60	58	12	99	44	

* LEGEND:
(A) Shielded Sensor with Heat Sink
(B) Unshielded Sensor with Heat Sink
(C) Sensor Attached to 1 x 4 Lumber

Table 2-2. Summary of Events as Observed on Motion Pictures

TEST NUMBER	START OF DEFLAGRATION SECONDS	MOST INTENSE FIRE FROM SECONDS	MOST INTENSE FIRE TO SECONDS	HEIGHT OF FLAMES FT.	LAST VISIBLE FLAMES SECONDS	END OF TEST (NO SMOKE) APPROXIMATE SECONDS
1	92	150	220	8	380	900
2	40	48	88	>20	148	600
3	3	11	65	>25	82	90

SECTION 3
PASSIVE SENSOR STUDY

3.1 TECHNICAL APPROACH

The passive sensor study was added to the heat flux study as a supplement to investigate whether passive sensors can be effectively used to determine pyrotechnic safety criteria. The passive sensors referred to here were paper thermometers with sensitivity ranges of 200, 250, 300, 350, 400, and 470^{o}F and samples of pyrotechnic materials all placed in the same pattern and at discrete distances from the heat source (stack of pyrotechnic end items). The "Operational Shielding Panel" described in paragraph 2.2.2, test 1, was used as a heat shield in all tests of this particular study.

The objectives of the passive sensor study were:

- To determine whether the operational shielding panel will attenuate flames and heat during prolonged fires of different intensities.
- To determine whether screening will effectively attenuate heat and protect against ignition by firebrand.
- To determine temperature ranges in close vicinity of deflagrating pyrotechnic stacks by using inexpensive expandable sensors.
- To determine how much effect wind has on fire propagation.

3.2 TEST PLAN

The general test pattern used was the same for all tests and is shown in Figure 3-1. In order to simplify describing the placement of the sensors, the following system will be used throughout this section:

a. All angular units will be measured in a clockwise direction from a base line (O^{o}) which starts at the center of the heat source (pyrotechnic stack) and continues perpendicular through the heat shield.

b. All distances are measured from the center of the heat source unless a starting point is specifically mentioned.

One array of paper thermometer stations was placed on the base line (O^{o}) behind the heat shield and another at 135^{o} or 225^{o}. The paper thermometers were attached to lengths of 1 x 4 lumber and positioned in a staggered pattern in order to prevent heat attenuation.

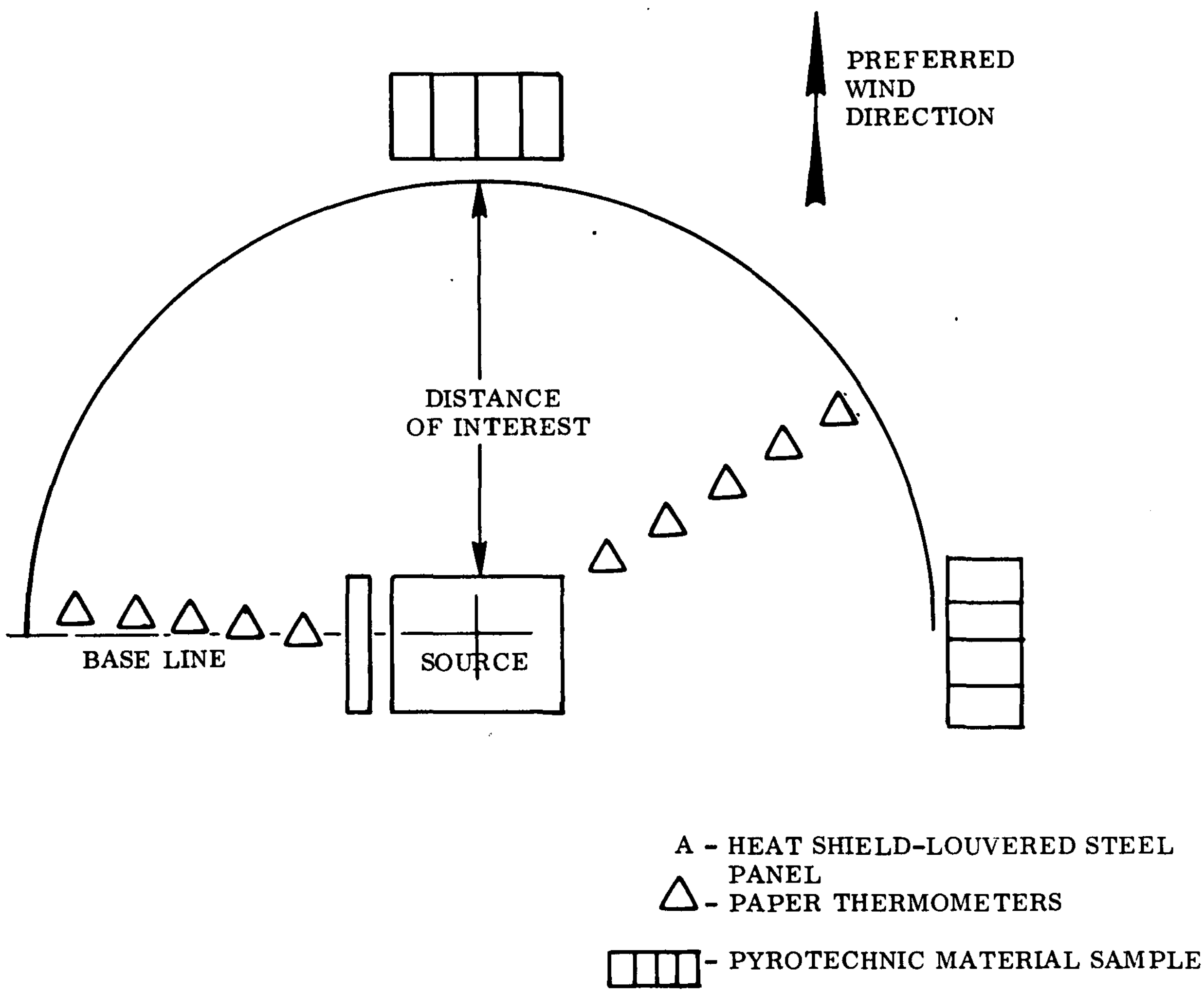

Figure 3-1. Passive Sensor Test Pattern

The two pyrotechnic sample arrays were placed at 90° or 270° and 180°. Under ideal conditions, the one at 90° or 270° would have been directly downwind from the pyrotechnic stack. The pyrotechnic sample array is shown in Figure 3-2 and consisted of four configurations with 100 g of pyrotechnic material placed in each:

- Open Tray - Direct access to flame, heat, or firebrand.
- Copper Screen Cover - A single sheet of copper screen supported above the sample hampering firebrand access but allowing free passage of flame and heat.
- Copper Screen Enclosure - A single layer of copper screen fashioned into a box configuration hampering direct contact from any ignition source.
- Steel Screen Enclosure - A coarse steel (1/4 inch) hardware screening material fashioned into an identical configuration as the copper enclosure.

The paper thermometer stations in the arrays were placed at two-foot intervals starting at four feet from the outside of the pyrotechnic stack. In test 3, two more stations with paper thermometers at 25 and 50 feet were added to each array. A typical paper thermometer array is shown in Figure 3-3.

The pyrotechnic sample arrays were placed at the following distances:

- Test 1: Both at 25 feet
- Test 2: 90° at 12 feet, 180° at 8 feet
- Test 3: 90° at 25 feet, 180° at 8 feet

Paper thermometers covering the entire range from 200° to 470°F were placed at each of the above sample stations.

In tests 1 and 2, the sample arrays were placed as shown in Figure 3-2, while in test 3 the four samples at each station were spaced one foot apart, in order to reduce the probability of flame propagation from one sample to the next.

A detailed description of the pyrotechnic end items used as heat source for the tests is given in Section 2, paragraphs 2.2.1 and 2.2.2.

3.3 TEST RESULTS

The test results have been tabulated for convenient comparison and are shown in Tables 3-1 and 3-2. The wind direction is that which prevailed during the test and is given from the base line. The wind velocities were as follows:

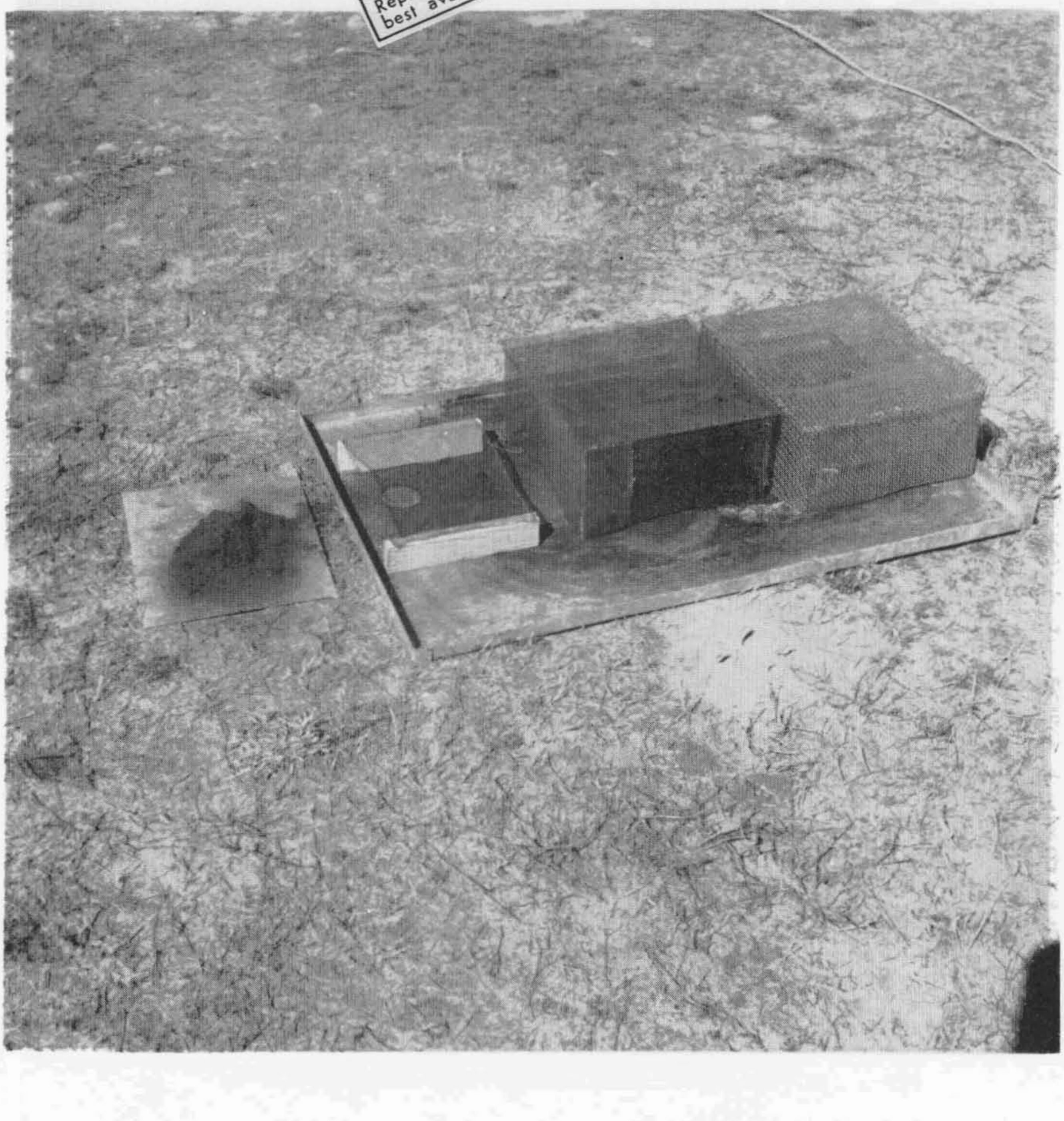

Figure 3-2. Pyrotechnic Material Array

Figure 3-3. Typical Paper Thermometer Array

Table 3-1. Summary of Test Results for Paper Thermometer Arrays

		TEST NO. 1				TEST NO. 2				TEST NO. 3			
Wind Direction													
Location		0^o		225^o		0^o		135^o		0^o		135^o	
Distance	Range	Reaction				Reaction				Reaction			
Ft	of	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
4	200	-	-	-	-	x		x		x		x	
	250	-	-	-	-	x		x		x		x	
	300		x	-	-	x		x		x		x	
	400	-	-	x		-	-	-	-	x		x	
	470	-	-	-	-	-	-	-	-	x		x	
6	200	-	-	-	-	x		x		x		x	
	250	-	-	-	-	x		x		x		x	
	300		x	-	-	x		x		x		x	
	400	-	-	x		-	-	-	-	x		x	
	470	-	-	-	-	-	-	-	-	x		x	
8	200	-	-	-	-	x		x		x		x	
	250	-	-	-	-	x		x		x		x	
	300		x	-	-	x		x		x		x	
	400	-	-		x	-	-	-	-	x		x	
	470	-	-	-	-	-	-	-	-	x		x	
10	200	-	-	-	-	x		x		x		x	
	250	-	-	-	-	x		x		x		x	
	300		x	-	-	x		x		x		x	
	400	-	-		x	-	-	-	-	x		x	
	470	-	-	-	-	-	-	-	-	x		x	
12	200	-	-	-	-	x		x		x		x	
	250	-	-	-	-	x		x		x		x	
	300		x	-	-	x		x		x		x	
	400	-	-		x	-	-	-	-	x		x	
	470	-	-	-	-	-	-	-	-	x		x	
25	200	-	-	-	-	-	-	-	-	x		x	
	250	-	-	-	-	-	-	-	-	x		x	
	300	-	-	-	-	-	-	-	-		x		x
50	200	-	-	-	-	-	-	-	-		x		x
	250	-	-	-	-	-	-	-	-		x		x
	300	-	-	-	-	-	-	-	-		x		x

NOTE: Dashes in the above columns indicate that temperature range was not used.

Table 3-2. Summary Of Test Results For Pyrotechnic Material Arrays

	TEST 1						TEST 2						TEST 3						
Sample Material	Sulfur Green						Sulfur Yellow						Sulfur Yellow						
Wind Direction	300^{o}						80^{o}						240^{o}						
Location	180^{o}			270^{o}			90^{o}			180^{o}			90^{o}			180^{o}			Remarks*
Configuration	Distance Ft.	React. yes	React. no	Distance Ft.	React. yes	React. no	Distance Ft.	React. yes	React. no	Distance Ft.	React. yes	React. no	Distance Ft.	React. yes	React. no	Distance Ft.	React. yes	React. no	
Open	25		x	25		x	12	x		8	x		25	S*		8	x		S=Pyrotechnic Material was Scorched
Copper Cover			x			x		x			x				x		x		
Copper Encl.			x			x		x			x				x		x		
Steel Encl.			x			x		x			x				x		x		
Paper Thermometer Range ^{o}F																			
200			x			x		x			x			x			x		
250			x			x		x			x			x			x		
300			x			x		x			x				x		x		
350			x			x		x			x				x		x		
400			x			x		x			x				x		x		
470			x			x		x			x				x		x		

- Test 1 - 7 to 8 knots
- Test 2 - 6 to 8 knots
- Test 3 - 14 to 20 knots

In the following paragraphs the test results and observations made at the test site and with motion pictures are discussed briefly.

3.3.1 TEST 1

The temperature behind the heat shield (0°) did at no time reach 300°F while downwind (225°) a temperature of 400°F was indicated (see Table 3-1). None of the pyrotechnic material arrays were ignited or even scorched (see Table 3-2), despite the fact that the downwind array showed considerable firebrand deposits (see Figures 3-4 and 3-5).

3.3.2 TEST 2

The temperature at both paper thermometer arrays reached at least 300°F at a distance of 12 feet (see Table 3-1). Both pyrotechnic material arrays burned completely. Checking the motion picture taken at this test, the downwind array (90°) ignited at approximately 60 seconds after time 0. Because of the position of the camera and heavy smoke, it could not be determined whether all configurations ignited simultaneously. However, just before their ignition, they were completely engulfed by flames from the deflagrating stack.

The open configuration of the array at 180° ignited at approximately 80 seconds in the test, followed one second later by the copper screen covered sample next to it. The copper and steel enclosed samples ignited approximately two seconds and nine seconds respectively after ignition of the open sample. Whether the open sample ignited due to flames or firebrand or heat radiation from the deflagrating stack is unknown. According to the paper thermometer arrays, the temperature exceeded 470°F at both locations.

3.3.3 TEST 3

The temperature at both paper thermometer arrays exceeded 470°F at 12 feet and 250°F at 25 feet, but did not reach 200°F at 50 feet (see Table 3-1).

The pyrotechnic material array at 180° burned completely. The motion picture shows that this array was engulfed by flames from approximately 11 seconds after time 0. Therefore, it is impossible to determine time and sequence of ignition. The paper thermometers at this location show a temperature in excess of 470°F.

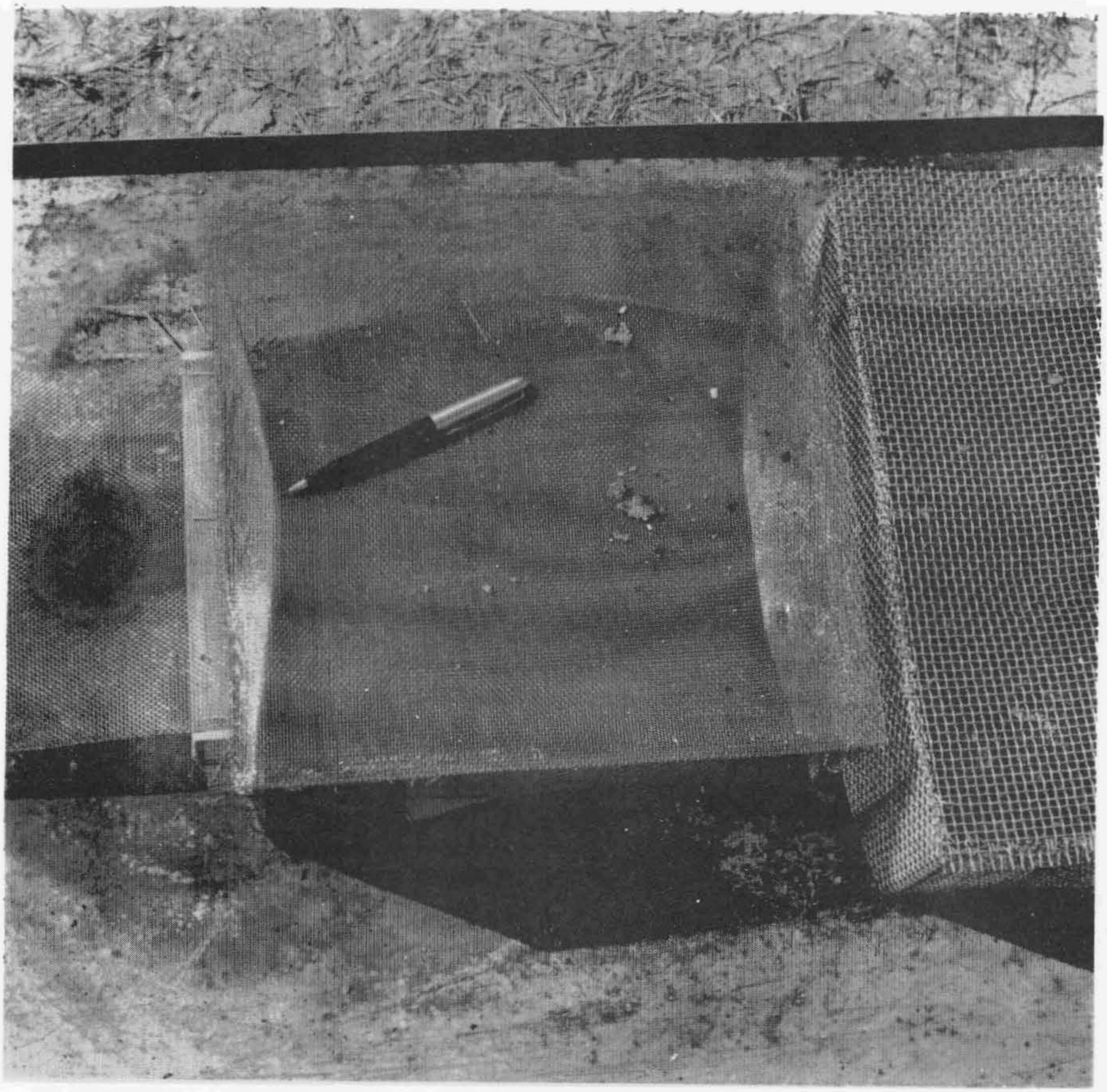

Figure 3-4. Firebrand Deposits on Screen of Pyrotechnic Material Array (Test 1, Downwind)

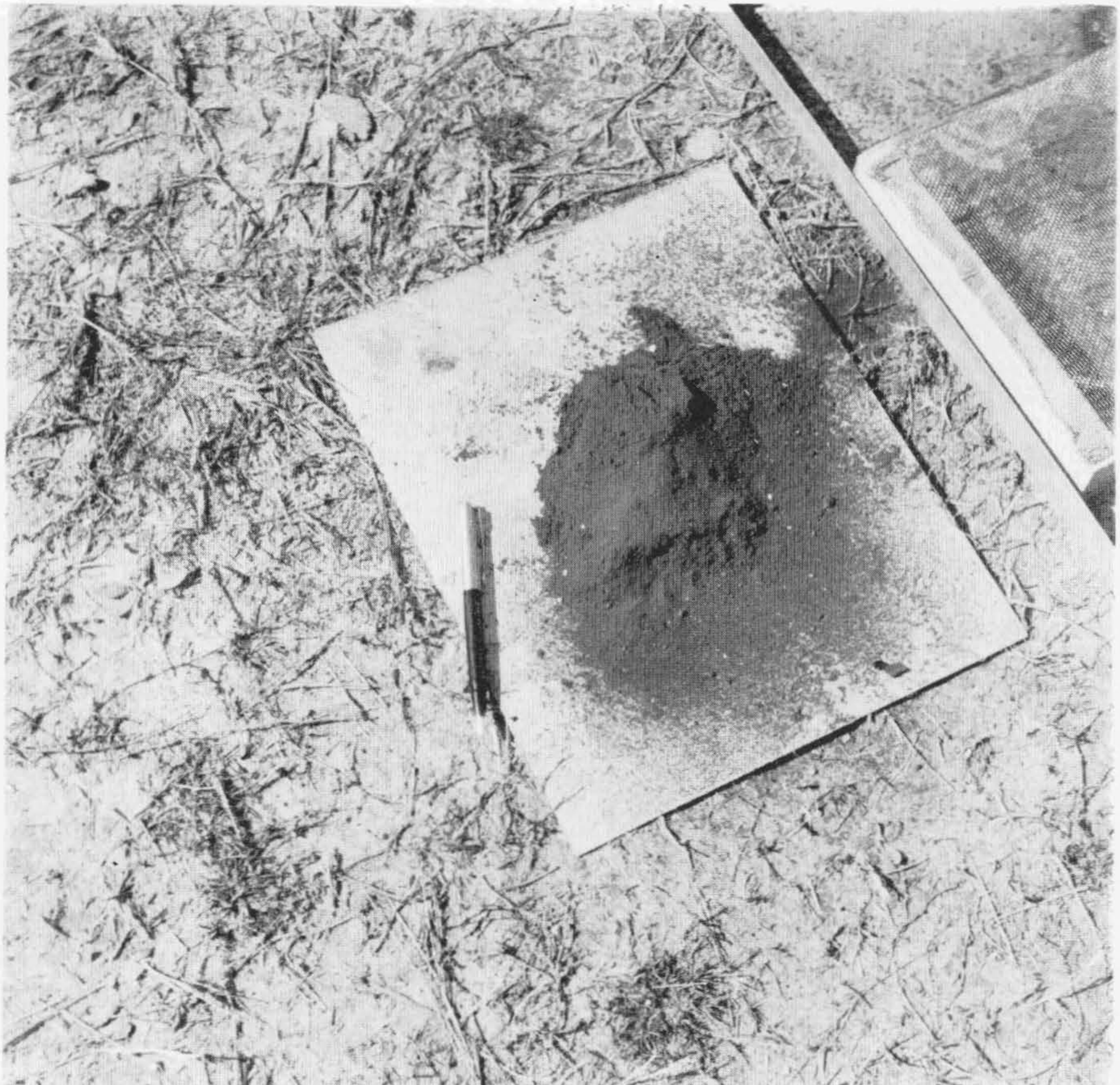

Figure 3-5. Firebrand Deposits on Open Sample of Pyrotechnic Material Array
(Test 1, Downwind)

The open sample of the material array at 80° was only scorched while the others stayed intact. The paper thermometers at this location showed that the temperature did not reach 300°F which is considerably below the ignition temperature of sulfur yellow. Several XM-9 CS canisters were thrown out of the deflagrating stack. One fell less than two feet from this material array which may explain the scorching of the open sample.

A one hundred and fifty square foot area 50 feet downwind from the pyrotechnic stack was covered with paper and was set on fire presumably by firebrand.

SECTION 4

CONCLUSIONS AND RECOMMENDATIONS

This study, despite its limited number of tests authorized, has indicated that heat flux measurements may be used as effective hazards evaluation criteria to determine safe quantity distances for pyrotechnics. However, it must be realized that data, observations, and results of only three tests do not permit drawing of conclusions decisive enough to make specific recommendations. Therefore, an attempt will be made in this section to compare and correlate some assumptions and findings made during the discussions of test results in the two previous sections of this report.

The operational shielding studies (see reports GE-MTSD-R-058 and R-060) have shown that the type panel used as heat shield in this study will attenuate the fireball from an exploding white phosphorous round. In test 1 (HC smoke), the 4 x 4 foot heat shield placed approximately two feet from the edge of the pyrotechnic stack appeared to attenuate heat flux as measured by heat flux and passive sensors. However, test 3 (XM-9 CS canisters) resulted in a flame diameter sufficiently large to engulf the panel; therefore, evaluation of attenuating effects was impossible. It is believed that a panel of larger dimensions may have confirmed the findings of Test 1.

Wind undoubtedly has some influence on heat transfer as shown by the heat flux data at stations 3 and 4 in tests 2 and 3 and the reaction of some downwind paper thermometers in test 1. However, how much smoke, convective heat, wind velocity, cooling effect on exposed sensors, etc., contribute to the differences in the heat flux measurements is yet unknown.

The ignition cause of the open sample in the pyrotechnic material array at the 180^{o} location in test 2 could not be determined. However, within nine seconds the other three samples ignited in sequence starting with the one closest to the burning sample. The motion picture shows that after ignition of the first sample, flames from the deflagrating stack did not reach the array location for at least 60 seconds. Therefore, it can be assumed that ignition of the three samples occurred through flame propagation between them. The last sample (which was covered by a steel screen enclosure) did not ignite for seven seconds after ignition of the sample positioned next to it (which was in a copper enclosure) and was aflame within two seconds following ignition of the open (without an enclosure) sample. This shows that this type of steel screening is a better heat and flame attenuator than copper window screening which confirmed laboratory tests previously performed.

Generally, the use of passive sensors can be of appreciable value in providing useful, empirical information at low cost.

Based on the results of this study, heat flux measurements can be used to effectively evaluate hazards criteria of pyrotechnics and to determine safe quantity distances. It is therefore recommended to continue these studies using more instrumentation, such as heat flux sensors and thermocouples, and more flame and heat attenuating devices.

APPENDIX A
HEAT FLUX DATA ACQUISITION SYSTEM

The heat flux data acquisition system is designed to be completely portable so that it can be used in the field for test data transmission to the data processing facilities in the Data Handling Center at MTF.

The package consists of a bank of DC amplifiers, a thermocouple reference ice bath, an FM/FM multiplexer/transmitter, and a portable intermediate band magnetic tape recorder for backup. The signals from the sensors in the field are received, amplified, and multiplexed. They can now be either transmitted to the Data Handling Center or recorded on the portable tape recorder in the Test Control Center or both. Prior to testing, the measuring systems are verified from end to end and calibrated by transmitting a 0 and a 100 percent (full scale) calibration signal to the Data Handling Center, where with the aid of a computer, a direct real-time readout in corrected engineering units is made on a line printer. Should the test be lengthy or delayed, the computer can be released for other use. In this case, the transmitted raw data will be recorded on a tape recorder for data processing at a later time.

However, if the test is reasonably short and the computer can stay on line, the transmitted data will be processed immediately and the line printer will provide a real-time running tab listing in corrected engineering units. Figure A-1 shows an actual printout of a verification and calibration run prior to heat flux test 2. The two top lines are channel designations. The first three vertical columns represent the hours, minutes, and seconds of the day in Central Standard Time. Columns F1-02 through F1-05 represent temperature measured by thermocouples in ^{o}F and columns F1-06 through F1-09 are heat flux measured by heat flux sensors in $Btu/ft^2 \cdot h$. The lines between 10:05:48 and 10:06:06 show calibration at 0 percent and those between 10:06:15 and 10:06:33 at 100% or full scale.

Figures A-2 and A-3 show schematically the different data acquisition capabilities.

Figure A-4 depicts the actual setup of the portable telemetry package in the field. The Precision Potentiometer and the Frequency Counter are used only for setup and calibration.

To further demonstrate the different capabilities of data acquisition discussed above, the pages following this section show actual data of test 3 for the first 38 seconds of the test. Since the computer was not available at the time of the test, the data were taped and processed five days later. Therefore, the first column of the printouts show the elapsed time in milliseconds from the time data collection started shortly before the first calibration and verification run. The data shown are in one-tenth of a second intervals. Time 0 (ignition) occurred at 616.021 seconds as marked. The figures in the third and fourth lines of the heading on each sheet are

			F1 02	F1 03	F1 04	F1 05	F1 06	F1 07	F1 08	F1 09	
10	05	41	93.359	83.218	80.390	81.109	-2.0683	-.47460	-.47460	-.49414	
10	05	42	93.416	82.246	80.361	81.710	-1.9394	-.38281	-.23632	-.40234	
10	05	43	94.187	82.904	79.705	82.013	-2.0859	-.27343	-.25585	-.47460	
10	05	44	93.531	83.046	79.960	76.439	-2.2519	-.41992	-.62109	-.41992	
10	05	45	93.416	83.560	80.503	76.740	-2.3613	-.34765	-.34765	-.51171	
10	05	46	93.644	82.560	80.046	75.234	-1.9394	-.23632	-.49414	-.67578	
10	05	47	92.759	82.990	80.619	76.740	-2.2324	-.23632	-.29296	-.78710	
10	05	48	32.884	29.201	28.744	20.703	-1.9941	-.49414	-.56640	-.76757	← 0% calibration begins
10	05	49	32.798	28.515	28.800	24.167	-2.3066	-.38281	-.80468	-.84179	
10	05	50	32.941	28.972	28.572	23.414	-2.1777	-.27343	-.47460	-.76757	
10	05	51	32.941	29.087	28.601	21.003	-2.3066	-.43945	-.91406	-.80468	
10	05	52	32.855	29.058	28.458	22.660	-2.3066	-.38281	-.75000	-1.0253	
10	05	53	32.855	28.402	28.687	22.962	-2.0683	-.38281	-.82226	-.67578	
10	05	54	32.798	28.744	28.830	26.878	-2.2695	-.40234	-.76757	-.98828	
10	05	55	32.998	29.316	28.773	23.865	-2.0507	-.38281	-.73242	-.58593	
10	05	56	32.998	28.601	28.716	22.509	-2.3789	-.43945	-.78710	-.71289	
10	05	57	32.685	28.601	28.830	24.919	-2.3613	-.38281	-.69531	-.69531	
10	05	58	32.884	28.859	28.429	26.878	-2.2695	-.34765	-.85937	-.51171	
10	05	59	32.884	29.115	28.488	22.660	-2.4531	-.32812	-.75000	-.60351	
10	06	00	32.970	28.886	28.601	25.824	-2.2519	-.51171	-.89648	-1.0429	
10	06	01	32.884	28.630	28.343	27.783	-2.3066	-.31054	-.67578	-.76757	
10	06	02	33.083	28.886	28.945	22.962	-2.4902	-.40234	-.75000	-.95117	
10	06	03	33.027	29.115	28.630	23.865	-2.0683	-.43945	-.80468	-.58593	
10	06	04	33.142	29.173	28.630	25.974	-2.2148	-.40234	-.58593	-.64062	
10	06	05	33.083	28.830	28.544	22.208	-2.3066	-.43945	-.84179	-.75000	
10	06	06	32.855	28.601	28.945	19.347	-2.3242	-.34765	-.78710	-.75000	← 0% calibration ends
10	06	07	91.816	82.904	79.904	79.300	-2.0859	-.41992	-.29296	-.85937	
10	06	08	91.617	82.619	79.589	76.138	-2.3242	-.56640	-.29296	-.54882	
10	06	09	92.416	82.675	79.675	77.191	-1.9394	-.51171	-.18164	-.51171	
10	06	10	92.703	82.390	79.818	82.464	-1.9941	-.38281	-.27343	-.75000	
10	06	11	92.302	82.447	79.476	76.138	-1.8671	-.40234	-.27343	-.73242	
10	06	12	92.474	82.675	79.847	77.191	-1.9394	-.41992	-.23632	-.54882	
10	06	13	92.302	83.218	80.304	82.765	-1.9765	-.51171	-.07226	-.62109	
10	06	14	91.873	82.246	79.589	83.218	-2.0859	-.58593	-.25585	-.64062	
10	06	15	500.28	501.31	498.97	2500.3	299.52	300.84	299.79	299.57	← 100% calibration begins
10	06	16	500.34	501.37	499.28	2497.5	299.65	300.93	299.63	299.52	
10	06	17	500.37	501.28	498.94	2497.1	299.35	301.06	299.50	299.43	
10	06	18	500.22	501.51	498.79	2497.4	299.43	300.98	299.65	299.55	
10	06	19	500.25	501.54	498.74	2498.4	299.41	300.95	299.90	299.48	
10	06	20	500.22	501.28	498.68	2497.4	299.32	301.06	299.48	299.48	
10	06	21	500.02	501.25	498.48	2496.3	299.41	301.02	299.15	299.76	
10	06	22	499.97	500.99	498.00	2497.5	299.15	300.98	299.15	299.32	
10	06	23	500.02	501.48	498.14	2496.3	299.10	300.96	299.37	299.24	
10	06	24	500.00	501.19	497.68	2493.2	299.17	301.06	299.37	299.32	
10	06	25	500.00	501.02	497.71	2495.3	299.13	301.04	299.43	299.08	
10	06	26	500.02	500.91	497.54	2493.9	299.15	301.06	299.06	299.06	
10	06	27	499.97	501.14	497.85	2497.5	299.00	301.06	299.19	299.11	
10	06	28	499.97	500.99	497.45	2494.1	298.90	300.93	298.99	299.11	
10	06	29	499.97	500.99	497.71	2493.8	298.91	300.89	299.00	299.00	
10	06	30	570.17	500.88	497.77	2494.8	299.08	300.82	298.95	299.08	100% calibration
10	06	31	500.02	500.99	497.88	2495.0	299.00	300.91	299.23	299.26	
10	06	32	500.00	500.91	498.02	2495.3	299.00	300.93	299.06	299.19	← ends
10	06	33	499.57	497.88	481.40	2115.2	187.91	111.33	48.324	-7.4335	
10	06	34	91.216	82.447	79.562	77.644	-2.4707	-.84179	-1.0058	-.98828	
10	06	35	91.644	82.818	78.904	81.710	-2.4531	-.85937	-1.1718	-.75000	
10	06	37	91.388	82.990	79.562	76.439	-2.2148	-.85937	-.56640	-.91406	

Figure A-1. Heat Flux Test Data Processed During this Test

20

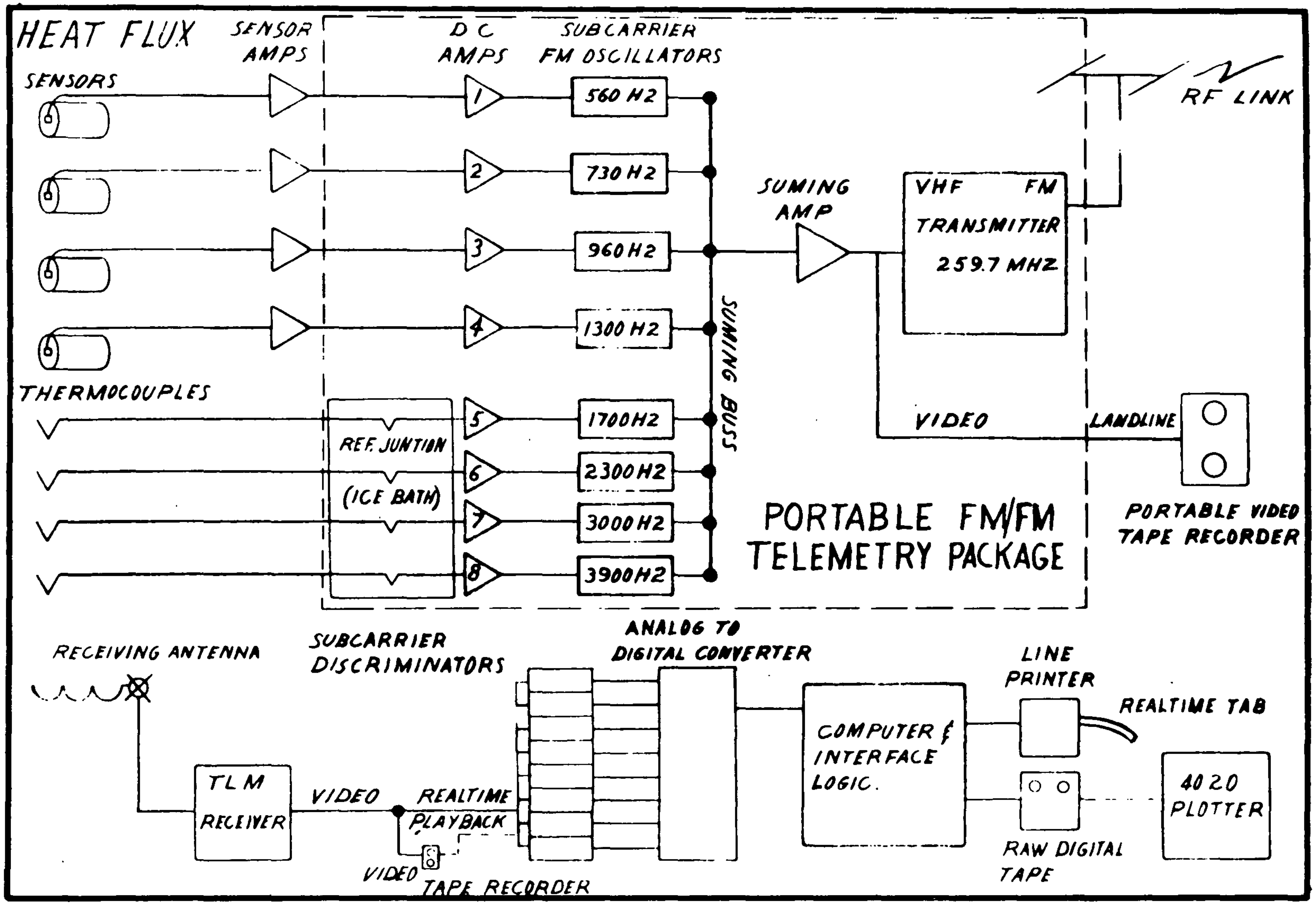

Figure A-2. Block Diagram of Portable Telemetry Package for Heat Flux Measurements

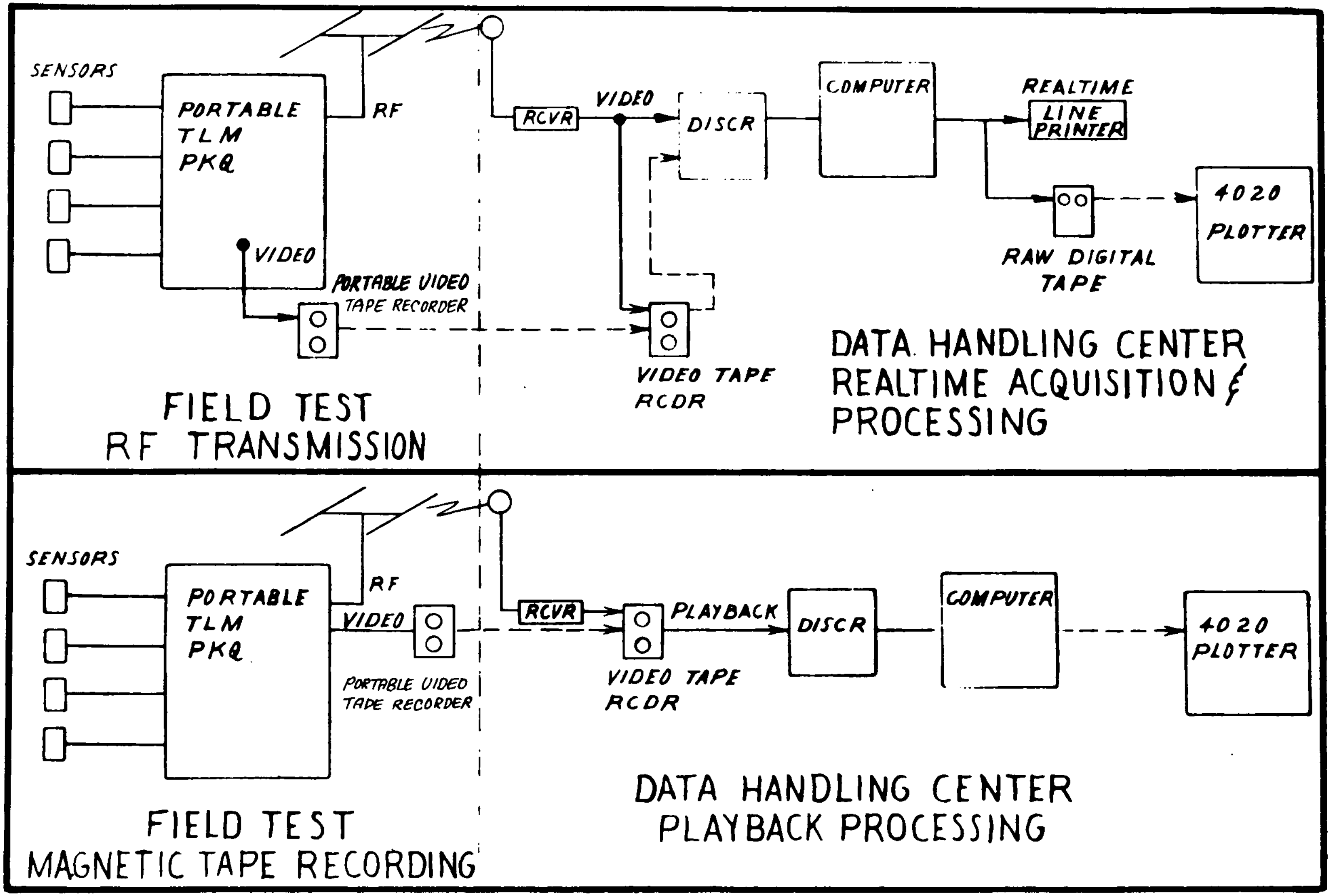

Figure A-3. Block Diagram of Various Data Acquisition Systems for Heat Flux Measurements

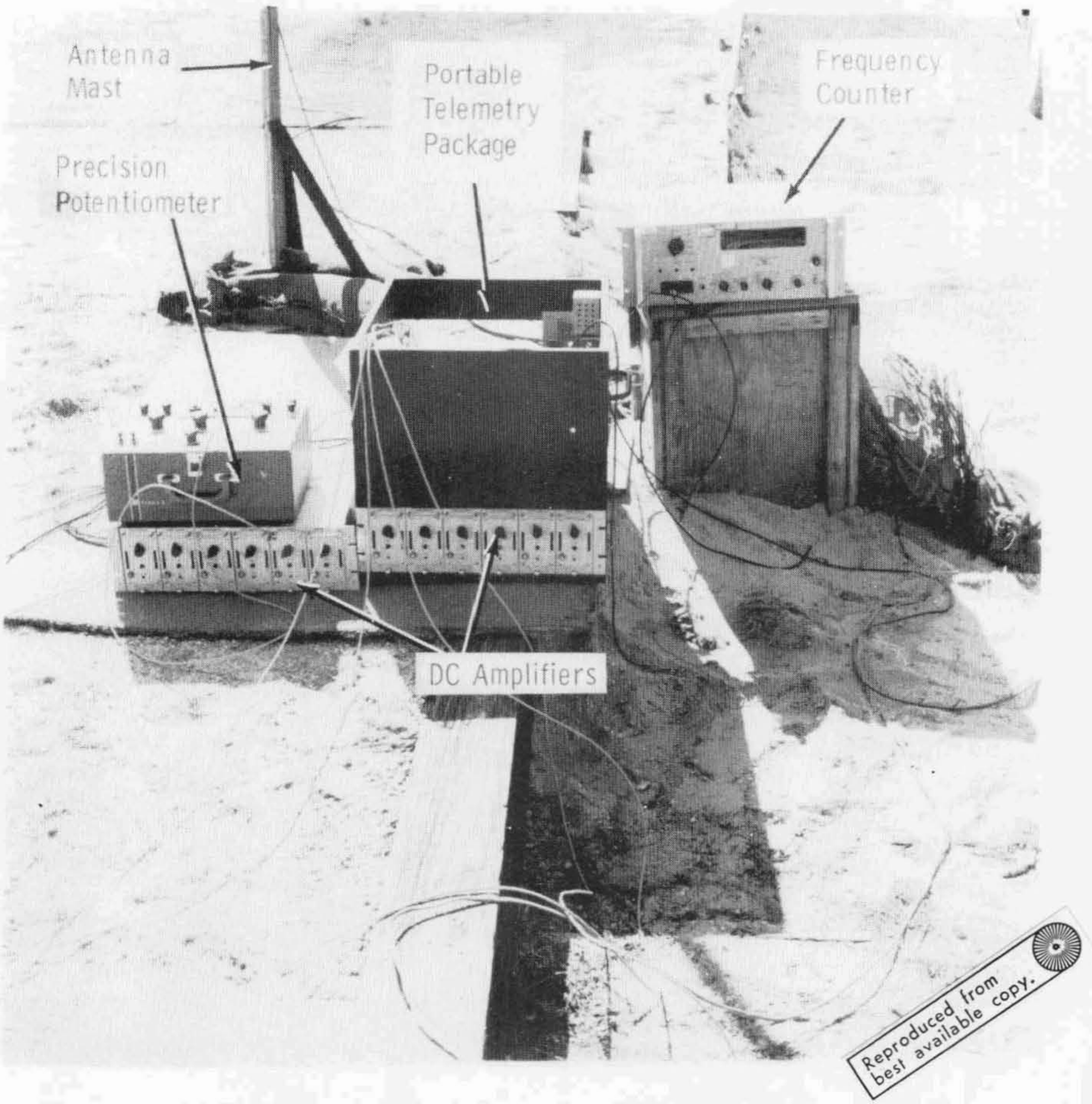

Figure A-4. Portable Telemetry Package for Heat Flux Measurements are channel identification numbers for the computer. The data in the columns headed by these figures represent the following measurements taken during test 3:

- C001-001: Actual Temperature of the heat sink at Station 1
- C001-002: Actual Temperature at Station 4
- C001-003: Actual Temperature at Station 3
- C001-004: Actual Temperature at Station 5 (pyrotechnic stack)
- N001-001: Heat flux at Station 2
- N001-002: Heat flux at Station 1
- N001-003: Heat flux at Station 4
- N001-004: Heat flux at Station 3

The data for heat flux in columns N001-001 through N001-004 have to be multiplied by a factor of 10.

HEAT FLUX TEST DATA RECORDED
DURING TEST AND
PROCESSED AT A LATER DATE

REMOPS FLX 1 03-31-71

ID.-FLX1 TYP= FM - TABULATION OF VALUES TIME 0 =15 31 30

		TIME SEC	C001 001 DEGS FAH	C001 002 DEGS FAH	C001 003 DEGS FAH	C001 004 DEGS FAH	N001 001 BTU/SQ FT/SEC	N001 002 BTU/SQ FT/SEC	N001 003 BTU/SQ FT/SEC	N001 004 BTU/SQ FT/SEC
+	611.420	69.6000	71.6000	71.3000	96.0000	1.83000	-2.22000	.930000	.470000
+	611.520	69.2000	70.4000	69.7000	85.9000	2.07000	-1.72000	1.28000	.730000
+	611.620	70.2000	72.0000	71.1000	83.9000	1.19000	-2.23000	.280000	.160000
+	611.720	69.2000	71.4000	70.2000	92.4000	1.94000	-2.13000	1.06000	.380000
+	611.820	71.0000	70.5000	69.4000	64.1000	1.69000	-1.98000	.890000	.660000
+	611.920	70.6000	72.1000	71.8000	86.5000	1.27000	-2.60000	.630000	.350000
+	612.020	70.2000	71.1000	70.9000	93.3000	2.08000	-2.25000	.710000	.240000
+	612.120	69.8000	70.2000	69.4000	79.9000	1.43000	-2.05000	.830000	.750000
+	612.220	70.5000	71.1000	71.1000	84.1000	1.39000	-2.68000	.720000	.080000
+	612.320	68.7000	70.0000	70.1000	90.5000	2.16000	-1.82000	1.20000	.570000
+	612.420	69.6000	72.2000	69.7000	77.6000	.980000	-2.25000	.790000	.550000
+	612.520	70.3000	72.9000	71.3000	87.2000	1.48000	-2.48000	.450000	.060000
+	612.620	69.1000	72.0000	69.7000	89.9000	1.92000	-1.72000	1.40000	.610000
+	612.720	69.8000	69.5000	70.2000	78.8000	1.59000	-2.23000	.520000	.460000
+	612.820	70.7000	71.1000	71.0000	87.5000	1.22000	-2.22000	.280000	.160000
+	612.920	69.4000	70.3000	70.2000	91.5000	1.83000	-1.62000	1.14000	.510000
+	613.020	70.3000	72.1000	70.7000	79.1000	1.57000	-2.21000	.200000	.060000
+	613.120	70.2000	74.2000	71.7000	89.8000	1.37000	-2.30000	.210000	.080000
+	613.221	69.3000	71.4000	69.9000	85.1000	1.97000	-1.46000	1.21000	.660000
+	613.321	70.2000	71.3000	70.2000	82.0000	1.37000	-2.23000	.250000	.310000
+	613.421	69.3000	71.1000	71.6000	91.6000	1.38000	-2.28000	.140000	-.200000
+	613.521	70.6000	68.8000	69.6000	86.8000	2.30000	-1.46000	.850000	.710000
+	613.621	69.7000	71.4000	69.9000	81.5000	1.40000	-2.17000	.260000	.200000
+	613.721	71.3000	71.5000	71.3000	94.5000	1.83000	-2.20000	.230000	.350000
+	613.821	68.5000	70.3000	69.4000	82.9000	1.95000	-1.74000	1.20000	.870000
+	613.921	70.7000	72.3000	70.7000	80.9000	1.14000	-2.58000	.100000	-.020000
+	614.021	70.6000	72.3000	70.6000	95.8000	2.04000	-2.09000	.450000	.460000
+	614.121	69.1000	70.3000	69.6000	80.3000	1.53000	-1.70000	1.22000	.800000
+	614.221	70.6000	73.4000	70.2000	82.3000	1.07000	-2.44000	.590000	.400000
+	614.321	69.3000	72.8000	70.5000	95.7000	1.75000	-2.21000	.800000	.360000
+	614.421	69.8000	71.0000	69.2000	77.9000	1.49000	-1.80000	1.04000	.800000
+	614.521	69.5000	73.4000	71.5000	83.2000	1.69000	-2.24000	.550000	.200000
+	614.621	69.8000	72.0000	71.4000	91.5000	1.64000	-1.66000	.680000	.380000
+	614.721	68.9000	72.1000	70.1000	77.3000	1.52000	-1.52000	.420000	.630000
+	614.821	71.0000	72.8000	71.7000	89.2000	1.04000	-1.88000	.360000	-.120000
+	614.921	68.9000	72.5000	70.3000	93.4000	2.11000	-1.15000	.450000	.300000
+	615.021	69.3000	71.9000	69.8000	80.8000	1.52000	-1.68000	.550000	.360000
+	615.121	68.5000	73.1000	71.4000	88.3000	.960000	-1.95000	.310000	-.160000
+	615.221	70.4000	72.3000	69.7000	89.6000	2.47000	-1.50000	1.21000	.310000
+	615.321	70.7000	71.5000	69.4000	77.1000	1.29000	-1.72000	.470000	.040000
+	615.421	70.5000	73.2000	71.7000	89.3000	1.39000	-1.76000	.210000	-.020000
+	615.521	69.2000	71.3000	69.5000	85.9000	1.94000	-1.20000	1.19000	.390000
+	615.621	70.1000	72.7000	70.2000	79.2000	1.38000	-1.93000	.000000	-.070000
+	615.721	70.8000	72.9000	70.8000	91.8000	1.78000	-1.76000	.400000	-.060000
+	615.821	68.4000	69.6000	70.2000	86.3000	1.88000	-1.10000	1.14000	.720000
+	615.921	69.6000	70.9000	70.5000	80.0000	1.60000	-1.62000	.390000	.120000
+	616.021	69.1000	71.7000	72.1000	93.9000	1.57000	-1.52000	.420000	-.290000
+	616.121	68.9000	68.8000	69.4000	82.4000	2.04000	-.720000	1.20000	.840000

Time 0 ←(ignition)

KEMOPS FLX 1 03-31-71

ID.-FLX1 TYP- FM

TABULATION OF VALUES

TIME 0 =15 31 30

	TIME SEC	C001 001 DEGS FAH	C001 002 DEGS FAH	C001 003 DEGS FAH	C001 004 DEGS FAH	N001 001 BTU/SQ FT/SEC	N001 002 BTU/SQ FT/SEC	N001 003 BTU/SQ FT/SEC	N001 004 BTU/SQ FT/SEC
+	616.221	70.9000	72.3000	70.7000	79.2000	1.55000	-1.46000	.910000	.200000
+	616.321	69.2000	71.2000	70.4000	91.0000	1.61000	-1.09000	1.11000	.390000
+	616.421	69.2000	71.4000	69.5000	77.3000	1.97000	-.500000	1.20000	1.32000
+	616.521	70.7000	72.1000	70.6000	78.5000	1.35000	-1.28000	.760000	.630000
+	616.621	69.8000	72.9000	70.7000	92.8000	1.96000	-1.62000	.870000	.590000
+	616.721	69.3000	70.2000	69.2000	77.9000	2.00000	-.760000	.980000	1.14000
+	616.821	71.1000	71.0000	71.8000	82.4000	1.09000	-1.16000	.460000	.480000
+	616.921	69.3000	70.2000	70.7000	92.4000	2.10000	-.540000	.570000	.710000
+	617.021	70.8000	69.5000	69.9000	81.5000	1.77000	-.180000	.980000	.880000
+	617.121	67.9000	72.3000	71.6000	83.6000	1.36000	-.410000	.370000	.430000
+	617.222	69.3000	71.9000	70.3000	88.3000	2.22000	.370000	.770000	.540000
+	617.322	67.5000	72.1000	69.4000	80.9000	1.79000	.100000	1.04000	1.00000
+	617.422	70.0000	72.0000	71.5000	83.5000	1.32000	-.220000	.640000	.360000
+	617.522	68.7000	69.5000	70.4000	91.6000	2.61000	.500000	.980000	.760000
+	617.622	69.6000	71.7000	69.6000	78.5000	2.23000	.280000	.960000	1.08000
+	617.722	70.5000	73.2000	71.1000	89.8000	1.95000	.030000	.800000	.710000
+	617.822	69.6000	71.1000	69.8000	90.7000	2.69000	.910000	1.38000	1.17000
+	617.922	70.2000	70.3000	69.9000	77.0000	2.19000	.600000	.920000	.770000
+	618.022	68.8000	70.6000	71.3000	86.6000	2.30000	.060000	.750000	.830000
+	618.122	68.9000	71.7000	69.9000	87.2000	2.79000	.570000	1.24000	1.39000
+	618.222	69.9000	71.5000	70.0000	76.4000	2.18000	.060000	1.02000	.710000
+	618.322	70.2000	71.3000	70.6000	88.4000	2.28000	-.090000	.880000	.530000
+	618.422	68.9000	68.6000	69.2000	82.9000	3.37000	.630000	1.56000	1.20000
+	618.522	70.6000	73.1000	70.5000	76.2000	2.75000	.020000	.950000	.590000
+	618.622	69.2000	72.2000	71.3000	92.8000	2.90000	.060000	.980000	.770000
+	618.722	69.8000	69.5000	69.3000	80.2000	2.92000	.640000	1.73000	1.47000
+	618.822	70.7000	71.2000	70.8000	76.7000	2.41000	-.170000	.910000	.770000
+	618.922	70.5000	72.9000	71.4000	95.4000	2.48000	.040000	1.28000	.790000
+	619.022	67.3000	69.8000	68.5000	77.3000	2.64000	.940000	2.23000	1.45000
+	619.122	69.3000	72.0000	70.3000	79.7000	2.48000	.120000	1.12000	.830000
+	619.222	70.4000	71.3000	70.2000	93.9000	3.03000	.510000	1.56000	1.06000
+	619.322	68.6000	70.2000	69.4000	75.6000	2.96000	.470000	1.87000	1.47000
+	619.422	70.8000	72.6000	70.7000	82.7000	2.46000	.140000	1.10000	.930000
+	619.522	69.7000	70.7000	70.6000	91.9000	3.03000	1.07000	1.56000	1.23000
+	619.622	69.3000	69.2000	69.6000	75.9000	2.48000	1.27000	1.90000	1.56000
+	619.722	69.6000	72.6000	71.5000	81.7000	1.87000	.980000	1.17000	.910000
+	619.822	68.1000	71.8000	69.8000	92.2000	3.18000	1.77000	1.46000	1.16000
+	619.922	67.9000	68.9000	69.4000	73.4000	2.83000	1.86000	1.85000	1.55000
+	620.022	70.1000	72.6000	71.4000	82.1000	3.08000	1.90000	1.60000	1.17000
+	620.122	69.5000	70.2000	69.3000	88.7000	3.63000	2.58000	1.87000	1.67000
+	620.222	69.2000	70.6000	69.5000	70.4000	2.88000	1.73000	1.61000	1.49000
+	620.322	68.2000	73.3000	71.6000	85.0000	3.03000	1.65000	1.49000	1.12000
+	620.422	68.3000	68.9000	69.3000	87.8000	3.97000	2.66000	1.73000	1.83000
+	620.522	70.0000	71.5000	69.3000	72.9000	3.26000	2.24000	1.35000	1.37000
+	620.622	69.5000	72.1000	71.9000	84.7000	3.16000	2.49000	.930000	1.40000
+	620.722	69.9000	70.8000	69.2000	79.7000	3.98000	3.99000	1.79000	1.84000
+	620.822	68.9000	71.0000	70.3000	72.8000	3.58000	3.57000	1.28000	1.19000
+	620.922	70.1000	71.3000	71.4000	86.0000	4.29000	3.75000	1.41000	1.21000

KEMOPS FLX 1 03-31-71

ID.-FLX1 TYP= FM TABULATION OF VALUES TIME 0 =15 31 30

	TIME SEC	C001 001 DEGS FAH	C001 002 DEGS FAH	C001 003 DEGS FAH	C001 004 DEGS FAH	N001 001 BTU/SQ FT/SEC	N001 002 BTU/SQ FT/SEC	N001 003 BTU/SQ FT/SEC	N001 004 BTU/SQ FT/SEC
+	621.022	68.5000	70.6000	69.5000	77.3000	5.05000	4.39000	2.55000	1.83000
+	621.122	69.3000	70.2000	70.2000	72.5000	4.40000	3.88000	1.70000	1.41000
+	621.223	70.4000	72.7000	71.3000	63.9000	5.21000	4.37000	1.98000	1.10000
+	621.323	68.5000	69.5000	69.8000	72.3000	5.43000	5.15000	2.85000	2.00000
+	621.423	70.0000	71.8000	71.1000	74.4000	4.82000	4.52000	2.03000	1.30000
+	621.523	68.7000	71.9000	71.6000	68.0000	5.67000	4.96000	2.33000	1.56000
+	621.623	68.9000	70.9000	69.3000	71.3000	5.62000	5.64000	2.87000	2.20000
+	621.723	69.8000	71.9000	71.5000	73.4000	5.15000	5.13000	2.14000	1.36000
+	621.823	69.6000	72.8000	71.2000	83.5000	6.14000	6.06000	2.64000	1.69000
+	621.923	68.3000	71.0000	69.8000	66.3000	5.64000	6.26000	2.80000	2.10000
+	622.023	70.4000	73.4000	71.6000	74.1000	5.93000	5.73000	2.13000	1.08000
+	622.123	69.7000	72.7000	70.5000	79.6000	6.63000	6.46000	2.39000	1.70000
+	622.223	70.1000	70.4000	69.5000	68.0000	5.97000	6.57000	2.81000	2.12000
+	622.323	69.2000	72.1000	71.7000	72.8000	5.53000	6.32000	2.24000	1.84000
+	622.423	68.7000	71.4000	71.1000	80.5000	6.72000	6.84000	2.15000	1.96000
+	622.523	69.4000	71.5000	70.4000	67.7000	6.11000	6.66000	2.48000	2.10000
+	622.623	70.3000	73.1000	71.3000	76.7000	5.96000	6.48000	2.12000	1.52000
+	622.723	69.6000	71.7000	70.2000	78.3000	6.63000	7.52000	2.72000	1.52000
+	622.823	68.8000	71.1000	70.2000	64.3000	6.30000	6.78000	2.58000	1.73000
+	622.923	70.2000	72.1000	72.0000	77.7000	6.47000	6.94000	2.30000	1.57000
+	623.023	68.9000	72.1000	69.9000	72.5000	7.50000	7.57000	2.99000	2.21000
+	623.123	70.9000	70.3000	70.1000	63.7000	6.93000	6.89000	2.46000	1.53000
+	623.223	69.1000	72.8000	71.7000	75.2000	7.03000	6.62000	2.61000	1.76000
+	623.323	69.6000	72.4000	70.0000	70.5000	7.98000	7.35000	3.02000	2.06000
+	623.423	70.4000	70.8000	71.3000	61.8000	7.15000	6.59000	2.87000	1.47000
+	623.523	68.8000	73.7000	72.0000	76.1000	7.55000	7.10000	2.50000	.930000
+	623.623	69.1000	71.8000	70.0000	63.7000	8.31000	8.19000	3.34000	1.83000
+	623.723	68.7000	71.0000	71.0000	61.5000	7.66000	7.61000	3.24000	1.64000
+	623.823	70.4000	72.8000	71.9000	74.1000	8.10000	7.85000	2.94000	1.76000
+	623.923	68.9000	70.2000	69.7000	64.3000	7.65000	8.19000	3.73000	2.13000
+	624.023	69.8000	72.5000	71.3000	58.9000	7.44000	7.62000	2.94000	1.40000
+	624.123	68.6000	72.1000	71.8000	70.8000	8.00000	8.13000	2.99000	1.55000
+	624.223	69.3000	71.7000	68.7000	55.6000	8.11000	8.56000	3.79000	2.50000
+	624.323	69.3000	71.9000	71.9000	62.5000	8.03000	8.13000	2.92000	1.69000
+	624.423	69.1000	71.1000	71.3000	74.4000	8.86000	8.54000	3.09000	2.13000
+	624.523	69.3000	72.1000	69.7000	55.9000	8.96000	8.96000	3.73000	2.71000
+	624.623	69.8000	71.5000	71.3000	61.6000	8.66000	8.53000	2.96000	2.10000
+	624.723	69.7000	71.5000	70.3000	67.3000	9.33000	8.90000	3.94000	2.85000
+	624.823	68.7000	70.3000	69.5000	53.2000	8.70000	8.76000	3.43000	2.98000
+	624.923	71.6000	73.7000	71.6000	60.4000	7.96000	8.19000	2.98000	2.16000
+	625.023	69.5000	70.9000	70.9000	68.0000	8.82000	8.70000	3.79000	2.52000
+	625.123	69.8000	71.8000	70.0000	51.2000	8.28000	8.51000	3.28000	2.44000
+	625.224	71.3000	73.7000	72.3000	62.2000	8.43000	8.32000	2.71000	2.28000
+	625.324	69.5000	72.7000	70.7000	67.7000	9.15000	8.96000	2.90000	2.42000
+	625.424	69.3000	71.8000	70.0000	46.9000	8.72000	8.12000	2.41000	2.32000
+	625.524	69.8000	72.5000	72.1000	66.4000	9.14000	8.25000	2.91000	2.48000
+	625.624	69.2000	73.2000	70.2000	62.2000	10.8400	8.98000	3.63000	3.38000
+	625.724	69.7000	72.9000	71.5000	46.4000	10.1000	8.39000	3.13000	3.04000

FOLDOUT FRAME

KEMOPS FLX 1 03-31-71

ID.-FLX1 TYP= FM TABULATION OF VALUES TIME 0 =15 31 30

TIME SEC	C001 001 DEGS FAH	C001 002 DEGS FAH	C001 003 DEGS FAH	C001 004 DEGS FAH	N001 001 BTU/SQ FT/SEC	N001 002 BTU/SQ FT/SEC	N001 003 BTU/SQ FT/SEC	N001 004 BTU/SQ FT/SEC
625.824	71.1000	73.0000	71.4000	63.3000	9.65000	8.19000	2.86000	2.63000
625.924	68.8000	72.3000	70.5000	56.1000	10.2300	9.21000	3.29000	3.39000
626.024	71.0000	72.7000	70.6000	48.2000	9.27000	8.37000	2.60000	3.23000
626.124	68.8000	74.1000	71.9000	61.6000	9.27000	9.04000	2.31000	3.30000
626.224	69.8000	70.4000	70.7000	49.0000	10.2300	10.3900	3.49000	4.10000
626.324	69.3000	73.1000	71.7000	49.3000	9.80000	9.78000	2.61000	3.41000
626.424	70.2000	72.9000	72.0000	63.7000	10.8800	10.2100	3.10000	3.38000
626.524	68.7000	71.9000	70.0000	46.9000	11.2700	10.4100	4.12000	4.24000
626.624	70.3000	73.1000	71.7000	50.2000	10.5500	9.22000	2.87000	3.75000
626.724	68.8000	73.1000	71.8000	61.3000	11.5799	9.66000	3.19000	4.15000
626.824	68.7000	72.5000	70.5000	42.9000	12.0299	9.72000	3.52000	4.54000
626.924	71.6000	73.2000	72.3000	48.2000	11.9700	9.74000	2.83000	3.94000
627.024	69.2000	72.4000	71.5000	61.8000	13.0299	10.2900	3.55000	4.31000
627.124	71.1000	72.3000	70.4000	41.4000	13.0299	10.7700	3.47000	4.90000
627.224	70.3000	72.9000	72.6000	51.1000	12.7000	10.7200	2.44000	3.90000
627.324	70.3000	73.7000	71.5000	59.7000	13.8700	11.2700	2.95000	4.43000
627.424	69.5000	73.1000	70.6000	37.4000	13.9100	11.4799	2.48000	4.55000
627.524	69.8000	74.1000	72.1000	49.0000	13.8700	11.7999	2.71000	3.96000
627.624	69.4000	72.5000	71.3000	54.8000	14.9100	12.4600	3.68000	4.06000
627.724	69.2000	73.2000	71.5000	39.0000	14.5400	12.2900	3.63000	4.20000
627.824	71.0000	75.1000	72.5000	50.5000	14.8100	12.7400	4.04000	4.25000
627.924	68.5000	73.4000	71.2000	45.7000	15.5400	13.8299	4.31000	5.19000
628.024	69.5000	72.4000	71.8000	34.5000	15.0099	13.5799	3.71000	5.05000
628.124	69.9000	74.1000	73.0000	50.0000	14.5000	13.5500	2.76000	4.84000
628.224	69.2000	72.7000	70.8000	45.7000	15.4700	14.4000	3.35000	5.59000
628.324	69.5000	73.5000	70.8000	55.3000	15.3200	14.0200	3.32000	5.05000
628.424	70.9000	74.0000	73.0000	48.1000	15.8100	13.9700	3.19000	4.99000
628.524	70.2000	72.9000	70.0000	42.9000	16.8100	14.9500	3.80000	5.67000
628.624	69.5000	74.3000	71.9000	37.4000	16.4000	14.4600	2.87000	5.06000
628.724	69.4000	74.6000	72.2000	50.0000	17.3000	15.2100	2.81000	5.10000
628.824	68.7000	72.6000	70.4000	53.8000	17.7700	16.4599	3.68000	5.74000
628.924	71.7000	73.8000	72.3000	55.7000	17.6300	15.9500	3.90000	5.28000
629.024	69.4000	74.0000	72.9000	45.8000	18.1000	16.4900	4.80000	5.27000
629.124	70.5000	72.7000	70.9000	28.8000	18.5500	17.4200	6.42000	6.39000
629.225	70.3000	75.1000	72.7000	33.6000	17.7700	16.3600	5.33000	5.78000
629.325	69.7000	74.5000	72.4000	42.8000	18.5900	17.0300	5.67000	5.91000
629.425	69.2000	72.7000	70.9000	26.1000	18.1200	17.3300	6.35000	7.05000
629.525	70.3000	74.0000	72.1000	29.7000	17.7300	17.6900	5.63000	6.35000
629.625	69.5000	74.3000	72.5000	42.3000	19.2400	19.7200	6.71000	6.54000
629.725	69.0000	72.1000	70.7000	23.1000	18.9300	20.5500	7.17000	6.91000
629.825	71.0000	73.9000	73.4000	28.8000	18.3900	20.7800	5.99000	5.48000
629.925	68.7000	75.9000	71.9000	38.3000	19.1900	21.1300	6.49000	6.26000
630.025	71.0000	73.3000	71.2000	19.1000	19.7500	20.2300	6.60000	6.50000
630.125	70.1000	75.1000	72.7000	33.6000	21.1500	20.4500	5.94000	6.35000
630.225	70.7000	73.4000	72.1000	35.4000	22.9900	21.9800	6.35000	7.45000
630.325	69.8000	73.9000	71.3000	20.8000	22.5400	23.3100	6.38000	7.75000
630.425	70.1000	75.1000	73.4000	33.6000	22.5700	24.5900	6.37000	7.96000
630.525	69.1000	74.2000	71.5000	31.6000	24.0500	25.0900	7.22000	8.56000

KEMOPS FLX 1 03-31-71

ID.-FLX1 TYP= FM TABULATION OF VALUES TIME 0 =15 31 30 PAGE- 29

TIME SEC	C001 001 DEGS FAH	C001 002 DEGS FAH	C001 003 DEGS FAH	C001 004 DEGS FAH	N001 001 BTU/SQ FT/SEC	N001 002 BTU/SQ FT/SEC	N001 003 BTU/SQ FT/SEC	N001 004 BTU/SQ FT/SEC
+ 630.625	68.9000	73.8000	72.1000	18.8000	24.2900	23.9200	6.90000	8.02000
+ 630.725	70.9000	75.6000	73.3000	30.4000	25.0200	22.7500	6.96000	8.01000
+ 630.825	67.6000	73.6000	71.3000	24.4000	26.0500	23.2700	7.84000	8.64000
+ 630.925	70.3000	75.3000	72.7000	13.9000	25.0500	22.5000	7.19000	7.98000
+ 631.025	68.8000	76.4000	73.3000	30.7000	25.5500	22.4200	6.84000	8.23000
+ 631.125	69.8000	73.3000	71.6000	18.4000	27.3000	23.6500	8.06000	9.61000
+ 631.225	70.4000	75.3000	73.0000	13.0000	28.1300	22.8300	8.00000	9.24000
+ 631.325	69.8000	75.7000	73.7000	27.0000	29.9900	23.0200	8.58000	9.33000
+ 631.425	68.4000	74.6000	71.5000	14.8000	31.2400	24.1000	9.25000	10.0700
+ 631.525	70.2000	73.6000	73.0000	12.4000	31.1500	23.2800	8.29000	9.43000
+ 631.625	70.0000	75.8000	73.6000	24.7000	32.1000	23.5600	8.69000	9.67000
+ 631.725	68.7000	73.8000	71.9000	6.00000	32.9900	24.1900	9.76000	10.6600
+ 631.825	70.6000	74.1000	73.2000	6.00000	33.6700	23.7600	9.18000	10.0100
+ 631.925	68.7000	75.1000	73.5000	20.8000	35.2200	24.3900	9.64000	10.1499
+ 632.025	70.4000	75.1000	71.7000	.900000	35.4800	24.6900	9.64000	10.4300
+ 632.125	69.2000	74.5000	74.2000	9.70000	35.6700	23.7300	8.29000	8.64000
+ 632.225	70.6000	75.9000	72.9000	13.0000	37.7700	23.5700	9.16000	8.28000
+ 632.325	69.4000	73.9000	72.3000	=10.4000	38.5200	22.5600	10.2500	8.54000
+ 632.425	71.5000	75.8000	74.8000	=.100000	40.0600	21.8300	10.6100	8.02000
+ 632.525	68.9000	74.9000	72.5000	3.30000	43.8200	22.9100	12.1500	9.04000
+ 632.625	70.4000	74.5000	73.2000	=14.4000	45.0800	23.1800	12.3100	8.69000
+ 632.725	69.5000	75.5000	74.6000	=8.70000	44.8600	22.9300	11.2099	7.87000
+ 632.825	68.5000	77.3000	73.2000	=4.80000	44.9800	24.1800	11.8200	8.46000
+ 632.925	70.0000	74.6000	73.1000	=20.6000	44.2900	24.9900	11.2099	7.83000
+ 633.025	69.8000	77.8000	75.1000	=10.1000	43.3300	24.8300	10.2700	7.79000
+ 633.125	69.5000	75.6000	73.3000	=10.8000	44.4900	26.2500	9.92000	7.98000
+ 633.226	70.5000	76.4000	73.8000	=23.6000	45.0900	26.7500	9.84000	7.39000
+ 633.326	70.7000	76.5000	75.1000	=10.2000	47.8600	28.2400	10.5000	8.10000
+ 633.426	68.9000	75.2000	72.9000	=24.2000	50.9800	29.1600	11.9500	9.35000
+ 633.526	69.7000	77.7000	74.7000	=28.5000	50.5000	28.5100	11.5799	8.79000
+ 633.626	69.1000	76.4000	75.0000	=16.0000	50.2000	28.3300	11.6400	8.72000
+ 633.726	70.4000	76.0000	73.4000	=33.3000	49.9900	27.6900	12.4200	9.82000
+ 633.826	69.5000	76.4000	75.7000	=36.6000	49.0400	25.6800	12.2300	9.74000
+ 633.926	68.8000	78.3000	75.0000	=24.2000	50.4700	25.8600	12.9100	9.92000
+ 634.026	70.2000	74.1000	72.9000	=41.9000	52.7200	27.5600	14.0900	10.5599
+ 634.126	69.9000	78.8000	75.1000	=40.4000	52.5200	27.0000	13.3400	9.63000
+ 634.226	69.2000	77.9000	74.1000	=29.5000	53.3800	27.7600	13.3300	10.1400
+ 634.326	69.6000	75.7000	73.3000	=45.9000	52.8900	27.4500	12.7200	10.7800
+ 634.426	70.2000	77.5000	75.3000	=40.1000	51.8200	26.1700	10.8200	9.68000
+ 634.526	69.3000	77.9000	74.7000	=33.6000	51.5800	26.3600	11.7200	10.0799
+ 634.626	69.7000	76.0000	73.5000	=52.3000	49.3700	26.1900	12.2099	11.4100
+ 634.726	70.2000	78.8000	76.1000	=44.0000	48.1100	25.7500	11.5900	9.84000
+ 634.826	69.5000	77.9000	74.9000	=36.6000	49.8000	27.0300	12.1500	10.2100
+ 634.926	69.3000	76.9000	73.8000	=54.7000	50.7200	27.8000	12.5600	10.3900
+ 635.026	69.8000	78.8000	75.7000	=43.7000	51.4300	28.1900	12.1699	9.34000
+ 635.126	69.7000	78.0000	74.3000	=34.8000	51.4700	28.8400	12.0699	9.94000
+ 635.226	69.9000	77.1000	73.9000	=57.8000	49.2700	27.1100	10.9000	9.86000
+ 635.326	69.8000	79.0000	76.0000	=44.3000	49.9000	26.5600	10.4100	9.66000

KEMOPS FLX 1 03-31-71

ID.-FLX1 TYP- FM TABULATION OF VALUES TIME 0 =15 31 30

	TIME SEC	C001 001 DEGS FAH	C001 002 DEGS FAH	C001 003 DEGS FAH	C001 004 DEGS FAH	N001 001 BTU/SQ FT/SEC	N001 002 BTU/SQ FT/SEC	N001 003 BTU/SQ FT/SEC	N001 004 BTU/SQ FT/SEC
+	635.426	69.0000	78.3000	74.6000	-45.3000	53.0100	27.6500	11.9500	10.8300
+	635.526	70.0000	77.4000	74.4000	-62.6000	54.3200	27.5900	13.3400	11.0700
+	635.626	69.3000	79.0000	75.7000	-46.8000	54.7500	28.4300	14.1600	11.4799
+	635.726	69.7000	77.9000	74.3000	-53.8000	56.0600	29.5800	15.2200	12.6400
+	635.826	69.3000	77.4000	75.1000	-63.9000	56.6500	30.3800	14.7000	12.7800
+	635.926	69.1000	80.5000	75.5000	-51.0000	58.6500	32.8900	14.0900	12.8100
+	636.026	69.4000	79.8000	74.3000	-58.7000	62.1700	37.2800	15.1100	12.6800
+	636.126	70.3000	77.8000	75.0000	-69.1000	62.9600	38.8200	14.3200	11.3499
+	636.226	70.2000	79.6000	76.5000	-58.7000	62.3200	38.7500	14.0300	11.3300
+	636.326	69.4000	79.7000	74.6000	-65.5000	62.3900	39.0200	15.0500	12.1699
+	636.426	69.9000	80.2000	76.3000	-74.2000	62.1300	37.9100	14.4800	11.7099
+	636.526	68.7000	79.0000	75.9000	-58.6000	63.8400	39.1100	14.4199	12.3700
+	636.626	69.5000	79.1000	74.5000	-78.3000	65.2800	41.2200	15.6500	13.2600
+	636.726	70.5000	79.4000	76.8000	-77.1000	64.3800	40.3200	15.1399	13.0299
+	636.826	70.9000	79.5000	77.0000	-61.6000	63.8100	39.9200	15.7100	13.1699
+	636.926	69.0000	78.5000	75.1000	-63.0000	63.1900	40.8500	16.0900	13.6800
+	637.026	69.8000	80.1000	76.8000	-79.1000	63.3300	41.1400	14.5200	12.9700
+	637.126	68.4000	80.0000	76.4000	-65.7000	65.3300	43.5600	14.8299	13.6800
+	637.227	69.1000	78.7000	74.7000	-83.7000	66.5600	46.4500	14.4600	15.0099
+	637.327	70.9000	80.1000	77.5000	-79.1000	66.8500	47.7500	14.2600	14.3000
+	637.427	67.8000	78.5000	76.5000	-70.2000	67.2900	49.0800	15.9500	15.8900
+	637.527	70.4000	78.2000	76.4000	-91.0000	66.5200	48.1500	16.7900	17.0300
+	637.627	69.5000	80.8000	77.3000	-81.5000	67.0100	46.5900	15.8300	16.3800
+	637.727	70.6000	82.4000	76.2000	-73.3000	67.7800	45.9000	16.0300	17.4100
+	637.827	68.9000	80.6000	76.4000	-88.6000	66.3800	45.3100	14.8699	16.1200
+	637.927	70.0000	81.6000	77.6000	-82.1000	65.7400	45.2500	14.1800	14.5100
+	638.027	68.9000	77.5000	76.9000	-83.6000	66.8900	47.6000	14.0700	15.2799
+	638.127	70.5000	79.1000	77.0000	-92.8000	66.8800	48.4200	13.4399	14.9300
+	638.227	70.3000	82.0000	79.0000	-77.3000	68.8000	50.9700	13.9700	15.3200
+	638.327	69.7000	79.1000	76.4000	-89.3000	70.5700	54.0800	15.5900	15.4500
+	638.427	69.6000	81.1000	77.1000	-103.000	69.7300	53.7800	15.4599	13.7100
+	638.527	69.6000	81.8000	78.6000	-86.4000	70.3900	53.4000	15.3400	13.6600
+	638.627	68.4000	79.5000	76.4000	-94.7000	73.2200	53.4600	16.5100	15.8500
+	638.727	69.0000	81.5000	77.4000	-102.100	74.7100	52.3400	15.6700	15.6700
+	638.827	70.1000	81.1000	78.5000	-88.9000	75.6900	51.3600	16.0200	15.9700
+	638.927	69.0000	78.9000	76.2000	-104.500	74.8300	51.4500	17.0500	16.9100
+	639.027	71.2000	80.3000	78.3000	-103.500	71.4100	50.0500	15.9900	16.3100
+	639.127	69.6000	80.3000	78.0000	-91.1000	70.5000	50.9100	15.5499	16.0300
+	639.227	70.0000	79.0000	76.6000	-108.300	71.3800	51.9200	17.1400	15.5700
+	639.327	70.7000	80.6000	78.9000	-107.700	73.1300	51.2400	16.5100	14.6200
+	639.427	68.8000	79.4000	78.7000	-94.9000	76.6500	51.5300	18.1000	15.7500
+	639.527	70.4000	79.7000	77.9000	-110.200	77.6700	51.2000	19.1100	17.7600
+	639.627	69.6000	80.5000	79.8000	-102.400	75.9400	50.1200	18.1900	16.8800
+	639.727	69.1000	79.7000	78.5000	-92.6000	74.8700	51.6200	19.1000	16.8300
+	639.827	68.8000	78.9000	77.4000	-112.199	73.2700	51.1700	18.8800	17.3500
+	639.927	71.1000	80.3000	80.0000	-110.600	72.7300	50.5800	18.5100	17.0300
+	640.027	69.5000	80.6000	76.9000	-109.200	73.8300	52.7000	20.8300	19.8300
+	640.127	69.7000	79.7000	78.5000	-123.700	74.2100	53.5000	21.8200	20.7900

FOLDOUT FRAME 1

FOLDOUT FRAME 2

KEMOPS FLX 1 03-31-71

ID.=FLX1 TYP= FM TABULATION OF VALUES TIME 0 =15 31 30

TIME SEC	C001 001 DEGS FAH	C001 002 DEGS FAH	C001 003 DEGS FAH	C001 004 DEGS FAH	N001 001 BTU/SQ FT/SEC	N001 002 BTU/SQ FT/SEC	N001 003 BTU/SQ FT/SEC	N001 004 BTU/SQ FT/SEC
+ 640.227	70.6000	80.3000	80.3000	=112.700	75.0800	53.7100	22.6500	20.4700
+ 640.327	69.8000	81.0000	78.9000	=106.700	76.6700	54.8600	23.7400	21.5200
+ 640.427	70.6000	81.3000	78.5000	=124.700	76.8600	53.1100	23.6900	21.7300
+ 640.527	69.3000	82.4000	80.0000	=110.600	76.6800	52.0500	24.4000	22.1400
+ 640.627	68.9000	82.1000	79.2000	=116.100	77.6900	51.5000	26.5400	24.1000
+ 640.727	70.2000	82.8000	79.7000	=128.300	78.1200	51.8300	28.3700	24.9800
+ 640.827	69.9000	83.2000	80.3000	=111.199	79.5100	53.0100	29.8100	24.0100
+ 640.927	69.8000	81.9000	79.3000	=118.400	80.4600	54.6200	31.0000	24.5400
+ 641.027	70.4000	81.3000	79.5000	=132.100	80.3100	55.3200	30.1400	24.6300
+ 641.127	70.4000	82.0000	81.6000	=116.100	81.9600	58.2600	28.3900	25.3700
+ 641.227	69.6000	81.2000	78.9000	=129.200	84.2100	62.9200	27.5400	26.5800
+ 641.327	69.6000	82.9000	80.4000	=137.100	83.3600	62.6100	25.6900	24.3400
+ 641.427	69.7000	84.9000	80.9000	=119.899	82.1700	60.4200	25.0300	23.1000
+ 641.527	69.5000	82.4000	79.3000	=130.400	80.8200	59.3100	26.4100	24.4400
+ 641.627	71.1000	81.2000	81.5000	=132.500	78.8800	57.9300	24.9900	24.5600
+ 641.727	69.8000	82.6000	82.4000	=118.099	78.9800	57.9000	25.5300	25.8300
+ 641.827	68.3000	83.1000	79.9000	=135.000	78.4500	59.1200	27.1200	26.2800
+ 641.927	70.6000	85.2000	81.4000	=133.000	76.0700	58.8400	26.2300	25.1000
+ 642.027	69.8000	84.0000	82.1000	=119.300	76.2700	60.1700	26.5500	25.2100
+ 642.127	70.2000	80.9000	80.1000	=143.500	76.8600	61.8000	27.1500	26.1700
+ 642.228	69.6000	83.7000	81.9000	=135.000	76.9500	62.4200	26.2000	24.3700
+ 642.328	70.0000	84.0000	81.3000	=127.099	77.1400	65.3400	26.6400	25.3800
+ 642.428	68.1000	83.7000	81.1000	=146.899	76.1800	67.8200	26.2000	25.4300
+ 642.528	69.5000	83.4000	82.5000	=137.100	76.0900	67.7400	25.3300	23.3400
+ 642.628	68.4000	82.6000	81.7000	=130.700	75.8600	67.8300	25.8300	23.1600
+ 642.728	69.1000	84.5000	81.3000	=148.500	74.2200	67.0800	24.7200	22.5000
+ 642.828	69.6000	85.4000	83.7000	=134.700	74.1400	66.9900	25.9900	22.3100
+ 642.928	69.6000	82.4000	81.1000	=129.100	75.8900	68.0700	28.1100	23.4200
+ 643.028	68.8000	84.6000	82.3000	=150.500	76.0000	67.3100	29.0700	23.1400
+ 643.128	70.0000	85.5000	84.0000	=138.400	77.6700	68.1100	30.1400	24.5100
+ 643.228	69.7000	83.0000	81.8000	=142.600	80.6400	70.6300	31.3200	25.9900
+ 643.328	69.8000	84.4000	82.0000	=153.300	81.5800	71.2600	31.0700	26.0100
+ 643.428	68.9000	85.6000	84.6000	=140.099	82.4400	71.4000	31.2300	26.8000
+ 643.528	70.0000	83.3000	83.2000	=140.400	82.3800	71.2700	31.5600	27.5500
+ 643.628	69.6000	86.0000	83.0000	=155.100	80.1500	69.6100	30.2800	26.4500
+ 643.728	69.6000	84.4000	85.1000	=133.600	79.8400	69.9500	28.7700	26.6900
+ 643.828	68.7000	84.2000	83.1000	=146.300	80.5500	71.7100	27.3000	28.9200
+ 643.928	69.7000	85.2000	83.9000	=152.000	80.4800	72.3000	26.4500	30.5100
+ 644.028	68.0000	84.3000	85.2000	=142.300	83.1800	74.0100	27.1500	32.5600
+ 644.128	69.7000	85.9000	83.5000	=154.099	84.5500	76.0500	27.8900	33.9300
+ 644.228	70.2000	85.0000	84.8000	=155.100	83.1400	75.7100	26.5500	32.6200
+ 644.328	70.7000	85.7000	85.6000	=144.100.	83.1900	76.3800	26.9100	32.7500
+ 644.428	68.1000	83.4000	84.1000	=163.300	83.4600	77.4100	30.2800	35.1800
+ 644.528	70.3000	85.2000	85.3000	=155.300	82.8200	76.5300	31.2600	35.0300
+ 644.628	70.1000	86.9000	85.8000	=143.500	82.7900	76.4000	34.0400	35.5200
+ 644.728	69.4000	84.8000	84.1000	=166.100	81.5700	76.1400	36.5400	36.5100
+ 644.828	69.6000	86.7000	86.4000	=159.400	81.5900	76.9500	36.6700	36.4000
+ 644.928	69.3000	84.3000	86.2000	=149.400	84.2100	79.3500	37.1500	38.8600

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ID.-FLX1 TYP= FM TABULATION OF VALUES TIME 0 =15 31 30

	TIME SEC	C001 001 DEGS FAH	CM01 002 DEGS FAH	C001 003 DEGS FAH	C001 004 DEGS FAH	N001 001 BTU/SQ FT/SEC	N001 002 BTU/SQ FT/SEC	N001 003 BTU/SQ FT/SEC	N001 004 BTU/SQ FT/SEC
+	645.028	69.0000	87.3000	84.5000	=172.900	85.8500	81.1500	36.5100	39.6400
+	645.128	69.7000	87.1000	88.7000	=159.099	86.5000	81.3500	35.1200	37.3100
+	645.228	70.5000	87.1000	85.8000	=158.199	86.1600	81.6400	35.9600	36.9600
+	645.328	69.5000	84.1000	85.2000	=169.100	83.5100	81.5700	35.3400	36.4300
+	645.428	71.5000	86.7000	88.1000	=155.999	81.7200	83.0700	34.1800	36.0800
+	645.528	68.7000	87.8000	86.0000	=156.900	82.3500	86.2100	33.0900	36.0600
+	645.628	69.5000	85.3000	87.1000	=175.500	81.9000	87.9100	32.1200	34.1000
+	645.728	69.6000	89.3000	87.8000	=152.600	81.6800	88.8500	31.5600	34.1300
+	645.828	68.4000	87.2000	87.4000	=160.900	81.9800	88.5400	32.2700	35.6800
+	645.928	70.1000	87.9000	87.1000	=171.300	81.4900	86.4500	32.8100	35.5400
+	646.028	70.8000	88.6000	88.8000	=152.299	82.1100	85.4100	33.6200	34.9800
+	646.128	68.5000	86.0000	88.2000	=160.700	83.2800	86.3500	34.1400	35.3500
+	646.229	69.8000	88.9000	88.3000	=166.700	82.1000	86.8700	32.5300	35.9100
+	646.329	70.9000	88.5000	89.1000	=156.600	82.1300	87.9500	31.9000	35.8900
+	646.429	69.3000	88.1000	87.7000	=160.900	82.2800	88.6400	32.8700	36.0900
+	646.529	70.5000	90.0000	90.3000	=164.500	82.0100	87.9700	32.8300	33.6200
+	646.629	69.1000	87.9000	89.1000	=153.200	83.2100	88.3700	32.8200	32.1200
+	646.729	68.7000	87.3000	88.9000	=164.000	83.4600	89.0100	33.8000	29.6600
+	646.829	70.5000	90.4000	90.1000	=164.500	82.4100	88.0500	32.9400	26.6900
+	646.929	69.1000	90.1000	90.5000	=154.099	84.0300	90.0500	33.1900	25.8800
+	647.029	69.5000	87.8000	87.7000	=172.000	85.8900	93.3900	33.8000	26.9100
+	647.129	69.3000	91.8000	91.5000	=170.200	87.8700	94.2900	32.8600	26.0400
+	647.229	68.9000	90.9000	89.7000	=154.099	90.6500	95.5500	34.0600	26.8100
+	647.329	68.9000	89.0000	89.1000	=174.700	90.8900	95.3100	35.8700	29.2100
+	647.429	70.3000	90.8000	90.4000	=166.600	91.6700	93.9000	35.9800	29.8000
+	647.529	67.8000	91.6000	90.6000	=155.300	95.6100	95.2800	38.4100	31.7900
+	647.629	70.3000	91.6000	89.4000	=179.800	97.4600	97.3900	40.3800	33.0900
+	647.729	68.1000	91.5000	91.3000	=168.400	97.1200	99.2300	42.0100	32.4500
+	647.829	69.2000	91.5000	90.3000	=165.100	95.3600	100.210	44.2900	33.2300
+	647.929	70.0000	91.5000	90.0000	=179.500	91.8800	97.7100	43.1500	33.0300
+	648.029	69.8000	94.1000	92.4000	=169.300	91.1000	96.4100	41.5000	31.9300
+	648.129	70.1000	93.0000	90.5000	=170.200	92.1800	96.4200	41.4000	31.5400
+	648.229	69.2000	93.7000	91.9000	=186.800	92.5500	96.3300	40.3800	27.0300
+	648.329	70.5000	94.1000	92.0000	=171.400	94.3000	98.0000	40.4700	26.3300
+	648.429	68.3000	91.6000	91.3000	=179.400	96.3100	101.370	41.9100	29.9500
+	648.529	69.5000	92.5000	91.5000	=194.799	95.7100	102.890	41.0000	31.9500
+	648.629	69.5000	93.7000	93.6000	=175.200	95.4100	104.790	38.4300	32.4900
+	648.729	69.2000	92.8000	91.2000	=187.100	94.9600	106.040	37.3000	33.3400
+	648.829	68.4000	93.6000	91.8000	=197.000	93.1600	104.390	37.1000	31.7300
+	648.929	70.3000	93.8000	94.6000	=180.000	93.8900	104.270	38.4300	29.2700
+	649.029	69.2000	93.3000	90.8000	=194.500	94.9600	104.679	40.8400	28.0700
+	649.129	69.5000	94.6000	94.8000	=197.200	93.3500	103.110	38.9400	26.6700
+	649.229	69.1000	96.7000	94.0000	=186.500	93.1400	102.210	38.9400	24.8200
+	649.329	68.4000	93.2000	92.0000	=204.100	93.0400	103.010	39.1000	24.2100
+	649.429	70.8000	95.4000	94.5000	=200.200	93.2400	105.160	37.3500	22.7500
+	649.529	68.4000	95.4000	93.5000	=182.000	95.2300	108.200	36.5000	23.9700
+	649.629	69.1000	92.3000	92.3000	=211.900	95.5700	109.670	35.6700	26.5900
+	649.729	69.7000	93.8000	95.1000	=204.800	96.3800	107.890	33.2400	25.5400

FOLDOUT FRAME 1

FOLDOUT FRAME 2

KEMOPS FLX 1 03-31-71

ID.-FLX1 TYP- FM TABULATION OF VALUES TIME 0 =15 31 30

TIME SEC	C001 001 DEGS FAH	C001 002 DEGS FAH	C001 003 DEGS FAH	C001 004 DEGS FAH	N001 001 BTU/SQ FT/SEC	N001 002 BTU/SQ FT/SEC	N001 003 BTU/SQ FT/SEC	N001 004 BTU/SQ FT/SEC
+ 649.829	68.5000	94.9000	93.8000	-197.000	99.3700	108.370	33.5600	25.2500
+ 649.929	69.7000	93.6000	93.4000	-217.200	99.9200	108.880	33.1800	23.7700
+ 650.029	70.0000	96.1000	95.4000	-210.000	99.2000	108.250	32.5300	22.1200
+ 650.129	68.8000	95.1000	94.4000	-202.600	97.8200	107.399	32.5800	24.2700
+ 650.230	68.9000	92.8000	94.3000	-215.700	94.9500	104.710	31.9500	23.7600
+ 650.330	71.0000	95.8000	96.0000	-199.000	93.5100	101.680	32.0200	22.3600
+ 650.430	68.6000	94.4000	94.3000	-198.700	94.0100	101.780	33.1300	24.3100
+ 650.530	70.1000	94.7000	95.7000	-218.600	93.5900	102.309	33.2800	25.5700
+ 650.630	69.3000	96.6000	96.3000	-205.000	93.6800	104.210	32.6000	25.2400
+ 650.730	67.3000	95.2000	93.7000	-208.300	93.8300	106.660	32.2500	25.5100
+ 650.830	69.3000	95.3000	96.5000	-222.300	90.9100	106.160	31.2300	25.5100
+ 650.930	69.6000	96.2000	97.1000	-206.400	88.7100	105.480	30.6600	26.1000
+ 651.030	66.6000	94.1000	94.1000	-210.000	88.8700	105.500	30.6200	28.5300
+ 651.130	69.3000	96.3000	97.2000	-216.100	88.4400	103.220	29.6900	28.7400
+ 651.230	69.1000	97.1000	98.4000	-196.100	89.7300	101.390	29.6700	29.7400
+ 651.330	68.9000	95.4000	94.9000	-207.100	90.3900	101.549	30.2900	31.2900
+ 651.430	70.5000	97.7000	96.5000	-214.800	89.0300	100.350	28.5900	31.2200
+ 651.530	67.7000	96.1000	98.9000	-195.699	88.6400	98.3900	27.2200	29.9500
+ 651.630	69.3000	94.1000	95.1000	-226.700	88.9700	96.2000	26.8600	28.0300
+ 651.730	69.3000	96.9000	97.3000	-269.800	89.0500	93.5900	26.5200	23.2000
+ 651.830	69.3000	96.8000	98.6000	-264.000	89.2100	91.7300	26.5100	19.6700
+ 651.930	69.8000	96.0000	96.8000	-279.300	87.1900	90.2400	26.9600	18.8500
+ 652.030	70.6000	97.2000	98.0000	-264.600	85.3100	87.7600	25.1900	17.8200
+ 652.130	68.9000	95.6000	97.7000	-248.100	85.0100	86.4800	23.7300	18.4399
+ 652.230	68.3000	96.6000	97.7000	-270.100	84.1100	85.8600	23.3300	21.6300
+ 652.330	70.1000	97.5000	100.200	-264.300	84.7800	86.5200	22.6000	22.5800
+ 652.430	68.7000	96.0000	98.0000	-254.700	87.9300	90.5200	23.6000	24.9400
+ 652.530	69.1000	94.7000	96.2000	-267.100	89.9500	92.6300	23.4600	24.4600
+ 652.630	70.6000	97.4000	99.8000	-262.500	91.7500	93.7500	21.7900	21.1500
+ 652.730	67.7000	97.0000	99.5000	-255.200	92.4200	94.9000	22.8000	21.3900
+ 652.830	69.9000	95.5000	98.1000	-268.400	91.0700	93.0800	22.8100	20.5500
+ 652.930	69.0000	96.8000	99.3000	-254.000	89.9100	91.5700	22.3000	18.1300
+ 653.030	69.0000	96.8000	98.6000	-246.600	89.8100	91.2800	22.7100	19.0200
+ 653.130	69.3000	96.2000	99.1000	-264.300	88.7900	90.0500	21.5700	17.9900
+ 653.230	69.1000	96.6000	101.499	-240.700	89.7400	91.1000	21.2700	17.5900
+ 653.330	68.7000	96.5000	98.5000	-247.000	91.4400	94.7600	22.1200	19.8100
+ 653.430	69.9000	95.4000	98.2000	-258.500	90.1000	96.2900	20.2600	18.8400
+ 653.530	69.0000	96.3000	100.600	-236.500	90.0300	98.7000	19.8500	17.0800
+ 653.630	67.6000	95.2000	98.4000	-246.600	92.4100	103.760	20.5500	16.2400
+ 653.730	70.0000	98.2000	100.600	-249.300	93.4100	106.660	19.5500	16.1800
+ 653.830	68.9000	97.2000	101.100	-224.700	94.5900	107.189	19.7999	20.3899
+ 653.930	68.7000	95.7000	98.0000	-239.300	94.9600	107.130	20.9000	22.8200
+ 654.030	68.3000	98.0000	99.9000	-236.900	93.0200	104.319	20.2700	21.9500
+ 654.130	68.8000	96.9000	101.200	-223.400	92.9800	103.390	19.9799	22.4800
+ 654.230	68.9000	95.4000	99.9000	-231.700	93.1300	103.460	21.5100	25.2300
+ 654.330	69.2000	97.4000	101.200	-226.400	92.8300	99.3700	20.9300	24.4500
+ 654.430	68.3000	96.8000	100.399	-209.100	94.3500	96.3800	21.7300	23.0400
+ 654.530	67.4000	96.1000	98.4000	-210.000	95.0500	93.8500	23.9100	23.3100