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SECHT III
AN EXPERIMENTAL INVESTIGATION OF TOP AND BOTTOM
FLOODING OF A NUCLEAR BUNDLE SIMULATOR

By

C. M. Moser R. W. Griebel

IDAHO NUCLEAR CORPORATION

NATIONAL REACTOR TESTING STATION

IDAHO FALLS, IDAHO

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IDAHO NUCLEAR CORPORATION
A Jointly Owned Subsidiary of
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ALLIED CHEMICAL CORPORATION
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ABSTRACT

The Scoping Emergency Cooling Heat Transfer (SECHT) Project was an experimental project directed at scoping the parameters of bottom and top flooding modes of emergency core cooling for nuclear reactor fuel bundles. The SECHT Project consisted of four series of tests of which the third series (SECHT III tests) is described in this report. The primary objective of the SECHT III tests was to perform timely sensitivity studies by using readily available hardware. Exact scaling of a segment of a reactor core was not accomplished; therefore, the results presented in this report are more qualitative than quantitative. The SECHT III testing program consisted of 55 experiments that were designed to form a parametric study over the range of variables thought possible at the initiation of the emergency core coolant injection in contemporary water cooled reactors. The test parameter variations included: initial bundle temperatures between 800 and 2000°F, cold flooding rates between 0.45 and 7.2 in./sec, average bundle power between 0 and 15,000 Btu/hr-ft², and coolant inlet temperatures between 100 and 200°F. The test vessel was fitted with a constrictive device which was placed over the exit as a means of providing preliminary data on the effects of water carry-over. Specific results show that the arrest and turnaround of the bundle temperature excursion occurs more quickly in tests which have high initial temperatures and that the sensitivity of turnaround time to bundle power decreases with increasing bundle initial temperature. The effect of the constriction is shown to be strongly dependent on flow rate. The experience gained from this project in electric heater design, instrumentation, and test procedures has been valuable to the Full Length Emergency Cooling Heat Transfer (FLECHT) Project.

SUMMARY

The evaluation of the ECC systems presently being designed and built into large pressurized water reactors is based primarily on analysis. Experimental data to evaluate this analysis are being provided by several separate effects programs. The SECHT Project was directed at scoping the parameters which determine the heat transfer effectiveness for both top and bottom flooding of a test assembly for various initial core conditions.

The SECHT III experimental configuration consisted of a vessel housing 37 six-foot-long, stainless steel clad, electrical power heaters with a uniform, axial power profile. This configuration is in contrast to that of SECHT I and II and other laboratory flooding experiments that have been carried out using pin bundles up to three feet long. The SECHT III heaters had an OD of 0.57 inch and were located on a square pitch of 0.75 inch. Sixty-eight spaded junction thermocouples were attached to the exterior cladding of the electrical heaters which were used as fuel rod simulators. Hydraulic systems were provided to flood the bundle from either the top or bottom. The flow housing was unheated, but insulated.

The test parameters and the range over which each parameter was varied are as follows:

Parameter	Operation Limits
Initial Bundle Temperature	600 to 2000°F
Average Heat Flux	0 to 15,000 Btu/hr-ft ² (0 to 0.667 kW/ft)
Coolant Temperature	100 to 200°F
Cold Flooding Rate	0.45 to 7.2 in./sec

The specific conclusions derived from the SECHT III test series are as follows:

- (1) Bottom flooding is an adequate technique to cool nuclear fuel rod bundles provided severe radial flow through the fuel pin matrix does not occur. The effect of radial flow could not be evaluated in the small SECHT array.
- (2) At all initial bundle temperatures investigated, the temperature excursion in the bundle was arrested or turned around for all elevations of nine inches or higher before the liquid level would have reached the corresponding elevation had the bundle been cold. The cause of the temperature excursion at a particular location has been shown to be related to the liquid entrainment in the steam flow generated by the hot fuel rod simulators.

- (3) For the temperature range investigated the time to turn the temperature transient was found to be inversely proportional to the initial bundle temperature; that is, the higher the initial bundle temperature, the shorter the time to turn the temperature transient for any given elevation. Also, the higher the initial temperature, the smaller the delay in turnaround between upper and lower elevations for a given cold flooding rate.
- (4) For a given cold flooding rate, the higher the initial bundle temperature, the smaller the effect of bundle power density on the turnaround time.
- (5) Placing a constriction over the exit of the test vessel aided cooling at the low flooding rate and retarded cooling at the high flooding rate. This conclusion implies that for a given set of test conditions, some critical constriction ratio (or flow blockage) must exist for which no effect on bundle cooling will result.

Further testing is needed on rod bundles of large radial dimensions in order to determine whether radial flow exists in a large open lattice core structure and to determine the extent of flow redistribution due to large and small flow blockage.

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SECHT III

AN EXPERIMENTAL INVESTIGATION OF BOTTOM AND TOP FLOODING USING ELECTRICAL HEATERS TO SIMULATE A NUCLEAR BUNDLE

This report summarizes the test results obtained from the Series III Scoping Emergency Cooling Heat Transfer (SECHT) Project, conducted by Idaho Nuclear Corporation.

The SECHT III Project was conducted as an experimental investigation of bottom and top entry flooding as emergency core cooling (ECC) techniques for commercial nuclear power reactors. This project fits into a sequence of related ECC investigations funded by the Atomic Energy Commission^[1]. In general, the SECHT Project was intended to investigate that portion of the loss-of-coolant accident (LOCA) between the time of ECC injection and the time at which all rod temperatures are reduced to a level at which rod damage can no longer occur due to a temperature transient. In particular, its purpose was to complement and extend the research conducted in SECHT I and II which has been reported previously^[2,3].

The basic SECHT Project consisted of a series of reflooding experiments on a 37-pin electrically heated rod bundle with the outside diameter of the heaters being 0.57 inches and with the heaters arranged on a square pitch with 0.75 inch center-to-center spacing for all four test series. The SECHT I and II tests used stainless steel clad heater rods three feet in length. The SECHT III tests used stainless steel clad heater rods six feet in length. The SECHT IV tests will use Zircaloy-2 clad heater rods six feet in length to evaluate the thermal behavior of Zircaloy-2 clad heaters relative to stainless steel clad heaters and to determine the behavior of Zircaloy-2 cladding when subjected to flooding at elevated temperatures. The primary variables for all four series were core initial temperature, reflooding rate, subcooling, and rod power.

Section I summarizes the project objectives, relationship to other ECC safety projects and project contributions. Section II provides a detailed description of the test assembly and instrumentation systems. Section III details the test sequence, provides a summary of typical results, and discusses the significance of the information obtained. Conclusions are included in the report summary and in Section IV. Section V is a list of references. Appendix A is a tabulation of key SECHT III data.

I. PROJECT DESCRIPTION

The core thermal transient initiated by a loss-of-coolant accident in a large power reactor can result in destruction of the core, primary vessel, and containment systems, with consequent release of fission products, if the ECC systems are unable to arrest the transient. Therefore, experiments must be conducted to determine the actual emergency cooling requirements to determine whether safety margins exist in the design of safety systems. The SECHT III test series which employed fuel rod simulators six feet in length represents an extension of the earlier SECHT I and II scoping tests which employed three-foot fuel rod simulators.

1. PROJECT OBJECTIVES

As one of several emergency core cooling projects, SECHT was intended to:

- (1) Provide an early evaluation of ECC effectiveness
- (2) Determine whether any unexpected phenomena occur during the ECC process and if such phenomena do occur to identify them
- (3) Evaluate the sensitivity of core heat transfer to various temperature and flow conditions
- (4) Provide guidance to the more sophisticated projects which are to follow (such as PWR-FLECHT and BWR-FLECHT).

2. RELATIONSHIP TO OTHER ECC SAFETY PROJECTS

The SECHT Project is part of a sequence of related water reactor safety programs directed by Idaho Nuclear Corporation. These include Fuel Heatup Simulation Test (FHUST) Program, Full Length Emergency Cooling Heat Transfer Tests (FLECHT) Project, Semiscale Blowdown and ECC Program, and the LOFT Emergency Core Cooling System Integral Test Program.

SECHT, Series III, which followed Series I and II, employed the same experimental configuration with only minor modifications. Six-foot heated length electrically powered fuel pin simulators replaced the previously used three-foot heaters of Series I and II. The capability for additional parametric combinations of the experimental variables was added, and a mechanism was constructed to investigate the effects of a constriction of the test vessel exit plenum on the ECC process. The number of experiments was such as to allow a single parameter to be studied effectively.

The experimental data obtained from Series III can be combined or compared with that obtained from both the Series I and II test results and the

FLECHT results. In this manner, significant data have been made available for use in development of analytical codes describing the ECC process. Also, the data will be compared with that obtained in Series IV to investigate stainless steel versus Zircaloy clad electric heaters. This information is to be used extensively in the FLECHT Project.

3. PROJECT CONTRIBUTION

As one of a series of ECC projects, SECHT III has provided immediately applicable information on bottom flooding as an ECC technique. Not only have phenomenological aspects been demonstrated and recorded, but significant data have also been collected and compiled as a result of the parametric experimental program. Whereas extensive analytical work must be completed before the total benefit of this project can be realized, the project has been beneficial to all parties interested in ECC in that it has demonstrated the:

- (1) Relative importance and interdependency of each experimental parameter on the cooling mechanism
- (2) Usefulness of the "margin of ECCS operation" philosophy for design considerations and direction of subsequent ECC projects
- (3) Effectiveness of a flooding technique in arresting the temperature excursion of a simulated nuclear bundle.

The data from SECHT III can be correlated with data from the previously reported SECHT I and II Series [2,3]. In effect, a demonstration of the geometric dependency of the cooling mechanism can be obtained from the results acquired from the two different core lengths. The addition of a constriction to the exit plenum of the test section simulated a flow restriction which could occur in an actual reactor system.

Stainless steel cladding used in SECHT III simulated the Zircaloy cladding used in a reactor to provide a basis from which the information obtained in SECHT, Series IV (which has Zircaloy clad heaters similar in every other aspect to the stainless clad rods), can be used to demonstrate the limitations, if any, which exist in using stainless steel.

The SECHT Project has advanced the technology of electrically powered heater rods (fuel pin simulators). The successful design developed for SECHT III has been further refined for application to the PWR-FLECHT Project.

II. EXPERIMENTAL APPARATUS

The SECHT III experimental facility is located at the National Reactor Testing Station (NRTS) approximately 45 miles west of Idaho Falls, Idaho.

1. PHYSICAL DESCRIPTION

The experimental apparatus, shown in Figures 1 and 2, consisted of an insulated cylindrical test vessel, a flood reservoir, a remote controlled pneumatic flood valve, throttling valves, a constant head flooding and recirculation pump, a coolant preheater and temperature controller, electrical fuel rod simulators, pressure transducers, and Chromel-Alumel thermocouples. A portion of the experimental apparatus which is not shown in Figures 1 and 2 includes the power source and control equipment as well as the electronic signal conditioning, acquisition, recording, and data reduction equipment.

2. TEST VESSEL

The SECHT III test vessel was fabricated from two identical four-foot length, six-inch diameter, type 304 stainless steel schedule 40 pipes, the details of which are shown in Figure 3. The top section of this vessel was used in the SECHT I and II tests. This vessel was open at the top to allow steam and water to be discharged directly to the atmosphere after traversing two 90 degree turns at the exit. Four inner grid structures provided lateral support for the electrically simulated fuel rods. These grids were constructed of 0.0625-inch diameter stainless steel welding rod laid out on a square pitch with 0.75-inch center-to-center spacing and were located at the 24-, 42-, 60-, and 78-inch elevations measured from the bottom flange. Support for the weight of the rods, as well as additional lateral support, was provided by the rod support and hold-down plate located at the top of the test vessel.

The test vessel contained eight viewing ports; one each at the 12-, 27-1/2-, 64-, and 82-inch elevations from the bottom flange of the test vessel and two each at the 43- and 73-inch elevations. The two ports located at each of the 43- and 73-inch elevations were 180 degrees apart to provide views of the heaters at the 40- and 70-inch elevations (relative to the bottom of the rods) as well as coolant flow around the grid at the 42-inch elevation (Figure 3). One viewing port at each of these two elevations was made of Vycor glass and positioned 0.375-inch from the electrical simulated fuel rods to facilitate high speed films of the cooling phenomenon.

The top of the test vessel was fitted with an adjustable annular ring so that the coolant flow exiting from the top of the vessel could be reduced or completely shut off. This annular ring was placed between the rod support plate and the steam deflector (Figure 3).

Fig. 1 Thermal hydraulic equipment.

Fig. 2 SECHT III test apparatus.

Fig. 3 SECHT III test vessel assembly.

The array of electrically simulated fuel rods consisted of thirty-seven 0.58-inch diameter stainless steel clad rods on a square 0.75-inch pitch with the lower end of the heaters positioned five inches above the bottom flange (Figure 3). These electrically simulated fuel rods or heaters had a six-foot heated length and an 18-inch passive length at the top for mechanical support. As shown in Figure 4, the top end of the heaters had a moisture-proof seal and a stainless steel flexible hose swaged into place to protect the power leads. The heaters were commercial Watlow "Firerods" rated for 4000 watts at 220 volts. A magnesium oxide (MgO) dielectric surrounded two Nichrome center pin conductors and multiple Nichrome heater elements wired in parallel. Each rod contained eleven 6-1/4-inch long heater elements. One-half inch spacers of high density magnesium oxide separated the elements. Portions of three heater rods are shown in Figure 5.

Fig. 4 SECHT III heater rod details.

A manually controlled rectifier was used to provide direct current to three saturable reactors which in turn supplied current to the heaters. The power was supplied to the heater rods on three phases with 12 heater rods connected in parallel on each of two phases and 13 heater rods in parallel on the third phase, as shown in the circuit diagrams of Figure 6. Each heater rod was instrumented to monitor individual heater power levels. Meters located on the front of the reactrol control console, as shown in Figure 7, were used to detect open circuit heater elements and to assist in maintaining a balanced load on all phases. Twelve extra heater rods, located in a water tank separate from the test vessel, could be switched into the circuit to correct for load imbalance (Figure 6).

Fig. 5 SECHT III heater rods (6-1/4-inch elements).

Fig. 6 SECHT III circuit diagram.

Fig. 7 Reactrol control console.

3. RESERVOIR AND PIPING

The facility had a single flooding system which provided both top and bottom flooding capabilities (Figures 2 and 3). This system consisted of a temperature controlled coolant reservoir with two-inch galvanized pipe flood lines, a remotely controlled pneumatic flood valve, a flooding and recirculating pump, and two throttle valves, as shown in Figures 1 and 8. The flood reservoir was 46 inches high and 22-1/4 inches in diameter and had a capacity of about 77 gallons. The bottom of the reservoir was located 19 feet above the horizontal run of pipe leading to the bottom inlet of the vessel (Figure 1) such that a maximum flooding head of 22 feet 10 inches was provided at the start of a test.

For all tests the coolant used to flood the test assembly was demineralized water. The technique used for top or bottom flooding was either gravity flooding with a pseudo-constant head or forced pump flooding with a constant head. The coolant temperature could be varied from ambient to 200°F.

Fig. 8 Test vessel and flooding system.

4. INSTRUMENTATION

The sensing instruments for the SECHT III tests were type K, Chromel-Alumel stainless steel sheathed thermocouples and diaphragm gage-type pressure transducers with a star-type pickup. Ninety-four thermocouples and three pressure transducers were used in this test series.

Average flooding rate data and the amount of coolant reserve at any time were provided by a pressure transducer (0 to 2 psid) mounted in the bottom of the flood reservoir.

The internal pressure of the test vessel was monitored by two pressure transducers (0 to 100 psid) which were mounted diametrically opposite on 0.5-inch diameter, six-inch long nipples through the bottom flange of the test vessel. The entire exterior lengths of these nipples were wrapped with cooling coils, and these coils were attached with silver solder to improve the thermal coupling (Figures 1 and 2). The nipples were filled with water prior to testing, and coolant flowed continuously around them, through the cooling coils, during the tests, to eliminate effects due to temperature gradients at the head of the transducer. The pressure transducers were calibrated before testing by using a dead-weight tester and a pressure gage. They were then calibrated in place under actual test conditions.

Four intrinsic, 7 standard grounded, and 83 grounded spade junction thermocouples were used in this test series. These thermocouples had response times in the range of 5 to 25 milliseconds. The response time was measured by plunging the thermocouple at room temperature into water at nearly the boiling temperature and then displaying the resulting signal on a photo-oscilloscope. All response times were taken as 63% of the rise time. Typical response times are shown in Figure 9. The junctions of all the intrinsic and grounded spade junction thermocouples were spot welded to the surface of either the heater rods or the vessel, and the sheath was held by straps spaced at four-inch intervals. The seven standard grounded junction thermocouples were held in place by tube fittings.

The external surface temperature of the heater rods was monitored by 68 thermocouples positioned at the 0-, 9-, 18-, 27-, 36-, 45-, 54-, 63-, and 72-inch elevations relative to the bottom of the heated length. These thermocouples were spot welded to the rod at the thermocouple junction. The sheath was secured to the heater rod by straps spaced at four-inch intervals along the rod. These straps were loose enough to prevent damage if the heater rod sagged or warped. Figure 10, although not an instrumented heater rod, illustrates the two types of thermocouple junctions and the method of attachment.

Whereas most of the thermocouples were used to measure the external surface temperature of the heater rods, 17 spade junction thermocouples were used to measure the vessel temperature at positions on a level with heater rod elevations of 0, 9, 18, 27, 36, 45, 54, 63, 72, and 81 inches. Of the 17 thermocouples used for measuring vessel temperature, 11 were located on the outside of the vessel and six were located on the inside. Figure 11 shows the locations of these thermocouples.

0.007" thick junction
Vertical axis: 0.02 V/cm
Horizontal axis: 10msec/cm

0.008" thick junction
Vertical axis: 0.02 V/cm
Horizontal axis: 10msec/cm

$t = V = 0$ at bottom right

Fig. 9 Response time of grounded spade junction thermocouples.

Nine thermocouples were used to measure the coolant temperature. Two thermocouples were used to measure the inlet coolant temperature, two measured the mid-elevation coolant temperature within the vessel, and five measured the temperature of the fluid exiting the vessel. Five of these thermocouples were specially designed probes which measured the adiabatic stagnation temperature. Figure 12 shows the location of these thermocouples and Figure 13 shows a cross section of one of the probes.

Figure 14 is a top view of the heater rods as they were located in the test assembly. The figure also shows the thermocouple locations. The thermocouples are designated by the rod position and elevation. For example, thermocouple D-1-18 is in the D row of column 1 and at the 18-inch elevation relative to the bottom of the heated length. The intrinsic junction thermocouples are depicted by double dots on the outside of the circle representing the heater rod. Figure 15 depicts the thermocouples at each elevation on a separate test array.

Fig. 10 Intrinsic and grounded spade junction thermocouples.

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Fig. 11 Test vessel thermocouple locations.

Fig. 12 Vapor and liquid coolant temperature probes.

Fig. 13 Cross section of vapor or steam probe.

Fig. 14 Thermocouple orientation, elevation, and location.

Fig. 15 Thermocouple positions and elevations.

5. SIGNAL CONDITIONING, DATA ACQUISITION, AND RECORDING EQUIPMENT

The SECHT signal conditioning and data acquisition and recording equipment shown in Figure 16 consisted of a Model 201 analog data multiplexer, Honeywell Accudata Model 120 Amplifiers, an Ampex Model FR-1300 Recorder/Reproducer, a Honeywell Model 1108 Visicorder Oscillograph, and two multi-channel Bristol recorders.

The data acquisition system consisted primarily of the Model 201 analog data multiplexer. Figure 17 is a simplified block diagram of this system. Up to 100 low level, analog inputs can be multiplexed in groups of 10 channels or tracks with respect to the output of the multiplexer. Each of the 10 multiplexer outputs is conditioned by a separate low level recorder amplifier. The outputs from the 10 recorder amplifiers and a signal for analog-to-digital conversion drive the electronics of the magnetic tape recorder. This system has a frequency response from dc to 5 Hz.

The three methods of data acquisition were the wide-band FM magnetic tape system which recorded signals with frequency variations in the range of dc to 20 kHz, a wide-band direct recording oscillograph with a frequency

Fig. 16 SECHT III signal conditioning, data acquisition, and recording equipment.

Fig. 17 Simplified block diagram of the Model 201 analog data multiplexer.

range of dc to 5 kHz, and two multichannel strip chart recorders having an essentially dc frequency response.

The Ampex Model FR-1300 Recorder/Reproducer is a multichannel instrument with a 14-track recording and reproducing capability. All of the data recorded on the FR-1300 in SECHT III were reproduced on the FR-600 machine located at the SPERT facility.

The Visicorder is a direct recording oscillograph that monitored up to 24 channels with a frequency range of dc to 5 kHz. Because the Visicorder allowed immediate observation of the data traces, it provided the opportunity for spotting and correcting instrumentation problems. The Visicorder, as well as a digital voltmeter, also monitored the reference thermocouples to indicate when flooding should begin and cease.

The signals generated at all thermocouple junctions were referenced to two multichannel thermocouple 150°F reference junctions, then transmitted to a switching arrangement for comparison with a calibration source, and on to the analog data multiplexer. Each of the multiplexer outputs was conditioned by a separate low level recorder amplifier and the outputs of these amplifiers were monitored by an oscilloscope and recorded on magnetic tape, light sensitive paper, or strip chart paper.

All SECHT instrumentation was calibrated weekly and after each alteration or replacement of electronic equipment.

Figure 6 of Section II-2 shows a circuit diagram containing four wiring schematics of the SECHT system.

6. DATA REDUCTION

As noted previously, all of the data recorded on analog magnetic tape by the SECHT data acquisition system were subsequently processed by the high speed analog-to-digital conversion facilities for storage and computer analysis. The general flow of data through the complete data system is indicated in Figure 18.

7. TEST PROCEDURE

The following general test procedure was used in all tests:

- (1) The flow control valves were adjusted to provide the desired flooding technique and cold flooding rate as determined by measuring the flooding rate in the unheated test array.
- (2) A preoperational instrument and electrical systems check-out was conducted.
- (3) The coolant in the flood tank was heated to the desired test temperature.
- (4) The heater power was switched on.
- (5) The test array was heated in air to a temperature between 200 and 400°F below the desired test temperature and held at this temperature while final instrumentation checks were conducted. A power level below the desired test value was employed to minimize heater damage.
- (6) The heater voltage was adjusted to give the desired test power rating.
- (7) The preselected reference thermocouple on the Visicorder was monitored and the data recording equipment was activated at the desired temperature. These operations automatically opened the flood valve.
- (8) Flooding was continued until the preselected reference thermocouple at the top of the test array indicated the saturation temperature.
- (9) The flood valve was closed and the heater power was switched off. (The data recording equipment stopped automatically.)
- (10) Postoperational instrument and electrical checkout was performed.

Fig. 18 SECHT III data system flow diagram.

III. EXPERIMENTAL PROGRAM

This section presents the information requirements, the ranges of parameter variations, a tabulation of parameters for each test in the series, significant test data and results, temperature traces, and conclusions drawn from the data.

1. INFORMATION REQUIREMENTS

The variables required to specify ECC requirements for a given reactor include break size, break location, operation history of the core, blowdown heat transfer, water inventory remaining in the vessel at the end of blowdown, and the effectiveness of coolant injected for the various core conditions. Also to determine the performance margins in existing ECC systems, degraded flow rates must be considered because of the possibility of the unavailability of electrical power sources and the possibility of equipment failures.

The SECHT III experimental program was intended to provide experimental information in the parameter regions believed to be of most interest in terms of minimum ECC requirements. The test series was limited to temperatures below 2000°F because of the upper temperature limits on the electrical heaters. The parameters and corresponding limits are shown in Table I.

TABLE I

SECHT III EXPERIMENTAL PARAMETERS

<u>Parameter</u>	<u>Operation Limits</u>
Initial Bundle Temperature	600 to 2000°F
Heater Power Level at Flooding	0 to 15,000 Btu/hr-ft ²
Coolant Temperature	100 and 200°F
Cold Flooding Rate	0.45 to 7.2 in./sec
Coolant Entry Mode	Bottom and Top Flooding

All but one of the experimental parameters were held constant and the parameter of interest was varied. In this manner, the significance of the particular parameter and the sensitivity of the resulting core cooling could be determined. The resulting matrix of experimental runs and corresponding system parameters is shown in Table II.

TABLE II

SECHT III TEST SERIES

Test [a]		31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	49	50	51	52	53	54	55	56	57	58
Power at Flcoding (Q/A) _{avg} $\left(\frac{1000 \text{ Btu}}{\text{hr-ft}^2}\right)$	C																											
	6.4																											
	15																											
Initial Reference Surface Temper- ature (°F)	600																											
	800																											
	1000																											
	1200																											
	1400																											
	1600																											
	1800																											
	2000																											
Coolant Temper- ature (°F)	100																											
	200																											
Cold Flooding Rate (in./sec)	0.45																											
	0.9																											
	1.8																											
	3.6																											
	7.2																											
Top Flooding																												
Bottom Flooding																												
Pseudo Constant Head																												
Constant Head																												
No Constriction																												
Constriction																												

[a] Test 48 was not completed because of instrument failure.

TABLE II (Contd.)

SECHT III TEST SERIES

Test Number		59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
Power at Flooding	0																											
(Q/A) _{avg} $\left(\frac{1000 \text{ Btu}}{\text{hr-ft}^2}\right)$	6.4																											
	15																											
Initial Reference Surface Temperature (°F)	600																											
	800																											
	1000																											
	1200																											
	1400																											
	1600																											
	1800																											
	2000																											
Coolant Temperature (°F)	100																											
	200																											
Cold Flooding Rate (in./sec)	0.45																											
	0.9																											
	1.8																											
	3.6																											
	7.2																											
Top Flooding																												
Bottom Flooding																												
Pseudo Constant Head																												
Constant Head																												
No Constriction																												
Constriction																												

2. PRESENTATION OF DATA

The data presented in this section are intended to be representative of all significant results obtained from this test series. Each figure is referenced to the appropriate run numbers, and Table II provides a summary of test conditions for all runs. In many cases the specific thermocouples which were used as a source for the plots are also noted on the figures. Figure 15 provides the specific locations of the thermocouples in the bundles (for example, the number D-5-45 represents a thermocouple on rod D-5 at the 45-inch elevation). The zero time in Figures 19 through 24 represents the time when flooding was initiated. The time when the water level reached the bottom of the heated elements is zero time on all other figures. The time when the water level reached the bottom of the heater is marked on Figures 19 through 24; however, care should be exercised in comparing one figure with another.

2.1 Temperature Traces

First consideration must be given to a discussion of typical temperature time information for a thermocouple located on the cladding surface of a rod. The traces in Figure 19 are photographic reproductions of data print-out for the same thermocouple in four different experiments. Several characteristics of the cladding temperature response to bottom flooding are evident in this figure.

First, the thermocouples were attached externally to the rod surface such that coolant impinging unevenly on the junction probably caused the fluctuations in temperature. The unevenness at point B is probably due to white noise caused by boiling.

Second, all the traces show an abrupt change in slope shortly after initiation of cooling. This change in slope, as noted at points A in Figure 19, defines the turnaround time for the temperature transient. At this time, sufficient coolant has arrived at the location of the thermocouple to generate a heat transfer coefficient sufficiently large such that the temperature difference between the cladding and the environment (coolant) provides a net heat flux out from the exterior surface of the cladding. The net heat flux to the cladding from the rod internals is a combination of stored energy and the simulated decay energy from the heater filament.

Third, after a long period of monotonically decreasing temperature, the thermocouple trace exhibits another abrupt change in slope. These changes, labeled B in Figure 19, correspond to the quenching point of the rod at which a transition is made from film boiling to nucleate boiling. Quenching usually occurred at about 800°F and seemed to be rather unpredictable from the standpoint of repeatability at a given time for the same location and experimental conditions. Some thermocouples exhibited irregular quenching on one experimental run (such as the quenching for the 1500°F initial temperature full power case in Figure 19) and then a regular quenching on another run (such as the quenching for the 1500°F initial temperature zero power case in Figure 19). The data from tests using internal thermocouples indicate that quenching occurs at temperatures 200 to 400°F higher than indicated by external thermocouples but that quenching occurs at about the same time in both cases.

Fig. 19 Center rod surface temperature at midelevation after flooding begins for two initial temperatures as a function of power level.

The temperature traces in Figures 20 and 21 provide additional information for typical temperature behavior. The two plots represent traces from several thermocouples on the same rod. The quenching is irregular for thermocouple D-3-27 in both cases. From other data not presented, this quenching behavior at the 27-inch elevation appears to be a function of the local coolant behavior because it appears consistently at thermocouples on other rods. The irregular quenching also occurred randomly at other elevations.

Some differences in the temperature behavior of the rods can be noted in Figures 22 and 23 which present temperature traces obtained when a constriction was placed over the exit of the test vessel. The temperature of the rod cladding appears to drop at a higher rate immediately following turnaround for the constricted case than for the unconstricted case. A temperature drop after turnaround of approximately 100°F for the unrestricted cases as compared to approximately 200°F for the restricted cases can be seen in Figures 20 through 23, respectively.

2.2 Marginal Emergency Core Cooling Conditions

The temperature profiles presented to this time have shown the typical characteristics of turnaround and cooldown to quenching. The temperature time behavior shown in Figure 24 presents a situation of marginal cooling. That is, the temperature excursion was arrested early in the transient; however,

Fig. 20 Surface temperature versus time after flooding begins.

Fig. 21 Typical profiles of temperature versus time after flooding begins.

Fig. 22 Surface temperature versus time after flooding begins for constricted vessel -- Run 57.

turnaround did not occur until an additional 184 seconds had elapsed. In this period, a quasi-steady state condition existed during which the heat flux from the cladding surface to the coolant equaled that to the cladding from the rod interior.

A simple calculation was based on the assumption that the rod was at quasi-steady state during the 184 seconds and all energy transferred to the coolant was the decay energy and not the stored energy in the rod. This assumption allows a film coefficient to be calculated from the following expression:

$$(Q/A)_{\text{avg}} = h (T_{\text{clad}} - T_{\text{environment}})$$

where

$$T_{\text{environment}} = T_{\text{saturation}} \sim 210^{\circ}\text{F} \quad \text{and} \quad T_{\text{clad}} \cong 1900^{\circ}\text{F}.$$

Then

$$h = \frac{15,000}{(T_{\text{clad}} - 210)} = 8.9 \frac{\text{Btu}}{\text{hr-ft}^2\text{-}^{\circ}\text{F}}$$

Fig. 23 Surface temperature versus time after flooding begins for constricted vessel -- Run 58.

Fig. 24 An example of a marginal emergency core cooling condition.

2.3 Liquid Entrainment

The temperature information presented to this point has shown typical response of the simulated core segment to bottom flooding ECC. Some explanation of the causes for such phenomena as turnaround of the temperature transient can be made.

The fact that quenching time for the four thermocouple locations, represented by the temperature traces illustrated in Figure 21, increase with time as a function of elevation from the rod bottom is evident. However, the significant fact is that the time to terminate the temperature transients for the four locations is nearly equal, implying that a heat transfer coefficient of sufficiently large magnitude is generated nearly simultaneously over the length of the core. The explanation can be found in the photo sequence of Figures 25 and 26.

Fig. 25 Schematic of the views shown in Figure 26.

Fig. 26 Sequence showing development of liquid entrainment.

Figure 25 is a schematic of the lower viewing port of the SECHT vessel. It is used to introduce the sequence of photographs shown in Figure 26, which is a composite taken from a high-speed 16-mm motion picture taken through the bottom viewing port of the test vessel. From the time when the liquid level reaches the bottom of the heated section of the core to the time of the first view (approximately 4.5 seconds) only single phase vapor has passed the port. At the time indicated in View 1, several small droplets of liquid water can be seen entrained in the steam. Thus, entrainment of water in the bundle appears to occur after some as yet unspecified threshold is reached by the liquid water entering the vessel. As time continues through View 6, a correspondingly increasing amount of water was entrained in the steam. The total time elapsed from Views 1 to 6 was 664 milliseconds.

A motion analyzer was used to obtain both the velocities of entrained water droplets and dimensions in two coordinates. The data presented in Table III were obtained from the same high speed film as the sequence shown in Figure 26. As a result, the droplets have been identified in Figure 26 so that the tabular data can be correlated with the actual water droplet.

TABLE III

LIQUID DROPLET ENTRAINMENT -- RUN 70

(Data Obtained from Bottom Viewport;

$T_1 = 1400^\circ\text{F}$, Flooding Rate = 3.6 in./sec, Coolant Temperature = 200°F)

Identification in Figure 26	X-Dimension (in.)	Y-Dimension (in.)	Upward Velocity (ft/sec)
A	0.115	0.089	5.21
B	0.214	0.150	0.6
C	0.111	0.096	7.5
D	0.374	0.286	5.0

Additional entrainment information not correlated to a photographic sequence is presented in Tables IV and V.

TABLE IV

LIQUID DROPLET ENTRAINMENT -- RUN 75

(Data Obtained from Bottom Viewport;
 $T_i = 2000^\circ\text{F}$, Flooding Rate = 3.6 in./sec, Coolant Temperature = 100°F)

<u>Time From Liquid at Zero Elevation (sec)</u>	<u>X-Dimension (in.)</u>	<u>Y-Dimension (in.)</u>	<u>Upward Velocity (ft/sec)</u>
~5.5	0.053	0.053	6.6
~5.6	0.058	0.082	8.1
~5.6	0.113	0.105	9.04
~5.8	0.146	0.082	7.5
~5.9	0.069	0.078	9.1

TABLE V

LIQUID DROPLET ENTRAINMENT -- RUN 58

(Data Obtained from Top Viewport;
 $T_i = 1800^\circ\text{F}$, Flooding Rate = 1.8 in./sec, Coolant Temperature = 100°F ,
 Constricted Vessel)

<u>Time From Liquid at Zero Elevation (sec)</u>	<u>X-Dimension (in.)</u>	<u>Y-Dimension (in.)</u>	<u>Upward Velocity (ft/sec)</u>
~4.7	0.048	0.153	21.2
~4.7	0.070	0.153	23.0
~5.4	0.043	0.017	21.6
~5.7	0.068	0.096	18.8
~7.7	0.060	0.142	18.0

Whereas Table III and IV are representative of conditions at the bottom viewing port, Table V was derived from photographs taken at the top port.

The evaporation of water droplets as they move up the bundle results in higher steam velocities and a lower slip ratio (smaller droplets).

To determine the magnitude of liquid entrainment, an experiment was conducted in which the liquid carryover was measured as a function of time. Figure 27 shows that for the given test conditions, the first entrained liquid appeared approximately 4.5 seconds after the liquid level reached the bottom of the heated portion of the fuel pin simulators. At approximately 40 seconds, the asymptotic carry-over was first achieved. After this time, the rate remained constant at 67% of the input coolant rate.

2.4 Time to Terminate the Temperature Transient

The factors associated with the process by which the temperature transient is terminated have been presented in the temperature traces and shown to be due to liquid entrainment in the steam flow up through the core. More definitive information regarding when turnaround occurs as a function of experimental parameters can be made.

The data in Figure 28 show turnaround times in the bundle having zero power input (that is, after the desired initial bundle temperature was achieved, flooding was initiated and the power was terminated simultaneously). The turnaround time increased with elevation up to the midplane of the bundle. Then, the top half of the bundle achieved turnaround as a unit.

The same type of behavior is seen in Figure 29 for the full power case. That is, for each initial temperature presented, some asymptotic value of turnaround time was achieved. The higher the initial temperature, the sooner this asymptotic value was reached. Thus, for a given flooding rate and bundle power, the higher the initial temperature, the sooner the temperature rise of the full length of the rods was terminated. The earlier termination of the temperature transient at high temperatures can be attributed to a low liquid level generating sufficient vapor velocity up through the core for liquid entrainment. Thus, a given cold flooding rate results in a smaller time increment to turnaround for the higher initial bundle temperature. The steam generation is proportional to the area of the rod experiencing film boiling and the rod temperature for a given subcooling.

Data shown in Figures 30 and 31 indicate the sensitivity of turnaround time to bundle power level. At the lower (800°F) bundle initial temperature the effect of power is more pronounced than at the higher initial bundle temperature (1600°F), because of insufficient steam generation in the lower section until the water level reaches a higher elevation for the 800°F case (more surface area in film boiling).

The effect on turnaround time of placing a constriction device over the exit plenum of the test vessel in the SECHT vessel can be seen in Figures 32 and 33. The net effect of constricting the exit was to decrease turnaround times for the 1.8 in./sec flooding rate and to increase turnaround times for the 3.6 and 7.2 in./sec flooding rates. The constriction complicates the heat transfer processes inside the vessel by forcing changes in several parameters simultaneously. Some general remarks as to a most probable explanation for the change in turnaround times can be made.

Fig. 27 Volumetric liquid carry-over for Run 83.

Fig. 28 Time to terminate the temperature transient as a function of axial position and initial bundle temperature -- zero power cases.

Fig. 29 Time to terminate the temperature transient as a function of axial position and initial bundle temperature -- 15,000 Btu/hr-ft² cases.

Fig. 30 Time to terminate the temperature transient as a function of axial position and power density -- initial bundle temperature of 800°F.

Fig. 31 Time to terminate the temperature transient as a function of axial position and power density -- initial bundle temperature of 1600°F.

Fig. 32 Time to terminate the temperature transient as a function of flooding rate and axial position for a given initial bundle temperature.

Fig. 33 Time to terminate the temperature transient as a function of flooding rate and axial position for a given initial bundle temperature.

The fact that entrainment is dependent upon both velocity and density of the carrier fluid as well as surface tension and the method of formation or apparatus dimensions must be considered. Since the method of droplet formation and apparatus (bundle) remain the same, differences in the two-phase entrainment between the open and constricted vessel experiments apparently are due to velocity and density differences. The effect of the constriction was to raise the average pressure in the vessel and thus the density of the steam and to lower the mass flow rate out of the bundle and thus lower the average steam velocity up through the core. The maximum pressure difference recorded during a test with no constriction was 3.8 psid, and for a test with a constriction the maximum pressure difference was 8.8 psid.

As can be seen in Figures 32 and 33 for the 3.6 and 7.2 in./sec flooding rates, the differences between the constricted and unconstricted test data are smaller for the higher initial temperature of 1600°F. However, the differences at the low flooding rate of 1.8 in./sec are larger at the higher initial bundle temperature. The increase in convective heat transfer and entrainment capability for the low flooding rate helps generate conditions for turnaround; whereas the relative decrease in mass flux through the bundle for the high flood rates retards the conditions for turnaround.

Some flooding rate for each initial temperature of the bundle must exist for which the effect of the constriction on turnaround would not exist. Since only one constriction was investigated the net effect of various area changes has not been shown; however, the possibility exists of having some critical area ratio (exit area to bundle cross section area) for which no effect occurs on turnaround. Also these results could be dependent on test geometry (that is, in SECHT III the abnormally large annulus between the rods and the flow housing, which is unheated, provides an ideal path for coolant entrained in the steam to separate from the steam at the constriction and return to the bottom of the bundle). In a PWR core this path would not be available.

2.5 Quenching Time

In the quenching information presented in Figures 34, 35, and 36, the differences in quenching times for thermocouples located at the same elevation but different radial positions in the bundle are more significant at the low flooding rate. These greater differences are due to the water entrainment and subsequent cooling at any given position in the bundle acting as random phenomena. The longer times to cool at the low flooding rate due to the smaller coolant input cause the differences in local conditions to be more significant than for the higher flooding rates.

The straight line data-fit curves and the data in Table VI show some of the effects that initial bundle conditions have on quenching. For the 1.8 in./sec flooding rate at the three initial bundle temperatures of 800, 1200, and 1600°F, the rate that the quenching front moves up the core decreases as the initial temperatures increase. The higher the initial temperature, the larger the amount of stored energy in the rod, and subsequently, energy generated in the rods before the surface temperature can be reduced to approximately 800°F is also larger.

Fig. 34 Quenching time as a function of position and flooding rate -- initial bundle temperature of 800°F .

Fig. 35 Quenching time as a function of position and flooding rate -- initial bundle temperature of 1200°F .

Fig. 36 Quenching time as a function of position and flooding rate -- initial bundle temperature of 1600°F .

TABLE VI

ASYMPTOTIC QUENCHING—FRONT RATE (NO CONSTRICTION)

Cold Flooding Rate (in./sec)	Initial Bundle Temperature (°F)	Quenching Rate Up The Bundle (in./sec)
1.8	800	0.31
1.8	1200	0.27
1.8	1600	0.18
3.6	800	6.95
3.6	1200	0.66
7.2	1200	5.6
7.2	1600	0.67

The effect of the constriction on quenching is similar to that seen for the turnaround time. That is, as shown in Figure 35, at the 1.8 in./sec flooding rate quenching occurred earlier for the constricted experiment than for the open vessel. At the higher flood rate of 7.2 in./sec, the effect of the constriction was to increase the time to quenching.

2.6 Axial and Radial Temperature Profiles

To obtain the axial temperature profiles shown in Figures 37, 38, and 39, several thermocouples at each elevation were used wherever possible. Generally, the axial profiles show the quenching front as it progresses up the bundle and the subsequent effect on the temperature redistribution as time progresses.

The radial temperature profiles in Figures 40, 41, and 42 were taken at the mid-elevation of the bundle. At time zero, a definite gradient with the lower temperatures on the outer row of rods can be seen. As time progresses, this radial gradient becomes more pronounced. The gradient existed initially because of radiation loss to the cooler vessel walls during heatup. As time progresses, the outer course of rods cools much more quickly than the center region. Some channeling of the coolant towards the colder vessel wall may have been the cause for the preferential cooling that the radial profiles indicate.

Fig. 37 Axial temperature profiles as functions of time for center of bundle -- Run 34.

Fig. 38 Axial temperature profiles as functions of time for center of bundle -- Run 39.

Fig. 39 Axial temperature profiles as functions of time for center of bundle -- Run 42.

Fig. 40 Radial temperature profiles at mid-elevation as functions of time -- Run 34.

Fig. 41 Radial temperature profiles at mid-elevation as functions of time -- Run 30.

Fig. 42 Radial temperature profiles at mid-elevation as functions of time -- Run 42.

2.7 Top Flooding

The temperature-time traces shown in Figure 43 are for the same rod and thermocouple elevation (D-3-45) of four separate runs. A possibility of a small time discrepancy exists for Runs 67 and 73. Although this time discrepancy could not be resolved exactly because of the method of flooding employed, the general trends and conclusions concerning top versus bottom flooding are not affected. The traces for bottom flooding (Runs 42 and 57) begin when the water level in the test apparatus reaches the bottom of the heater rods. Several characteristics of the cladding temperature response to bottom and top flooding are evident.

First, regarding the time to quenching, top flooding is more effective in the upper one-third of the bundle than bottom flooding. Thus, it is more effective than bottom flooding in removing the stored heat in this region.

Second, regarding the time to quenching, bottom flooding is more effective in the lower two-thirds of the bundle than top flooding.

Although these two conclusions are not completely obvious from Figure 43, they become obvious when the data for all elevations are compared for both types of flooding.

Third, quenching occurs earlier for both top and bottom flooding when the top is constricted.

Fig. 43 Surface temperature versus time for top and bottom flooding.

Fourth, the constricted top has more effect on the time to quenching for bottom flooding than for top flooding.

The top flooding pipe enters the side of the vessel and no means exist for distributing the coolant over the entire top of the bundle. Thus, channeling of the coolant down the cold vessel wall may have caused preferential cooling.

Results from the two top flooding tests indicate that top flooding is essentially as effective a cooling mechanism as bottom flooding. However, the geometry of the SECHT test apparatus, in regard to the outer periphery flow area, is such as to minimize any steam binding effects. Some steam binding is, however, evident in the high speed films of Run 73.

IV. CONCLUSIONS

The results from the SECHT Project have provided the quantitative information required to meet all program objectives and have made a significant contribution to the overall ECC experimental program. The specific conclusions derived from this project are as follows:

- (1) Bottom flooding is an adequate technique to cool electrically simulated nuclear fuel rod bundles as long as the bundle is not so large as to induce significant radial flow through the fuel pin matrix. The effect of radial flow could not be evaluated in the small SECHT array.
- (2) At all initial bundle temperatures investigated, the temperature excursion in the bundle was arrested or turned around for all elevations of nine inches or higher before the liquid level would have reached the corresponding elevation had the bundle been cold. The cause for this phenomenon was shown to be related to the liquid entrainment in the steam flow generated by the hot fuel pin simulators.
- (3) For the temperature range investigated, the time to terminate the temperature transient was found to be inversely proportional to the initial bundle temperature (that is, the higher the initial bundle temperature, the shorter the time to terminate the temperature transient for any given elevation). Also, the higher the initial temperature, the smaller the delay in the time to terminate the transient between upper and lower elevations for a given cold flooding rate.
- (4) For a given cold flooding rate, the higher the initial bundle temperature, the smaller the effect of bundle power density on turnaround times.
- (5) The effect of placing a constriction over the exit of the test vessel was to aid cooling at the low flooding rate and to retard cooling at the high flooding rate. The implication of this conclusion is that for a given set of test conditions, some critical constriction ratio (or flow blockage) must exist for which no effect on bundle cooling can be seen.
- (6) Results from the two top flooding SECHT III tests indicate that top flooding is essentially as effective a cooling mechanism as bottom flooding; however, this result is believed to be unique to the SECHT test configuration and not directly applicable to power reactor cores. The geometry of the SECHT test apparatus, in regard to the outer periphery flow area, is such as to minimize any steam binding effects.
- (7) The externally mounted spade junction thermocouples proved to be a reliable method for obtaining temperature data on simulated nuclear reactor fuel bundles during reflood type experiments.

V. REFERENCES

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2. L. D. Schlenker, C. M. Moser, and W. S. Little, Interim Report on SECHT Series I and II Tests and Analysis, IDO-17278 (August 1968).
3. J. L. Plum and C. M. Moser, Scoping Emergency Cooling Heat Transfer (SECHT) Tests Project, IDO-17258D (April 1969).

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APPENDIX A --
TABULATION OF KEY SECHT III DATA

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APPENDIX A -- TABULATION OF KEY SECHT III DATA

The following key SECHT III data have been tabulated for the convenience of those who are involved in the loss-of-coolant accident, especially for those who do not have temperature-time data available for their specific needs. Users of these data should be aware of the geometrical differences between the SECHT experimental apparatus and a nuclear bundle.

Selected data has been tabulated for all tests from Runs 31 through 85, inclusive, with the following exceptions:

- (1) Run 38 (Run 64 replaces)
- (2) Run 46 (Run 83 replaces)
- (3) Run 48 (Run 49 replaces)
- (4) Run 50 (Run 79 replaces).

The tabulated data are in rough form, and no attempt has been made to correct computational errors or errors due to thermocouple malfunctions.

The following notation will be used for all tabular data:

- (1) T_i = the initial temperature or the temperature at the time that flooding is initiated
- (2) T_t = the temperature at the time the rise is terminated (the temperature at point A in Figure 19)
- (3) T_q = the temperature at the point of transition from film to nucleate boiling (the temperature at point B in Figure 19)
- (4) t_t = the time from the initiation of flooding until the time that the temperature rise is terminated (the time at point A in Figure 19)
- (5) t_q = the time from the initiation of flooding until the time that quenching occurs (the time at point B in Figure 19).

A reference temperature of 150°F must be added to all tabulated temperature data.

Run 31

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	730	777	472	12.0	28.4
C-4-36	772	810	529	12.4	47.8
C-4-54	812	829	445	13.6	83.6
D-1-0	398	381	---	6.0	---
D-1-18	513	551	366	10.5	28.9
D-1-36	593	636	391	9.7	48.0
D-1-54	614	652	462	10.9	58.6
D-2-0	342	372	372	5.3	5.3
D-3-9	740	733	632	10.4	13.3
D-3-27	712	777	469	10.4	51.2
D-3-45	758	775	435	13.6	68.9
D-3-63	803	813	421	12.9	106.6
D-4-18	735	735	529	12.5	30.0
D-4-36	756	762	420	13.7	64.1
D-4-54	791	810	349	11.7	89.3
D-5-9	717	754	754	10.5	10.5
D-5-27	743	767	446	12.1	50.9
D-5-45	760	790	463	10.9	76.4
D-5-63	807	816	633	18.0	61.2
D-7-18	529	529	250	10.8	38.9
D-7-36	576	617	408	10.7	38.5
D-7-54	615	634	406	10.9	62.8
E-4-0	423	485	466	4.0	5.3
E-4-18	736	797	502	12.1	33.1
E-4-36	805	850	459	10.5	67.7
E-4-54	828	864	424	12.0	89.6
F-2-18	622	653	366	9.1	41.6
F-2-36	651	689	399	11.9	57.3
F-2-54	687	693	479	13.3	60.0
G-4-18	464	464	305	10.5	34.4
G-4-36	579	619	219	13.1	66.8
G-4-54	530	564	325	13.3	59.4

Run 32

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	667	667	501	14.0	16.0
C-4-36	729	729	328	17.6	42.1
C-4-54	740	740	328	22.5	50.4
D-1-0	332	332	324	5.3	5.6
D-1-18	511	511	429	12.8	15.7
D-1-36	586	586	503	17.3	22.7
D-1-54	583	583	461	19.9	35.6
D-2-0	310	310	293	4.4	5.5
D-3-9	645	645	544	9.3	11.3
D-3-27	660	660	272	16.5	29.3
D-3-45	657	657	496	21.3	39.1
D-3-63	708	708	421	25.3	75.4
D-4-18	632	632	557	13.7	16.3
D-4-36	663	663	310	20.1	35.5
D-4-54	691	691	427	22.7	54.2
D-5-9	652	652	599	10.1	10.7
D-5-27	662	662	574	16.0	20.8
D-5-45	666	666	440	22.7	30.4
D-5-63	708	708	494	25.3	41.2
D-7-18	500	500	459	13.3	15.7
D-7-36	557	557	486	20.0	22.1
D-7-54	578	578	515	23.5	30.1
E-4-0	387	387	387	5.6	5.6
E-4-18	674	674	563	13.6	18.1
E-4-36	725	725	586	18.7	27.7
E-4-54	743	743	293	24.0	50.0
F-2-18	586	586	377	13.3	18.7
F-2-36	624	624	482	20.0	25.6
F-2-54	639	639	348	22.7	41.3
G-4-18	465	465	414	13.6	14.4
G-4-36	561	561	505	18.8	23.3
G-4-54	523	523	463	24.0	25.9

Run 33

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	768	768	558	12.0	16.0
C-4-36	814	814	653	15.5	27.3
C-4-54	824	856	461	17.9	66.2
D-1-0	407	374	374	5.3	5.3
D-1-18	611	624	438	8.0	17.5
D-1-36	689	699	523	11.6	25.5
D-1-54	679	714	414	12.0	58.9
D-2-0	402	402	402	4.5	4.5
D-3-9	775	775	775	9.1	9.1
D-3-27	796	796	586	13.3	31.3
D-3-45	802	802	513	16.9	60.4
D-3-63	854	859	609	16.3	54.8
D-4-18	754	754	632	12.8	17.5
D-4-36	806	806	150	14.7	48.1
D-4-54	842	856	616	14.4	25.7
D-5-9	787	787	787	9.2	9.2
D-5-27	796	815	588	14.4	24.0
D-5-45	808	850	609	14.7	48.0
D-5-63	861	867	544	16.1	52.2
D-7-18	614	632	514	8.0	17.3
D-7-36	666	674	528	12.7	22.4
D-7-54	672	691	486	14.3	51.3
E-4-0	510	510	510	4.8	4.8
E-4-18	809	809	650	12.7	21.9
E-4-36	861	882	586	12.9	41.1
E-4-54	890	903	565	17.7	58.2
F-2-18	695	691	410	12.0	19.1
F-2-36	727	735	494	15.9	34.8
F-2-54	737	733	456	17.5	61.3
G-4-18	553	591	467	11.1	16.5
G-4-36	668	691	565	12.5	21.5
G-4-54	614	649	425	13.2	46.8

Run 34

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	996	996	631	10.8	24.5
C-4-36	1046	1057	689	12.3	48.2
C-4-54	1076	1078	486	12.9	93.3
D-1-0	457	498	498	4.5	4.5
D-1-18	773	777	461	9.6	30.9
D-1-36	877	861	563	12.4	38.3
D-1-54	844	858	510	9.6	70.5
D-2-0	310	314	314	4.5	4.5
D-3-9	984	984	754	9.3	14.8
D-3-27	1022	1028	624	12.1	48.4
D-3-45	1001	1042	540	13.9	68.0
D-3-63	1068	1068	415	13.9	114.9
D-4-18	971	971	730	10.9	27.9
D-4-36	1030	1038	614	12.9	53.8
D-4-54	1051	1060	660	12.0	50.4
D-5-9	1001	1005	1005	9.3	9.3
D-5-27	1005	1005	626	12.1	42.7
D-5-45	1009	1047	563	13.2	75.2
D-5-63	1074	1091	540	13.5	92.2
D-7-18	771	777	648	11.1	17.6
D-7-36	836	838	544	10.1	38.7
D-7-54	846	840	528	13.2	63.0
E-4-0	602	602	602	4.7	4.8
E-4-18	1005	1005	706	10.5	31.9
E-4-36	1068	1068	624	12.0	82.7
E-4-54	1095	1099	605	10.8	80.4
F-2-18	859	867	450	9.3	33.3
F-2-36	921	915	505	12.3	54.0
F-2-54	913	921	500	12.0	79.2
G-4-18	657	673	426	12.1	25.2
G-4-36	854	859	348	12.1	50.0
G-4-54	777	796	394	11.6	72.0

Run 35

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1146	1150	638	10.0	35.3
C-4-36	1163	1169	675	10.8	64.0
C-4-54	1220	1224	453	11.3	118.0
D-1-0	555	555	555	3.9	3.9
D-1-18	910	916	477	9.6	41.5
D-1-36	989	1011	580	10.4	29.2
D-1-54	1001	1001	535	9.6	85.3
D-2-0	675	675	675	3.9	3.9
D-3-9	1131	1131	761	8.0	20.0
D-3-27	1195	1191	621	11.7	62.6
D-3-45	1205	1205	553	12.4	90.2
D-3-63	1230	1230	422	12.1	134.4
D-4-18	1165	1151	736	9.9	38.8
D-4-36	1205	1214	607	11.5	72.6
D-4-54	1220	1236	687	11.9	73.4
D-5-9	1146	1146	750	6.8	15.9
D-5-27	1203	1211	646	11.2	58.2
D-5-45	1223	1228	559	11.9	93.4
D-5-63	1246	1242	594	12.8	110.5
D-7-18	925	943	745	9.7	22.1
D-7-36	947	966	520	9.3	59.8
D-7-54	947	951	543	10.4	83.0
E-4-0	718	738	738	3.3	3.3
E-4-18	1150	1162	687	10.3	41.3
E-4-36	1242	1242	571	12.0	80.9
E-4-54	1234	1247	578	12.0	103.0
F-2-18	973	973	430	10.7	42.8
F-2-36	1035	1045	492	11.7	70.6
F-2-54	1031	1031	450	13.0	102.0
G-4-18	800	804	541	10.4	32.1
G-4-36	991	997	621	12.0	52.1
G-4-54	912	941	411	10.7	90.6

Run 36

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _g	t _t	t _g
C-4-18	1368	1368	792	9.1	39.3
C-4-36	1410	1410	716	9.3	73.0
C-4-54	1448	1452	481	10.8	115.2
D-1-0	640	640	640	4.1	4.1
D-1-18	1152	1152	543	8.0	46.5
D-1-36	1238	1238	495	8.0	60.4
D-1-54	1210	1231	582	6.7	89.6
D-2-0	874	874	874	4.4	874.4
D-3-9	1347	1347	843	6.7	22.4
D-3-27	1419	1419	656	9.6	68.0
D-3-45	1421	1440	551	10.0	101.4
D-3-63	1437	1444	411	10.5	141.2
D-4-18	1384	1395	775	9.1	42.9
D-4-36	1421	1421	722	10.0	66.9
D-4-54	1461	1461	716	9.5	65.3
D-5-9	1373	1373	972	7.7	14.3
D-5-27	1439	1433	696	9.1	64.6
D-5-45	1456	1456	582	9.5	102.2
D-5-63	1250	1267	573	10.4	127.0
D-7-18	1173	1190	804	9.1	34.3
D-7-36	1174	1174	561	8.1	64.1
D-7-54	1168	1168	594	9.2	83.4
E-4-0	968	950	950	4.1	413.6
E-4-18	1399	1395	749	8.7	42.7
E-4-36	1487	1487	660	9.1	82.8
E-4-54	1460	1460	605	10.0	99.2
F-2-18	1195	1195	780	9.2	42.4
F-2-36	1296	1296	516	9.6	82.0
F-2-54	1238	1244	557	10.0	94.9
G-4-18	1046	1046	615	8.0	42.4
G-4-36	1269	1269	660	8.0	72.1
G-4-54	1146	1146	456	8.0	96.0

Run 37

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1526	1530	650	8.1	49.4
C-4-36	1563	1583	710	9.2	87.0
C-4-54	1603	1628	490	8.8	128.2
D-1-0	864	864	864	4.1	4.1
D-1-18	1317	1317	458	8.0	54.0
D-1-36	1370	1366	487	9.2	69.4
D-1-54	1354	1358	570	7.5	102.9
D-2-0	1047	1043	1043	3.9	3.9
D-3-9	1518	1526	864	6.5	27.6
D-3-27	1563	1588	699	8.0	77.3
D-3-45	1600	1609	576	8.4	112.6
D-3-63	1587	1616	665	9.3	150.8
D-4-18	1576	1596	812	7.9	49.7
D-4-36	1613	1633	646	9.2	93.3
D-4-54	1614	1618	714	9.3	82.4
D-4-72	677	714	496	9.6	52.0
D-5-9	1545	1549	631	6.8	25.5
D-5-27	1603	1599	282	9.1	74.9
D-5-45	1599	1624	627	9.2	110.9
D-5-63	1628	1653	573	8.4	139.7
D-7-18	1587	1597	962	8.1	42.7
D-7-36	1321	1317	---	8.1	---
D-7-54	1280	1292	594	8.8	96.0
E-4-0	1108	1108	1108	4.0	1107.8
E-4-18	1563	1567	745	8.5	49.6
E-4-36	1662	1662	648	9.3	94.5
E-4-54	1609	1621	576	8.7	113.3
F-2-18	1321	1358	769	7.7	51.7
F-2-36	1473	1477	498	9.1	108.4
F-2-54	1362	1366	498	9.2	110.9
G-4-18	1448	1462	765	8.3	54.1
G-4-36	1445	1441	388	8.3	97.6
G-4-54	1284	1284	450	9.1	107.2

Run 39

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	706	843	592	17.3	20.3
C-4-36	718	841	408	21.6	80.4
C-4-54	757	881	661	22.7	98.2
D-1-0	333	422	349	6.5	7.7
D-1-18	601	665	508	17.1	19.9
D-1-36	623	722	514	19.7	25.2
D-1-54	632	735	550	24.9	114.1
D-2-0	435	464	447	6.8	7.7
D-3-9	679	741	605	10.9	15.1
D-3-27	706	786	256	20.1	47.2
D-3-45	708	808	583	23.6	78.8
D-3-63	752	872	565	26.4	167.8
D-4-36	706	811	599	21.2	67.0
D-4-54	740	861	695	23.1	28.0
D-4-72	114	140	114	24.4	25.9
D-5-9	666	728	708	11.5	13.3
D-5-27	704	797	675	20.3	23.6
D-5-45	725	824	565	23.5	116.9
D-5-63	751	874	787	28.0	85.3
D-7-18	626	699	591	16.3	19.7
D-7-36	623	714	579	21.3	30.0
D-7-54	619	712	601	24.0	92.6
E-4-0	409	431	431	6.8	6.8
E-4-18	714	827	576	16.3	20.9
E-4-36	749	876	644	21.6	67.3
E-4-54	805	927	251	24.1	116.0
F-2-18	663	749	650	16.4	20.1
F-2-36	702	801	596	22.5	56.1
G-4-18	554	634	474	17.3	20.1
G-4-36	634	724	590	22.8	44.1
G-4-54	555	665	537	25.2	91.7

Run 40

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1054	1119	568	15.2	29.8
C-4-36	1093	1191	711	16.7	93.3
C-4-54	1145	1254	607	19.3	206.6
C-4-72	472	555	501	21.5	27.1
D-1-0	527	527	527	8.0	8.0
D-1-18	908	987	526	13.9	55.3
D-1-36	954	1032	537	16.1	61.6
D-1-54	930	1011	571	18.8	189.1
D-2-0	656	687	687	8.0	8.0
D-3-9	1013	1075	702	13.3	23.8
D-3-27	1055	1141	658	17.7	85.3
D-3-45	1059	1163	598	18.0	137.3
D-3-63	1121	1231	565	20.0	252.2
D-4-36	1053	1152	642	18.9	103.2
D-4-54	1125	1225	787	20.0	98.6
D-5-9	1024	1103	770	13.3	16.0
D-5-27	1080	1163	737	17.6	67.4
D-5-45	1077	1167	641	19.1	166.6
D-5-63	1136	1249	851	20.0	182.7
D-7-18	930	998	866	15.6	25.2
D-7-36	929	997	619	15.2	82.9
D-7-54	908	991	601	16.7	168.6
E-4-0	613	640	640	7.7	7.7
E-4-18	1071	1095	657	16.4	50.8
E-4-36	1142	1241	691	17.1	110.5
F-2-18	959	1034	642	14.5	39.2
F-2-36	1032	1115	495	17.6	141.1
F-2-54	1038	1135	1135	16.0	16.0
G-4-18	843	920	601	17.1	44.3
G-4-36	970	1057	739	17.1	73.8
G-4-54	846	941	460	17.7	189.3

Run 41

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1233	1330	633	15.6	50.8
C-4-36	1264	1350	749	16.0	118.1
C-4-54	1311	1337	573	15.7	247.7
D-1-0	681	681	681	9.2	9.2
D-1-18	1042	1102	599	13.3	67.2
D-1-36	1094	1156	584	16.1	86.9
D-1-54	1055	1133	536	14.1	225.0
D-2-0	793	814	814	8.8	8.8
D-3-9	1201	1271	745	13.2	38.5
D-3-27	1238	1319	644	14.8	107.0
D-3-45	1248	1329	681	16.1	165.3
D-3-63	1277	1368	621	16.0	282.6
D-4-36	1240	1323	654	16.1	132.2
D-4-54	1321	1393	890	16.8	125.0
D-5-9	1234	1290	628	11.9	30.9
D-5-27	1250	1329	729	15.7	90.5
D-5-45	1264	1351	627	17.2	202.2
D-5-63	1309	1398	874	16.1	233.9
D-7-18	1070	1137	822	14.5	40.4
D-7-36	1040	1108	594	14.5	113.4
D-7-54	1032	1094	601	15.7	205.1
E-4-0	761	783	783	8.9	8.9
E-4-18	1225	1322	649	15.9	68.2
E-4-36	1306	1381	747	16.0	128.0
F-2-18	1075	1150	394	14.9	64.1
F-2-36	1170	1455	495	14.9	167.3
G-4-18	969	1031	544	15.9	66.5
G-4-36	1125	1201	731	16.5	106.6
G-4-54	972	1053	435	14.5	233.0

Run 42

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1409	1481	636	14.5	66.0
C-4-36	1457	1544	784	16.0	140.0
C-4-54	1529	1603	595	16.0	282.9
D-1-0	755	767	757	8.9	9.9
D-1-18	1240	1298	580	15.2	75.4
D-1-36	1296	1360	630	16.1	88.4
D-1-54	1249	1323	574	13.6	263.5
D-2-0	938	961	961	9.5	9.5
D-3-9	1412	1459	745	14.7	48.8
D-3-27	1438	1502	710	15.2	121.3
D-3-45	1452	1535	633	13.6	199.1
D-3-63	1493	1572	610	17.7	332.0
D-4-36	1416	1502	638	15.3	155.6
D-4-54	1518	1596	759	16.1	181.3
D-5-9	1448	1500	838	12.9	36.7
D-5-27	1448	1518	751	15.9	111.4
D-5-45	1462	1531	633	16.5	225.0
D-5-63	1542	1621	898	14.7	270.6
D-7-18	1254	1311	831	14.9	51.3
D-7-36	1238	1286	582	14.3	138.5
E-4-0	913	934	923	8.1	9.5
E-4-18	1419	1485	658	15.3	76.1
F-2-18	1270	1315	451	15.7	81.0
F-2-36	1379	1443	581	16.8	172.2
F-2-54	1362	1432	387	14.7	306.6
G-4-18	1211	1274	616	15.7	250.6
G-4-36	1327	141	737	16.0	132.0
G-4-54	1179	1404	454	15.7	273.3

Run 43

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1656	1685	664	14.7	81.3
C-4-36	1719	1769	809	13.3	161.0
C-4-54	1750	1804	653	15.5	288.2
C-4-72	892	954	718	15.7	101.3
D-1-0	860	882	882	8.5	8.5
D-1-18	1434	1475	600	14.1	88.5
D-1-36	1495	1538	616	13.6	125.3
D-1-54	1416	1465	563	13.1	282.3
D-2-0	1073	1105	1105	9.3	9.3
D-3-9	1590	1648	804	12.8	55.7
D-3-27	1664	1709	702	13.6	145.3
D-3-45	1678	1719	695	15.5	189.0
D-3-63	1638	1703	618	15.5	336.4
D-4-36	1666	1709	667	15.2	170.9
D-4-54	1728	1781	763	13.3	176.2
D-4-72	526	598	526	15.7	63.2
D-5-9	1653	1696	915	11.2	44.0
D-5-27	1676	1713	790	13.3	133.6
D-5-63	1696	1757	877	14.1	295.9
D-7-18	1434	1477	878	14.1	66.6
D-7-36	1407	1440	620	12.0	149.3
D-7-54	1376	1415	616	14.1	258.6
E-4-0	1131	1153	1153	9.3	9.3
E-4-18	1648	1691	699	13.3	88.8
F-2-18	1457	1504	923	13.6	67.2
F-2-36	1601	1644	513	13.3	214.1
F-2-54	1526	1578	588	15.5	314.0
G-4-18	1358	1414	429	14.1	103.7
G-4-36	1545	1600	741	13.6	149.3
G-4-54	1354	1378	450	14.1	282.9

Run 44

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	733	758	758	5.3	5.3
C-4-36	768	806	479	8.3	14.1
D-1-0	362	364	364	2.1	2.1
D-1-18	628	649	685	5.3	5.3
D-1-36	663	693	691	7.5	8.3
D-1-54	649	695	597	9.3	13.9
D-2-0	419	423	423	1.9	1.9
D-3-9	712	728	728	2.9	2.9
D-3-27	714	758	756	5.6	6.9
D-3-45	707	758	753	8.0	9.6
D-3-63	779	837	837	10.9	10.9
D-4-36	726	774	774	8.0	8.0
D-4-54	764	812	804	8.3	10.1
D-5-9	686	697	697	2.9	2.9
D-5-27	716	751	747	5.6	7.2
D-5-63	776	835	440	10.7	42.1
D-7-18	607	630	630	5.3	5.3
D-7-36	622	657	657	8.5	8.5
D-7-54	607	657	582	9.9	13.9
E-4-0	393	396	396	1.3	1.3
E-4-18	745	772	772	5.3	5.3
F-2-18	653	693	693	4.3	5.3
F-2-36	695	720	716	8.3	13.6
F-2-54	737	797	542	10.7	24.3
G-4-18	586	605	605	5.3	5.3
G-4-36	659	693	693	8.3	8.3
G-4-54	586	605	605	10.7	10.7

Run 45

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	523	523	523	5.3	5.3
C-4-36	1137	1179	494	5.9	45.6
C-4-72	519	563	523	7.5	9.9
D-1-0	---	---	---	0.0	0.0
D-1-18	877	915	624	3.5	8.3
D-1-36	990	990	990	5.6	5.6
D-1-54	987	1013	674	7.7	67.2
D-2-0	---	---	---	0.0	0.0
D-3-27	1091	1114	775	5.1	28.5
D-3-45	1091	1129	777	7.5	18.7
D-3-63	1152	1177	760	7.7	79.4
D-4-36	1104	1124	666	6.7	39.5
D-4-54	1127	1156	854	5.6	16.8
D-5-27	1110	1127	848	5.9	17.1
D-5-63	1108	1173	733	8.3	105.0
D-7-18	959	1018	946	2.1	5.1
D-7-36	942	944	710	5.1	19.5
D-7-54	949	949	672	5.6	54.1
E-4-18	528	519	523	5.1	5.1
F-2-18	986	1009	---	3.5	---
F-2-36	1055	1083	628	5.6	52.0
F-2-54	484	517	128	7.7	77.3
G-4-18	884	884	639	4.3	13.9
G-4-36	936	1053	402	4.8	56.0
G-4-54	905	932	536	7.2	56.5

Run 47

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	668	683	666	1.3	1.9
C-4-36	729	745	660	5.3	7.2
D-1-36	628	647	628	4.3	5.1
D-1-54	620	651	546	6.4	10.7
D-2-0	251	251	251	7.5	7.5
D-3-45	704	718	693	6.7	7.2
D-3-63	739	775	691	8.0	9.6
D-4-36	712	729	586	5.1	7.5
D-4-72	136	136	136	8.0	8.0
D-7-18	597	597	580	0.8	2.1
D-7-54	603	624	580	8.0	10.7
E-4-18	687	706	687	1.1	2.4
F-2-36	672	695	565	6.0	9.3
F-2-54	672	697	431	5.3	20.0
G-4-36	649	662	446	5.3	9.6
G-4-54	580	601	461	6.9	8.8

Run 49

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1064	1087	1087	4.5	4.5
C-4-36	1099	1143	543	6.8	25.3
C-4-72	501	539	334	8.1	12.1
D-1-0	534	542	534	1.3	1.6
D-1-18	892	919	919	4.3	4.3
D-1-36	978	1007	1003	6.4	6.8
D-1-54	934	978	708	6.7	37.3
D-2-0	656	656	656	1.9	1.9
D-3-9	1005	1029	1026	2.0	2.5
D-3-45	1107	1139	846	6.7	10.1
D-3-63	1116	1187	873	8.0	13.6
D-4-36	1027	1108	693	6.9	22.4
D-4-54	1152	1191	963	7.3	9.3
D-5-9	1044	1067	1053	2.9	3.3
D-7-18	890	913	913	4.4	4.4
D-7-36	940	965	712	6.7	13.2
D-7-54	917	963	700	7.1	34.4
E-4-0	628	632	632	1.6	1.6
F-2-36	1020	1057	622	6.7	26.5
F-2-54	1024	1068	492	7.1	56.5
G-4-18	842	869	869	4.3	4.3
G-4-36	1017	1044	497	6.5	27.3
G-4-54	873	921	541	7.3	35.1

Run 51

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	659	672	272	13.3	17.3
D-1-0	249	249	249	7.1	7.1
D-1-18	521	530	523	13.6	16.0
D-1-36	578	596	523	18.9	22.1
D-1-54	569	584	453	22.9	50.4
D-2-0	324	332	319	6.7	7.1
D-3-9	628	634	632	10.8	11.9
D-3-45	657	678	481	21.7	25.1
D-3-63	689	714	622	21.6	26.7
D-4-36	651	672	186	21.2	34.3
D-4-54	689	716	636	22.3	24.7
D-5-9	628	628	615	11.9	12.3
D-7-18	511	521	448	14.5	17.3
D-7-36	561	573	507	18.8	23.2
D-7-54	567	586	515	22.4	30.4
E-4-0	347	356	347	5.7	6.9
F-2-36	580	599	507	18.7	23.5
F-2-54	617	634	427	22.7	49.6
G-4-18	471	490	486	15.1	15.9
G-4-36	573	599	523	19.9	24.0
G-4-54	507	530	421	22.8	30.8

Run 52

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	655	674	481	16.3	18.4
D-1-0	257	268	262	7.2	7.7
D-1-18	504	527	519	15.7	16.9
D-1-36	590	613	601	19.7	22.3
D-1-54	576	597	447	21.1	57.4
D-2-0	345	359	359	7.6	7.6
D-3-9	634	645	544	11.6	13.3
D-3-45	670	695	684	21.1	24.5
D-3-63	691	720	682	24.5	27.5
D-4-36	657	682	555	22.3	26.5
D-4-54	686	714	691	22.3	25.9
D-5-9	636	642	642	25.9	25.9
D-7-18	513	530	450	16.1	18.7
D-7-36	573	588	504	21.3	25.3
D-7-54	565	592	511	22.3	31.9
E-4-0	373	373	373	7.1	7.1
F-2-36	594	617	527	20.8	25.2
F-2-54	609	638	437	25.3	54.1
G-4-18	481	500	481	14.7	17.1
G-4-36	590	620	414	21.6	28.5
G-4-54	517	544	498	22.8	30.4

Run 53

Thermocouple Location	Temperature ($^{\circ}\text{F}$)			Time (sec)	
	T_i	T_t	T_q	t_t	t_q
C-4-18	745	816	617	15.6	18.7
D-1-0	318	339	331	7.1	7.6
D-1-18	638	697	697	16.0	16.0
D-1-36	697	781	362	19.6	24.0
D-1-54	693	782	632	24.0	125.3
D-2-0	419	443	443	7.3	7.3
D-3-9	691	749	264	12.1	14.4
D-3-45	722	816	682	22.5	25.2
D-3-63	766	881	728	24.3	37.7
D-4-36	728	823	356	20.0	66.8
D-4-54	774	881	764	22.4	25.5
D-5-9	692	749	745	12.0	12.5
D-7-18	638	705	603	16.0	18.5
D-7-36	676	753	647	16.9	26.0
D-7-54	674	764	645	18.3	105.3
E-4-0	458	475	475	7.2	7.2
F-2-36	733	833	657	20.0	32.8
F-2-54	764	866	636	24.0	137.0
G-4-18	626	693	475	16.0	20.9
G-4-36	712	800	423	20.3	51.7
G-4-54	628	728	657	23.5	65.4

Run 54

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	921	994	663	15.5	20.7
C-4-72	400	490	670	23.3	23.3
D-1-0	440	446	446	7.3	7.3
D-1-18	795	860	670	14.5	17.1
D-1-36	869	948	640	17.5	23.2
D-1-54	875	964	624	19.9	152.1
D-2-0	524	539	532	7.2	7.5
D-3-9	881	942	670	11.5	14.9
D-3-45	900	1000	733	19.5	24.0
D-3-63	954	1053	841	20.7	66.4
D-4-36	910	992	381	19.2	80.6
D-4-54	944	1046	816	18.7	25.9
D-5-9	884	941	767	11.6	13.2
D-7-18	791	856	620	13.7	20.5
D-7-36	843	910	722	16.5	34.3
D-7-54	841	923	638	17.3	126.9
E-4-0	536	557	553	6.7	7.3
F-2-36	906	996	651	18.5	66.4
F-2-54	929	1016	479	20.0	162.9
G-4-18	770	831	586	15.7	28.3
G-4-36	885	969	354	20.0	70.5
G-4-54	785	869	743	18.7	86.9

Run 55

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1061	1109	658	11.7	25.3
C-4-72	533	606	495	18.4	23.5
D-1-0	498	517	507	4.5	6.9
D-1-18	906	952	624	11.2	18.4
D-1-36	990	1037	715	13.9	21.6
D-1-54	942	984	600	11.2	163.2
D-2-0	604	620	614	4.0	6.7
D-3-9	1038	1070	804	9.9	16.3
D-3-45	1074	1138	832	13.9	25.1
D-3-63	1107	1170	849	16.0	109.6
D-4-36	1072	1149	336	13.9	98.9
D-4-54	1104	1177	916	14.7	26.9
D-5-9	1028	1070	1044	9.9	11.5
D-7-18	889	934	758	10.9	18.9
D-7-36	956	996	688	10.4	51.4
D-7-54	938	983	644	11.2	138.5
E-4-0	623	635	623	5.3	6.7
F-2-36	1003	1078	656	13.3	70.4
F-2-54	1024	1078	637	14.7	166.9
G-4-18	843	891	482	12.8	35.7
G-4-36	1004	1062	439	13.6	81.0
G-4-54	879	936	707	13.3	129.8

Run 56

Thermocouple Location	Temperature (°F)			Time (sec)	
	T_i	T_t	T_q	t_t	t_q
C-4-18	1241	1273	675	11.5	34.4
C-4-72	616	675	589	12.8	28.5
D-1-0	610	621	625	5.3	5.3
D-1-18	1060	1096	627	10.4	21.3
D-1-36	1152	1189	786	10.4	34.1
D-1-54	1090	1128	623	10.9	178.9
D-2-0	698	714	714	5.1	5.1
D-3-45	1269	1313	1005	10.7	27.7
D-3-63	1284	1334	880	11.5	133.0
D-4-36	1270	1312	700	10.7	85.3
D-4-54	1312	1360	1003	12.0	45.6
D-4-72	331	403	366	13.3	16.3
D-5-9	1207	1235	1230	7.7	9.9
D-7-18	1055	1086	841	11.5	20.8
D-7-36	1110	1143	730	9.9	64.0
D-7-54	1098	1125	653	10.7	157.8
E-4-0	745	747	747	5.3	5.3
F-2-54	1169	1219	681	11.5	178.4
G-4-18	1011	1048	438	11.5	50.9
G-4-36	1177	1227	376	10.7	98.6
G-4-54	1017	1058	694	11.7	155.2

Run 57

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1453	1495	644	10.1	50.9
C-4-72	769	823	685	11.5	56.0
D-1-0	737	762	762	6.0	6.0
D-1-18	1266	1308	767	10.7	34.1
D-1-36	1370	1420	690	8.0	61.3
D-1-54	1274	1320	620	11.2	207.1
D-2-0	831	852	852	5.6	5.6
D-3-45	1492	1540	697	11.2	48.0
D-3-63	1492	1540	710	11.2	224.7
D-4-36	1504	1550	700	9.6	115.2
D-4-54	1536	1586	913	11.2	98.9
D-4-72	462	520	495	9.1	29.9
D-5-9	1418	1454	1333	9.1	10.7
D-7-18	1246	1289	913	8.5	32.5
D-7-36	1314	1351	736	10.1	98.1
D-7-54	1285	1326	688	9.3	174.1
E-4-0	889	897	897	5.1	5.1
F-2-36	1431	1466	645	11.2	122.1
F-2-54	1366	1403	673	10.9	207.7
G-4-18	1196	1229	494	8.5	66.6
G-4-36	1395	1451	805	9.6	95.7
G-4-54	1206	1247	723	8.3	181.3

Run 58

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1630	1656	630	10.4	62.1
C-4-72	814	885	686	11.7	70.6
D-1-0	862	862	862	6.4	6.4
D-1-18	1438	1465	747	9.6	44.5
D-1-36	1528	1566	758	9.6	70.4
D-1-54	1404	1465	580	10.4	210.1
D-2-0	944	959	942	4.8	6.4
D-3-45	1670	1700	820	11.2	70.6
D-3-63	1660	1693	797	11.2	218.9
D-4-36	1685	1718	373	11.5	154.4
D-4-54	1712	1758	1013	11.2	88.0
D-4-72	429	502	234	12.0	24.0
D-5-9	1582	1610	1610	9.9	9.9
D-7-18	1413	1438	923	10.1	44.0
D-7-36	1455	1490	693	10.4	113.3
D-7-54	1413	1434	668	9.3	189.8
E-4-0	1034	1034	1034	6.1	6.1
F-2-36	1570	1612	697	10.1	125.3
F-2-54	1496	1517	676	10.4	216.7
G-4-18	1340	1375	617	10.7	71.7
G-4-36	1557	1593	779	10.1	111.4
G-4-54	1329	1365	730	11.2	191.7

Run 59

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	706	752	752	6.1	7.7
C-4-72	303	343	343	15.5	15.5
D-1-0	384	384	384	2.9	2.9
D-1-18	590	622	622	7.2	7.2
D-1-36	642	684	663	9.9	11.2
D-1-54	608	679	589	12.8	19.5
D-2-0	355	366	366	2.7	2.7
D-3-45	710	764	764	11.5	12.8
D-3-63	747	812	687	14.4	16.0
D-4-54	747	810	810	13.3	13.3
D-5-9	689	710	710	5.3	5.3
D-7-18	602	644	644	7.5	7.5
D-7-36	622	665	549	11.5	13.3
D-7-54	611	674	605	13.6	17.3
E-4-0	384	392	392	2.9	2.9
F-2-36	696	744	627	10.7	12.8
F-2-54	706	772	473	12.5	49.6
G-4-18	592	623	623	7.5	7.5
G-4-36	659	707	416	11.5	18.7
G-4-54	580	644	570	13.3	21.1

Run 60

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1088	1117	622	6.9	13.3
C-4-72	545	595	380	10.1	18.1
D-1-0	600	600	601	2.9	2.9
D-1-18	931	958	644	6.1	9.6
D-1-36	1000	1027	1021	6.9	8.3
D-1-54	946	982	650	8.5	70.6
D-2-0	597	597	597	2.7	2.7
D-3-45	1107	1134	853	8.5	13.1
D-3-63	1130	1147	864	9.9	34.1
D-4-54	1144	1183	976	8.3	12.0
D-4-72	312	362	362	10.1	10.1
D-5-9	1047	1067	1067	5.3	5.3
D-7-18	934	957	764	6.1	10.9
D-7-36	956	985	696	7.2	24.3
D-7-54	952	977	665	8.0	63.7
E-4-0	617	617	617	2.7	2.7
F-2-36	1070	1101	717	7.2	40.0
F-2-54	1048	1080	515	8.5	92.0
G-4-18	891	913	747	7.5	11.5
G-4-36	1029	1071	707	8.3	32.3
G-4-54	898	938	730	7.7	58.1

Run 61

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-72	781	805	353	6.9	36.1
D-1-0	729	729	729	2.9	2.9
D-1-18	1238	1259	724	6.3	18.8
D-1-36	1331	1351	692	5.3	30.8
D-1-54	1225	1250	681	6.8	103.4
D-2-0	816	816	816	2.8	2.8
D-3-45	1469	1490	1033	6.0	10.9
D-3-63	1426	1452	870	7.1	85.6
D-4-54	1496	1519	1051	6.3	37.3
D-4-72	497	528	453	7.3	8.9
D-5-9	1394	1409	916	5.1	8.0
D-7-18	1222	1244	874	4.9	21.3
D-7-36	1279	1293	751	5.9	49.6
D-7-54	1225	1249	667	6.4	96.0
E-4-0	812	816	812	2.4	2.8
F-2-36	1374	1399	747	5.6	62.6
G-4-18	1157	1182	772	5.6	25.3
G-4-36	1356	1391	439	6.3	76.5
G-4-54	1146	1183	501	6.0	102.4

Run 62

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-72	846	882	591	7.3	38.8
D-1-0	706	718	710	2.7	3.2
D-1-18	1240	1261	633	6.5	23.1
D-1-36	1350	1373	707	6.7	32.0
D-1-54	1265	1286	719	6.0	100.4
D-2-0	794	806	800	2.7	3.1
D-3-45	1483	1523	---	6.7	10.7
D-3-63	1489	1523	848	6.7	93.7
D-4-54	1529	1554	966	7.1	45.5
D-4-72	597	635	506	7.7	10.7
D-5-9	1384	1411	923	5.1	8.0
D-7-18	1223	1246	886	5.5	23.1
D-7-36	1291	1314	763	6.4	52.2
D-7-54	1263	1289	671	6.5	98.5
E-4-0	787	787	787	2.8	2.8
F-2-36	1385	1412	702	6.4	65.4
F-2-54	1329	1349	486	6.8	122.4
G-4-18	1170	1192	732	6.4	28.3
G-4-36	1375	1407	422	7.1	80.1
G-4-54	1183	1219	517	6.4	106.1

Run 63

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	523	628	402	19.7	42.8
C-4-36	544	693	507	26.8	66.6
C-4-54	553	718	615	30.8	81.3
D-1-0	237	260	260	7.7	7.7
D-1-18	393	486	486	19.6	19.6
D-1-36	435	553	500	25.3	28.0
D-1-54	412	565	513	31.1	69.3
D-2-0	188	228	228	6.7	6.7
D-3-9	467	540	429	13.9	17.1
D-3-27	498	615	337	23.7	42.0
D-3-45	511	653	387	30.5	85.6
D-3-63	544	722	473	32.0	136.5
D-4-18	498	601	435	19.7	31.7
D-4-36	515	653	322	26.7	63.4
D-4-54	540	703	406	30.5	113.8
D-4-72	421	578	563	30.3	58.9
D-5-9	560	561	561	14.0	14.0
D-5-27	488	609	387	24.4	56.5
D-5-45	500	649	448	29.9	88.8
D-5-63	538	720	511	31.7	138.6
D-7-18	379	483	442	19.9	20.8
D-7-36	421	553	502	26.7	29.5
D-7-54	377	532	500	30.3	38.3
E-4-0	278	314	314	8.1	8.1
E-4-18	532	651	479	19.7	26.4
E-4-36	565	735	356	26.8	52.9
E-4-54	586	774	567	31.1	110.0
F-2-36	463	617	481	26.7	29.6
F-2-54	463	649	628	31.2	59.2
G-4-18	370	471	469	20.5	20.5
G-4-36	442	584	544	27.1	29.6

Run 64

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	971	1023	500	15.6	71.6
C-4-36	984	1070	381	18.7	133.3
C-4-54	1633	1095	582	22.7	179.4
D-1-0	477	496	496	6.9	6.9
D-1-18	768	827	716	15.3	17.3
D-1-36	835	898	661	16.0	22.3
D-1-54	816	885	632	16.1	138.4
D-2-0	458	477	477	6.8	6.8
D-3-9	884	942	582	11.9	29.5
D-3-27	913	988	553	18.0	73.3
D-3-45	931	1019	624	21.3	122.0
D-4-18	923	986	628	16.4	65.6
D-4-36	942	1028	429	19.7	122.5
D-4-54	984	1074	507	23.6	173.4
D-4-72	423	523	412	25.3	38.9
D-5-9	908	956	726	12.5	23.2
D-5-27	921	986	602	18.7	88.6
D-5-45	938	1019	366	20.4	162.0
D-7-18	774	837	722	16.3	20.5
D-7-36	823	885	609	15.1	34.3
D-7-54	816	898	630	16.5	129.3
E-4-0	594	609	609	7.2	38.8
E-4-18	965	1036	561	16.0	58.2
E-4-36	1029	1109	460	19.7	102.9
E-4-54	1026	1118	467	19.2	145.7
F-2-36	913	938	680	20.3	67.2
F-2-54	894	982	657	19.7	142.9
G-4-18	733	795	540	16.1	27.7
G-4-36	862	940	753	20.0	35.7
G-4-54	735	816	592	18.9	129.4

Run 65

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1298	1151	358	13.3	92.4
C-4-36	1281	1277	408	15.1	113.3
C-4-54	1300	1300	481	14.9	108.0
D-1-0	527	523	523	8.3	8.3
D-1-18	1005	1005	559	11.9	27.7
D-1-36	1105	1086	693	14.0	19.5
D-1-54	1036	1036	375	13.3	126.5
D-2-0	626	626	626	8.3	8.3
D-3-9	1210	1195	408	12.3	61.3
D-3-27	1070	1067	322	13.3	94.9
D-3-45	1293	1293	617	15.2	78.4
D-3-63	1291	1291	597	13.3	142.9
D-4-18	1266	1266	463	13.9	83.3
D-4-36	1304	1300	375	15.2	115.3
D-4-54	1319	1319	504	14.8	127.7
D-4-72	686	712	601	7.2	35.9
D-5-9	1210	1208	753	12.7	40.0
D-5-27	1262	1262	816	14.7	95.3
D-5-45	1287	1298	366	15.3	145.8
D-5-63	1298	1298	419	13.3	169.8
D-7-18	1005	992	576	13.5	30.8
D-7-36	1067	1067	565	11.3	58.6
D-7-54	1030	1030	477	13.3	95.3
E-4-0	776	776	776	8.1	8.1
E-4-18	1360	1319	456	13.9	70.4
E-4-36	1314	1314	335	15.1	103.3
E-4-54	1310	1300	435	14.9	116.5
F-2-54	1090	1084	440	13.3	117.2
G-4-18	896	896	504	12.0	35.5
G-4-36	1136	1136	657	14.4	60.6
G-4-54	938	938	496	14.7	93.8

Run 66

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1488	1528	659	10.7	77.3
C-4-36	1532	1576	381	8.0	166.4
C-4-54	1551	1597	504	10.1	181.0
D-1-0	747	756	756	5.3	5.3
D-1-18	1260	1287	744	8.8	32.0
D-1-36	1358	1388	954	7.7	20.0
D-1-54	1287	1329	620	10.1	210.1
D-2-0	779	795	995	5.1	5.1
D-3-9	1444	1471	722	8.0	38.4
D-3-27	1480	1528	586	10.1	107.2
D-3-45	1503	1557	640	10.1	107.2
D-3-63	1555	1614	615	10.9	283.1
D-4-18	1471	1515	776	10.4	72.0
D-4-36	1524	1572	643	9.7	141.3
D-4-54	1570	1612	588	10.7	231.9
D-4-72	712	749	645	10.9	42.1
D-5-9	1446	1478	938	8.5	34.7
D-5-27	1465	1507	684	10.1	110.6
D-5-45	1505	1553	440	10.7	198.6
D-5-63	1584	1628	810	10.9	307.1
D-7-18	1226	1484	666	9.9	39.5
D-7-36	1298	1321	728	8.0	80.5
D-7-54	1283	1319	693	10.1	179.2
E-4-0	944	944	944	5.3	5.3
E-4-18	1520	1551	651	10.1	74.1
E-4-36	1576	1610	486	8.0	140.8
E-4-54	1580	1628	653	10.1	161.6
F-2-36	789	1478	657	10.7	120.0
F-2-54	1350	1419	567	10.7	206.6
G-4-18	1153	1201	513	10.4	65.8
G-4-36	1534	1657	728	10.7	98.4
G-4-54	1193	1247	544	10.7	184.5

Run 67

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-0	---	---	---	8.0	8.0
C-4-18	1507	1534	358	5.1	186.3
C-4-36	1532	1559	550	4.8	275.9
C-4-54	1576	1591	772	5.3	99.4
D-1-0	---	---	---	7.5	7.5
D-1-18	1308	1319	630	5.1	52.5
D-1-36	1354	1360	850	5.1	47.4
D-1-54	1316	1335	559	4.8	194.6
D-2-0	---	---	---	7.5	7.5
D-3-9	1446	1457	542	5.0	102.4
D-3-27	1507	1528	527	5.3	207.1
D-3-45	1509	1532	555	5.3	184.2
D-3-63	1566	1589	601	5.3	249.3
D-4-18	1505	1528	532	5.3	197.3
D-4-36	1530	1555	632	8.0	258.6
D-4-54	1589	1601	423	5.6	195.1
D-4-72	714	743	615	9.3	13.3
D-5-9	1442	1459	546	5.6	114.4
D-5-27	1490	1507	653	16.5	261.5
D-5-45	1507	1532	917	5.3	175.2
D-5-63	1574	1607	609	7.2	197.3
D-7-18	1262	1298	833	5.9	54.6
D-7-36	1281	1298	680	5.3	147.7
D-7-54	1304	1325	735	5.3	90.6
E-4-0	---	---	---	7.2	7.2
E-4-18	1526	1551	565	4.8	160.2
E-4-36	1553	1576	728	5.3	226.9
E-4-54	1586	1612	628	5.1	53.3
F-2-36	1446	1467	691	5.1	165.0
F-2-54	1386	1419	509	5.3	140.5
G-4-18	1241	1258	779	5.1	68.2
G-4-54	1260	1283	666	5.6	60.2

Run 68

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1459	1530	475	18.9	105.6
C-4-36	1536	1612	458	19.5	170.6
C-4-54	1557	1626	569	16.8	207.1
D-1-0	724	751	741	10.1	10.9
D-1-18	1245	1304	712	14.7	48.5
D-1-36	1367	1427	1046	13.1	32.0
D-1-54	1300	1360	630	14.1	293.0
D-2-0	735	768	751	8.3	10.7
D-3-9	1427	1494	615	16.5	63.4
D-3-27	1494	1563	385	16.5	154.6
D-3-45	1509	1591	651	16.5	166.9
D-3-63	1570	1637	561	19.2	376.4
D-4-18	1457	1530	473	18.1	130.4
D-4-36	1540	1620	448	19.2	216.5
D-4-54	1578	1664	368	19.2	327.4
D-4-72	720	804	758	57.3	69.3
D-5-9	1421	1486	774	13.3	60.0
D-5-27	1469	1545	490	18.7	184.7
D-5-45	1522	1620	544	19.5	234.6
D-5-63	1578	1674	733	19.5	356.7
D-7-18	1235	1298	808	13.9	47.2
D-7-36	1293	1354	626	13.6	141.8
D-7-54	1277	1340	705	14.4	260.2
D-7-72	186	272	272	18.7	18.7
E-4-0	936	971	954	7.7	10.9
E-4-18	1478	1549	563	18.1	113.3
E-4-36	1572	1639	525	18.7	194.9
E-4-54	1580	1666	582	18.7	268.7
F-2-36	1450	1524	703	18.9	166.4
F-2-54	1373	1446	689	18.9	285.5
F-2-72	188	230	230	19.5	19.5
G-4-18	1162	1234	733	18.7	64.0
G-4-54	1201	1283	653	18.7	271.9
G-4-72	165	216	216	19.2	19.2

Run 69

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1241	1241	400	5.5	47.2
C-4-36	1256	1258	486	5.6	67.8
C-4-54	1304	1304	475	6.0	77.2
D-1-0	567	567	567	2.5	2.5
D-1-18	1030	1026	1026	5.5	5.5
D-1-36	1113	1109	1109	5.7	5.7
D-1-54	1059	1059	523	5.3	81.3
D-2-0	622	622	622	2.4	2.4
D-3-9	1195	1195	546	2.9	26.4
D-3-27	1243	1243	303	5.1	66.2
D-3-45	1266	1273	509	5.2	38.5
D-3-63	1298	1298	467	6.0	109.3
D-4-18	1241	1241	494	4.1	53.6
D-4-36	1260	1260	314	5.3	82.8
D-4-54	1304	1304	481	6.0	102.6
D-4-72	622	636	636	6.7	6.7
D-5-9	1203	1203	513	4.0	16.4
D-5-27	1235	1241	458	5.6	80.6
D-5-45	1260	1260	437	6.0	78.5
D-5-63	1310	1312	599	6.1	99.7
D-7-18	1013	1013	785	4.1	13.2
D-7-36	1067	1063	714	5.3	21.6
D-7-54	1051	1051	605	5.5	60.4
E-4-0	760	760	760	2.1	2.1
E-4-18	1226	1226	352	4.4	46.5
E-4-36	1283	1283	316	4.3	69.7
E-4-54	1291	1291	582	5.9	41.5
F-2-54	1107	1107	435	6.0	80.0
G-4-18	963	967	486	4.4	27.9
G-4-54	963	963	530	4.8	72.6

Run 70

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1296	1321	475	6.9	64.4
C-4-36	1342	1377	628	7.2	106.6
C-4-54	1383	1421	624	7.7	176.2
D-1-0	645	649	649	2.7	2.7
D-1-18	1105	1118	666	6.7	13.6
D-1-54	1162	1187	722	7.2	132.8
D-2-0	628	638	638	2.1	2.1
D-2-18	1189	1218	768	5.1	12.0
D-3-9	1224	1239	668	4.5	28.5
D-3-27	1266	1298	617	5.6	77.3
D-3-45	1293	1333	507	8.0	93.6
D-3-63	1379	1421	513	8.0	221.0
D-4-18	1260	1293	712	5.9	58.6
D-4-36	1314	1350	481	6.7	136.8
D-4-54	1365	1090	567	6.4	197.3
D-4-72	640	670	331	8.0	73.0
D-5-9	1235	1256	676	5.1	8.0
D-5-27	1266	1293	534	5.6	104.5
D-5-45	1298	1335	747	6.7	120.0
D-5-63	1388	1430	588	7.2	246.1
D-7-18	1099	1113	896	5.3	13.3
D-7-54	1153	1193	728	7.5	123.4
E-4-0	776	783	783	2.7	2.7
E-4-18	1243	1279	523	5.9	56.0
E-4-36	1354	1396	651	5.3	100.0
E-4-54	1377	1423	607	6.7	125.6
F-2-54	1237	1277	684	6.7	160.0
G-4-18	1070	1388	582	6.1	42.4

Run 71

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1310	1350	666	10.4	80.2
C-4-36	1337	1398	609	11.7	158.9
C-4-54	1358	1440	653	12.3	258.1
D-1-0	643	659	659	5.9	5.9
D-1-18	1093	1149	695	9.3	25.9
D-1-36	1208	1241	835	10.9	18.1
D-1-54	1130	1195	701	10.4	198.6
D-2-0	628	645	645	5.6	5.6
D-3-9	1220	1270	764	9.1	52.0
D-3-27	1270	1335	578	10.1	126.4
D-3-45	1298	1356	507	10.7	136.2
D-3-63	1356	1421	582	9.6	311.9
D-4-18	1260	1323	530	10.7	117.6
D-4-36	1306	1377	502	10.1	192.2
D-4-54	1358	1415	544	11.2	295.9
D-4-72	605	655	414	13.3	41.9
D-5-9	1235	1287	760	8.8	45.6
D-5-27	1279	1327	523	12.0	170.1
D-5-45	1300	1358	707	12.0	197.5
D-5-63	1365	1427	718	12.0	298.9
D-7-18	1090	1145	839	9.6	26.1
D-7-36	1170	1199	630	12.8	136.0
D-7-54	1132	1187	689	9.1	223.4
E-4-0	793	814	814	5.3	5.3
E-4-18	1262	1312	460	9.6	100.5
E-4-36	1363	1419	540	11.7	175.7
E-4-54	1381	1427	586	11.5	224.5
F-2-54	1226	1279	584	10.1	240.2
G-4-18	1070	1113	613	9.3	38.9
G-4-54	1070	1113	776	11.2	183.1

Run 72

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1505	1551	788	9.1	65.6
C-4-36	1528	1586	603	10.7	128.5
C-4-54	1576	1628	684	10.9	191.4
D-1-0	715	731	731	4.5	4.5
D-1-18	1302	1350	770	9.3	31.4
D-1-36	1381	1427	1026	10.4	165.3
D-1-54	1291	1335	661	8.8	182.1
D-2-0	751	772	772	4.8	4.8
D-3-9	1459	1501	949	9.3	32.8
D-3-27	1501	1547	637	8.5	94.6
D-3-45	1496	1545	602	8.3	106.6
D-3-63	1524	1567	497	11.5	252.2
D-4-18	1501	1545	779	10.7	66.9
D-4-36	1519	1574	637	10.9	137.3
D-4-54	1576	1620	611	10.7	210.7
D-4-72	756	820	676	10.9	42.7
D-5-9	1465	1499	948	8.5	31.2
D-5-27	1476	1536	817	10.9	98.1
D-5-45	1490	1540	817	11.2	123.7
D-5-63	1551	1599	632	9.3	266.6
D-7-18	1277	1319	797	5.9	34.7
D-7-54	1293	1340	753	9.3	165.6
E-4-0	948	971	952	4.5	5.9
E-4-18	1463	1513	654	8.0	61.8
E-4-36	1519	1578	853	10.9	105.8
E-4-54	1526	1586	631	11.5	164.2
F-2-54	1361	1400	688	10.7	189.5
G-4-18	1218	1275	839	10.7	47.4

Run. 73

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _g	t _t	t _g
C-4-18	1471	1482	688	0.8	131.2
C-4-36	1509	1526	842	0.8	174.6
C-4-54	1557	1567	617	1.6	148.8
D-1-0	731	731	709	1.3	10.1
D-1-18	1290	1290	663	1.3	63.2
D-1-36	1369	1375	1072	1.1	36.8
D-1-54	1271	1271	667	1.1	146.6
D-2-0	719	719	502	10.4	13.1
D-3-9	1436	1417	734	15.7	88.0
D-3-27	1463	1463	531	27.2	185.3
D-3-45	1467	1467	798	0.8	107.7
D-3-63	1484	1494	552	1.1	211.9
D-4-18	1476	1484	539	1.6	180.7
D-4-36	1511	1517	621	1.1	234.1
D-4-54	1545	1549	500	0.8	173.6
D-4-72	761	761	667	7.7	15.2
D-5-9	1436	1404	706	1.3	84.0
D-5-27	1453	1465	652	3.2	235.9
D-5-45	1467	1467	1045	0.8	103.4
D-5-63	1517	1528	700	1.6	165.8
D-7-18	1250	1262	796	1.3	53.6
D-7-54	1271	1277	991	0.8	41.1
E-4-0	922	945	568	10.4	36.0
E-4-18	1421	1434	731	1.3	114.9
E-4-36	1507	1509	744	0.8	196.7
E-4-54	1526	1530	798	0.8	71.2
F-2-54	1331	1338	581	1.3	130.9
G-4-18	1212	1212	834	0.5	66.9
G-4-54	1192	1204	807	0.8	61.0

Run 74

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1526	1528	804	9.1	61.8
C-4-36	1704	1735	676	8.0	121.6
C-4-54	1850	1880	638	10.7	194.1
D-1-0	785	797	797	5.1	5.1
D-1-18	1321	1363	839	8.5	28.0
D-1-36	1377	1400	814	8.3	42.1
D-1-54	1520	1549	668	10.4	184.7
D-2-0	783	802	802	4.8	4.8
D-3-9	1484	1517	948	6.9	31.2
D-3-27	1511	1559	607	10.1	90.6
D-3-45	1760	1806	603	8.8	118.4
D-3-63	1748	1796	582	9.1	245.3
D-4-18	1513	1559	795	8.3	62.6
D-4-36	1691	1727	676	9.3	130.6
D-4-54	1861	1880	624	9.6	214.3
D-4-72	1000	1049	670	10.1	101.3
D-5-9	1499	1528	965	7.7	27.5
D-5-27	1509	1553	810	8.5	93.6
D-5-45	1766	1810	666	9.1	113.3
D-5-63	1815	1861	601	9.6	285.5
D-7-18	1279	1319	919	8.5	31.7
E-4-0	1007	1021	1013	3.5	5.3
E-4-18	1486	1530	689	8.5	55.4
E-4-36	1779	1842	502	8.5	125.6
E-4-54	1825	1865	691	9.6	151.4
F-2-54	1591	1618	730	9.3	187.9
G-4-18	1260	1302	848	8.3	46.1
G-4-54	1455	1494	814	8.0	165.8

Run 75

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1771	1780	925	3.5	41.3
C-4-54	1840	1859	814	5.1	108.0
D-1-0	961	977	969	1.6	2.4
D-1-18	1578	1597	818	4.3	33.3
D-1-36	1653	1668	881	2.7	21.3
D-1-54	1471	1505	710	4.3	112.2
D-2-0	952	952	952	2.1	2.1
D-3-9	1733	1739	1009	3.5	18.4
D-3-27	1802	1827	---	4.0	---
D-3-45	1771	1802	898	4.0	54.1
D-3-63	1718	1746	776	2.7	130.1
D-4-18	1813	1821	1009	4.8	40.0
D-4-36	1821	1850	944	3.2	71.2
D-4-72	988	1023	837	5.3	8.0
D-5-9	1716	1729	1070	3.5	16.0
D-5-27	1779	1798	969	5.3	62.4
D-5-45	1754	1792	1111	4.0	54.1
D-5-63	1796	1821	737	4.3	158.1
D-7-18	1528	1545	952	4.3	34.1
E-4-0	1193	1199	1199	1.3	1.3
E-4-18	1771	1785	984	4.5	31.5
E-4-36	1779	1815	869	5.3	77.3
E-4-54	1764	1800	879	4.0	61.8
F-2-54	1532	1553	779	4.5	109.3
G-4-18	1482	1492	883	4.5	36.8
G-4-36	1821	1840	900	5.1	65.3
G-4-54	1402	1419	724	4.8	108.0

Run 76

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	712	733	733	4.0	4.0
C-4-36	724	764	561	5.3	10.3
D-1-0	230	230	230	1.5	1.5
D-1-18	561	584	565	3.7	4.3
D-1-36	630	661	653	4.5	6.5
D-1-54	620	653	563	5.1	12.1
D-2-0	230	230	230	1.1	1.1
D-3-9	626	636	636	2.7	2.7
D-3-45	682	693	684	3.3	7.5
D-3-63	712	756	381	8.0	28.0
D-4-18	668	693	693	3.7	3.7
D-4-36	691	716	423	5.7	11.6
D-4-54	733	776	567	7.7	18.7
D-4-72	335	358	358	8.3	8.3
D-5-9	649	655	655	2.7	2.7
D-5-27	670	699	594	4.1	7.3
D-5-45	691	724	710	4.1	7.2
D-5-63	735	774	592	6.1	30.7
D-7-18	555	588	584	3.6	4.3
E-4-0	375	387	387	1.5	1.5
E-4-18	653	684	684	4.0	4.0
E-4-36	739	776	444	4.1	10.1
E-4-54	716	776	776	7.5	7.5
F-2-54	653	695	458	8.1	19.9
G-4-18	548	576	576	4.1	4.1
G-4-54	565	605	483	8.0	10.7

Run 77

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1130	1130	856	4.0	7.7
C-4-36	1172	1193	812	4.3	17.2
D-1-0	496	496	496	0.8	8.0
D-1-18	959	967	963	3.1	4.0
D-1-36	1040	1051	1042	4.4	5.6
D-1-54	980	1002	730	5.3	32.0
D-3-9	1067	1074	1074	2.5	2.5
D-3-45	1057	1124	1109	5.3	6.3
D-3-63	1118	1151	636	5.9	55.2
D-4-18	1090	1113	854	3.6	6.8
D-4-36	1118	1153	548	5.3	25.5
D-4-72	544	576	504	6.7	9.3
D-5-9	1070	1063	1063	2.7	2.7
D-5-27	1072	1107	858	4.3	11.7
D-5-45	1111	1134	814	4.4	8.9
D-5-63	1166	1201	768	5.3	62.2
D-7-18	938	1051	1051	4.0	4.0
E-4-0	670	670	670	1.5	1.5
E-4-18	1072	1072	1072	4.0	4.0
E-4-54	1157	1191	1185	4.1	5.7
F-2-36	1162	1187	1185	4.1	5.9
F-2-54	858	1049	486	5.6	51.7
G-4-18	917	921	544	4.0	6.3
G-4-54	915	944	553	4.3	11.5

Run 78

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1484	1499	921	3.9	14.5
C-4-36	1536	1549	877	4.1	28.0
D-1-0	701	701	701	1.5	1.5
D-1-18	1287	1298	1287	2.7	3.7
D-1-36	1402	1402	1402	4.0	4.0
D-1-45	1279	1279	733	4.5	60.0
D-2-0	649	649	649	1.5	1.5
D-3-9	1406	1425	1005	2.7	4.8
D-3-45	1471	1486	624	4.3	15.9
D-3-63	1471	1494	490	4.1	82.4
D-4-18	1453	1467	366	2.1	51.3
D-4-36	1461	1528	630	4.3	41.3
D-4-72	697	728	728	4.7	6.1
D-5-9	1614	1633	1622	2.1	2.7
D-5-45	1463	1486	879	4.3	17.2
D-5-63	1530	1551	751	4.3	83.3
D-7-18	1275	1275	879	3.7	6.7
E-4-0	875	875	875	1.3	1.3
E-4-18	1423	1444	486	3.7	11.6
E-4-54	1507	1530	883	4.1	8.4
F-2-54	1344	1363	513	4.5	77.4
G-4-54	1201	1222	588	4.0	65.8

Run 79

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1488	1509	877	2.9	12.0
C-4-36	1538	1549	963	4.0	26.7
D-1-0	730	730	712	0.7	1.3
D-1-18	1283	1300	814	3.7	6.7
D-1-36	1392	1404	1392	2.5	4.3
D-1-54	1283	1300	760	3.3	54.6
D-2-0	651	651	647	0.7	1.3
D-3-9	1409	1409	1172	2.5	4.0
D-3-45	1484	1503	672	4.1	21.7
D-3-63	1496	1515	594	4.0	77.3
D-4-36	1507	1515	651	3.7	37.2
D-4-72	733	753	670	4.3	5.3
D-5-9	1442	1453	1446	2.0	2.5
D-5-45	1467	1490	883	4.0	16.1
D-5-63	1557	1574	776	4.3	75.6
D-7-18	1281	1302	1021	3.2	6.4
E-4-0	879	879	879	1.3	1.3
E-4-18	1440	1444	697	3.7	9.1
E-4-54	1528	1549	1549	4.0	4.0

Run 80

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	1764	1769	1009	4.3	28.5
C-4-36	1800	1804	961	5.1	53.3
D-1-0	896	896	896	1.9	1.9
D-1-18	1522	1543	630	2.9	30.1
D-1-36	1633	1639	1624	2.1	5.1
D-1-54	1528	1532	710	5.6	100.2
D-2-0	797	806	806	8.0	8.0
D-3-9	1831	1861	1432	2.7	10.4
D-3-45	1762	1790	607	5.1	58.6
D-3-63	1760	1785	360	5.3	146.1
D-4-72	894	929	929	5.3	5.3
D-5-9	1700	1710	1080	1.3	8.8
D-5-45	1741	1758	854	5.1	60.8
D-5-63	1831	1846	733	4.8	106.4
D-7-18	1534	1547	959	4.0	29.1
E-4-0	1053	1057	1057	1.3	1.3
E-4-18	1695	1727	659	1.3	28.0
E-4-54	1823	1823	1823	5.3	5.3

Run 81

Thermocouple Location	Temperature (°F)			Time (sec)	
	T_i	T_t	T_q	t_t	t_q
C-4-36	1821	1846	502	8.3	111.4
D-1-0	942	965	965	4.0	4.0
D-1-18	1580	1612	523	8.0	61.3
D-1-36	1656	1672	666	5.1	26.1
D-1-54	1505	1587	670	8.3	197.3
D-2-0	820	835	835	2.9	2.9
D-3-9	1842	1880	1046	8.0	36.0
D-3-45	1760	1804	209	8.3	117.3
D-3-63	1739	1777	550	8.8	226.6
D-4-18	1716	1718	513	8.3	53.0
D-4-72	919	965	362	9.1	62.6
D-5-9	1731	1754	984	7.2	32.0
D-5-45	1758	1781	860	8.5	114.6
D-5-63	1800	1838	615	8.5	232.5
D-7-18	1570	1591	890	4.0	52.8
E-4-0	1051	1061	1051	2.7	4.0
E-4-18	1756	1781	628	8.3	69.3
E-4-54	1819	1842	663	8.0	21.9

Run 82

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-36	1549	1771	980	77.8	267.7
D-1-0	764	839	753	32.0	34.7
D-1-18	1302	1457	848	45.6	120.2
D-1-36	1404	1543	672	47.7	233.3
D-1-54	1304	1455	668	48.2	549.7
D-2-0	586	649	628	29.9	31.7
D-3-9	1430	1718	795	49.8	114.1
D-3-45	1484	1683	640	48.0	414.6
D-3-63	1664	---	1193	247.9	508.9
D-4-72	733	1427	795	174.9	409.8
D-5-9	1448	1603	730	45.1	125.6
D-5-45	1478	1676	950	50.9	357.2
D-5-63	1559	---	1300	239.9	540.7
D-7-18	1298	1455	770	48.0	140.5
E-4-0	756	827	810	29.6	32.5
E-4-18	1436	1616	609	49.8	184.2
E-4-54	1534	1733	718	55.4	442.6

Run 83

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-18	230	463	454	5.6	7.1
C-4-36	1574	1628	862	6.3	52.7
D-1-0	791	791	791	2.8	2.8
D-1-18	1371	1398	629	6.4	28.4
D-1-36	1425	1425	712	6.0	11.2
D-1-54	1365	1392	682	4.7	110.9
D-2-0	649	649	649	2.4	2.4
D-2-18	1446	1471	728	6.3	24.1
D-3-45	1509	1522	527	6.7	60.2
D-3-63	1524	1561	653	5.6	140.0
D-4-72	716	751	751	7.2	7.2
D-5-9	1513	1532	785	5.3	10.7
D-5-45	1517	1545	843	6.7	42.5
D-5-63	1551	1593	921	6.5	10.7
D-7-18	1342	1373	915	6.4	28.4
E-4-18	1329	1344	674	4.7	23.5
E-4-54	1363	1386	1386	6.7	6.7
G-4-54	1260	1304	550	6.7	107.3

Run 84

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-36	1005	1176	674	36.3	137.8
D-1-0	454	488	488	16.8	16.8
D-1-18	864	969	532	29.9	42.1
D-1-36	904	1023	733	33.6	40.8
D-1-54	881	1005	567	30.1	294.1
D-2-0	260	291	283	13.6	16.0
D-3-45	890	1028	548	34.7	196.2
D-3-63	980	1139	837	40.0	216.2
D-4-72	360	473	419	35.7	36.3
D-5-9	942	1042	640	24.5	48.5
D-5-45	927	1074	892	36.8	58.6
D-5-63	1000	1172	898	37.9	75.2
D-7-18	843	963	764	29.6	40.3
E-4-18	617	730	356	32.3	39.5
E-4-54	712	908	695	36.3	50.9

Run 85

Thermocouple Location	Temperature (°F)			Time (sec)	
	T _i	T _t	T _q	t _t	t _q
C-4-36	1314	1314	666	4.3	36.8
D-1-0	617	628	617	0.7	1.7
D-1-18	1116	1116	525	4.0	13.9
D-1-54	1120	1105	542	4.3	65.2
D-2-0	515	515	515	1.7	1.7
D-3-45	1279	1279	584	4.5	15.2
D-3-63	1287	1283	649	4.7	63.4
D-4-72	603	617	617	4.9	4.9
D-5-9	1262	1266	1266	2.9	2.9
D-5-45	1283	1275	787	4.5	9.3
D-5-63	1312	1308	1308	4.4	4.4
D-7-18	1118	1118	659	3.7	17.1
E-4-18	1120	1132	555	2.5	19.7
E-4-54	1168	1168	1168	4.3	4.3