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NUREG-2164

Consolidation of the 1985 Sandia National Laboratories/Factory Mutual Main Control Room and Electrical Cabinet Fire Test Data

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Consolidation of the 1985 Sandia National Laboratories/Factory Mutual Main Control Room and Electrical Cabinet Fire Test Data

Manuscript Completed: September 2014
Date Published: May 2015

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ABSTRACT

This report consolidates and refines the details and all the data recorded during the 1985 series of 25 main control room (MCR) fire tests performed by Sandia National Laboratories (SNL). These tests were conducted at the Factory Mutual Research Corporation (FMRC) for the U.S. Nuclear Regulatory Commission (NRC) under direct contract to SNL. The objective of these tests was to provide experimental data to validate computer fire models in the analysis of nuclear power plant (NPP) large enclosure fires. While select parts of the data have previously been reported, no single consolidated report was prepared to produce the data in a high quality, usable manner; this report fills that need.

FMRC performed these fire tests in a test enclosure simulating a typical space in an NPP MCR. The test enclosure measured 18.3 meters (m) x 12.2 m x 6.1 m [60 feet (ft) x 40 ft x 20 ft]. The original program had two phases: (1) the development of fire in electrical cabinets and (2) the effect of those fires on a simulated MCR. Propylene gas burner, heptane pool, methanol pool, polymethyl methacrylate (PMMA) solids, qualified cables and unqualified cables were used as fire sources. The parameters included were fire intensity, fire location, ventilation rate, and fire burning mode. The tests recorded over 300 data channels, which included measurements such as air and surface temperature, air velocity, heat fluxes, optical smoke density, and gas concentrations.

This report is an updated and expanded compilation of the test details as described in NUREG/CR-4681, “Enclosure Environment Characterization Testing for the Base Line Validation of Computer Fire Simulation Codes,” NUREG/CR-4527, “An Experimental Investigation of Internally Ignited Fires in Nuclear Power Plant Control Cabinets, Volume II: Room Effects Tests;” and Steve Nowlen’s “Survivor’s Guide for Users of the Baseline Validation Test Data” (Nowlen, 1999). These two NUREGs and the “Survivor’s Guide” are included on Supplement 1 (CD) and provide an historical discussion of the testing methods and examples of part of the data. Most of this data has never been used the lack of availability, lack of fire modeling research in this area, and the difficulty in accessing and extracting the original data, which is, in part, because these tests were ahead of their time. The purpose of this report is to make the data gathered by FMRC in 1985 more readily available and easier to use. The data was converted to a Microsoft Excel spreadsheet file format to facilitate its use and is contained in electronic format in Supplement 1 of this report; this data is also available through/by contacting the NRC’s Fire Research Branch. These completed data sets are now used in NUREG-1824, “Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications.”

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

We acknowledge the original efforts of authors J.M. Chavez, Steve Nowlen, and Factory Mutual Research Corporation (FMRC) for these fire tests and reports. For historical purposes, their original reports are included in Supplement 1 (CD). This report summarizes and in most descriptions utilizes the same wording as the original documents; hence, we would like to give credit to the original authors for the work described herein. We especially recognize Mr. Steve Nowlen for lending his support, responding to questions, and reviewing the report for details that may have been excluded or captured incorrectly/partially from the original reports.

We would also like to acknowledge the efforts of Dr. Kevin McGrattan from the National Institute of Standards and Technology (NIST), Dave W. Stroup, and Mark Henry Salley from the U.S. Nuclear Regulatory Commission (U.S. NRC) Office of Nuclear Regulatory Research (RES), Naeem Iqball from the Office of Nuclear Reactor Regulation (NRR), and Francisco Joglar from Hughes Associates for their comments and suggestions during the review of this NUREG. Finally, we would like to acknowledge the excellent assistance offered by Ms. Anita Aikins-Afful and Ms. Jade M. Garrison of U.S. NRC's, RES, Division of Risk Analysis for final technical editing of the document.

ACRONYMS AND ABBREVIATIONS

ch/hr	changes/hour; room air changes per hour
cfm	cubic foot per minute
FMRC	Factory Mutual Research Corporation
FPC	Fire Product Collector
MCR	main control room
NIST	National Institute of Standards and Technology
NPP	nuclear power plant
NRC	U.S. Nuclear Regulatory Commission
PMMA	Polymethyl methacrylate
ppm	parts per million
RES	Office of Nuclear Regulatory Research
RTV	room temperature vulcanization
SAIC	Science Applications International Corporation
SI	International System of Units
SNL	Sandia National Laboratories
TC	thermocouple
THC	total hydrocarbons
VB	Visual Basic

NOMENCLATURE

^oC	degrees Celsius
J/m	joules per meter
ft.	foot
ft^3	cubic foot
ft^3/s	cubic foot per second
m	meters
m/s	meters per second
m^3	cubic meter
m^3/s	cubic meter per second
s	seconds
kW/m^2	kilowatt per meter squared
ppm	part per million
W	watt

1. BACKGROUND AND INTRODUCTION

In 1985, Factory Mutual Research Corporation (FMRC) conducted a series of 25 full-scale electrical cabinet and main control room (MCR) fire tests for the U.S. Nuclear Regulatory Commission (NRC) under direct contract to Sandia National Laboratories (SNL). The primary purpose of these tests was to provide data on various characteristics of the fire environment in a large enclosure to aid in the development and validation of computer fire models.

These fire tests were performed in an enclosure simulating a typical space in a nuclear power plant (NPP) MCR. The MCR test enclosure measured 18.3 meters (m) x 12.2 m x 6.1 m [60 feet (ft.) x 40 ft. x 20 ft.]. FMRC performed 18 tests in the empty MCR test enclosure while it performed the other 7 tests with mock-up electrical cabinets inside the MCR enclosure. Tests 1 through 18 investigated the effects of various fire sources in a large enclosure. Tests 19 through 25 investigated the effects of simulated electrical cabinet fires in a large enclosure.

Propylene gas burner, heptane pool, methanol pool, polymethyl methacrylate (PMMA) solids, qualified cables, and unqualified cables were used as fire sources. Among the parameters varied were fire intensity, fire location, ventilation rate, and fire burning mode. Over 300 data channels were recorded during these fire tests, including air and surface temperatures, gas velocities, calorimeters, heat fluxes, optical smoke densities, and gas concentrations.

The purpose of this report is to make the fire test data and information more readily available and easier to understand and use. Revised figures, tables, test details, and data spreadsheets are included in this report. This report also includes a description of the process used to revise and convert the comma delimited original data files into Microsoft Excel spreadsheets.

This report was based on the test details and data as described in NUREG/CR-4681, “Enclosure Environment Characterization Testing for the Base Line Validation of Computer Fire Simulation Codes,” NUREG/CR-4527, “An Experimental Investigation of Internally Ignited Fires in Nuclear Power Plant Control Cabinets, Volume II: Room Effects Tests,” and Steve Nowlen’s “Survivor’s Guide for Users of the Baseline Validation Test Data” [Nowlen, 1999] which are included in the Supplement 1. The two NUREGs provide a detailed discussion of the testing methods and examples of part of the data. The intent of this report and its data CD is to update the above-mentioned documents. This report can be considered a revision and compilation of these documents since it summarizes and in most descriptions utilizes the same wording as the original documents.

Most of this data has never been used because of the lack of availability and the difficulty of accessing and extracting the data from the original data files. NUREG-1824, “Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications,” which was published in 2007, provides an example and analysis of how this data could be used to verify and validate computer fire models. The NRC expects information from the current report to be included in future updates of NUREG-1824.

2. REVISION OF THE TEST DESCRIPTIONS AND DATA

2.1 Revision of Figures and Test Descriptions

This document revises and compiles the test figures and descriptions from NUREG/CR-4681, "Enclosure Environment Characterization Testing for the Base Line Validation of Computer Fire Simulation Codes"; NUREG/CR-4527, "An Experimental Investigation of Internally Ignited Fires in Nuclear Power Plant Control Cabinets, Volume II: Room Effects Tests"; and Steve Nowlen's "Survivor's Guide for Users of the Baseline Validation Test Data" [Nowlen, 1999] into a single document. This report summarizes all the information, descriptions, and issues on the test enclosure and each of the 25 main control room (MCR) tests.

The figures included in the Sandia National Laboratories (SNL) reports were updated to reflect updated graphics and a three-dimensional view of the test configurations. The amount of detail in the dimensions and locations of the mock-up equipment, air ducts, instrumentation, and fire locations was increased to the extent possible. The three-dimensional figures were created from information found in the original documents. Other updates and additions include a revised test data channel map and addition of SI (International System of Units) and English units.

The original reports provide an example and discussion of some of the test data available. Some of the test data that is discussed includes Tests 4, 5, and 21 in NUREG/CR-4681 and Tests 21, 22, 23, 24, and 25 in NUREG/CR-4527. The "Survivor's Guide" provides details on common issues encountered through each of the tests. This report includes a general description of the tests.

The data files included in Supplement 1 contain one Excel "Workbook" file for each test. Each Workbook contains multiple spreadsheets (See Table 1). These spreadsheets contain information on test parameters, test issues, wall properties, and the sensor data from before ignition to extinction of the fire. A "Summary" sheet on the "General Report" data Excel spreadsheet contains the specific details and issues for each of the tests. Efforts were made to recover the original pictures taken during the tests but they were unsuccessful.

Table 1: Summary of the Excel File Sheet Titles and Description of the Data (See Section 4 on Instrumentation and Appendix A for the Exact Location of Each of the Sensors in the Enclosure)

Sheet Title	Description
Test Summary	Sheet containing a summary of the test fire parameters and specific issues during testing
Wall Properties	Test Enclosure Wall properties used by SNL
1-179 TC Data	Temperature data of the Thermocouples
180-197 Flow Probes	Vertical and Horizontal Flows data
198-203 P Diff	Pressure differential data
204-211 Opt Dens	Smoke optical density data
212-221 Gas	Gas concentration data
222-249 Heat & Mass	Surface heat flux data
250-306 Data	Processing channels of raw data. This data is used to generate the flow probes and gas analyzers data in the above channels
Collector Report	Contains the data of the fire products and exhaust gases
Heat Flux Report	Large and small sphere calorimeters located in matched pairs at various locations within the room to estimate the heat flux at a given location
Note: See “Appendix A: Test Data Channel Map” for specific description of each channel	

2.2 Extraction and Revision of the Test Data

SNL/Factory Mutual main control room (FM MCR) fire tests recorded data from over 300 sensors including thermocouples, gas velocity probes, smoke density meters, heat flux gauges, gas sampling ports, and mass loss. This data was recorded using a computer, data acquisition system, and associated software to collect, extract and display the data. Before this NUREG, there were two methods of accessing the original data from the 1980s tests. These two methods were either opening the file with a text editor or using FMREADR, a FORTRAN based DOS program. These two methods of accessing the data made the process of graphing and plotting extremely tedious because of the quantity of data points and manual extraction required.

This report makes the test data more accessible to fire modelers, engineers, and scientists who might be interested in MCR fires and fires in similar room geometries. By using a combination of the Text Import Wizard from Excel, “manual modifications,” and automation with Visual Basic (VB), the data was converted to Microsoft Excel. The Excel Text Import Wizard converted the text from the original file into the Excel-recognized format of rows, columns, and cells. The data for each test was then organized into a common template by performing manual modifications in the spreadsheet. Lastly, VB Macros were used to create organized spreadsheets with plots of each of the sensors. Random data point checks and maximum values were recalculated using Excel functions and compared with the original data for verification of the file conversion.

Among the revisions is the compilation of the “General Report,” “Flux Report,” and “Collector Report” data into a single spreadsheet file per test. The data from these reports can be found in the spreadsheets under the “SNL FM Baseline Validation Test Data Excel” folder on the included Supplement 1 (CD).

A sheet with each test summary was added. This “Summary” sheet includes a description of the test parameters and comments for each of the tests as found in NUREG/CR-4681, NUREG/CR-4528, and Steve Nowlen’s “Survivor’s Guide for Users of the Baseline Validation Test Data” [Nowlen, 1999]. These “Summary” sheets addition were added to make the data spreadsheets standalone and minimize the need to refer back to the reports (or “Survivor’s Guide”) for details of each tests. Other revisions to the data include:

(1) Time was changed to seconds instead of the “min: sec” format from the original data files or “minutes” format from the FMREADER program.

(2) The “Time Zero Double Logging” and other issues are now resolved as recommended in Nowlen’s Survivor’s Guide for Users of the Baseline Validation Test Data” [Nowlen, 1999].

(3) Sensor data is now plotted vs. time in the Excel spreadsheets.

In the original data files, the “Enclosure Surface Heat Flux Data” (Channels 231-243) were not reported correctly. The issue with this data could not be resolved as recommended by the “Survivor’s Guide” because of the unavailability of a conversion factor (milliampere [mA] to engineering units (watt per square meter [W/m^2]) needed to convert the raw data to the processed data. As such, this data is lost.

3. EXPERIMENTAL FACILITY

Note: The descriptions provided here were summarized from NUREG/CR-4681, NUREG/CR-4527, and the "Survivor's Guide for Users of the Baseline Validation Test Data."

3.1 Compartment Measurements and Characteristics

The test enclosure was located and isolated from the environment, enclosed by an exterior building in the Factory Mutual Research Corporation (FMRC) Test Center in Rhode Island (now known as FM Global Research Campus). The enclosure simulated the dimensions of a "typical" nuclear power plant main control room (MCR) and measured 18.3 meters (m) x 12.2 m x 6.1 m [60 feet (ft.) x 40 ft. x 20 ft.]. The inside surfaces of the walls and ceiling were lined with 25 millimeter (mm) (1 inch) thick marinite panels in an effort to simulate the behavior and characteristics of concrete walls such as those encountered in a nuclear power plant (NPP). An analysis of the wall temperature test data should validate this assumption, even though this analysis has never been performed. The marinite panels were securely fastened with lag screws to an external framework constructed of 50 mm x 150 mm (2 in x 6 in, nominal dimensions) framing lumber. It should be noted that oversized holes were drilled in the panels and washers provided for the lag screws in order to minimize both mechanical and thermal cracking effects. Additional support braces were provided between wall studs, at the ceiling corners, over doorways and observation windows. Seams formed by the marinite panels were backed by the wooden framework, and a bead of high-temperature silicone sealant was provided in all seams (i.e., room temperature vulcanization [RTV]). The RTV was to allow the panels to expand when subjected to elevated temperatures and help maintain a sufficient airtight environment. The ceiling was suspended from five 12.9 m (42.3 ft.), open-web steel joists which were supported and held in place by the north and south walls. This type of support system allowed the enclosure interior to be free of vertical obstructions. Observation windows (wire glass) were located on the north and south walls of the room for both visual and photographic monitoring of test events and access doors were provided along the north, east, and west walls (See Figure 1). The floor of the enclosure was comprised of the concrete slab that forms the foundation of the test building.

3.2 Ventilation

A forced ventilation system with six inlet ports (one inlet per 37 m^2 [400 ft^2] of floor area) and one outlet port were installed in the enclosure (See Figures 1, 2 and 3). This system was capable of providing ventilation rates from one to ten room air changes per hour. The inlet ports extended through the ceiling of the enclosure to a point 1.22 m (4 ft.) below the ceiling (See Figure 1). These inlets were capped with standard, commercially available four-way air diffusers. The inlet ports were extended in this way in order to simulate typical design practices in NPPs while at the same time introducing as few internal obstructions within the enclosure as possible. Typical NPP installations involve an air duct run at some distance (0.9-1.5 m [3-5 ft.]) below the true ceiling with ventilation grills set into the bottom of this air duct. Simulation of the height at which the inlet air was introduced into the enclosure and the available ventilation flow rate were considered the primary effects of interest.

A single outlet/exhaust port was located in the ceiling along the east wall of the test enclosure (See Figures 1 to 3). The exhaust port measured approximately 0.61 m (2 ft.) by 1.83 m (6 ft.)

with an open-grille and was equipped with damper control to help balance the system pressure. The outlet was placed in the ceiling in order to increase the sensitivity of the exhaust duct instrumentation to changes in the fire intensity. The outlet duct was sized such that the minimum pressure drop through the outlet for anticipated ventilation rates would be 30 Pa (1/8 inch of water). This pressure corresponds to typical control room operating pressures. Totally unrestricted air flow out of the enclosure would not be representative of actual NPP conditions.

Four ventilation rates were used: 1 room air change per hour, 4.4 room air changes per hour, 8 room air changes per hour, and 10 room air changes per hour. These rates correspond to 800 cubic feet per minute (cfm) (0.38 m^3/s), 3500 cfm (1.65 m^3/s), 6400 cfm (3.02 m^3/s), and 8,000 cfm (3.78 m^3/s), respectively. The lowest ventilation rate corresponds to a typical ventilation rate for general NPP enclosures and some control rooms. The highest rate corresponds to that suggested by proposed guidelines issued in June 1984 by the Control Room Habitability Working Group. The middle two rates correspond to typical ventilation rates under normal conditions for many NPP control rooms, with 8 room air exchanges per hour being on the high side of normal.

3.3 Room Configurations

Two room configurations were used for these fire tests. Tests 1 through 18 were conducted in configuration 1 of the enclosure, which consisted of an empty enclosure (See Figures 1 through 3). Tests 19 through 25 were conducted using the second configuration, which consisted of a control room mockup (See Figures 4 and 5). This control room mockup included six “real” electrical control cabinets (three bench-board style (cabinets A, B, and E), one mitered corner bench-board style [cabinet F], and two single-bay vertical styles [cabinets C and G]). The remainder of the mock-up was constructed from marinite panels bolted to metal framing material (cabinets D, H, and I). For the schematic of the cabinets, see Figures 6 and 7. The vertical cabinets were surplus cabinets obtained from an NPP vendor while the bench-board cabinets were constructed specifically for this test program to specifications typically used in NPP cabinets.

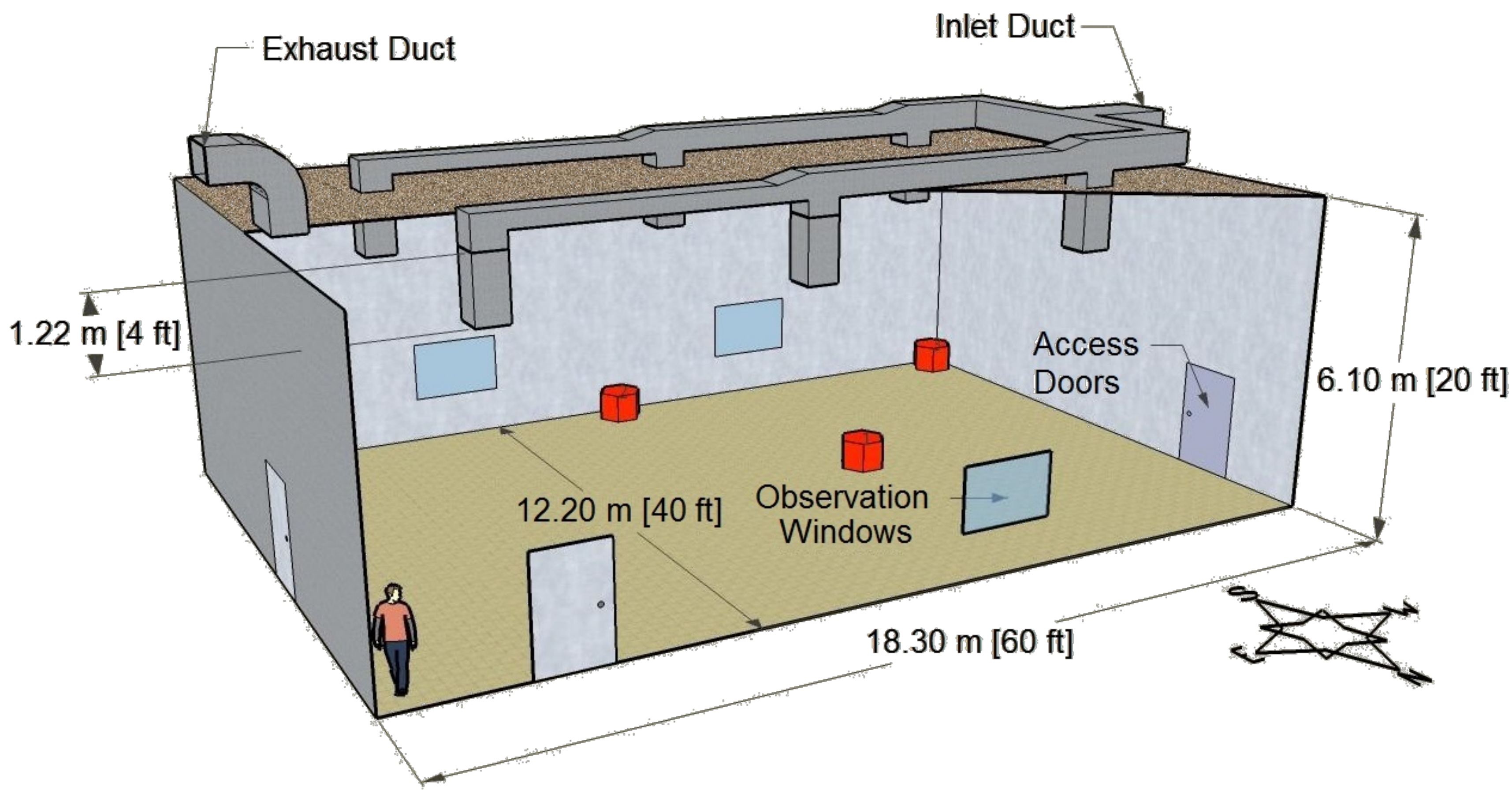

Figure 1: Isometric View of the Test Enclosure Configuration 1 with Its Three Fire Locations (Locations 1, 2 and 3) and the Ventilation System

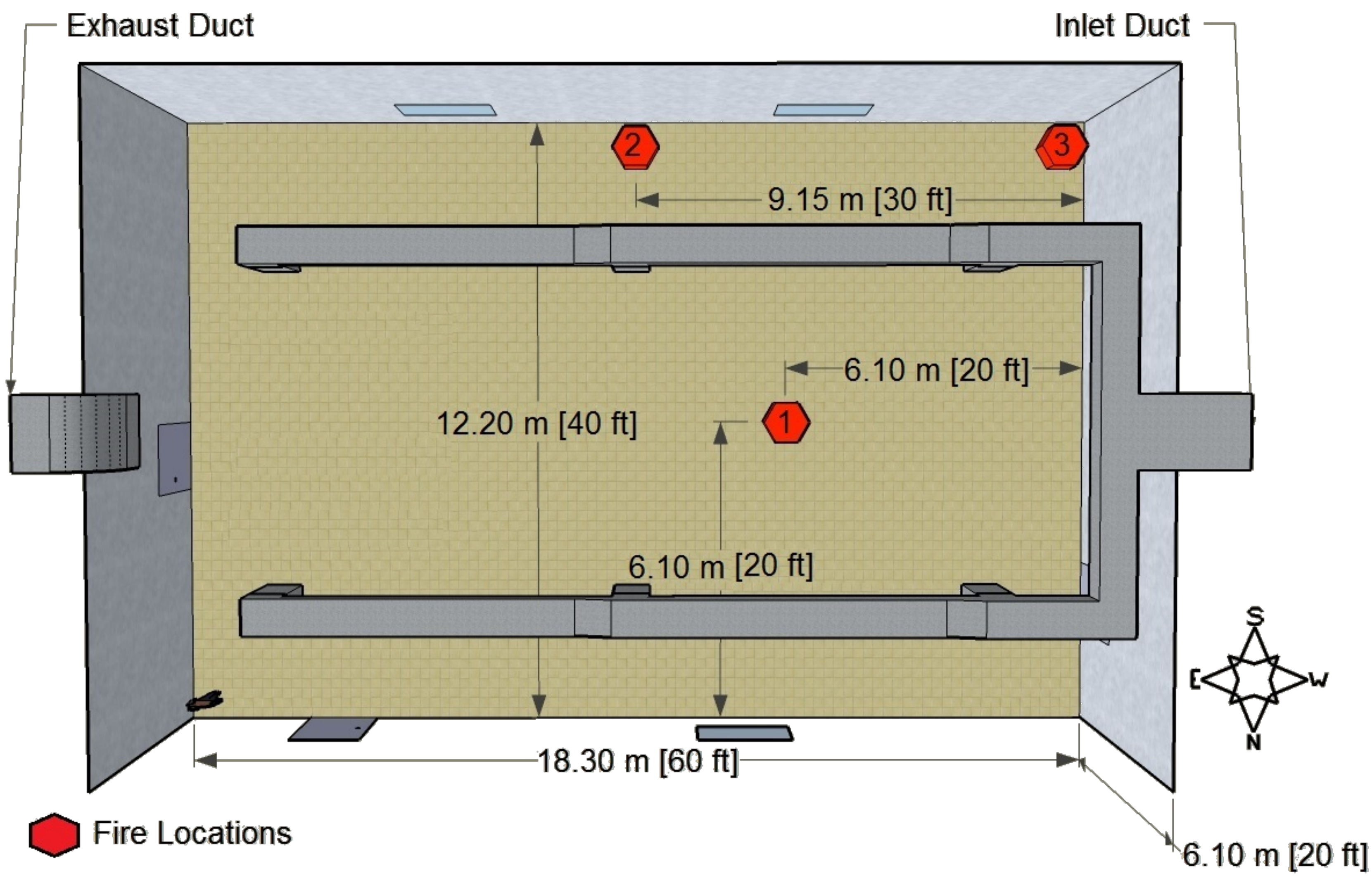

Figure 2: Plan View of the Test Enclosure Configuration 1 with the Three Fire Locations (Locations 1, 2 and 3) and the Ventilation System

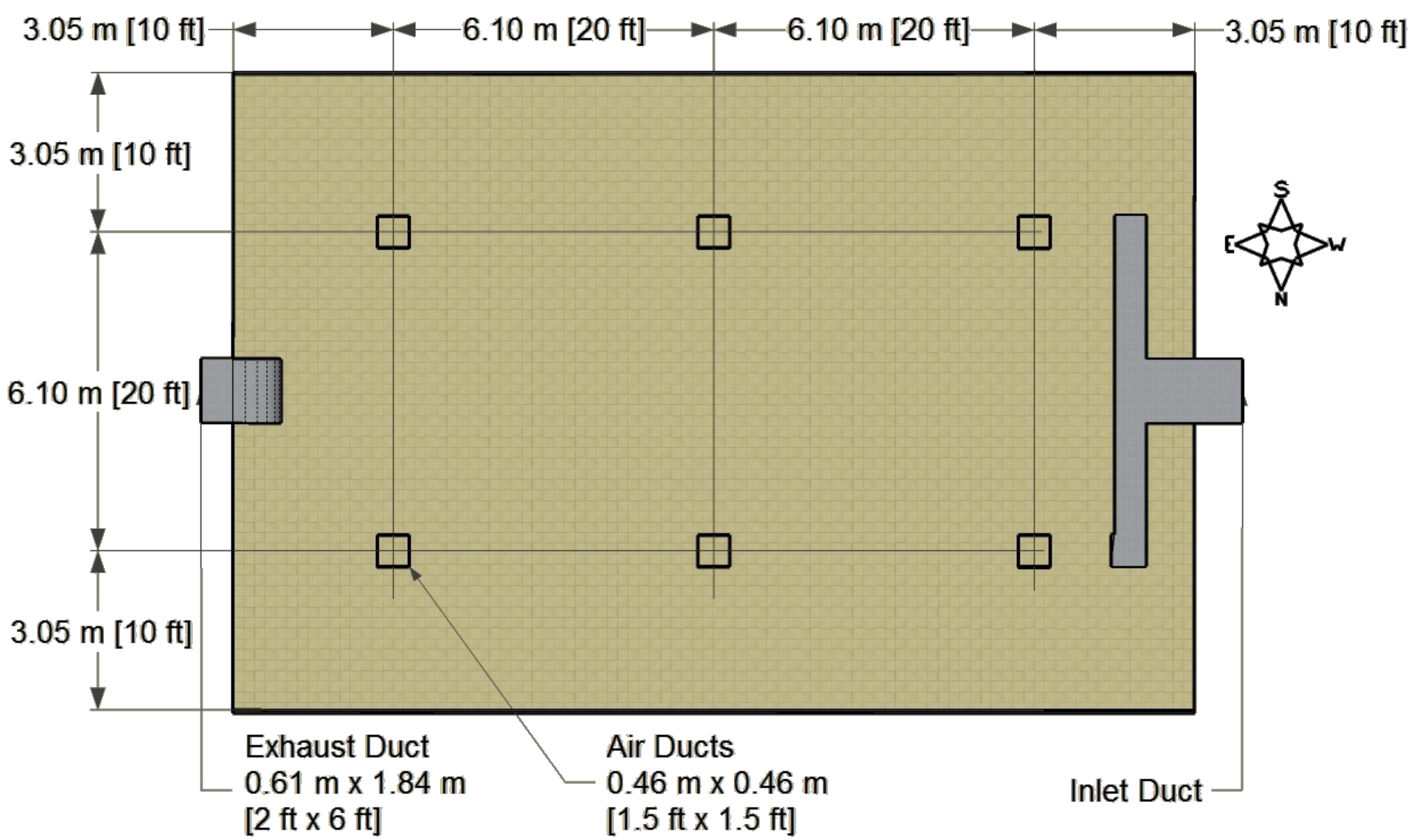

Figure 3: Plan View of Test Enclosure and Location of Air Ducts

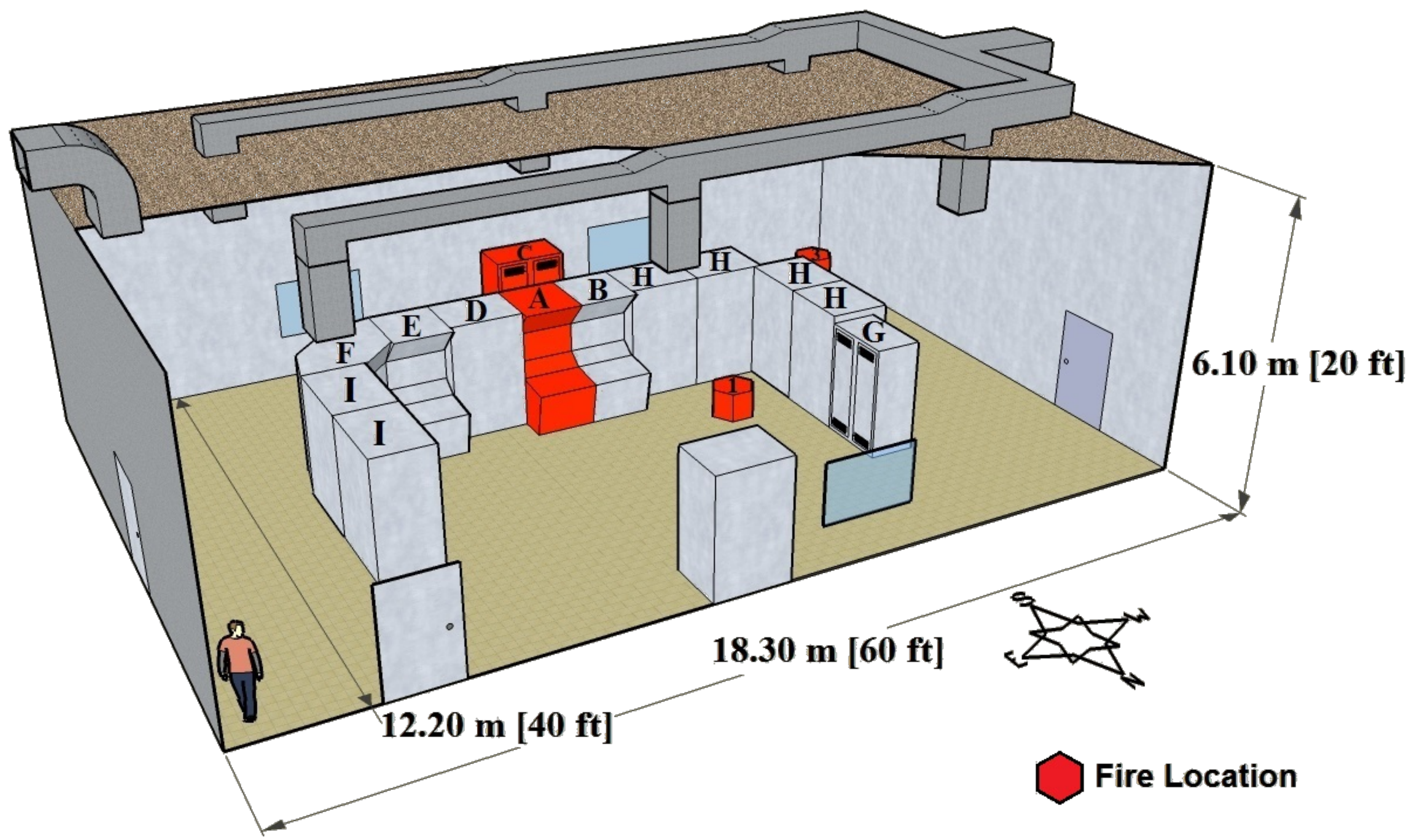

Figure 4: Isometric View of the Test Enclosure Configuration 2 with Its Four Fire Locations (Cabinets A and C and Locations 1 and 3)

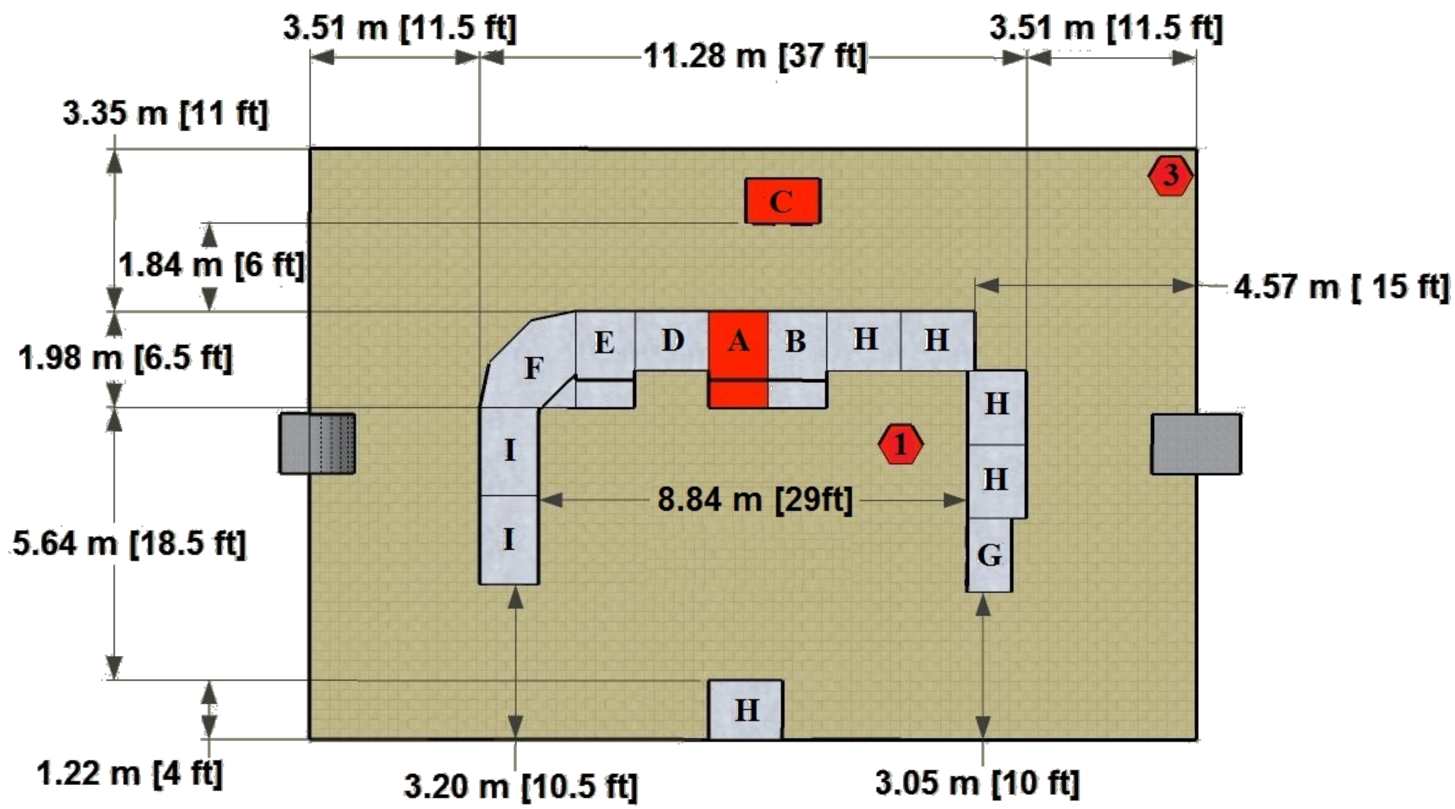

Figure 5: Plan View of the Test Enclosure Configuration 2 with Its Four Fire Locations (Cabinets A and C and Locations 1 and 3)

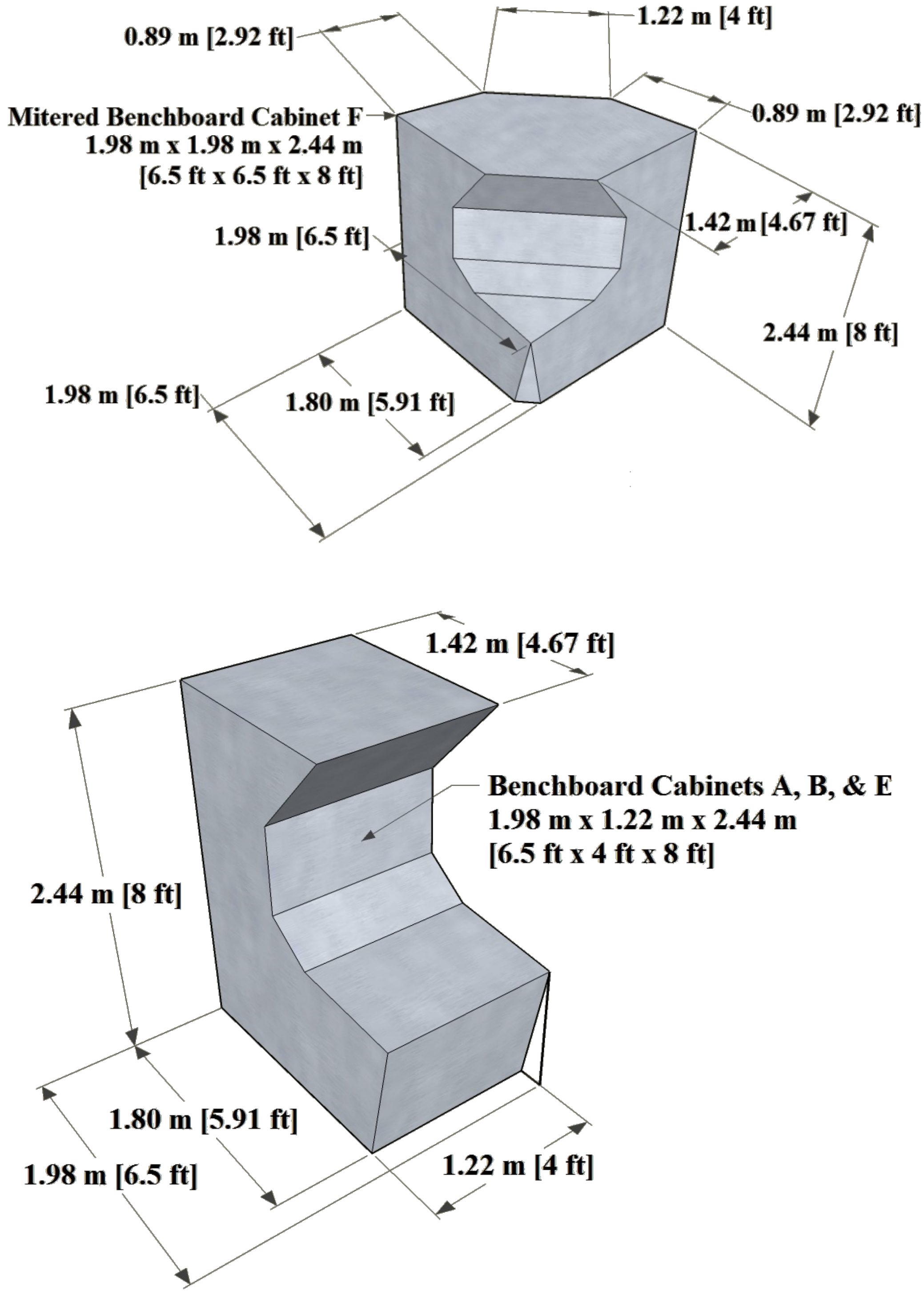

Figure 6: Schematic of Bench-Board Cabinets A, B, E, and F

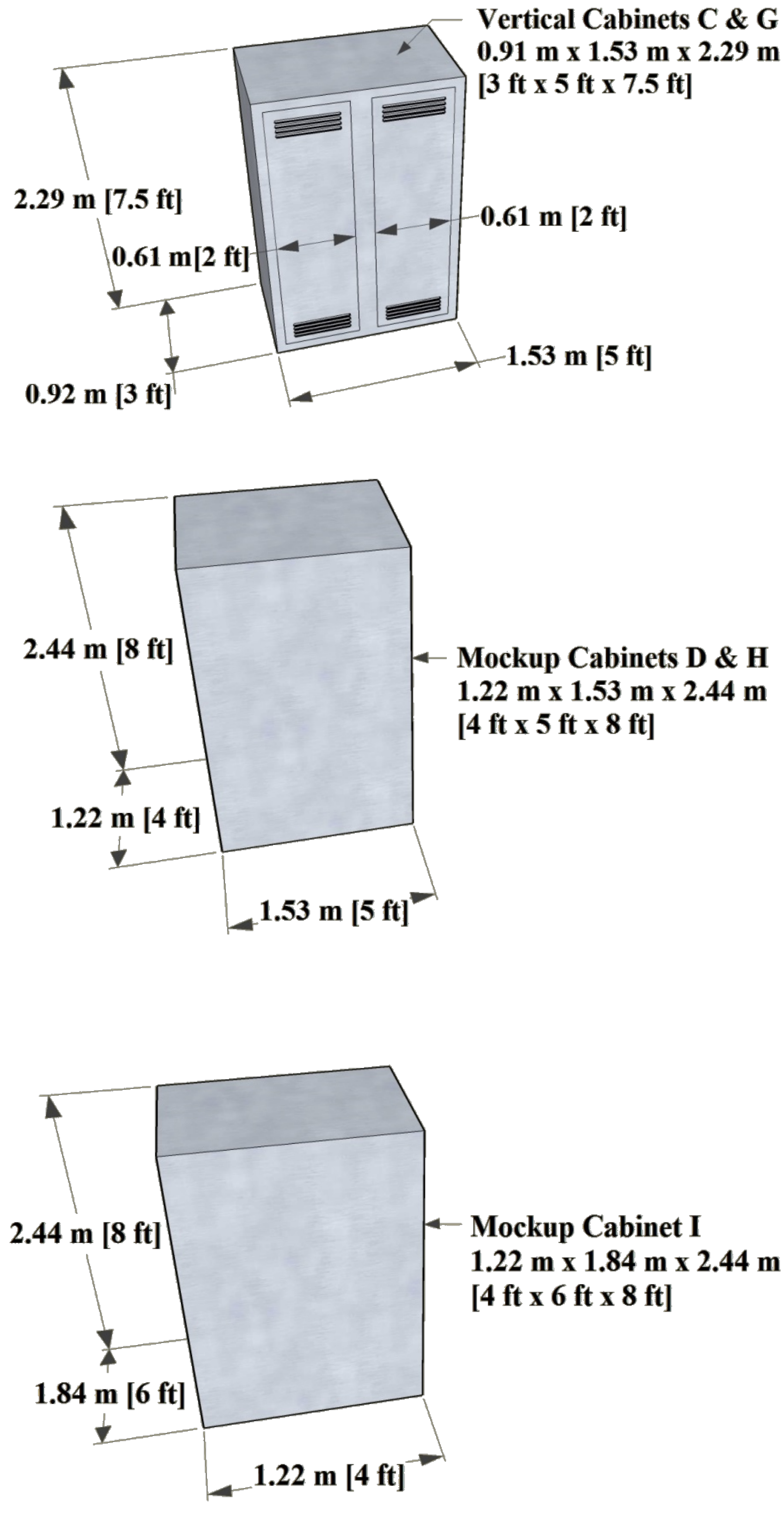

Figure 7: Schematic of Cabinets C, D, G, H, and I

4. INSTRUMENTATION

Over 300 data channels were used to measure air temperatures, surface temperatures, vertical air flow velocities, horizontal air flow velocities, pressure differentials, smoke densities, combustion gas concentrations, heat fluxes, and mass loss of fuel. The instrumentation was grouped into a total of 21 arrays designated as stations, expanded stations, corner rakes (thermocouple array) and sectors in different locations inside the test enclosure (see Figures 8-10). Other instrumentation included exhaust gas collector and the cabinet instrumentation for the configuration 2 (mock-up main control room [MCR]). These 21 arrays provided the following instrumentation for characterization of the environment in the enclosure:

- 31 aspirated thermocouples
- 59 bare-bead thermocouples
- 9 small sphere calorimeters
- 9 large sphere calorimeters
- 6 smoke turbidimeters (smoke density meters)
- 9 three-dimensional velocity probes
- 9 gas-sampling ports (for oxygen, carbon dioxide, and carbon monoxide)

Appendix A includes the Test Data Channel Map (Table A-1) which describes the type, number, and location of each sensor. This table is a revised version of the Table B-1 of Appendix B of NUREG/CR-4681, “Enclosure Environment Characterization Testing for the Base Line Validation of Computer Fire Simulation Codes.” The data channels are identified by their Channel No. in the spreadsheets.

The large and small sphere calorimeters were installed in nine locations within the room. Together with the gas temperature measurements provided by the aspirated thermocouples, these calorimeters can provide estimates of both the convective and radiative heat transfer rates to the spheres. The convective heat transfer rates can also be converted to bulk flow velocity information through correlations that relate the heat transfer coefficient to the velocity of the air flow. This calculation procedure has been described by Newman [Newman, 1980].

The optical smoke density meters, or smoke turbidimeters, are devices designed by Factory Mutual Research Corporation (FMRC) for use in fire testing. Of the six devices installed in the enclosure, five utilized a single color light extinction measurement. The final turbidimeter utilized a three-wavelength light extinction measurement. Through experimental use FMRC has shown a correlation between the optical densities of the smoke at a particular wavelength to the volume fraction of smoke; thus, the smoke volume fraction in the area of measurement. Data from the three-wavelength device can also be used to generate estimates of the particulate sizes in the area of the device. The details of construction and use of the turbidimeters have been described by Newman [Newman, 1980]. The procedures for processing the turbidimeter data have also been described by Newman [Newman, 1986].

The enclosure surfaces were instrumented at a number of locations for surface temperature and surface heat flux. Heat flux was measured in the inner and outer surfaces of the walls and ceiling and on the inner surface of the floor of the enclosure. See Appendix A for the Test Data Channel Map and the specific locations.

Differential pressure measurements were made in both the main inlet ventilation duct and the outlet ventilation duct for calculation of duct velocity. The static pressure in the chamber was also monitored.

Fuel burning rates for the liquid fuel pool fires and the solid fuel fire were monitored using a load platform to measure the fuel mass remaining throughout each test.

Concentrations of oxygen, carbon dioxide, carbon monoxide, and unburned hydrocarbons were continuously measured in the exhaust duct.

The cabinets C, A, and B and its adjacent cabinets D and H were instrumented because they were in the general location of the fires. Figure 11 shows the relative horizontal location of the sensors in each of the cabinets. The vertical location of the sensors is not available from NUREG/CR-4681, NUREG/CR-4527 ("An Experimental Investigation of Internally Ignited Fires in Nuclear Power Plant Control Cabinets, Volume II: Room Effects Tests"), Steve Nowlen's "Survivor's Guide for Users of the Baseline Validation Test Data" [Nowlen, 1999], or notes from the project file at SNL.

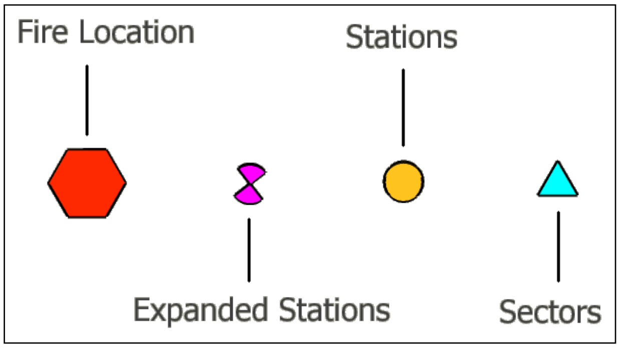

Figure 8: Legend for the Instrumentation set up and locations in Figure 10

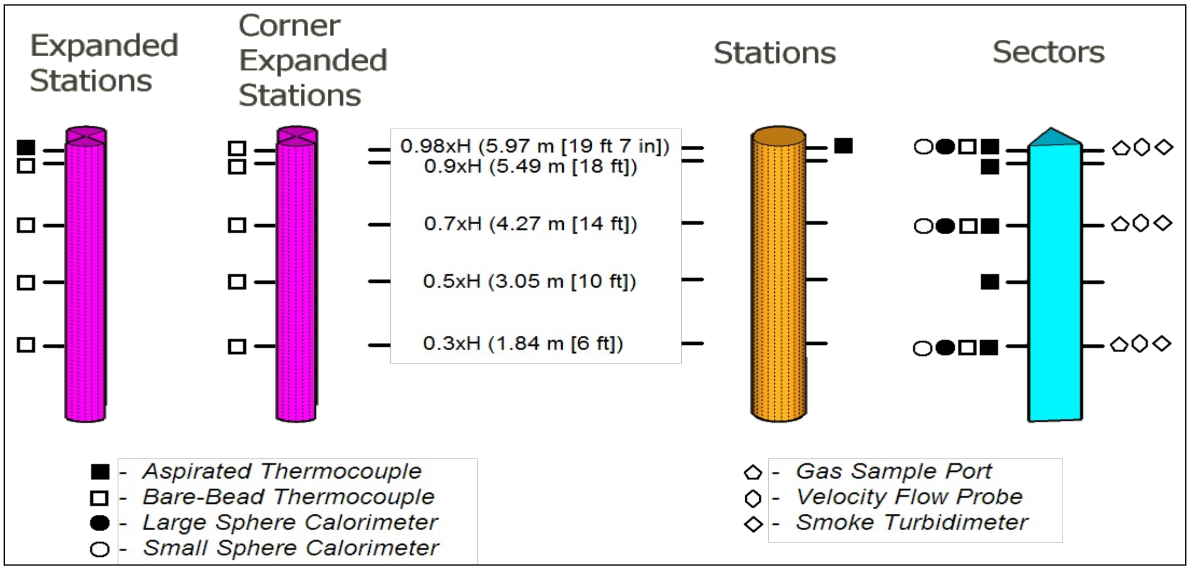

Figure 9: Vertical Location of the Instrumentation in each Array shown in Figure 10

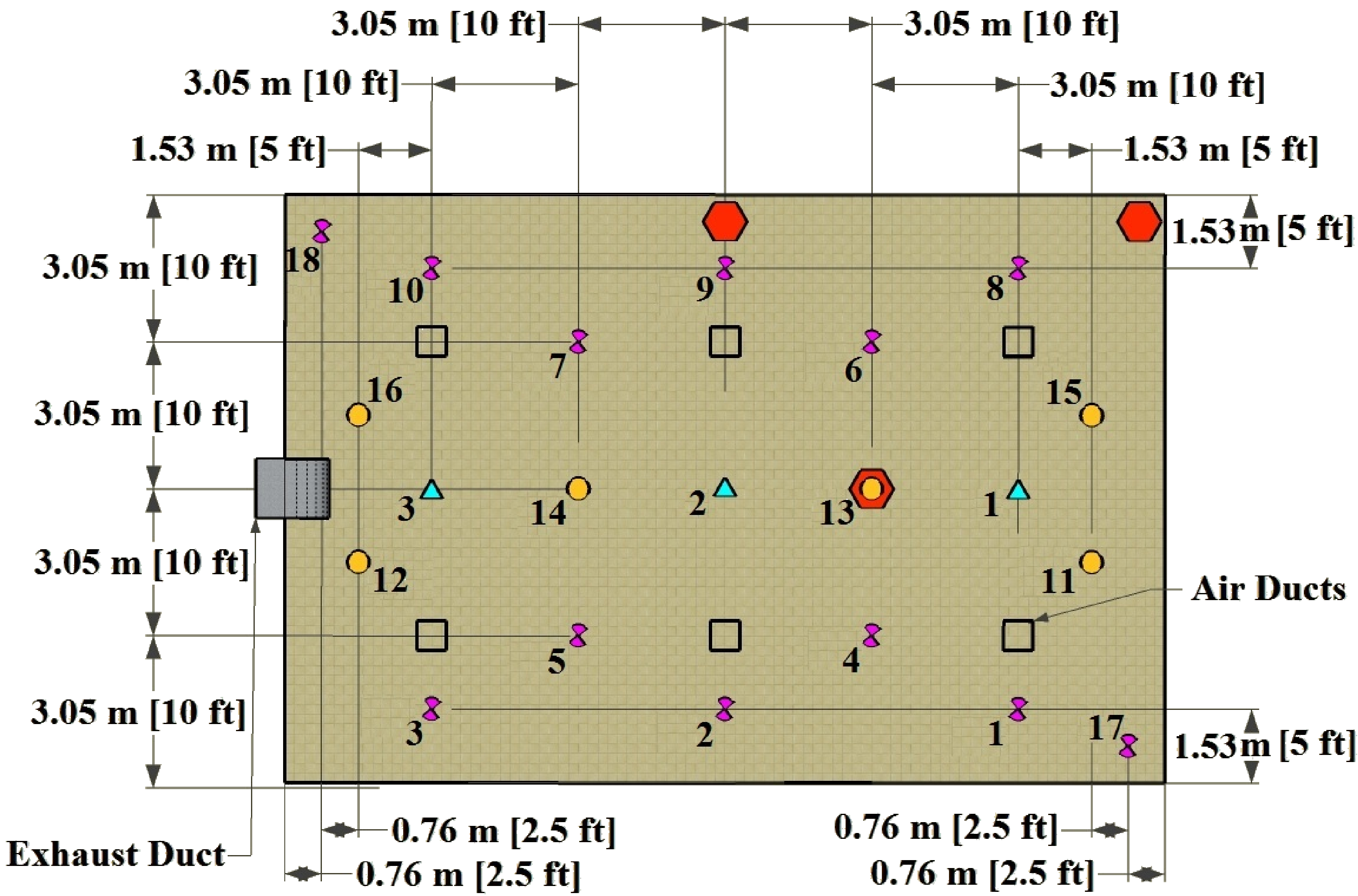

Figure 10: Plan View of the Instrumentation Set Up and Locations in the Test Enclosure

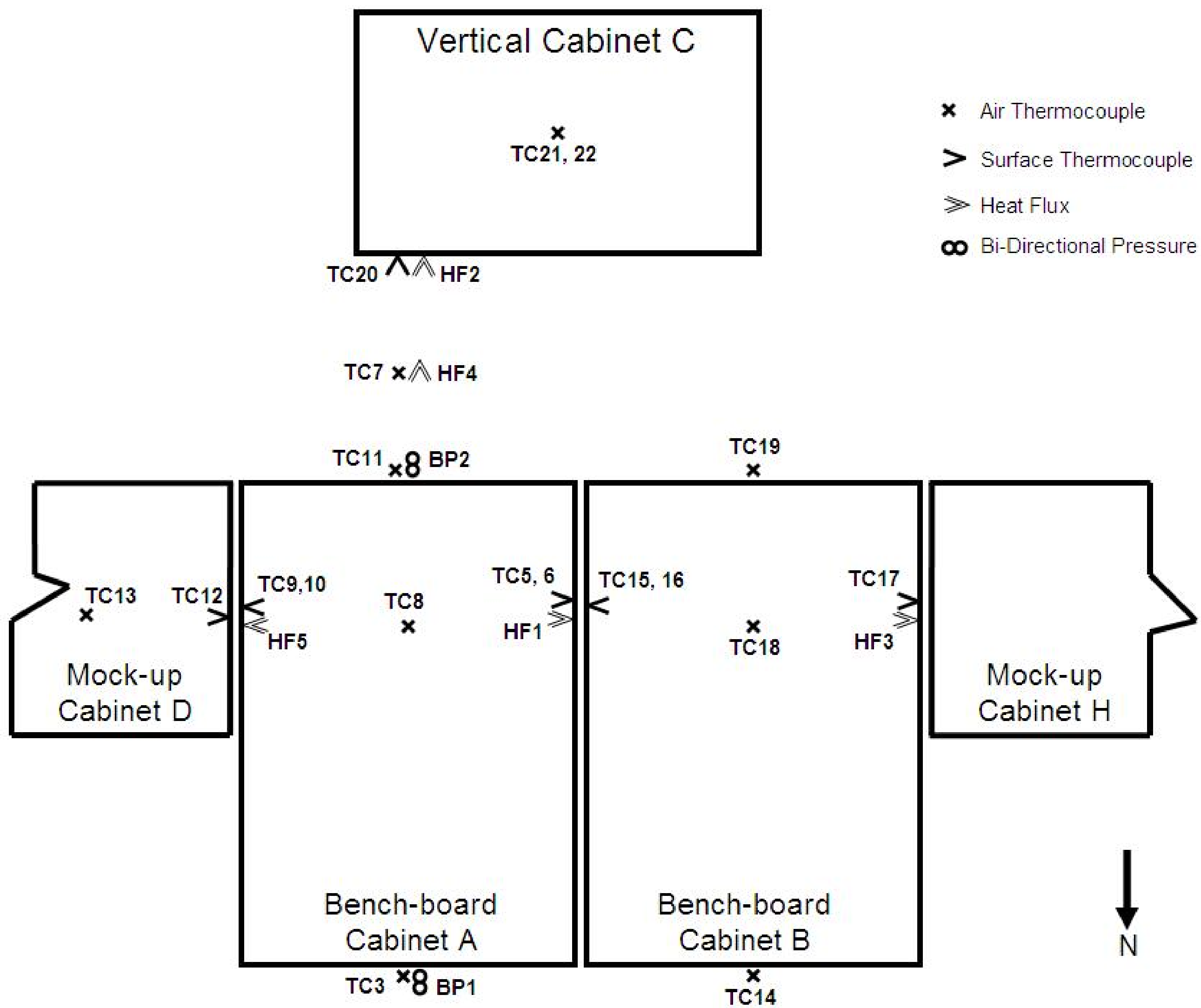

Figure 11: Top View Schematic of Cabinet Instrumentation Layout

The Fire Products Collector (FPC) at the test site was used to collect the exhaust gases from the fire tests. The FPC is a large capacity calorimeter that can measure fires in the megawatt range. It has a collecting funnel with a 6.10 m (20 ft.) inlet diameter located at 7.93 m (26 ft.) from the test floor. The FPC is connected to the pollution control system of the test center and can draw in at its maximum capacity, 28 m^3/s (988 ft^3/s) of air flow. The apparatus is instrumented with thermocouples, velocity probes, and gas sampling probes to measure temperature, velocity, and various gas concentrations of the gas stream flowing through the system. These measurements can be used to calculate the total and convective heat release rates. In addition, the generation rates of gaseous products such as carbon dioxide, carbon monoxide, and total hydrocarbons can be calculated. Approximately 20 channels of computer data are associated with the FPC. There is some uncertainty associated with the data from the FPC since not all fire products and exhaust gases were captured by the collector caused by leakage and other issues.

5. FIRE CHARACTERISTICS AND IGNITION SOURCES

5.1 Fire Sources

The fuel/fire sources utilized in these tests were:

(1) gas burner fires
(2) liquid pool fires
(3) simple solid fuel fires

Ten tests were conducted using the gas burner. Two of the 10 tests were conducted in the main control room (MCR) mock-up configuration with the burner placed inside one of the bench-board cabinets. The gas burner was a 91.44 cm (36 in) diameter sand box burner and the gas was propylene. Three nominal peak values of heat release rate (HRR) were used: 516, 1,000, and 2,000 kilowatt (kW). The tests were divided in two modes: steady state mode and growth mode. For the steady state mode, the burner was activated at the indicated peak rate and allowed to burn for 10 minutes. Four steady state tests were conducted where three were at 516 kW and one at 2,000 kW. Two growing mode tests were conducted following a "t-squared" curve to a maximum value of 516 kW and two growing mode tests to a maximum value of 1,000 kW (see Figures 12 and 13). The peak value was maintained for a prescribed period to provide total burn duration of 10 minutes for the 516 kW tests and 13 minutes for the 1,000 kW tests. The burner was shut off at peak intensity. Figures 12 and 13 show the graphs for the two peak fire intensities used for the growth mode. See Table 2 and Table 3 for descriptions of each test.

The two mock-up tests used the fire growth mode. The tests followed a "t-squared" curve to a maximum value of 516 kW and to a maximum value of 1,000 kW. The same procedure mentioned above was followed except that the fires were allowed to burn 19 minutes for the 516 kW peak and 14 minutes for the 1,000 kW peak. Figure 12 shows the graphs for the two peak fire intensities used for the growth mode. See Table 2 and Table 3 for descriptions of each test.

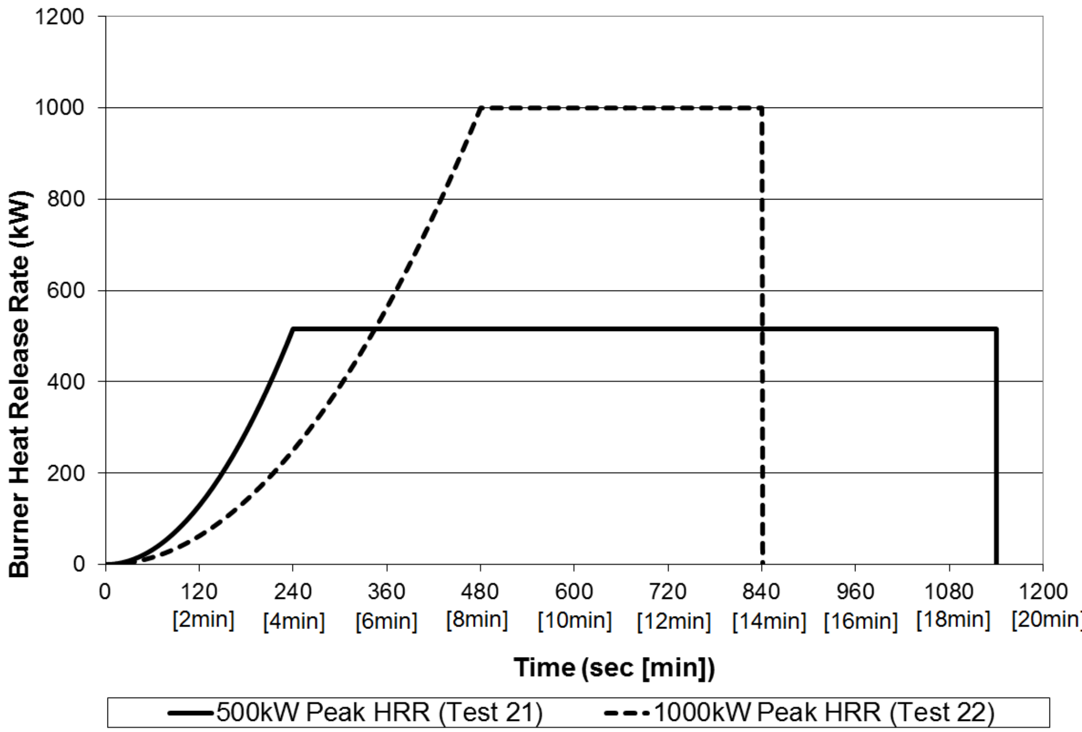

Figure 12: Growth Mode for the Gas Burner Tests

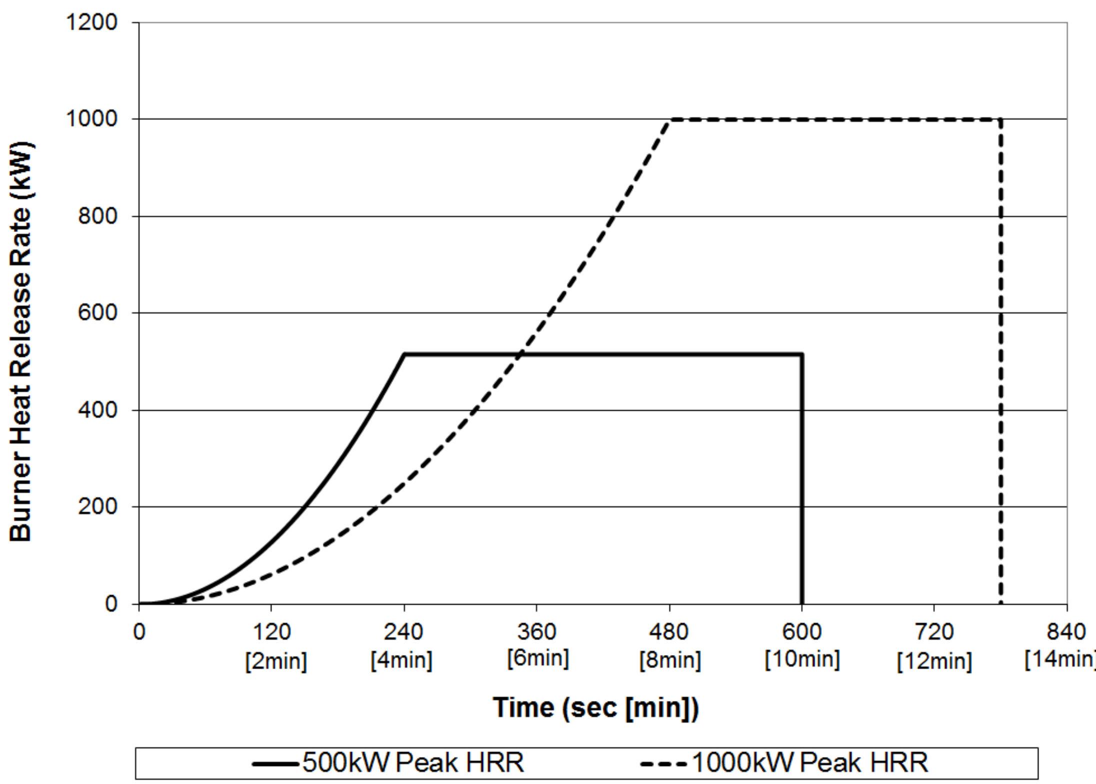

Figure 13: Growth Mode for Mock-Up Gas Burner Tests

Nine tests were conducted using liquid pool fires. The liquids used were: methanol (CH_3OH) and heptane (C_7H_{16}). These pool fires used three nominal HRRs: 500, 1,000, and 2,000 kW. The methanol was chosen as an example of a clean fuel and heptane was chosen as an example of a "dirty" fuel. To achieve the HRRs, different pan sizes were used. Exact diameters of these pans were not recorded in the original reports. By reviewing project notes and talking to one of the authors of the original reports, it was determined that the 500 kW fire used a 40.64 to 45.72 cm (16 to 18 inch) diameter pan, the 1,000 kW fire used a 60.96 cm (24 inch) diameter pan and the 2,000 kW fire used a 101.60 cm (40 inch) diameter pan.

One solid fuel was polymethyl methacrylate (PMMA). The report authors used two 0.6096 m x 0.6096 m x 2.54 cm (2 ft. x 2 ft. x 1 in) slabs of PMMA $[(C_5O_2H_8)_n]$ in a vertical orientation with a methanol pan placed between them as the ignition source. This fire was estimated to have a peak HRR of 1,000 kW. This fuel source was chosen to represent an uncontrolled solid fuel fire.

The other two solid fuels were qualified cables and unqualified cables. The IEEE-383 qualified cable was three-conductor, 12 AWG, with 0.76 mm (30-mil) cross-linked polyethylene (XPE) insulation, silicon glass tape, and a 1.65 mm cross-linked polyethylene (XPE) jacket, rated at 600 V. The unqualified cable was three conductors, 12 AWG, with 20/10 polyethylene/ polyvinylchloride (PE/PVC) insulation, and 1.14 mm (45 mil) polyvinylchloride (PVC) jacket. The fuel loading for the cabinets can be calculated by using the HRR data.

There were two fire ignition sources for the cables fuels: transient source and the electrical source. The transient source was made up of 9.5 liter (L) (2.5 gallon (gal)) polyethylene bucket, with 0.5 kilogram (kg) of Kimwipes in an open box, and 0.946 L (0.25 gal) of acetone placed in the bucket. One half of the acetone was poured into the bottom of the bucket and the rest of the acetone was placed with its bottle inside the bucket without the cap to simulate a spill. This ignition source was ignited by an electrically ignited pilot light setting fire to one of the Kimwipes hanging out of the bucket. This ignition source burns at an intensity of approximately 40 kW.

The electrical ignition source consisted of a terminal strip and 25 pieces of stripped unjacketed cables. This source was ignited by providing 165 kW of power to the terminal strip, resulting in overheating at the connection and culminating in a fire.

5.2 Fire Locations

For the tests conducted in the open enclosure, fires were placed in three locations: near the center of the room, along the center of the south wall and in the southwest corner. Figure 10 shows each of these locations.

For the tests conducted in the control room mock-up, fires were placed in four locations. For the two tests involving the gas burner, the burner was located inside the bench-board cabinet A. The room center and south wall were used for the two heptane pool fires. For the qualified cable, the fire was located in the bench-board cabinet A. For the two unqualified cables tests, the fires were located in the bench-board cabinet A and vertical cabinet C.

6. TEST DESCRIPTION AND PARAMETERS

The controlled parameters in each test were the fuel type, fire intensity, fire location, ventilation rate, burning mode, and ignition source. From test to test, different parameter combinations were tested.

Table 2: Matrix of Base Line Validation Tests Conducted in the Open Enclosure Configuration

Fuel Type

Test Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Propylene Burners	X	X	X	X	X		X	X	X									
Heptane Pool						X				X		X	X		X	X	X	
Methanol Pool											X			X				
PMMA Solid Slabs																		X

Nominal Peak Fire Intensity

Test Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
500 (516 for propylene burner) kW	X	X		X	X	X	X				X			X		X	X	
1,000 kW								X	X	X					X			X
2,000 kW			X									X	X					

Fire Location

Test Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Room Center (1)	X	X	X	X	X		X	X	X									
South Wall (2)						X				X	X	X	X	X	X			X
South-West Corner (3)																X	X	

Nominal Enclosure Ventilation Rate

Test Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 ch/hr (800 CFM)				X		X	X	X						X	X	X		X
4.4 ch/hr (3,500 CFM)										X	X	X						
8 ch/hr (6,400 CFM)									X				X					
10 ch/hr (8,000 CFM)	X	X	X		X												X	

Burner Fire Mode

Test Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Steady State Mode	X	X	X				X											
Growing Fire Mode				X	X			X	X									
Uncontrolled						X				X	X	X	X	X	X	X	X	X

Table 3: Matrix of Base Line Validation Tests Conducted in the Control Room Mock Up Configuration

Fuel Type

Test Number	19	20	21	22	23	24	25
Propylene Burners			X	X			
Heptane Pool	X	X					
Qualified Cable					X		
Unqualified Cable						X	X

Nominal Peak Fire Intensity

Test Number	19	20	21	22	23	24	25
500 kW			X				
1,000 kW	X	X		X			

Fire Location

Test Number	19	20	21	22	23	24	25
Room Center	X						
South-west Corner		X					
Bench-board Cabinet A			X	X	X	X	
Vertical Cabinet C							X

Nominal Enclosure Ventilation Rate

Test Number	19	20	21	22	23	24	25
1 ch/hr (800 CFM)	X		X	X	X	X	
8 ch/hr (6,400 CFM)		X					X

Burner Fire Mode

Test Number	19	20	21	22	23	24	25
Growing Fire Mode			X	X			
Uncontrolled	X	X			X	X	X

Ignition Source

Test Number	19	20	21	22	23	24	25
Gas Burner			X	X			
Transient Source					X		
Electrical Source						X	X
Other not specified	X	X					

7. REFERENCES

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2. Newman, J.S.; Hill, J.P.; “Assessment of Exposure Fire Hazards to Cable Trays,” Factory Mutual Research Corporation (FMRC), Report No. RC80-T-56, July 1980.

3. EPRI NP-1675; “Fire Test in Ventilated Rooms: Detection of Cable Tray and Exposure Fires,” Factory Mutual Research Corporation and Electric Power Research Institute, Report No. J.I.OF0R3.RC, January 1986.

4. Newman, J.S.; Steciak, J.; “Characterization of Particulate from Diffusion Flames,” Submitted for publication in *Combustion and Flame*, March 1986.

5. NUREG/CR-4681, SAND86-1296, “Enclosure Environment Characterization Testing for the Base Line Validation of Computer Fire Simulation Codes,” U.S. Nuclear Regulatory Commission, Washington, DC, and Sandia National Laboratories, Albuquerque, NM, March 1987. (Note: Included in Supplement 1.)

6. Nowlen, S.P.; “Survivor’s Guide for Users of the Baseline Validation Test Data”; Sandia National Laboratories; Revision 1; February 1999. (Note: Included in Supplement 1.)

7. NUREG-1824 and EPRI 1011999, “Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications,” U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research (RES), Washington, DC, and Electric Power Research Institute (EPRI), Palo Alto, CA, May 2007.

APPENDIX A: TEST DATA CHANNEL MAP

For the array (Sector and Stations) number locations see Section 4: Instrumentation.

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
"1-179 TC Data" Sheet in the Test Data File			
1	Aspirated T/C, Sector 1, 0.98H	^oC	
2	Aspirated T/C, Sector 1, 0.90H	^oC	
3	Aspirated T/C, Sector 1, 0.70H	^oC	
4	Aspirated T/C, Sector 1, 0.50H	^oC	
5	Aspirated T/C, Sector 1, 0.30H	^oC	
6	Aspirated T/C, Sector 2, 0.98H	^oC	
7	Aspirated T/C, Sector 2, 0.90H	^oC	
8	Aspirated T/C, Sector 2, 0.70H	^oC	
9	Aspirated T/C, Sector 2, 0.50H	^oC	
10	Aspirated T/C, Sector 2, 0.30H	^oC	
11	Aspirated T/C, Sector 3, 0.98H	^oC	
12	Aspirated T/C, Sector 3, 0.90H	^oC	
13	Aspirated T/C, Sector 3, 0.70H	^oC	
14	Aspirated T/C, Sector 3, 0.50H	^oC	
15	Aspirated T/C, Sector 3, 0.30H	^oC	
16	Aspirated T/C, Station 1, 0.98H	^oC	
17	Aspirated T/C, Station 2, 0.98H	^oC	
18	Aspirated T/C, Station 3, 0.98H	^oC	
19	Aspirated T/C, Station 4, 0.98H	^oC	
20	Aspirated T/C, Station 5, 0.98H	^oC	
21	Aspirated T/C, Station 6, 0.98H	^oC	
22	Aspirated T/C, Station 7, 0.98H	^oC	
23	Aspirated T/C, Station 8, 0.98H	^oC	
24	Aspirated T/C, Station 9, 0.98H	^oC	
25	Aspirated T/C, Station 10, 0.98H	^oC	
26	Aspirated T/C, Station 11, 0.98H	^oC	
27	Aspirated T/C, Station 12, 0.98H	^oC	
28	Aspirated T/C, Station 13, 0.98H	^oC	

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
29	Aspirated T/C, Station 14, 0.98H	°C	
30	Aspirated T/C, Station 15, 0.98H	°C	
31	Aspirated T/C, Station 16, 0.98H	°C	
32	Bare bead gas T/C, Sector 1, 0.98H	°C	
33	Bare bead gas T/C, Sector 1, 0.70H	°C	
34	Bare bead gas T/C, Sector 1, 0.30H	°C	
35	Bare bead gas T/C, Sector 2, 0.98H	°C	
36	Bare bead gas T/C, Sector 2, 0.70H	°C	
37	Bare bead gas T/C, Sector 2, 0.30H	°C	
38	Bare bead gas T/C, Sector 3, 0.98H	°C	
39	Bare bead gas T/C, Sector 3, 0.70H	°C	
40	Bare bead gas T/C, Sector 3, 0.30H	°C	
41	Bare bead gas T/C, Station 1, 0.90H	°C	
42	Bare bead gas T/C, Station 1, 0.70H	°C	
43	Bare bead gas T/C, Station 1, 0.50H	°C	
44	Bare bead gas T/C, Station 1, 0.30H	°C	
45	Bare bead gas T/C, Station 2, 0.90H	°C	
46	Bare bead gas T/C, Station 2, 0.70H	°C	
47	Bare bead gas T/C, Station 2, 0.50H	°C	
48	Bare bead gas T/C, Station 2, 0.30H	°C	
49	Bare bead gas T/C, Station 3, 0.90H	°C	
50	Bare bead gas T/C, Station 3, 0.70H	°C	
51	Bare bead gas T/C, Station 3, 0.50H	°C	
52	Bare bead gas T/C, Station 3, 0.30H	°C	
53	Bare bead gas T/C, Station 4, 0.90H	°C	
54	Bare bead gas T/C, Station 4, 0.70H	°C	
55	Bare bead gas T/C, Station 4, 0.50H	°C	
56	Bare bead gas T/C, Station 4, 0.30H	°C	
57	Bare bead gas T/C, Station 5, 0.90H	°C	
58	Bare bead gas T/C, Station 5, 0.70H	°C	
59	Bare bead gas T/C, Station 5, 0.50H	°C	
60	Bare bead gas T/C, Station 5, 0.30H	°C	
61	Bare bead gas T/C, Station 6, 0.90H	°C	
62	Bare bead gas T/C, Station 6, 0.70H	°C	

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
63	Bare bead gas T/C, Station 6, 0.50H	^{o}C	
64	Bare bead gas T/C, Station 6, 0.30H	^{o}C	
65	Bare bead gas T/C, Station 7, 0.90H	^{o}C	
66	Bare bead gas T/C, Station 7, 0.70H	^{o}C	
67	Bare bead gas T/C, Station 7, 0.50H	^{o}C	
68	Bare bead gas T/C, Station 7, 0.30H	^{o}C	
69	Bare bead gas T/C, Station 8, 0.90H	^{o}C	
70	Bare bead gas T/C, Station 8, 0.70H	^{o}C	
71	Bare bead gas T/C, Station 8, 0.50H	^{o}C	
72	Bare bead gas T/C, Station 8, 0.30H	^{o}C	
73	Bare bead gas T/C, Station 9, 0.90H	^{o}C	
74	Bare bead gas T/C, Station 9, 0.70H	^{o}C	
75	Bare bead gas T/C, Station 9, 0.50H	^{o}C	
76	Bare bead gas T/C, Station 9, 0.30H	^{o}C	
77	Bare bead gas T/C, Station 10, 0.90H	^{o}C	
78	Bare bead gas T/C, Station 10, 0.70H	^{o}C	
79	Bare bead gas T/C, Station 10, 0.50H	^{o}C	
80	Bare bead gas T/C, Station 10, 0.30H	^{o}C	
81	Bare bead gas T/C, Station 17, 0.98H	^{o}C	
82	Bare bead gas T/C, Station 17, 0.90H	^{o}C	
83	Bare bead gas T/C, Station 17, 0.70H	^{o}C	
84	Bare bead gas T/C, Station 17, 0.50H	^{o}C	
85	Bare bead gas T/C, Station 17, 0.30H	^{o}C	
86	Bare bead gas T/C, Station 18, 0.98H	^{o}C	
87	Bare bead gas T/C, Station 18, 0.90H	^{o}C	
88	Bare bead gas T/C, Station 18, 0.70H	^{o}C	
89	Bare bead gas T/C, Station 18, 0.50H	^{o}C	
90	Bare bead gas T/C, Station 18, 0.30H	^{o}C	
91	Bare bead gas T/C, Ventilation inlet	^{o}C	
92	Bare bead gas T/C, Ventilation outlet	^{o}C	
93	Inner ceiling surface T/C, Sector 1	^{o}C	
94	Outer ceiling surface T/C, Sector 1	^{o}C	
95	Inner ceiling surface T/C, Sector 2	^{o}C	
96	Outer ceiling surface T/C, Sector 2	^{o}C	

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
97	Inner ceiling surface T/C, Sector 3	^oC	
98	Outer ceiling surface T/C, Sector 3	^oC	
99	Inner ceiling surface T/C, Station 1	^oC	
100	Inner ceiling surface T/C, Station 2	^oC	
101	Inner ceiling surface T/C, Station 3	^oC	
102	Inner ceiling surface T/C, Station 4	^oC	
103	Inner ceiling surface T/C, Station 5	^oC	
104	Inner ceiling surface T/C, Station 6	^oC	
105	Inner ceiling surface T/C, Station 7	^oC	
106	Inner ceiling surface T/C, Station 8	^oC	
107	Inner ceiling surface T/C, Station 9	^oC	
108	Inner ceiling surface T/C, Station 10	^oC	
109	Inner wall surface T/C, North center, 0.90H	^oC	
110	Outer wall surface T/C, North center 0.90H	^oC	
111	Inner wall surface T/C, North center, 0.50H	^oC	
112	Outer wall surface T/C, North center 0.50H	^oC	
113	Inner wall surface T/C, North right, 0.90H	^oC	
114	Inner wall surface T/C, North right, 0.50H	^oC	
115	Inner wall surface T/C, North left, 0.90H	^oC	
116	Inner wall surface T/C, North left, 0.50H	^oC	
117	Inner wall surface T/C, South center, 0.90H	^oC	
118	Outer wall surface T/C, South center 0.90H	^oC	
119	Inner wall surface T/C, South center, 0.50H	^oC	
120	Outer wall surface T/C, South center 0.50H	^oC	
121	Inner wall surface T/C, South right, 0.90H	^oC	
122	Inner wall surface T/C, South right, 0.50H	^oC	
123	Inner wall surface T/C, South left, 0.90H	^oC	
124	Inner wall surface T/C, South left, 0.50H	^oC	
125	Inner wall surface T/C, East right, 0.90H	^oC	
126	Outer wall surface T/C, East right, 0.90H	^oC	
127	Inner wall surface T/C, East right, 0.50H	^oC	
128	Inner wall surface T/C, East left, 0.90H	^oC	
129	Outer wall surface T/C, East left, 0.90H	^oC	
130	Inner wall surface T/C, East left, 0.50H	^oC	

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
131	Inner wall surface T/C, West right, 0.90H	^oC	
132	Outer wall surface T/C, West right, 0.90H	^oC	
133	Inner wall surface T/C, West right, 0.50H	^oC	
134	Inner wall surface T/C, West left, 0.90H	^oC	
135	Outer wall surface T/C, West left, 0.90H	^oC	
136	Inner wall surface T/C, West left, 0.50H	^oC	
137	Cabinet Top T/C, Sector 1	^oC	Channels 137-161 were only used in tests 19-25. Some channels are unique to the cabinet fire tests 21-25.
138	Surface T/C Facing Cabinet A	^oC	
139	Cabinet Top T/C, Sector 3	^oC	
140	Cable Ignition T/C #1	^oC	
141	Cable Ignition T/C #2	^oC	
142	Cabinet C Door-Bottom Gas T/C	^oC	
143	Cabinet A Front Bench Wall	^oC	
144	Cabinet A Left Wall Low T/C	^oC	
145	Cabinet A Left Wall High T/C	^oC	
146	Surface T/C for Cabinet HF #4	^oC	
147	Cabinet A Center-High Gas T/C	^oC	
148	Cabinet A Right Wall Low T/C	^oC	
149	Cabinet A Right Wall High T/C	^oC	
150	Cabinet C Door-Top Gas T/C	^oC	
151	Cabinet D Gas T/C Near Wall	^oC	
152	Cabinet D Gas T/C Center	^oC	
153	Cabinet B Vent In Gas T/C	^oC	
154	Cabinet B Right Wall-Low T/C	^oC	
155	Cabinet B Right Wall-High T/C	^oC	
156	Cabinet B Left Wall-High T/C	^oC	
157	Cabinet B Gas T/C Center-High	^oC	
158	Cabinet B Gas T/C Center-Door	^oC	
159	Surface T/C Facing Cab C	^oC	
160	Cabinet C Gas T/C Center-Low	^oC	
161	Cabinet C Gas T/C Center-High	^oC	

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
162	Large sphere calorimeter, Sector 1, 0.98H	°C	Channels 162-179 are raw temperature responses for the large and small calorimeters
163	Small sphere calorimeter, Sector 1, 0.98H	°C	
164	Large sphere calorimeter, Sector 1, 0.70H	°C	
165	Small sphere calorimeter, Sector 1, 0.70H	°C	
166	Large sphere calorimeter, Sector 1, 0.30H	°C	
167	Small sphere calorimeter, Sector 1, 0.30H	°C	
168	Large sphere calorimeter, Sector 2, 0.98H	°C	
169	Small sphere calorimeter, Sector 2, 0.98H	°C	
170	Large sphere calorimeter, Sector 2, 0.70H	°C	
171	Small sphere calorimeter, Sector 2, 0.70H	°C	
172	Large sphere calorimeter, Sector 2, 0.30H	°C	
173	Small sphere calorimeter, Sector 2, 0.30H	°C	
174	Large sphere calorimeter, Sector 3, 0.98H	°C	
175	Small sphere calorimeter, Sector 3, 0.98H	°C	
176	Large sphere calorimeter, Sector 3, 0.70H	°C	
177	Small sphere calorimeter, Sector 3, 0.70H	°C	
178	Large sphere calorimeter, Sector 3, 0.30H	°C	
179	Small sphere calorimeter, Sector 3, 0.30H	°C	
"180-197 Flow Probe" Sheet in the Test Data File			
180	Horizontal flow probe, Sector 1, 0.98 H	m/s	Channels 182-197 are raw velocity measurement made using paired bi-directional pressure/velocity probes.
181	Vertical flow probe, Sector 1, 0.98H	m/s	
182	Horizontal flow probe, Sector 1, 0.70H	m/s	
183	Vertical flow probe, Sector 1, 0.70H	m/s	
184	Horizontal flow probe, Sector 1, 0.30H	m/s	
185	Vertical flow probe, Sector 1, 0.30H	m/s	
186	Horizontal flow probe, Sector 2, 0.98 H	m/s	
187	Vertical flow probe, Sector 2, 0.98H	m/s	
188	Horizontal flow probe, Sector 2, 0.70H	m/s	
189	Vertical flow probe, Sector 2, 0.70H	m/s	
190	Horizontal flow probe, Sector 2, 0.30H	m/s	
191	Vertical flow probe, Sector 2, 0.30H	m/s	
192	Horizontal flow probe, Sector 3, 0.98 H	m/s	
193	Vertical flow probe, Sector 3, 0.98H	m/s	
194	Horizontal flow probe, Sector 3, 0.70H	m/s	
195	Vertical flow probe, Sector 3, 0.70H	m/s	
196	Horizontal flow probe, Sector 3, 0.30H	m/s	

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
197	Vertical flow probe, Sector 3, 0.30H	m/s	
"198-203 P Diff" Sheet in the Test Data File			
198	Inlet Duct Flow Rate	ACH	
199	Outlet Duct Flow Rate	ACH	
200	Pressure differential, Enclosure Hi	in-H_2O	
201	Pressure differential, Atmosphere Lo	in-H_2O	
202	Pressure differential, Cabinet inlet	in-H_2O	Only used in the cabinet fire tests (19-25)
203	Pressure differential, Cabinet outlet	in-H_2O	
"204-211 Opt Dens" Sheet in the Test Data File			
204	Blue optical density, Sector 1, 0.98H	1/m	Channels 204-208 are single-beam smoke turbidimeters. Channels 209-211 represent a single three-beam turbidimeter.
205	Blue optical density, Sector 1, 0.30H	1/m	
206	Blue optical density, Sector 2, 0.30H	1/m	
207	Blue optical density, Sector 3, 0.98H	1/m	
208	Blue optical density, Sector 3, 0.30H	1/m	
209	Blue optical density, Sector 2, 0.98H	1/m	
210	Red optical density, Sector 2, 0.98H	1/m	
211	IR optical density, Sector 2, 0.98H	1/m	
"212-221 Gas" Sheet in the Test Data File			
212	CO_2 analyzer (multiplexed), Sector 1-3, 0.98H	%	This data is demultiplexed into channels 259-282.
213	CO analyzer (multiplexed), Sector 1-3, 0.98H	%	
214	O_2 analyzer (multiplexed), Sectors 1-3, 0.98H	%	
215	THC analyzer (multiplexed), Sectors 1-3, 0.98H	ppm	
216	CO_2 analyzer (multiplexed), Sector 1-3, 0.70H	%	
217	CO analyzer (multiplexed), Sector 1-3, 0.70H	%	
218	CO_2 analyzer (multiplexed), Sector 1-3, 0.30H	%	
219	CO analyzer (multiplexed), Sector 1-3, 0.30H	%	
"220-249 Heat & Mass" Sheet in the Test Data File			
220	CO_2 analyzer (nonmultiplexed), Sector 2, 0.98H	%	
221	CO_2 (nonmultiplexed), Ventilation outlet	%	
222	Ceiling heat flux, Sector 1	kW/m^2	
223	Ceiling heat flux, Sector 2	kW/m^2	
224	Ceiling heat flux, Sector 3	kW/m^2	
225	Ceiling heat flux, Station 1	kW/m^2	
226	Ceiling heat flux, Station 2	kW/m^2	
227	Ceiling heat flux, Station 3	kW/m^2	
228	Ceiling heat flux, Station 8	kW/m^2	
229	Ceiling heat flux, Station 9	kW/m^2	

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
230	Ceiling heat flux, Station 10	kW/m^2	
231	Wall heat flux, North center, 0.90H	kW/m^2	The data in these channels appears to be unreliable in all tests.
232	Wall heat flux, North right, 0.90H	kW/m^2	
233	Wall heat flux, North left, 0.90H	kW/m^2	
234	Wall heat flux, South center, 0.90H	kW/m^2	
235	Wall heat flux, South right, 0.90H	kW/m^2	
236	Wall heat flux, South left, 0.90H	kW/m^2	
237	Wall heat flux, East right, 0.90H	kW/m^2	
238	Wall heat flux, East left, 0.90H	kW/m^2	
239	Wall heat flux, West right, 0.90H	kW/m^2	
240	Wall heat flux, West left, 0.90H	kW/m^2	
241	Floor heat flux, Sector 1	kW/m^2	
242	Floor heat flux, Sector 2	kW/m^2	
243	Floor heat flux, Sector 3	kW/m^2	
244	Cabinet heat flux #1	kW/m^2	Channels 244-248 are water-cooled calorimeters and are only used in tests 21-25. The location of each probe is unique to each test; See NUREG/CR-4527 V2.
245	Cabinet heat flux #2	kW/m^2	
246	Cabinet heat flux #3	kW/m^2	
247	Cabinet heat flux #4	kW/m^2	
248	Cabinet heat flux #5	kW/m^2	
249	Mass loss	kg/s	Not used in the gas burner tests.
"250-306 Data" Sheet in the Test Data File			
250	Raw Channel for Reduced Channel No. 212		Channels 250-258 are intermediate processing channels and do not contain useful data.
251	Raw Channel for Reduced Channel No. 213		
252	Raw Channel for Reduced Channel No. 216		
253	Raw Channel for Reduced Channel No. 217		
254	Raw Channel for Reduced Channel No. 218		
255	Raw Channel for Reduced Channel No. 219		
256	Raw Channel for Reduced Channel No. 220		
257	Raw Channel for Reduced Channel No. 221		
258	Event Channel		
259	CO_2 Sector 1, 0.98H (From 212A)	%	Channels 259-282 are generated by
260	CO_2 Sector 2, 0.98H (From 212B)	%	

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
261	CO_2 Sector 3, 0.98H (From 212C)	%	de-multiplexing the gas analysis channels 212-219 to generate individual location gas concentration data values.
262	CO Sector 1, 0.98H (From 213A)	ppm	
263	CO Sector 2, 0.98H (From 213B)	ppm	
264	CO Sector 3, 0.98H (From 213C)	ppm	
265	O_2 Sector 1, 0.98H (From 214A)	%	
266	O_2 Sector 2, 0.98H (From 214B)	%	
267	O_2 Sector 3, 0.98H (From 214C)	%	
268	THC Sector 1, 0.98H (From 215A)	%	
269	THC Sector 2, 0.98H (From 215B)	%	
270	THC Sector 3, 0.98H (From 215C)	%	
271	CO_2 Sector 1, 0.70H (From 216A)	%	
272	CO_2 Sector 2, 0.70H (From 216B)	%	
273	CO_2 Sector 3, 0.70H (From 216C)	%	
274	CO Sector 1, 0.70H (From 217A)	ppm	
275	CO Sector 2, 0.70H (From 217B)	ppm	
276	CO Sector 3, 0.70H (From 217C)	ppm	
277	CO_2 Sector 1, 0.30H (From 218A)	%	
278	CO_2 Sector 2, 0.30H (From 218B)	%	
279	CO_2 Sector 3, 0.30H (From 218C)	%	
280	CO Sector 1, 0.30H (From 219A)	ppm	
281	CO Sector 2, 0.30H (From 219B)	ppm	
282	CO Sector 3, 0.30H (From 219C)	ppm	
283	Speed, Sector 1, 0.98H	m/s	Channels 283-306 are generated by processing of the bi-directional flow probes on Channels 180-197. A pair of (x-y) bi-direction probes is processed to estimate the total bulk fluid velocity and direction of flow per FMRC methods of analysis.
284	Direction, Sector 1, 0.98H (Horizontal)	Deg	
285	Speed, Sector 1, 0.70H	m/s	
286	Direction, Sector 1, 0.70H (Horizontal)	Deg	
287	Direction, Sector 1, 0.70H (Vertical)	sense	
288	Speed, Sector 1, 0.30H	m/s	
289	Direction, Sector 1, 0.30H (Horizontal)	Deg	
290	Direction, Sector 1, 0.30H (Vertical)	sense	
291	Speed, Sector 2, 0.98H	m/s	
292	Direction, Sector 2, 0.98H (Horizontal)	Deg	
293	Speed, Sector 2, 0.70H	m/s	
294	Direction, Sector 2, 0.70H (Horizontal)	Deg	
295	Direction, Sector 2, 0.70H (Vertical)	sense	
296	Speed, Sector 2, 0.30H	m/s	
297	Direction, Sector 2, 0.30H (Horizontal)	Deg	
298	Direction, Sector 2, 0.30H (Vertical)	sense	
299	Speed, Sector 1, 0.98H	m/s	

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
300	Direction, Sector 3, 0.98H (Horizontal)	Deg	
301	Speed, Sector 3, 0.70H	m/s	
302	Direction, Sector 3, 0.70H (Horizontal)	Deg	
303	Direction, Sector 3, 0.70H (Vertical)	sense	
304	Speed, Sector 3, 0.30H	m/s	
305	Direction, Sector 3, 0.30H (Horizontal)	Deg	
306	Direction, Sector 3, 0.30H (Vertical)	sense	
"Collector Report" Sheet in the Test Data File			
FPC 1	Fire Product Collector (FPC) Thermocouple 1	^{o}C	
FPC 2	FPC Thermocouple 2	^{o}C	
FPC 3	FPC Thermocouple 3	^{o}C	
FPC 4	FPC CO_2	ppm	
FPC 5	FPC CO	ppm	
FPC 6	FPC O_2	ppm	
FPC 7	FPC Total Hydrocarbon	ppm	
FPC 8	FPC Mass Flow	kg/s	
FPC 9	FPC Raw Data Channel		
FPC 10	FPC Raw Data Channel		
FPC 11	FPC Event Channel		
FPC 12	FPC CO_2 Gas Flow	g/s	
FPC 13	FPC CO Gas Flow	g/s	
FPC 14	FPC O_2 Gas Flow	g/s	
FPC 15	FPC THC Gas Flow	g/s	
FPC 16	FPC total heat (Q_T) CO2	kW	
FPC 17	FPC total heat (Q_T) O2	kW	
"Heat Flux Report" Sheet in the Test Data File			
HFR S1,0.98H TG	Heat Flux Report (HFR), Sector 1, 0.98H, True Gas Temperature	^{o}C	Derived from the calorimeters in the sectors
HFR S1,0.98H T1	HFR, Sector 1, 0.98H, Temperature 1	^{o}C	
HFR S1,0.98H T2	HFR, Sector 1, 0.98H, Temperature 2	^{o}C	
HFR S1,0.98H TE	HFR, Sector 1, 0.98H, TE	^{o}C	There is not enough detail in the historical documentation to determine what this channel measured

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
HFR S1,0.98H RHF1	HFR, Sector 1, 0.98H, Radiative Heat Flux 1	kW/m^2	Radiative and convective heat fluxes were calculated from the large and small sphere calorimeters installed in the instrumentation sectors
HFR S1,0.98H CHF1	HFR, Sector 1, 0.98H, Convective Heat Flux 1	kW/m^2	
HFR S1,0.98H RHF2	HFR, Sector 1, 0.98H, Radiative Heat Flux 2	kW/m^2	
HFR S1,0.98H CHF2	HFR, Sector 1, 0.98H, Convective Heat Flux 2	kW/m^2	
HFR S1,0.98H E1	HFR, Sector 1, 0.98H, E1	J/m^2	There is not enough detail in the historical documentation to determine what these channels measured
HFR S1,0.98H E2	HFR, Sector 1, 0.98H, E2	J/m^2	
HFR S1,0.98H VEL	HFR, Sector 1, 0.98H, Bulk Flow Velocity	m/s	
HFR S1,0.98H HF1	HFR, Sector 1, 0.98H,	kW/m^2	Total heat flux 1 (RHF1+CHF1)
HFR S1,0.7H TG	Heat Flux Report (HFR), Sector 1, 0.7H, True Gas Temperature	^oC	Derived from the calorimeters in the sectors
HFR S1,0.7H T1	HFR, Sector 1, 0.7H, Temperature 1	^oC	
HFR S1,0.7H T2	HFR, Sector 1, 0.7H, Temperature 2	^oC	
HFR S1,0.7H TE	HFR, Sector 1, 0.7H, TE	^oC	There is not enough detail in the historical documentation to determine what this channel measured

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
HFR S1,0.7H RHF1	HFR, Sector 1, 0.7H, Radiative Heat Flux 1	kW/m^2	Radiative and convective heat fluxes were calculated from the large and small sphere calorimeters installed in the instrumentation sectors
HFR S1,0.7H CHF1	HFR, Sector 1, 0.7H, Convective Heat Flux 1	kW/m^2	
HFR S1,0.7H RHF2	HFR, Sector 1, 0.7H, Radiative Heat Flux 2	kW/m^2	
HFR S1,0.7H CHF2	HFR, Sector 1, 0.7H, Convective Heat Flux 2	kW/m^2	
HFR S1,0.7H E1	HFR, Sector 1, 0.7H, E1	J/m^2	There is not enough detail in the historical documentation to determine what this channel measured
HFR S1,0.7H E2	HFR, Sector 1, 0.7H, E2	J/m^2	
HFR S1,0.7H VEL	HFR, Sector 1, 0.7H, Bulk Flow Velocity	m/s	
HFR S1,0.7H HF1	HFR, Sector 1, 0.7H,	kW/m^2	Total heat flux 1 (RHF1+CHF1)
HFR S1,0.3H TG	Heat Flux Report (HFR), Sector 1, 0.3H, True Gas Temperature	^{o}C	Derived from the calorimeters in the sectors
HFR S1,0.3H T1	HFR, Sector 1, 0.3H, Temperature 1	^{o}C	
HFR S1,0.3H T2	HFR, Sector 1, 0.3H, Temperature 2	^{o}C	
HFR S1,0.3H TE	HFR, Sector 1, 0.3H, TE	^{o}C	There is not enough detail in the historical documentation to determine what this channel measured

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
HFR S1,0.3H RHF1	HFR, Sector 1, 0.3H, Radiative Heat Flux 1	kW/m^2	Radiative and convective heat fluxes were calculated from the large and small sphere calorimeters installed in the instrumentation sectors
HFR S1,0.3H CHF1	HFR, Sector 1, 0.3H, Convective Heat Flux 1	kW/m^2	
HFR S1,0.3H RHF2	HFR, Sector 1, 0.3H, Radiative Heat Flux 2	kW/m^2	
HFR S1,0.3H CHF2	HFR, Sector 1, 0.3H, Convective Heat Flux 2	kW/m^2	
HFR S1,0.3H E1	HFR, Sector 1, 0.3H, E1	J/m^2	There is not enough detail in the historical documentation to determine what this channel measured
HFR S1,0.3H E2	HFR, Sector 1, 0.3H, E2	J/m^2	
HFR S1,0.3H VEL	HFR, Sector 1, 0.3H, Bulk Flow Velocity	m/s	
HFR S1,0.3H HF1	HFR, Sector 1, 0.3H,	kW/m^2	Total heat flux 1 (RHF1+CHF1)
HFR S2,0.98H TG	Heat Flux Report (HFR), Sector 2, 0.98H, True Gas Temperature	^oC	Derived from the calorimeters in the sectors
HFR S2,0.98H T1	HFR, Sector 2, 0.98H, Temperature 1	^oC	
HFR S2,0.98H T2	HFR, Sector 2, 0.98H, Temperature 2	^oC	
HFR S2,0.98H TE	HFR, Sector 2, 0.98H, TE	^oC	There is not enough detail in the historical documentation to determine what this channel measured

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
HFR S2,0.98H RHF1	HFR, Sector 2, 0.98H, Radiative Heat Flux 1	kW/m^2	Radiative and convective heat fluxes were calculated from the large and small sphere calorimeters installed in the instrumentation sectors
HFR S2,0.98H CHF1	HFR, Sector 2, 0.98H, Convective Heat Flux 1	kW/m^2	
HFR S2,0.98H RHF2	HFR, Sector 2, 0.98H, Radiative Heat Flux 2	kW/m^2	
HFR S2,0.98H CHF2	HFR, Sector 2, 0.98H, Convective Heat Flux 2	kW/m^2	
HFR S2,0.98H E1	HFR, Sector 2, 0.98H, E1	J/m^2	There is not enough detail in the historical documentation to determine what this channel measured
HFR S2,0.98H E2	HFR, Sector 2, 0.98H, E2	J/m^2	
HFR S2,0.98H VEL	HFR, Sector 2, 0.98H, Bulk Flow Velocity	m/s	
HFR S2,0.98H HF1	HFR, Sector 2, 0.98H,	kW/m^2	Total heat flux 1 (RHF1+CHF1)
HFR S2,0.7H TG	Heat Flux Report (HFR), Sector 2, 0.7H, True Gas Temperature	^oC	Derived from the calorimeters in the sectors
HFR S2,0.7H T1	HFR, Sector 2, 0.7H, Temperature 1	^oC	
HFR S2,0.7H T2	HFR, Sector 2, 0.7H, Temperature 2	^oC	
HFR S2,0.7H TE	HFR, Sector 2, 0.7H, TE	^oC	There is not enough detail in the historical documentation to determine what this channel measured

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
HFR S2,0.7H RHF1	HFR, Sector 2, 0.7H, Radiative Heat Flux 1	kW/m^2	Radiative and convective heat fluxes were calculated from the large and small sphere calorimeters installed in the instrumentation sectors
HFR S2,0.7H CHF1	HFR, Sector 2, 0.7H, Convective Heat Flux 1	kW/m^2	
HFR S2,0.7H RHF2	HFR, Sector 2, 0.7H, Radiative Heat Flux 2	kW/m^2	
HFR S2,0.7H CHF2	HFR, Sector 2, 0.7H, Convective Heat Flux 2	kW/m^2	
HFR S2,0.7H E1	HFR, Sector 2, 0.7H, E1	J/m^2	There is not enough detail in the historical documentation to determine what this channel measured
HFR S2,0.7H E2	HFR, Sector 2, 0.7H, E2	J/m^2	
HFR S2,0.7H VEL	HFR, Sector 2, 0.7H, Bulk Flow Velocity	m/s	
HFR S2,0.7H HF1	HFR, Sector 2, 0.7H,	kW/m^2	Total heat flux 1 (RHF1+CHF1)
HFR S2,0.3H TG	Heat Flux Report (HFR), Sector 2, 0.3H, True Gas Temperature	^oC	Derived from the calorimeters in the sectors
HFR S2,0.3H T1	HFR, Sector 2, 0.3H, Temperature 1	^oC	
HFR S2,0.3H T2	HFR, Sector 2, 0.3H, Temperature 2	^oC	
HFR S2,0.3H TE	HFR, Sector 2, 0.3H, TE	^oC	There is not enough detail in the historical documentation to determine what this channel measured

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
HFR S2,0.3H RHF1	HFR, Sector 2, 0.3H, Radiative Heat Flux 1	kW/m^2	Radiative and convective heat fluxes were calculated from the large and small sphere calorimeters installed in the instrumentation sectors
HFR S2,0.3H CHF1	HFR, Sector 2, 0.3H, Convective Heat Flux 1	kW/m^2	
HFR S2,0.3H RHF2	HFR, Sector 2, 0.3H, Radiative Heat Flux 2	kW/m^2	
HFR S2,0.3H CHF2	HFR, Sector 2, 0.3H, Convective Heat Flux 2	kW/m^2	
HFR S2,0.3H E1	HFR, Sector 2, 0.3H, E1	J/m^2	There is not enough detail in the historical documentation to determine what this channel measured
HFR S2,0.3H E2	HFR, Sector 2, 0.3H, E2	J/m^2	
HFR S2,0.3H VEL	HFR, Sector 2, 0.3H, Bulk Flow Velocity	m/s	
HFR S2,0.3H HF1	HFR, Sector 2, 0.3H,	kW/m^2	Total heat flux 1 (RHF1+CHF1)
HFR S3,0.98H TG	Heat Flux Report (HFR), Sector 3, 0.98H, True Gas Temperature	^{o}C	Derived from the calorimeters in the sectors
HFR S3,0.98H T1	HFR, Sector 3, 0.98H, Temperature 1	^{o}C	
HFR S3,0.98H T2	HFR, Sector 3, 0.98H, Temperature 2	^{o}C	
HFR S3,0.98H TE	HFR, Sector 3, 0.98H, TE	^{o}C	There is not enough detail in the historical documentation to determine what this channel measured

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
HFR S3,0.98H RHF1	HFR, Sector 3, 0.98H, Radiative Heat Flux 1	kW/m^2	Radiative and convective heat fluxes were calculated from the large and small sphere calorimeters installed in the instrumentation sectors
HFR S3,0.98H CHF1	HFR, Sector 3, 0.98H, Convective Heat Flux 1	kW/m^2	
HFR S3,0.98H RHF2	HFR, Sector 3, 0.98H, Radiative Heat Flux 2	kW/m^2	
HFR S3,0.98H CHF2	HFR, Sector 3, 0.98H, Convective Heat Flux 2	kW/m^2	
HFR S3,0.98H E1	HFR, Sector 3, 0.98H, E1	J/m^2	There is not enough detail in the historical documentation to determine what this channel measured
HFR S3,0.98H E2	HFR, Sector 3, 0.98H, E2	J/m^2	
HFR S3,0.98H VEL	HFR, Sector 3, 0.98H, Bulk Flow Velocity	m/s	
HFR S3,0.98H HF1	HFR, Sector 3, 0.98H,	kW/m^2	Total heat flux 1 (RHF1+CHF1)
HFR S3,0.7H TG	Heat Flux Report (HFR), Sector 3, 0.7H, True Gas Temperature	^oC	Derived from the calorimeters in the sectors
HFR S3,0.7H T1	HFR, Sector 3, 0.7H, Temperature 1	^oC	
HFR S3,0.7H T2	HFR, Sector 3, 0.7H, Temperature 2	^oC	
HFR S3,0.7H TE	HFR, Sector 3, 0.7H, TE	^oC	There is not enough detail in the historical documentation to determine what this channel measured

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
HFR S3,0.7H RHF1	HFR, Sector 3, 0.7H, Radiative Heat Flux 1	kW/m^2	Radiative and convective heat fluxes were calculated from the large and small sphere calorimeters installed in the instrumentation sectors
HFR S3,0.7H CHF1	HFR, Sector 3, 0.7H, Convective Heat Flux 1	kW/m^2	
HFR S3,0.7H RHF2	HFR, Sector 3, 0.7H, Radiative Heat Flux 2	kW/m^2	
HFR S3,0.7H CHF2	HFR, Sector 3, 0.7H, Convective Heat Flux 2	kW/m^2	
HFR S3,0.7H E1	HFR, Sector 3, 0.7H, E1	J/m^2	There is not enough detail in historical documentation to determine what this channel measured
HFR S3,0.7H E2	HFR, Sector 3, 0.7H, E2	J/m^2	
HFR S3,0.7H VEL	HFR, Sector 3, 0.7H, Bulk Flow Velocity	m/s	
HFR S3,0.7H HF1	HFR, Sector 3, 0.7H,	kW/m^2	Total heat flux 1 (RHF1+CHF1)
HFR S3,0.3H TG	Heat Flux Report (HFR), Sector 3, 0.3H, True Gas Temperature	^{o}C	Derived from the calorimeters in the sectors
HFR S3,0.3H T1	HFR, Sector 3, 0.3H, Temperature 1	^{o}C	
HFR S3,0.3H T2	HFR, Sector 3, 0.3H, Temperature 2	^{o}C	
HFR S3,0.3H TE	HFR, Sector 3, 0.3H, TE	^{o}C	There is not enough detail in the historical documentation to determine what this channel measured

Table A-1: Test Data Channel Map

Channel No.	Description	Units	Comments
HFR S3,0.3H RHF1	HFR, Sector 3, 0.3H, Radiative Heat Flux 1	kW/m^2	Radiative and convective heat fluxes were calculated from the large and small sphere calorimeters installed in the instrumentation sectors
HFR S3,0.3H CHF1	HFR, Sector 3, 0.3H, Convective Heat Flux 1	kW/m^2	
HFR S3,0.3H RHF2	HFR, Sector 3, 0.3H, Radiative Heat Flux 2	kW/m^2	
HFR S3,0.3H CHF2	HFR, Sector 3, 0.3H, Convective Heat Flux 2	kW/m^2	
HFR S3,0.3H E1	HFR, Sector 3, 0.3H, E1	J/m^2	There is not enough detail in the historical documentation to determine what this channel measured
HFR S3,0.3H E2	HFR, Sector 3, 0.3H, E2	J/m^2	
HFR S3,0.3H VEL	HFR, Sector 3, 0.3H, Bulk Flow Velocity	m/s	
HFR S3,0.3H HF1	HFR, Sector 3, 0.3H,	kW/m^2	Total heat flux 1 (RHF1+CHF1)

APPENDIX B: EXAMPLE OF DATA AVAILABLE ON THE CD: TEST 1 DATA

The purpose of this appendix is to provide an example of the data available in the Microsoft Excel spreadsheet files. These files are located on the data CD under the "SNL FM Baseline Validation Test Data Excel" folder. As discussed in the main body, Tests 1 through 18 were conducted in the empty main control room (MCR) test enclosure. The data collected in these tests is the same and the Microsoft Excel spreadsheet files were organized using the same format.

The tables, plots, and graphs in this appendix are applicable to Test 1 and are also found in the Test 1 Microsoft Excel spreadsheet.

Note: If there is no data shown in the data plots, read Appendix A or the Test Summary of Issues Table to verify that there were no issues. Data for all channels was reported even if the channel was not used (e.g., Tests 1-18, which were conducted in the empty MCR test enclosure, reported the cabinet sensor channels).

B.1 Test Summary Sheet

The first sheet in the data file titled "Test Summary," is a summary of the test parameters and issues encountered. This sheet includes the two tables below: Table B-1 on test parameters and Table B-2 on summary of issues encountered during testing.

Table B-1: Test 1 Summary

Test Number:	1
Fuel Type:	Propylene Burners
Nominal Peak Fire Intensity:	516 kW
Fire Location:	Room Center (1)
Nominal Enclosure Ventilation Rate:	10ch/hr (8,000 cfm)
Burner Fire Mode:	Steady State Mode

Table B-2: Summary of Issues Encountered during Testing

Issues	Impacted Tests	Issue Description
Test Specific Issues	1 & 2	Note that Tests 1 & 2 are virtually identical in setup. The only significant difference is slightly higher ventilation in **Test 1 (about 12.5 ACH)** as compared to **Test 2 (about 10 ACH).**
Common Issues during Testing	4, 6, 7, 8, 14, 15, 16, 18, 19, 20, 21, 22, 23, 24, 25 (the rest of the tests appear unaffected)	General Reliability of Exhaust Gas Venting Rate Data: The data stream for the outlet flow rate **(channel 199) is obviously in error.** In these tests, the outlet ventilation rate was recorded for a limited time under severe fire conditions (when there was a high rate of volumetric expansion active). The inlet ventilation rates are considered more reliable and less susceptible to error than the outlet ventilation rate. This is because the nominal ventilation rate was verified during the pre-ignition stage using an independent instrument (indication only).
	All 25 tests	Nominal Ventilation Rates: The nominal ventilation rate of the test enclosure during each test is identified and ranged from 1 to 10 air changes per hour (ACH). However, these values are only the nominal ventilation rates and should be viewed as rough estimates only. **The difference between nominal and actual ventilation rates appears to be as high as 20% based on the tests examined to date.** The actual ventilation rate in each test was measured and is reported.
	All 25 tests	Leakage: There was a considerable amount of air leakage from the test enclosure (bypassing the exhaust duct). **It would appear that the typical outlet flow was only about 70-80% of the inlet flow implying significant leakage.** During testing, leakage did occur, particularly, around the double doors' (closed during testing) edges, corners of the room where the walls met, at the wall-to-floor interface, and along the wall-to-ceiling interface. In some cases, leakage occurred around the edges of the inlet ventilation duct penetrations through the ceiling. For this reason, the reported inlet ventilation rate is considered a more reliable indication of the actual enclosure ventilation rates than is the reported outlet ventilation rate. If an estimate of the total outflow rate is needed, it is recommended that a full mass balance on the room be performed.
	All 25 tests	Fire Products Collector: - The enclosure exhaust gas represents only a very small fraction of the total flow through the fire products collector. **The exhaust gas stream was diluted significantly by air drawn into the collector from the general enclosure.** The actual gas concentration values, smoke density, and temperature all represent a mixture of ambient and enclosure gas streams. **- Due mostly to the very large volume of the test enclosure, there is a significant lag time between the fire behavior within the room and sensing of the associated effects at the fire products collector.**

Table B-2: Summary of Issues Encountered during Testing

Issues	Impacted Tests	Issue Description
	All 25 tests	Enclosure Surface Heat Flux Data: **Data from all of the surface heat flux probes as documented in the original data reports is in error.** It would appear that this was a problem that occurred when the raw test data was converted to engineering units. It may be possible to recover the lost data from the original raw data files. All of the enclosure surface heat flux data should be considered unreliable. Note that this does not impact the surface temperature response data.
General Comments	All 25 tests	Wall Properties: The walls and ceiling of the test enclosure were constructed of 2.54 cm (1 inch) thick Marinite panels. Marinite is a calcium-silicate mineral board material manufactured by Manville. The manufacturer reports a nominal density of 737 kg/m^3, and reports nominal material properties for thermal conductivity and specific heat are functions of temperature as documented in the table in the “Wall Properties” Sheet. However, when attempts were made to model the wall temperature response, the results of the analysis using the nominal material properties were less than satisfactory. A one-dimensional finite difference model was implemented by Sandia National Laboratories (SNL). The internal surface was modeled as a known temperature boundary condition driven by the measured test data. The outer surface was modeled as insulated (no heat loss). The results were validated by comparison of the predicted and measured outside surface temperatures for several locations with matched inner/outer surface temperature data pairs. Use of the nominal material properties resulted in outside surface temperature response predictions that were uniformly and substantially lower than the measured response. Nominally, this would be indicative of a thermal conductivity higher than reported by the manufacturer. SNL found that the manufacturer cited a range of material density values of 700 to 1,000 kg/m^3 in the associated Material Safety Data Sheet (MSDS). The original 737 kg/m^3 was found to be a nominal value reported in manufacturer sales literature. In general, the specific heat of a material is largely unaffected by density being a mass-related property. Hence, SNL assumed that the nominal specific heat values remained valid. Using the curve fit, a value of 1.16 kJ/kg*K was assumed as a nominal room-temperature specific heat value. To explore the impact of material properties, SNL assumed that the panels used in construction were at the upper end of the manufacturer’s density range (1,000 kg/m^3 was assumed). In the transient thermal model the thermal parameter of interest is actually the thermal diffusivity. This

Table B-2: Summary of Issues Encountered during Testing

Issues	Impacted Tests	Issue Description
		parameter was adjusted to obtain the best possible fit between predictions and data for a number of locations in several tests. The best results were obtained assuming a thermal diffusivity of 2.0×10^{-7} m^2/s. These results were quite good with the predictions and data matching quite well over a range of test conditions and locations. Assuming the above stated specific heat and density values, this implies a thermal conductivity of approximately 0.23 W/m*K. The floor of the test enclosure was the concrete floor slab of the FMRC test facility. SNL has no specific information regarding the thermal properties of the floor.

B.2 Wall Properties Sheet

The second sheet in the data file entitled "Wall Properties," contains a summary of the wall properties. This sheet includes the two tables shown below: Table B-3 on manufacturer reported nominal marinate material properties and Table B-4 on SNL's recommendation on test enclosure walls and ceiling properties.

Table B-3: Nominal Marinite Material Properties as Reported by the Manufacturer, and SNL Curve Fits Assuming Linear Behavior with Temperature

	Thermal Conductivity			Specific Heat	
	Temp (K)	k (W/m*K)		Temp (K)	C_p (J/kg*K)
	450	0.117		366	1172
	477	0.118		477	1255
	533	0.121		589	1339
	589	0.125		700	1423
	645	0.13			
	700	0.136			
SNL Fits:	$k=0.0819+(7.525E-5)*T_k$			$C_p=897+(0.751)*T_k$	

Table B-4: SNL's Recommendation that for the Analysis of the Test Enclosure Walls and Ceiling, the Following Material Properties Be Assumed:

Property	Value
Thickness	2.54 cm (1 inch)
Thermal Conductivity	0.23 W/m*K
Specific Heat	1.16 kJ/kg*K
Density	1,000 kg/m^3
Thermal Diffusivity	2.0×10^{-7} m^2/s
The floor of the test enclosure was the concrete floor slab of the FMRC test facility. SNL has no specific information	

B.3 1-179 TC Data Sheet

The third sheet in the data file entitled “1-179 TC Data,” contains the temperature data, channels #1-179. This section contains all the data plots on this sheet. Appendix A contains details on each data channel.

Note that this test has no cabinets. Any sensors related to cabinets will have no data.

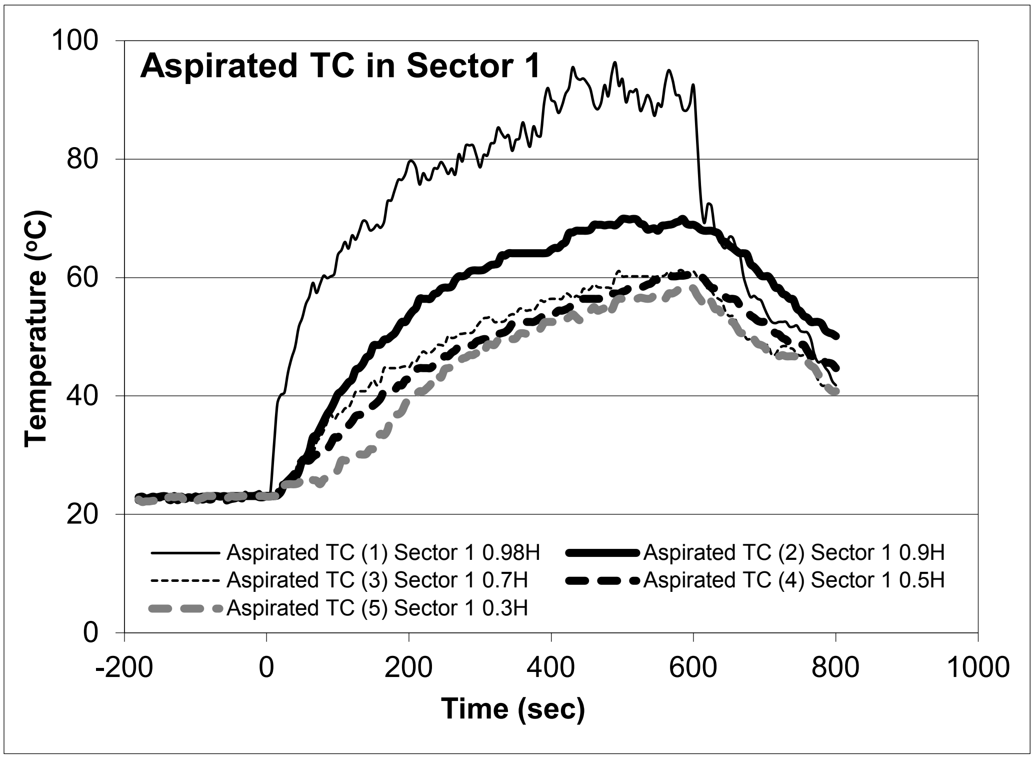

Figure B-1: Test 1 Plots of Thermocouple 1 to 5

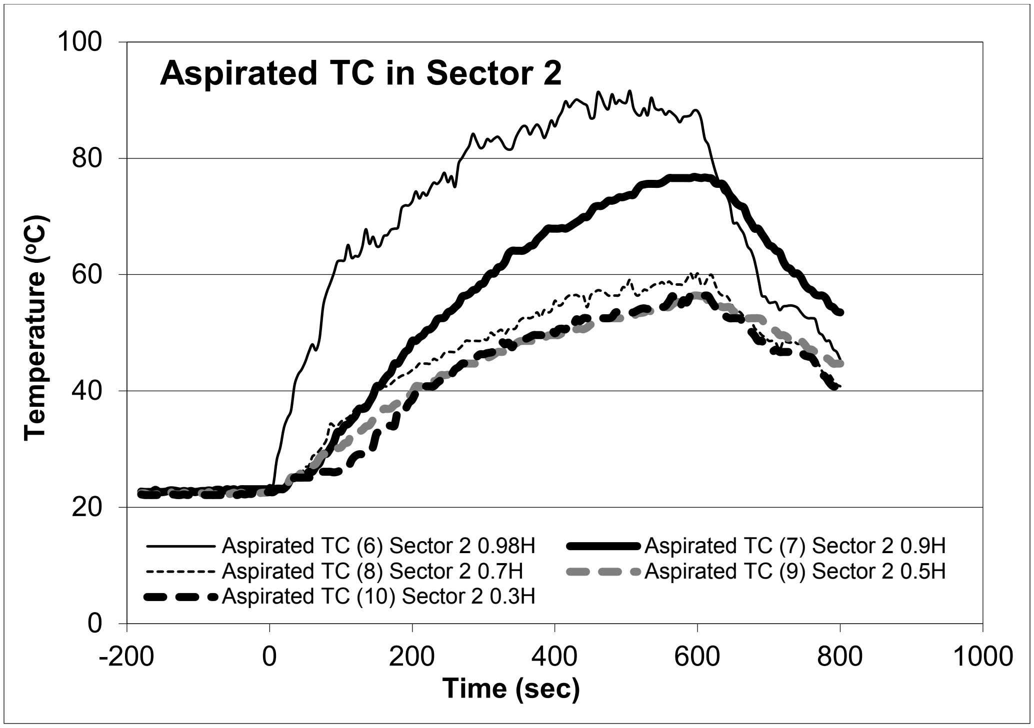

Figure B-2: Test 1 Plots of Thermocouples 6 to 10

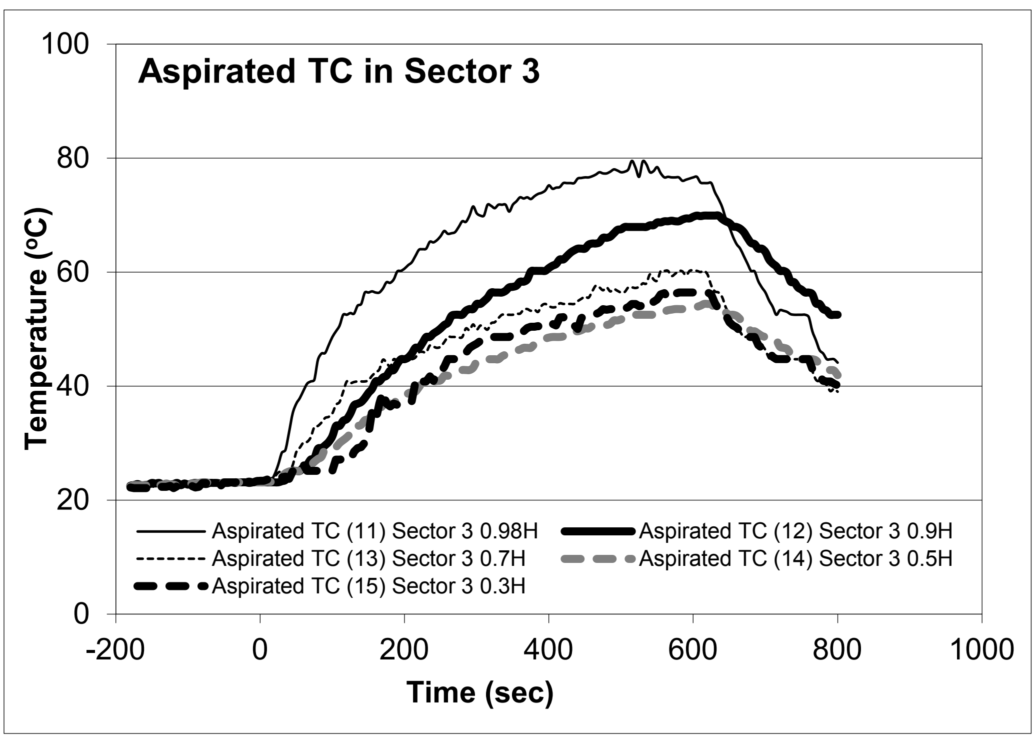

Figure B-3: Test 1 Plots of Thermocouples 11 to 15

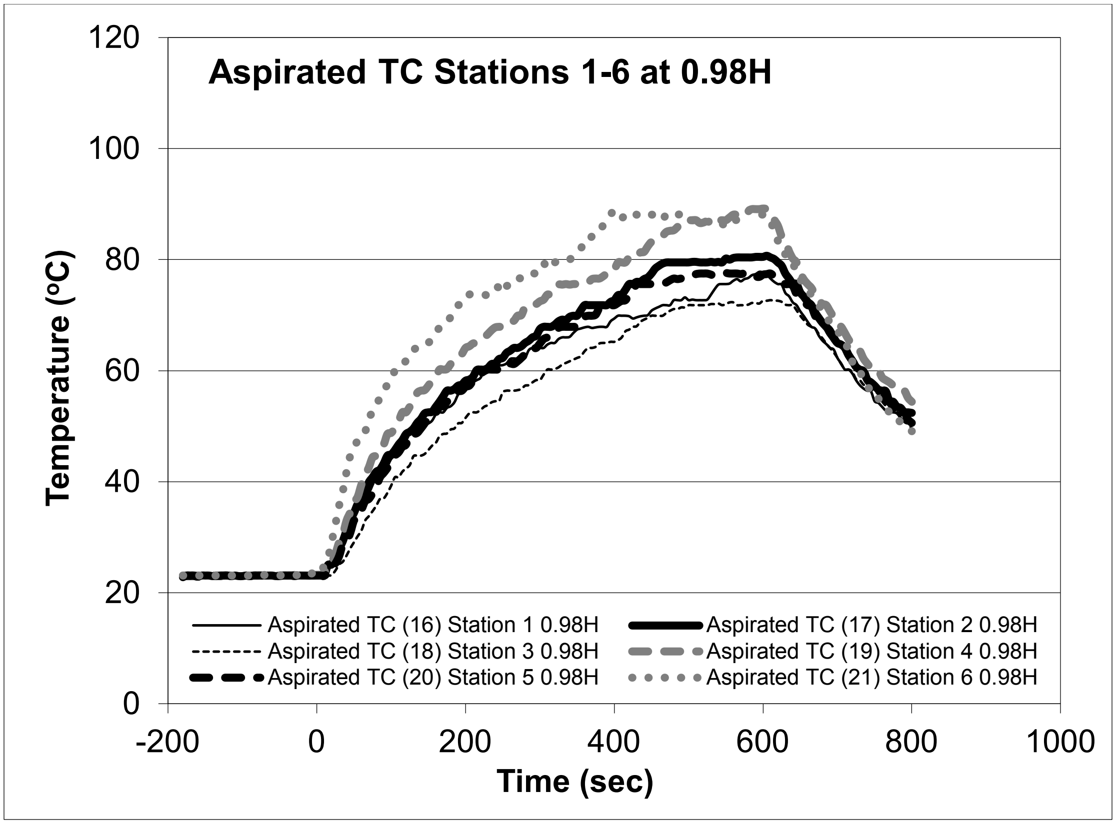

Figure B-4: Test 1 Plots of Thermocouples 16 to 21

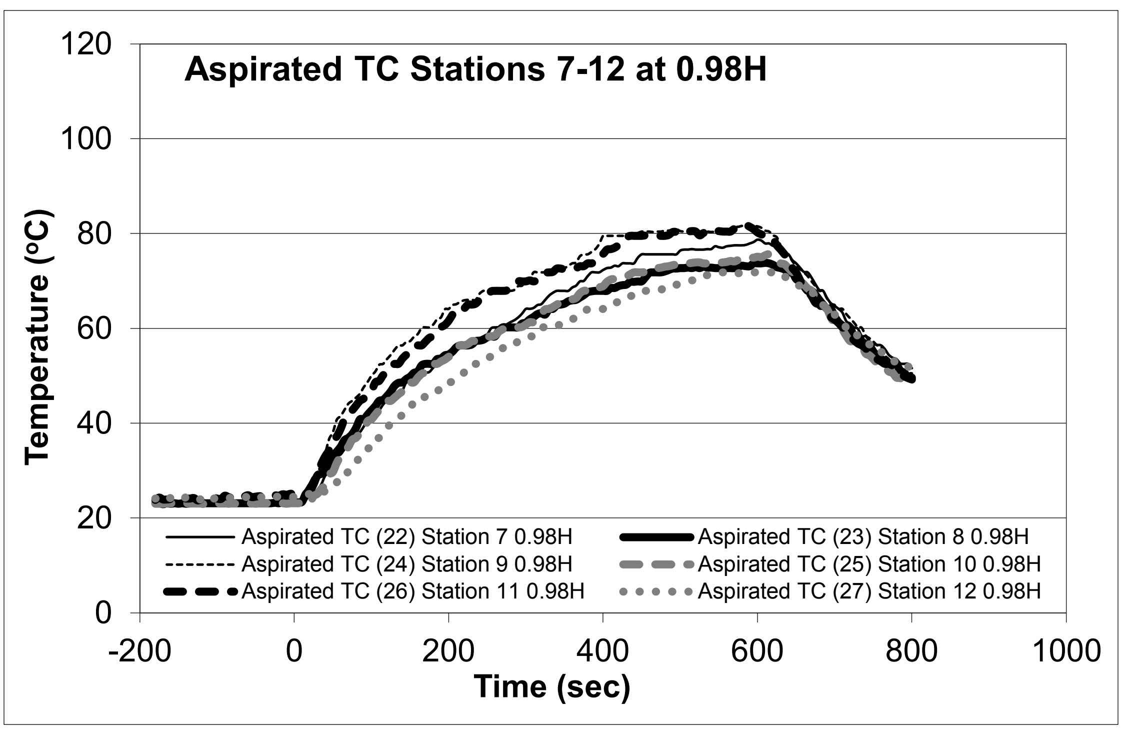

Figure B-5: Test 1 Plots of Thermocouples 22 to 27

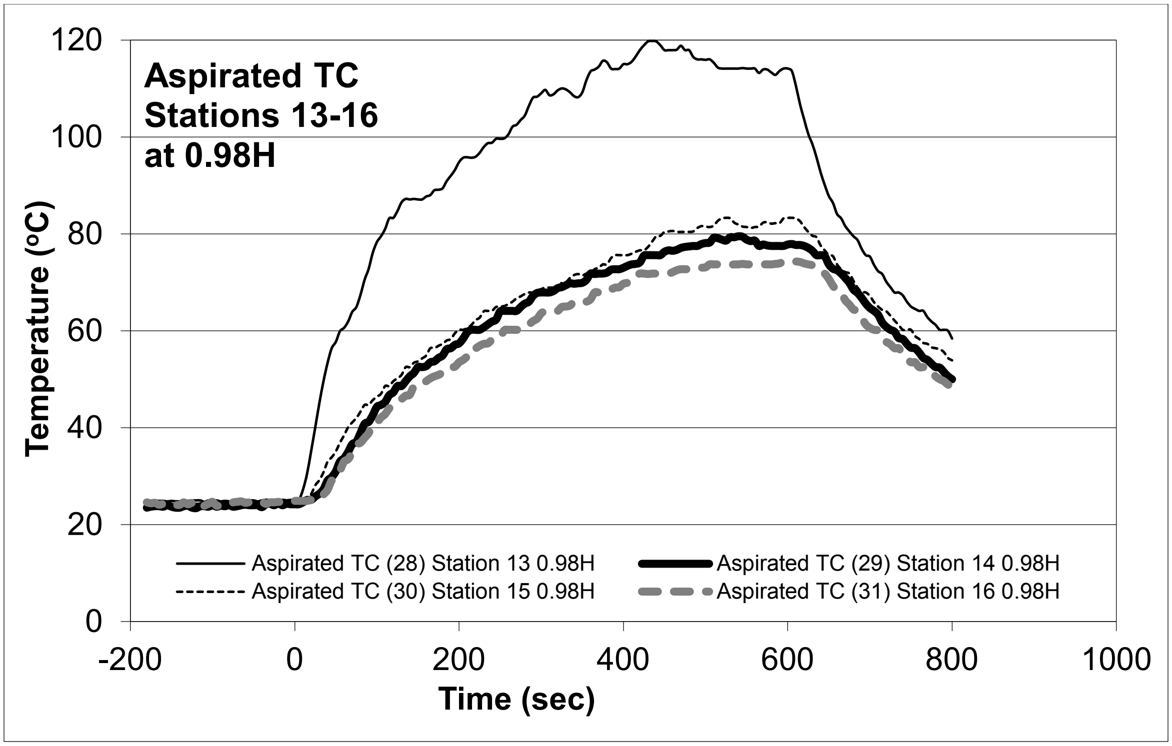

Figure B-6: Test 1 Plots of Thermocouples 28 to 31

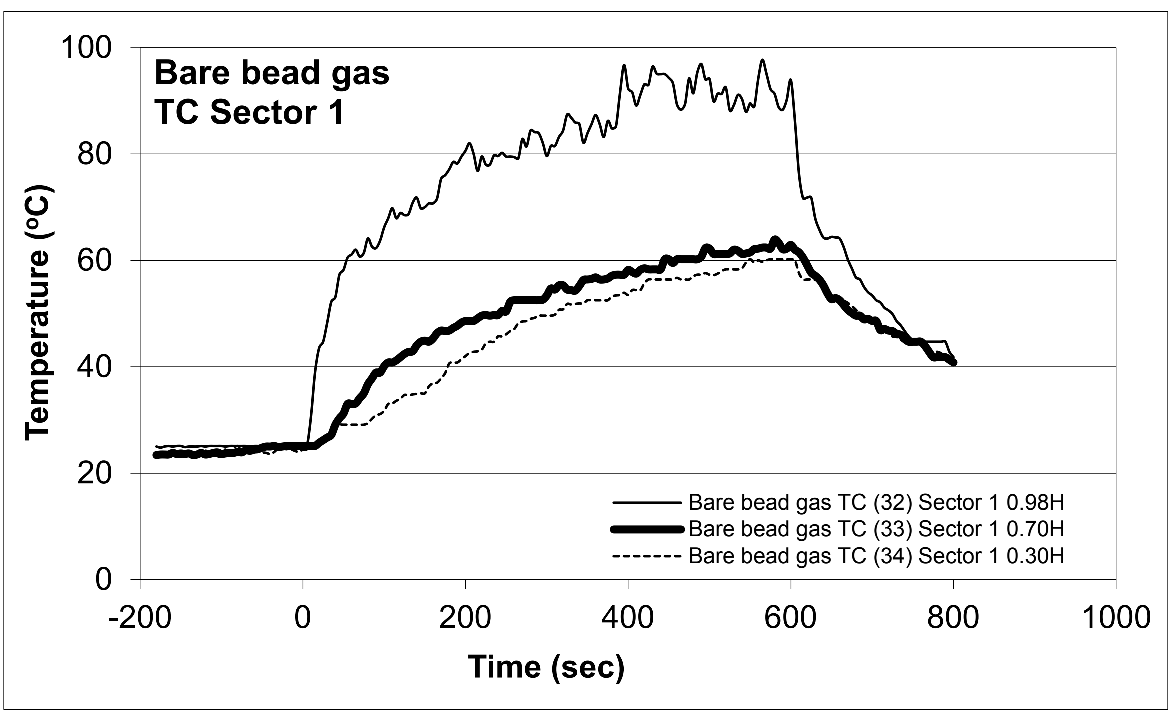

Figure B-7: Test 1 Plots of Thermocouples 32 to 34

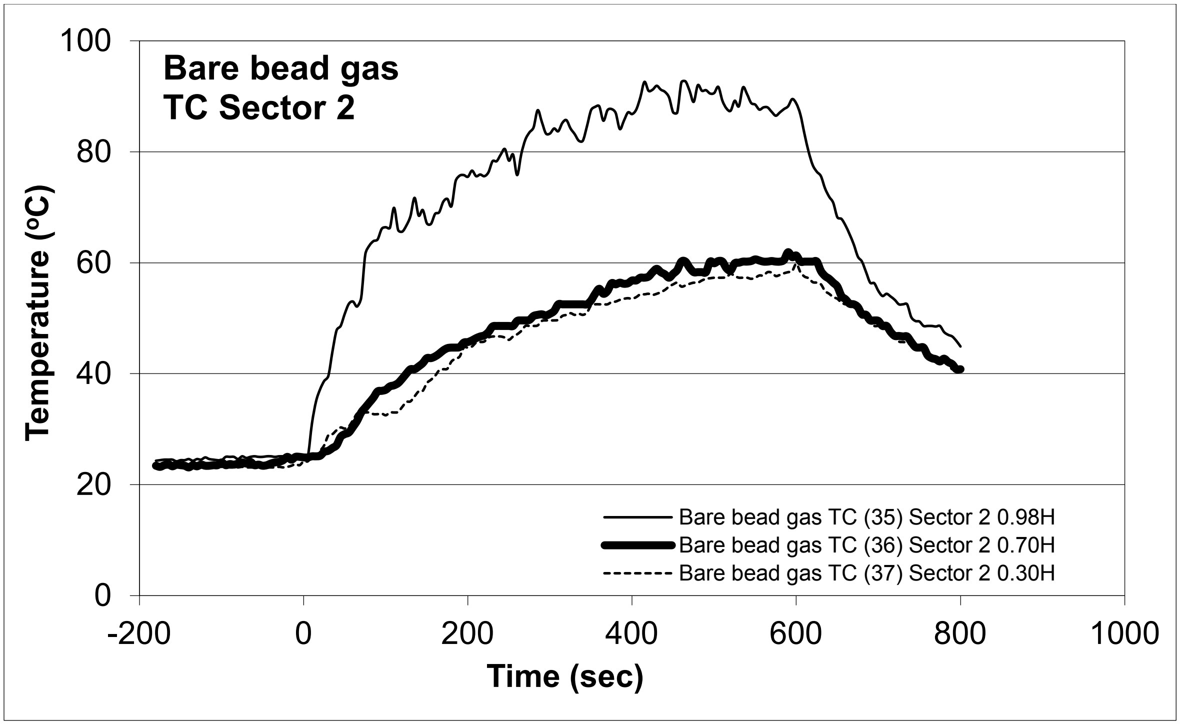

Figure B-8: Test 1 Plots of Thermocouples 35 to 37

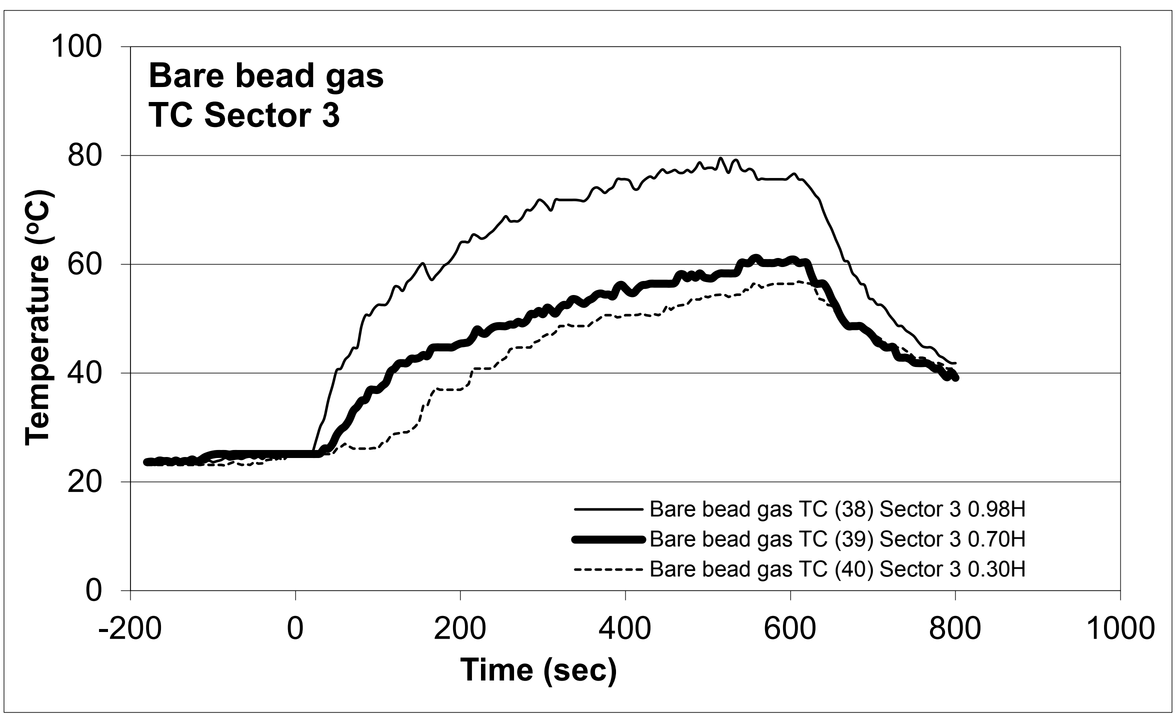

Figure B-9: Test 1 Plots of Thermocouples 38 to 40

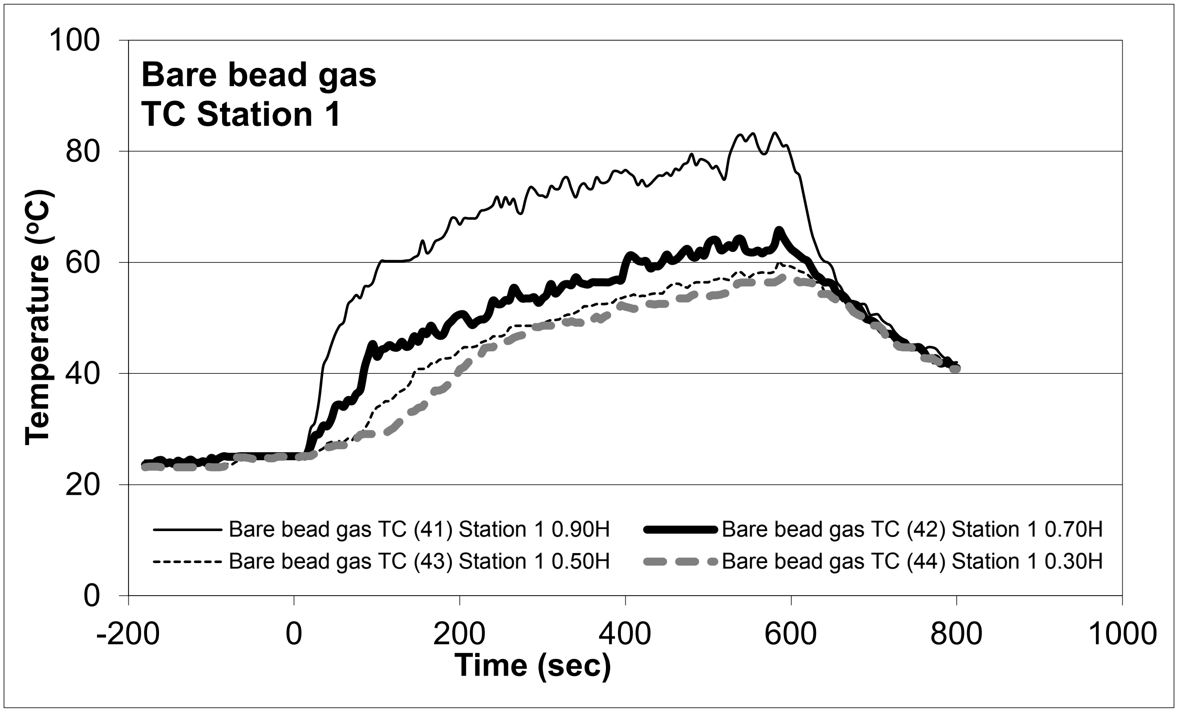

Figure B-10: Test 1 Plots of Thermocouples 41 to 44

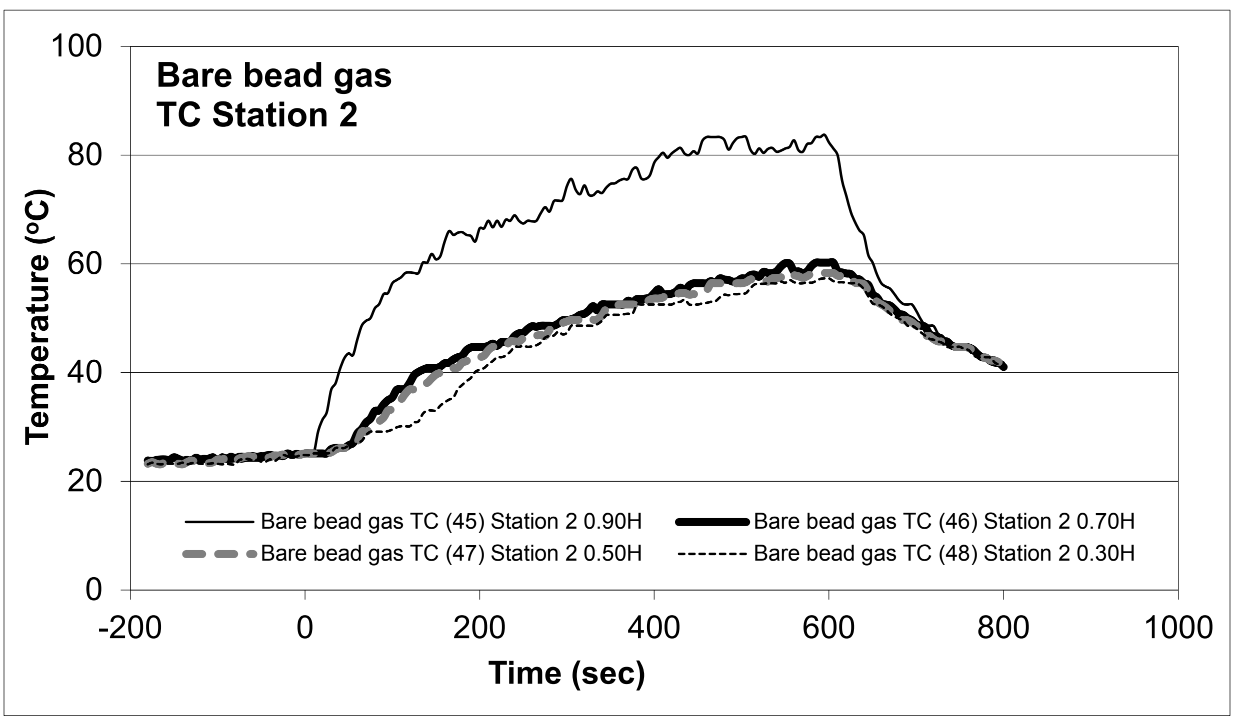

Figure B-11: Test 1 Plots of Thermocouples 45 to 48

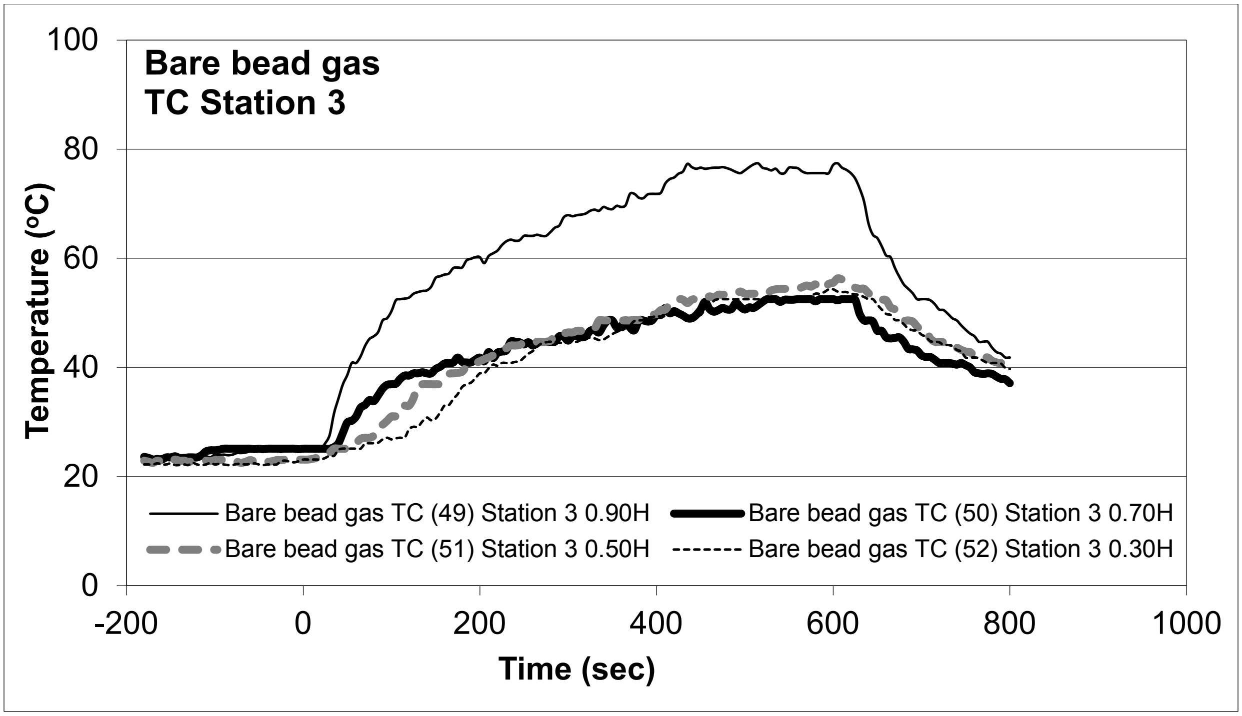

Figure B-12: Test 1 Plots of Thermocouples 49 to 52

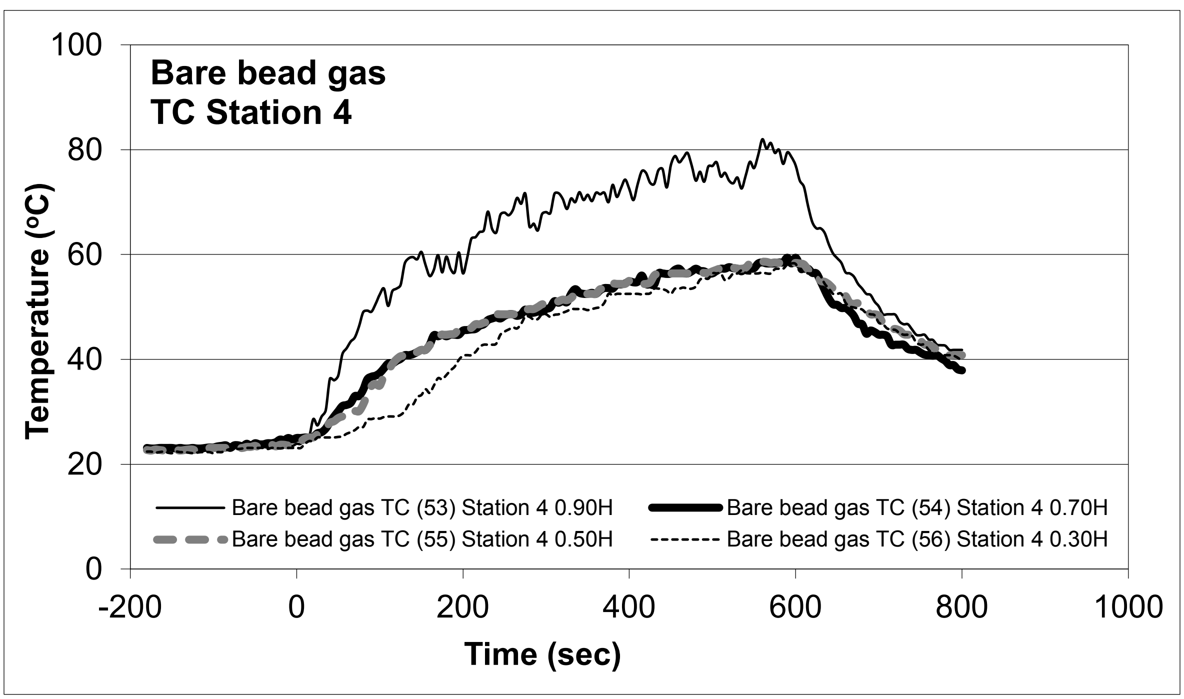

Figure B-13: Test 1 Plots of Thermocouples 53 to 56

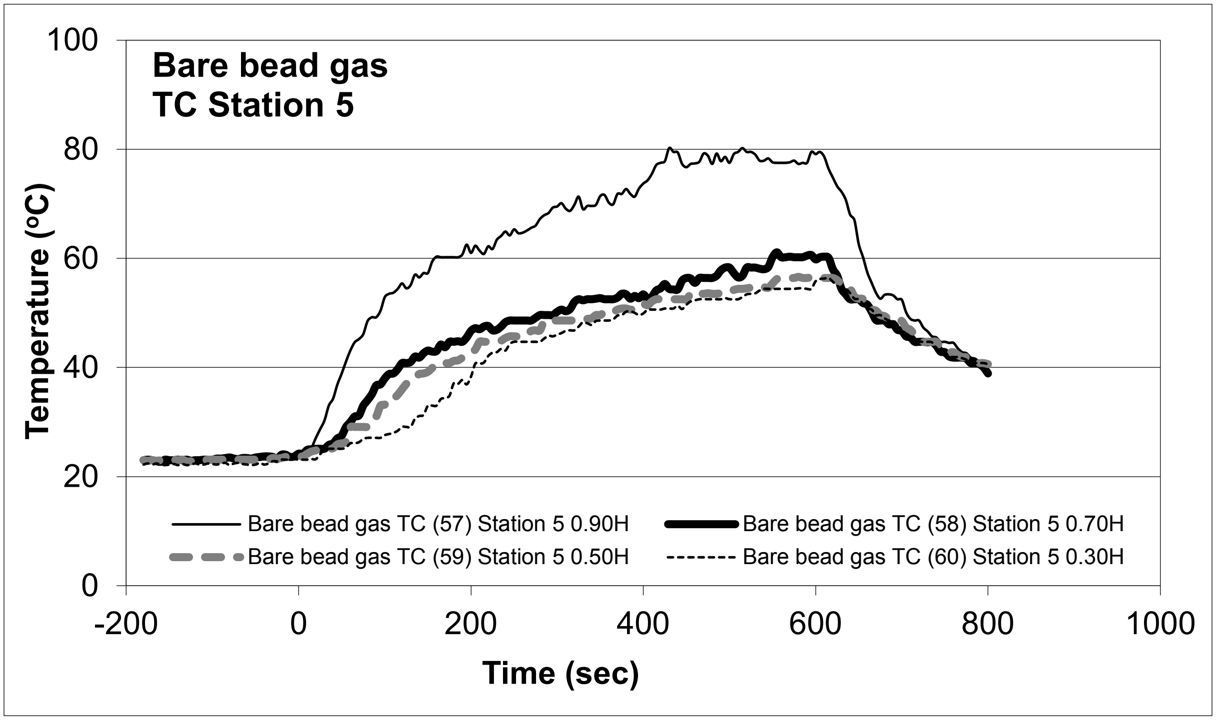

Figure B-14: Test 1 Plots of Thermocouples 57 to 60

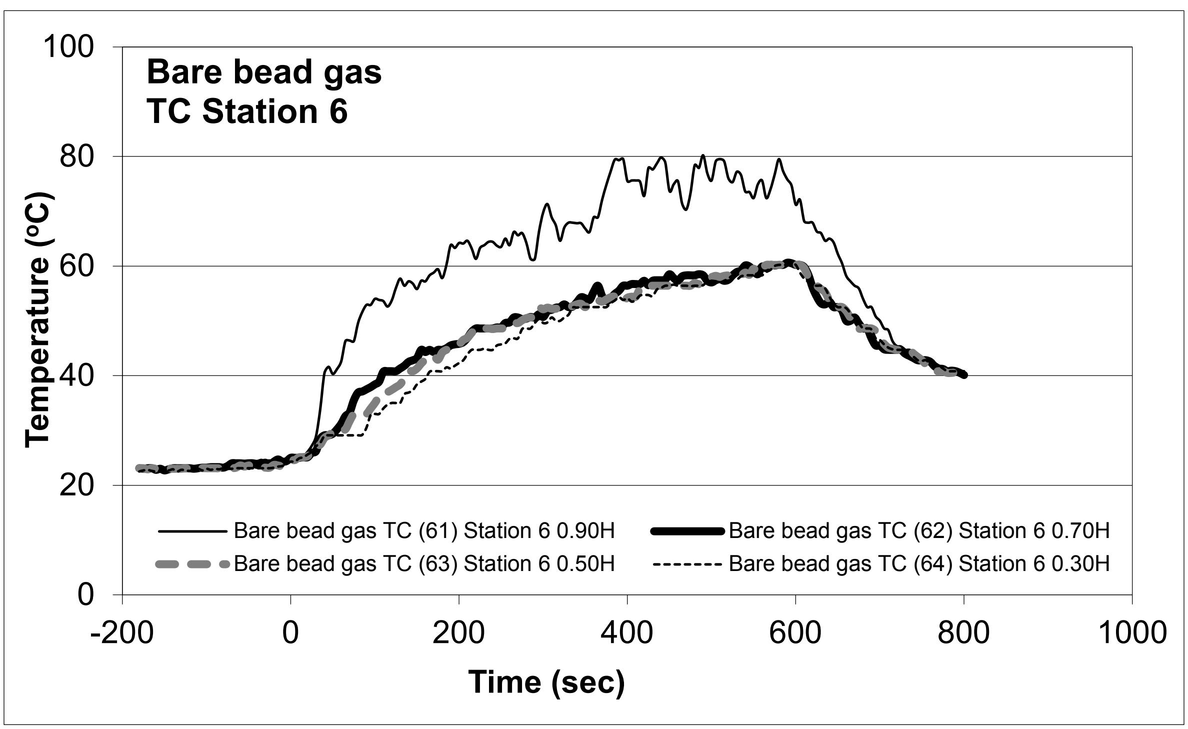

Figure B-15: Test 1 Plots of Thermocouples 61 to 64

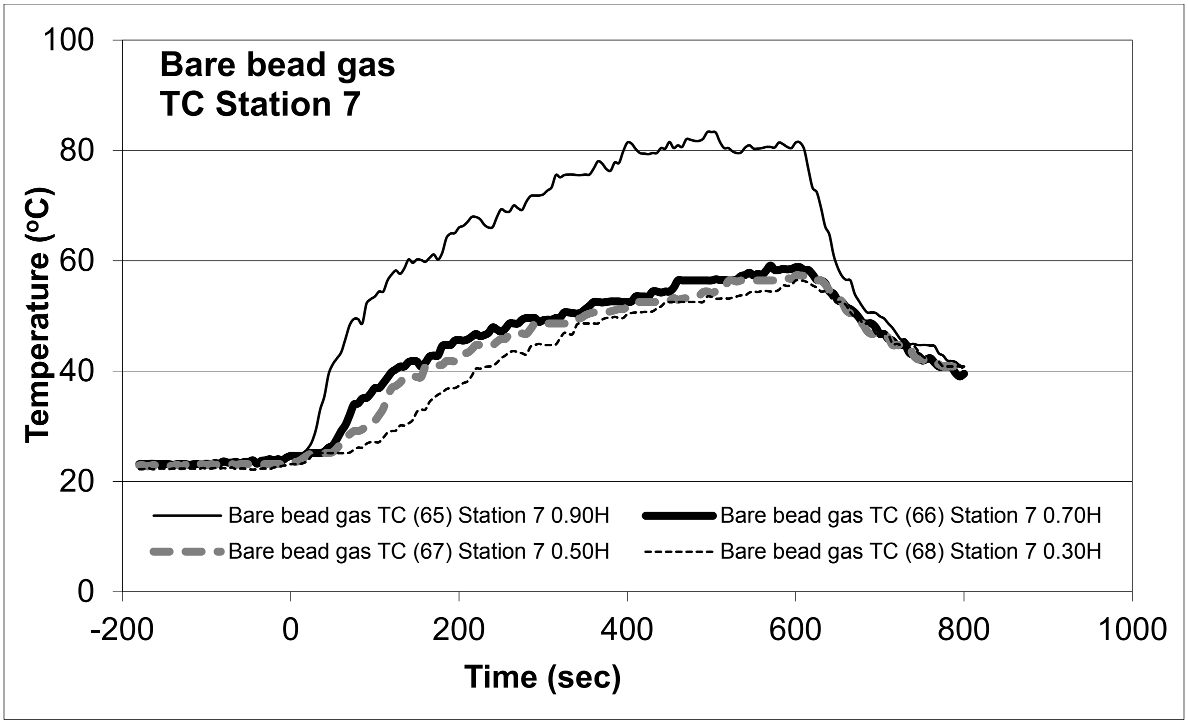

Figure B-16: Test 1 Plots of Thermocouples 65 to 68

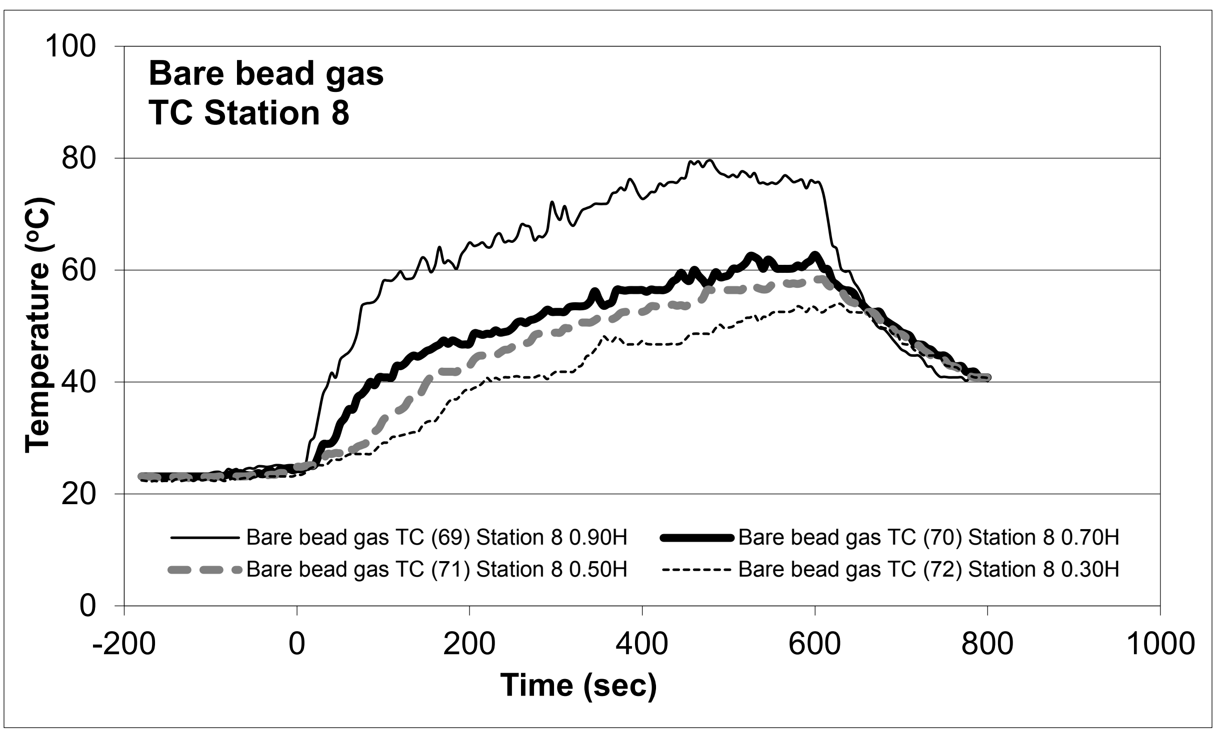

Figure B-17: Test 1 Plots of Thermocouples 69 to 72

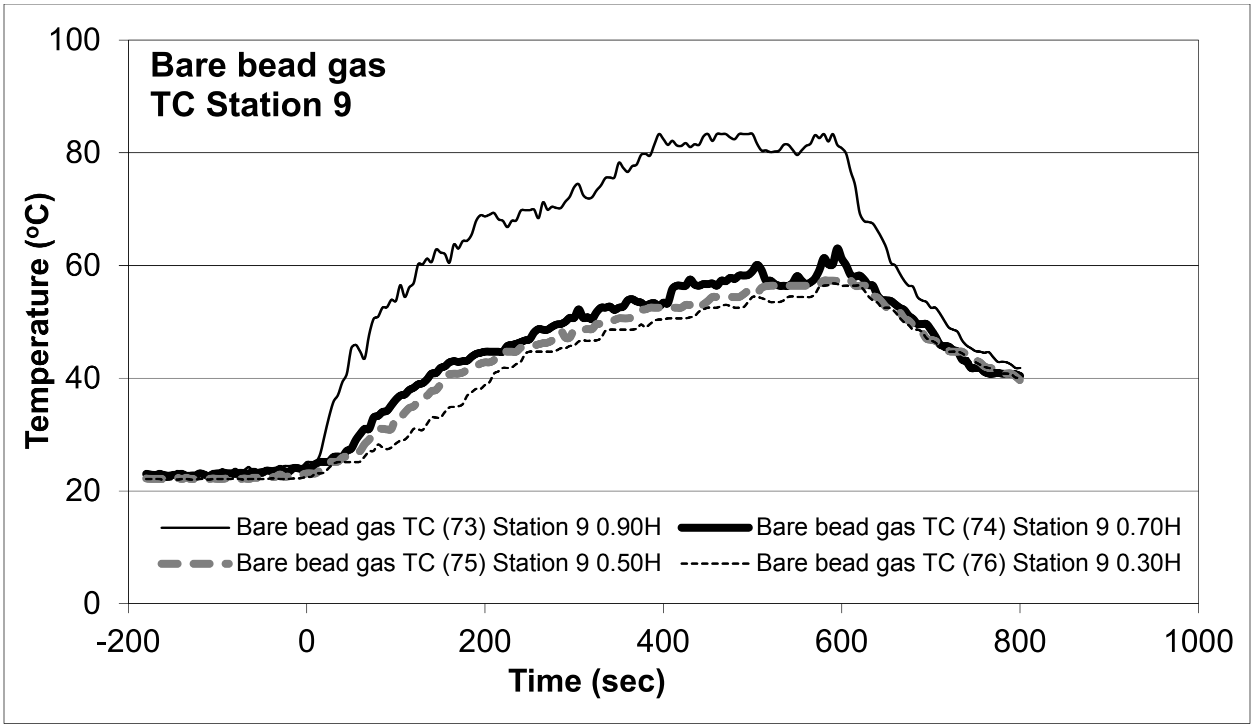

Figure B-18: Test 1 Plots of Thermocouples 73 to 76

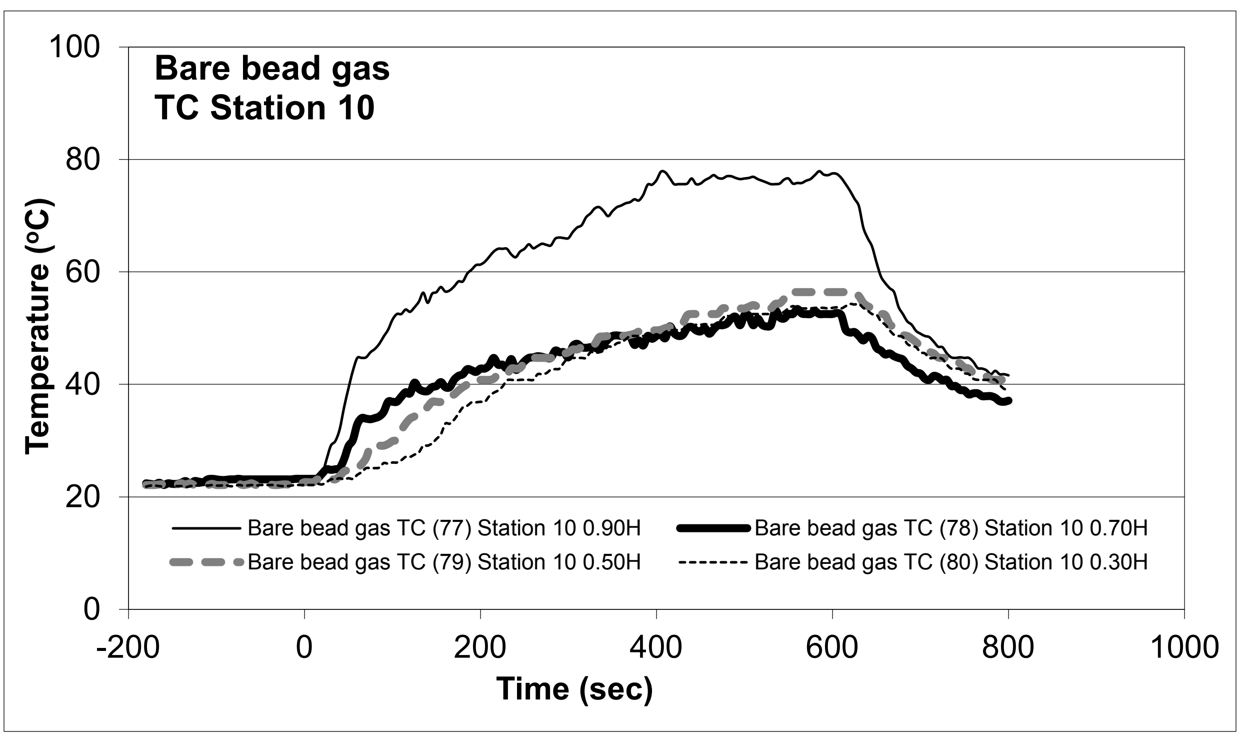

Figure B-19: Test 1 Plots of Thermocouples 77 to 80

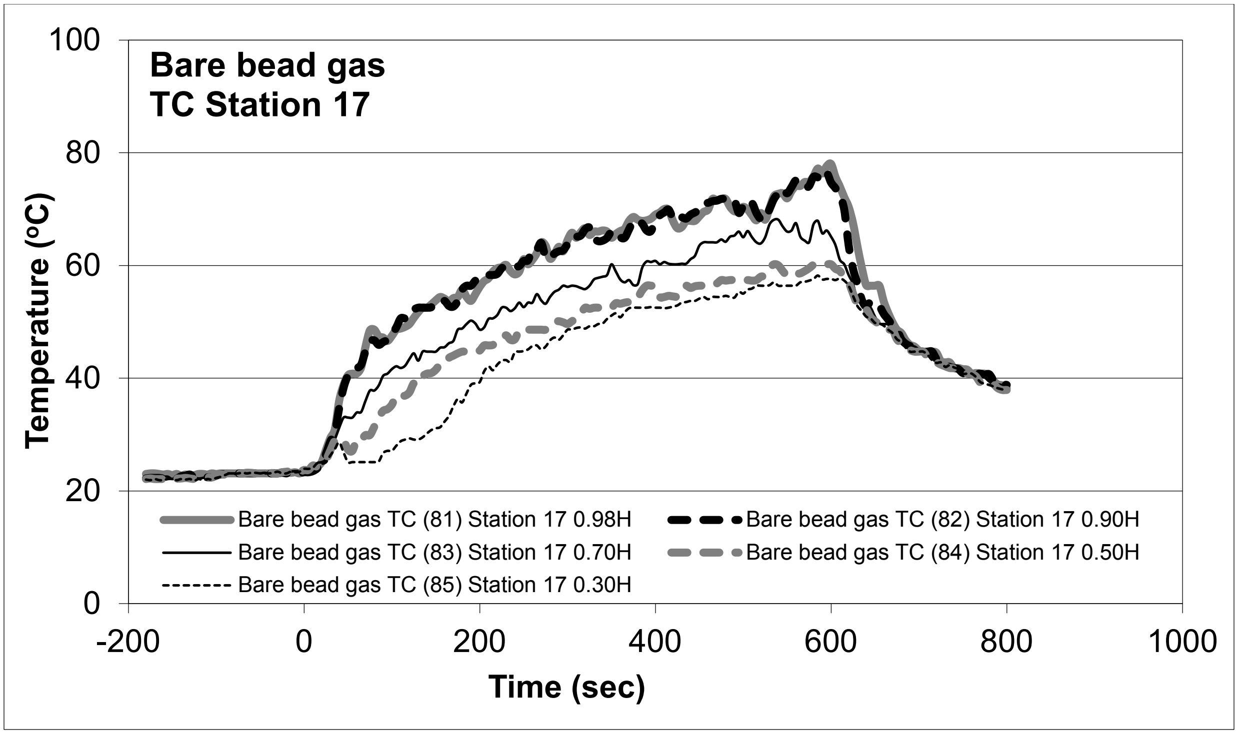

Figure B-20: Test 1 Plots of Thermocouples 81 to 85

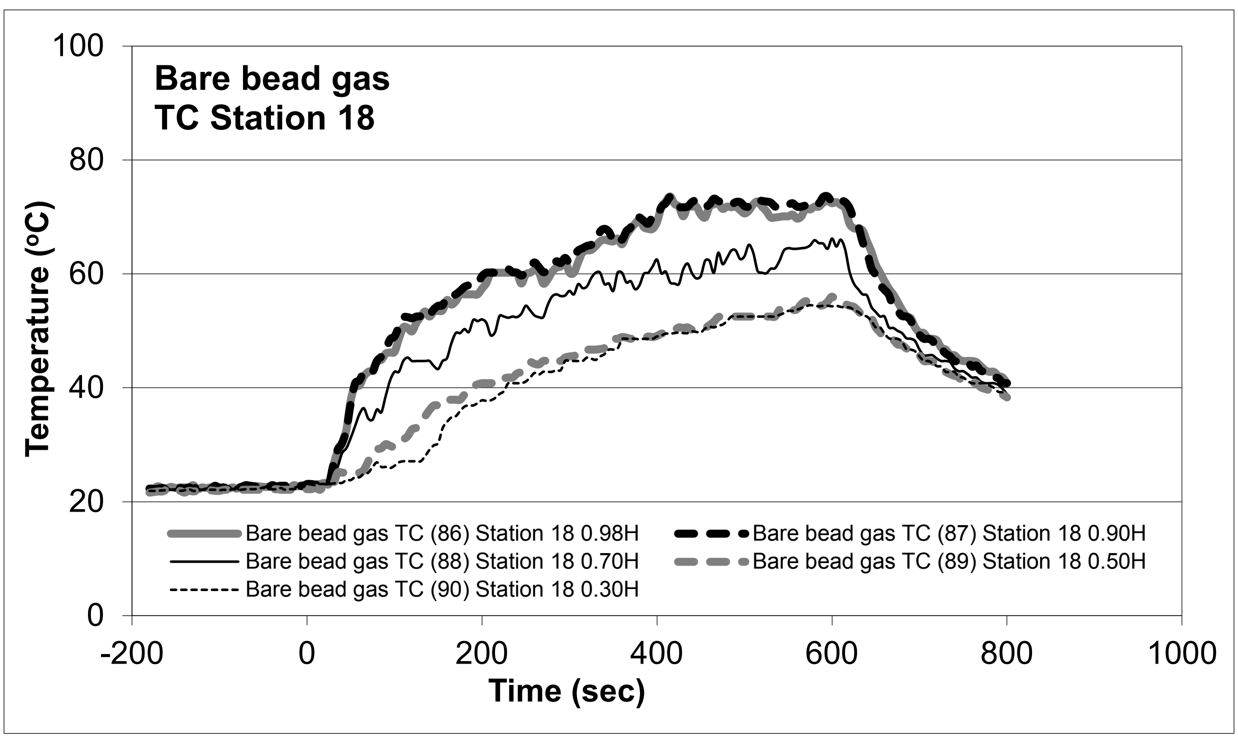

Figure B-21: Test 1 Plots of Thermocouples 86 to 90

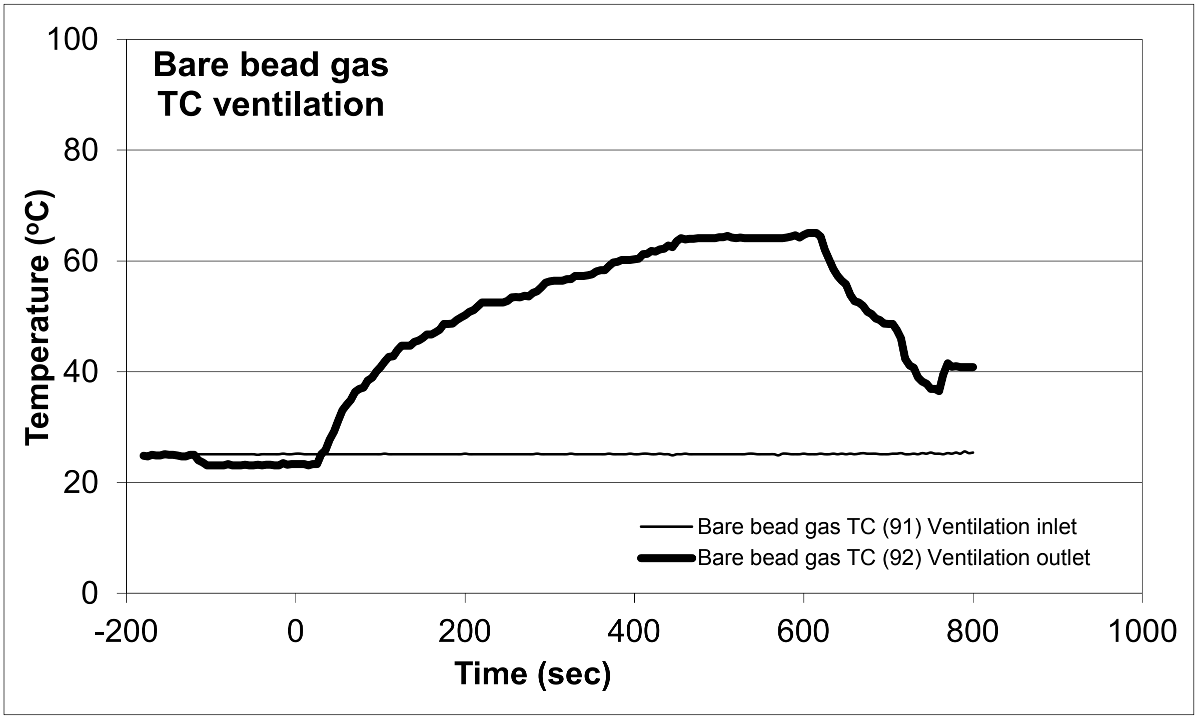

Figure B-22: Test 1 Plots of Thermocouples 91 to 92

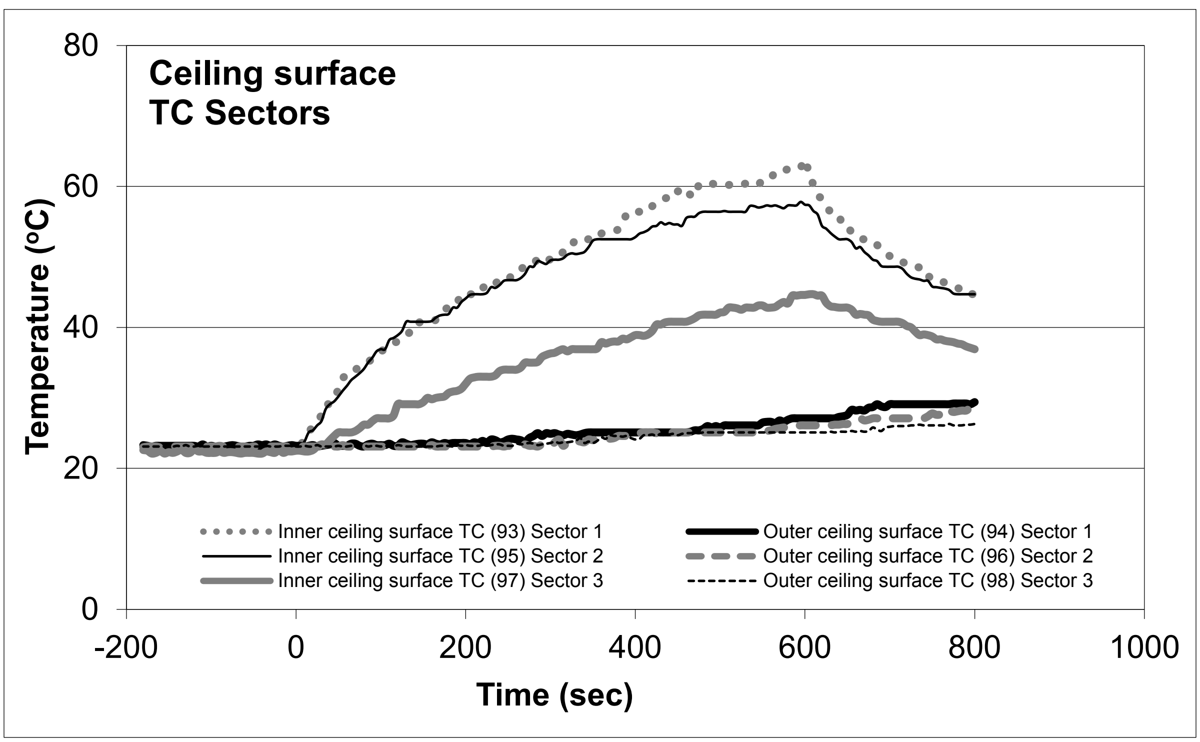

Figure B-23: Test 1 Plots of Thermocouples 93 to 98

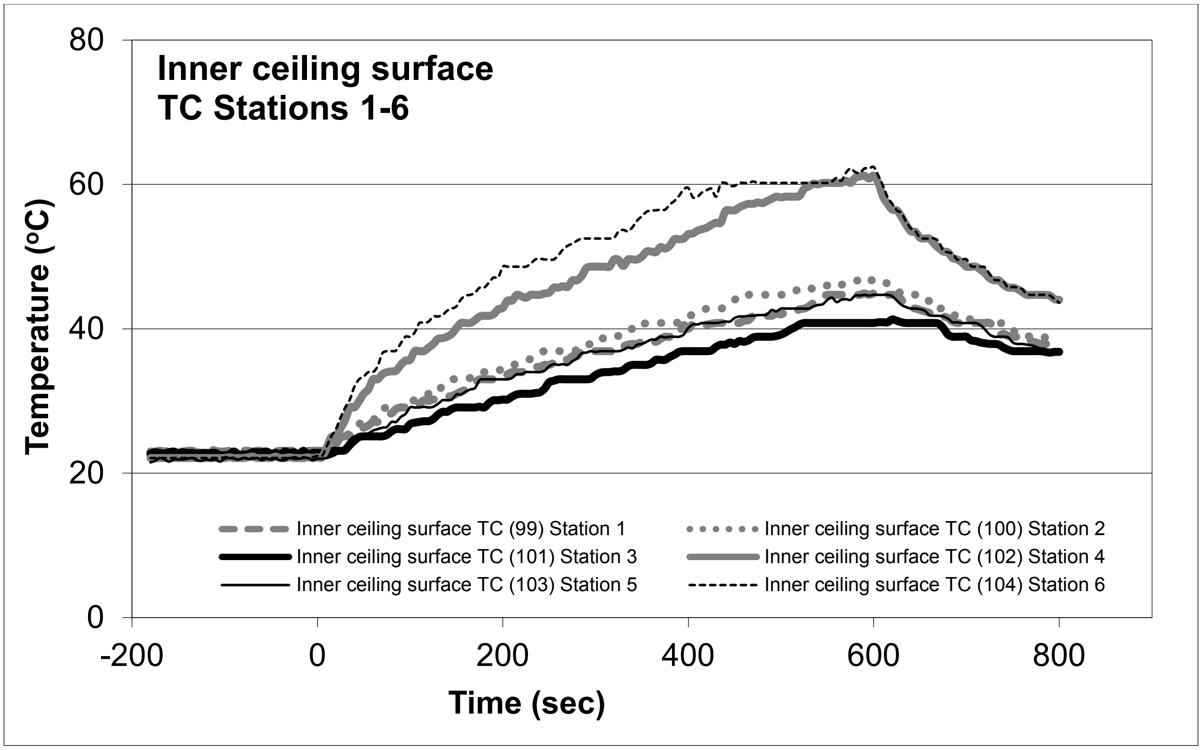

Figure B-24: Test 1 Plots of Thermocouples 99 to 104

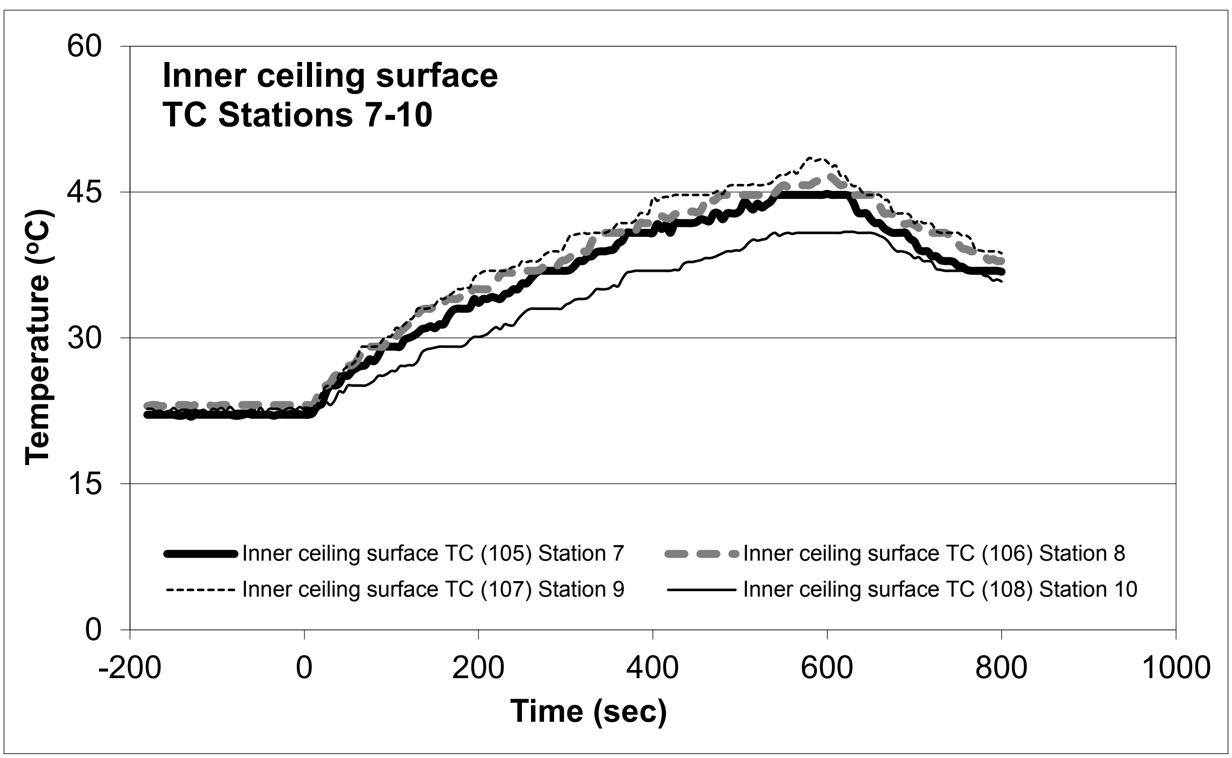

Figure B-25: Test 1 Plots of Thermocouples 105 to 108

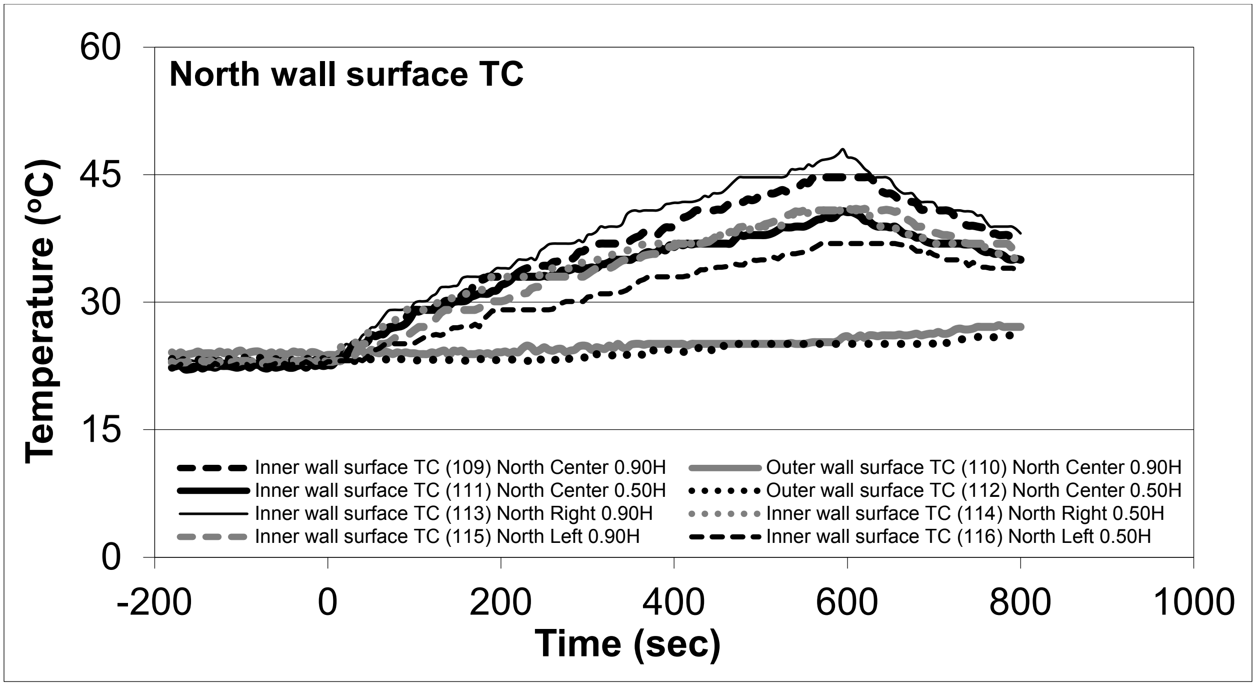

Figure B-26: Test 1 Plots of Thermocouples 109 to 116

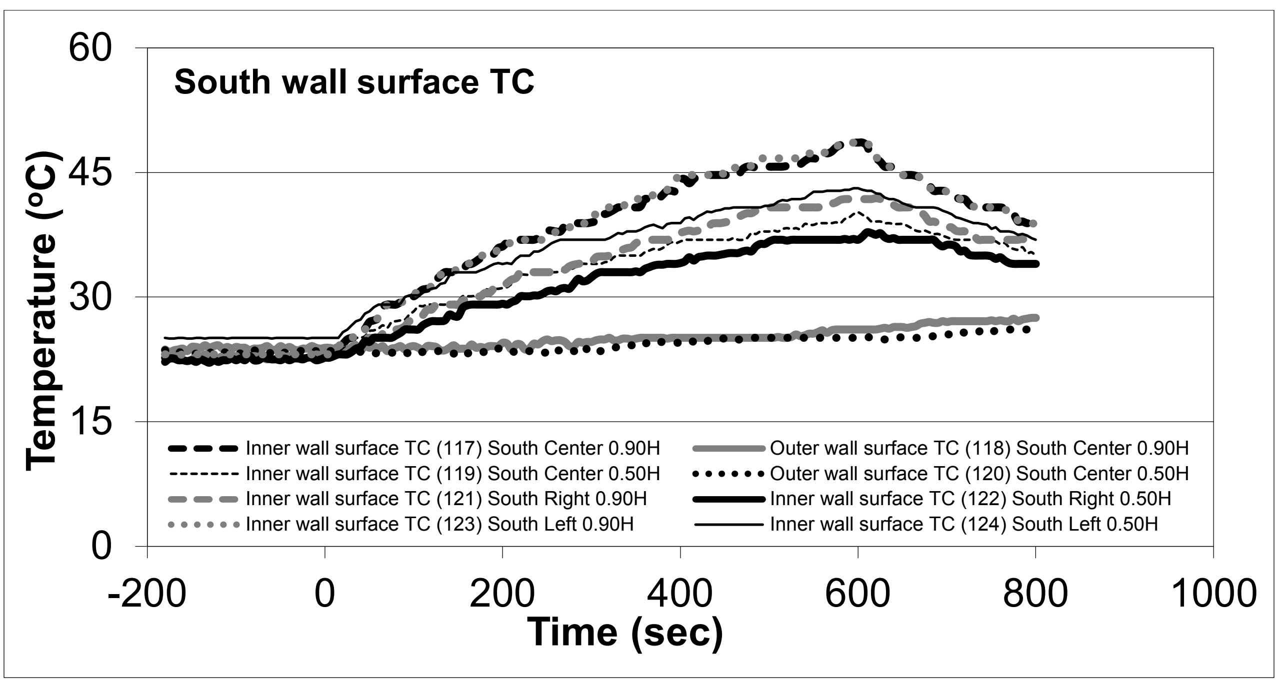

Figure B-27: Test 1 Plots of Thermocouples 117 to 124

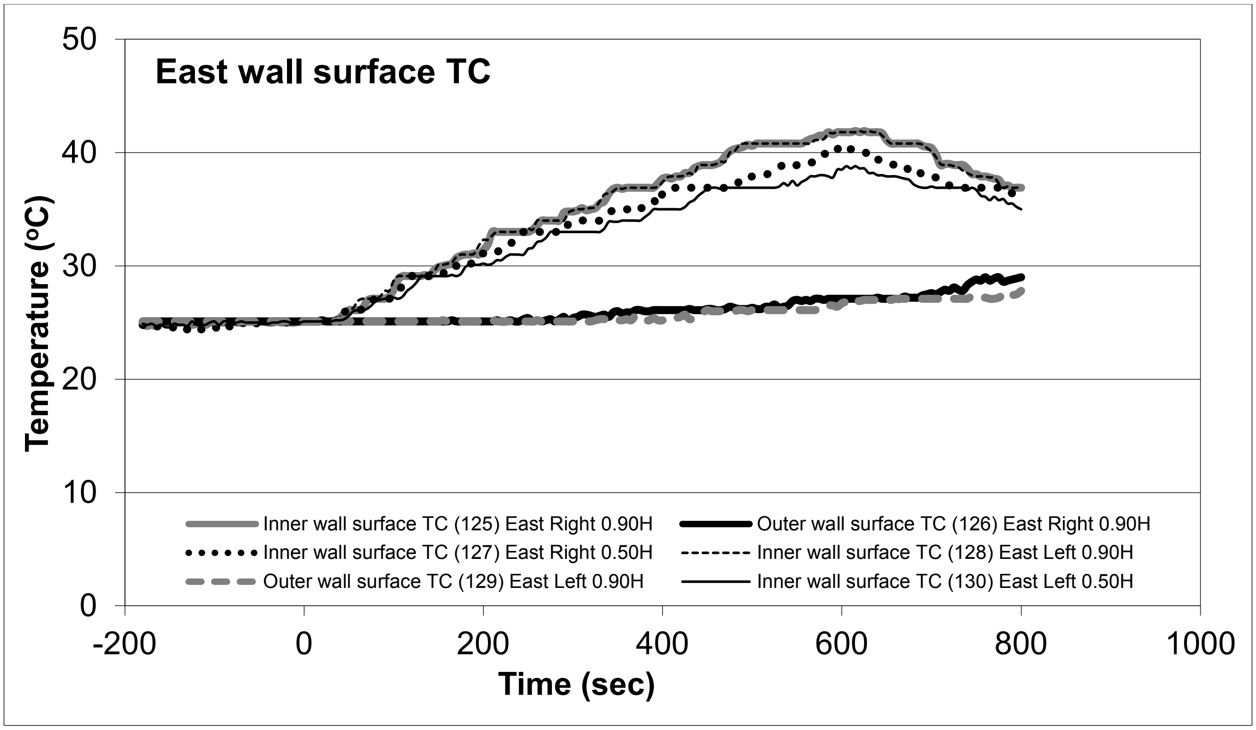

Figure B-28: Test 1 Plots of Thermocouples 125 to 130

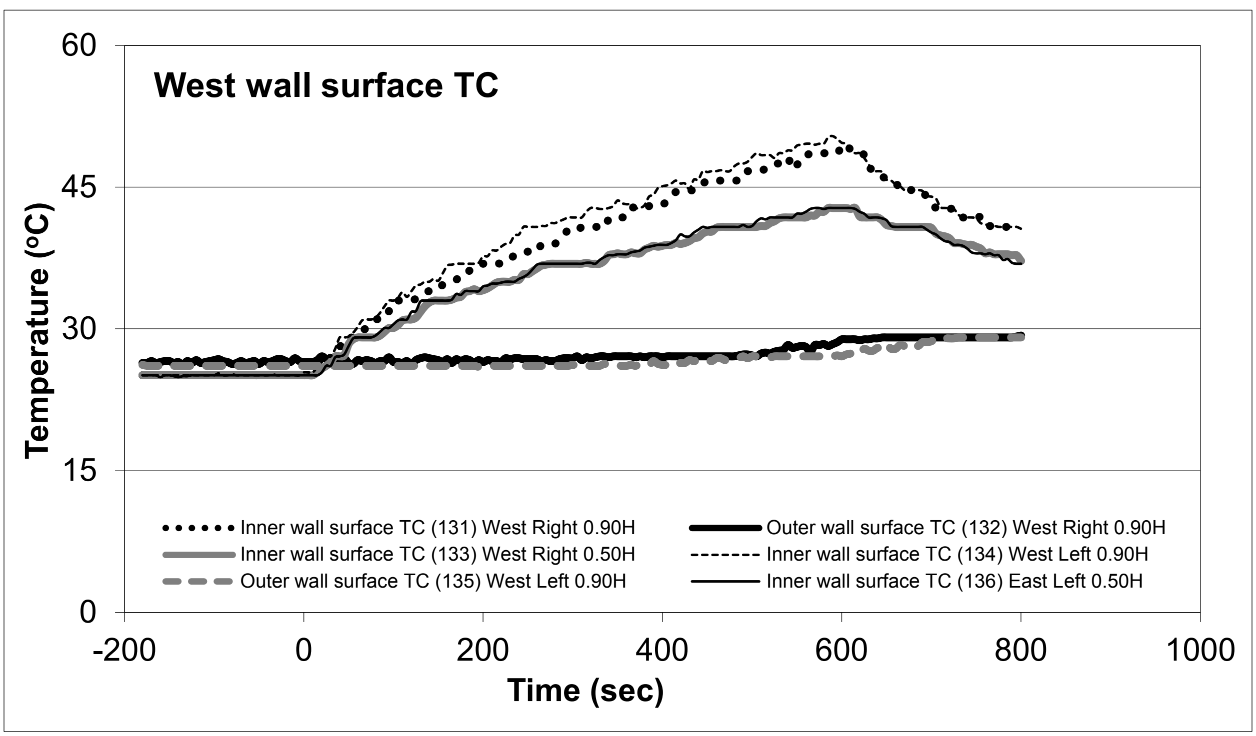

Figure B-29: Test 1 Plots of Thermocouples 131 to 136

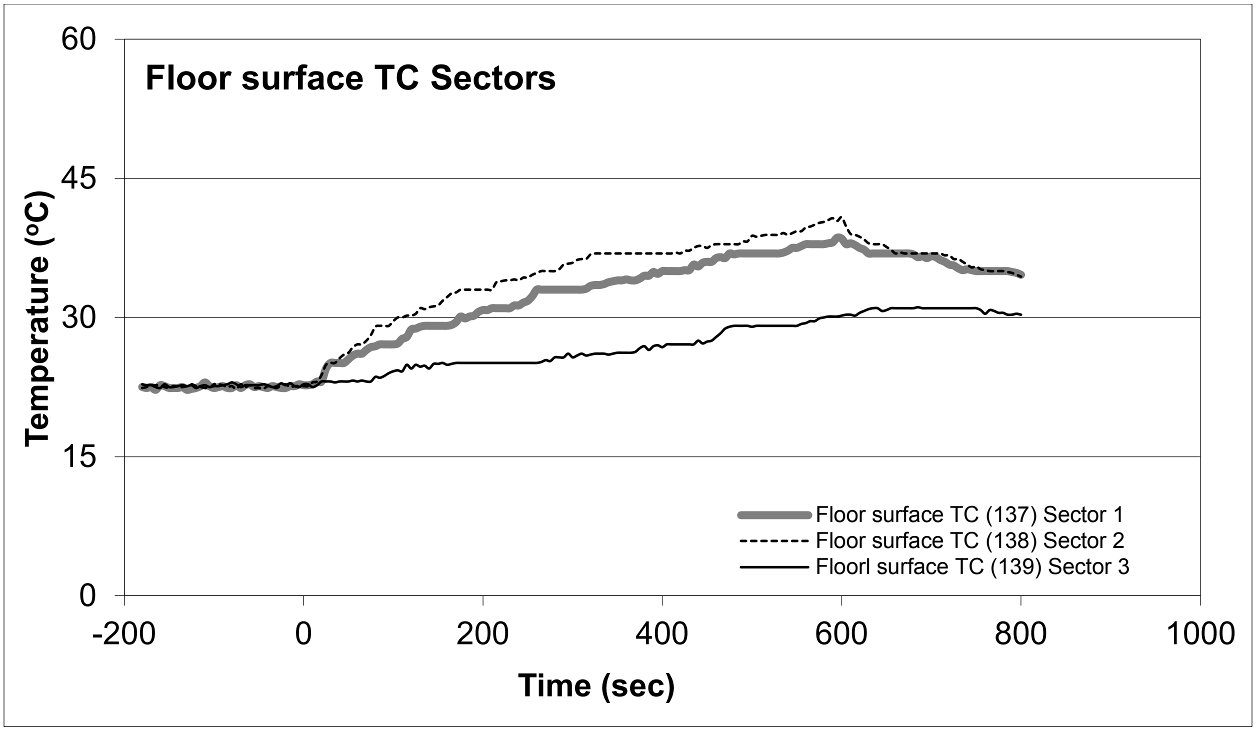

Figure B-30: Test 1 Plots of Thermocouples 137 to 139

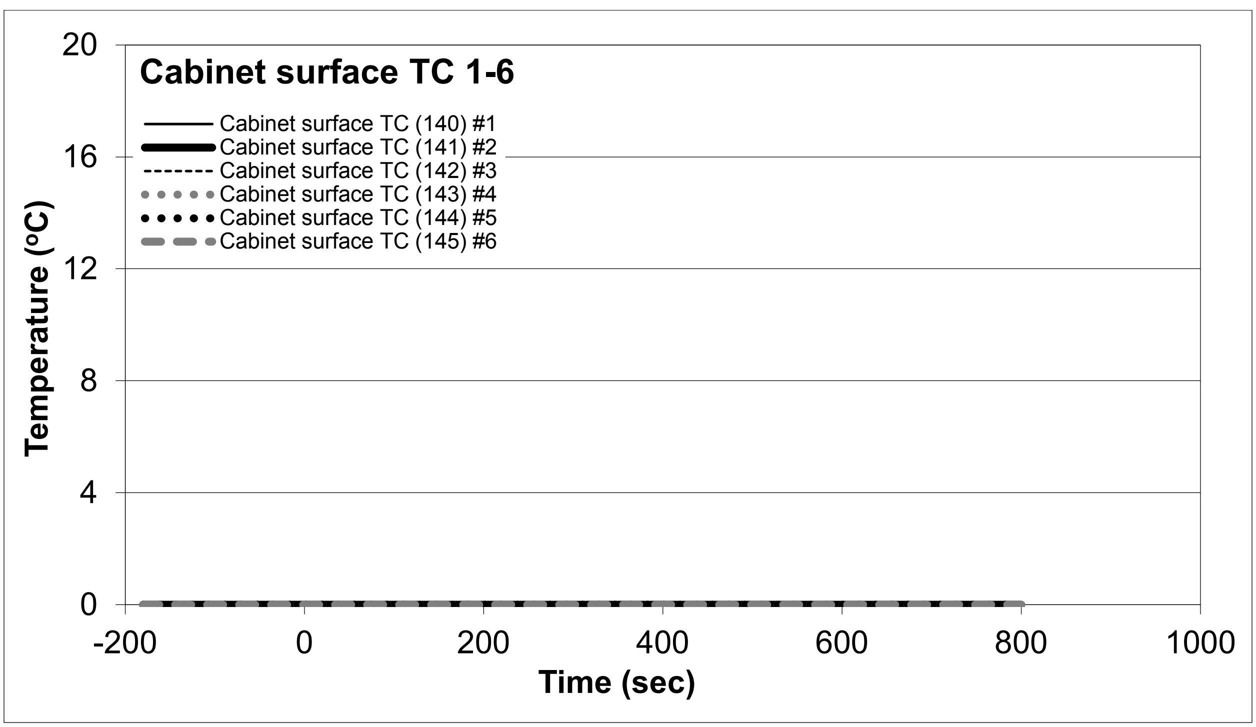

Figure B-31: Test 1 Plots of Thermocouples 140 to 145

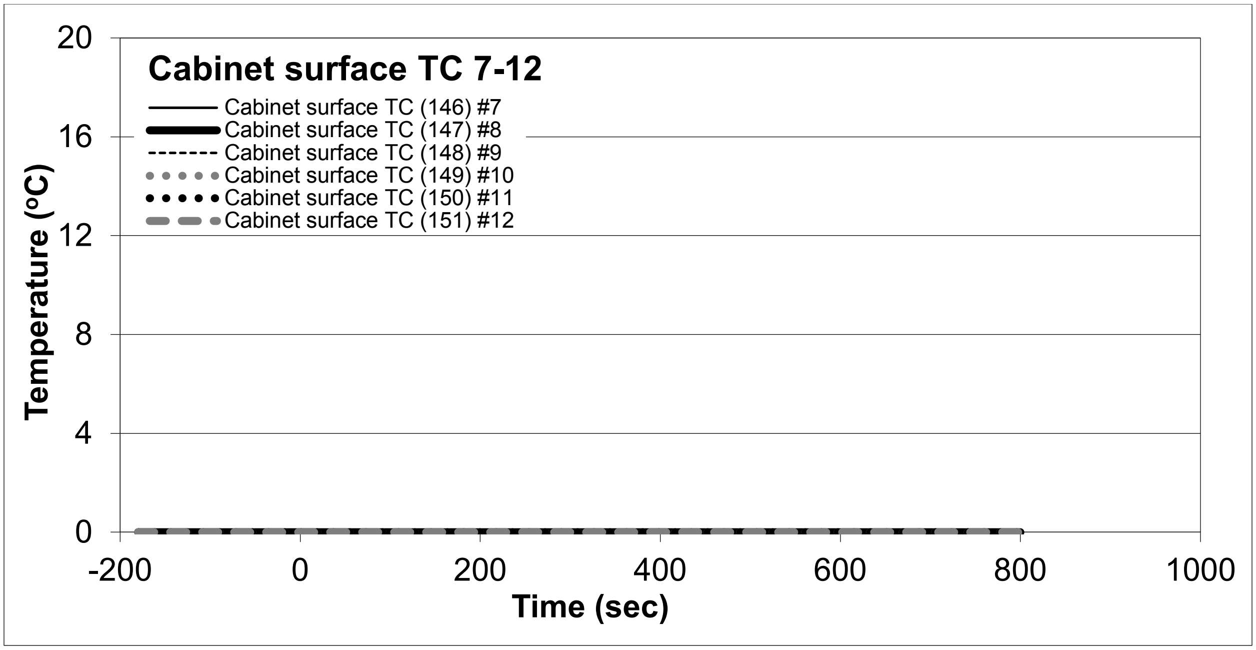

Figure B-32: Test 1 Plots of Thermocouples 146 to 151

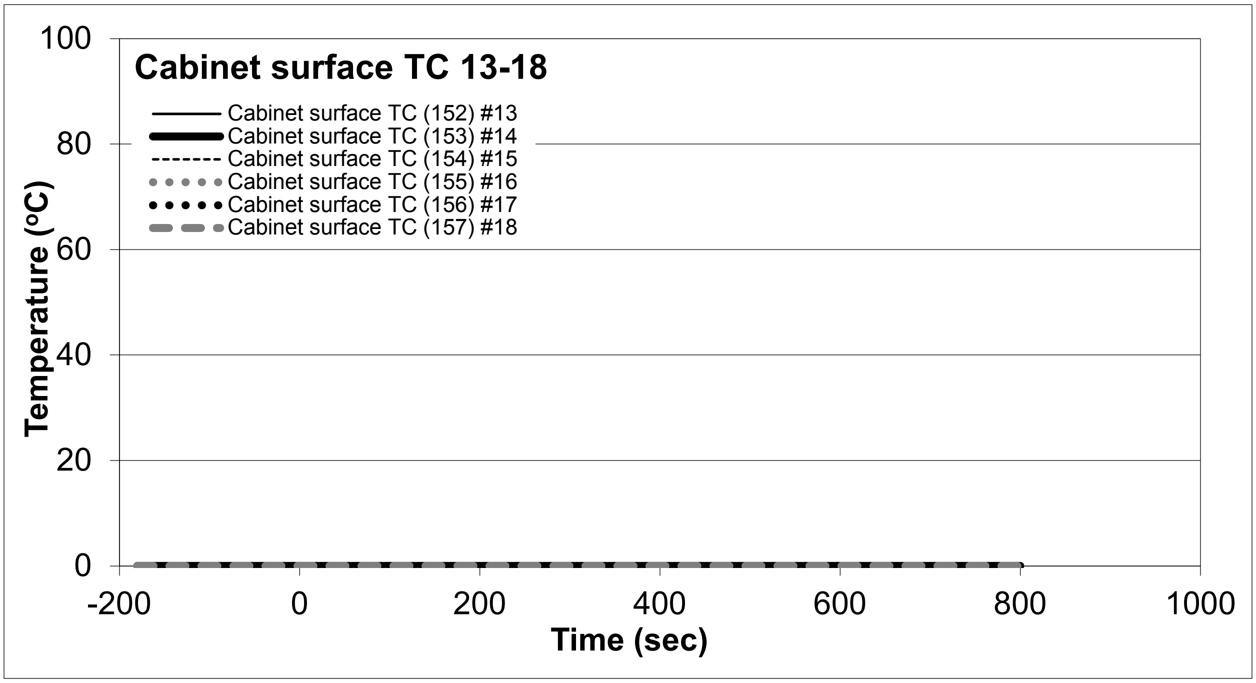

Figure B-33: Test 1 Plots of Thermocouples 152 to 157

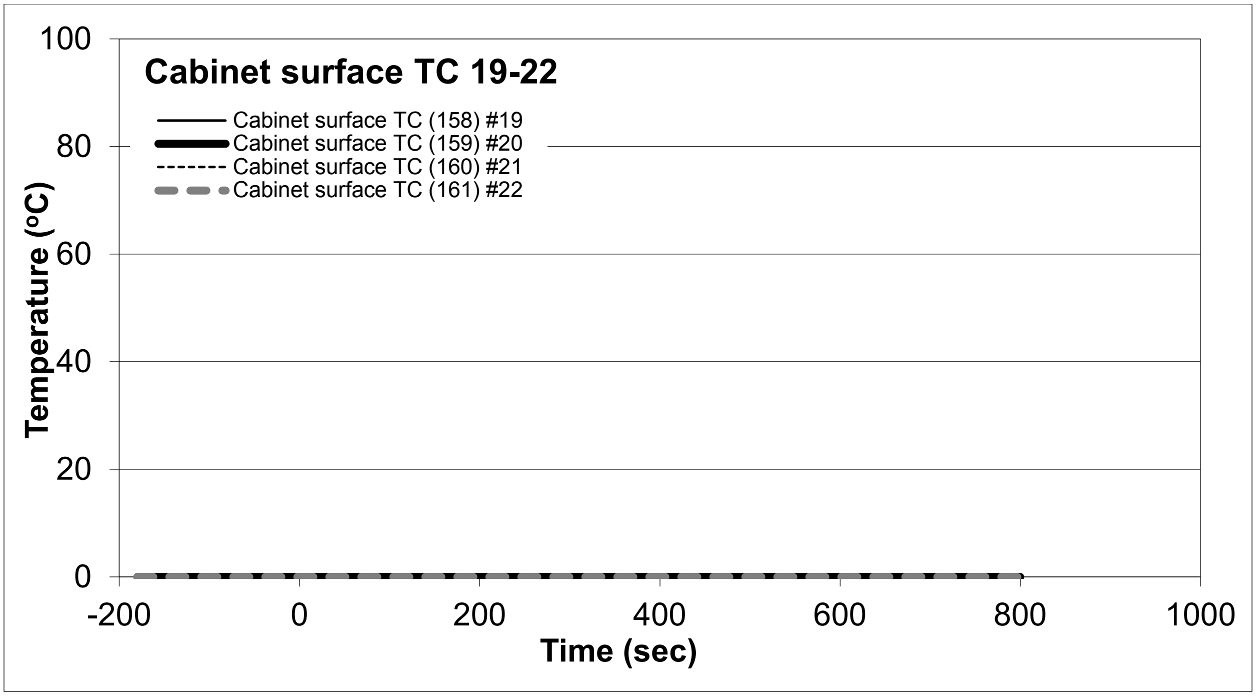

Figure B-34: Test 1 Plots of Thermocouple 158 to 161

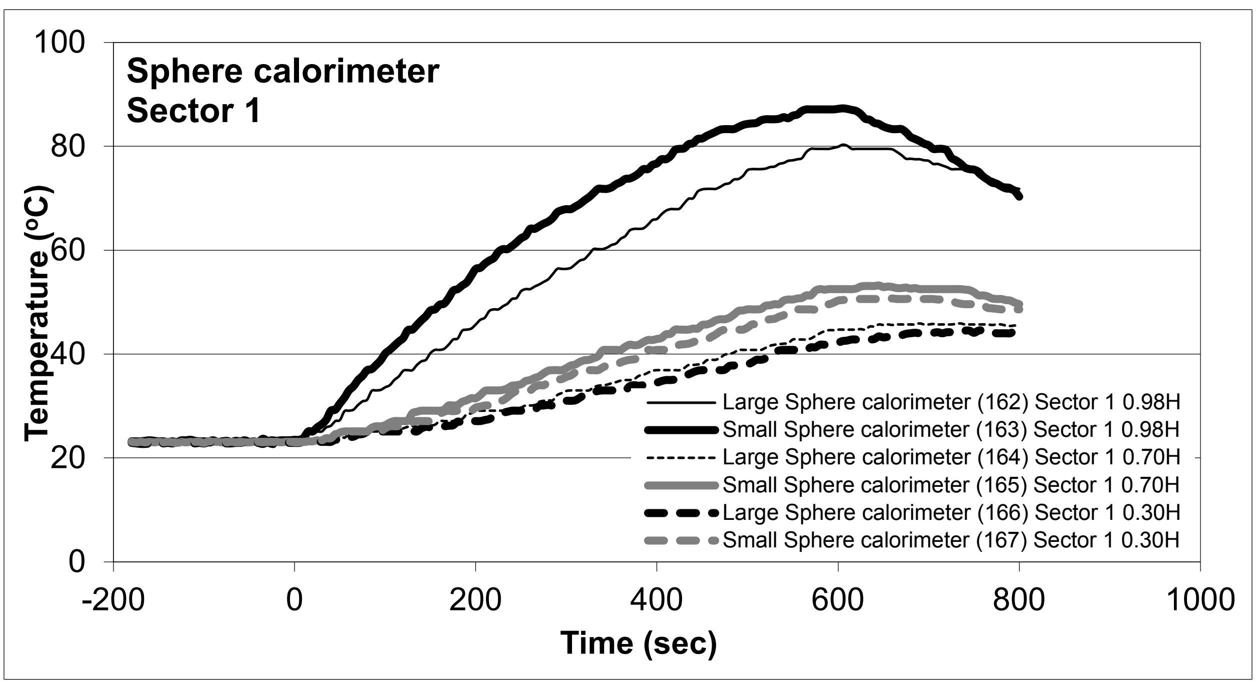

Figure B-35: Test 1 Plots of Thermocouples 162 to 167

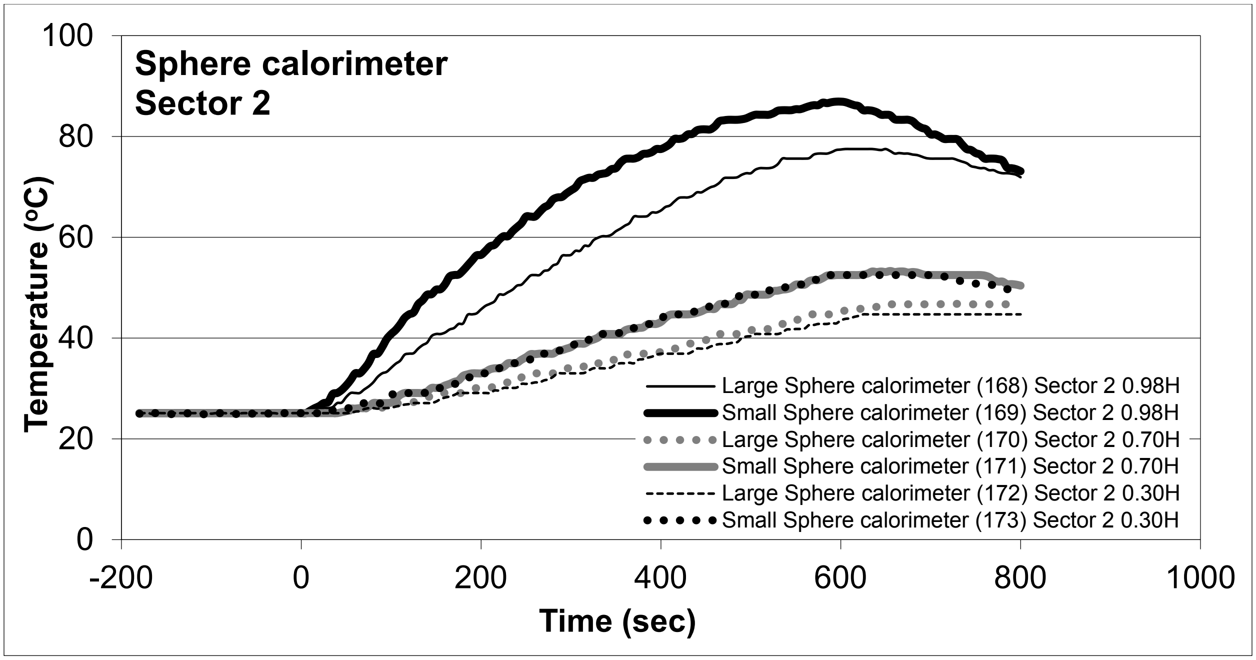

Figure B-36: Test 1 Plots of Thermocouples 168 to 170

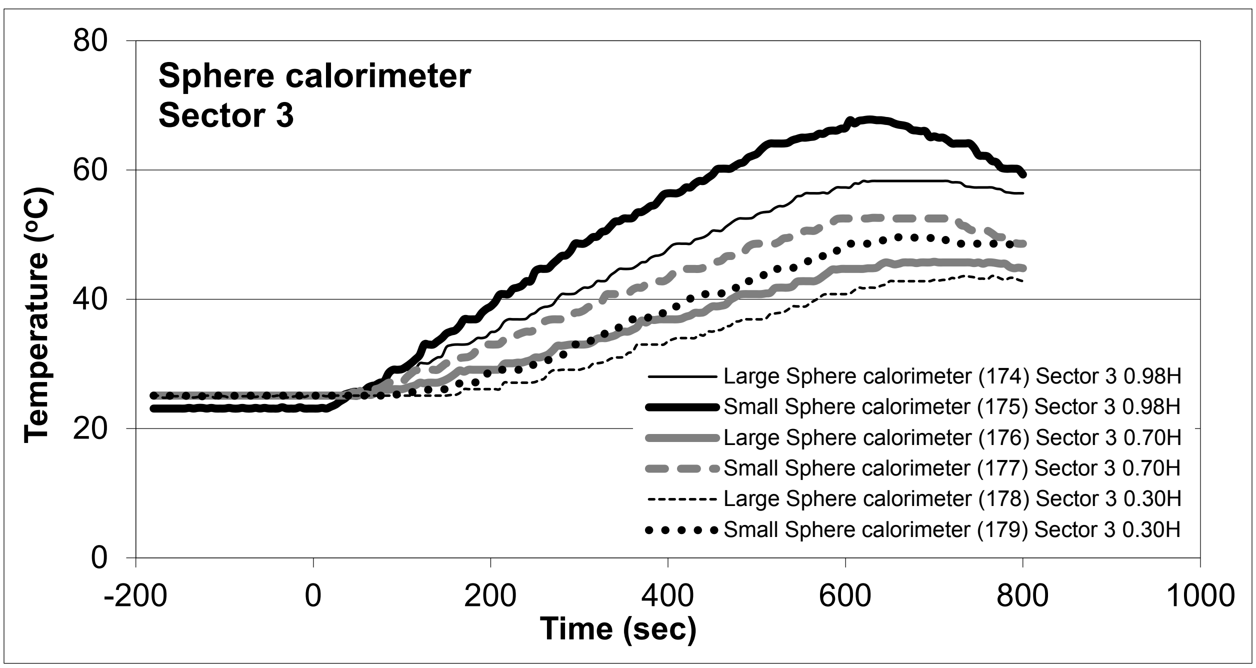

Figure B-37: Test 1 Plots of Thermocouples 174 to 176

B.4 180-197 Flow Probes Sheet

The fourth sheet in the data file entitled "180-197 Flow Probes," contains the vertical and horizontal flow velocity data, channels #180-197. This section contains all data plots on this sheet. Appendix A contains details on each data channel.

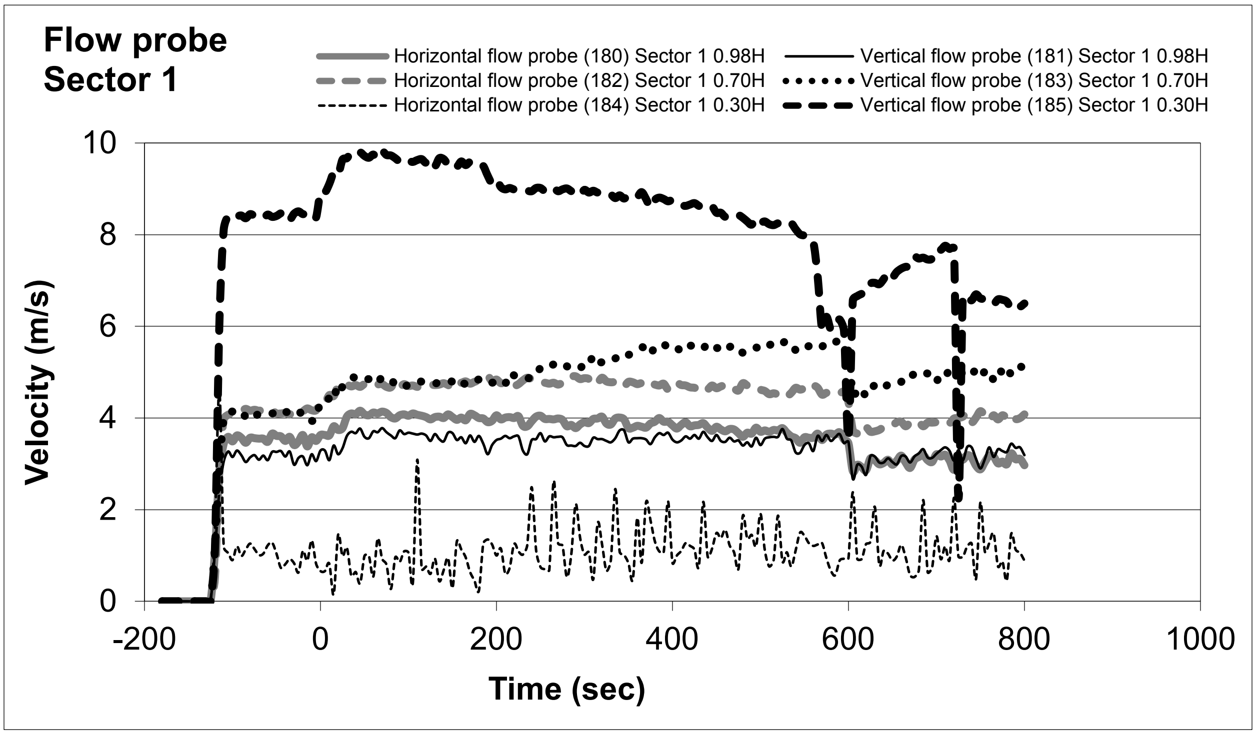

Figure B-38: Test 1 Plots of Flow Probes 180 to 185

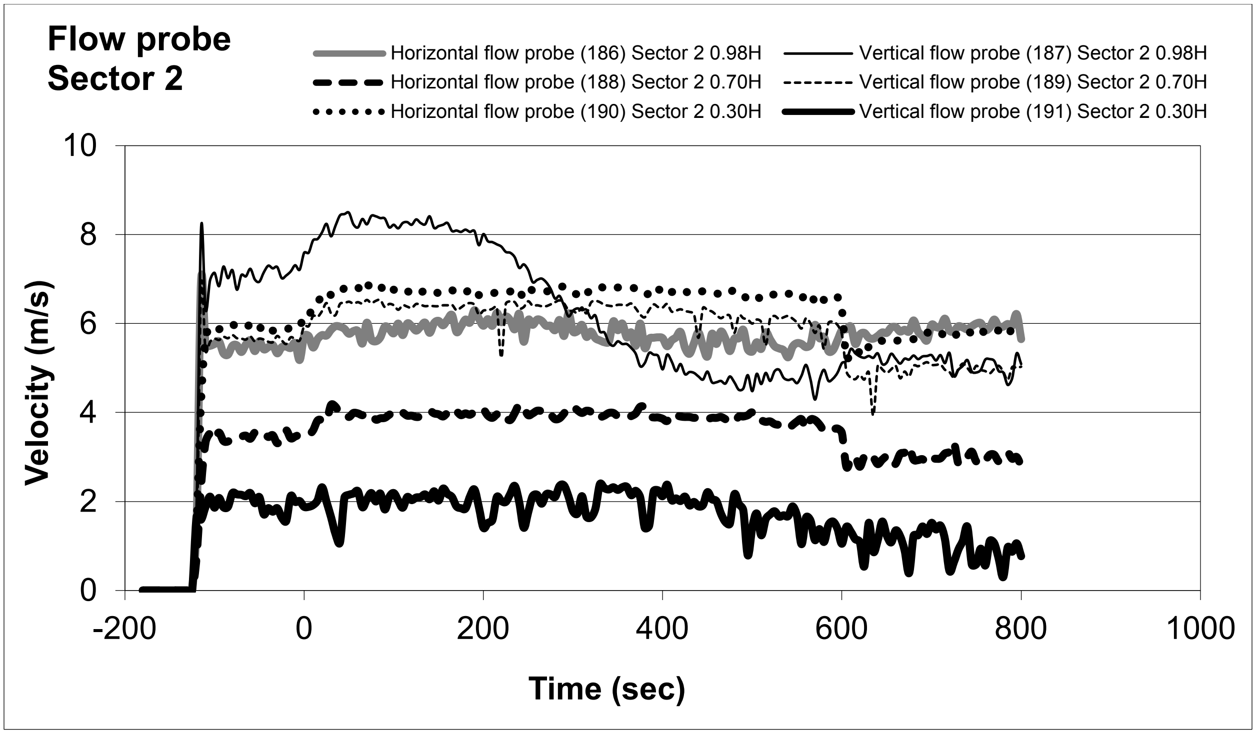

Figure B-39: Test 1 Plots of Flow Probes 186 to 191

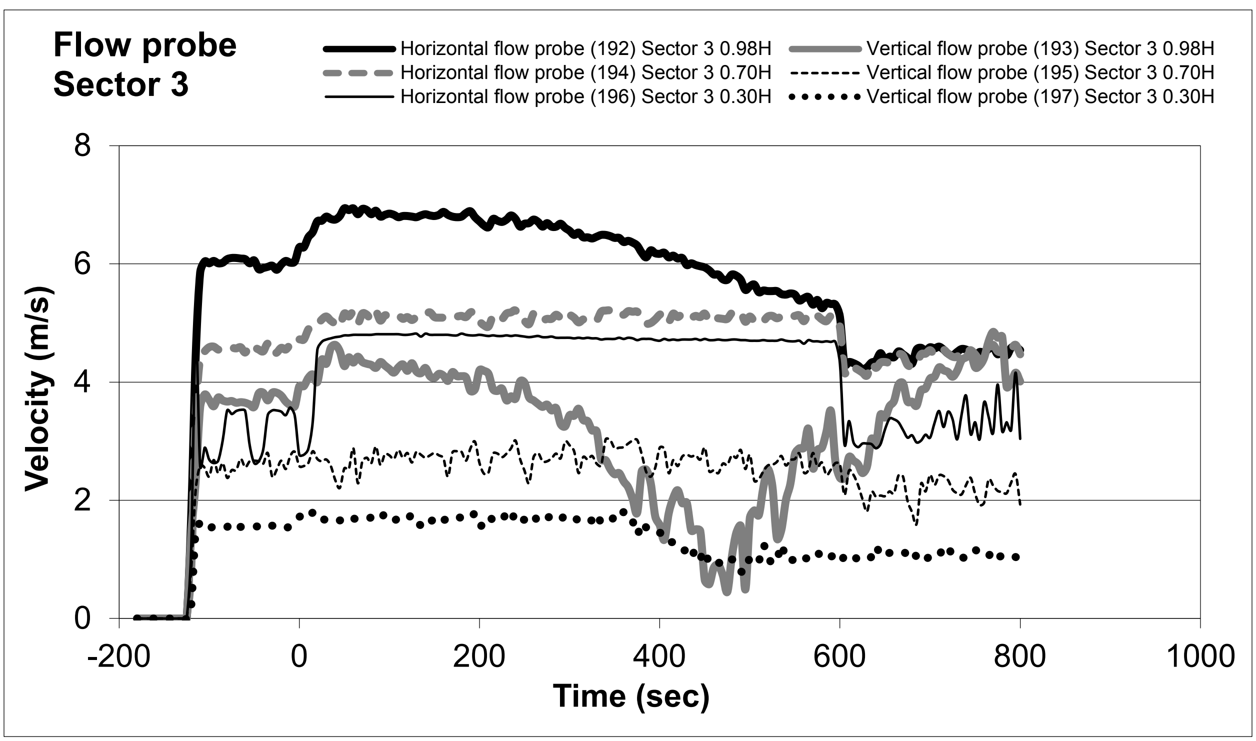

Figure B-40: Test 1 Plots of Flow Probes 192 to 197

B.5 198-203 Pressure Differential Sheet

The fifth sheet in the data file entitled “198-203 P Diff,” contains the pressure differential data, channels #198-203. This section contains all data plots in this sheet. Appendix A contains details on each data channel.

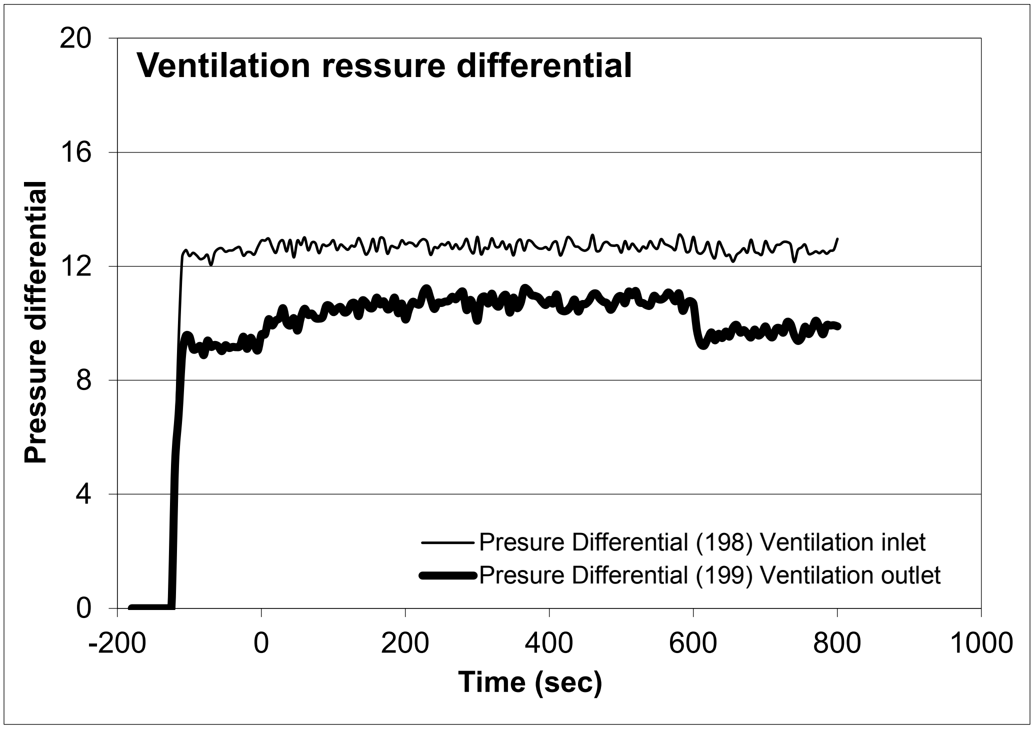

Figure B-41: Test 1 Plots of Pressure Differential Channels 198 to 199

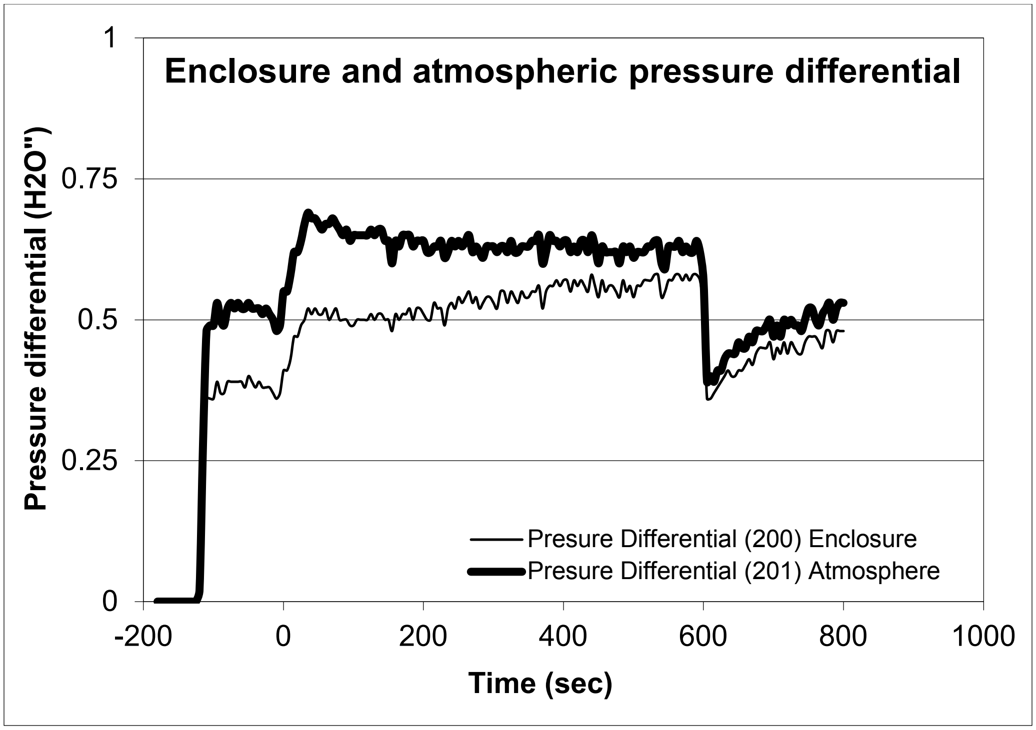

Figure B-42: Test 1 Plots of Pressure Differential Channels 200 to 201

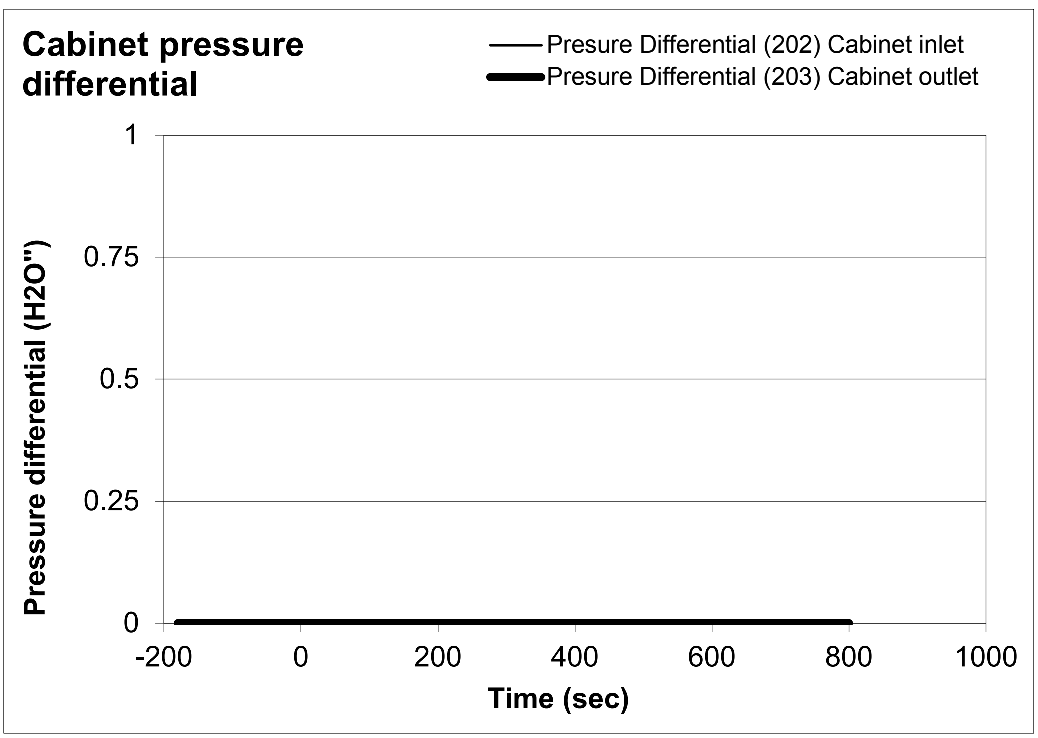

Figure B-43: Test 1 Plots of Cabinet Pressure Differential Channels 202 to 203[1]

[1] Channels 202 to 203 were only used in the cabinet fire tests 19-25

B.6 204-211 Optical Density Sheet

The sixth sheet in the data file entitled “204-211 Opt Dens,” contains the smoke optical density data, channels #204-211. This section contains all data plots on this sheet. Appendix A contains details on each data channel.

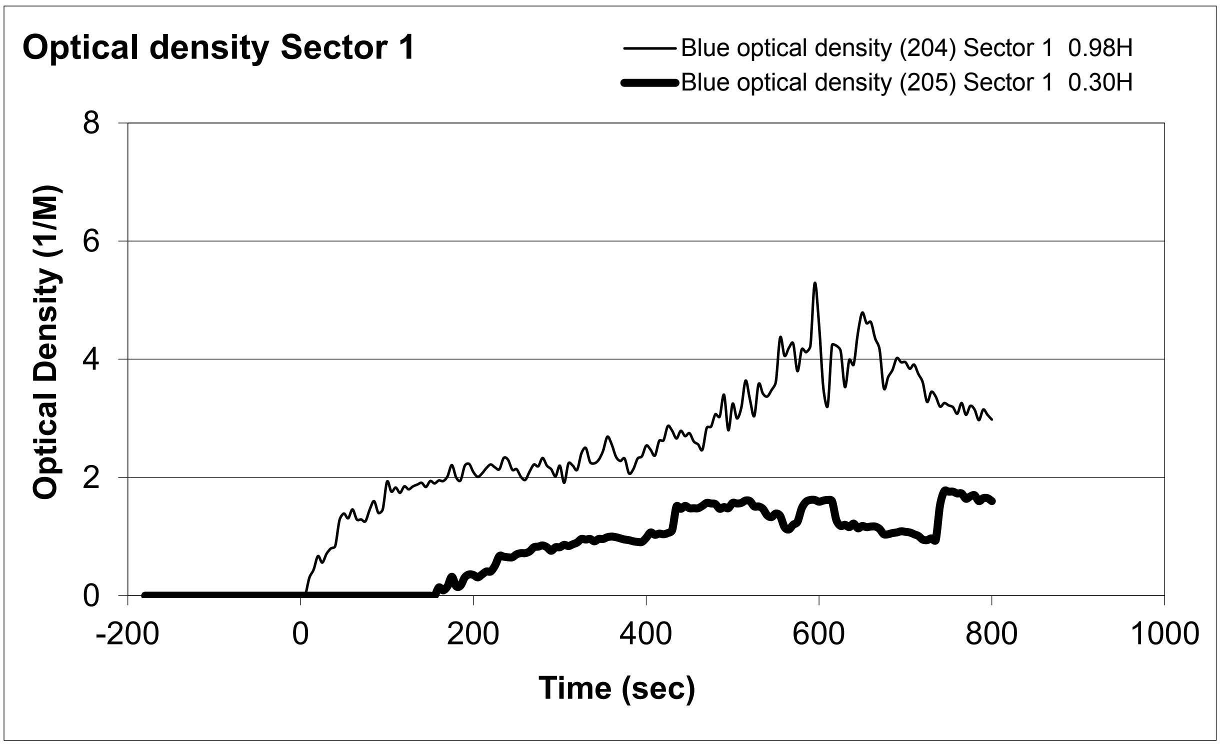

Figure B-44: Test 1 Plots of Optical Density Channels 204 to 205

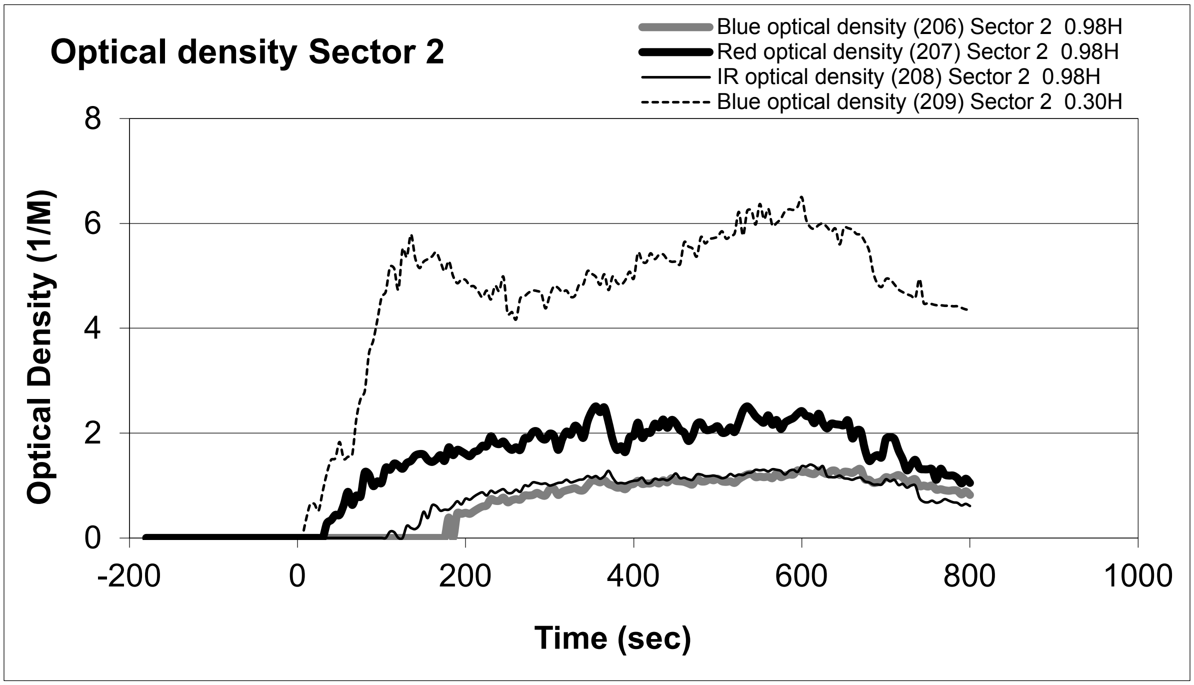

Figure B-45: Test 1 Plots of Optical Density Channels 206 to 209

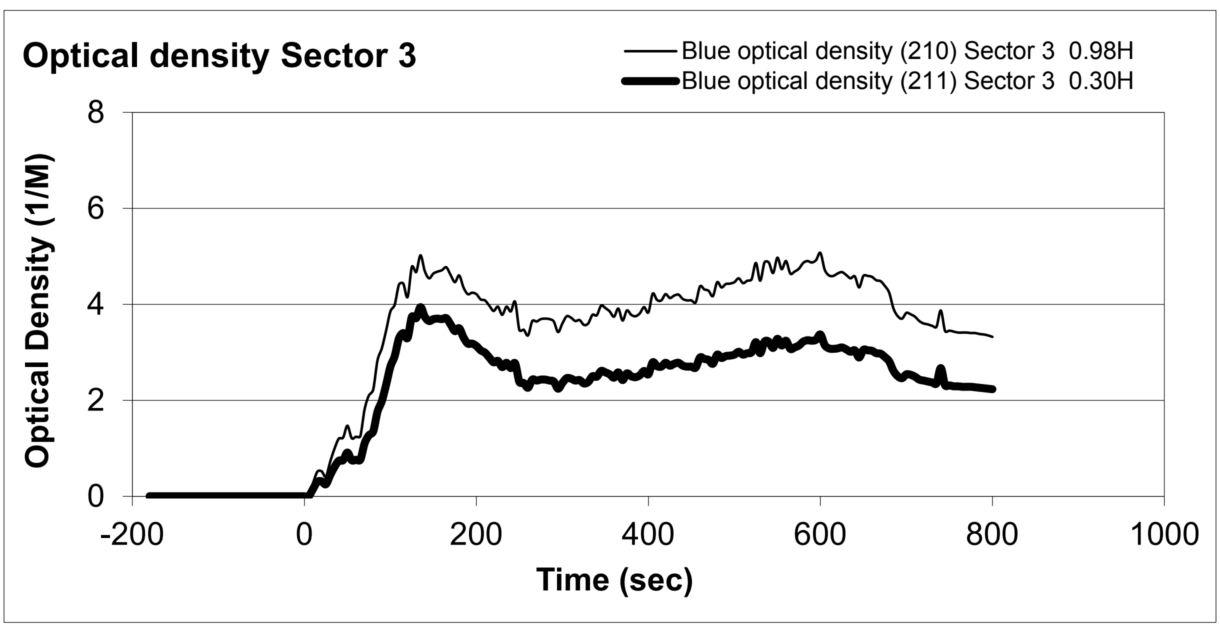

Figure B-46: Test 1 Plots of Optical Density Channels 210 to 211

B.7 212-221 Gas Concentration Sheet

The seventh sheet in the data file entitled "212-221 Gas", contains the gas concentration data, channels #212-221. This section contains all data plots on this sheet. Appendix A contains details on each data channel.

Note: Carbon monoxide (CO) and total hydrocarbons (THC) (Figure B-48) concentration was 0 or undetectable in Test 1.

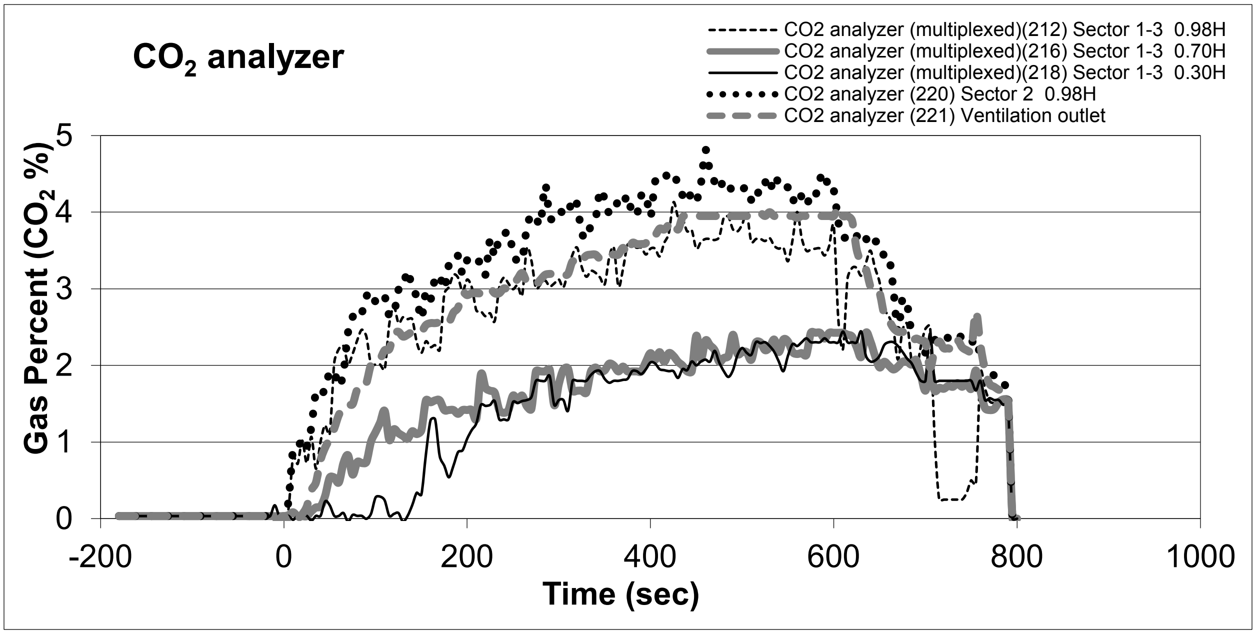

Figure B-47: Test 1 Plots of Gas Concentration Channels 212, 216, 218, 220, and 221

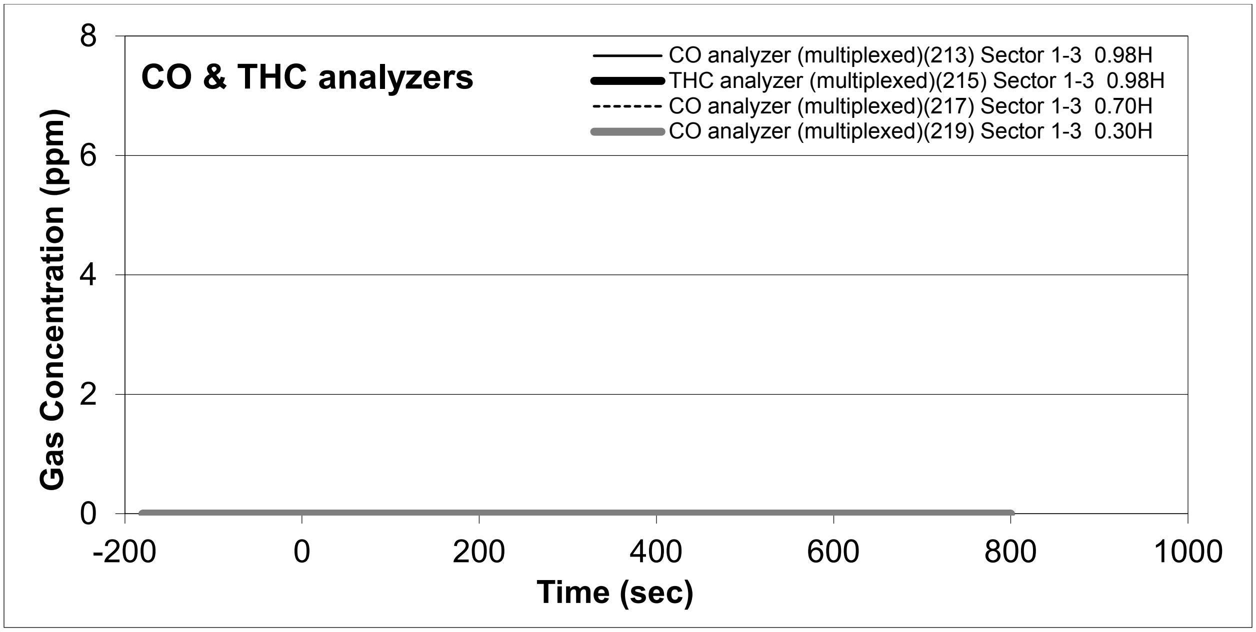

Figure B-48: Test 1 Plots of Gas Concentration Channels 213, 215, 217, and 219

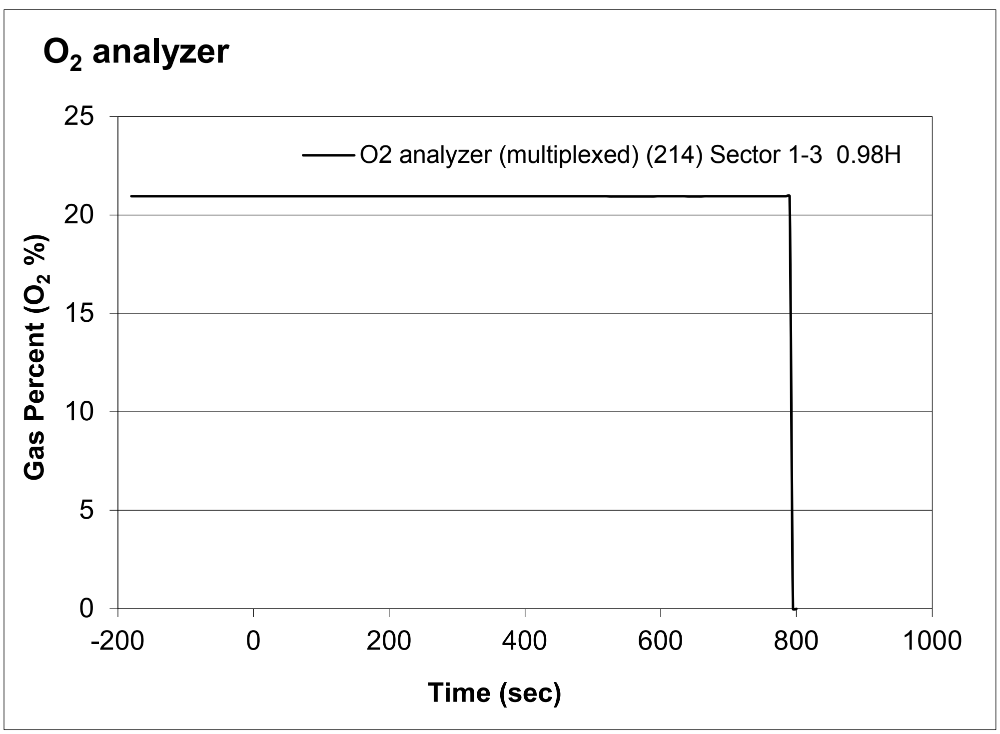

Figure B-49: Test 1 Plots of Gas Concentration Channel 214

B.8 222-249 Heat and Mass Loss Sheet

The eighth sheet, titled “222-249 Heat & Mass” in the data file, contains the surface heat flux and mass loss data, channels #222-249. This section contains all the data plots on this sheet. Appendix A contains details on each data channel.

In the original data files, the “Enclosure Surface Heat Flux Data” (Channels 231-243) were not reported correctly. The issue with this data could not be resolved as recommended by the “Survivor’s Guide” because of the unavailability of a conversion factor (milliampere [mA] to engineering units [W/m^2]) needed to convert the raw data to the processed data. As such, this data is lost.

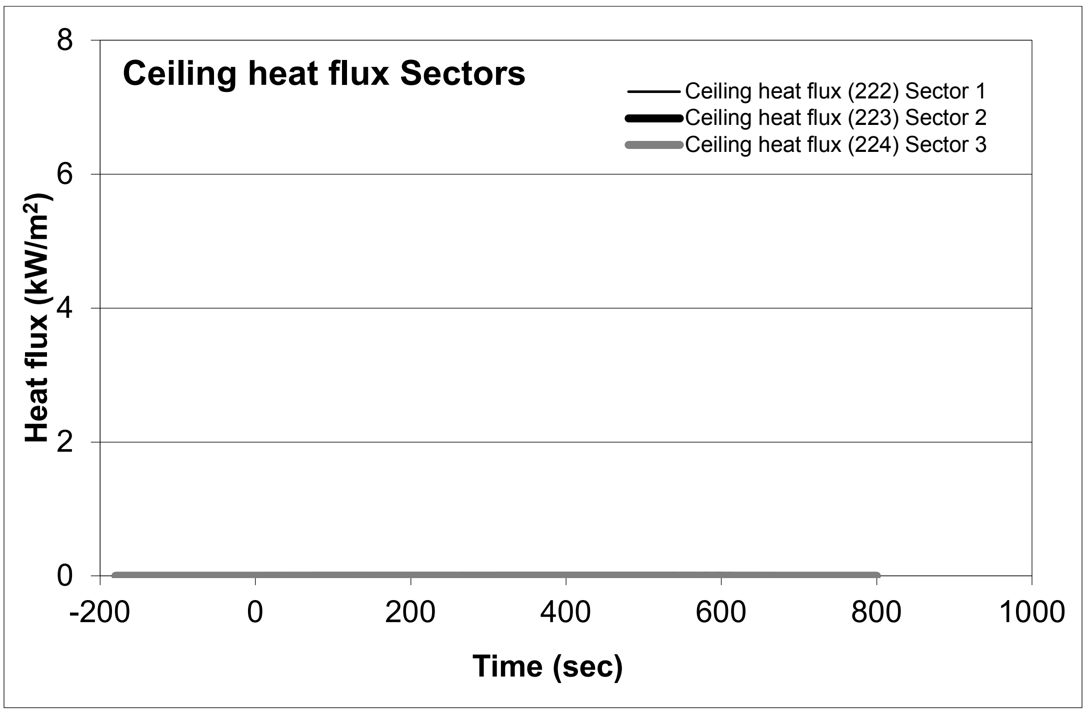

Figure B-50: Test 1 Plots of Heat Flux Channels 222 to 224

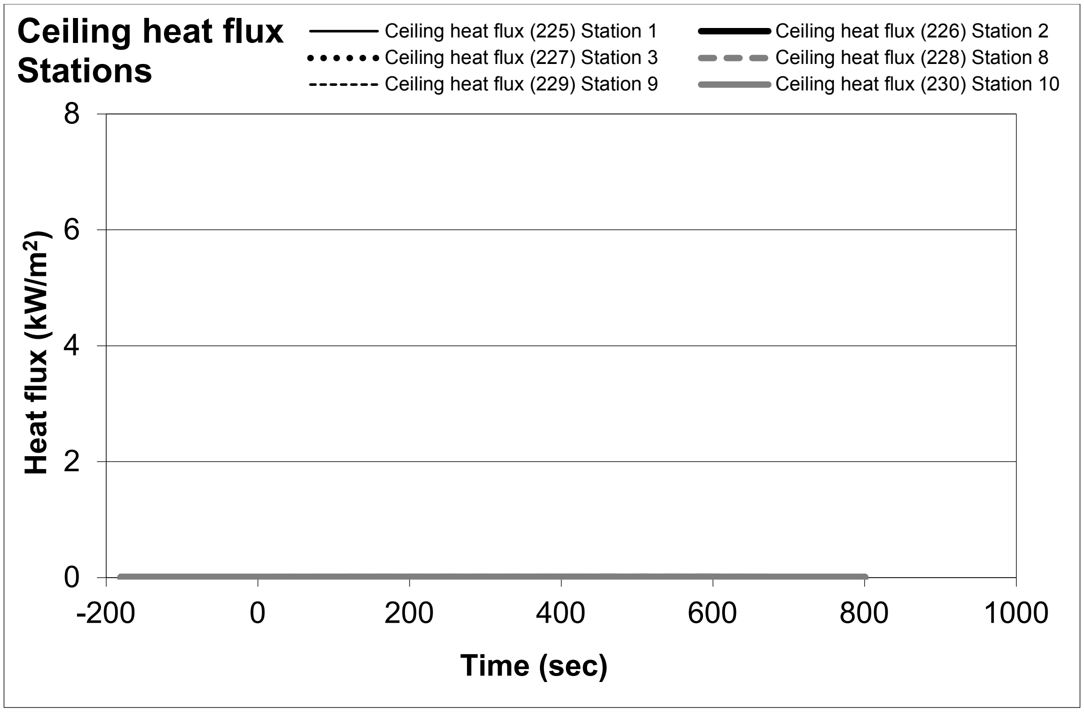

Figure B-51: Test 1 Plots of Heat Flux Channels 225 to 230

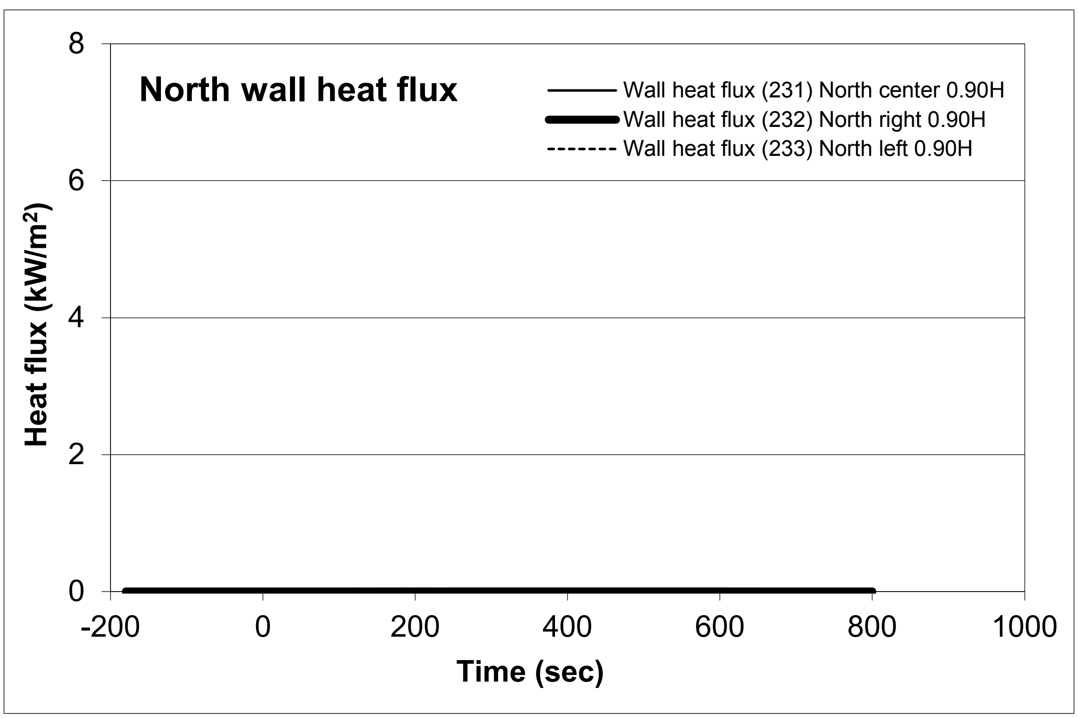

Figure B-52: Test 1 Plots of Heat Flux Channels 231 to 233

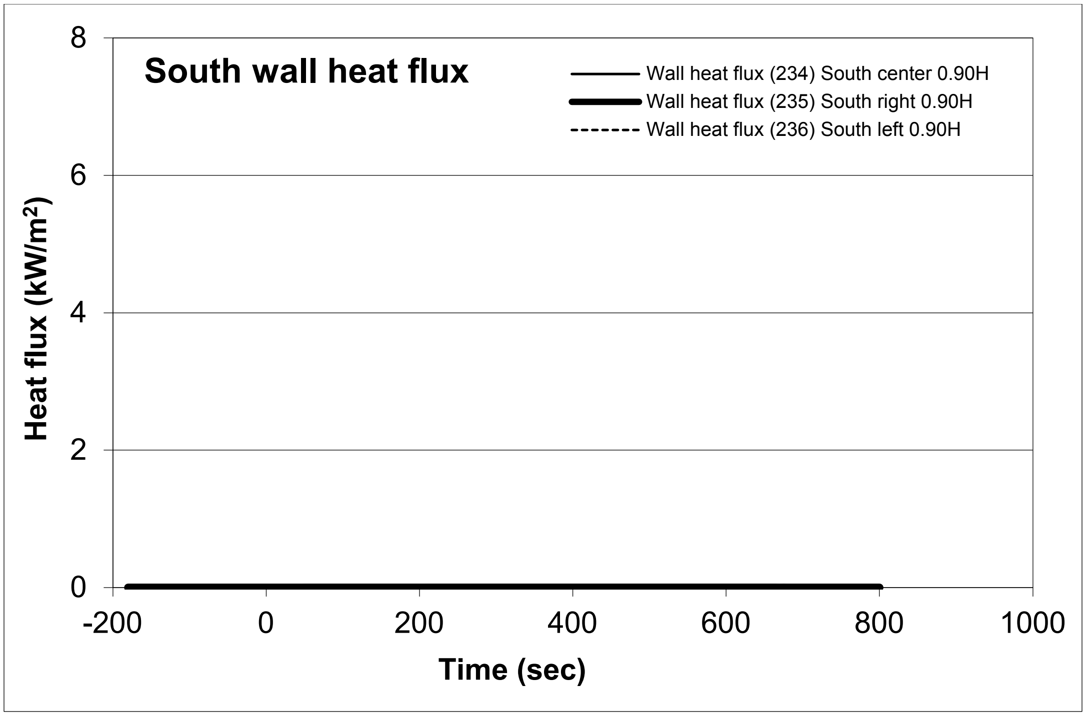

Figure B-53: Test 1 Plots of Heat Flux Channels 234 to 236

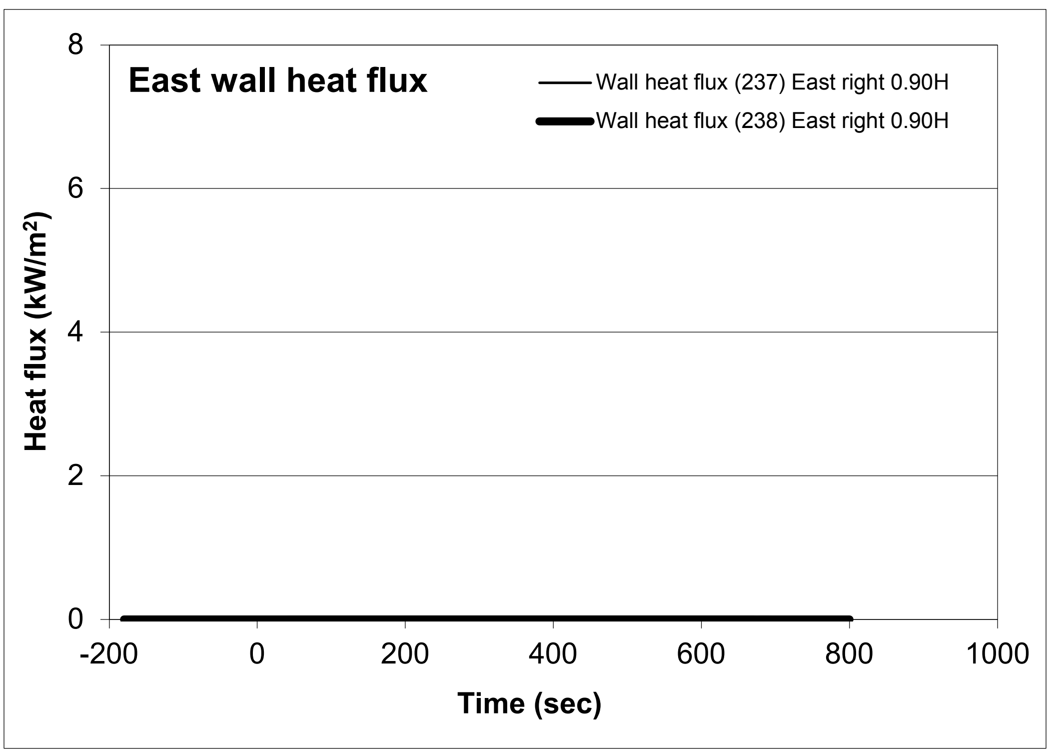

Figure B-54: Test 1 Plots of Heat Flux Channels 237 to 238

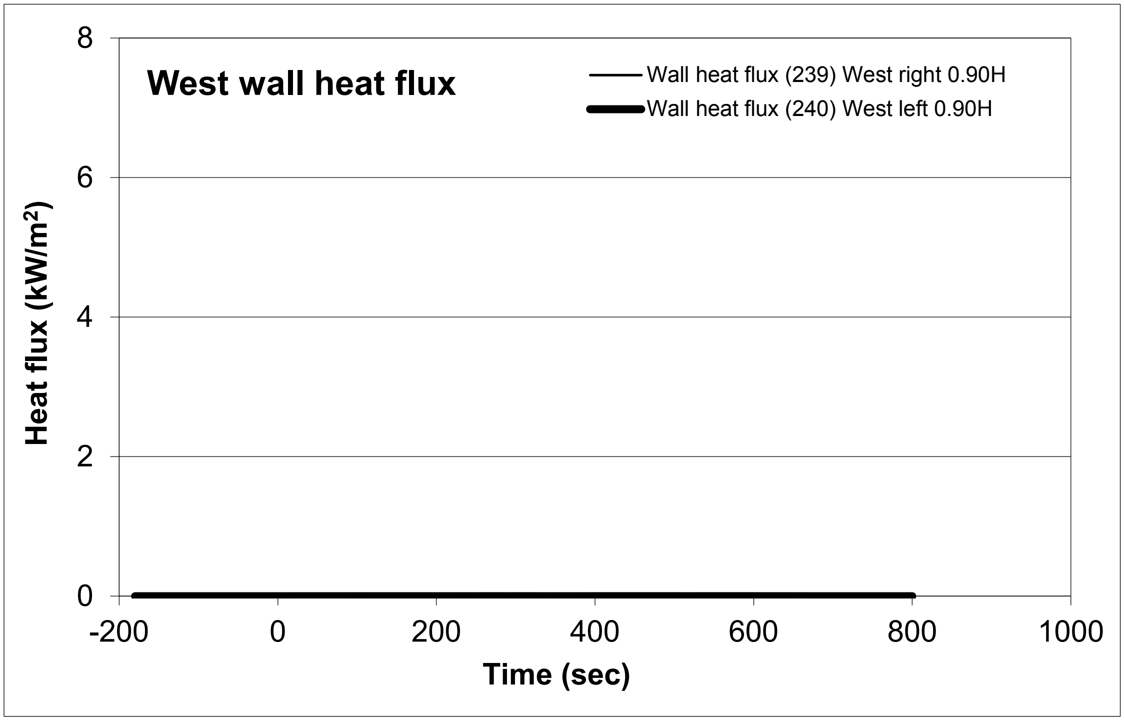

Figure B-55: Test 1 Plots of Heat Flux Channels 239 to 240

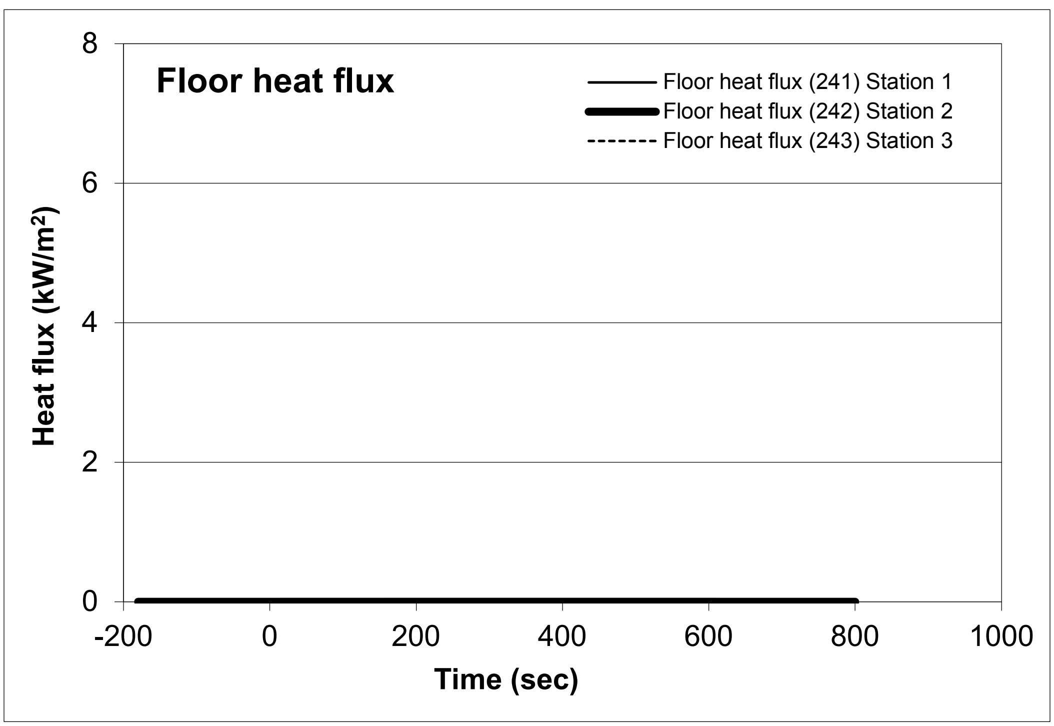

Figure B-56: Test 1 Plots of Heat Flux Channels 241 to 243

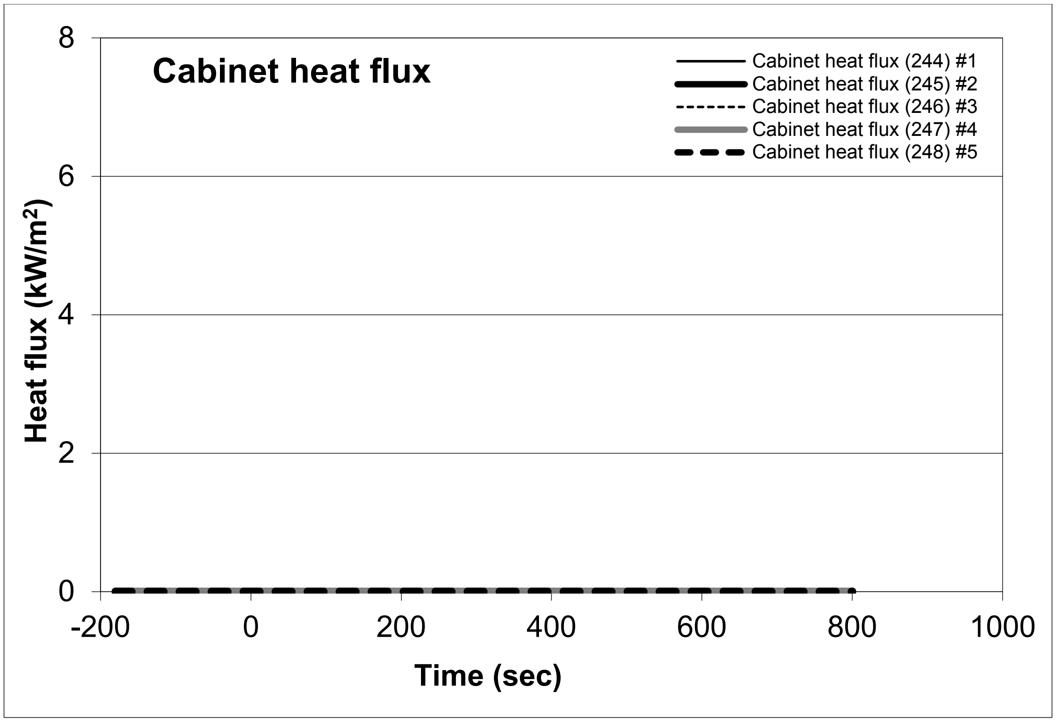

Figure B-57: Test 1 Plots of Heat Flux Channels 244 to 248

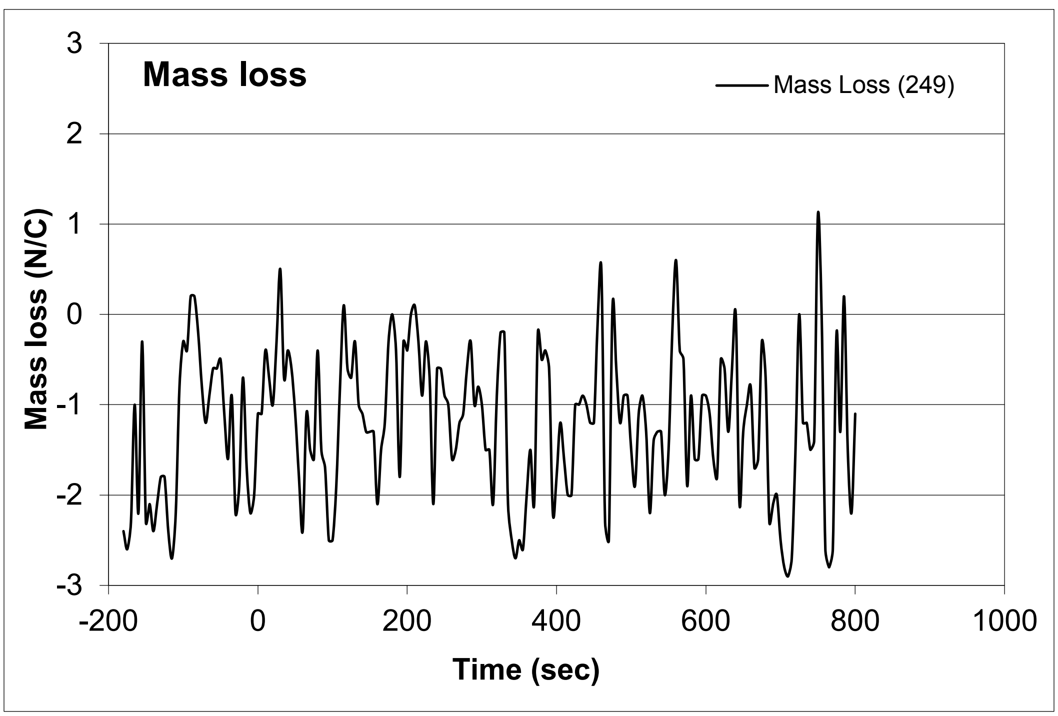

Figure B-58: Test 1 Plots of Mass Loss Channel 249

B.9 250-306 Raw Data Sheet

The ninth sheet in the data file entitled “250-306 Data”, contains the processing channels of raw data, channels #250-306. This data is used to generate the flow velocities and gas concentrations reported in the other channels. Appendix A contains details on each data channel.

B.10 Collector Report Sheet

The tenth sheet in the data file entitled “Collector Report” from the Fire Product Collector (FPC) related to the fire products and exhaust gases. Appendix A contains details on each data channel.

The enclosure exhaust gas represents only a very small fraction of the total flow through the fire products collector. The exhaust gas stream was diluted significantly by air drawn into the collector from the general enclosure. The actual gas concentration values, smoke density and temperature all represent a mixture of ambient and enclosure gas streams. Due mostly to the very large volume of the test enclosure, there is a significant lag time between the fire behavior within the room and sensing of the associated effects at the fire products collector.

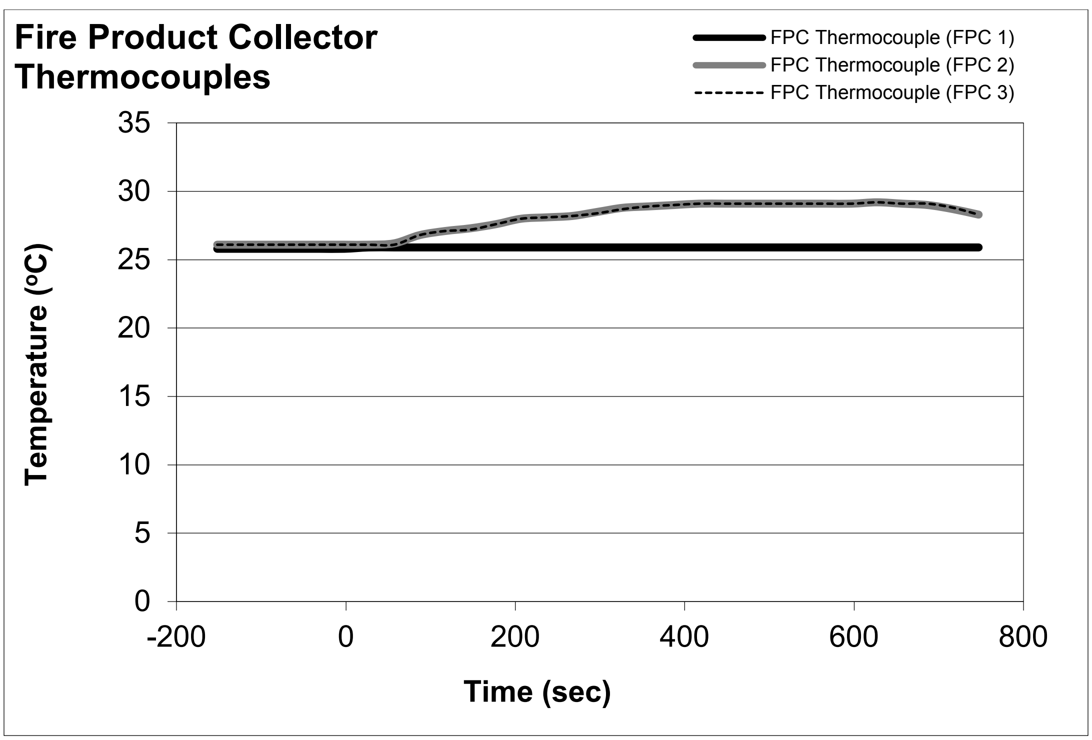

Figure B-59: Test 1 FPC Plots Thermocouple Channels FPC 1 to 3

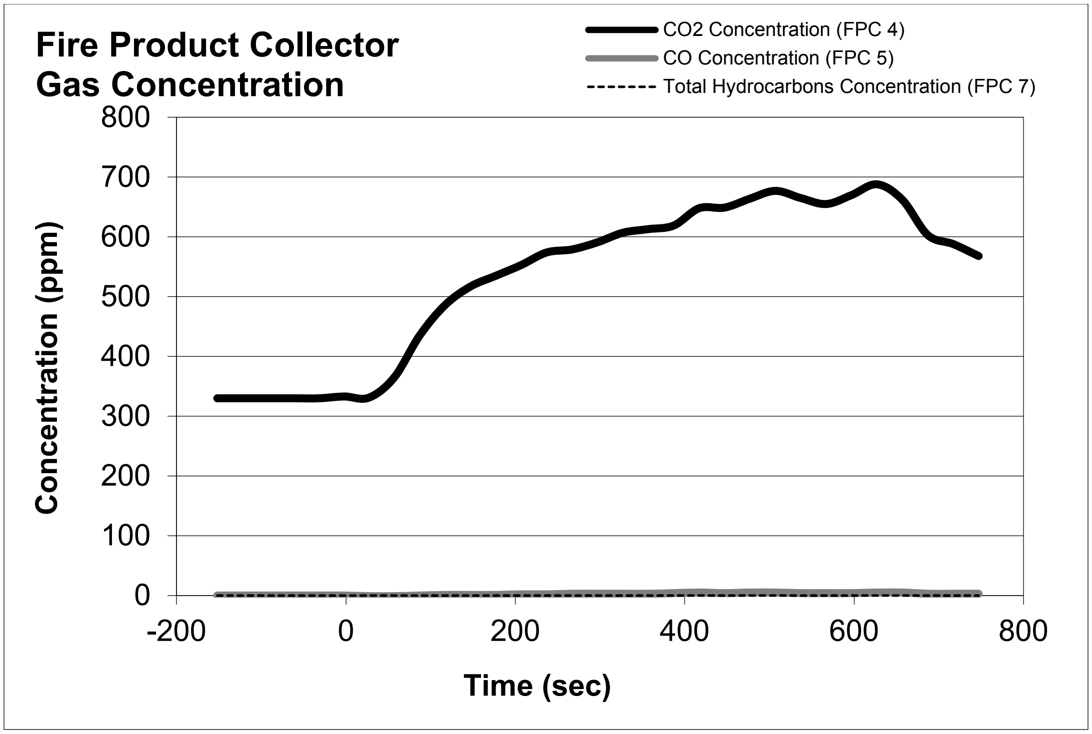

Figure B-60: Test 1 FPC Plots Gas Concentration Channels FPC 4, 5, and 7

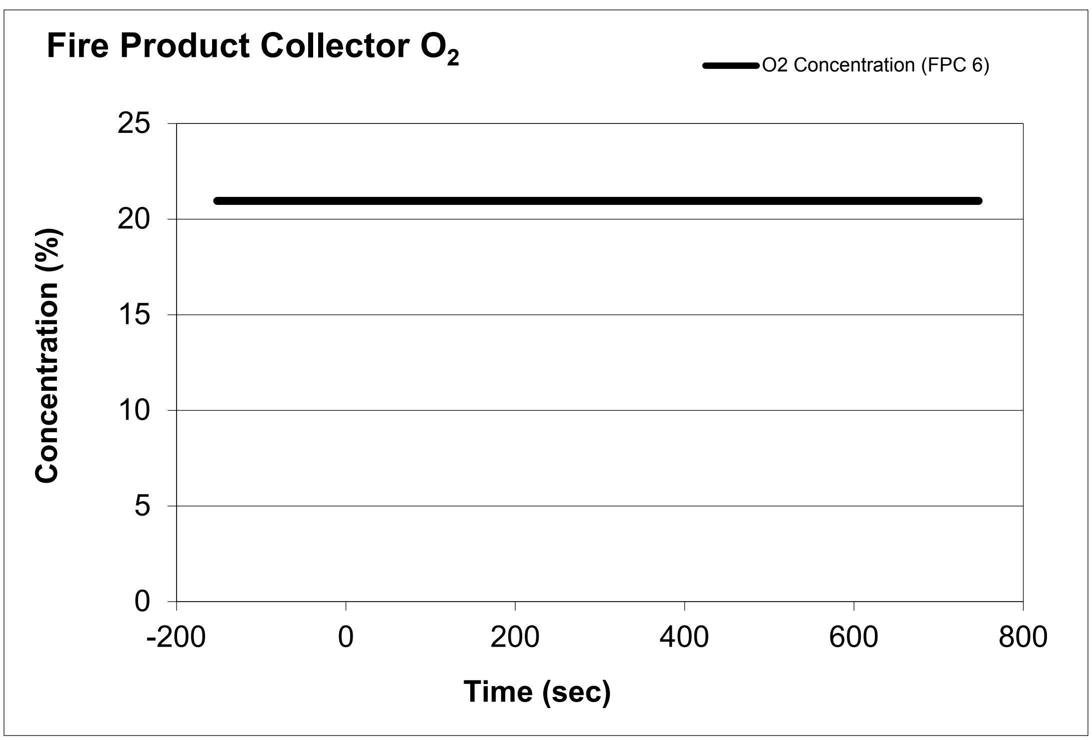

Figure B-61: Test 1 FPC Plots Oxygen Concentration Channels FPC 6

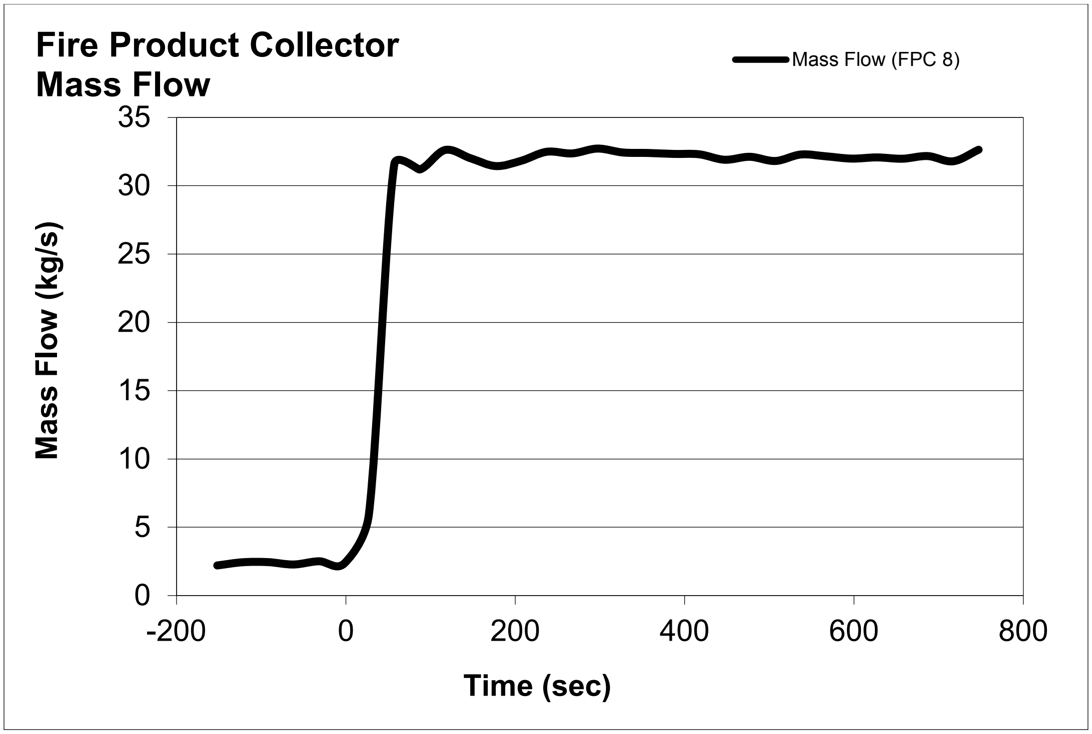

Figure B-62: Test 1 FPC Plots Mass Flow Channels FPC 8

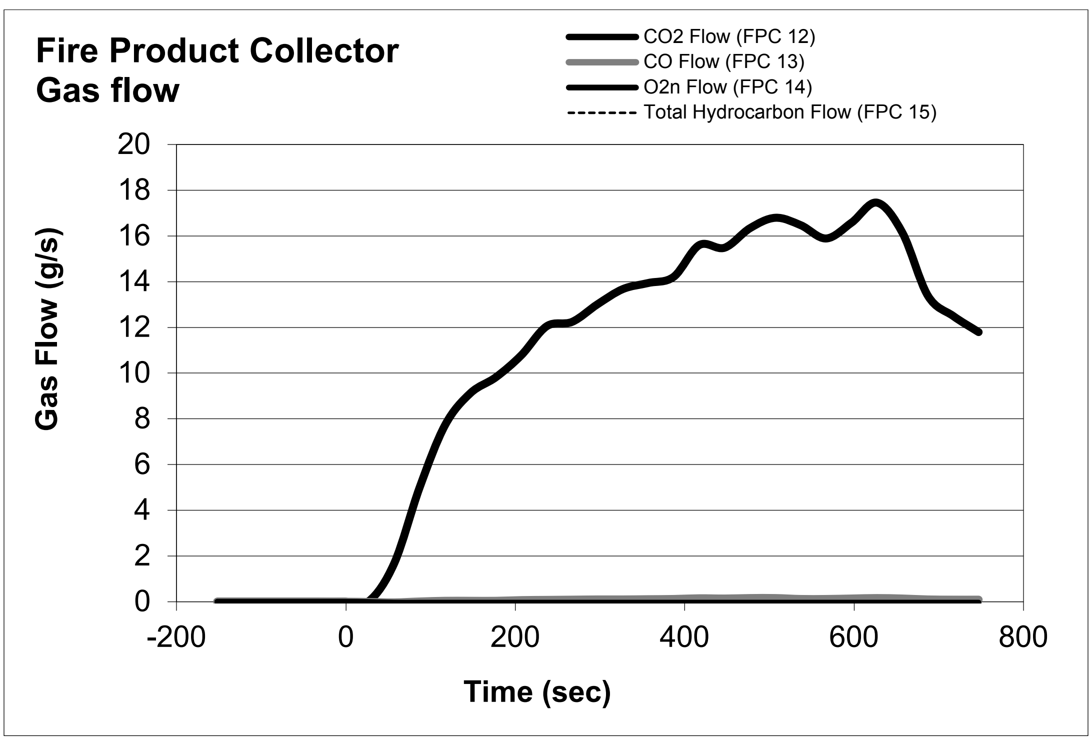

Figure B-63: Test 1 FPC Plots Gas Flow Channels FPC 12 to 15

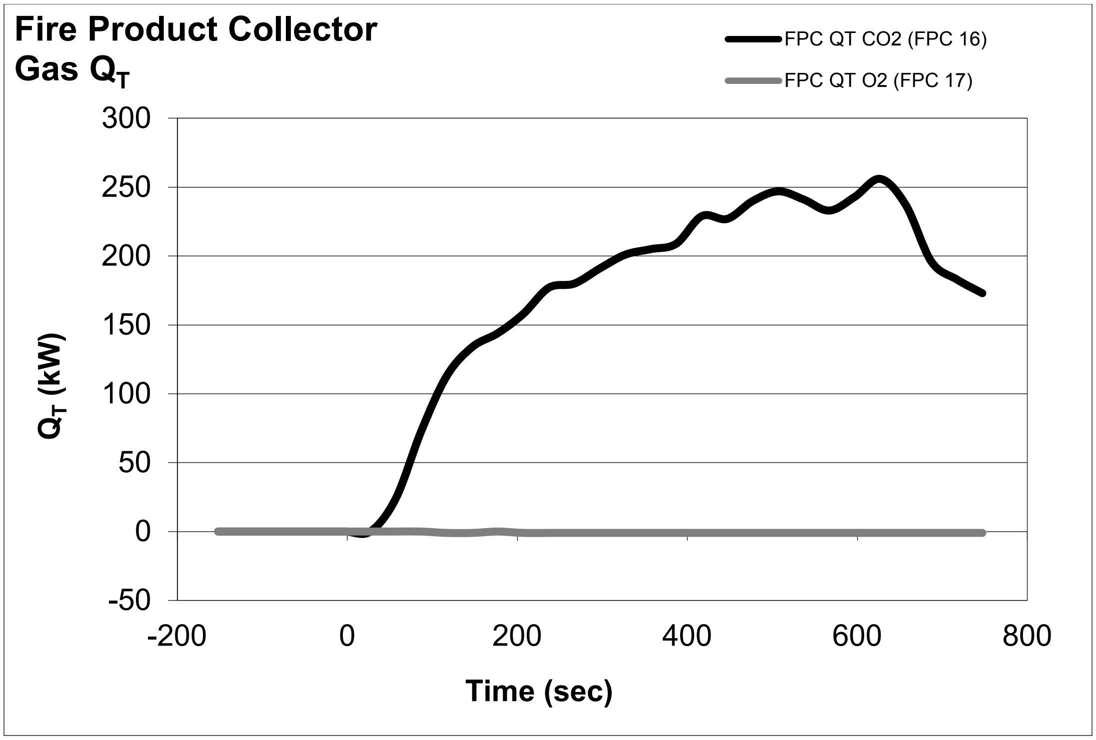

Figure B-64: Test 1 FPC Plots Gas Q_T Channels FPC 12 to 15

B.11 Heat Flux Report Sheet

The eleventh sheet, titled “Heat Flux Report” (HFR), is derived from the large and small sphere calorimeters located in matched pairs at various locations within the room to estimate the heat flux at a given location. Appendix A contains details on each data channel.

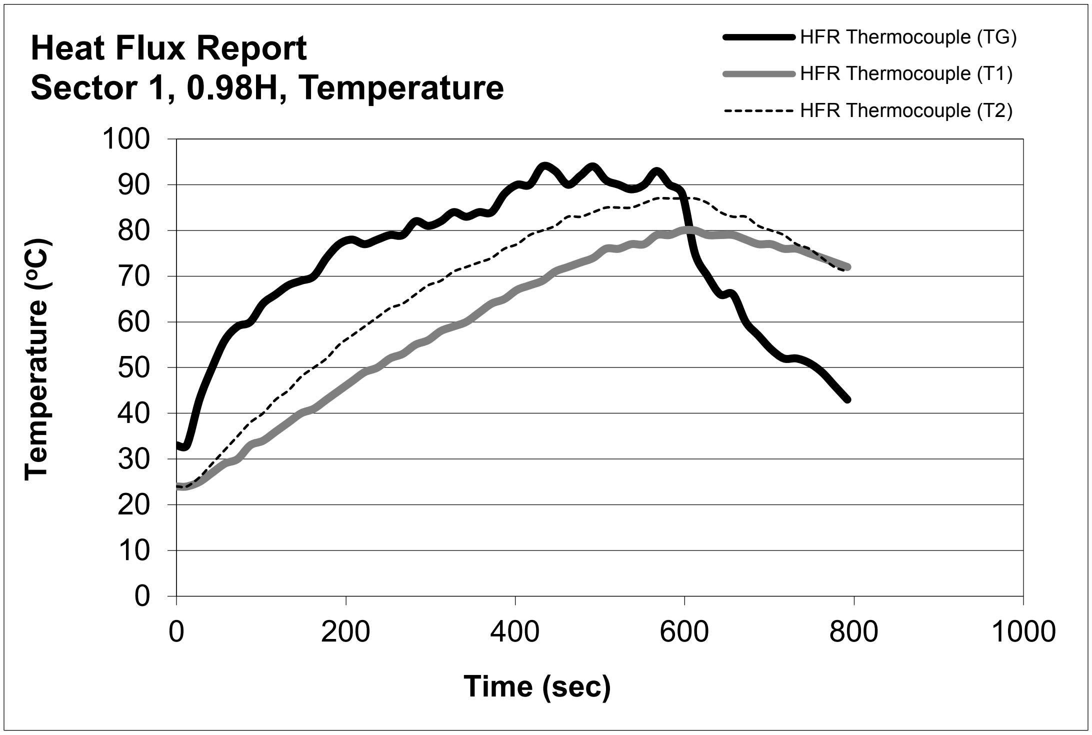

Figure B-65: Test 1 HFR, Sector 1, 0.98H, Plots Thermocouple Channels TG, T1 and T2

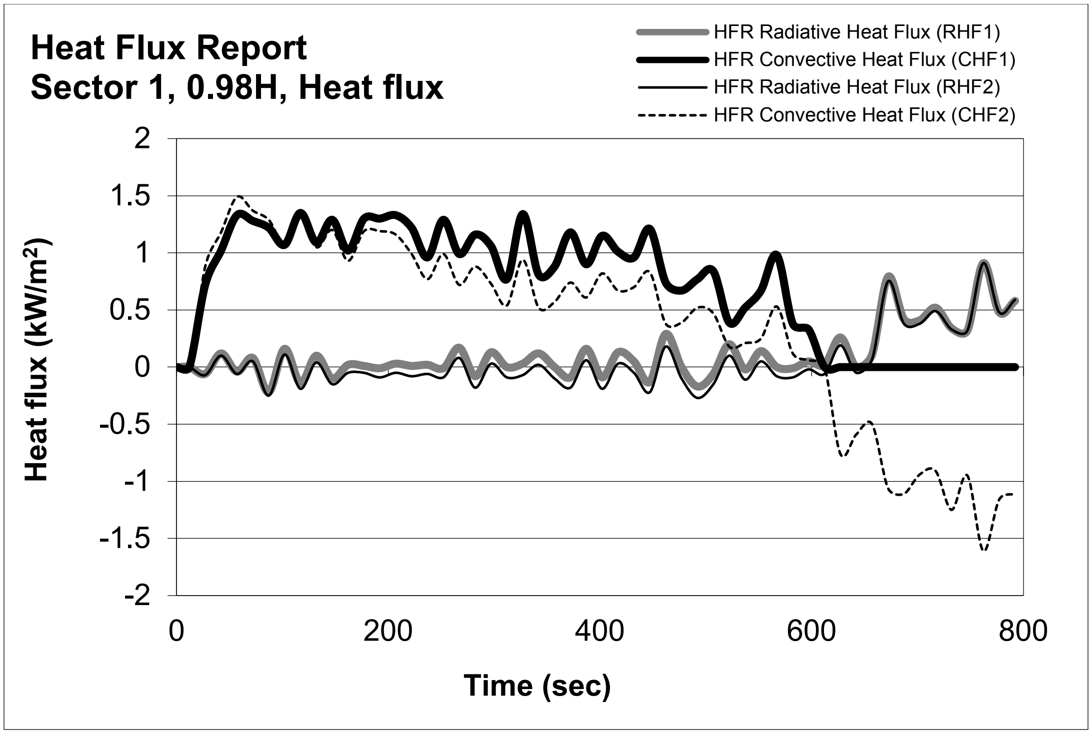

Figure B-66: Test 1 HFR, Sector 1, 0.98H, Plots Heat Flux Channels RHF1, CHF1, RHF2, and CHF2

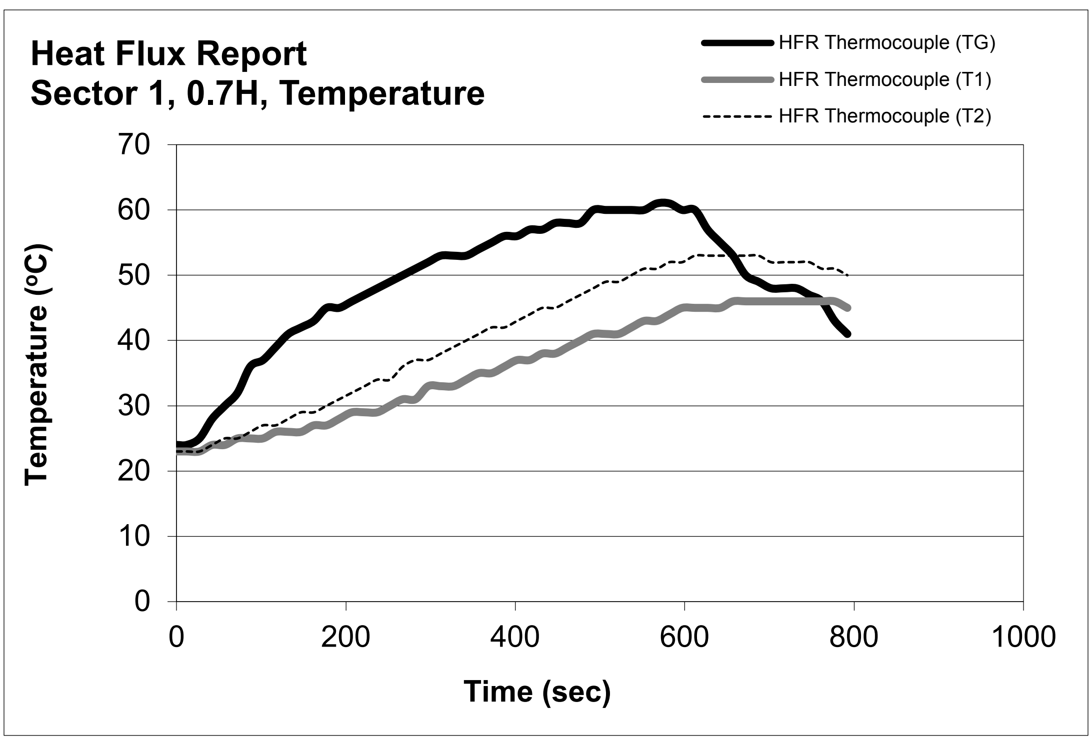

Figure B-67: Test 1 HFR, Sector 1, 0.7H, Plots Thermocouple Channels TG, T1, and T2

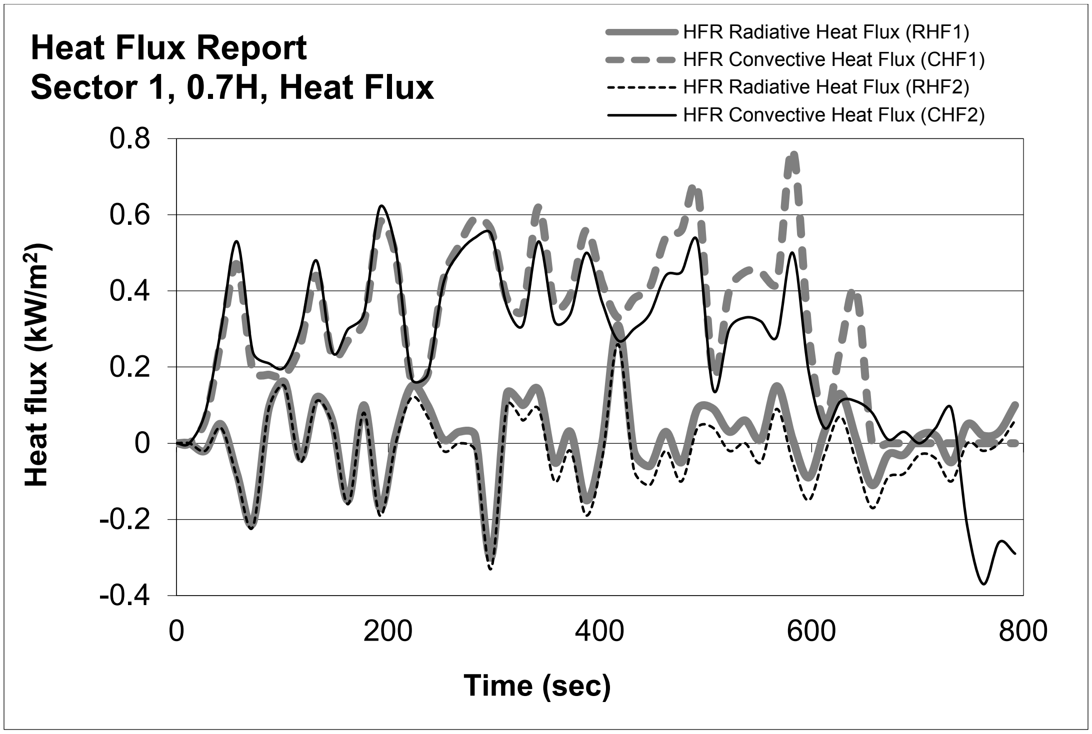

Figure B-68: Test 1 HFR, Sector 1, 0.7H, plots Heat Flux Channels RHF1, CHF1, RHF2, and CHF2

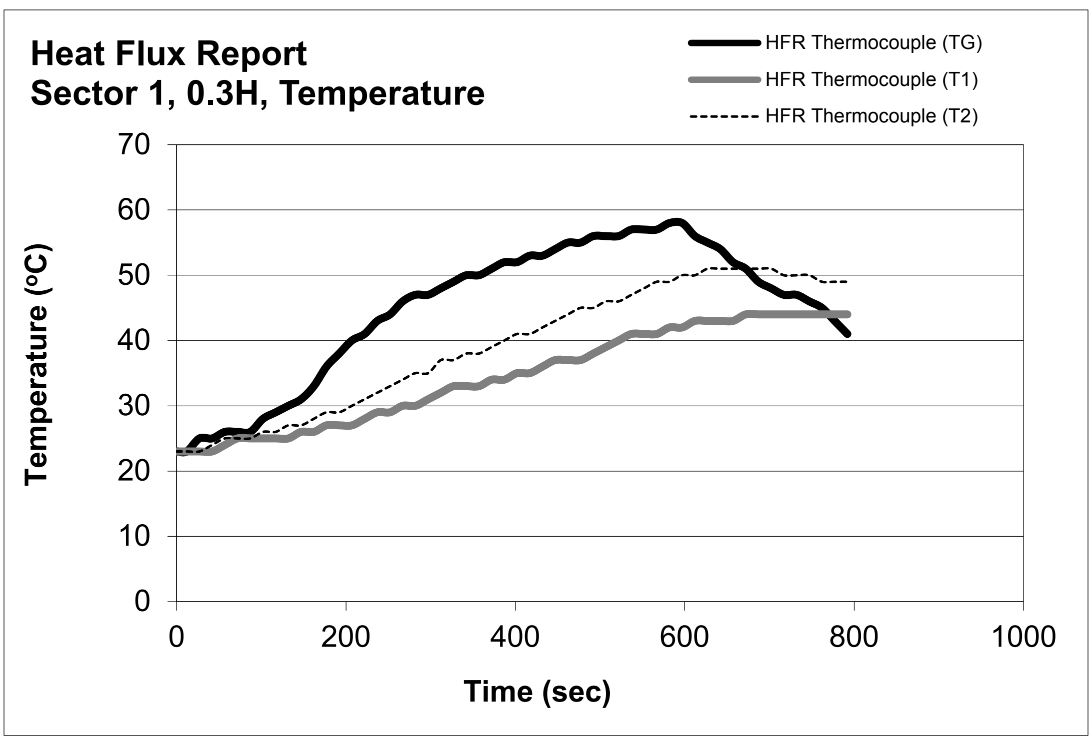

Figure B-69: Test 1 HFR, Sector 1, 0.3H, plots Thermocouple Channels TG, T1, and T2

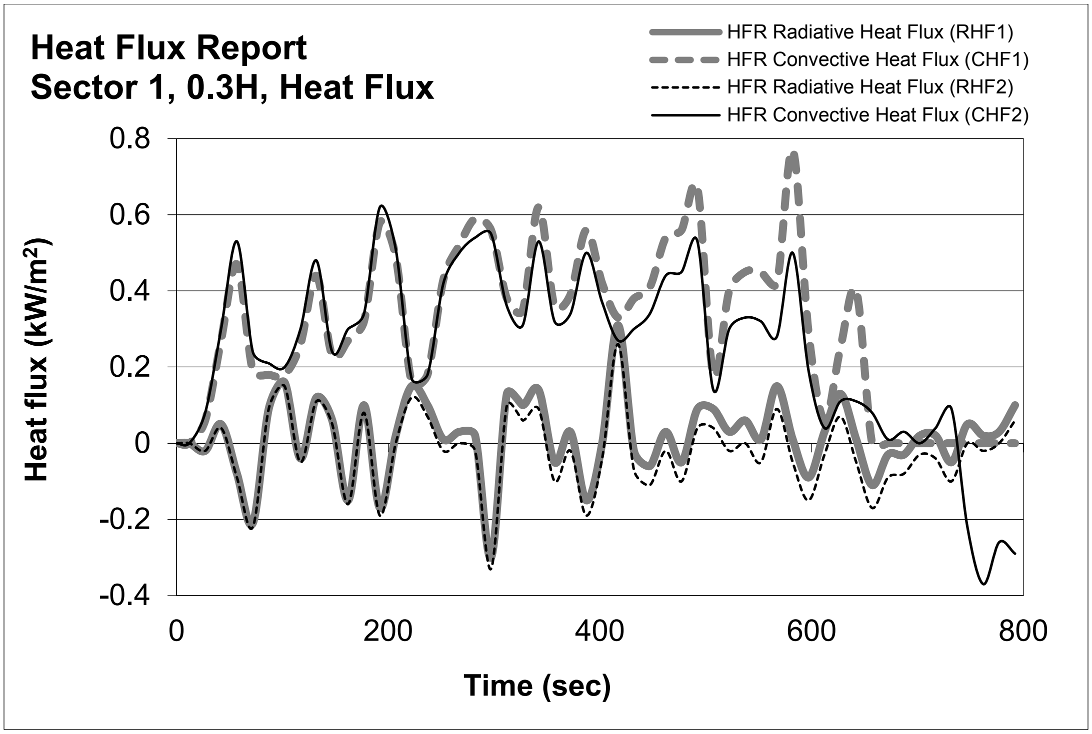

Figure B-70: Test 1 HFR, Sector 1, 0.3H, plots Heat Flux Channels RHF1, CHF1, RHF2 and CHF2

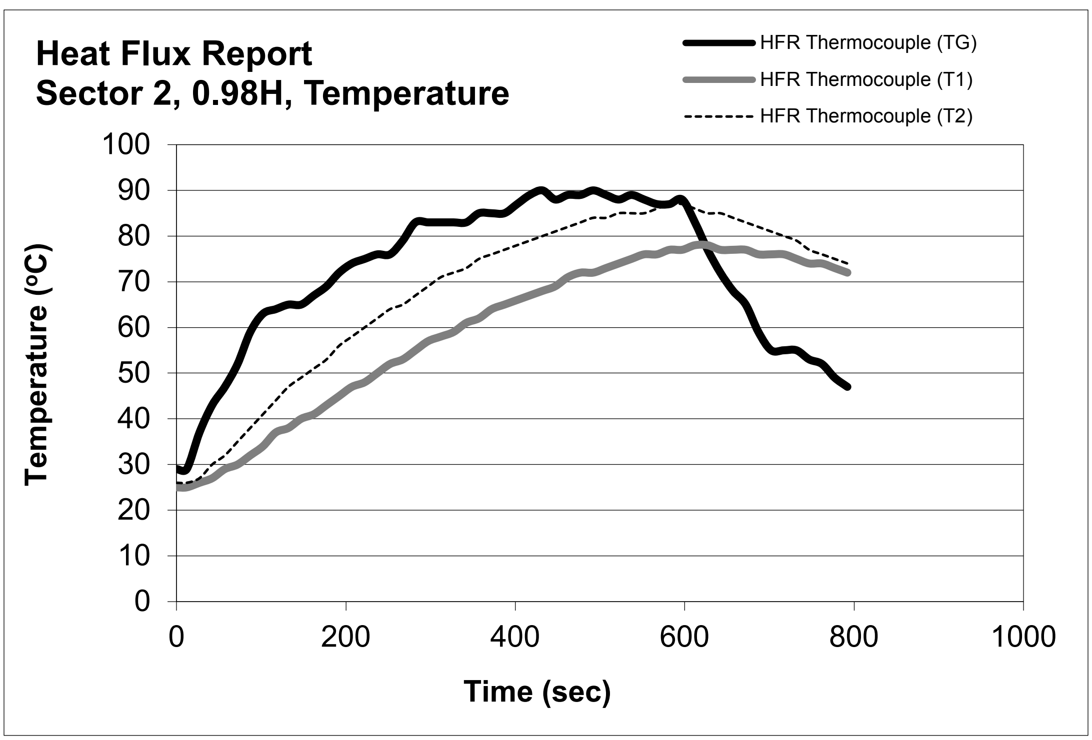

Figure B-71: Test 1 HFR, Sector 2, 0.98H, Plots Thermocouple Channels TG, T1, and T2

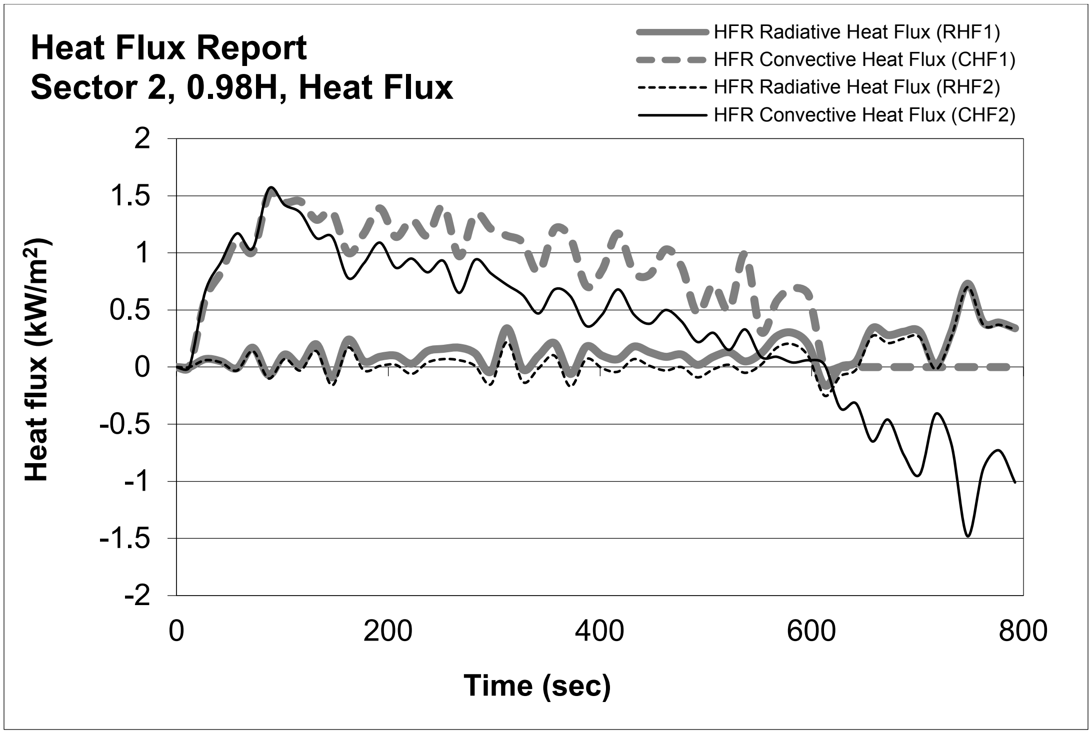

Figure B-72: Test 1 HFR, Sector 2, 0.98H, Plots Heat Flux Channels RHF1, CHF1, RHF2, and CHF2

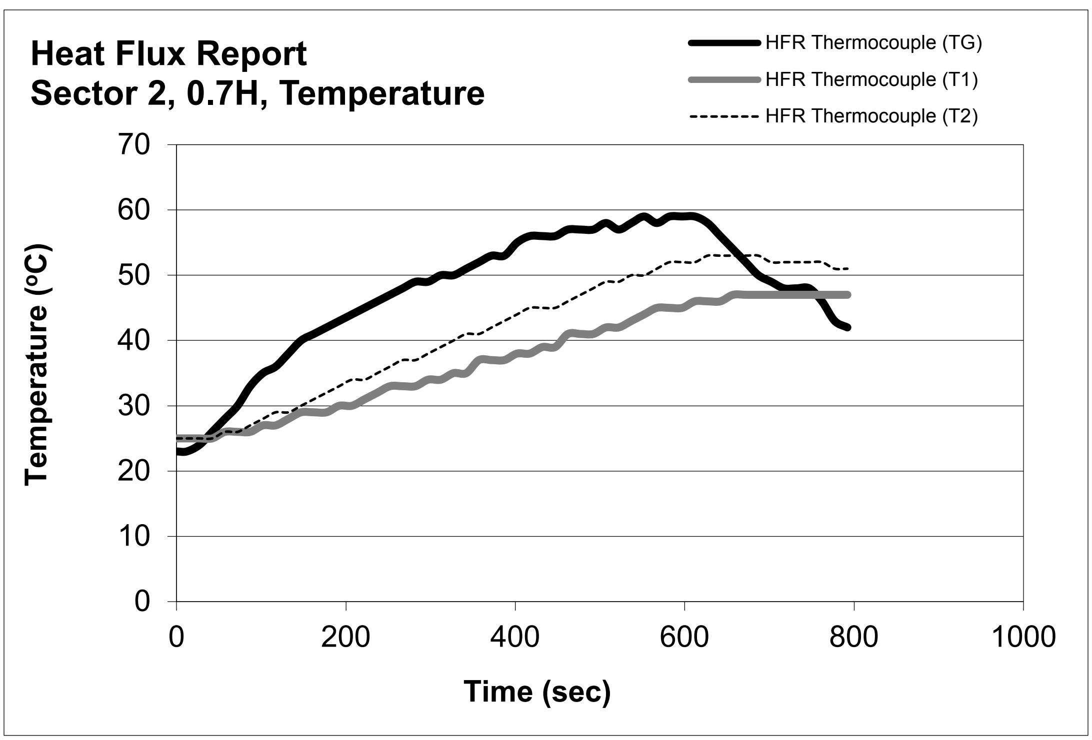

Figure B-73: Test 1 HFR, Sector 2, 0.7H, Plots Thermocouple Channels TG, T1, and T2

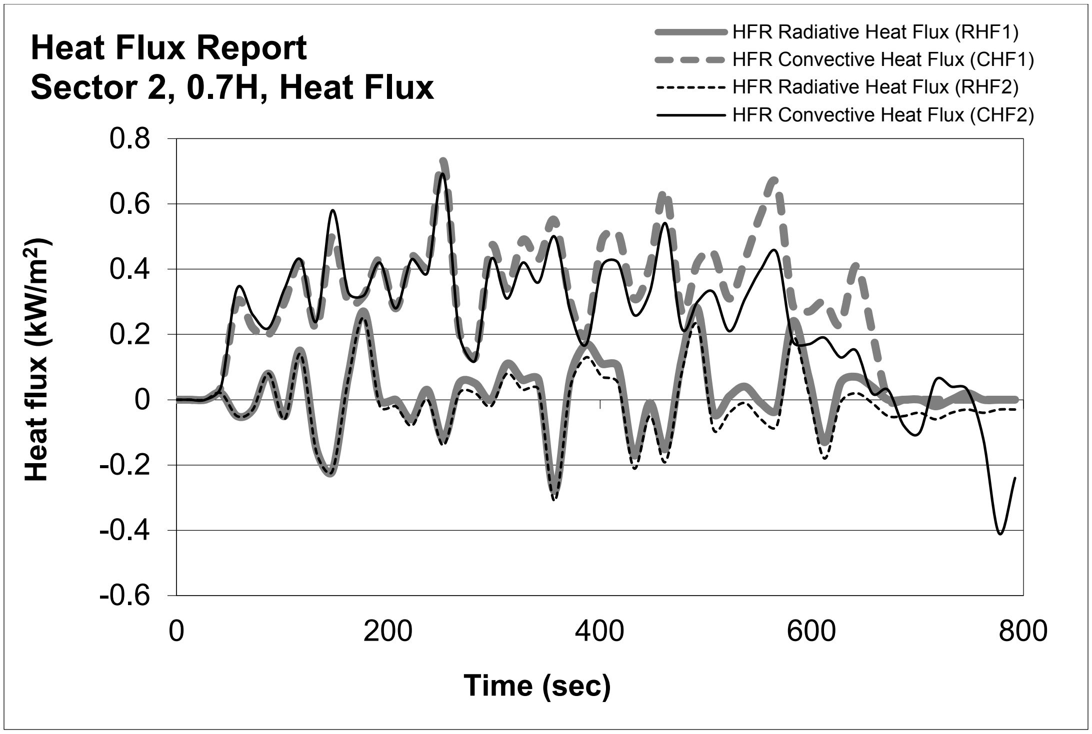

Figure B-74: Test 1 HFR, Sector 2, 0.7H, Plots Heat Flux Channels RHF1, CHF1, RHF2, and CHF2

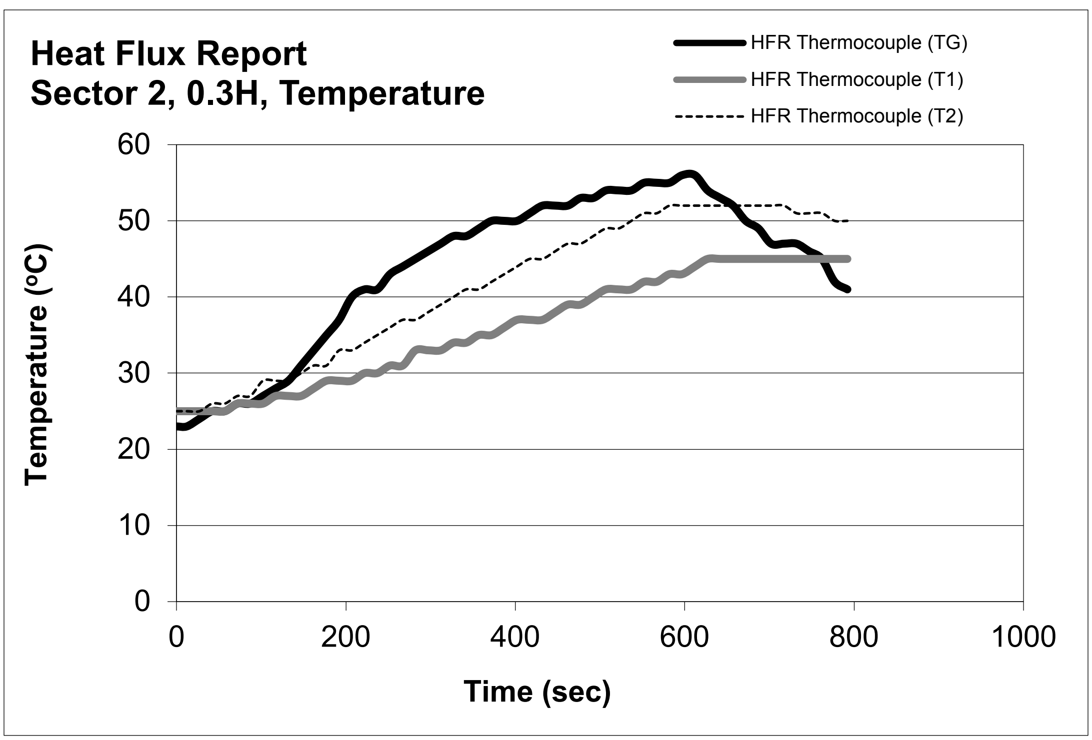

Figure B-75: Test 1 HFR, Sector 2, 0.3H, Plots Thermocouple Channels TG, T1, and T2

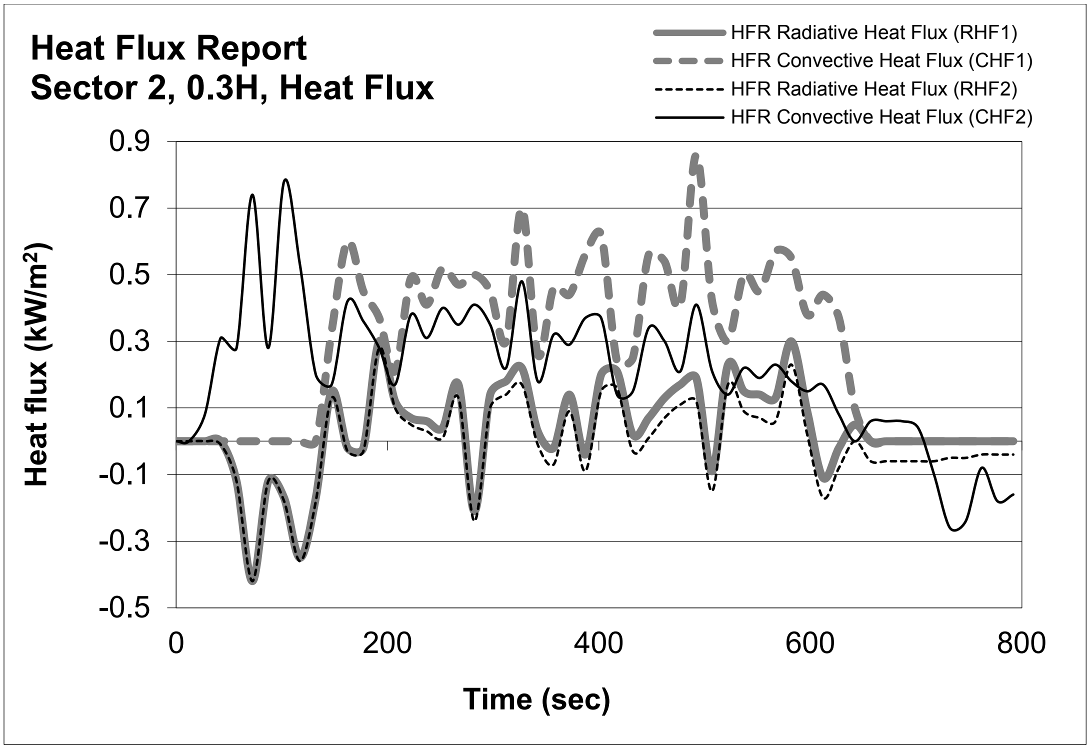

Figure B-76: Test 1 HFR, Sector 2, 0.3H, Plots Heat Flux Channels RHF1, CHF1, RHF2, and CHF2

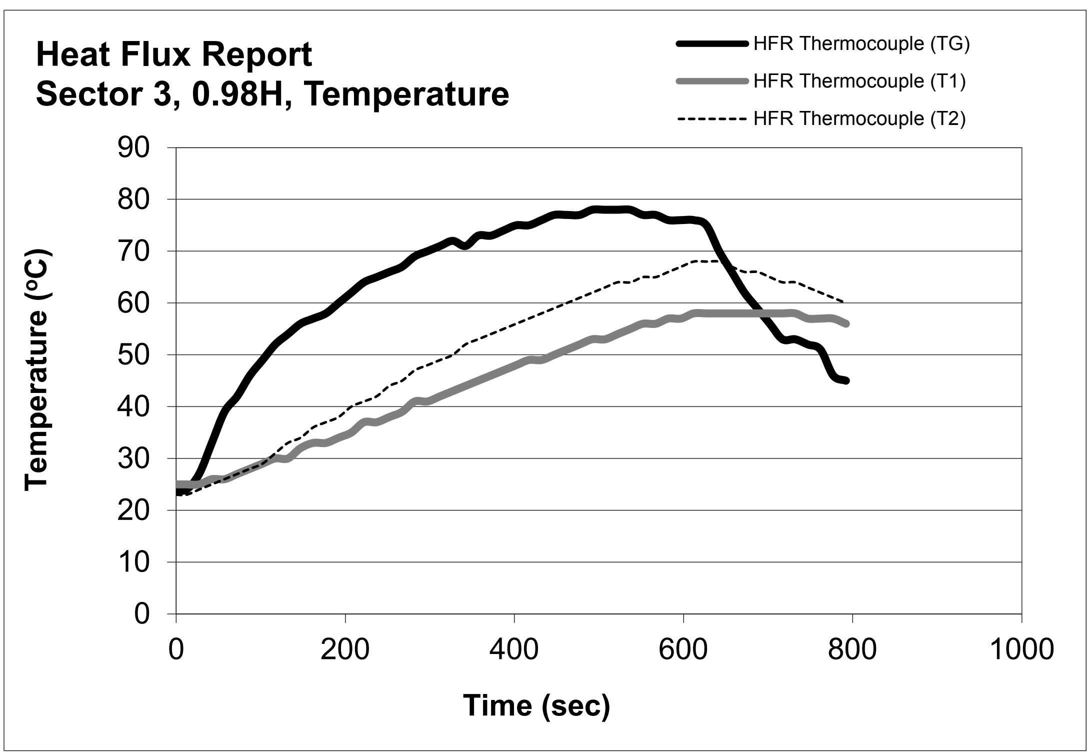

Figure B-77: Test 1 HFR, Sector 3, 0.98H, Plots Thermocouple Channels TG, T1, and T2

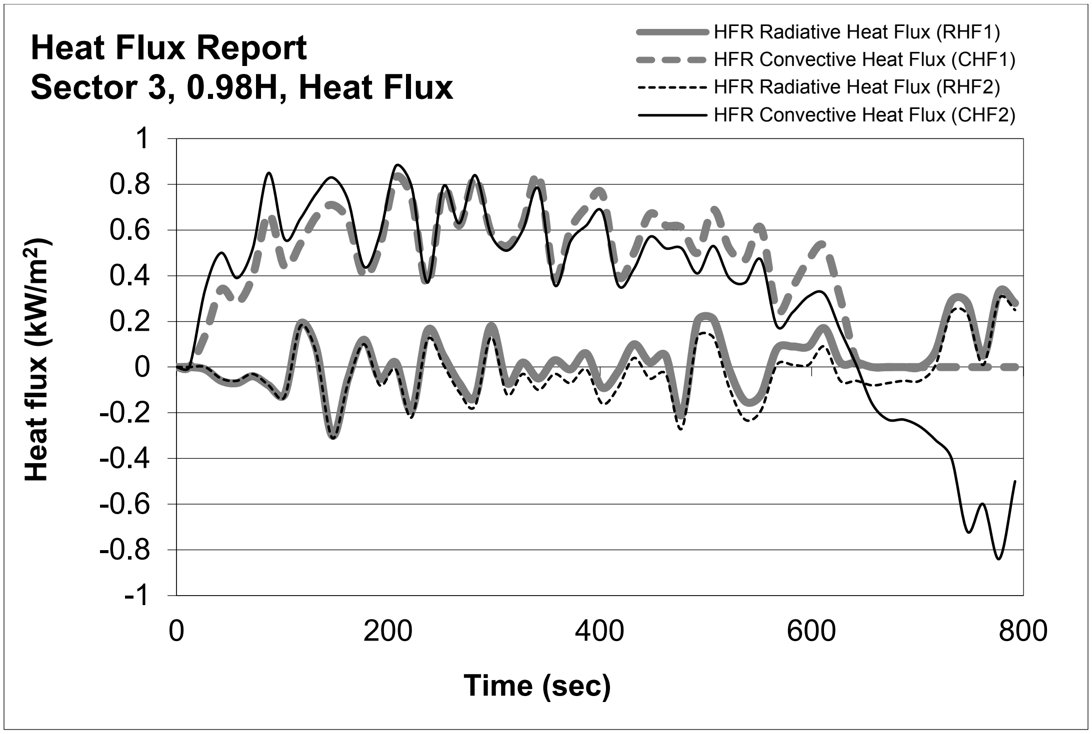

Figure B-78: Test 1 HFR, Sector 3, 0.98H, Plots Heat Flux Channels RHF1, CHF1, RHF2, and CHF2

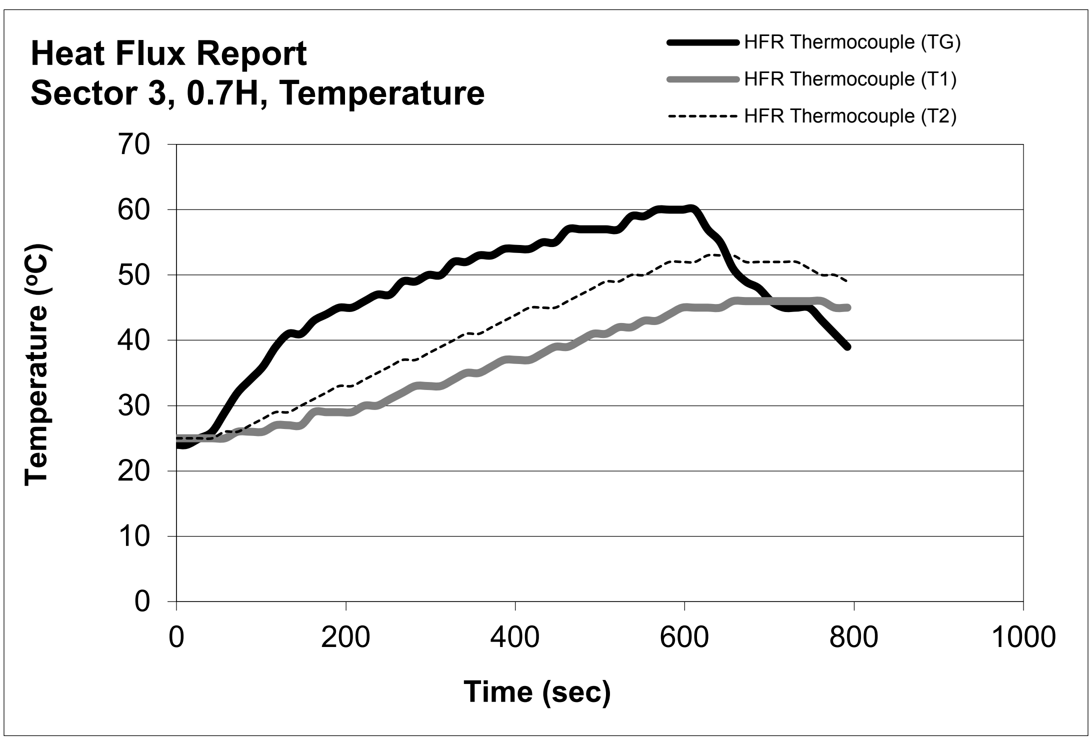

Figure B-79: Test 1 HFR, Sector 3, 0.7H, Plots Thermocouple Channels TG, T1, and T2

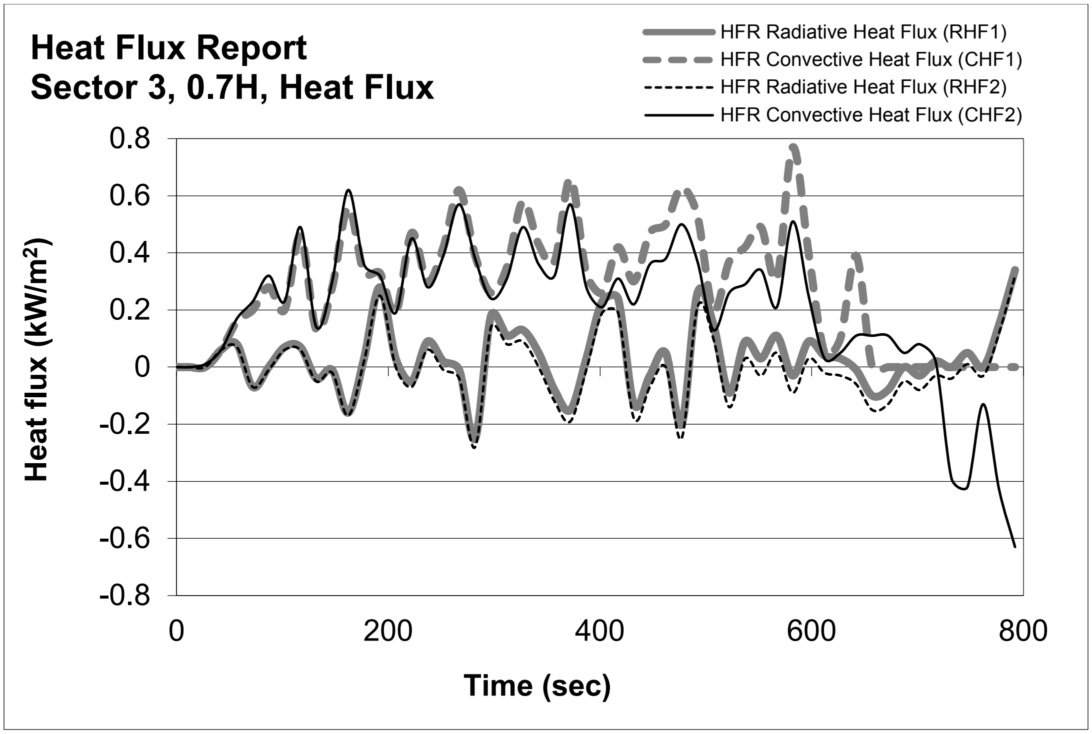

Figure B-80: Test 1 HFR, Sector 3, 0.7H, Plots Heat Flux Channels RHF1, CHF1, RHF2, and CHF2

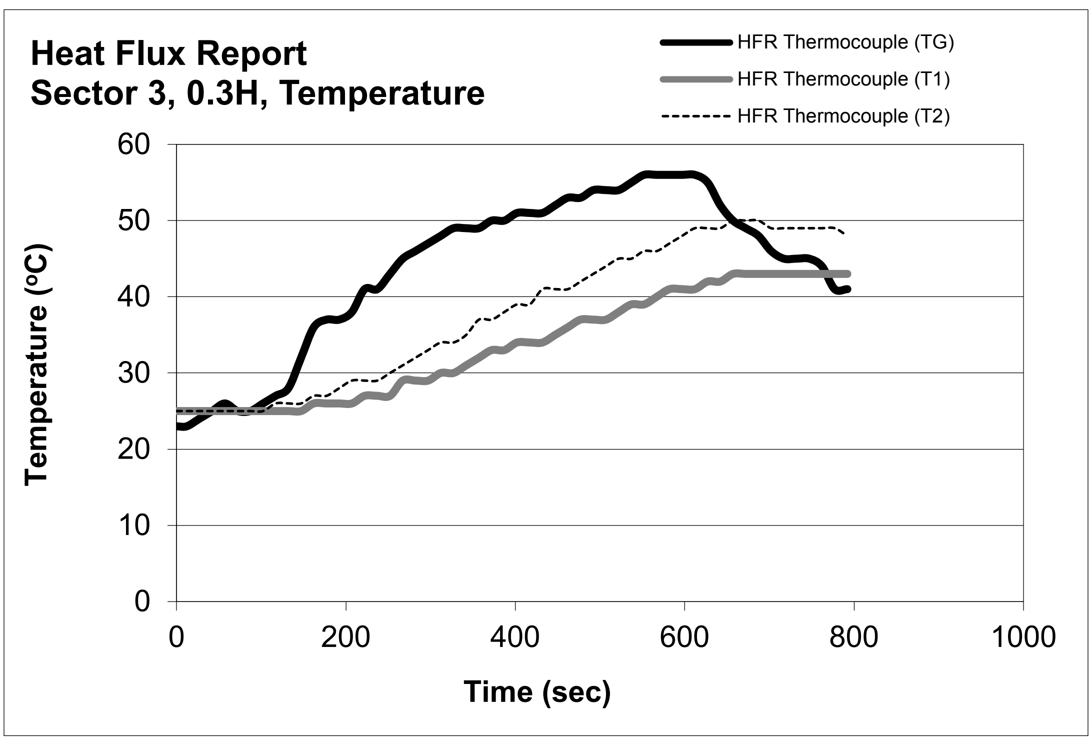

Figure B-81: Test 1 HFR, Sector 3, 0.3H, Plots Thermocouple Channels TG, T1, and T2

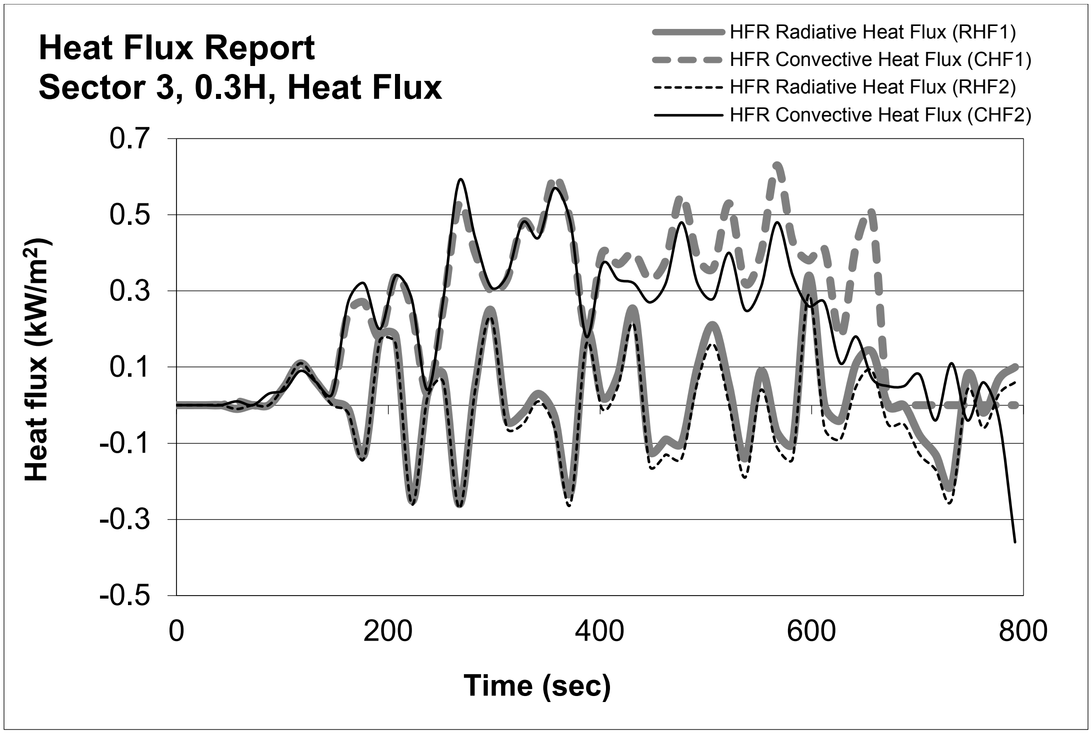

Figure B-82: Test 1 HFR, Sector 3, 0.3H, Plots Heat Flux Channels RHF1, CHF1, RHF2, and CHF2

NRC FORM 335 (12-2010) NRCMD 3.7 U.S. NUCLEAR REGULATORY COMMISSION **BIBLIOGRAPHIC DATA SHEET** *(See instructions on the reverse)*	1. REPORT NUMBER (Assigned by NRC, Add Vol., Supp., Rev., and Addendum Numbers, if any.) NUREG-2164
2. TITLE AND SUBTITLE Consolidation of the 1985 Sandia National Laboratories/Factory Mutual Main Control Room and Electrical Cabinet Fire Test Data	3. DATE REPORT PUBLISHED MONTH: May YEAR: 2015 4. FIN OR GRANT NUMBER N/A
5. AUTHOR(S) F. Gonzalez, N. Melly, S. Nowlen* and J.M. Chavez*	6. TYPE OF REPORT Technical Report 7. PERIOD COVERED (Inclusive Dates) 1985 to 1999

8. PERFORMING ORGANIZATION - NAME AND ADDRESS (If NRC, provide Division, Office or Region, U. S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.)

Division of Risk Analysis, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, and
*Sandia National Laboratories, Albuquerque, NM 87185, Operated by Sandia Corporation For the U.S. Department of Energy

9. SPONSORING ORGANIZATION - NAME AND ADDRESS (If NRC, type "Same as above", if contractor, provide NRC Division, Office or Region, U. S. Nuclear Regulatory Commission, and mailing address.)

Division of Risk Analysis
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

10. SUPPLEMENTARY NOTES

*NRC Project Manager: F. Gonzalez

11. ABSTRACT (200 words or less)

This report consolidates and refines the report's details and all the data recorded during the 1985 series of 25 main control room (MCR) fire tests performed by Sandia National Laboratories (SNL). These tests were conducted at the Factory Mutual Research Corporation (FMRC) for the U.S. Nuclear Regulatory Commission (NRC) under direct contract to SNL. The objective of these tests was to provide experimental data to validate computer fire models in the analysis of nuclear power plant (NPP) large enclosure fires. While select parts of the data have previously been reported, no single consolidated report was prepared in 1985 to produce the data in a high quality, usable manner. This report fulfills that need.

FMRC performed these fire tests in a test enclosure simulating a typical space in an NPP MCR. The test enclosure measured 18.3 meters (m) x 12.2 m x 6.1 m [60 feet (ft) x 40 ft x 20 ft]. The original program had two phases: (1) the development of fire in electrical cabinets and (2) the effect of those fires on a simulated MCR. Propylene gas burner, heptane pool, methanol pool, polymethyl methacrylate (PMMA) solids, qualified cables and unqualified cables were used as fire sources. The parameters included were fire intensity, fire location, ventilation rate, and fire burning mode. The tests recorded over 300 data channels, which included measurements such as air and surface temperature, air velocity, heat fluxes, optical smoke density, and gas concentrations.

12. KEY WORDS/DESCRIPTORS (List words or phrases that will assist researchers in locating the report.)	13. AVAILABILITY STATEMENT
Fire Protection Control Room Fire Fire Test	unlimited
	14. SECURITY CLASSIFICATION *(This Page)* unclassified *(This Report)* unclassified
	15. NUMBER OF PAGES
	16. PRICE $0.00

NRC FORM 335 (12-2010)

NUREG-2164

Consolidation of the 1985 Sandia National Laboratories/Factory Mutual Main Control Room and Electrical Cabinet Fire Test Data

May 2015