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**A STUDY OF THE TEMPERATURE DISTRIBUTION  
WITHIN AIRCRAFT-FUEL FIRES (U)**

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U N C L A S S I F I E D

U. S. NAVAL WEAPONS EVALUATION FACILITY

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Commanding Officer

NAVWEPS REPORT 8277

A STUDY OF THE TEMPERATURE DISTRIBUTION  
WITHIN AIRCRAFT-FUEL FIRES (U)

By

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FOREWORD

The work leading to this report originated as a result of the desire to find a relatively simple method to describe an aircraft-fuel fire environment for use in both a priori analyses and experimental studies of the vulnerability of nuclear weapons to fire. The data and conclusions presented in this report portray the temperature distribution within an aircraft-fuel fire with sufficient accuracy to enable this information to be useful to engineers and applied physicists studying the vulnerability of nuclear weapons to fire as well as to other individuals who may be concerned with the environment created by burning aircraft fuel.

It is planned to continue this analysis using data generated by other tests conducted by the Navy and data from tests conducted by other organizations.

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#### ABSTRACT

A relatively simple picture of the temperature distribution within 100/130-octane aviation gasoline and JP-4 aviation fuel fires is presented. JP-4 aviation fuel burns with a slightly hotter flame temperature than 100/130-octane aviation gasoline. The point of hottest temperature within the fire is in the center between 30 and 50 inches above the surface of the fuel. The interior of the fire is hotter than the edges at all heights 18 inches or greater above the fuel surface. At 6 inches above the fuel surface, the edges of the fire are hotter than the interior. No relationship between the temperature of the fire and the time it has burned was found.

#### ACKNOWLEDGMENT

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## INTRODUCTION

To be able to predict the temperature-time history within a nuclear weapon engulfed by an aircraft-fuel fire, it is necessary to have both an accurate, or at least a realistic, mathematical model of the weapon and a knowledge of the mechanism(s) by which heat is transferred from the fire to the weapon. Once known, its mathematical formulation will become one of the boundary conditions for solving the differential heat conduction equation, which in turn describes the temperature-time history for the interior of the weapon. However, even after the mathematical formulation of the boundary condition has been made, it is still necessary to know the temperature of the fire before one can begin to solve the heat-transfer equation. Because of the many complex variables that influence the flame temperature of a fire, no mathematical model will exactly describe the flame temperature.

The study of large, open, aircraft-fuel fires has been conducted predominantly to determine this environment for use in studying the vulnerability of nuclear weapons to fire. Only Armour Research Foundation, Sandia Corporation, and this command have investigated the fire environment.

Heat is transferred from a fire to an object engulfed in the flames both by radiation and by convection. According to Takata, about 95 per cent of the heat flow from a fire to an item engulfed by flames is received from the flames within a distance of two feet of the object being heated.<sup>1</sup> Since an aircraft-fuel fire has a luminous flame, it is more convenient to speak of the fire temperature, which can be considered the average flame temperature around the point being considered rather than the actual flame temperature at that point. It is also helpful to use the concept of average flame temperature because the size of the carbon particles formed in flames may vary widely according to the type of flame, usually between the limits 100 to 2,000 A. Thus, the emissivity is likely to vary rather markedly with wave length. The emissivity of a flame and the particles that it contains may differ; as the flame becomes larger, self-absorption will become important, and the emissivity will approach closer to that of a black body.<sup>2</sup>

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<sup>1</sup> Armour Research Foundation. Factors Affecting the Vulnerability of Atomic Weapons to Fire (U), by A. N. Takata. Chicago, ARF, October 1957. (AFSWP Report 1060), SECRET RESTRICTED DATA.

<sup>2</sup> Gaydon, A. G. and H. G. Wolfhard. Flames, Their Structure, Radiation, and Temperature, 2nd Ed. Revised, London, Chapman and Hall Ltd., 1960, p. 23.

When heat is transferred from a fire by radiation only, the amount of heat transferred is a function of the flame temperature. If all the incandescent particles in the fire can be considered to be black bodies, the heat radiation ( $q$ ) from any one particle is equal to  $\sigma T_p^4$ , where  $T_p$  is the temperature of the particle in degrees absolute and  $\sigma$  is the Stefan-Boltzman constant in the appropriate units. If, for purposes of analysis, the total heat radiated from the fire can be considered to be the sum of each individual quanta of heat, each quanta being different for each incandescent particle with a different temperature, then  $q_{total} = \Sigma \sigma T_p^4$ . Thus, when we speak of an average flame temperature, we mean the fourth root of the mean of the sum of the fourth power of each individual flame temperature. If heat is also transferred to the item being heated by means other than radiation (usually convection) and if radiation is still assumed to be the only mechanism by which heat is transferred, the average flame temperature will be a larger value than the fourth root of the mean of the sum of the fourth power of the temperature of each individual particle.

When experimentally determining the vulnerability of nuclear weapons to fire, the weapon is usually suspended in the flames from an overhead support by its lugs, or mounted on pedestals within the flames. (All of the Navy bombs tested to determine their vulnerability to fire have been suspended in the flames.) The method of suspension is to attach the lugs by which the bomb is secured to the aircraft pylon to supports that are attached to a large A-frame, as depicted in Fig. 1. In order to ensure that the bomb or other weapon being tested is placed in the hottest portion of the fire, it is necessary to know the temperature distribution within the fire. Results of tests conducted to determine this information are presented below.

#### TEST DESCRIPTION

A 12- by 24-foot fuel pan was placed under the A-frame. A grid was placed above the fuel pan and was supported from the A-frame. It had vertical rods (henceforth called "legs") suspended from it. The legs were spaced 42 inches apart on the 12-foot axis of the fuel pan and 54 inches apart on the 24-foot axis of the fuel pan. Along each leg were placed six thermocouples, spaced so that the thermocouple beads were at levels of 6, 12, 30, 42, 54, and 66 inches above the level of the fuel surface. The entire grid, the legs, and the A-frame were insulated with Eagle-Pilcher cement and asbestos wrappings until only the thermocouple leads were exposed (Fig. 2 and 3). Water was pumped into the fuel pan and the desired amount of fuel was pumped on top of the water. The quantity of water placed in the fuel pan was adjusted so as to place the thermocouple beads the desired height above the initial fuel surface. During the period of burning, water was pumped into the fuel pan to maintain the distances between the fuel surface and the thermocouple beads. Table 1 is a list of the various tests conducted.

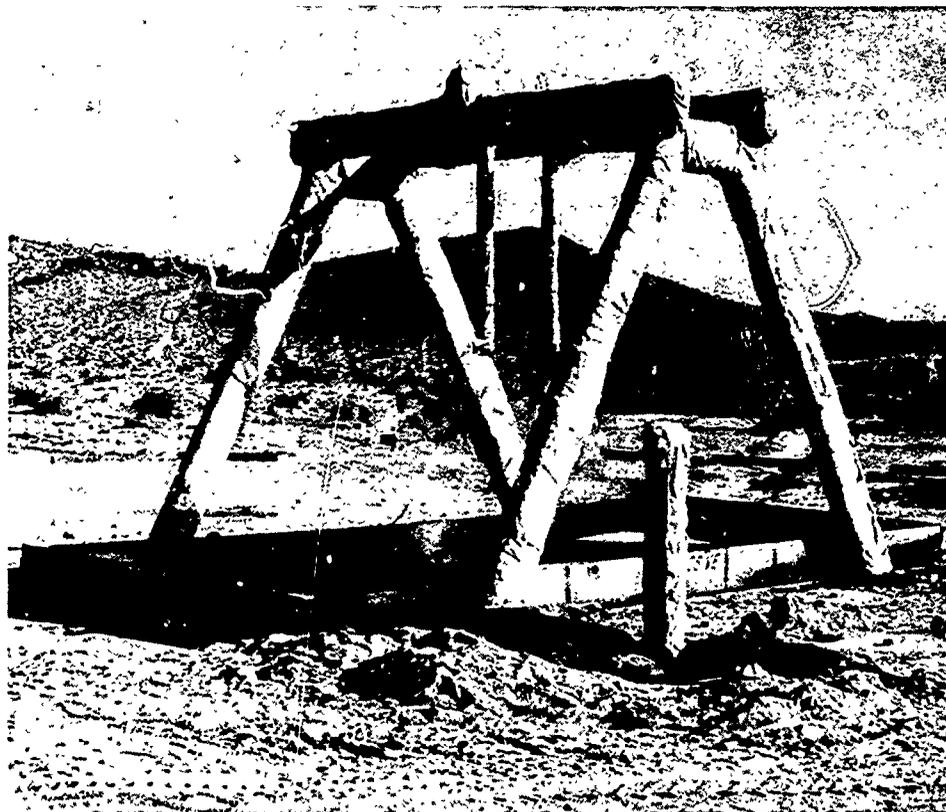


FIG. 1. Test Stand for Fire Vulnerability Testing.

TABLE 1. Tests Conducted

Burn number	Type of fuel	Quantity of fuel, gallons
1	Aviation gasoline	800
2	Aviation gasoline	1,200
3	JP-4	800
4	JP-4	800
5 <sup>a</sup>	JP-5	800.

<sup>a</sup>Burn Number 5 contained a solid steel cylinder, 18 inches in diameter and 108 inches long, supported with its centerline 30 inches above the fuel surface in the center of the pan.

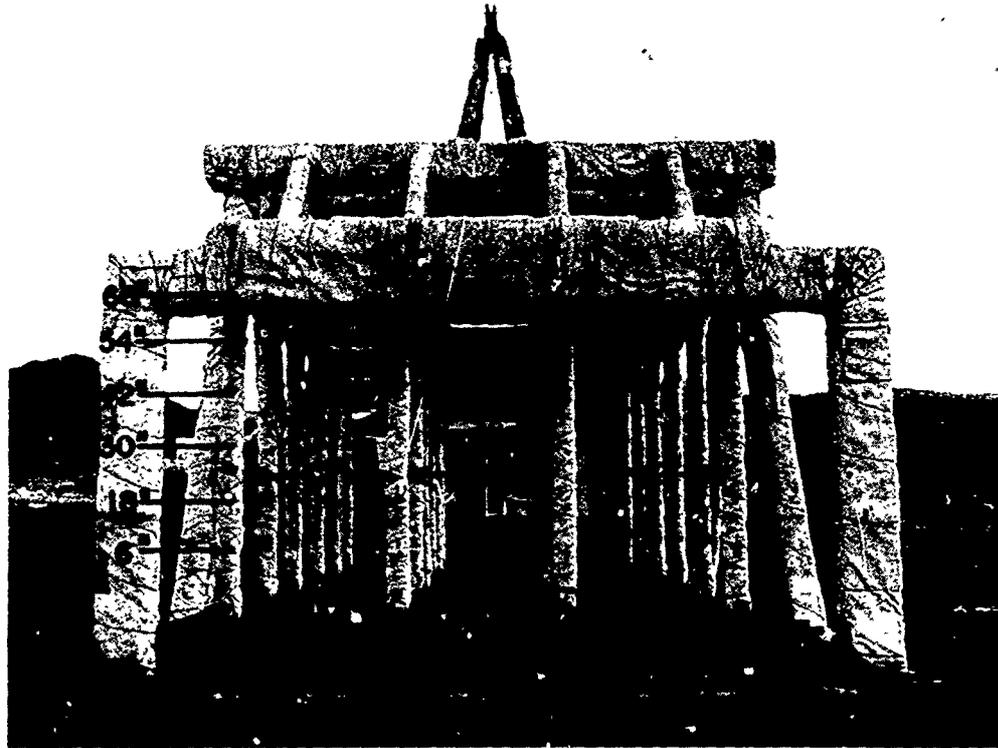


FIG. 2. Twelve Foot Axis of Test Stand and "Legs".

#### ANALYSIS OF THE DATA

Because of the turbulence of the fire and the corresponding rapid motion of the incandescent particles within the flames, very rapid changes in the average fire temperature occurred. Because of the rapid response of the thermocouple bead, these very rapid changes in the average fire temperature were measured and recorded. Fig. 4 is a representative picture of the temperature-time data obtained from one thermocouple during one of the tests. Because of the large deviance in the temperatures, as monitored by the thermocouples, the data was analyzed as follows. The thermocouples on the legs on the outer periphery of the grid were designated as OUTER and the remaining ones as INNER. Then the data was divided into subgroups. Each subgroup consisted of all the measurements in the INNER or OUTER designation for one level for one test. For

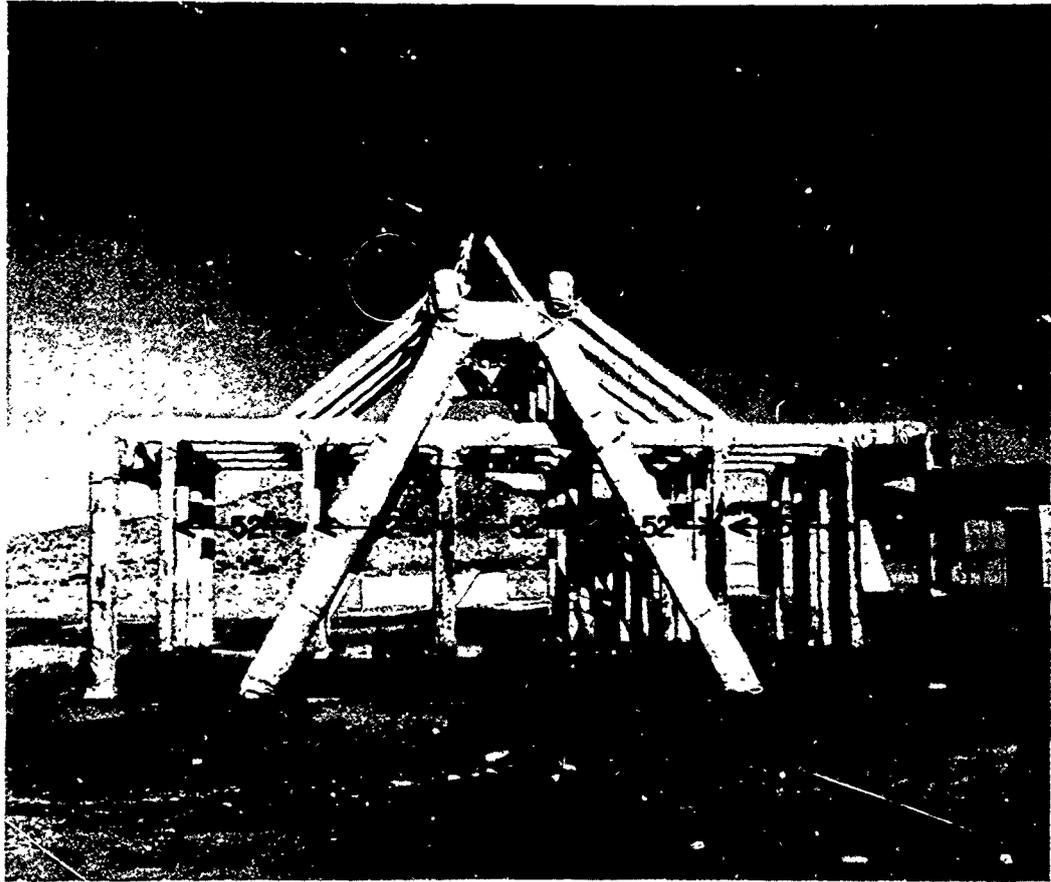


FIG. 3. Twenty-four Foot Axis of Test Stand and "Legs".

each subgroup, the mean, the variance (standard deviation squared), the standard deviation, the fourth root of the fourth moment (average of the fourth power of each temperature reading), and the number of measurements lying in specified intervals of 100 Fahrenheit degrees were computed on a CDC-1604 computer. The Appendix is a tabulation of all this data.

The data from the tests were analyzed to determine the following information.

1. Is there a significant variation in the average flame temperature when comparing JP-4 aviation fuel to 100/130-octane aviation gasoline?
2. Is there a significant variation in the average flame temperature when different quantities of fuel are burned?
3. Is there a significant variation in the average flame temperature between and within levels?

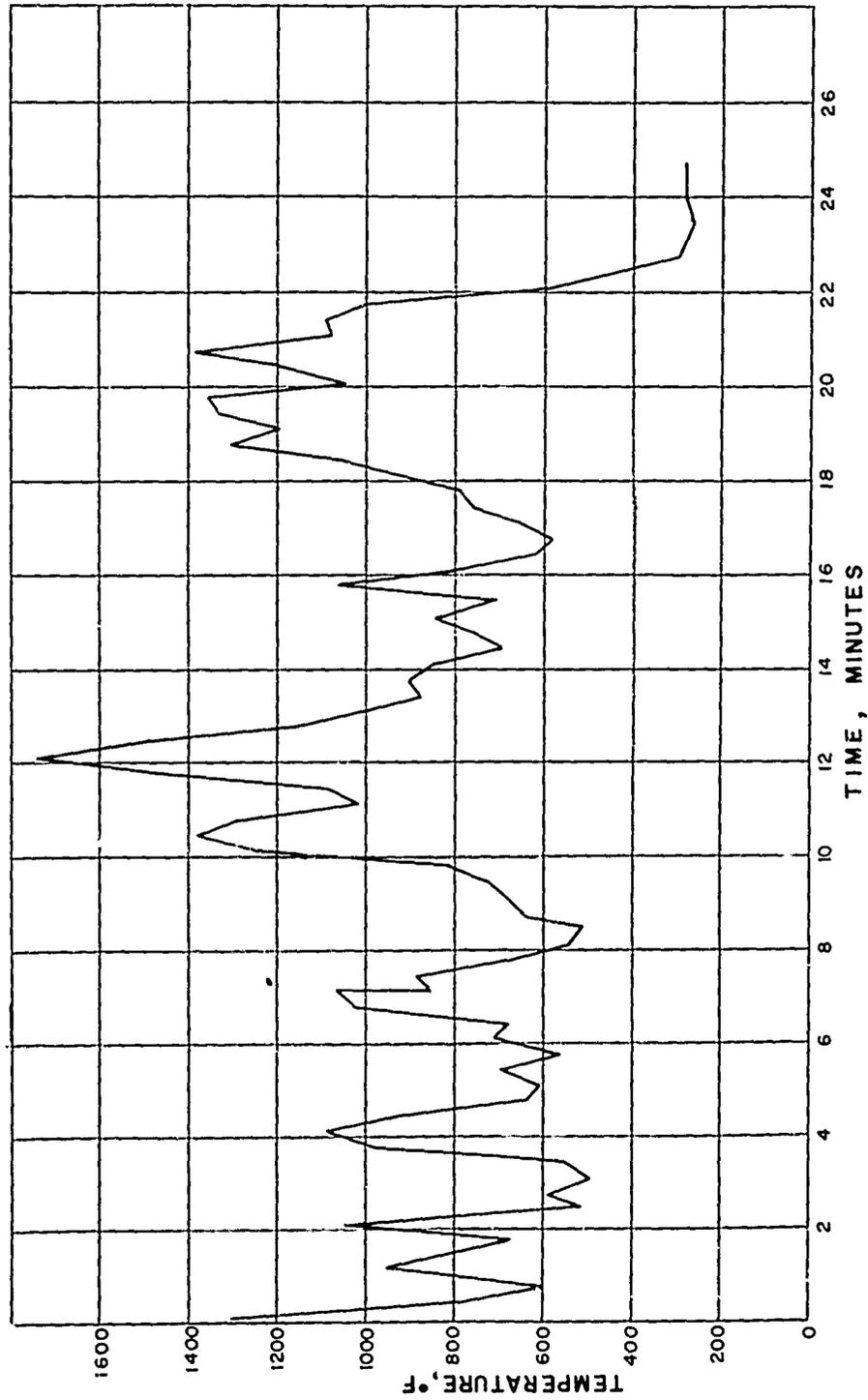


FIG. 4. Representative Picture of Average Fire Temperature--Time Data.

4. Is there a significant variation in the average flame temperature between tests conducted with and without a shape suspended in the flames?

5. Is there a significant variation in the average flame temperature between and within levels with respect to time?

#### COMPARISON BETWEEN FUELS

Data from five tests, two conducted with aviation gasoline and three with JP-4, were analyzed. The data indicate that JP-4 burns with a higher temperature than aviation gasoline, as can be seen in Table 2.

Because of the large standard deviation, no conclusive statement concerning the significance of the difference in temperatures can be made at present. However, based on these five tests, it can be stated that up to a height of about four feet above the fuel surface, the INNER portion of a JP-4 fuel fire is between 200 and 300 Fahrenheit degrees hotter than the corresponding volume of an aviation-fuel fire.

In addition, if each individual data point is assumed to represent a flame temperature from the time of that data point until the time the next data point is taken, a comparison of the number of data points above any specified temperature for JP-4 and aviation gasoline should show which fuel burned hotter. This data is shown in Table 3, and, as can be seen, for all temperatures except those above 2,000 and 2,500°F in test 3, JP-4 had a higher percentage of observations above a specified temperature than did aviation gasoline.

TABLE 2. Comparison of Temperatures Between JP-4 and Aviation Gasoline

Height above fuel, inches	Temperature, °F														
	JP-4										Aviation Gasoline				
	INNER					OUTER					INNER		OUTER		
	Test 3	Test 4	Test 5	Test 3	Test 4	Test 5	Test 3	Test 4	Test 5	Test 3	Test 4	Test 1	Test 2	Test 1	Test 2
6	1017	908	1094	1114	1115	1146	892	784	937	904					
18	1343	1405	1455	1117	1171	1207	1201	1253	1102	1120					
30	1598	1697	1594	1200	1269	1447	1484	1558	1207	1183					
42	1490	1607	1697	1124	1198	1368	1462	1468	1182	1199					
54	1467	1598	1545	1093	1083	1307	1419	1519	1164	1215					
66	1409	1587	1573	1034	1064	1124	1515	1471	1120	1130					

TABLE 3. Percentage of Observations Greater than Specified Temperatures

Temperature, °F	100/130-octane aviation gasoline		JP-4		
	Test 1	Test 2	Test 3	Test 4	Test 5
0	100.0	100.0	100.0	100.0	100.0
500	77.6	72.5	86.0	85.7	88.2
1,000	43.7	41.2	45.5	44.7	50.5
1,500	17.3	17.9	16.9	20.7	20.7
2,000	0.2	0.4	0	1.9	3.3
2,500	0	0	0	0.01	0.5

## COMPARISON BETWEEN DIFFERENT QUANTITIES OF FUEL

In tests 1 and 2, 800 and 1,200 gallons of aviation gasoline, respectively, were burned. Comparison of the means, presented in Table 4, for the two tests at the various levels shows no appreciable difference in temperature. In addition, comparison of the percentage of observations above a specified temperature in columns 1 and 2 of Table 3 shows no appreciable difference. Thus, it can be concluded that the quantity of fuel had no effect upon the average fire temperature.

TABLE 4. Comparison of Fire Temperatures for Different Quantities of Aviation Gas

Quantity of fuel, gallons	Location of thermo- couples	Mean fire temperature for different heights above the fuel					
		Level					
		6"	18"	30"	42"	54"	66"
800	INNER	752	1,073	1,363	1,287	1,251	1,324
	OUTER	798	881	914	861	823	753
1,200	INNER	647	1,133	1,385	1,276	1,304	1,208
	OUTER	744	841	855	838	865	741

## COMPARISON BETWEEN AND WITHIN LEVELS

Between Levels

Examination of the data from the tests shows that there are differences in the average fire temperature between levels. However, for fires in which 100/130-octane aviation gasoline is burned, there is not as great a difference between levels 30 inches and higher above the fuel surface as there is between levels below 30 inches (Fig. 5 and 6). For the INNER area, the average fire temperature increases from about 800°F at the 6-inch level to about 1,500°F at the 30-inch level and remains constant at that temperature between the 30- and 66-inch levels. For the OUTER area, the average fire temperature is about 900°F at a height of 6 inches above the fuel, increases to about 1,150°F at a height of 18 inches above the fuel, and then remains essentially constant from that height up to the 66-inch level.

Fires with JP-4 aviation fuel show a somewhat different picture as to the variation in the average fire temperature with heights above the fuel surface (Fig. 7 and 8). For the INNER area, the average fire temperature increases from about 1,000°F at the 6-inch level to about 1,650°F at the 30- to 40-inch level and then drops off slightly to about 1,500°F at the 66-inch level. For the OUTER area, the average fire temperature is about 1,000°F at the 6-inch level, increases to between 1,150 and 1,250°F at the 30-inch level, and then decreases to about 1,100°F at the 66-inch level.

Within Levels

Examination of the data contained in Table 2 leads to the conclusion that there is a variation in flame temperature at any one level in a fire. For both 100/130-octane aviation gasoline and JP-4 aviation fuel at a height of 6 inches above the fuel surface, the OUTER area has a higher average fire temperature than the INNER area. At all other levels above the fuel surface, the INNER area has a higher average fire temperature than the OUTER area. Thus, it may be said that, in general, for fuel fires of this size (approximately 12 by 24 feet) the fire is coolest at the exterior of the flames and increases in temperature toward the center of the flames.

## COMPARISON BETWEEN AN OBJECT AND NO OBJECT IN THE FLAMES

Examination of the data contained in Table 2 (tests 4 and 5) reveals very little difference between a fire with a closed-end cylinder, 18 inches in diameter by 108 inches long, engulfed by the flames, and one without an object in the flames. In the test with the object in the flames, the OUTER area had a higher average flame temperature at all levels than those measured for the test with no object in the flames. There was no significant difference in temperatures for the INNER area.

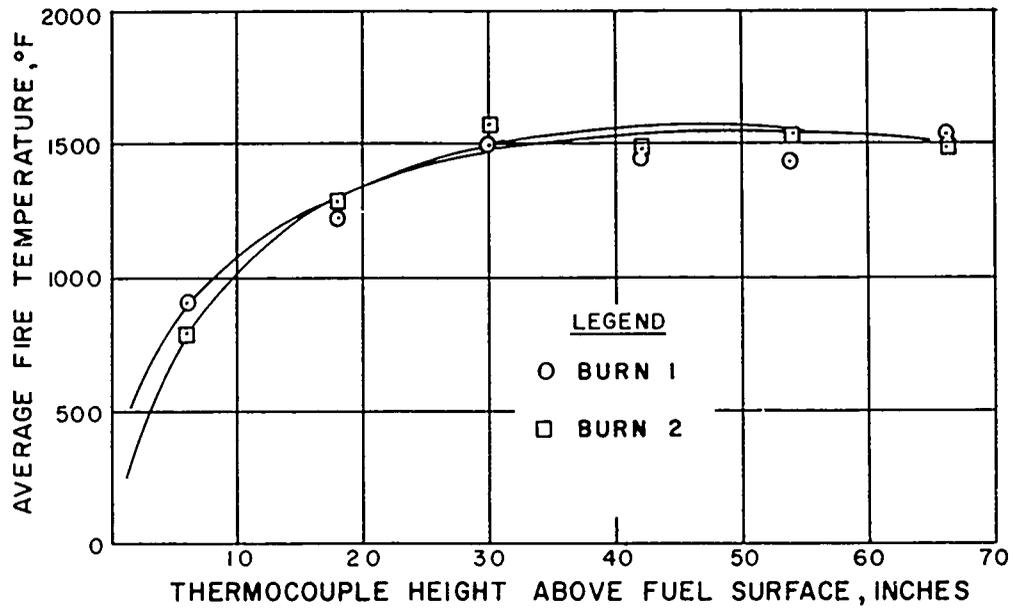


FIG. 5. Variation in Average Fire Temperature as a Function of Height Above Fuel Surface for Inner Area of 100/130 Octane Aviation Gasoline Fire.

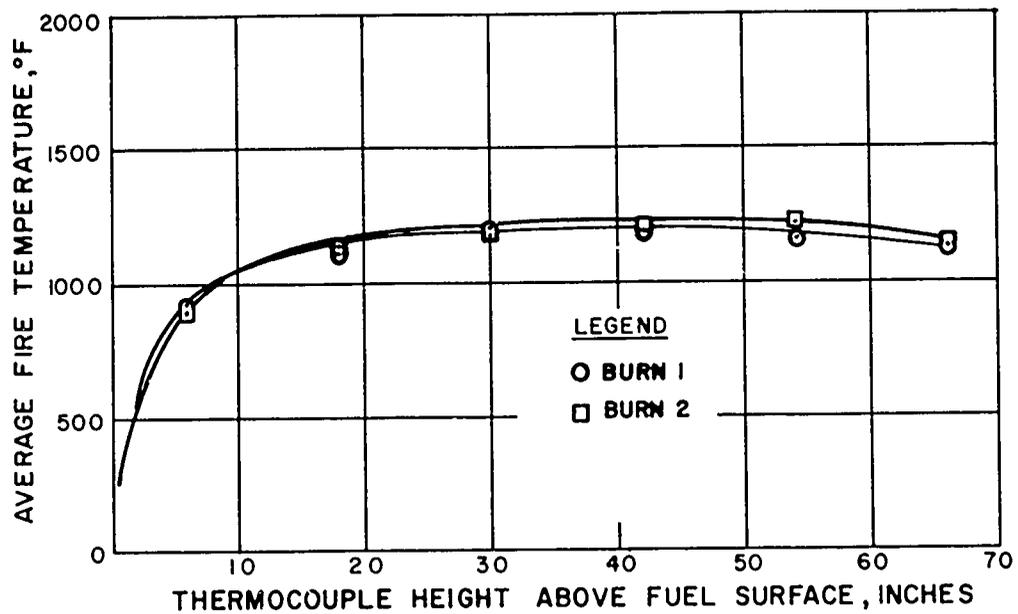


FIG. 6. Variation in Average Fire Temperature as a Function of Height Above Fuel Surface for Outer Area of 100/130 Octane Aviation Gasoline Fire.

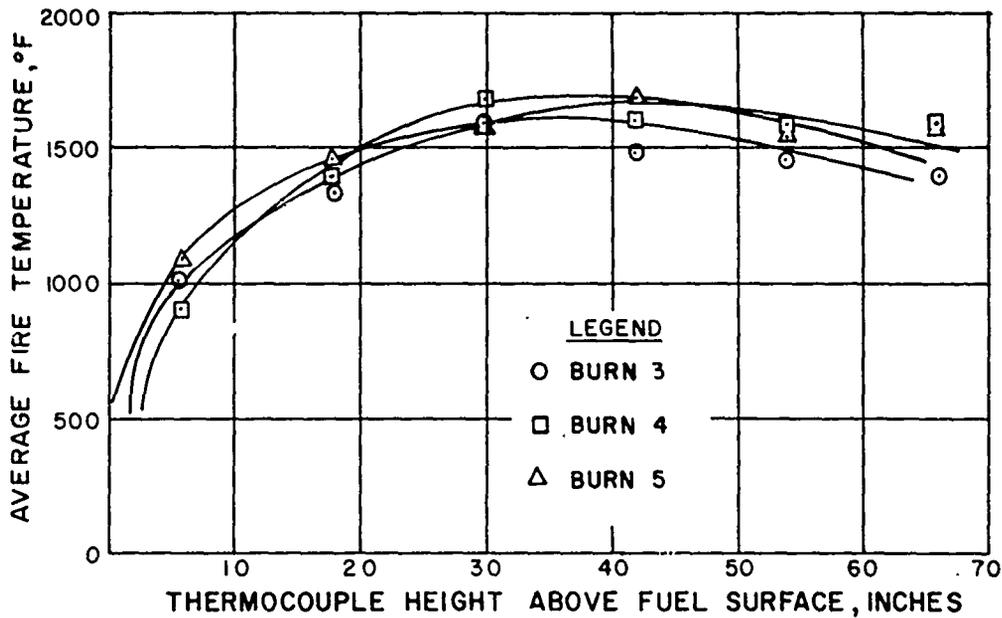


FIG. 7. Variation in Average Fire Temperature as a Function of Height Above Fuel Surface for Inner Area of JP-4 Aviation Fuel Fire

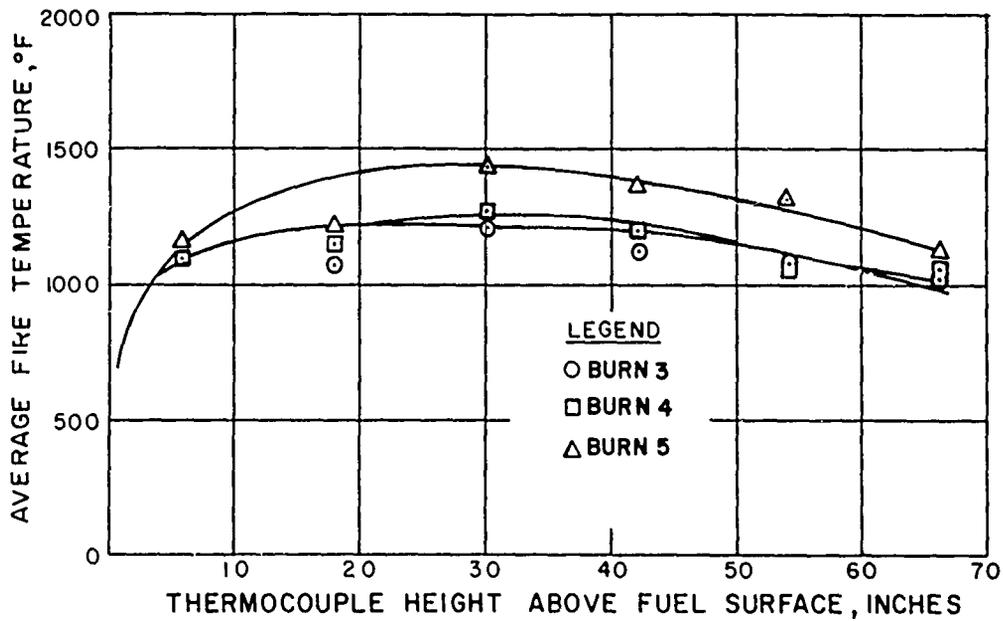


FIG. 8. Variation in Average Fire Temperature as a Function of Height Above Fuel Surface for Outer Area of JP-4 Aviation Fuel Fire.

In general, it appears that there was no greater difference in the average fire temperatures for a fire with an object in it and one without an object in it than for two different fires without any object in them. Thus, it appears that there is insufficient data to conclusively show whether or not an object engulfed by the flames from an aircraft-fuel fire influences the temperature distribution within the fire.

#### VARIATIONS IN TEMPERATURE WITH TIME

The initial analysis to determine variations in temperature with time was made to find if there was an induction period (a time during which the fire was building up to the average temperature), a constant period (a time during which the average temperature of the fire was essentially constant), and a period of decline (a time during which the average temperature of the fire was declining). However, it was not possible to obtain a temperature-time history for any level for either the INNER or the OUTER area that fits this hypothesis. At the present time, all that can be said is that there is insufficient data to accurately depict the temperature-time history of an area inside the flames of an aircraft-fuel fire.

#### CONCLUSIONS

The conclusions drawn from analysis of these test data are as follows.

1. There is a difference, although not a statistically significant one, in the average flame temperature of fires burning 100/130-octane aviation gasoline and those burning JP-4 aviation fuel.
2. There is no difference in the average flame temperature of fires burning different quantities of the same fuel in the quantity range tested.
3. There is a difference, although not a statistically significant one, in the average flame temperature between and within levels of an aircraft-fuel fire.
4. There is no significant difference in the average flame temperature between a large, open, aircraft-fuel fire with an object in the flames and one without.
5. It has not yet been possible to determine a variation in the average flame temperature of a fire between and within levels with respect to time. However, analysis of the data is continuing.

#### FUTURE WORK

It is planned to continue the analysis of the data to attempt to obtain more statistically significant values for the mean fire temperature as a function of height and, if possible, some picture of the variation in fire temperature as a function of time. In addition, other data, supplied to this command, will be analyzed to obtain additional information about the temperature of an aircraft-fuel fire as a function of position in the flames or time.

Appendix

REDUCED DATA OBTAINED FROM THE CDC-1604 COMPUTER

BURN NUMBER 1

IN-TER THEROCOUPLES

LEVEL	MEAN	VARIANCE	DEVIATION	4TH ROOT	0-100	1-200	2-300	3-400	4-500	5-600	6-700	7-800	8-900	9-1000	10-1100	11-1200
1	752.819	71869.8	268.035	692.224												
2	1073.238	140830.9	374.758	1201.872												
3	1363.892	154721.3	393.346	1484.457												
4	1287.051	219988.0	463.625	162.832												
5	1251.268	192384.8	436.617	1419.363												
6	1323.788	223084.4	477.812	1913.778												
LEVEL	0-100	1-200	2-300	3-400	4-500	5-600	6-700	7-800	8-900	9-1000	10-1100	11-1200				
1	0	0	1	1	46	67	38	29	33	28	25	13				
2	4	12	14	6	5	6	8	9	16	22	32	42				
3	0	2	10	6	2	1	7	6	7	10	23	14				
4	3	2	9	4	2	5	11	10	7	10	15	17				
5	0	5	7	5	7	6	2	14	18	15	21	19				
6	0	4	5	7	8	9	16	13	13	10	18	15				
LEVEL	12-1300	13-1400	14-1500	15-1600	16-1700	17-1800	18-1900	19-2000	20-2100	21-2200	22-2300	23-2400				
1	8	3	1	4	2	0	0	0	0	0	0	0				
2	58	75	34	5	1	0	0	0	0	0	0	0				
3	15	32	40	51	53	56	6	0	0	0	0	0				
4	14	16	21	25	31	36	16	1	0	0	0	0				
5	15	24	32	25	43	26	15	0	0	0	0	0				
6	21	36	21	24	38	28	32	20	6	1	0	0				
LEVEL	24-2500	25-2600	26-2700	27-2800	28-2900	29-3000	30-3100	31-3200	32-3300	33-3400	34-3500	OVER 3500				
1	0	0	0	0	0	0	0	0	0	0	0	0				
2	0	0	0	0	0	0	0	0	0	0	0	0				
3	0	0	0	0	0	0	0	0	0	0	0	0				
4	0	0	0	0	0	0	0	0	0	0	0	0				
5	0	0	0	0	0	0	0	0	0	0	0	0				
6	0	0	0	0	0	0	0	0	0	0	0	0				

BURN NUMBER 1

OUTER THERMOCOUPLES

LEVEL	MEAN	1-200	2-300	3-400	4-500	5-500	6-700	7-800	8-900	9-1000	10-1100	11-1200
1	799.836		20080.3	282.945	937.648							
2	881.234		16530.2	406.621	1102.413							
3	914.055		230824.8	480.442	1207.934							
4	861.835		23720.0	487.575	1182.098							
5	823.424		236019.7	485.819	1164.989							
6	752.579		230144.4	479.734	1127.624							
LEVEL	0-100	1-200	2-300	3-400	4-500	5-500	6-700	7-800	8-900	9-1000	10-1100	11-1200
1	0	0	2	19	79	67	71	50	78	65	63	23
2	0	13	17	30	79	50	61	31	45	40	33	41
3	0	2	22	63	48	62	90	36	27	10	16	24
4	0	12	42	64	76	78	60	49	40	24	19	17
5	0	9	36	69	106	75	49	45	23	25	28	20
6	12	19	45	302	124	84	51	50	31	22	28	24
LEVEL	12-1300	13-1400	14-1500	15-1600	16-1700	17-1800	18-1900	19-2000	20-2100	21-2200	22-2300	23-2400
1	18	13	11	7	1	1	0	0	0	0	0	0
2	51	49	29	17	14	6	1	1	0	0	0	0
3	33	25	23	45	53	26	10	1	0	0	0	0
4	29	26	37	35	24	30	14	4	1	0	0	0
5	19	21	18	21	27	25	14	6	1	0	0	0
6	13	28	17	13	19	20	18	9	2	1	0	0
LEVEL	24-2500	25-2600	26-2700	27-2800	28-2900	29-3000	30-3100	31-3200	32-3300	33-3400	34-3500	OVER 3500
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0

BURN NUMBER 2

INNER THERMOCOUPLES

LEVEL	MEAN	VARIANCE	DEVIATION	4TH ROOT
1	647.485	75647.7	276.853	784.328
2	1133.213	129719.3	360.156	1253.911
3	1385.224	242853.5	492.842	1559.990
4	1278.729	237636.8	487.490	1469.329
5	1304.151	274973.7	528.180	1519.375
6	1208.012	304256.0	551.590	1471.360

LEVEL	0-100	1-200	2-300	3-400	4-500	5-600	6-700	7-800	8-900	9-1000	10-1100	11-1200
1	35	14	5	31	90	106	74	77	60	35	40	25
2	0	10	37	3	6	7	7	14	14	34	59	87
3	0	19	25	4	6	9	9	6	14	14	22	24
4	1	28	5	3	6	7	18	21	14	23	34	34
5	1	22	13	7	8	7	13	14	14	19	16	25
6	1	27	24	11	11	20	31	32	35	26	32	25

LEVEL	12-1300	13-1400	14-1500	15-1600	16-1700	17-1800	18-1900	19-2000	20-2100	21-2200	22-2300	23-2400
1	9	1	0	0	0	0	0	0	0	0	0	0
2	119	116	54	7	8	7	6	5	1	0	0	0
3	38	41	40	46	64	108	84	17	2	0	0	0
4	33	30	47	34	51	82	44	1	2	0	0	0
5	15	28	24	40	45	51	24	19	2	1	0	0
6	18	33	29	42	30	62	56	31	10	0	0	0

LEVEL	24-2500	25-2600	26-2700	27-2800	28-2900	29-3000	30-3100	31-3200	32-3300	33-3400	34-3500	OVER 3500
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0

BURN NUMBER 2

OUTER THERMOCOUPLES

LEVEL MEAN VARIANCE DEVIATION 4TH ROOT

1	743.890	102922.2	320.815	904.264
2	840.506	206076.6	453.957	1120.540
3	853.215	250410.6	500.410	1183.081
4	836.361	273359.9	522.838	1199.754
5	864.832	275702.4	525.074	1215.698
6	740.770	245510.5	495.490	1130.930

LEVEL 0-100 1-200 2-300 3-400 4-500 5-600 6-700 7-800 8-900 9-1000 10-1100 11-1200

1	60	19	10	60	87	100	109	153	154	137	47
2	2	17	35	130	91	83	42	92	65	59	91
3	2	40	44	120	101	57	53	41	33	42	33
4	1	68	125	109	99	81	77	63	46	46	38
5	11	55	50	74	91	58	61	38	38	52	36
6	3	75	110	165	141	100	83	56	44	32	40

LEVEL 12-1300 13-1400 14-1500 15-1600 16-1700 17-1800 18-1900 19-2000 20-2100 21-2200 22-2300 23-2400

1	32	11	2	4	2	1	2	0	0	0	0
2	57	55	41	36	26	6	3	3	0	0	0
3	47	32	37	51	46	13	4	3	0	0	0
4	44	37	40	46	56	24	17	9	1	0	0
5	41	29	26	29	37	30	15	2	0	0	0
6	27	34	24	29	27	19	22	10	1	0	0

LEVEL 24-2500 25-2600 26-2700 27-2800 28-2900 29-3000 30-3100 31-3200 32-3300 33-3400 34-3500 OVER 3500

1	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0

BURN NUMBER 3

INNER THERMOCOUPLES

LEVEL	MEAN	VARIANCE	DEVIATION	4TH ROOT	0-100	1-200	2-300	3-400	4-500	5-600	6-700	7-800	8-900	9-1000	10-1100	11-1200
1	956.721	4232.59	205.721	1017.832												
2	1248.789	102250.7	319.747	1343.216												
3	1469.875	173516.8	416.583	1594.929												
4	1335.746	163265.8	428.054	1490.671												
5	1300.532	181167.3	431.471	1467.181												
6	1243.436	171292.6	413.746	1409.859												
LEVEL 12-1300 13-1400 14-1500 15-1600 16-1700 17-1800 18-1900 19-2000 20-2100 21-2200 22-2300 23-2400																
1	60	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	67	122	94	86	6	5	0	0	0	0	0	0	0	0	0	0
3	21	31	50	50	77	64	42	0	0	0	0	0	0	0	0	0
4	24	31	39	43	38	47	43	7	0	0	0	0	0	0	0	0
5	44	50	54	54	34	43	25	0	0	0	0	0	0	0	0	0
6	42	36	35	31	36	36	5	0	0	0	0	0	0	0	0	0
LEVEL 24-2500 25-2600 26-2700 27-2800 28-2900 29-3000 30-3100 31-3200 32-3300 33-3400 34-3500 OVER 3500																
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

BURN NUMBER 3

OUTER THERMOCOUPLES

LEVEL	MEAN	VARIANCE	DEVIATION	4TH ROOT	0-100	1-200	2-300	3-400	4-500	5-600	6-700	7-800	8-900	9-1000	10-1100	11-1200
1	979.000	92999.5	304.943	1114.739												
2	912.211	147843.2	384.530	1117.906												
3	970.857	164813.5	410.849	1200.187												
4	855.811	185454.9	430.845	1124.412												
5	774.965	167444.1	432.948	1091.844												
6	716.596	171886.0	414.591	1034.922												
LEVEL	0-100	1-200	2-300	3-400	4-500	5-600	6-700	7-800	8-900	9-1000	10-1100	11-1200				
1	1	2	9	12	18	59	109	121	156	181	181	140				
2	0	6	17	34	79	106	133	108	68	57	52	60				
3	1	5	13	39	47	78	103	118	148	102	85	58				
4	0	12	53	79	108	165	184	154	61	66	41	36				
5	2	13	66	125	144	175	177	136	73	44	40	24				
6	0	9	70	154	168	169	131	73	55	33	28	22				
LEVEL	12-1300	13-1400	14-1500	15-1600	16-1700	17-1800	18-1900	19-2000	20-2100	21-2200	22-2300	23-2400				
1	62	29	26	25	26	30	7	3	0	0	0	0				
2	91	62	53	33	20	15	3	0	2	1	0	0				
3	27	52	26	34	40	39	32	11	0	0	0	0				
4	38	40	32	32	43	42	27	5	0	0	0	0				
5	20	20	32	29	27	33	31	13	0	0	0	0				
6	24	20	26	20	30	27	15	2	0	0	0	0				
LEVEL	24-2500	25-2600	26-2700	27-2800	28-2900	29-3000	30-3100	31-3200	32-3300	33-3400	34-3500	OVER 3500				
1	0	0	0	0	0	0	0	0	0	0	0	0				
2	0	0	0	0	0	0	0	0	0	0	0	0				
3	0	0	0	0	0	0	0	0	0	0	0	0				
4	0	0	0	0	0	0	0	0	0	0	0	0				
5	0	0	0	0	0	0	0	0	0	0	0	0				
6	0	0	0	0	0	0	0	0	0	0	0	0				

HURN NUMBER 4

INNER THERMOCOUPLES

LEVEL	MEAN	VARIANCE	DEVIATION	4TH ROOT	0-100	1-200	2-300	3-400	4-500	5-600	6-700	7-800	8-900	9-1000	10-1100	11-1200
1	842.500	4.302.4	200.755	903.562												
2	1284.815	135684.0	368.357	1407.023												
3	1596.443	142443.1	377.416	1597.663												
4	1454.234	197929.9	444.893	1507.138												
5	1473.667	157437.8	390.413	1593.988												
6	1333.392	182249.8	426.917	1587.512												
LEVEL	0-100	1-200	2-300	3-400	4-500	5-600	6-700	7-800	8-900	9-1000	10-1100	11-1200				
1	0	0	2	0	4	44	45	61	78	55	29	33				
2	1	3	3	4	5	5	7	8	14	11	20	20				
3	2	0	2	1	1	1	4	4	7	7	10	12				
4	1	0	2	3	4	6	9	12	11	8	15	16				
5	0	1	1	1	1	7	16	16	14	16	26	39				
6	0	0	2	1	5	14	15	10	34	25	29	41				
LEVEL	12-1300	13-1400	14-1500	15-1600	16-1700	17-1800	18-1900	19-2000	20-2100	21-2200	22-2300	23-2400				
1	17	0	0	0	0	0	0	0	0	0	0	0				
2	38	45	57	34	26	15	9	3	2	0	0	0				
3	19	16	32	36	45	80	48	42	36	2	0	0				
4	23	20	28	32	25	50	37	30	19	2	0	0				
5	35	32	41	51	57	89	48	37	27	0	0	0				
6	60	37	48	34	34	59	55	65	17	9	0	0				
LEVEL	24-2500	25-2600	26-2700	27-2800	28-2900	29-3000	30-3100	31-3200	32-3300	33-3400	34-3500	OVER 3500				
1	0	0	0	0	0	0	0	0	0	0	0	0				
2	0	0	0	0	0	0	0	0	0	0	0	0				
3	0	0	0	0	0	0	0	0	0	0	0	0				
4	0	0	0	0	0	0	0	0	0	0	0	0				
5	0	0	0	0	0	0	0	0	0	0	0	0				
6	0	0	0	0	0	0	0	0	0	0	0	0				

BURN NUMBER 4

OUTER THERMOCOUPLES

LEVEL	MEAN	VARIANCE	DEVIATION	4TH ROOT
1	979.311	114694.1	345.974	114.987
2	919.406	168082.6	433.645	137.558
3	1017.771	200055.9	447.279	126.500
4	930.241	191505.4	436.449	119.712
5	806.433	162485.7	403.075	108.242
6	742.499	163619.6	404.475	106.316

LEVEL	0-100	1-200	2-300	3-400	4-500	5-600	6-700	7-800	8-900	9-1000	10-1100	11-1200
1	0	1	1	20	40	50	80	114	96	112	92	50
2	1	2	39	45	91	109	88	55	59	53	37	70
3	2	6	6	12	71	122	98	141	96	101	75	56
4	0	1	26	63	110	138	105	143	122	114	76	71
5	0	3	39	135	155	157	169	116	118	93	92	59
6	0	4	37	203	145	91	79	126	136	92	42	29

LEVEL	12-1300	13-1400	14-1500	15-1600	16-1700	17-1800	18-1900	19-2000	20-2100	21-2200	22-2300	23-2400
1	43	17	11	16	19	12	7	5	5	2	0	0
2	41	44	58	31	22	20	12	2	9	0	0	0
3	51	46	54	49	43	59	47	26	7	0	0	0
4	49	50	38	31	39	51	35	21	12	0	0	0
5	53	17	25	14	19	23	25	14	7	0	0	0
6	17	14	16	15	9	11	8	4	10	8	1	0

LEVEL	24-2500	25-2600	26-2700	27-2800	28-2900	29-3000	30-3100	31-3200	32-3300	33-3400	34-3500	OVER 3500
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0

BURN NUMBER 5

INNER THERMOCOUPLES

LEVEL	MEAN	VARIANCE	DEVIATION	4TH ROOT	0-100	1-200	2-300	3-400	4-500	5-600	6-700	7-800	8-900	9-1000	10-1100	11-1200
1	999.544	75335.2	274.473	1094.982												
2	1242.287	203977.2	451.678	1455.119												
3	1260.481	437045.9	659.542	1594.074												
4	1528.865	209392.7	457.524	1597.498												
5	1682.353	521861.9	567.329	1545.318												
6	1426.843	167210.6	408.914	1373.941												
LEVEL	0-100	1-200	2-300	3-400	4-500	5-600	6-700	7-800	8-900	9-1000	10-1100	11-1200				
1	0	1	9	8	4	4	32	52	56	62	68	59				
2	1	4	5	2	3	3	5	4	1	7	7	27				
3	0	10	64	2	0	1	4	7	4	4	13	10				
4	0	1	2	2	4	4	2	4	19	17	10	21				
5	0	2	34	22	19	3	25	8	23	16	10	26				
6	0	1	6	1	1	8	14	12	16	18	23	34				
LEVEL	12-1300	13-1400	14-1500	15-1600	16-1700	17-1800	18-1900	19-2000	20-2100	21-2200	22-2300	23-2400				
1	49	40	29	2	0	1	6	0	0	0	0	0				
2	26	26	19	19	17	12	7	7	4	3	0	0				
3	11	15	25	40	44	20	13	14	12	6	2	7				
4	16	36	31	41	47	37	36	21	13	8	6	5				
5	30	21	27	33	42	62	31	24	8	5	0	0				
6	41	26	33	38	42	51	40	16	14	4	2	3				
LEVEL	24-2500	25-2600	26-2700	27-2800	28-2900	29-3000	30-3100	31-3200	32-3300	33-3400	34-3500	OVER 3500				
1	0	0	0	0	0	0	0	0	0	0	0	0				
2	0	0	0	0	0	0	0	0	0	0	0	0				
3	0	4	4	1	0	0	0	0	0	0	0	0				
4	7	1	1	2	0	0	0	0	0	0	0	0				
5	0	0	1	0	0	0	0	0	0	0	0	0				
6	1	1	1	0	0	0	0	0	0	0	0	0				

BURN NUMBER 5

OUTER THERMOCOUPLES

LEVEL	MEAN	VARIANCE	DEVIATION	4TH ROOT
1	991.086	111810.6	334.331	1145.323
2	1009.442	163707.4	404.638	1207.090
3	1128.363	282015.1	531.051	1447.705
4	1032.853	263870.3	513.633	1369.094
5	1005.868	227621.1	477.027	1307.334
6	757.674	192275.9	446.433	1121.220

LEVEL	0-100	1-200	2-300	3-400	4-500	5-600	6-700	7-800	8-900	9-1000	10-1100	11-1200
1	0	2	5	50	52	64	79	108	126	174	171	156
2	3	3	23	35	63	84	107	106	74	93	93	80
3	0	0	4	17	43	74	119	90	72	70	57	53
4	0	2	14	42	78	143	107	113	50	86	91	61
5	0	1	11	36	66	74	116	122	77	63	122	59
6	10	60	43	78	109	144	151	94	79	56	48	34

LEVEL	12-1300	13-1400	14-1500	15-1600	16-1700	17-1800	18-1900	19-2000	20-2100	21-2200	22-2300	23-2400
1	174	40	30	25	21	13	16	9	6	0	0	0
2	178	82	52	59	40	15	21	6	3	2	1	0
3	53	46	53	40	36	47	45	38	18	15	6	7
4	51	43	48	39	42	55	33	24	12	8	4	5
5	50	47	42	30	33	29	21	18	11	10	3	2
6	34	25	23	15	15	9	9	5	7	2	2	0

LEVEL	24-2500	25-2600	26-2700	27-2800	28-2900	29-3000	30-3100	31-3200	32-3300	33-3400	34-3500	OVER 3500
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	5	4	2	4	1	0	0	0	0	0	0	0
4	8	3	4	3	0	0	1	0	0	0	0	0
5	2	4	1	1	0	0	0	0	0	0	0	0
6	1	2	2	1	0	2	0	0	0	0	0	0

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and JP-4 aviation fuel fires is pre-  
sented. JP-4 aviation fuel burns with a  
slightly hotter flame temperature than

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100/130-octane aviation gasoline. The point of hottest temperature within the fire is in the center between 30 and 50 inches above the surface of the fuel. The interior of the fire is hotter than the edges at all heights 18 inches or greater above the fuel surface. At 6 inches above the fuel surface, the edges of the fire are hotter than the interior. No relationship between the temperature of the fire and time it has burned was found.

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