NATIONAL TRANSPORTATION SAFETY BOARD
Investigative Hearing
Washington Metropolitan Area Transit Authority Metrorail train 302 that encountered heavy smoke in the tunnel between the L'Enfant Plaza Station and the Potomac River Bridge on January 12, 2015

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EXHIBIT	
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Agency / Organization

WMATA

Title

Tunnel Ventilation Project Report Phase II July 1991

Docket ID: **DCA 15 FR 004**

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

PHASE - II

TUNNEL VENTILATION PROJECT REPORT

WMATA

Results of Prototype Development and Test Program

Prepared by

Parsons Brinckerhoff/TEMA

July 1991

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EXECUTIVE SUMMARY

This report documents the second phase of a ventilation program for the Washington Metropolitan Area Transit Authority's Metrorail subway system. The purpose of this Prototype Development and Test Program was to evaluate ways to improve the ability of the Metrorail ventilation system to control the direction of smoke movement during a fire emergency.

Recommendations

On the basis of the results of the testing program, barriers are recommended as the preferred means of redirecting tunnel airflows in the Metrorail system during fire emergencies because they were found to be:

- o Capable of redirecting tunnel airflows
- o Operationally reliable
- o Operable without motor power
- o In need of fewer modifications to the central control system than jet fans
- o Less expensive than jet fans.

It is also recommended that a pre-production or production barrier be installed in the Metrorail system for an "in service" test lasting approximately 24 months with deployments after 12 and 24 months.

Jet fans are recommended as alternatives to barriers only where tunnel geometries preclude the installation of barriers.

Tests showed that both systems meet the goal of the program in that they supply resistance to airflow sufficient to direct smoke and heat in a fire emergency. Furthermore, both systems satisfy the criteria established for acceptable systems in that they:

- o Require no additional fan shafts
- o Involve minimal civil/structural modifications
- o Have minimal impact on transit system operations
- o Are cost effective.

Background

At its inception, the Metrorail system met or exceeded the state-of-the-art ventilation criteria for transit systems and was constructed with an absolute minimum of combustible materials. In recent years, however, greater attention has been given to "life safety" throughout the industry. Therefore, the Authority decided to initiate a program to understand the available options more fully and learn what the alternatives might involve to achieve directional smoke control.

A primary concern is that the existing ventilation system does not make adequate provision for removal of hot smoke in the event of a large train fire. Two systems for redirecting the tunnel airflows, barriers and jet fans, were recommended for analysis in the report on Phase I of this program, the Ventilation System Analysis. Both of the systems described here were evaluated and tested in the Phase II study.

Barriers have not been used in vehicle tunnels before, but canvas barriers called "brattices" have been used in mining ventilation quite extensively. The barriers proposed for transit tunnels differ from those used in mining applications in that they are similar to parachutes held in place along the tunnel perimeter by air-inflated toruses and are repidly deployed on command in response to an emergency situation. Jet fans have been used in vehicle tunnels and subway systems for over forty years because they are especially suitable for the longitudinal ventilation of these spaces. The jet fans proposed for tunnel use are axial-flow fans attached to the tunnel walls.

Testing Program

The evaluation program consisted of field measurements of airflows and pressures in the tunnel. The data collected provided the aerodynamic characteristics needed to generalize the performance of the barrier and fan prototypes in typical Metrorail tunnels with steel ribbing and concrete wall linings. The findings of the current study will be used in Phase III of the Tunnel Ventilation Program as input to the design of modifications to the Metrorail system.

INTRODUCTION

Phase II of the Washington Metropolitan Area Transit Authority (WMATA) Tunnel Ventilation Program (Prototype Development and Testing) was based upon the recommendations of the Phase I Tunnel Ventilation Study (Ventilation System Analysis). The Phase I study recommended that two strategies -- barriers and jet fans -- be tested to determine whether they could be used to direct additional quantities of air past a stopped Metrorail train during an emergency. The test results indicate that barriers and/or jet fans are usable for the purpose intended. Therefore, this report is a valuable future reference for retrofit design at specific fan shaft locations.

In this program, tests were conducted to:

- o Determine whether barriers and jet fans can function safely and reliably in the Metrorail
- o Obtain the functional data required for final design of the Metrorail systemwide upgrade, for the design of the equipment (barriers and jet fans), and for the calibration or modification of the Subway Environment Simulation (SES) computer program which will become the basis for subsequent evaluation of the required ventilation modifications throughout the Metrorail.

The report includes the following sections and appendices that contain supporting data and documents:

Section 1. describes the tests conducted, including the ventilation concepts and test parameters established as the bases for these tests.

Section 2. describes the evolution of the test program and the details of actual tests conducted.

Section 3. describes the test results.

Section 4. describes the computer programs used, a separate analysis to develop the train fire heat release rate; a typical application of the results to the Metrorail; and the estimated quantities of barriers and jet fans required for the systemwide retrofit of the Metrorail.

Section 5. contains the systemwide retrofit cost estimate and the recommendations.

Section 6. contains the conclusions and the recommendations.

Appendix A includes a description of the the SES computer program.

Appendix B deals with data reduction.

Appendix C is the report on the investigation of a post-flashover model for subway trains.

Appendix D describes the data acquisition hardware.

Appendix E lists test nomenclature.

Appendix F includes test descriptions.

1. TEST OBJECTIVES

1.1 PROTOTYPE CONCEPT

Barriers

Barriers would be used, in conjunction with the existing or slightly increased tunnel ventilation fan capacity, to direct the airflows to the involved tunnel section and achieve the airflow rates necessary to control the direction of spread of smoke. The barrier test program included both a performance/deployment test series and ventilation tests.

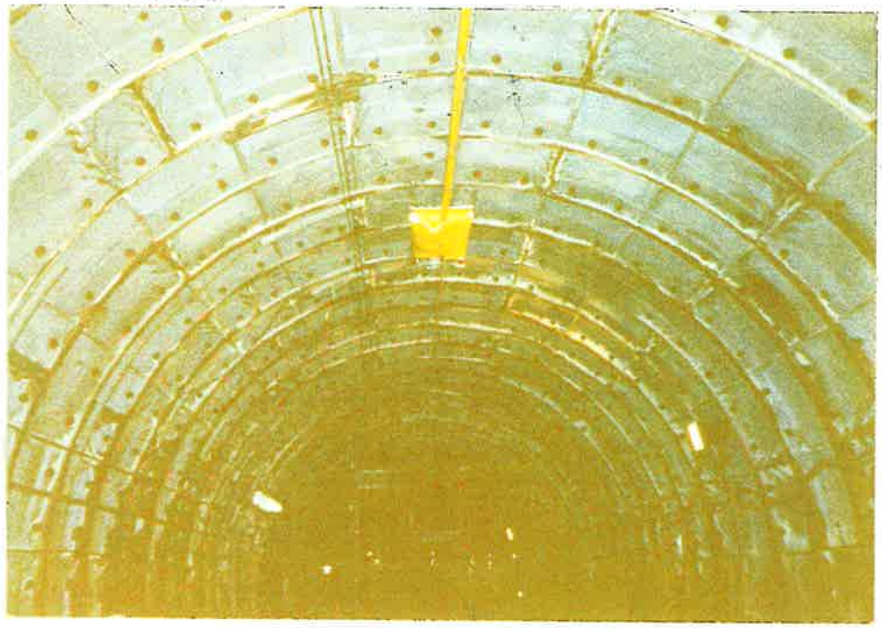
The prototype barrier (Figure 1-1) is the outgrowth of an air inflated blockage device used in mines known as a "Brattice". Once inflated, the barrier has the appearance of a parachute and will have a vertical slot in the center fabric that will provide patron egress. The Sheldahl Corporation has been the principal developer of this type of device, using fabrics and films currently used in a variety of aerospace and defense products. (Sheldahl has developed a number of other tunnel blockage devices including the Inflatable Air Block for WMATA in 1985.)

The Phase I Report [14] stated that three barriers would be required for a test since three barriers would be deployed during a typical fire emergency. However, the more detailed evaluation done during Phase II provided an assurance that a test could be accomplished with one barrier rather than three. This arrangement allowed the tests to include the effects of barriers being deployed in the other trackways without installing them, thus reducing the number of barriers required for a test by two-thirds, as well as the test instrumentation and the work effort required. The one barrier was located in the same trackway as the stopped train but on the opposite side of the fan shaft (Figure 1-4). Temporary dampers were installed in the fan shaft to restrict the flow of air into the fan shaft from the tunnel legs for the other track. The tests were performed in some instances with and without dampers to extend the range of information gathered.

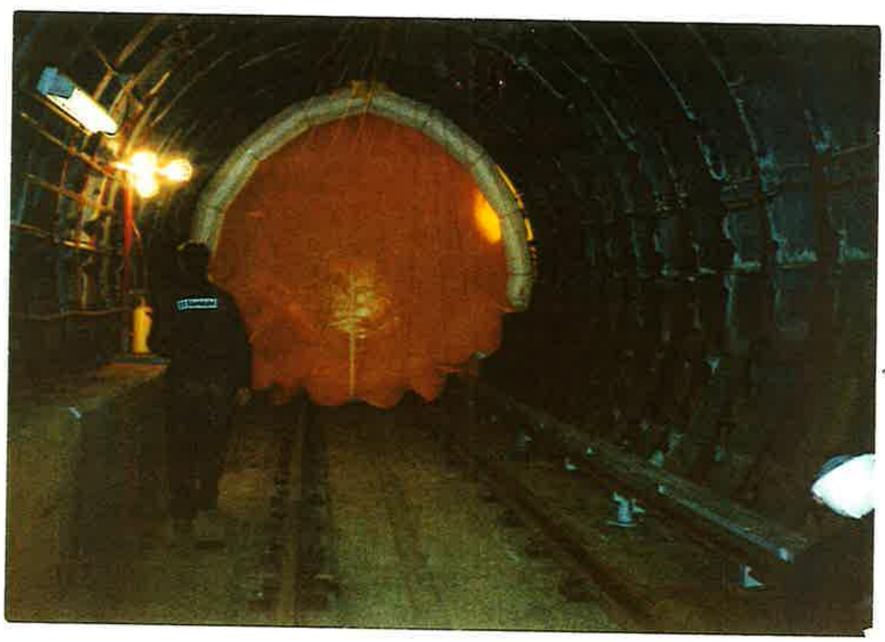
Only one barrier was used for the tests. Four or more barriers would be installed permanently in the event that barriers turn out to be the best alternative for a tunnel section.

Jet Fans

Jet fans were used to achieve results similar to those achieved by the barriers by directing sufficient airflow to



BARRIER STORED



BARRIER DEPLOYED

FIGURE 1-1 PROTOTYPE BARRIER

the affected tunnel. During a typical fire emergency, at least three sets of jet fans would be expected to operate.

Jet fans have been installed in approximately 50 highway tunnels world-wide in the last 40 years. They were installed in two sections of the Pittsburgh Light Rail Transit System in 1985 and in the Singapore Mass Rapid Transit System in 1987. Questions concerning equipment safety and reliability have been resolved. Therefore, these issues would be addressed during final design by using proven specifications and conducting factory and start-up tests.

The Phase I Report suggested that the test program would require three sets of jet fans, each set having six 16-inch diameter jet fans. However, during Phase II, a more detailed evaluation indicated that the tests could be accomplished with only one set of jet fans (Figure 1-2). This set was comprised of four 24-inch diameter jet fans delivering 21,000 cubic feet per minute (cfm).

One set of jet fans could be used because dampers were installed in the fan shaft to restrict the flow of air into the fan shaft from the tunnel legs on the other trackway without installing two sets of fans on the other track. This arrangement reduced the number of jet fans required for a test by three-quarters, as well as the test instrumentation and the work effort required.

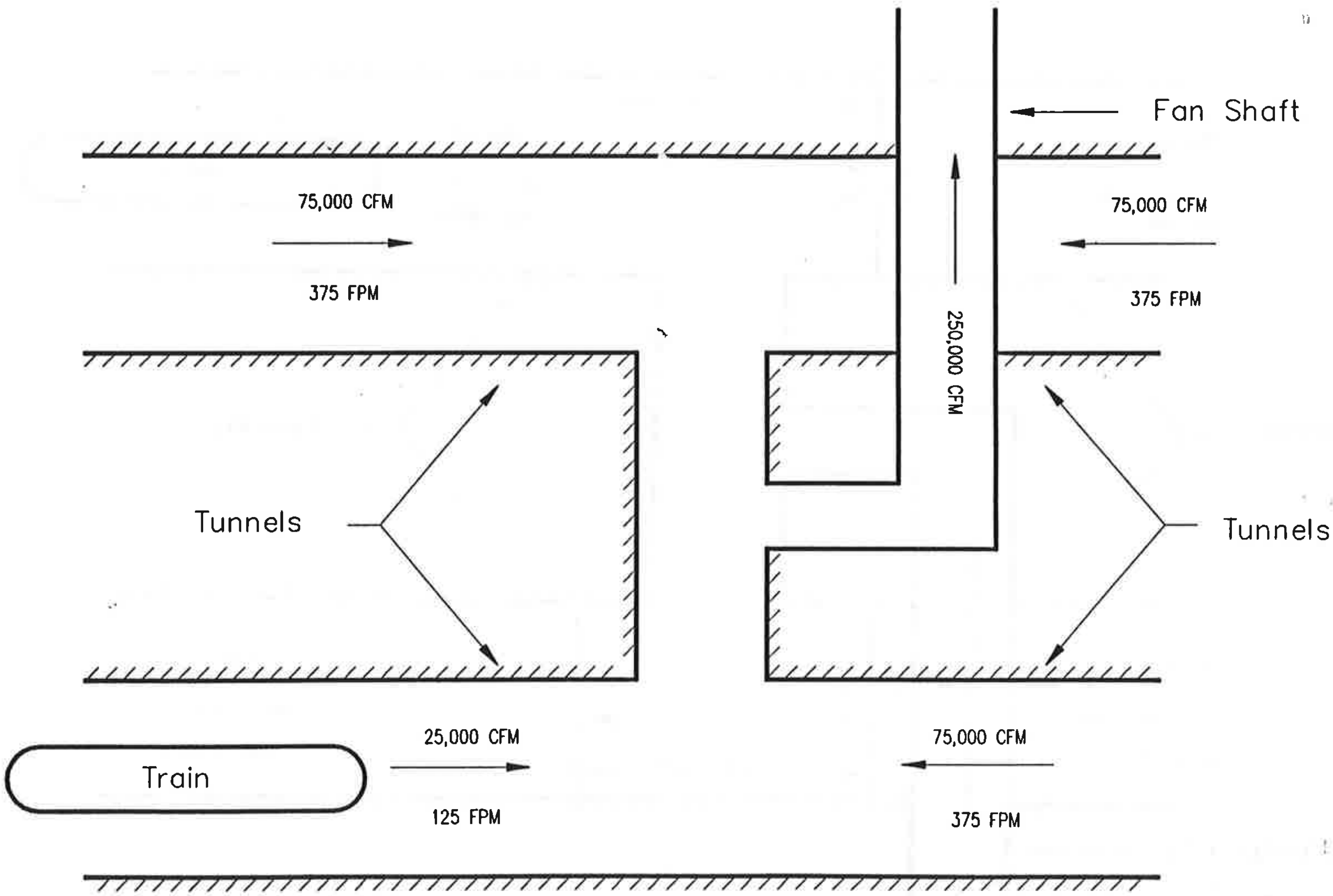
The four 24-inch diameter jet fans were used only for the tests. Smaller jet fans would be installed permanently in the event that jet fans turn out to be the best alternative for a particular tunnel configuration. The number of jet fans and their size would be determined during final design based on the differential between the existing air tunnel airflows and those to be achieved.

1.2 VENTILATION CONCEPT

The current configuration (Figure 1-3) shows the anticipated airflow pattern in the tunnels adjacent to a fan shaft when 250,000 cfm of air is being exhausted through the fan shaft and a train is stopped in the tunnel. Since the unaffected tunnels are open, the quantity of air is being directed past the train is estimated to be 25,000 cfm, which provides an approximate tunnel air velocity of 125 feet per minute (fpm) - less than desired.

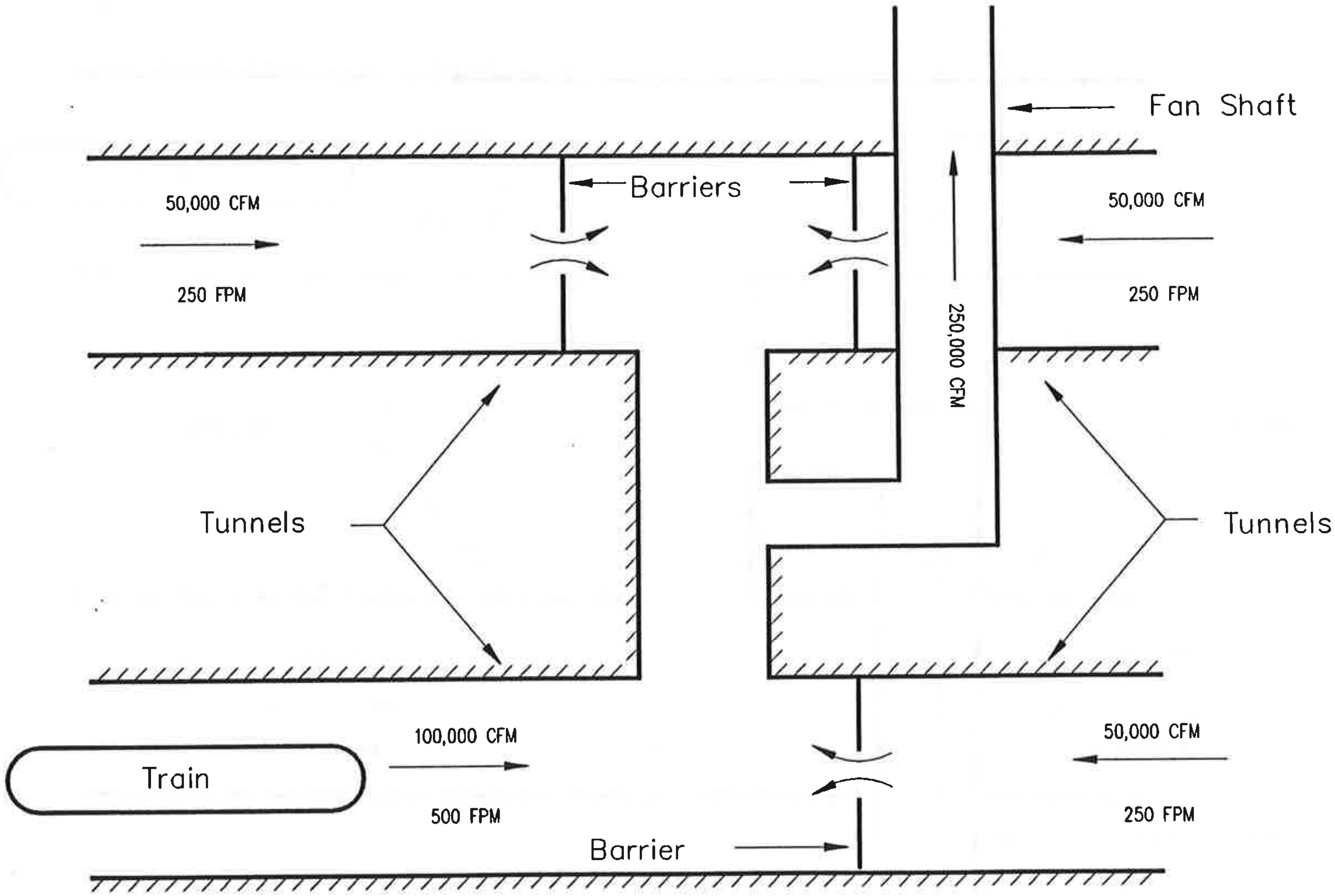
Figure 1-4 shows the anticipated airflow pattern in the tunnels adjacent to a fan shaft when 250,000 cfm of air is being exhausted through the fan shaft, a train is stopped in a tunnel, and barriers are deployed in the other, unaffected, tunnels. The barriers increase the resistance to airflow in their tunnels. The net effect is more airflow

FIGURE 1-2 JET FAN



Typical Tunnel Airflows without Barriers

FIGURE 1-3



Typical Tunnel Airflows with Barriers

FIGURE 1-4

directed past the train. The airflow past the train is, therefore, estimated to be 100,000 cfm, which provides an estimated tunnel air velocity of 500 fpm - approximately what is desired. It is anticipated that barriers would be installed in all the tunnels adjacent to the ventilation shaft, but the barrier in the affected tunnel would not be deployed since it would then reduce airflow past the incident train.

Jet fans would be used to accomplish objectives similar to those achieved by the barriers. They would increase the resistance to airflow in specific tunnel segments by discharging a high velocity jet of air against the tunnel airflow. For the tunnels shown in Figure 1-4, jet fans instead of barriers would be installed in each tunnel. For the circumstance shown, the jet fans in the unaffected tunnels would be operated with their discharge directed away from the fan shaft against the tunnel airflow. The net effect, as in the case of the barriers, is more airflow directed past the train.

1.3 VENTILATION TEST PARAMETERS

The Phase II test program confirmed that barriers and/or jet fans are suitable for forcing additional quantities of air past a stopped Metrorail train during an emergency. In addition, the test program involved the accurate collection of airflow and static pressure measurements for the barriers and jet fans. These measurements provide the basis for inputs to the Subway Environment Simulation (SES) computer program that will allow subsequent evaluation of the required ventilation throughout the Metrorail.

Two series of tests were involved primarily: basic tests that provided a number of measurement factors that form the basis for the remainder of the test program, and individual airflow and static pressure measurements involving the actual equipment. The air velocities and pressures were measured with an accuracy of plus or minus five percent.

Basic Tests

The purpose of the basic tests was to determine:

- o The single point measurement factors for the ribbed wall tunnel and the smooth wall tunnel in the tunnel and the ventilation shafts.
- o The friction factors for the ribbed wall tunnel and the smooth wall tunnel. These include the effects of ribs, fire lines, conduits and signaling devices.

- The pressure loss coefficient of the jet fan supports.

The basic tests also provided experience for the remaining tests in the areas of logistics, instrumentation and communication. The single point measurement factor and the friction factor are mathematically defined in Appendix B.

Barrier Tests

The barrier tests determined the relationship between the static pressure differential across the barrier and the airflow through it. For a rigid barrier having an opening of known size, theory and previous experiments have shown the relationship is a constant times the airflow velocity pressure. However, the barrier tested is not rigid and the size of the opening may vary with the airflow. Furthermore, the air leakage through the borders of the barrier is different for a circular tunnel than for a rectangular tunnel. Therefore, full-scale experimental tests were necessary for both types of tunnels to determine the static pressure-airflow relationship, which is mathematically described in Appendix B.

Jet Fan Tests

Experiments in vehicular tunnels [8] have shown that the jet fan pressure efficiency varies as a function of:

- The distance from the center line of the jet fan to the tunnel wall
- The tunnel wall roughness - smooth and ribbed
- The longitudinal spacing of the jet fans along the tunnel.

Unfortunately, experimental data does not exist for the ranges of these parameters that exist in the Metrorail. Therefore, the jet fan pressure efficiency had to be measured so that it can be input into the design process accurately. To study the effect of the tunnel wall roughness on the jet fan pressure efficiency, two general groups of tests were performed: ribbed wall tunnel tests and smooth wall tunnel tests.

The efficiency also varies as a function of the jet fan discharge air velocity. However, the discharge air velocity selected for these tests is similar to that of the jet fans that would be installed.

Double-Track Tests

The purpose of the double-track tunnel tests is to measure the effect columns have on the distribution of airflow between two adjacent trackways, one of these containing a stopped train. Previous scale model tests [1] were made for a double-track tunnel having no columns. These tests showed that the air velocity on each side of the train was essentially the same even if the train was eccentrically located in the tunnel. For example, the tests showed that for a 30-foot-wide tunnel having a 10-foot-wide train, the air velocity on each side of a train 3 feet from one wall and 17 feet from the other was about the same. The double-track tests would confirm this effect in full scale.

1.4 DATA REDUCTION

Data reduction is the process used to transform the raw test data into data for input to subsequent tests or to the SES computer program during implementation. The specialty computer programs developed for this purpose are described below and their mathematical development are presented in Appendix B.

The input to each computer program was a raw test data file or the output of a previous program. The output of each computer program was a file for input to a subsequent computer program, and/or for printing or plotting into a table or figure used in this report, or eventually for SES input. The calculations included the effects of ambient pressure, temperature and humidity on air density and viscosity.

The friction factor program used the field-measured friction factors and air velocities to develop the equivalent relative roughness of the tunnel by a least-squares curve fit using Colebrook's Formula. The resulting equivalent relative roughness was then input to the remaining computer programs.

The barrier program used the equivalent relative roughness and the field-measured air velocities and pressure changes across the barrier to compute the barrier head loss coefficients. The output was the barrier head loss coefficient as a function of the tunnel air velocity.

The jet fan mounting program used the equivalent relative roughness and the field-measured air velocity and pressure change across the jet fan mountings to compute its output, the jet fan mounting head loss coefficient. The results were organized in file, table and figure form as a function of the distance between jet fan mounting spacings.

The jet fan pressure efficiency program used the equivalent relative roughness, the jet fan airflow and discharge velocity, the jet fan mounting head loss coefficients, and the field-measured air velocity and pressure change to compute the jet fan pressure efficiency. These results were organized in file, table and figure form as a function of the spacing between jet fans and the distance from the centerline of the jet fans to the tunnel wall.

2. TEST PROGRAM

The Test Program included two types of tests:

- **Equipment Tests.** These tests demonstrated that the equipment related to the alternative ventilation systems had structural, functional, mechanical and electrical integrity, and that it would function as intended in the subway system in accordance with WMATA's safety, reliability, maintainability and operating requirements.

- **Ventilation Tests.** These tests involved the accumulation of data on airflow and air pressure measurements sufficient for the design of a tunnel ventilation system that would meet the ultimate objective of increasing the fire safety of the system.

2.1 EVOLUTION OF DECISIONS LEADING TO FINAL TEST PROGRAM

This program grew out of studies, field tests, and site investigations commissioned by WMATA. The aim of the investigations was to evaluate the ability of the Metrorail ventilation systems to control the movement of smoke during a fire emergency. The conclusions led to a three-phase program.

Phase I, the study phase of the program, included:

- Review of prior studies

- Development of ventilation strategies (or concepts) and assessment of their anticipated effectiveness

- The identification of locations in the Metrorail where field test of viable concepts could be conducted.

Phase II, the analytical phase of the program was based on the results of the Phase I work, and it included:

- Design of the field test program and related system modifications

- Implementation of the testing program

Phase III, the implementation phase, will include the design of modifications predicated upon the findings of the Phase II program. These modifications will then be implemented throughout the Metrorail system to achieve desired ventilation performance objectives.

Criteria for Ventilation Strategies

The ventilation strategies considered in the Phase I Report [14] for improving smoke control in the running tunnels had to satisfy the following criteria:

- o No additional fan shafts
- o Minimal civil/structural modifications
- o Minimal construction impact on transit system operations
- o Cost-effective solutions.

Phase I Report Highlights

The highlights of the Phase I findings and recommendations are summarized below.

Airflows. Earlier studies had identified the airflows required to meet the ventilation criteria for controlling the movement of smoke and heat in a fire emergency. In Phase I (report pages 12-13), these airflows were determined to be less than previously suggested.

Heat Release Rates. A need was identified to develop a more detailed approach to estimate the train fire heat release rate.

Blockage Devices. The deployment of blockage devices -- used to direct ventilation airflow to the fire site -- appeared to provide a cost-effective solution to the problem of achieving effective control of smoke and heat in a fire emergency. The Phase I report suggested that further consideration be given to the following issues before making a firm commitment to the application of such barriers:

- o The technical feasibility of using them
- o Their compatability with overall operational safety and maintenance requirements.

Jet Fans. Jet fans appeared to approach the performance capability of blockage devices for smoke control in a fire situation and thus were considered to be a viable alternative. Jet fans, however, were thought to be more costly to implement than blockage devices.

Test Sites. The tunnel section between McPherson Square and Metro Center Stations was recommended as the location for performing both the single-track and double-track test program, based on the analyses performed during Phase I. The prototype tests to be conducted at this site were intended to:

- o Demonstrate the viability of the recommended ventilation strategies and their required physical modifications.

- o Permit "fine-tuning calibration" of the SES computer program. The test results would allow the SES computer program to be applied to all other existing or future sections of the Metrorail to determine the required modifications, if any, necessary to achieve the emergency ventilation objectives.

2.2 TEST SITE LOCATIONS

The Phase I Report recommended that Phase II testing be conducted in the revenue service tunnel section between Metro Center and McPherson Square stations on the Blue/Orange lines because this site represented the need for significant attention to fire life safety. The initial test program was developed around this tunnel section.

Subsequently, as the schedule for testing was finalized, WMATA made additional locations available in tunnel sections not yet in revenue service. Testing in these tunnels provided longer, more time-efficient test periods. The tests that were eventually conducted at three sites are listed below.

At 7th and I Streets SW Fan Shaft (Figure 2-1)
- -- Barrier Equipment Tests
- -- Ribbed Wall Tunnel Friction Factor
- -- Jet Fan Tests-Ribbed Wall Tunnel
- -- Jet Fan Equipment Drag Tests Ribbed Wall Tunnel

At N.Y. Avenue Fan Shaft (Figure 2-2)
- -- Barrier Ventilation Tests
- -- Ribbed Wall Friction Factor Tests
- -- Single Point Measurement Factor experiment

At Blueridge Avenue Fan Shaft (Figure 2-3)
- -- Smooth Wall Tunnel Friction Factor Tests
- -- Jet Fan Tests-Smooth Wall Tunnel

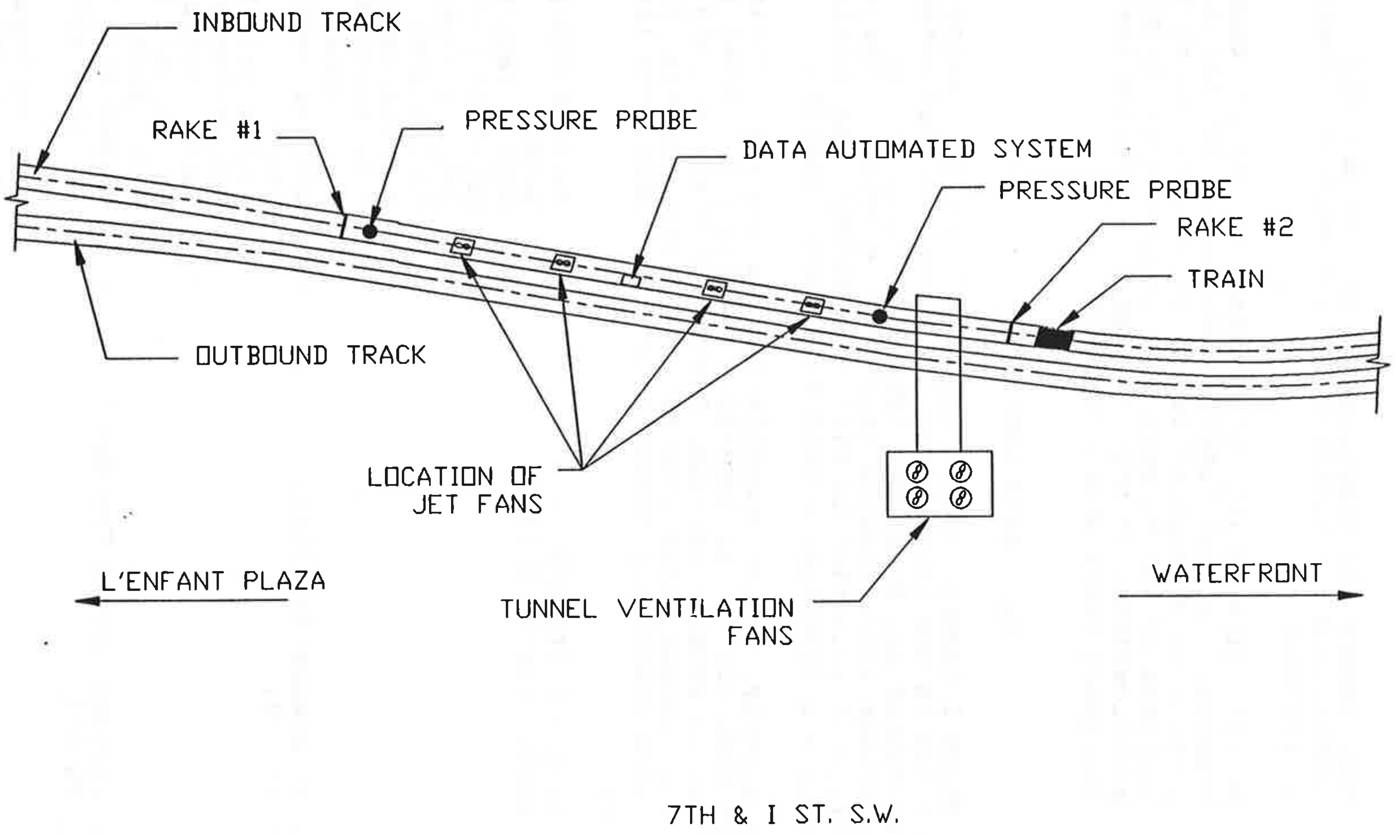
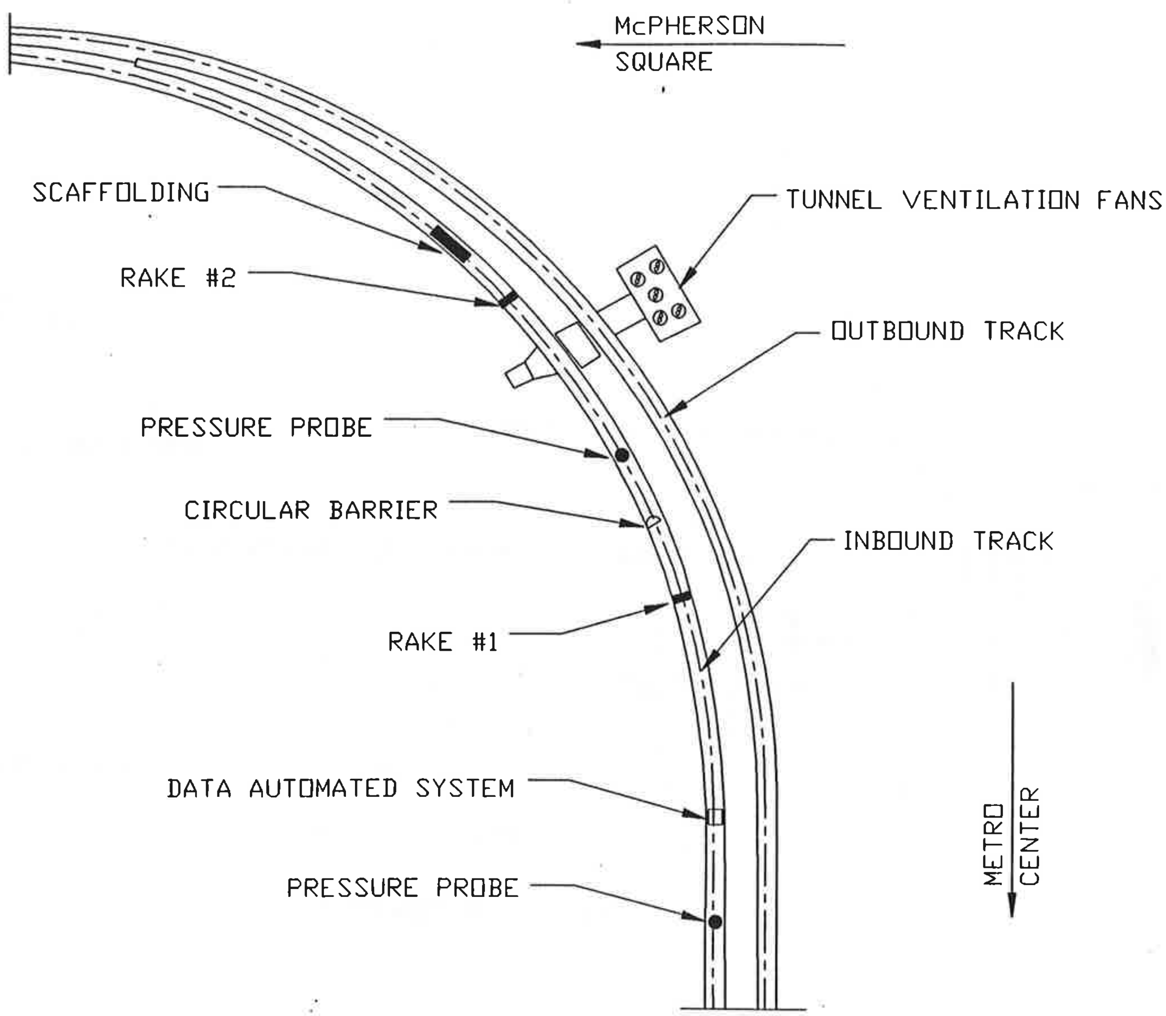
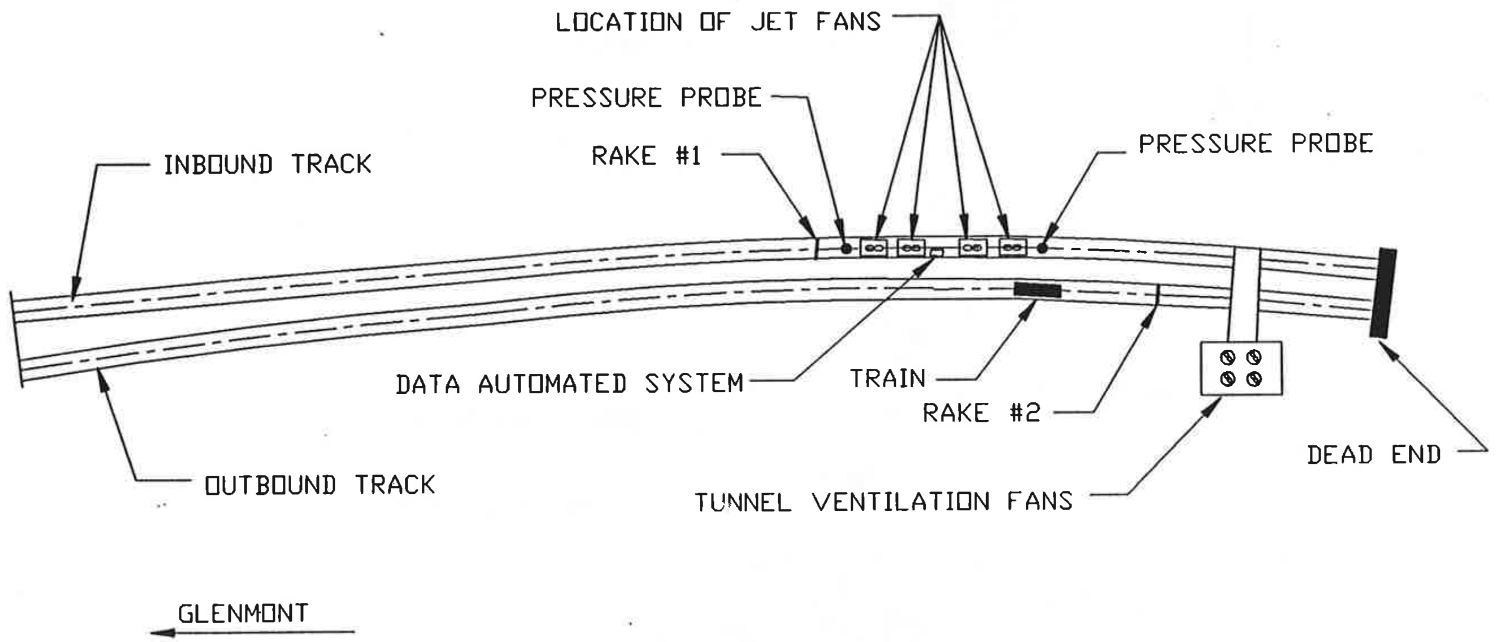

INBOUND TRACK
RAKE #1
PRESSURE PROBE
DATA AUTOMATED SYSTEM
PRESSURE PROBE
RAKE #2
TRAIN
OUTBOUND TRACK
LOCATION OF
JET FANS
L'ENFANT PLAZA
TUNNEL VENTILATION
FANS
WATERFRONT
7TH & I ST. S.W.

FIGURE 2-1



METRO CENTER / McPHERSON SQUARE

FIGURE 2-2



BLUERIDGE AVE. FAN SHAFT

FIGURE 2-3

-- Jet Fan Equipment Drag Tests-Smooth Wall Tunnel

2.3 MODIFICATIONS TO TESTING SCHEDULE AND SITES

Original Test Site

The recommended site -- the tunnels between Metro Center and McPherson Square Stations and the New York Avenue fan shaft -- was used only for the initial tests because it became apparent that testing in a revenue service tunnel was not cost effective. Furthermore, the restricted window of availability in this revenue tunnel meant that there was not enough time to set up and check out the instrumentation and equipment, perform the tests, and then remove the entire system.

New Test Sites

Fortunately, when the test schedule was being worked out and test site alternatives were being reviewed, WMATA was able to make available the three test sites referred to previously and shown in Figures 2-1, 2-2 and 2-3. Therefore, changes were made in the program to adapt to these sites which offered two advantages.

- The test schedule was greatly simplified by the elimination of the requirement to remove the instrumentation and equipment after each night's test and set up again the next night.
- The use of the fan anemometer "rakes" instead of single point measurement (see Appendix D, Section D.6.) became less of an inconvenience because the rakes had to be set up only once at each test site for the entire test series.

The reasons and objectives for recommending the Metro Center Station/New York Avenue test site in the Phase I Report were not in any way compromised by the site change. In fact, better repeatability of test results occurred. As a result of the site shift:

- The use of the 7th and I Streets fan shaft test site was found to be an acceptable substitute for the Metro Center Station/New York Avenue fan shaft test site for ribbed-tunnel tests.
- The smooth-wall modified-horseshoe tunnel adjacent to the Blueridge Avenue fan shaft was selected as a

substitute for the smooth-wall box tunnel East of McPherson Square Station.

- o The double-track tests were cancelled. More detailed analyses determined the output of the double track tests was not necessary for determining if barriers or jet fans could be used to re-direct tunnel airflow during Metrorail emergencies.

2.4 EQUIPMENT INVOLVED IN THE VENTILATION TESTS

Existing Fan Shaft Fans

The tests used the existing tunnel ventilation fan shaft fans at each test locations, described below. (Typical fan shaft fans are shown in Figure 2-4.)

- o The Blueridge Avenue and 7th and I Streets SW fan shafts each have four fans. Each location has a combined capacity of 200,000 cfm when operating in the exhaust mode.

- o The New York Avenue fan shaft has five fans with a combined compacity of 250,000 cfm operated in the exhaust mode. These fans are operated in exhaust to reduce tunnel temperatures during normal summer operations and in either exhaust or supply during emergency operations.

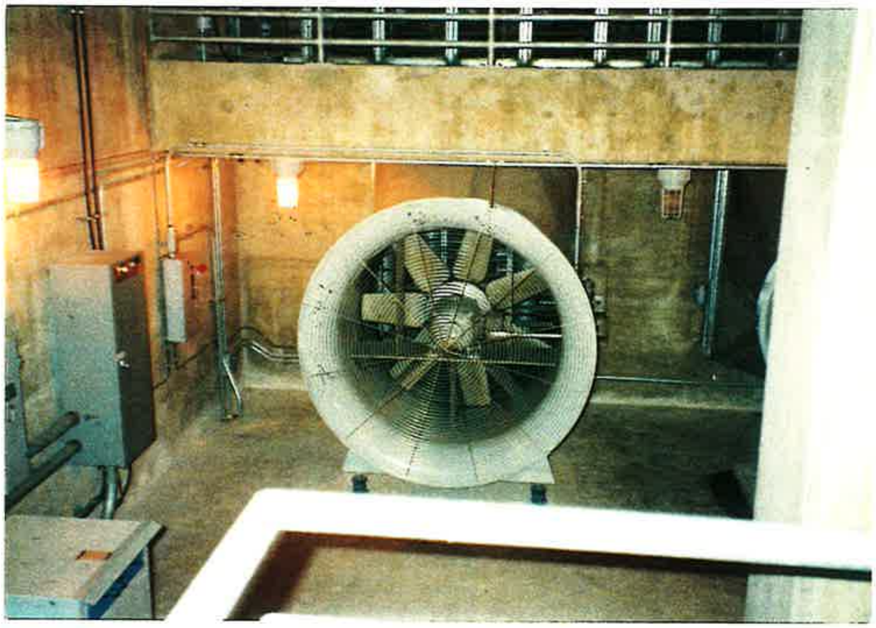
WMATA Clearance Car

The ventilation tests involve measuring air flow past a transit train. The WMATA Department of Rail Service provided its clearance car for the ventilation tests.

Use of this car had the added advantage of providing space for the data acquisition center and for storage of test equipment between tests (Figure 2-5).

Temporary Power Supply for Jet Fans

Temporary power for the jet fans was provided by leasing a generator, cable and load center. This flexible arrangement allowed the Jet Fan Tests to be performed at more than one location with minimal installation work (Figure 2-6).



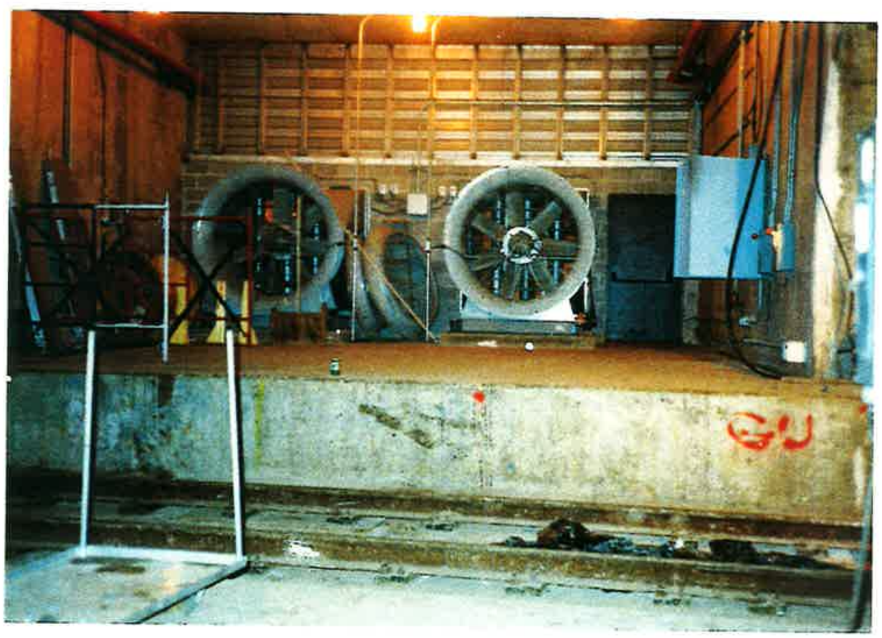


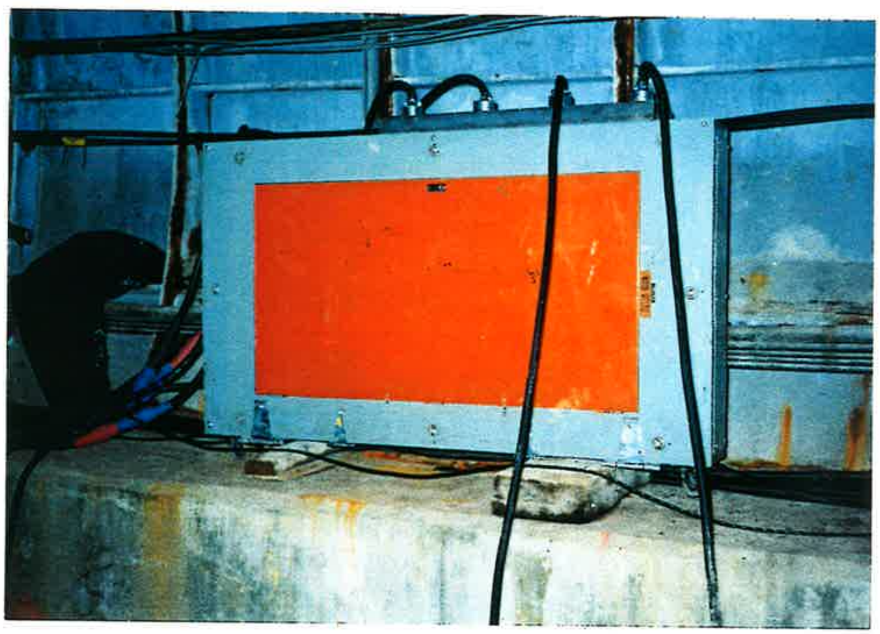
FIGURE 2-4 TYPICAL FAN SHAFT FANS

COMPUTER CENTER INSIDE CLEARANCE CAR

CLEARANCE CAR IN POSITION FOR AIR FLOW MEASUREMENTS

FIGURE 2-5 WMATA CLEARANCE CAR

300KW GENERATOR



LOAD CENTER

FIGURE 2-6 POWER SUPPLY TO JET FANS

Dampers

As detailed in other sections of this report, dampers were temporarily installed at the New York Avenue and 7th and I Streets fan shafts (Figure 2-7). Use of these dampers minimized the quantity of barriers and jet fans needed to do the testing. The end of the tunnel at the Blueridge Avenue fan shaft fulfilled the same requirement as the dampers.

Jet Fan Equipment

Rehabilitated rail buggies were used to allow for mobility in the testing of the jet fans. A lift table was installed on top of the buggies and the jet fans were mounted on top of the lift tables (Figure 2-8). This strategy enhanced the entire jet fan test program because it enabled the jet fans to be tested in a variety of positions.

Barrier

Sheldahl, Inc. designed the barrier using information and criteria developed from the design of air blocking devices for underground mine shafts. The barrier was designed to deploy fully within two minutes, at a very low tunnel air velocity. When deployed, the barrier is designed to conform to the general shape of the tunnel with special features for the third rail and the walkway.

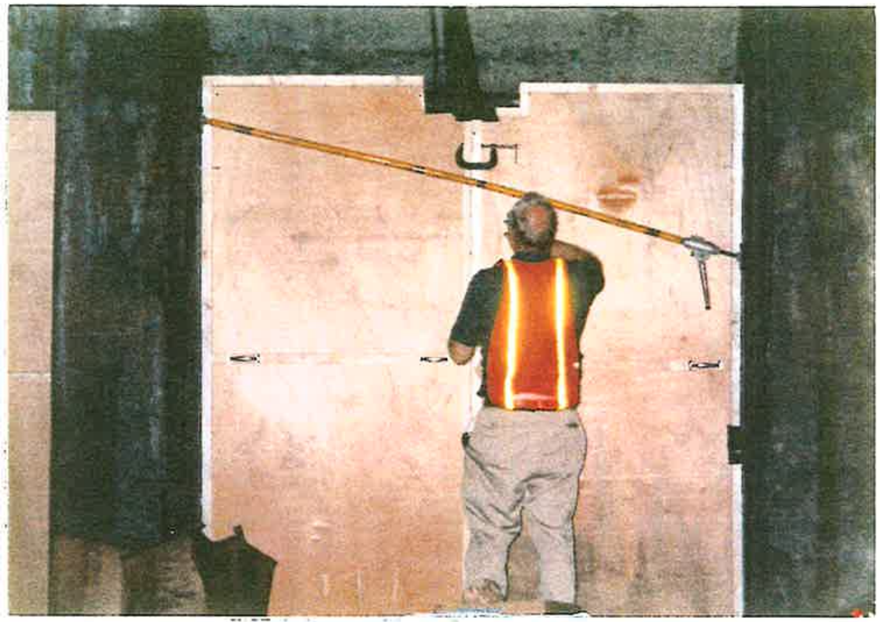
2.5 BARRIER EQUIPMENT TESTS

Functional and Physical Characteristics

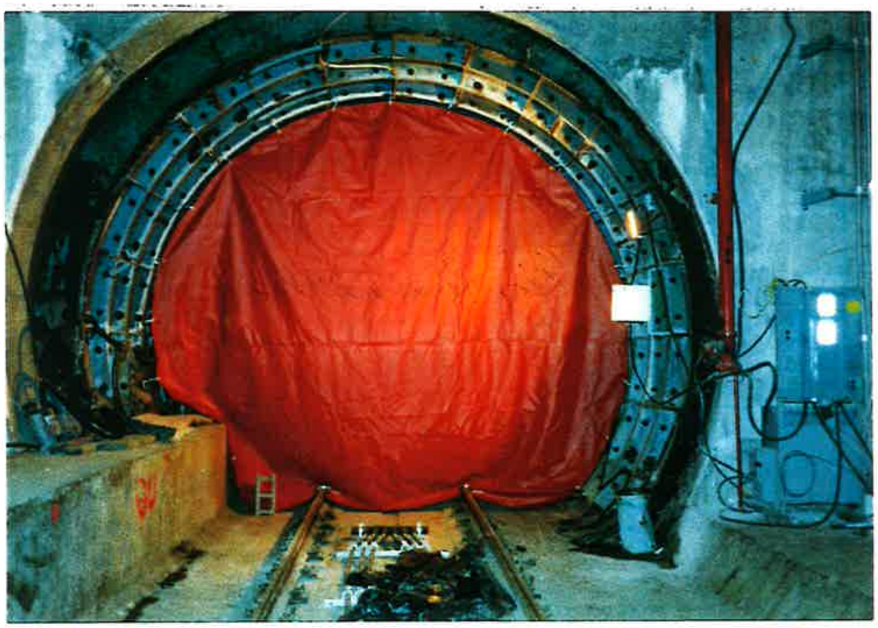
The barrier must be bi-directional (capable of throttling airflow in either direction), because the fan shaft fans may have to operate in either the exhaust or the supply mode during an emergency. No metal or hard objectives can be part of the barrier in the deployed condition, other than the barrier containment in the stored condition. The barrier must conform to the National Fire Protection Association's Standard 130, Fixed Guideway Transit System, 1990 Edition as accepted by the local WMATA fire protection jurisdictions.

The barrier shall conform to the following requirements:

- **Containment.** It must clear the subway car dynamic outline in its stored condition.
- **Deployment.** It must be fully deployed within two minutes after activation.



WOOD DAMPER AT N.Y. AVE FAN SHAFT



TARPAULIN DAMPER AT 7th & I ST. SW FAN SHAFT

FIGURE 2-7 DAMPERS

FIGURE 2-8 JET FAN MOBILE MOUNTING

- **Egress.** It must have a personnel egress passage in accordance with NFPA requirements described above.
- **Abrasion.** It must withstand being deployed and rubbing against a variety of tunnel fittings without damage, and also withstand considerable passenger egress through it without damage.
- **Fire Resistance.** It must meet the tests required by NFPA 130.
- **Electric Resistivity.** It must have a resistance at 750 volts direct current of a minimum of 10 megaohms per inch.

Test Requirements and Methodology

Eight types of barrier equipment tests were conducted. They included:

- Deployment time and geometry
- Third Rail
- Release mechanism reliability (two tests)
- Storage latch reliability
- Abrasion
- Fire resistance
- Electrical resistivity
- In-service monitoring of the system

The criteria, configurations and procedures for these tests are shown in Table 2-1.

Design Development

Original Concept --360-Degree Torus. During earlier experiments with the parachute type air block, the barrier collapsed when an egress passage was opened. Therefore, Sheldahl's original concept was to combine the parachute type air block with a 360-degree air-inflated torus that would hold the barrier in position whether or not air was flowing through the tunnel. The torus represented the least complicated means of providing enough rigidity to the barrier under the various deployment conditions.

Table 2-1
Barrier Equipment Tests

Test	Criteria	Configuration	Test
Barrier Deployment Time and Geometry	The barrier release mechanism shall function on command and the barrier fully deploy within two minutes.	Package the barrier in its storage container and close the storage latch. Install the barrier storage container with the storage latch and barrier in an overhead position.	Time the deployment of the barrier with zero airflow and maximum airflow with torus deflated.
Third Rail Tests	A value judgment on how well the barrier is to conform to the third and running rails in the tunnel.	Place a restriction in the general shape of the WMATA third rail and two running rails in the appropriate position.	Photograph the conformity of the barrier to the simulated third rail/running rail restrictions with legible scales in each view.
Release Mechanism Reliability - A	The barrier release mechanism shall function on command and drop free of the container within one minute of the release command.	Package the barrier in its storage container and close the storage latch. Install the barrier storage container with the storage latch and barrier in an overhead position.	Exercise the release mechanism on three separate release mechanisms, six times each, without gas introduced to the torus, and repeat with gas introduced to the torus for a total of 36 tests.
Release Mechanism Reliability - B	The barrier and its container shall remain attached to the tunnel wall during the ventilation test. The barrier shall not deploy prior to the ventilation test. The barrier shall deploy on command.	Repackage all four test barriers in their respective containers and recharge torus gas cylinder pressure for each test configuration specified for ventilation testing. Package the barrier in its storage container and close the storage latch. Install the barrier storage container with the storage latch and barrier in an overhead position.	Determine that the barrier and its container remain attached to the tunnel wall prior to and during the ventilation test and that the barrier shall not deploy prior to the ventilation tests. Release the barrier at the initiation of each ventilation test in accordance with requirements in the ventilation testing.
Storage Latch Reliability	The barrier and its container remain attached to the tunnel wall during the test. The barrier shall not deploy during the test.	Package the barrier in its storage container and close the storage latch. Install the barrier storage container with the storage latch and barrier in an overhead position.	Expose the barrier to an external pressure of 3 inches water gage (in. wg) for 30 seconds. Release the pressure within 0.1 second.Repeat 30 times for each of three barrier units. Expose the barrier to an external vacuum of 2 in. wg for 30 seconds. Release the pressure within 0.1 second. Repeat 30 times for each of three barrier units.

Table 2-1
Barrier Equipment Tests (Continued)

Test	Criteria	Configuration	Test
Abrasion Tests	Engineering judgment shall be made of resulting material damage.	Leave barrier in deployed position.	Thoroughly inspect the barrier materials after each deployment. Walk test personnel on the portions of the barrier which passengers would step on during an evacuation from the system or the emergency personnel would step on while accessing the system.
Fire Resistance	The torus, membrane tether lines and all the components of the barrier (all materials) shall meet the requirements of the small scale test contained in the NFPA-701, "Standard Methods of Fire Tests for Flame-Resistant Textiles and Films". For the purpose of these experiments, all the materials were not required to satisfy the criteria set by NFPA-130 which states that all ventilation-related components exposed to the ventilation airflow shall be designed to operate at 300°F ambient temperature for a period of at least one hour. Those installed in the Metrorail will be required to meet this standard. All materials shall have a flame spread index of no more than 25, as determined by tests in accordance with NFPA-255, "Standard Method of Test of Surface Burning Characteristics of Building Materials". All materials shall have a fuel contributed and a smoke developed rating. Both ratings would not exceed 50 as determined by tests in accordance with NFPA-255, "Standard Method of Tests of Surface Burning Characteristics of Building Materials". All materials shall have a smoke toxicity test. This test shall determine the amounts of carbon monoxide, carbon dioxide and hydrogen cyanide released as a result of combustion of one square foot (sf) of the material. Any of the five major test methods for assessing the toxicity of combustion products shall be used: the West Germany - Deutches Institute for Nurmung 53436 method, the U.S. Federal Aviation Administration method, the U.S. University of Pittsburgh method, or the U.S. University of San Francisco method. If any of the materials used for the barriers shall have already been tested by an organization acceptable to the Fire Protection Jurisdictions (FPJ), the test reports shall be submitted for review.	Follows the configuration specified by NFPA standards and methods for each particular test.	Test for : Flame resistance Flame spread index Fuel contributed rating Smoke developed rating Smoke toxicity

Table 2-1
Barrier Equipment Tests

Test	Criteria	Configuration	Test
Electrical Resistivity	The resistance at 750 volts direct current (Vdc) shall be a minimum of 10 megaohms per inch. The barrier material shall not be visibly damaged.	Use a 4 feet x 1.5 feet piece of barrier fabric. Place one of the 4 feet sides along the floor touching the floor. Hold the other 4 feet side above the floor. Pull the fabric to its maximum stretch possible.	Measure the bulk resistance of the barrier torus and membrane by applying 750 Vdc along four feet of the barrier referenced to ground and measuring, to a two percent accuracy, the resistance between the voltage application points.
In-Service Monitoring System Tests	The monitoring system shall function without failure or erroneous data output. The barrier shall not self-release within two years.	Install prior to the release mechanism reliability tests and barrier deployment. The monitoring system shall consist of a pressure transducer at each gas cylinder, a multichannel programmable data logger and a recording device. Place three barrier containers in their full in-service configuration at tunnel locations to be determined. Wire the release indicator circuit with the control and monitor wiring to a multi-channel data logger.	Measure and print out the gas pressure at each cylinder every hour for two years. Sample the cylinder average pressure and the release indicator for once every 24 hours for two years. An alarm system shall be activated if the cylinder pressure falls below a predetermined value or if the release indicator opens.

Sheldahl's in-plant tests, using a mock-up of a circular tunnel cross-section, showed that the initial designs involving the 360-degree torus were not successful. The torus would not align with the tunnel wall and there were entanglements of the shroud lines. To solve this problem a significantly larger volume of air and a higher air pressure would be required. These options were not considered practical.

Design Refinement -- 180-Degree Torus. This design refinement became the solution. The lower half of the barrier adhered to the sides of the tunnel by gravity. The upper half of the torus adhered to the upper half to the tunnel (Figure 2-9). With minor modifications to the shrouds, the barrier was considered ready for the next step -- deployment testing prior to advancing the design to an operational prototype.

Deployment Tests

The barrier deployment tests conducted at the 7th and I Streets SW Fan Shaft were intended as proof-of-concept tests of the barrier design. As shown in the barrier deployment sequence (Figures 2-10 and 2-11), the deployment is assisted by the air torus on the upper perimeter of the air block canopy.

The tests -- conducted in zero airflow or worst-case deployment conditions -- demonstrated the barrier's release and deployment and showed the percent of tunnel cross section blockage. The prototype was judged to be very close to final design based on the following results:

	Criteria	Results
1.	Release to full deployment in 3 minutes with no release mechanism failure.	Full deployment in 45 sec.; no release failure. Minor shroud line entanglement in one trial.
2.	Shrouds, canopy & torus resistant to damage from tunnel appurtenances.	No damage observed after two deployments.

The success of these tests led to the decision to test the barrier performance with the fan shaft fan operating (Figure 2-12) and the design was shown to be self-supporting (without the torus). The barrier filled over 90 percent (estimated) of the tunnel cross-section with the fans operating in exhaust mode and the other three tunnel approaches to the fan shaft open. The torus was needed, however, to obtain the initial deployment shape.

FIGURE 2-9 SHOP TEST OF BARRIER

FIGURE 2-10 BARRIER DEPLOYMENT SEQUENCE

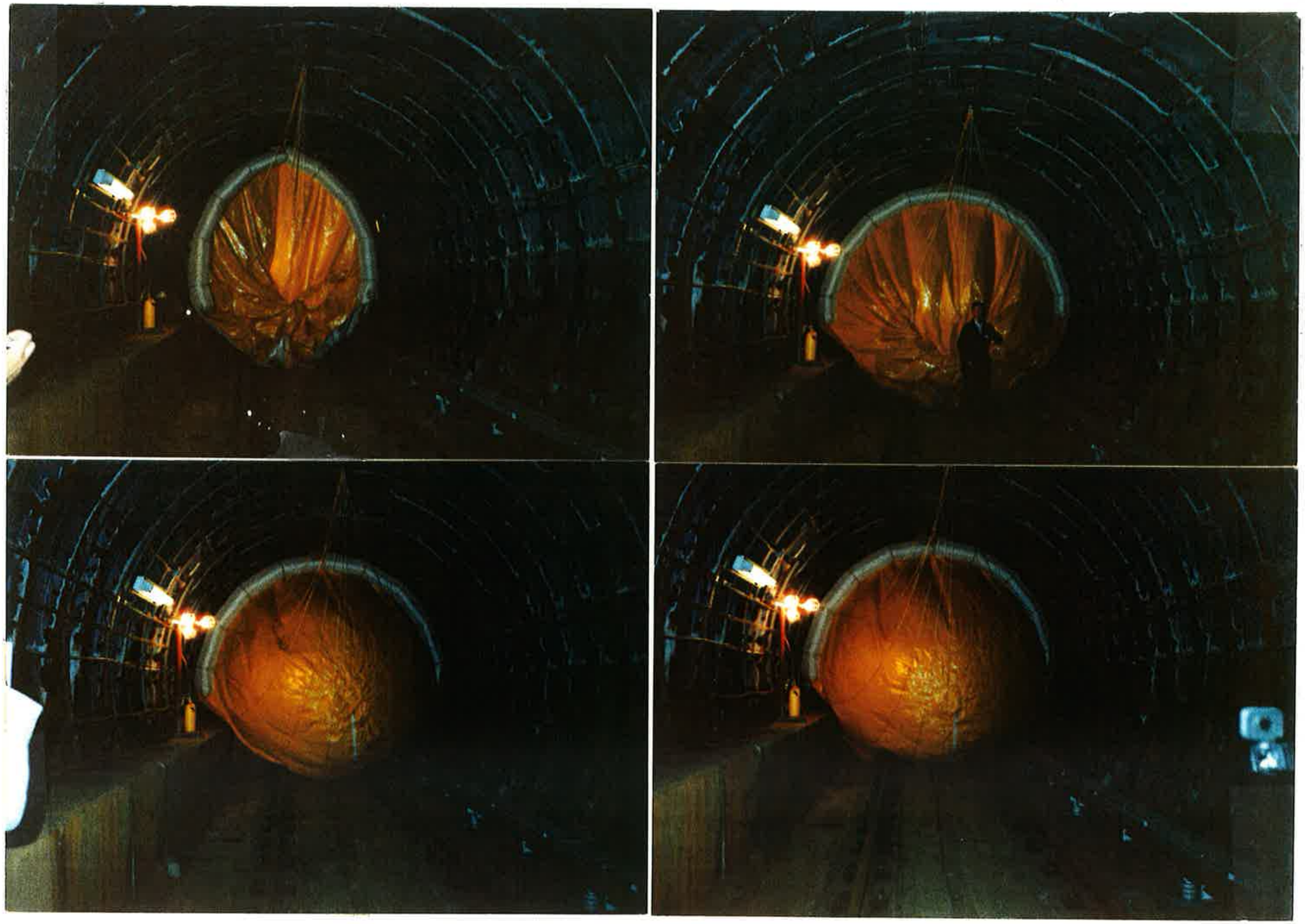


FIGURE 2-11 BARRIER DEPLOYMENT SEQUENCE

FIGURE 2-12 BARRIER WITH FAN SHAFT FANS IN OPERATION

2.6 VENTILATION TESTS

The ventilation tests used to accumulate accurate airflow and static pressure measurements for the barriers and jet fans involved three series of tests:

- o Basic Tests
- o Barrier Tests
- o Jet Fan Tests.

Basic Tests

The basic tests were used to determine:

- o The single point measurement factors for the ribbed wall tunnel and the smooth wall tunnel
- o The single point measurement factors for the ventilation shafts
- o The friction factors for the ribbed wall tunnel and the smooth wall tunnel, including the effects of ribs, fire lines, conduits, signaling devices, etc.
- o The jet fan mounting head loss coefficient.

These basic tests also provided experience for the remaining tests in the areas of logistics, instrumentation, communication, etc. The single point measurement factor and the friction factor are mathematically defined in Appendix B.

Barrier Tests

The barrier tests were used to determine the relationship between the static pressure differential across the barrier and the airflow through it. For a rigid barrier having an opening of known size, theory and previous experiments have shown the relationship is a constant times the airflow velocity pressure. In this test, however, the barrier was not rigid and the size of the opening varied with the airflow. Therefore, full-scale experimental tests were necessary to determine the static pressure-airflow relationship (mathematically described in Appendix B). If it was decided to implement barriers for tunnels having shapes other than round or horse shoe (such as square or double box) then additional ventilation tests for these barriers would be required. The need for these, if any, would be determined during the site specific designs in Phase III.

Jet Fan Tests

Experiments in vehicular tunnels have shown that the jet fan pressure efficiency varies as a function of the following:

- o The distance from the center line of the jet fan to the tunnel wall
- o The tunnel wall roughness smooth and ribbing
- o The longitudinal spacing of the jet fans along the tunnel.

Unfortunately, experimental data did not exist for the ranges of these parameters that exist in the Metrorail. Therefore, the jet fan pressure efficiency had to be measured so that it could be input into the design process accurately. To study the effect of the tunnel wall roughness on the jet fan pressure efficiency, two general groups of tests were performed: ribbed wall tunnel tests and smooth wall tunnel tests.

The efficiency also varies as a function of the jet fan discharge air velocity. However, the discharge air velocity selected for these tests is similar to that of the jet fans that would be installed.

Data Acquisition System

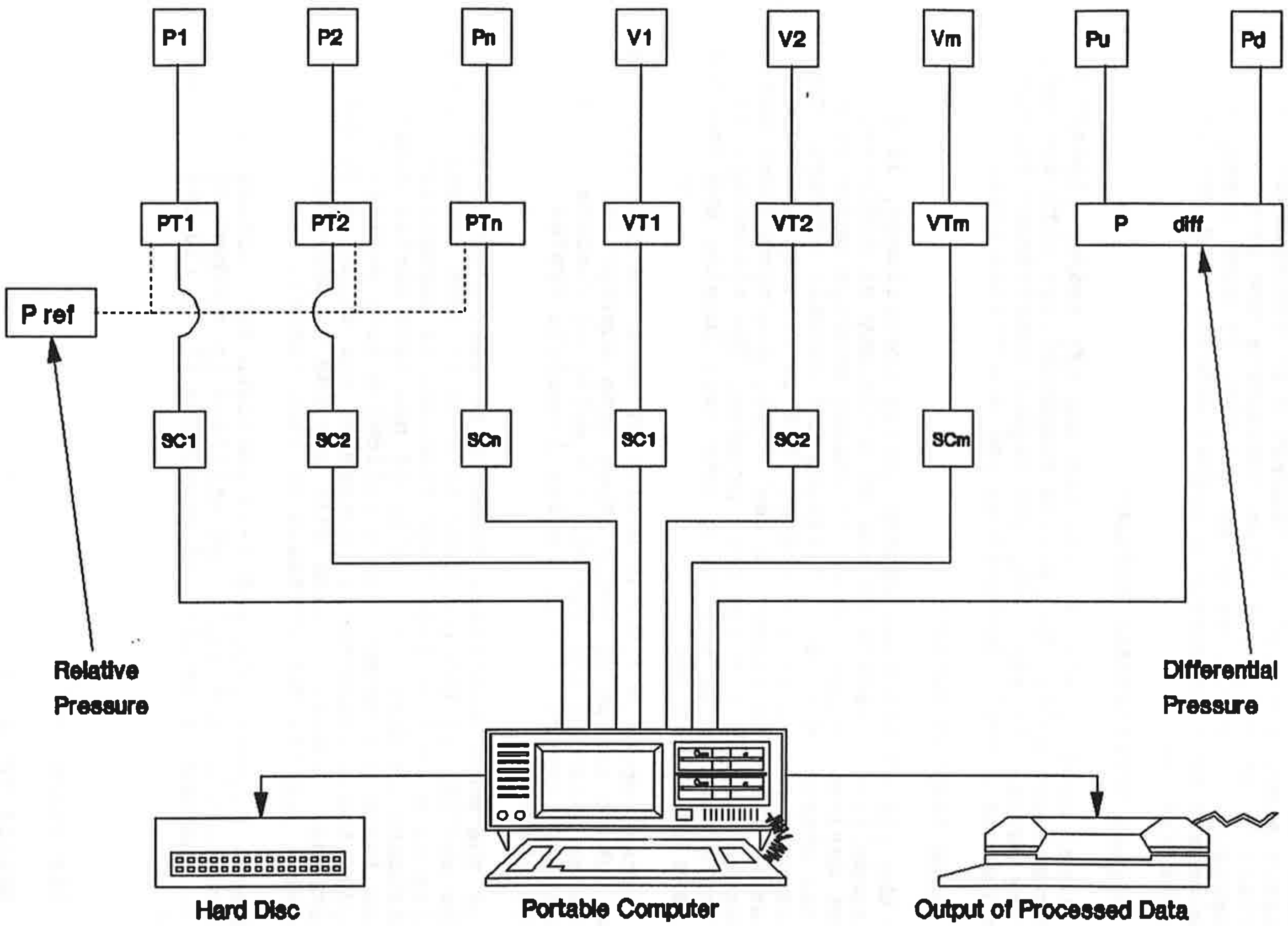
During the selection process of the data collection equipment, it quickly became apparent that a real-time data acquisition system (DAS) would be necessary to:

- o Simplify and expedite the collection of data
- o Provide real-time calculation capabilities
- o Determine the quality of the collected data immediately
- o Simplify analysis of the results.

The following brief review of DAS concepts is presented below to show the applicability of real-time DAS to the testing program. These concepts form the basis for the design and implementation of the KLD Labs' DAS, the system that is discussed in detail in the sections to follow.

Data acquisition systems are used to measure and record a wide range of real-world phenomena. The overall system consists of transducers/sensors, signal conditioning modules and a data logging device (Figure 2-13).

- o **Tranducers/Sensors**



DATA ACQUISITION SYSTEM

FIGURE 2-13

The transducers are the means by which the physical phenomena are sensed and converted into electrical signals. The basic electrical signals generated by transducers are sometimes quite small and often transgress the range appropriate for digitization by the DAS. In such cases, it is necessary to incorporate a signal conditioning module into the system.

- **Signal Conditioning Modules**

The signal conditioning module can amplify and/or linearize the transducer output to provide compatibility with the data logging device. In addition, the signal conditioner filters out unwanted signal fluctuations and electrical noise.

- **Data Logging Devices**

Once the signal has been appropriately conditioned, it can be transmitted directly to one of a variety of different output devices, either using an analog storage media or a digital storage device. Digitizing the signals converts the conditioned output into a format that is readily analyzed by computer. For this reason, a real-time, microprocessor-based system was chosen for the test program. The microcomputer has the advantage of providing both data logging and on-line analysis capabilities.

The system supports the collection of numerous data channels whose output can be directly input into appropriate equations allowing for real-time viewing of results. This capability provides the means for immediate system verification.

One of the most beneficial elements of real-time processing is the ability of the operator to have instant access to the results of a test series. This feedback is especially significant in that the results of one test series often become input parameters for a following test series. For example, tests conducted to determine the friction factor of a particular tunnel section will provide an important parameter for all future tests of that tunnel.

Hardware. Figures 2-14 and 2-15 indicate the variety of instrumentation and equipment utilized in conducting the tests. The DAS is capable of measuring the following in real time:

- Air Velocity
- Static Pressure
- Temperature

FIGURE 2-14 MEASUREMENT INSTRUMENTS

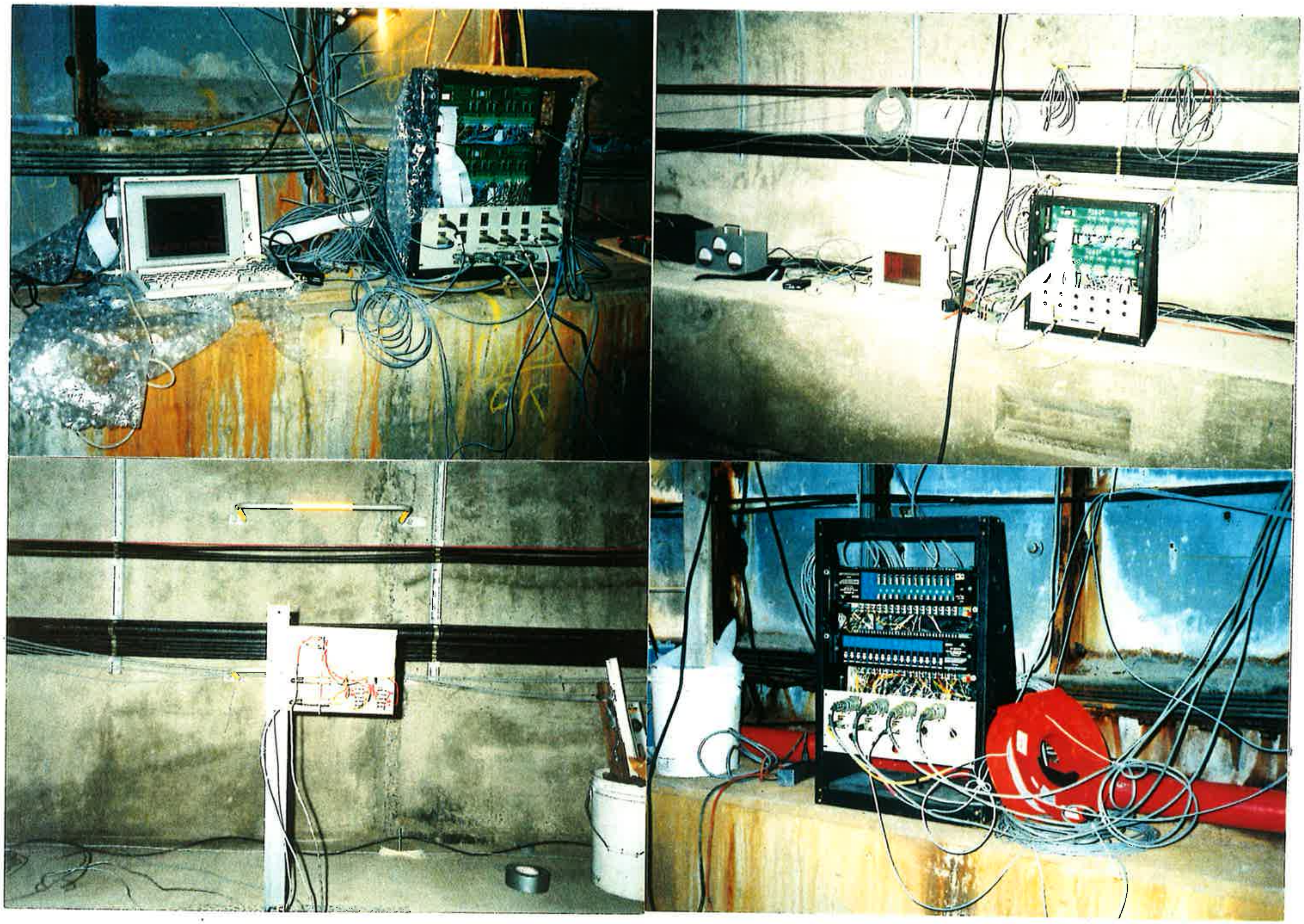


FIGURE 2-15 DATA COLLECTION INSTRUMENTATION

- o Humidity
- o Barometric Pressure.

Detailed descriptions of the hardware used by the system to measure these factors are included in Appendix D.

Software. The software provides a stand-alone and self-sufficient means of capturing and analyzing real-time data for a wide variety of ventilation tests, when executed on the PC and combined with custom airflow, temperature and pressure instrument configurations.

The software was entirely custom developed since no commercially available packages had the right mix of functionality and performance. Instrument configurations, real-time calculations, on-line displays and off-line reports based upon changing analysis requirements also had to be customized. In short, the software was written to provide a large degree of flexibility as an up-front requirement.

The capability of making in-field modifications to the software was essential. The few modifications the were necessary were made by KLD.

2.7 SOFTWARE DESIGN

The executable software, "pw_daq.exe" was designed as a real-time program. That is, it has the ability to process data acquisition input data, perform specified calculations, update the real-time display, and monitor the keyboard for user input simultaneously.

The software is also set up/controlled by test-specific inputs that are described in detail in the section on software inputs below. In order to provide maximum flexibility, the mapping of these inputs to the actual processing relies to a large extent on a table cross-reference. For example, the data channels and instrument types that are collected on a test-by-test basis are specified by tables rather than by in-line code. This feature proves invaluable for making "on-site" modifications to the configuration in a short period of time.

The application software executes under PC/MSDOS 3.3. It was developed in Microsoft "C" 5.1. Version control is maintained through the Microsoft "Make" utility.

Application Software Description

The application software was written to produce two separate executables--"debug" and "real". The debug executable:

o Provides known inputs as channel data

o Allows intermediate outputs to be analyzed through the use of a debug data file that is created in real-time

o Allows all calculations to be broken down into intermediate results.

The debug executable is used for validating real- time processing and calculations based on known inputs. It is invaluable as a check-out of any software additions/modifications prior to the actual test.

For purposes of increasing speed, the real executable eliminates any intermediate debug outputs. The final outputs are those produced in the report and raw data files to be described in following sections. The debug output, raw data and report files are written to random access memory disk files, also for speed reasons. After each round of testing, the files that must be saved are off-loaded to the hard drive and/or floppy disk for safe storage.

The software is organized to require user selection of the test to be run. The test in question has a one-to-one mapping to those indicated by the program requirements. The output file names are encoded with the name of the test for ease of reference.

Software Inputs

The user is required to specify inputs which will control both the test to be executed and the individual controls that can be variable within a particular test. A certain number of inputs are required to control the specifics of the data acquisition process. The user is presented with a screen as shown in Figure 2-16. All parameters in the screen can be changed by the user.

The user is also required to select the test location, type and airflow characteristics. This information (Figure 2-16) not only controls the mapping of the output file name, but also determines the exact data acquisition configuration, valid channels to capture data, and calculations that are to be made in real time.

The following is a mapping of Blueridge Avenue, 7th and I Streets, and New York Avenue test types:

The Initial Screen Shown at the Beginning of the Test.

Date	:	12/17/90	Time of Day	:	17:37
AT-MIO Slot/ID	:	1	# of MUX-64 Boards	:	2
DAQ(Pts/Sec	:	1	Test Name	:	
Gain/Channel	:	1	Max Test Len(sec)	:	1800
Barometric Pr.	:	31.00	Temperature(C)	:	N/A
Rel. Humidity	:	N/A	Vt Direction	:	+

Comments : This is a TEST of the KLD LABS P-WMATA Software

For default shown, hit return

Select Test Name [Y]?

FIGURE 2-16

Test Categories: Single Point Tunnel
Single Point Fan Shaft
Tunnel Friction
Jet Fan Mounting Head Loss
Jet Fan (100-foot spacing)
Jet Fan (75-foot spacing)
Jet Fan (50-foot spacing)

Associated with each of these categories is the selection of an individual test which specifies the actual flow characteristics and other unique setup constraints. For example, after selecting a given test such as "Jet Fan (50 ft.)," another select menu would be presented to the operator. In this mode the operator will select the test name that was specified for that test. The pertinent information would be the number of tunnel ventilation fans, with or without a train, and with or without dampers. The software was designed such that by selecting the appropriate test name, all channel setup information and formulas would be configured automatically. This design provided a key benefit by reducing the amount of work required of the user, thus reducing the potential for operator error and the time between tests.

Certain tests require "interpolated" inputs to complete calculations. These inputs are obtained through files which reside on the hard disk and are built by the user. They provide the ability to construct a mapping, for example, between the bulk flow or Reynolds number and the friction factor that allows a calculation to be based upon an interpolated value obtained from the input file. The calculation that is obtained is used as a variable in follow-on calculations.

In order to construct these tests, the software provides a means of automatically collecting the actual data that can provide "points" in the interpolation file across the entire range of executed tests. This output is collected in a single file. In constructing the input file, the user is free to use the real-world data that best fits the application.

Software Outputs (Reports)

The outputs of the software consist of:

- Channel data
- Real-time calculations
- Raw acquisition data

Each test has valid channels that are configured according to the test definition. The channel output report presents only those channels that are actually used in the given configuration. This setup is controlled automatically by the software after the test is selected. This report is used to see the lowest level inputs, the actual channel data, and to verify the calculations.

All required channel values are reported for each time interval in which the acquisition is performed (normally once per second). The header describes the particulars of the test.

Software Real-Time Calculations

A separate report file contains all the calculations that are made based upon the channel data and the interpolated input values where required. The mapping of the calculations performed is controlled by the software via the selected test.

All required calculations are reported for each time interval the acquisition is performed (normally once per second). The header describes the particulars of the test. In addition, the software maintains "running totals" for key calculations. The "test-wide" average for each is shown after the test has been completed.

Raw Data Files

The raw data that is produced by the AT-MIO-16 board is also saved to disk in real time. This allows the user to rerun valid field-collected data with modified calculations.

User Interface

The user interface was created to provide a great deal of flexibility in terms of real time operation. Key elements of this interface are described in the following sections.

Real-Time Control. The interface allows the user the following real-time controls activated by pressing the associated PC function key. This control includes starting and ending sampling, the ability to view any channel output or the review of the result of a calculation, and to exit the program.

Display of Calculations and Channel Data. The user has the ability to display calculations that are being performed in real time. Up to five concurrent calculations and/or data channel outputs may be displayed at any one time in the five scrolling windows. This allows the user to validate the correct operation of channels and output of calculations while the test is running instead of after the test is complete. This can save tremendous amounts of critical test time when, for example, the test configuration is being checked-out.

The specifics of the test program for which the KLD Labs' data acquisition system was designed are provided in Appendix D.

3. TEST RESULTS

3.1 BARRIER DEPLOYMENT TESTS

Test Locations

Barrier deployment tests were conducted at the following locations:

- o In mock-ups at the Sheldahl plant
- o Without ventilation in the tunnel adjacent to the 7th and I Streets SW fan shaft
- o As part of the ventilation tests in the tunnel between Metro Center Station and the New York Avenue fan shaft
- o As part of the ventilation tests in the tunnel adjacent to the 7th and I Streets fan shaft.

Factory Test Results

A variety of barrier configurations were tested in a mock-up at the Sehldahl Plant with unsuccessful results until the version with the 180-degree inflatable air torus was found to deploy successfully. Initial testing as part of the development process was concerned primarily with the barrier configuration that, when deployed, would fill a major portion of the tunnel cross section. These tests are discussed in Section 2.5.

Field Test Results

The barrier deployment with the 180-degree inflatable air torus was tested successfully in the tunnel adjacent to the 7th and I Streets fan shaft without ventilation and in the tunnel between Metro Center Station and New York Avenue fan shaft as part of the initial ventilation tests. The strategy of barrier development precluded attempting to answer all the environmental and operating criteria in the initial phase of development. The basic concept of barrier deployment and blockage was the first concern.

As the result of the initial successful tests, Sheldahl was directed to continue with the development of the barrier to include the entire design criteria presented in Section 2.5. The resulting operational prototype barrier was then successfully deployed in the tunnel adjacent to the 7th & I Streets fan shaft during the ventilation tests with representatives from the fire department present.

3.2 VENTILATION TESTS AND ANALYSES

Tunnel Friction Factor Tests

Smooth Wall Tunnel - Blueridge Avenue. Table 3-1 shows the Reynolds numbers and friction factors measured in the tunnel adjacent to the Blueridge Avenue fan shaft. These values were obtained using the data reduction methodology described in Appendix B and the procedure outlined in Section B.19. The equivalent relative roughness of the tunnel was determined by a least-squares curve fit using Colebrook's formula (Equation 36, Appendix B).

The results were as follows:

- o Equivalent relative roughness - 0.00122
- o Friction factor for fully-developed turbulent flow - 0.021, a value that compared favorably with the range of data provide by various handbooks.

Figure 3-1 is a Moody Chart depicting the field measured values of the friction factor and the friction factor versus Reynolds number for a relative roughness of 0.00122. This relative roughness was used for all Blueridge Avenue tunnel data reduction.

Ribbed Wall Tunnel - Metro Center. Table 3-2 shows the Reynolds number and friction factors measured in the tunnel between Metro Center Station and the New York Avenue Fan Shaft, values obtained using the methodology and procedure referenced in the previous section. The results were as follows:

- o Equivalent relative roughness - 0.05190
- o Friction factor for fully-developed turbulent flow - 0.073.

This value was compared with that predicted by the methodology of the Subway Environmental Design Handbook (SEDH)[6] for a 15.1-foot diameter pipe having six-inch high ribs on 30-inch centers. The SEDH nomograph (page 3-27)

TABLE 3-1

WMATA VENTILATION TESTS — TEST DATE: AUGUST 22, 1990
FRICTION FACTOR TESTS AT BLUERIDGE AVENUE
SMOOTH WALL TUNNEL

RUN NAME	No. FANS EXHAUST	FRICTION FACTOR	REYNOLDS NUMBER	TUNNEL AVERAGE VELOCITY (FPM)	COMMENTS
BRFF4	4	0.0206	1.11250E+06	772.300	
BRFF3	3	0.0199	8.28093E+05	574.800	
BRFF2	2	0.0209	5.59661E+05	388.100	
BRFF1	1	0.0232	2.80379E+05	194.300	

TABLE 3-2

WMATA VENTILATION TESTS — TEST DATE: JUNE 23, 1990
FRICTION FACTOR TESTS AT METRO CENTER
RIBBED WALL TUNNEL

RUN NAME	No. FANS EXHAUST	FRICTION FACTOR	REYNOLDS NUMBER	DAMPERS CLOSED	TUNNEL AVERAGE VELOCITY (FPM)	COMMENTS
MCFFD5	5	0.0713	9.88862E+05	Y	669.006	
MCFFD4	4	0.0705	7.52753E+05	Y	509.750	
MCFFD3	3	0.0723	5.07067E+05	Y	386.401	
MCFFD2	2	0.0729	4.18981E+05	Y	284.187	
MCFFD1	1	0.0773	3.01387E+05	Y	204.400	

TABLE 3-3

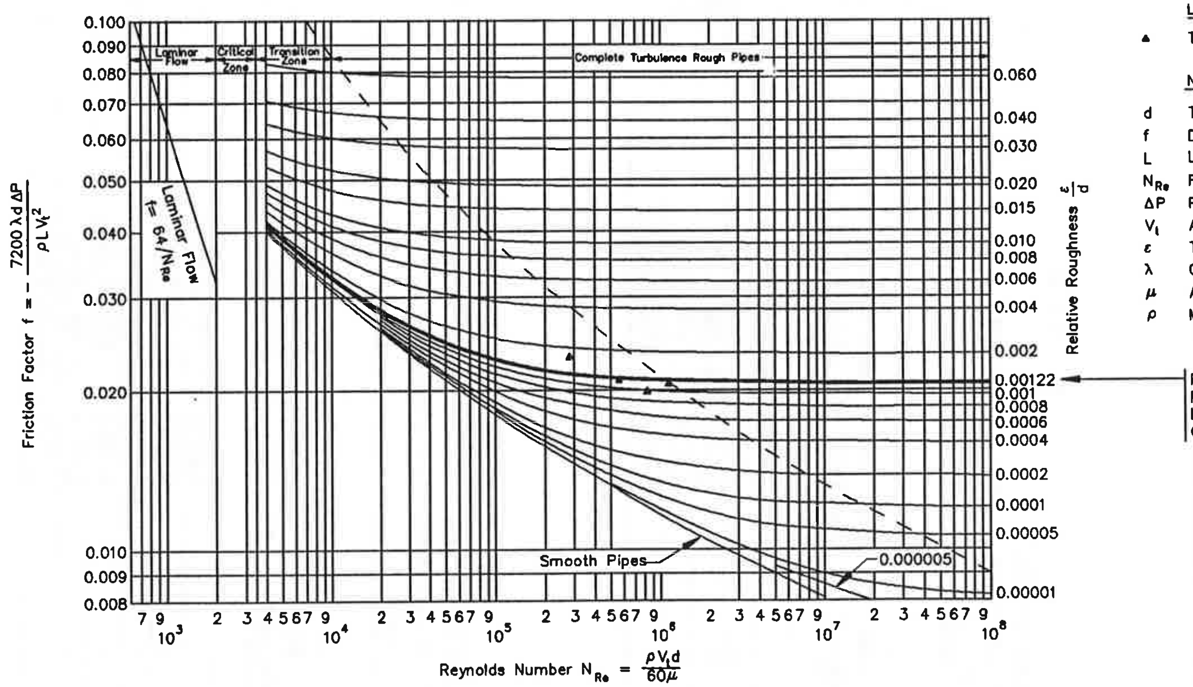
WMATA VENTILATION TESTS — TEST DATE: SEPTEMBER 6, 1990
FRICTION FACTOR TESTS AT 7TH & I STREETS
RIBBED WALL TUNNEL

RUN NAME	No. FANS EXHAUST	FRICTION FACTOR	REYNOLDS NUMBER	No. CANVAS UP	TUNNEL AVERAGE VELOCITY (FPM)	COMMENTS
7IFF2D4	4	0.0749	8.43603E+05	2	505.987	
7IFF2D3	3	0.0738	6.44347E+05	2	421.129	
7IFF2D2	2	0.0749	4.40137E+05	2	287.385	
7IFF2D1	1	0.1256	1.63193E+05	2	106.456	NOT USED
7IFF1D4	4	0.0774	6.08862E+05	1	397.088	
7IFF0D4	4	0.0798	4.81851E+05	0	313.806	

WMATA VENTILATION TESTS

TEST DATE: AUGUST 22, 1990

FRICTION FACTOR TEST AT BLUERIDGE AVENUE



LEGEND

▲ TEST RESULTS

NOMENCLATURE

d	Tunnel hydraulic diameter (ft)
f	Darcy Weisbach friction factor
L	Length of test section (ft)
N_{Re}	Reynolds Number
ΔP	Pressure change (in. wg)
V_t	Average tunnel air velocity (ft/min)
ε	Tunnel surface roughness (ft)
λ	Conversion factor (=5.2 lbf/(ft^2-in. wg))
μ	Absolute viscosity of air (lbf-sec/ft^2)
ρ	Mass density of air (slug/ft^3)

FIGURE 3-1

predicted a friction factor of 0.09 at a Reynolds number of 2E+05 (200,000).

The following two effects would decrease the measured friction factor, therefore the comparison is good.

- o Friction factors decrease with increasing Reynolds number and the test Reynolds numbers range from about 3E+05 (300,000) to about 1E+06 (1,000,000).

- o Because of the trackbed detail, the ribs are not exposed for the full perimeter of the tunnel.

Figure 3-2 is a Moody Chart depicting the field-measured values of the friction factor and the friction factor versus Reynolds number curve for a relative roughness of 0.05190. This relative roughness was used for all Metro Center tunnel data reduction.

Ribbed Wall Tunnel - 7th and I Streets. Table 3-3 shows the Reynolds number and friction factors measured in the tunnel adjacent to the 7th and I Streets fan shaft in September 1990. These values were obtained using the data reduction methodology and procedure referenced previously for the Blueridge Avenue tunnel. The results were as follows:

- o Equivalent relative roughness - 0.05705

- o Friction factor for fully developed turbulent flow - 0.075

Use of the approach discussed above for the Metro Center tunnels showed that these results compared favorably with that of other predictions.

Figure 3-3 is a Moody Chart depicting the field-measured values of the friction factor and the friction factor versus Reynolds number curve for a relative roughness of 0.05705. This relative roughness was used for all 7th and I Streets tunnel data reduction.

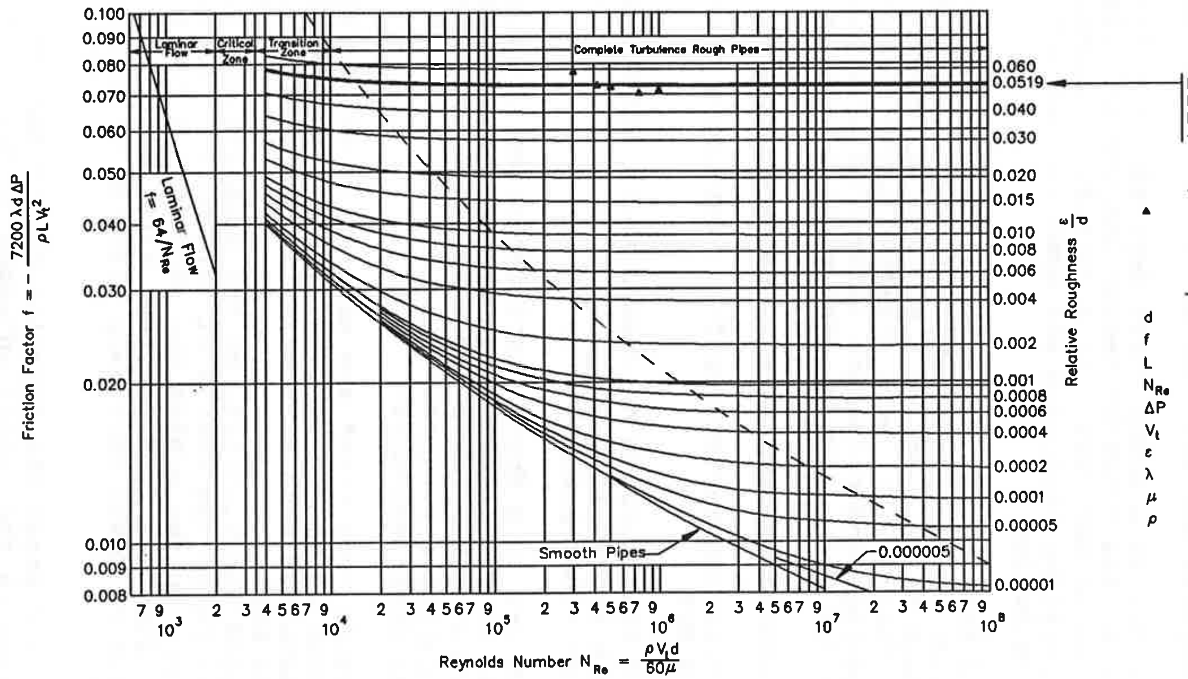
The words "not used" are entered in the fourth row of the Comments column in Table 3-3. After each series of tests, the data for each test were reviewed, often on a second-by-second basis, to determine if an isolated problem had affected the viability of the test adversely. For example, it was found the domain of influence of nighttime train movement in the system was such that a train movement a great distance from the test site could affect a test adversely. Tests adversely affected were labelled "not used".

Table 3-4 shows the Reynolds number and friction factors measured in the tunnel adjacent to the 7th and I Streets fan

WMATA VENTILATION TESTS

TEST DATE: JUNE 23, 1990

FRICTION FACTOR TESTS AT METRO CENTER



LEGEND

▲ TEST RESULTS

NOMENCLATURE

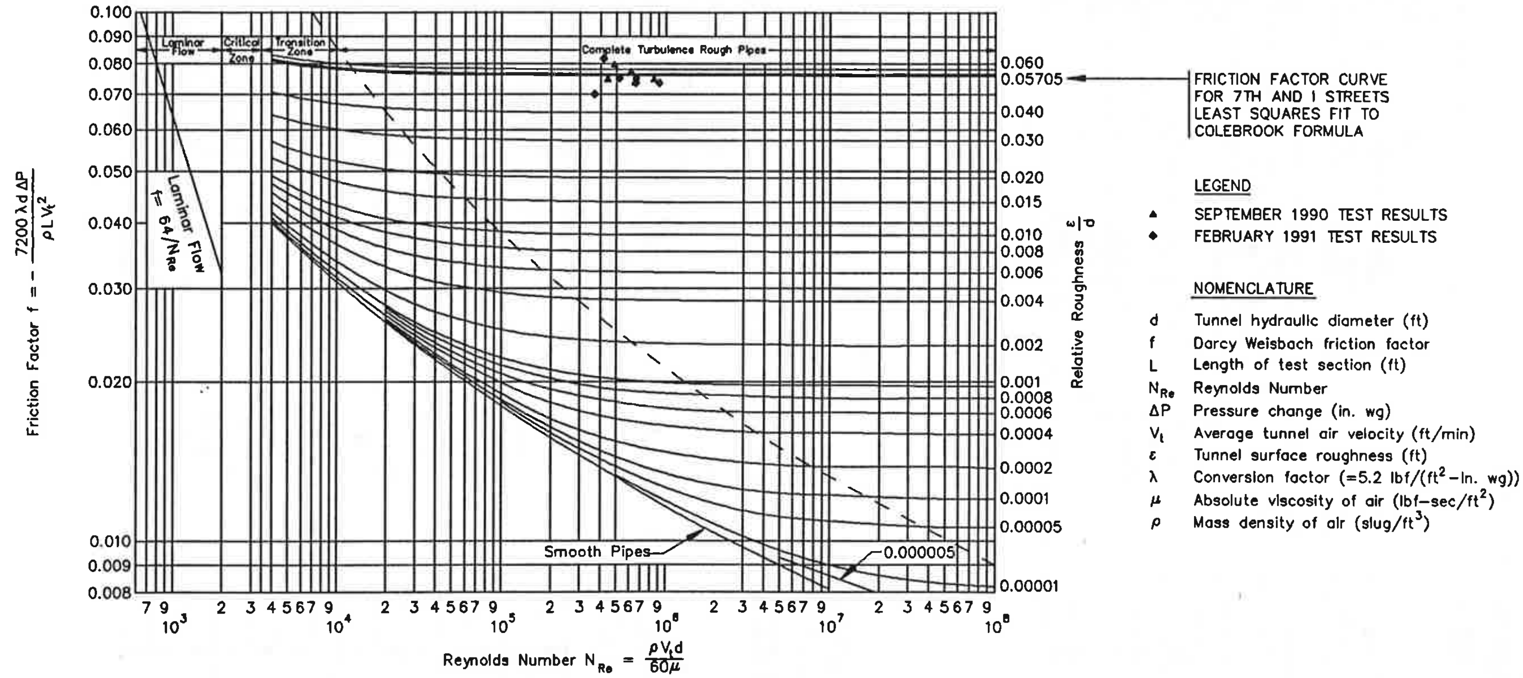
d	Tunnel hydraulic diameter (ft)
f	Darcy Weisbach friction factor
L	Length of test section (ft)
N_{Re}	Reynolds Number
ΔP	Pressure change (in. wg)
V_t	Average tunnel air velocity (ft/min)
ε	Tunnel surface roughness (ft)
λ	Conversion factor (=5.2 $lbf/(ft^2-in.\ wg)$)
μ	Absolute viscosity of air ($lbf-sec/ft^2$)
ρ	Mass density of air ($slug/ft^3$)

FIGURE 3-2

WMATA VENTILATION TESTS

FRICTION FACTOR TESTS AT 7TH & I STREETS

TEST DATES: SEPTEMBER 6, 1990
& FEBRUARY 24, 1991



LEGEND

▲ SEPTEMBER 1990 TEST RESULTS

◆ FEBRUARY 1991 TEST RESULTS

NOMENCLATURE

d	Tunnel hydraulic diameter (ft)
f	Darcy Weisbach friction factor
L	Length of test section (ft)
N_{Re}	Reynolds Number
ΔP	Pressure change (in. wg)
V_t	Average tunnel air velocity (ft/min)
ε	Tunnel surface roughness (ft)
λ	Conversion factor (=5.2 lbf/(ft^2-in. wg))
μ	Absolute viscosity of air (lbf-sec/ft^2)
ρ	Mass density of air (slug/ft^3)

FIGURE 3-3

TABLE 3-4

WMATA VENTILATION TESTS
FRICTION FACTOR TESTS AT 7TH & I STREETS
RIBBED WALL TUNNEL

TEST DATE: FEBRUARY 24,1991

RUN NAME	No. FANS EXHAUST	FRICTION FACTOR	REYNOLDS NUMBER	No. CANVAS UP	TUNNEL AVERAGE VELOCITY (FPM)	COMMENTS
7IFF2D4	4	0.0737	9.07584E+05	2	584.452	
7IFF2D3	3	0.0737	6.55734E+05	2	422.962	
7IFF2D2	2	0.0819	4.18923E+05	2	270.100	
7IFF2D2R	2	0.0700	3.69186E+05	2	238.384	
7IFF2D1	1	0.1112	8.74297E+04	2	56.812	NOT USED
7IFF1D4	4	0.0747	6.56441E+05	1	422.610	
7IFF1D3	3	0.0752	5.20366E+05	1	335.665	
7IFF1D2	2	0.0658	2.84468E+05	1	183.65	NOT USED

TABLE 3-5

WMATA VENTILATION TESTS
BARRIER TESTS AT METRO CENTER
RIBBED WALL TUNNEL

TEST DATE: JUNE 24, 1990

RUN NAME	No. FANS EXHAUST	BARRIER HEAD LOSS COEFFICIENT (K)	DAMPERS CLOSED	BARRIER TUNNEL AVERAGE VELOCITY (FPM)	ADJACENT TUNNEL AVERAGE VELOCITY (FPM)	COMMENTS
MCB5DT	5	75.2792	Y	269.654	925.849	
MCB4DT	4	66.1140	Y	212.489	684.230	
MCB3DT	3	66.7931	Y	157.754	502.649	
MCB2DT	2	61.0933	Y	103.695	294.505	
MCB1DT	1	11.6961	Y	128.411	20.045	NOT USED
MCB5T	5	84.1231	N	127.049	392.232	
MCB4T	4	92.0406	N	98.413	291.58	
MCB3T	3	102.3930	N	74.821	228.523	
MCB2T	2	99.7479	N	56.493	109.973	
MCB5DTR	5	59.1547	Y	294.408	912.254	
MCB4DTR	4	55.4181	Y	229.461	675.501	
MCB3DTR	3	54.8476	Y	170.435	497.253	
MCB2DTR	2	58.2989	Y	109.565	281.679	
MCB1DTR	1	481.9170	Y	22.732	103.016	NOT USED

shaft in February 1991. These values were obtained using the data reduction methodology and procedure referenced previously. These tests repeated the September 1990 tests:

- o To provide assurance that the on-going construction had not changed the tunnel friction factor
- o To confirm the repeatability of the measurements.

The difference between these tests and the September 1990 tests was less than the manufacturer's accuracy of the instruments. The results are plotted on Figure 3-3 to show this comparison.

Commentary On Friction Factor Tests. The results of the friction factor tests agreed well with those predicted by handbooks. The handbook values were developed by accurate scale-model laboratory tests that have been found to accurately predict full-scale phenomena.

The ribbed tunnel friction factors for the 7th and I Street and Metro Center tunnels differed by 0.002 or about three percent. This was much less than the specified error of the instrumentation and may have been caused by differences in fire lines and electrical conduits mounted along the tunnel walls. From a design viewpoint, a tunnel relative roughness of 0.057 and a fully-developed turbulent flow friction factor of 0.075 can be used.

The smooth wall friction factor results provide data suitable for design with a relative roughness of 0.012 and a fully-developed turbulent flow friction factor of 0.021 being appropriate.

To sum up, the results of the friction factor tests were suitable for Metrorail design and as inputs to the remaining tests. For any future tests that may be required, it appears necessary to measure the friction factor for the individual tunnel in order to reduce the error in the test results.

Barrier Tests

Barrier Tests - Metro Center. Table 3-5 shows the results obtained for a barrier tested in the tunnel between Metro Center Station and the New York Avenue fan shaft in June 1990. These values were obtained using the data reduction methodology described in Appendix B. The procedure was that outlined in Section B.22. Two air velocities are tabulated:

- o In the tunnel having the barrier
- o In the same tunnel but on the other side of the fan shaft.

These air velocities show that the barrier redirected the airflow from its tunnel to the other tunnel.

Figure 3-4 shows the barrier head loss coefficient, K, as a function of the tunnel air velocity. These results were indicative, pending tests of the next design configuration of the barrier.

The results show the barrier head loss coefficient decreasing from about 100 for low tunnel air velocities to about 50 for higher tunnel air velocities. This effect was consistent with design of the personnel egress opening in the middle of the barrier. The increased pressure difference across the barrier deflects the barrier in such a manner that the personal egress opening is bowed open further, thus allowing more air to pass through it and reducing K.

The scatter of the data was most likely caused by variations in the barrier torus internal air pressure.

Figure 3-4 also shows the equivalent flat plate K for various percentages of blockage - the head loss coefficients that would occur if the tunnel was blocked to these percentages with an orifice plate. It shows an equivalent flat plate blockage of between 80 and 85 percent. However, it should be noted that the barrier may be actually blocking the tunnel and that streamlining or drag effects may be decreasing or increasing its actual K. Equation 25 in Appendix B provides the flat plate K as a function of the blockage. The numerical values are tabulated following Equation 27.

An estimate was made as to the ability of a barrier with known constant head loss coefficient to redirect the tunnel airflow. The results indicated that:

- A single barrier per tunnel leg would suffice for the case of a train stopped in a smooth wall tunnel.
- Two barriers per tunnel leg would probably be required for the case of a train stopping in a ribbed wall tunnel.

As discussed in Section 4.3, these preliminary estimates were then evaluated in detail using the SES computer program after the test results for the final design configuration barriers were available. They provided early confirmation, however, that the barriers would function as needed.

Barrier Tests - 7th and I Streets. Table 3-6 shows the results obtained for an improved barrier tested in the tunnel adjacent to the 7th and I Streets fan shaft in February 1991. These values were obtained using the

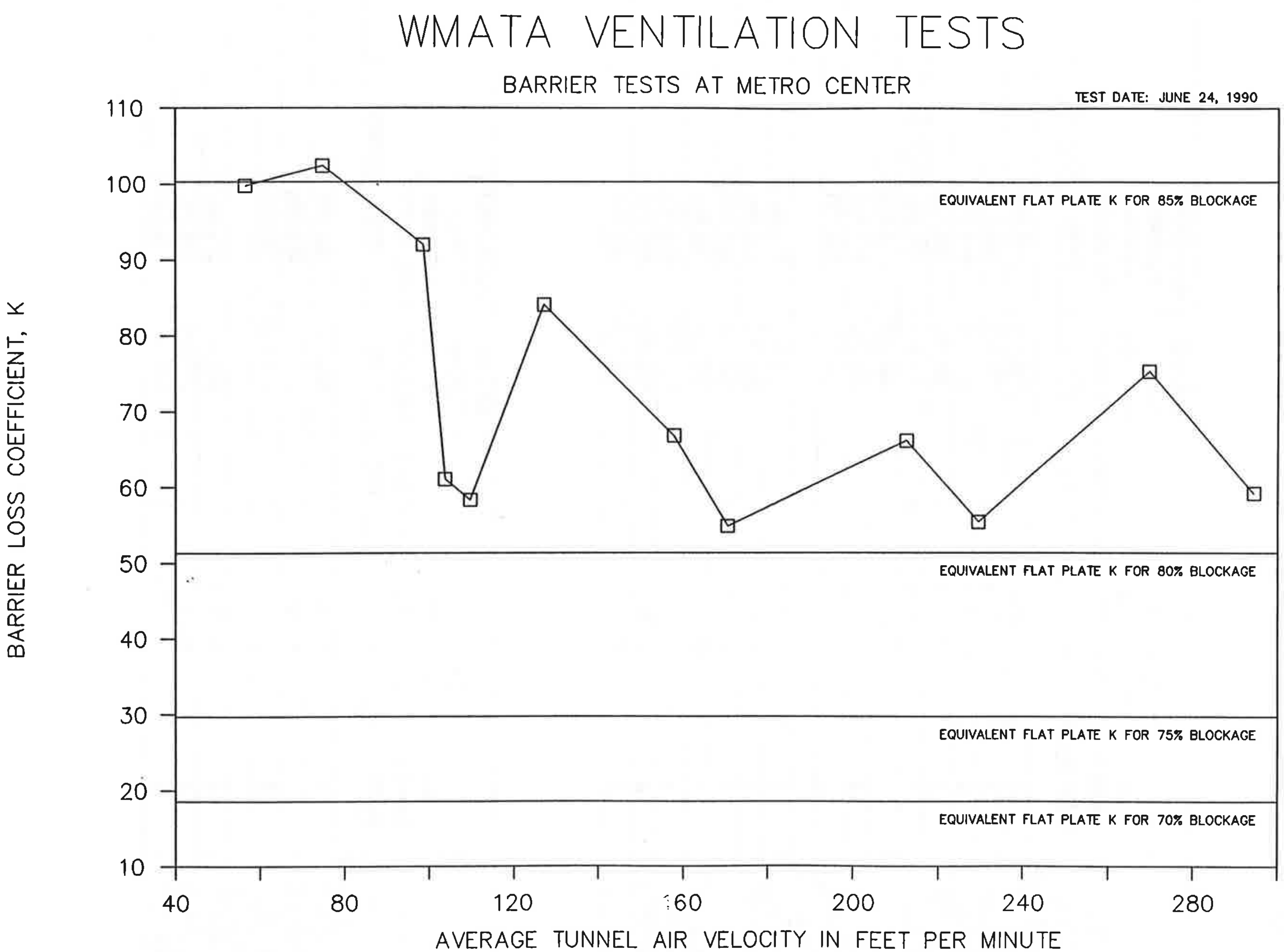

WMATA VENTILATION TESTS
BARRIER TESTS AT METRO CENTER
TEST DATE: JUNE 24, 1990
BARRIER LOSS COEFFICIENT, K
110
100
90
80
70
60
50
40
30
20
10
EQUIVALENT FLAT PLATE K FOR 85% BLOCKAGE
EQUIVALENT FLAT PLATE K FOR 80% BLOCKAGE
EQUIVALENT FLAT PLATE K FOR 75% BLOCKAGE
EQUIVALENT FLAT PLATE K FOR 70% BLOCKAGE
40
80
120
160
200
240
280
AVERAGE TUNNEL AIR VELOCITY IN FEET PER MINUTE

FIGURE 3-4

TABLE 3-6

WMATA VENTILATION TESTS
BARRIER TESTS AT 7 & I STREETS
RIBBED WALL TUNNEL

TEST DATE: FEBRUARY 25, 1991

RUN NAME	No. FANS IN EXHAUST	BARRIER HEAD LOSS COEFFICIENT (K)	DAMPERS CLOSED	BARRIER TUNNEL AVERAGE VELOCITY (FPM)	ADJACENT TUNNEL AVERAGE VELOCITY (FPM)	COMMENTS
EGRESS CLOSED						
7IB4D2EC	4	86.4841	2	238.405	565.522	
7IB3D2EC	3	84.2249	2	185.708	440.540	
7IB3D2ECR	3	88.1277	2	180.845	444.356	
7IB2D2EC	2	143.9369	2	86.667	290.140	
7IB1D2EC	1	107.8959	2	53.297	170.381	NOT USED
7IB4D1EC	4	117.9135	1	148.027	422.312	
7IB3D1EC	3	134.2416	1	104.212	317.992	
7IB2D1EC	2	200.1141	1	53.327	222.721	
EGRESS OPEN						
7IB4D2EO	4	40.4327	2	313.056	538.485	
7IB3D2EO	3	40.0859	2	245.395	420.841	
7IB2D2EO	2	46.4086	2	156.129	297.240	
7IB1D2EO	1	67.4571	2	63.284	169.880	
7IB4D1EO	4	42.5865	1	220.217	413.387	
7IB3D1EO	3	45.6754	1	155.020	335.746	
7IB2D1EO	2	53.7114	1	87.335	237.877	

RUN NAME	No. FANS IN SUPPLY	BARRIER HEAD LOSS COEFFICIENT (K)	DAMPERS CLOSED	BARRIER TUNNEL AVERAGE VELOCITY (FPM)	ADJACENT TUNNEL AVERAGE VELOCITY (FPM)	COMMENTS
EGRESS CLOSED						
7IB4D2SC	4	58.2846	2	189.147	289.278	
7IB3D2SC	3	50.7216	2	157.764	252.394	
7IB2D2SC	2	55.2754	2	111.650	182.859	
EGRESS OPEN						
7IB4D2SO	4	24.7217	2	248.037	278.345	
7IB3D2SO	3	25.4045	2	200.470	226.717	
7IB2D2SO	2	22.1273	2	140.740	134.141	

methodology and procedure referenced in the previous section. Two air velocities are tabulated:

- o In the tunnel having the barrier
- o In the same tunnel but on the other side of the fan shaft.

These air velocities show the barrier redirected the airflow from its tunnel to the other tunnel.

Figures 3-5, 3-6, 3-7 and 3-8 show the barrier head loss coefficient, K, as a function of the tunnel air velocity for the egress closed and open with the tunnel ventilation fans operating in exhaust and supply. The figures show:

- o K decreasing with air velocity as discussed above
- o K being decreased by the egress being opened, an expected phenomena since the opening of the egress allowed the barrier to pass more air
- o K in the fan exhaust mode being much greater than K in the supply mode.

A close examination of the deployed barrier during the ventilation tests concluded the following:

- o The supply performance could be made more similar to the exhaust performance by shifting the attachment between the barrier and the torus from the side edge of the torus to center edge of the torus. This shift would make the barrier truly bi-axial.
- o Although the barrier fit the tunnel satisfactorily, some localized improvement in the fit of the barrier to the sidewalk and third rail corners of the tunnel could be achieved. This improvement would serve to increase the barrier head loss coefficient and hence its ability to re-direct tunnel airflow.

The production barriers will have these improvements so it was concluded that the exhaust data should be used for design.

Figure 3-9 presents the barrier ventilation performance data. The test results were curve fitted with exponential curves passing through their extreme values. The formula is:

$$K = C_1 + C_2 e^{C_3 V}$$

The numerical values of the C coefficients are:

Egress

WMATA VENTILATION TESTS

BARRIER TESTS AT 7 & I ST., EXHAUST MODE, EGRESS CLOSED

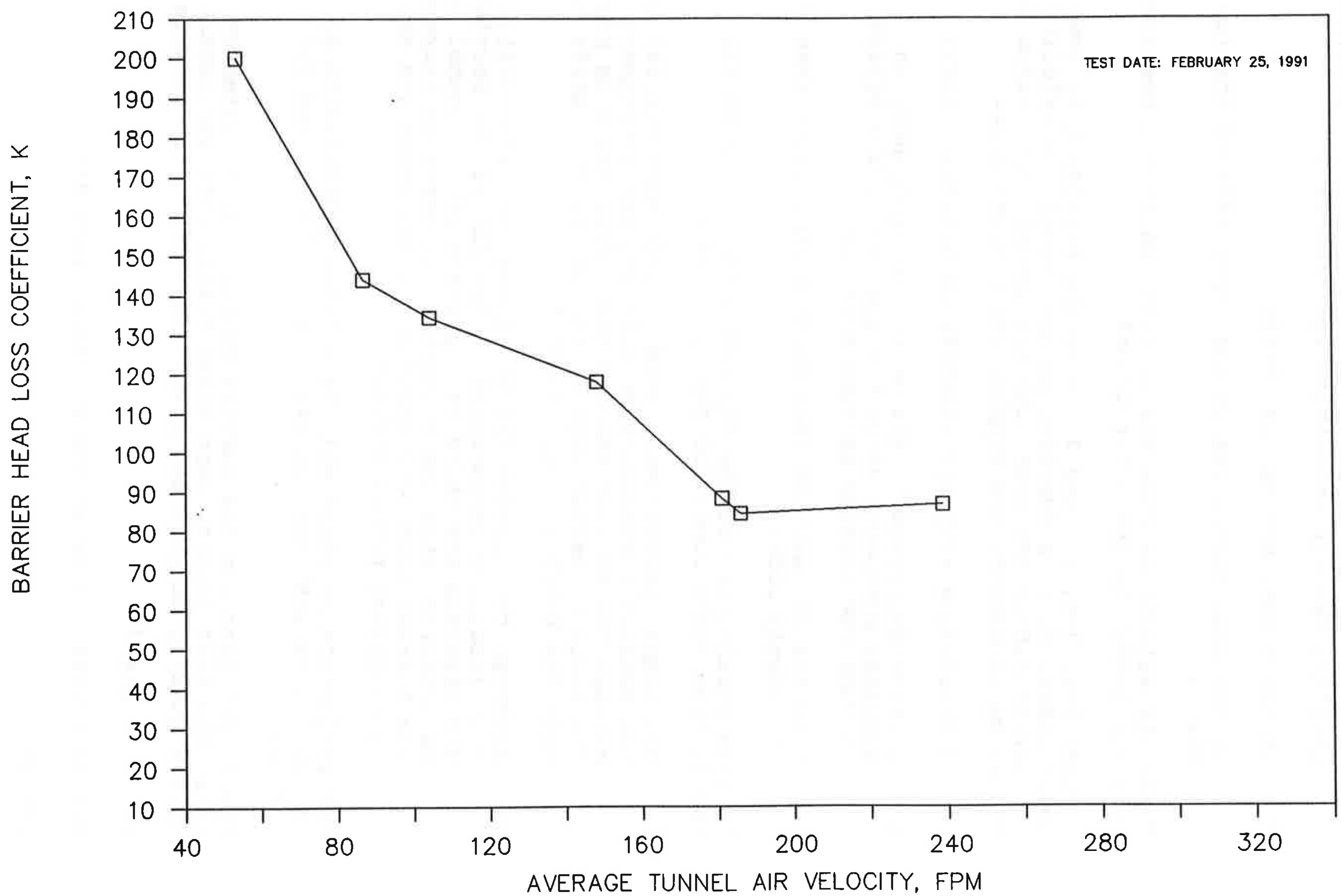


FIGURE 3-5

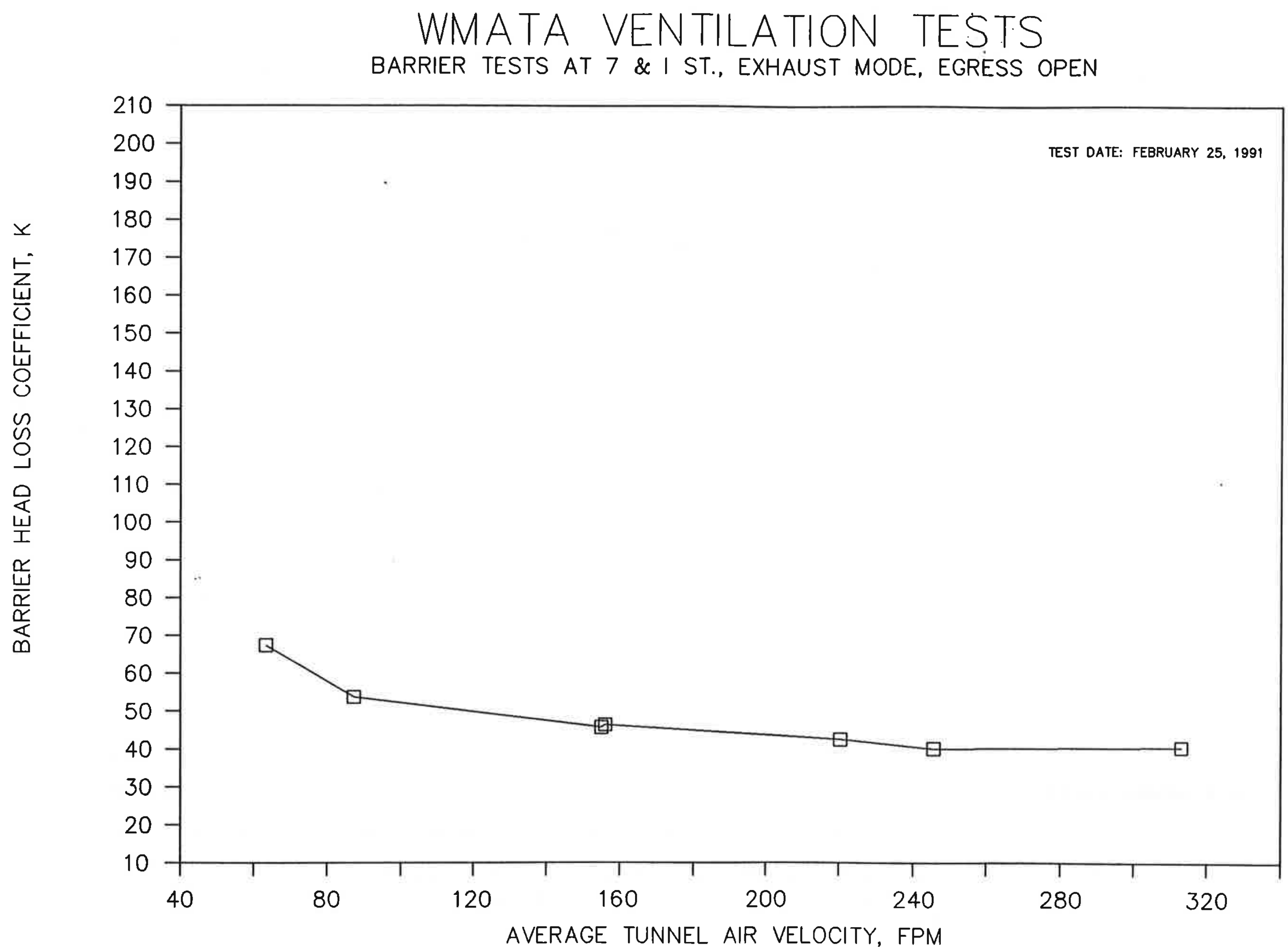

WMATA VENTILATION TESTS
BARRIER TESTS AT 7 & I ST., EXHAUST MODE, EGRESS OPEN
TEST DATE: FEBRUARY 25, 1991
BARRIER HEAD LOSS COEFFICIENT, K
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
40
80
120
160
200
240
280
320
AVERAGE TUNNEL AIR VELOCITY, FPM

FIGURE 3-6

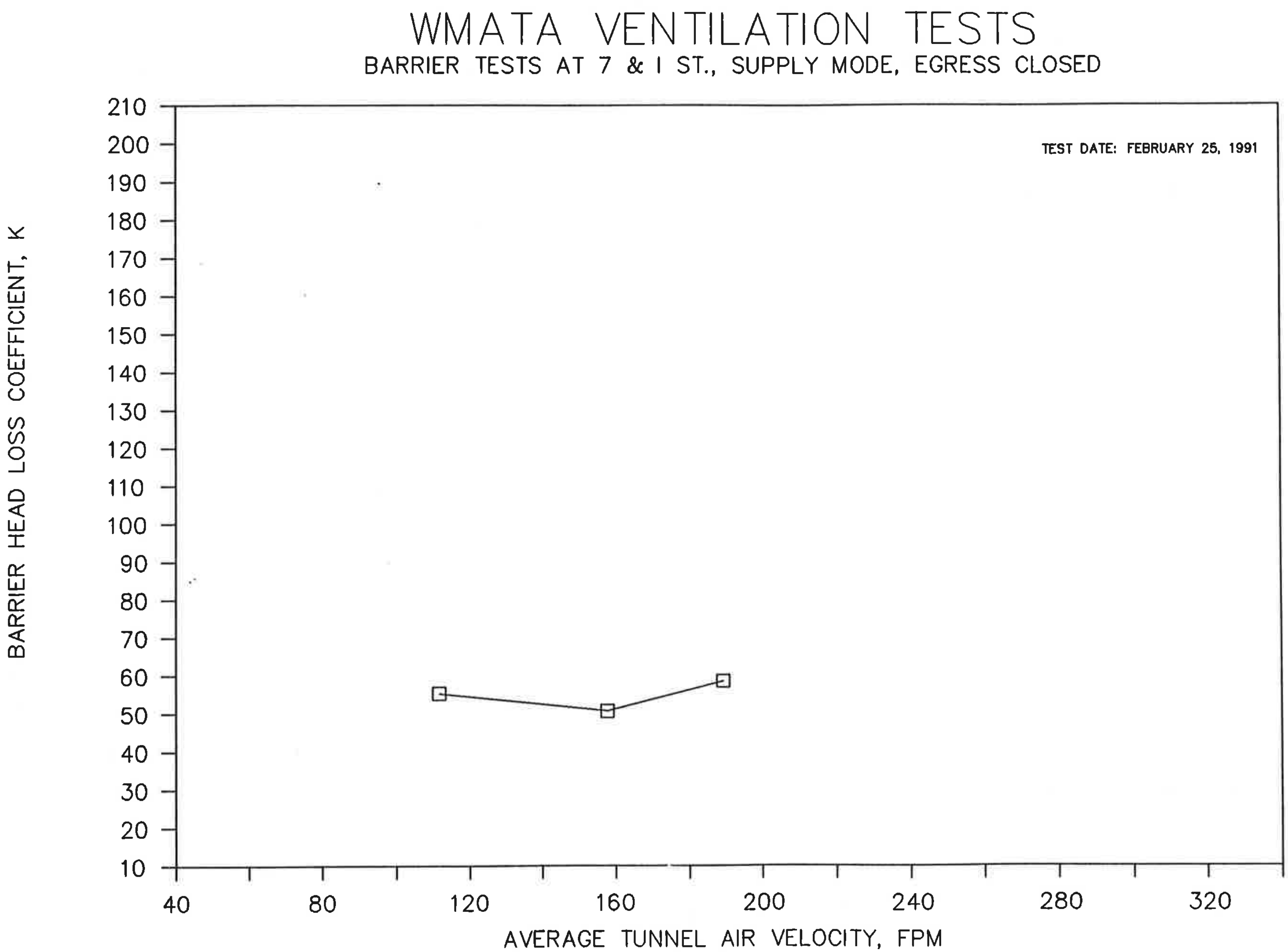

WMATA VENTILATION TESTS
BARRIER TESTS AT 7 & I ST., SUPPLY MODE, EGRESS CLOSED
TEST DATE: FEBRUARY 25, 1991
BARRIER HEAD LOSS COEFFICIENT, K
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
40
80
120
160
200
240
280
320
AVERAGE TUNNEL AIR VELOCITY, FPM

FIGURE 3–7

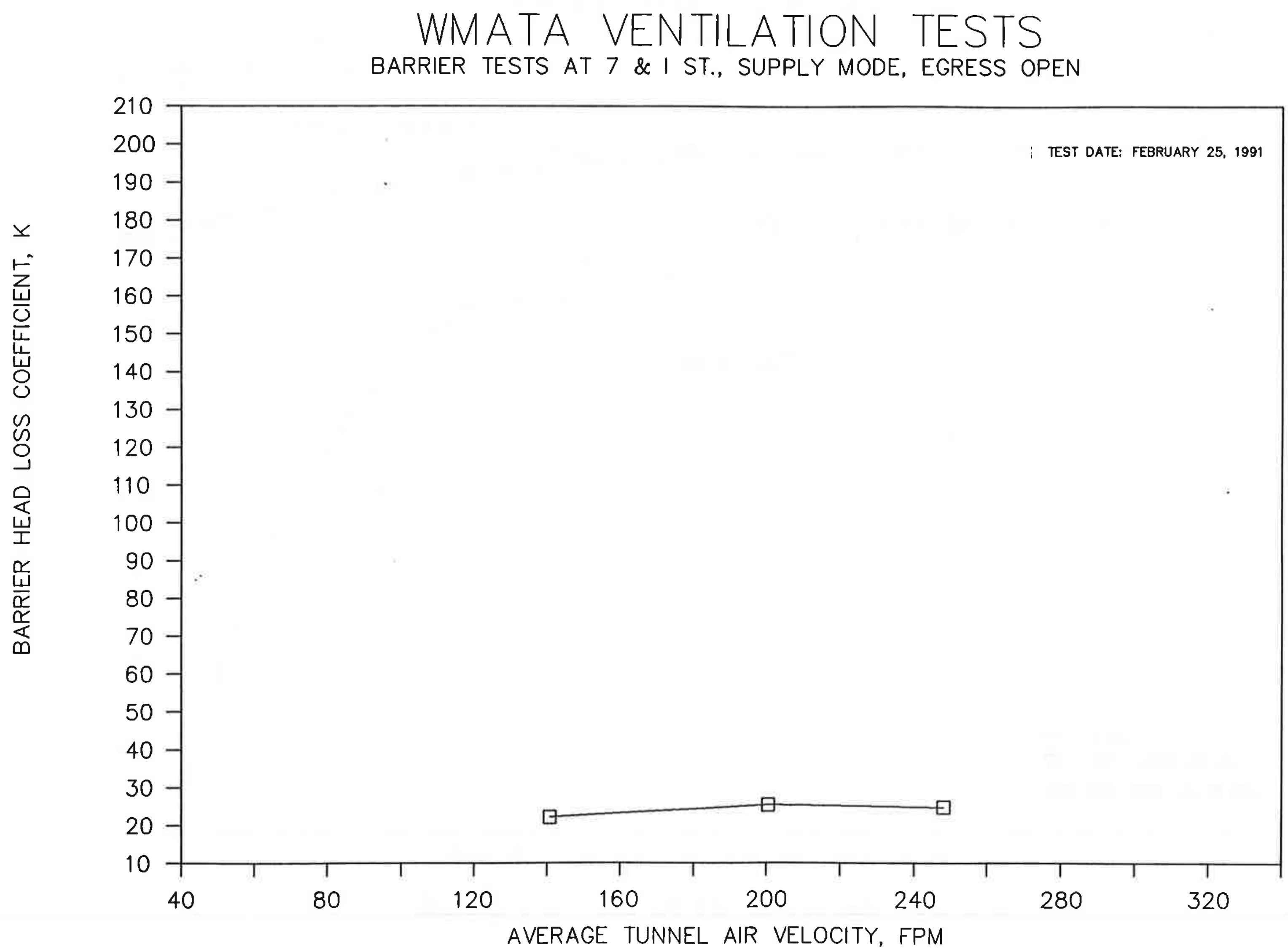

WMATA VENTILATION TESTS
BARRIER TESTS AT 7 & I ST., SUPPLY MODE, EGRESS OPEN
TEST DATE: FEBRUARY 25, 1991
BARRIER HEAD LOSS COEFFICIENT, K
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
40
80
120
160
200
240
280
320
AVERAGE TUNNEL AIR VELOCITY, FPM

FIGURE 3-8

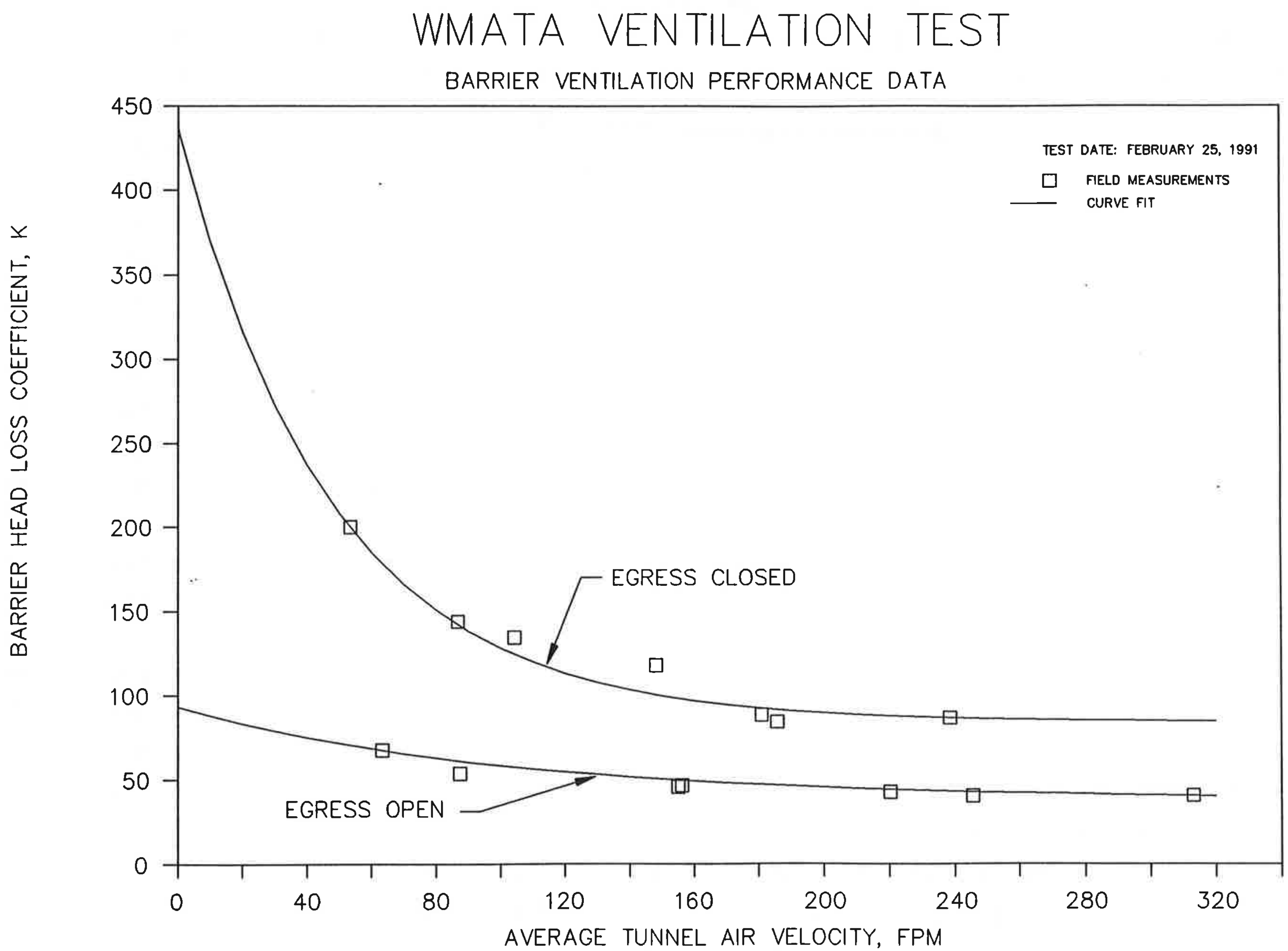

WMATA VENTILATION TEST
BARRIER VENTILATION PERFORMANCE DATA
TEST DATE: FEBRUARY 25, 1991
FIELD MEASUREMENTS
CURVE FIT
EGRESS CLOSED
EGRESS OPEN
BARRIER HEAD LOSS COEFFICIENT, K
AVERAGE TUNNEL AIR VELOCITY, FPM
0
50
100
150
200
250
300
350
400
450
0
40
80
120
160
200
240
280
320

FIGURE 3–9

Opening	C_1	C_2	C_3
Closed	84.00	352.06	-0.0208
Open	38.00	55.41	-0.0100

Commentary on Barrier Tests. The tests demonstrated that inflatable barriers can be used to direct sufficient quantities of air past a stopped train during an emergency. The ventilation performance data in the form of the barrier head loss coefficients can be directly used for SES computer program input and/or modification during final design.

Jet Fan Mounting Head Loss Tests

Smooth Wall Tunnel. Table 3-7 and Figure 3-10 show the results of the jet fan mounting tests in the tunnel adjacent to the Blueridge Avenue fan shaft. These values were obtained in preliminary form using the data reduction methodology described in Appendix B. The procedure was that outlined in Section B.20.

Actual site logistics made it necessary to obtain the pressure loss data with the jet fans mounted in their position on top of the jet fan mountings for one tunnel airflow. To obtain the loss caused by the jet fan mounting, it was then necessary to manually estimate and subtract out the loss caused by the jet fan only. The procedure raised some concern because the clearance between the top of the jet fan and the smooth tunnel wall was only about five inches. However, the results are reasonable.

As the distance between the jet fans decreases, the head loss coefficient increases slightly and then decreases slightly. The initial increase is most likely caused by the trailing jet fan mountings beginning to encounter the increased turbulence of the upstream jet fan mountings. The subsequent decrease is most likely caused by the trailing jet fan mountings becoming entrained in the wake of the upstream jet fans and encountering reduced air velocities.

Ribbed Wall Tunnel. Table 3-8 and Figure 3-11 show the results of the jet fan mounting tests in the tunnel adjacent to the 7th and I Streets fan shaft. These values were obtained in preliminary form using the methodology and procedure referenced in the previous section.

As was the case in the smooth wall tunnel, actual site logistics made it necessary to obtain the pressure loss data with the jet fans mounted in their position on top of the jet fan mountings for one tunnel airflow, and manually estimate and subtract out the loss caused by the jet fan only to obtain the loss caused by the jet fan mounting only.

TABLE 3-7

WMATA VENTILATION TESTS TEST DATES: AUGUST 22-24, 1990
JET FAN MOUNTING HEAD LOSS COEFFICIENT TESTS AT BLUEREIDGE AVE.
SMOOTH WALL TUNNEL

RUN NAME	No. FANS EXHAUST	JET FAN MOUNTING HEAD LOSS COEFFICIENT Cd	JET FAN SPACING (FT.)	TUNNEL AVERAGE VELOCITY (FPM)	COMMENTS
BRD50	4	0.1414	50	742.886	
BRD75	4	0.1471	75	732.500	
BRD100	4	0.1315	100	737.500	

TABLE 3-8

WMATA VENTILATION TESTS TEST DATES: AUG. 30-SEP. 6, 1990
JET FAN MOUNTING HEAD LOSS COEFFICIENT TESTS AT 7TH & I STREETS
RIBBED WALL TUNNEL

RUN NAME	No. FANS EXHAUST	JET FAN MOUNTING HEAD LOSS COEFFICIENT Cd	JET FAN SPACING (FT.)	TUNNEL AVERAGE VELOCITY (FPM)	COMMENTS
7ID50	4	0.2860	50	520.200	
7ID75	4	0.2763	75	520.400	
7ID100	4	0.3107	100	521.200	

WMATA VENTILATION TESTS

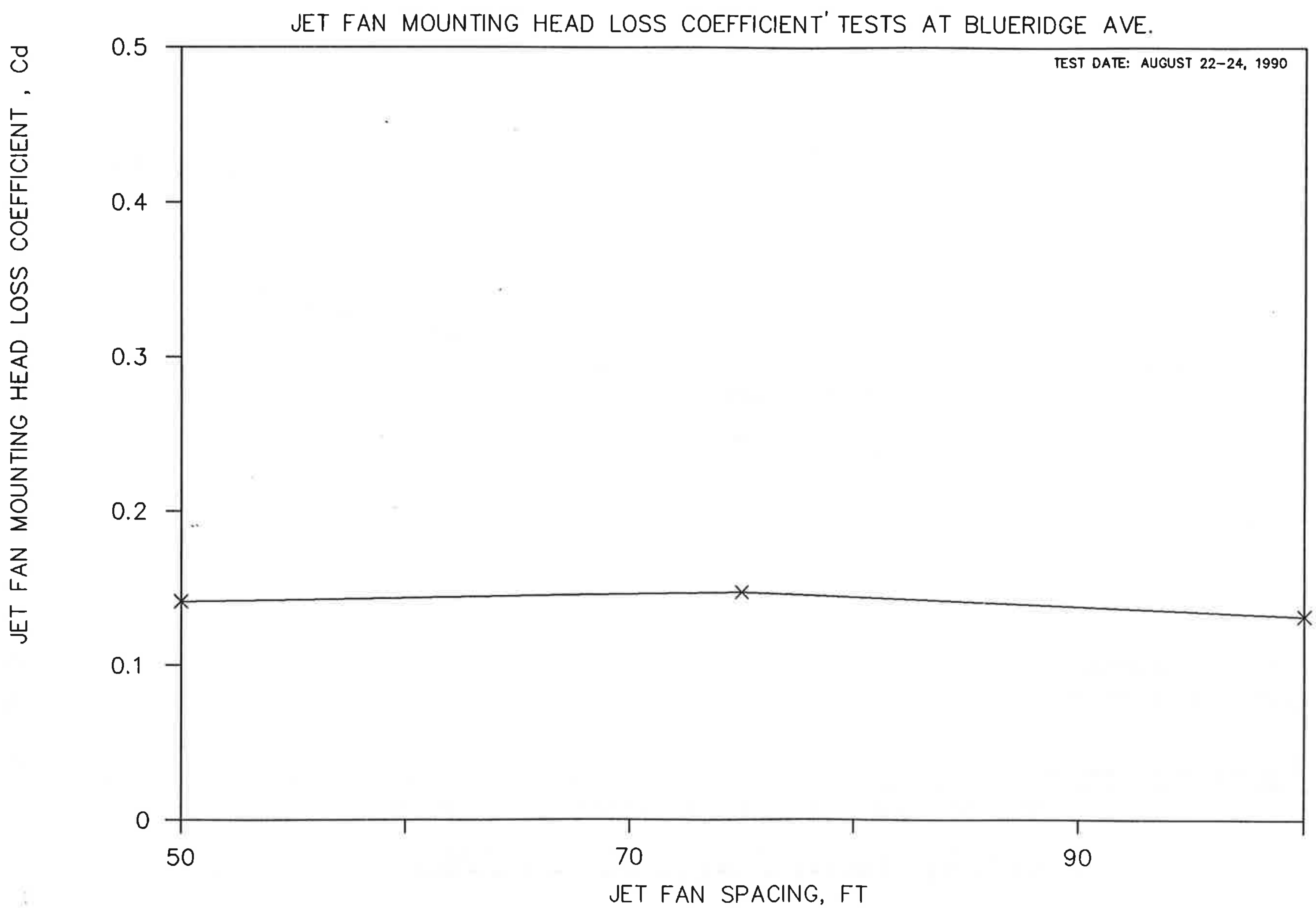


FIGURE 3-10

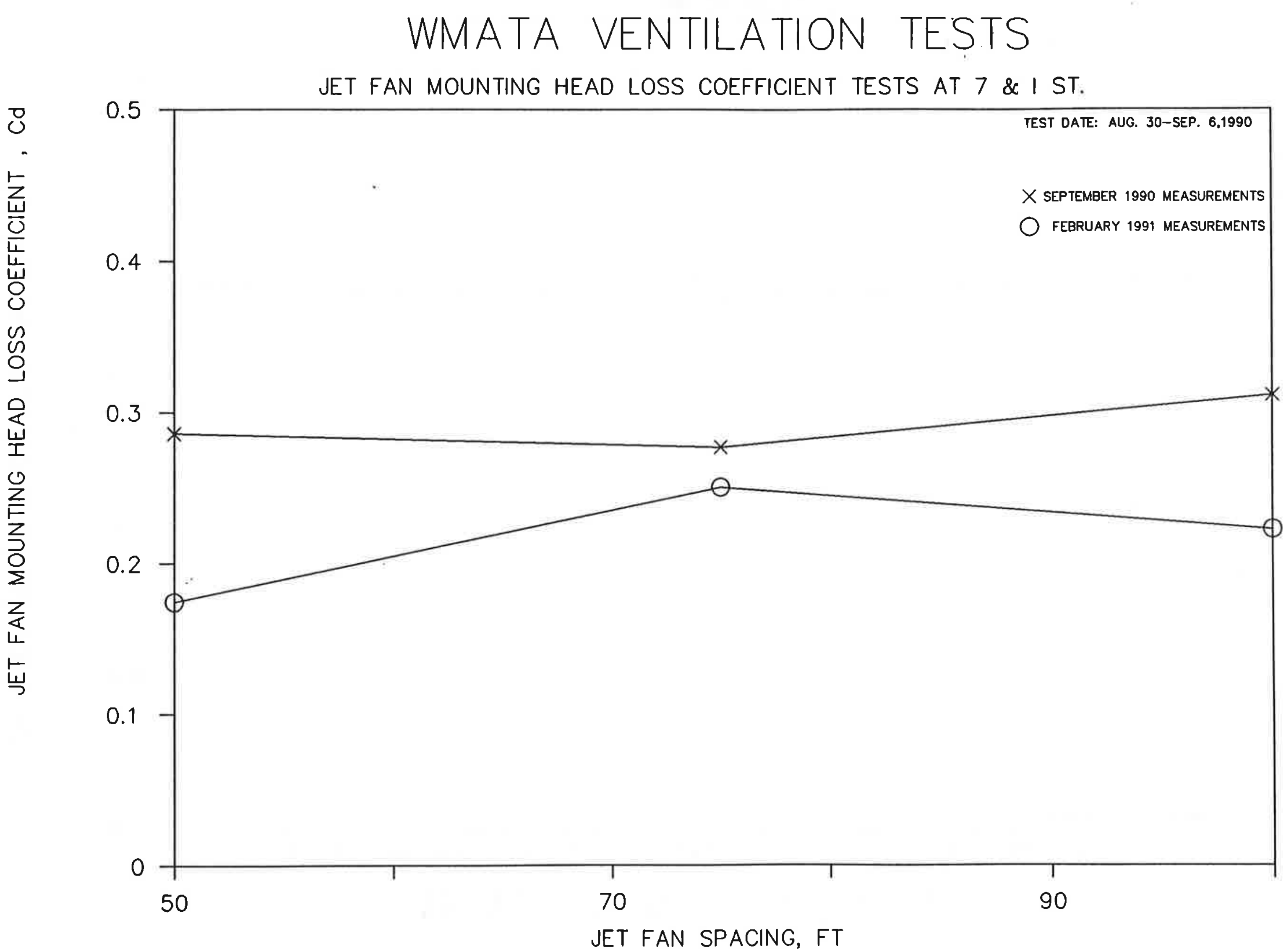

WMATA VENTILATION TESTS
JET FAN MOUNTING HEAD LOSS COEFFICIENT TESTS AT 7 & I ST.
TEST DATE: AUG. 30-SEP. 6,1990
SEPTEMBER 1990 MEASUREMENTS
FEBRUARY 1991 MEASUREMENTS
JET FAN MOUNTING HEAD LOSS COEFFICIENT , Cd
0.5
0.4
0.3
0.2
0.1
0
50
70
90
JET FAN SPACING, FT

FIGURE 3-11

This procedure also raised some concern because the clearance between the top of the jet fan and the ribbed tunnel wall was only about five inches.

This concern appeared to be justified by the difference between the results for the smooth and ribbed wall tunnels. The jet fan mounting head loss coefficient for the ribbed wall tunnel is about twice that for the smooth-wall tunnel. An extrapolation of previous experiments [2] predicted the wall roughness should only have a slight effect on the jet fan mounting head loss coefficient. It appeared that the turbulence in the five-inch gap between the ribs and the top of the jet fans increased the drag of the jet fans beyond that predicted by manual calculation.

It was therefore decided to test the jet fan mountings without the jet fans during the final design barrier tests. The results of these February 1991 tests - which used the only two jet fan mountings available - are shown in Figure 3-11. Manually accounting for the effect of the jet fans being in place rather than directly testing without them was demonstrated to be an acceptable procedure.

The differences between the smooth and ribbed wall jet fan mounting head loss coefficient tests were then reviewed with a Cal Tech/JPL experimenter who had previously done scale model tests for ribbed wall tunnels but who was not available during the earlier tests. He was not surprised by the differences between the smooth and ribbed wall tests. It was therefore concluded that the results of the ribbed wall jet fan mounting head loss coefficients tests were appropriate to use in the jet fan pressure efficiency tests.

Commentary on the Jet Fan Mounting Head Loss Coefficient Tests. The results were deemed appropriate for use in the jet fan pressure efficiency tests.

Jet Fan Pressure Efficiency Tests

Smooth Wall Tunnel. Table 3-9 shows the results of the jet fan tests in the tunnel adjacent to the Blueridge Avenue fan shaft for jet fan spacings of 100, 75 and 50 feet. These values were obtained using the data reduction methodology described in Appendix B. The procedure was that outlined in Section B.21.

The table shows some air measurements of zero. This is caused by the range of the test anemometers. The calibrated operating range of the fan anemometer is limited to 50 fpm. Since a linear response below 50 fpm could not be assured, the software was designed to assign any velocity less than 50 fpm to 0 fpm. The resulting output is a zero. A sensitivity study was done to determine the importance of

TABLE 3-9

WMATA VENTILATION TESTS — TEST DATES: AUGUST 22-24, 1990
JET FAN TESTS AT BLUERIDGE AVENUE - 100 FOOT SPACING
SMOOTH WALL TUNNEL

RUN NAME	No. FANS EXHAUST	JET FAN PRESSURE EFFICIENCY	TUNNEL AVERAGE VELOCITY (FPM)	TUNNEL AVERAGE AIRFLOW (CFM)	QT/QF	VT/VF	X (FT.)	X/DT	X/DF	Z (IN.)	Z/DF
BRJF100H4	4	0.9137	286.421	52602.4	-2.449	-0.042	100	7.034	50	20	0.833
BRJF100H3	3	0.8968	0.000	0.0	0.000	0.000	100	7.034	50	20	0.833
BRJF100H2	2	0.7978	-192.474	-35348.6	1.646	0.028	100	7.034	50	20	0.833
BRJF100H1	1	0.7328	-421.204	-77355.8	3.602	0.062	100	7.034	50	20	0.833
BRJF100H0	0	0.6060	-897.423	-164815.3	7.674	0.131	100	7.034	50	20	0.833
BRJF100M4	4	0.9353	274.161	50350.8	-2.344	-0.040	100	7.034	50	26	1.083
BRJF100M3	3	0.9158	0.000	0.0	0.000	0.000	100	7.034	50	26	1.083
BRJF100M2	2	0.8174	-209.042	-38391.4	1.788	0.031	100	7.034	50	26	1.083
BRJF100M1	1	0.7555	-435.345	-79952.9	3.723	0.064	100	7.034	50	26	1.083
BRJF100M0	0	0.6334	-922.279	-169380.2	7.887	0.135	100	7.034	50	26	1.083
BRJF100L4	4	0.9455	279.031	51245.2	-2.386	-0.041	100	7.034	50	32	1.333
BRJF100L3	3	0.9245	0.000	0.0	0.000	0.000	100	7.034	50	32	1.333
BRJF100L2	2	0.8445	-215.065	-39497.5	1.839	0.031	100	7.034	50	32	1.333
BRJF100L1	1	0.7708	-442.538	-81273.9	3.784	0.065	100	7.034	50	32	1.333
BRJF100L0	0	0.6532	-935.163	-171746.4	7.997	0.137	100	7.034	50	32	1.333

X=JET FAN SPACING.
Z= DISTANCE FROM TUNNEL WALL TO JET FAN CENTER LINE.
DT= TUNNEL HYDRAULIC DIAMETER, 14.2174 FT.
DF= JET FAN DISCHARGE DIAMETER, 24 IN. (2 FT.)
QT= AVERAGE TUNNEL AIRFLOW (CFM).
QF= AVERAGE JET FAN AIRFLOW CAPACITY (CFM)= -21477.
VT= AVERAGE TUNNEL AIR VELOCITY (FPM).
VF= AVERAGE JET FAN DISCHARGE VELOCITY (FPM)= -6836.34.

TABLE 3-9

WMATA VENTILATION TESTS
JET FAN TESTS AT BLUERIDGE AVENUE – 75 FOOT SPACING
SMOOTH WALL TUNNEL

TEST DATES: AUGUST 22-24, 1990

RUN NAME	No. FANS EXHAUST	JET FAN PRESSURE EFFICIENCY	TUNNEL AVERAGE VELOCITY (FPM)	TUNNEL AVERAGE AIRFLOW (CFM)	QT/QF	VT/VF	X (FT.)	X/DT	X/DF	Z (IN.)	Z/DF
BRJF75H4	4	0.9143	274.710	50451.6	-2.349	-0.040	75	5.275	37.5	20	0.833
BRJF75H3	3	0.9000	5.360	984.4	-0.046	-0.001	75	5.275	37.5	20	0.833
BRJF75H2	2	0.7902	-179.868	-33033.5	1.538	0.026	75	5.275	37.5	20	0.833
BRJF75H1	1	0.7351	-420.534	-77232.8	3.596	0.062	75	5.275	37.5	20	0.833
BRJF75H0	0	0.6328	-882.027	-161987.8	7.542	0.129	75	5.275	37.5	20	0.833
BRJF75M4	4	0.9405	275.919	50673.6	-2.359	-0.040	75	5.275	37.5	26	1.083
BRJF75M3	3	0.9117	0.291	53.4	-0.002	-0.000	75	5.275	37.5	26	1.083
BRJF75M2	2	0.8135	-199.795	-36693.2	1.708	0.029	75	5.275	37.5	26	1.083
BRJF75M1	1	0.7477	-428.764	-78744.2	3.666	0.063	75	5.275	37.5	26	1.083
BRJF75M0	0	0.6427	-901.140	-165498.0	7.706	0.132	75	5.275	37.5	26	1.083
BRJF75L4	4	0.9470	272.695	50081.5	-2.332	-0.040	75	5.275	37.5	32	1.333
BRJF75L3	3	0.9467	0.000	0.0	0.000	0.000	75	5.275	37.5	32	1.333
BRJF75L2	2	0.8325	-201.072	-36927.7	1.719	0.029	75	5.275	37.5	32	1.333
BRJF75L1	1	0.7683	-428.969	-78781.9	3.668	0.063	75	5.275	37.5	32	1.333
BRJF75L0	0	0.6824	-912.234	-167535.4	7.801	0.133	75	5.275	37.5	32	1.333

X=JET FAN SPACING.
Z= DISTANCE FROM TUNNEL WALL TO JET FAN CENTER LINE.
DT= TUNNEL HYDRAULIC DIAMETER, 14.2174 FT.
DF= JET FAN DISCHARGE DIAMETER, 24 IN. (2 FT.)
QT= AVERAGE TUNNEL AIRFLOW (CFM).
QF= AVERAGE JET FAN AIRFLOW CAPACITY (CFM)= -21477.
VT= AVERAGE TUNNEL AIR VELOCITY (FPM).
VF= AVERAGE JET FAN DISCHARGE VELOCITY (FPM)= -6836.34.

TABLE 3-9

WMATA VENTILATION TESTS TEST DATES: AUGUST 22-24, 1990

JET FAN TESTS AT BLUERIDGE AVENUE – 50 FOOT SPACING

SMOOTH WALL TUNNEL

RUN NAME	No. FANS EXHAUST	JET FAN PRESSURE EFFICIENCY	TUNNEL AVERAGE VELOCITY (FPM)	TUNNEL AVERAGE AIRFLOW (CFM)	QT/QF	VT/VF	X (FT.)	X/DT	X/DF	Z (IN.)	Z/DF
BRJF50H4	4	0.9273	281.342	51669.6	-2.406	-0.041	50	3.517	25	20	0.833
BRJF50H3	3	0.8705	18.959	3482.0	-0.162	-0.003	50	3.517	25	20	0.833
BRJF50H2	2	0.7849	-176.779	-32466.2	1.512	0.026	50	3.517	25	20	0.833
BRJF50H1	1	0.7062	-401.561	-73748.3	3.434	0.059	50	3.517	25	20	0.833
BRJF50H0	0	0.6077	-839.537	-154184.3	7.179	0.123	50	3.517	25	20	0.833
BRJF50M4	4	0.9449	273.832	50290.3	-2.342	-0.040	50	3.517	25	26	1.083
BRJF50M3	3	0.8870	15.869	2914.4	-0.136	-0.002	50	3.517	25	26	1.083
BRJF50M2	2	0.8004	-187.335	-34404.8	1.602	0.027	50	3.517	25	26	1.083
BRJF50M1	1	0.7261	-413.565	-75952.9	3.536	0.060	50	3.517	25	26	1.083
BRJF50M0	0	0.6015	-856.469	-157294.0	7.324	0.125	50	3.517	25	26	1.083
BRJF50L4	4	0.9659	263.974	48479.9	-2.257	-0.039	50	3.517	25	32	1.333
BRJF50L3	3	0.9292	0.486	89.2	-0.004	-0.000	50	3.517	25	32	1.333
BRJF50L2	2	0.8240	-198.307	-36419.9	1.696	0.029	50	3.517	25	32	1.333
BRJF50L1	1	0.7467	-428.249	-78649.6	3.662	0.063	50	3.517	25	32	1.333
BRJF50L0	0	0.6419	-896.349	-164618.1	7.665	0.131	50	3.517	25	32	1.333

X=JET FAN SPACING.
Z= DISTANCE FROM TUNNEL WALL TO JET FAN CENTER LINE.
DT= TUNNEL HYDRAULIC DIAMETER, 14.2174 FT.
DF= JET FAN DISCHARGE DIAMETER, 24 IN. (2 FT.)
QT= AVERAGE TUNNEL AIRFLOW (CFM).
QF= AVERAGE JET FAN AIRFLOW CAPACITY (CFM)= -21477.
VT= AVERAGE TUNNEL AIR VELOCITY (FPM).
VF= AVERAGE JET FAN DISCHARGE VELOCITY (FPM)= -6836.34.

this result and it was concluded that the test program recommendations were not affected. Table 3-9 defines DF, DT, QF, QT, VF, VT, X, Z, and β.

A comparison was made between the results of these tests and those previously reported by Ohashi [8]. The comparison is:

<u>Z/DF</u>	<u>Jet Fan Pressure Efficiency - β</u>					
		Number of Tunnel Ventilation Fans Running*				
	Ref. [8]	4 Fans	3 Fans	2 Fans	1 Fan	0 Fan
0.833	0.857	0.927	0.870	0.785	0.706	0.601
1.083	0.876	0.945	0.887	0.800	0.726	0.602
1.333	0.895	0.966	0.929	0.824	0.747	0.642

* The comparison was made using the test results at 100 foot spacing.

The Reference [8] does not provide the direction of tunnel airflow. However, the jet fan pressure efficiencies for positive airflows (i.e., the results for four and three tunnel ventilation fans operating in exhaust) compare favorably. These are the most likely range of tunnel air velocities that would be encountered in the actual application of the jet fan test results to the Metrorail.

The jet fan pressure efficiency, β, varied greatly with the tunnel airflow, a phenomenon not documented in previous tests [8,9,13]. The values of QT/QF, VT/VF, X/DT, X/DF and Z/DF were computed as part of the effort to gain insight into this variation. Since most of the references expressed the jet fan pressure efficiency as a function of VT/VF, it was decided to plot the jet fan pressure efficiency as a function of this ratio.

Figures 3-12, 3-13 and 3-14 show the behavior of the jet fan pressure efficiency as a function of VT/VF for jet fan spacings of 100, 75 and 50 feet. The three plots per figure show the effect of varying the distance from the tunnel ceiling to the centerline of the jet fan. The plots show β increasing as Z is increased.

Figures 3-15, 3-16, and 3-17 show the behavior of β as a function of VT/VF for Z values of 20, 26 and 32 inches. The three plots per figure show the effect of varying the distance between jet fans, X. The plots should show β increasing as X increases but sometimes they do not. However, the differences are small and for the most part

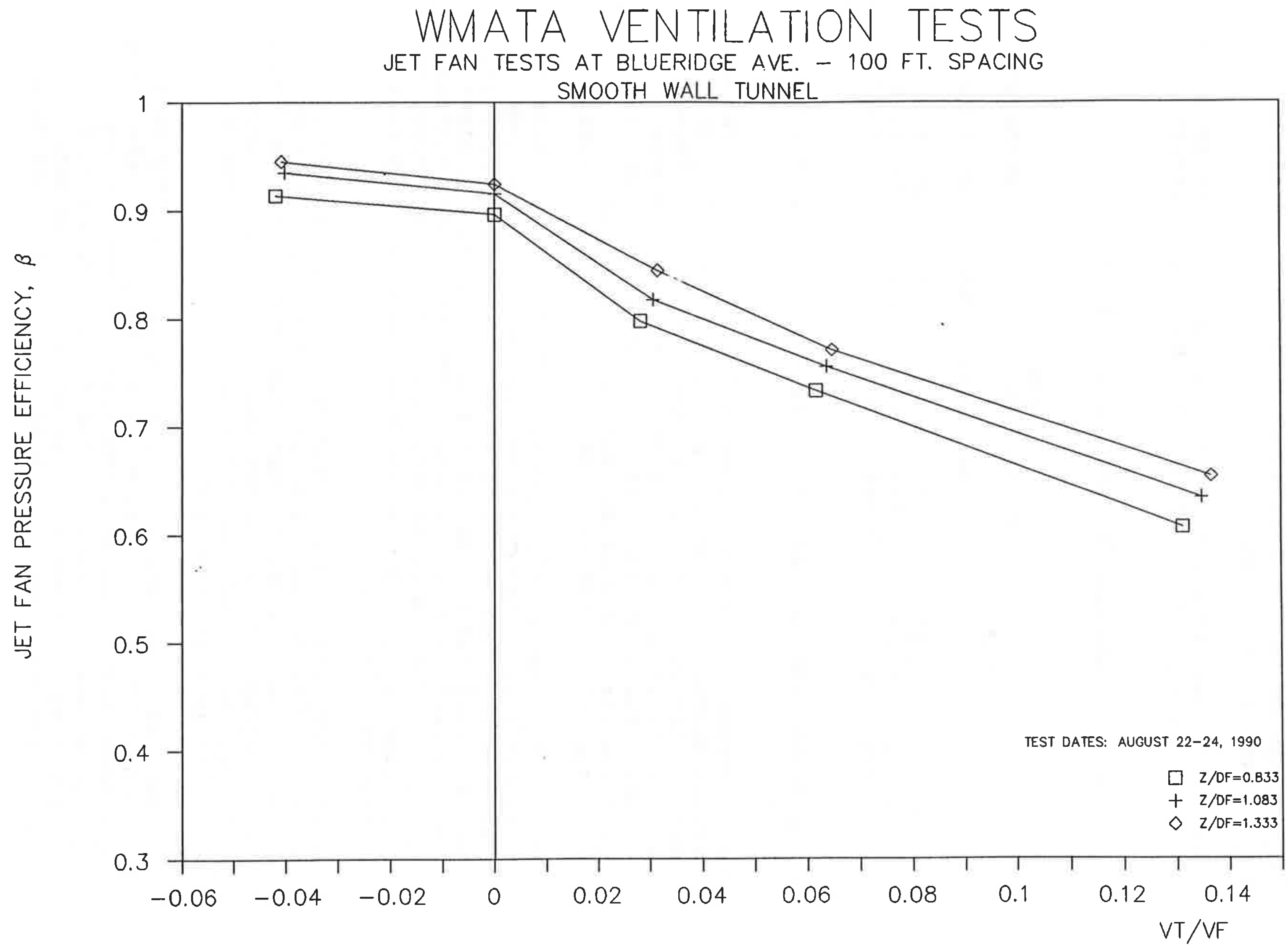

WMATA VENTILATION TESTS
JET FAN TESTS AT BLUERIDGE AVE. – 100 FT. SPACING
SMOOTH WALL TUNNEL
JET FAN PRESSURE EFFICIENCY, β
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
VT/VF
TEST DATES: AUGUST 22–24, 1990
Z/DF=0.833
Z/DF=1.083
Z/DF=1.333

FIGURE 3–12

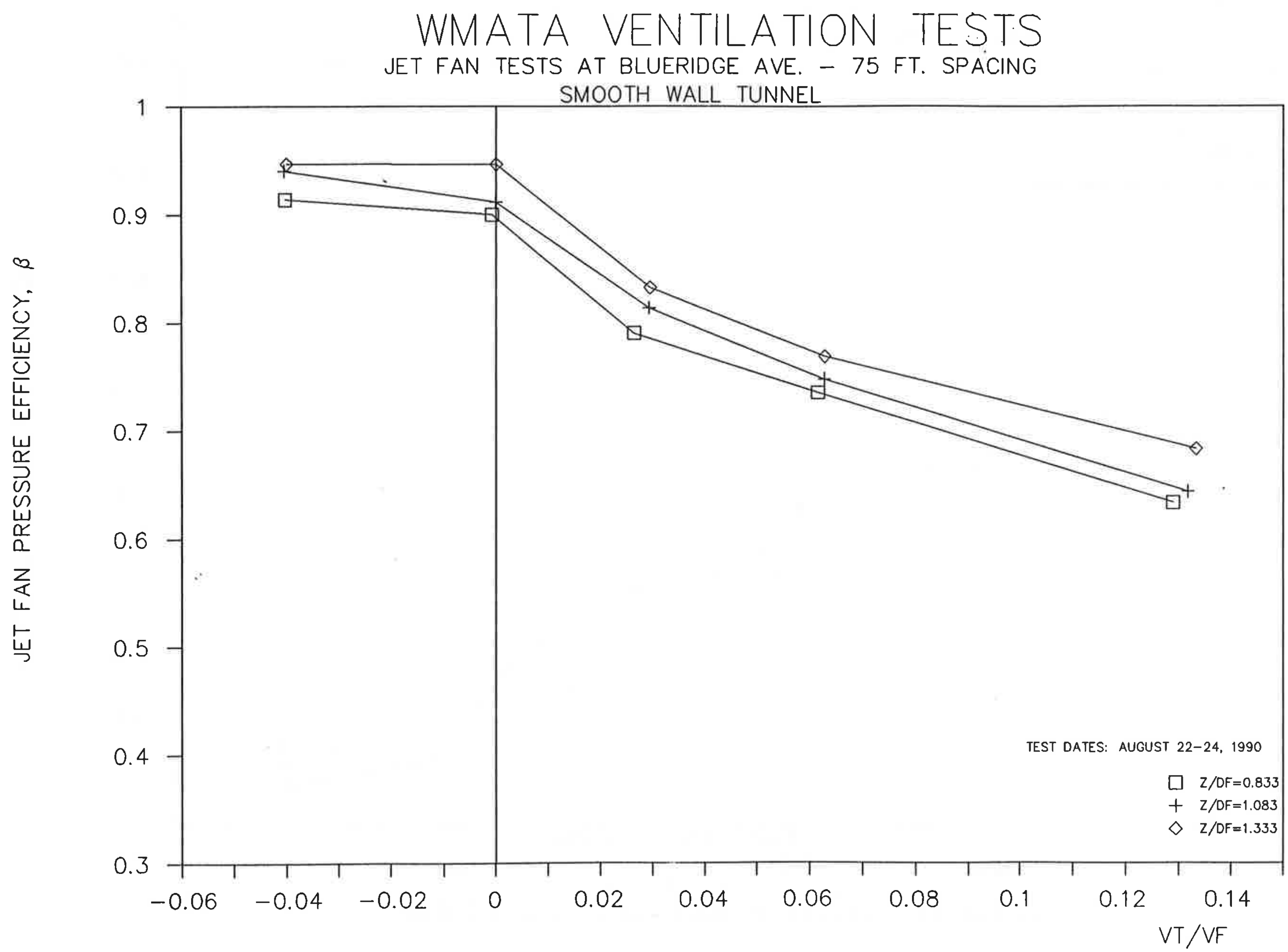

WMATA VENTILATION TESTS
JET FAN TESTS AT BLUERIDGE AVE. – 75 FT. SPACING
SMOOTH WALL TUNNEL
JET FAN PRESSURE EFFICIENCY, β
VT/VF
TEST DATES: AUGUST 22-24, 1990
Z/DF=0.833
Z/DF=1.083
Z/DF=1.333

FIGURE 3–13

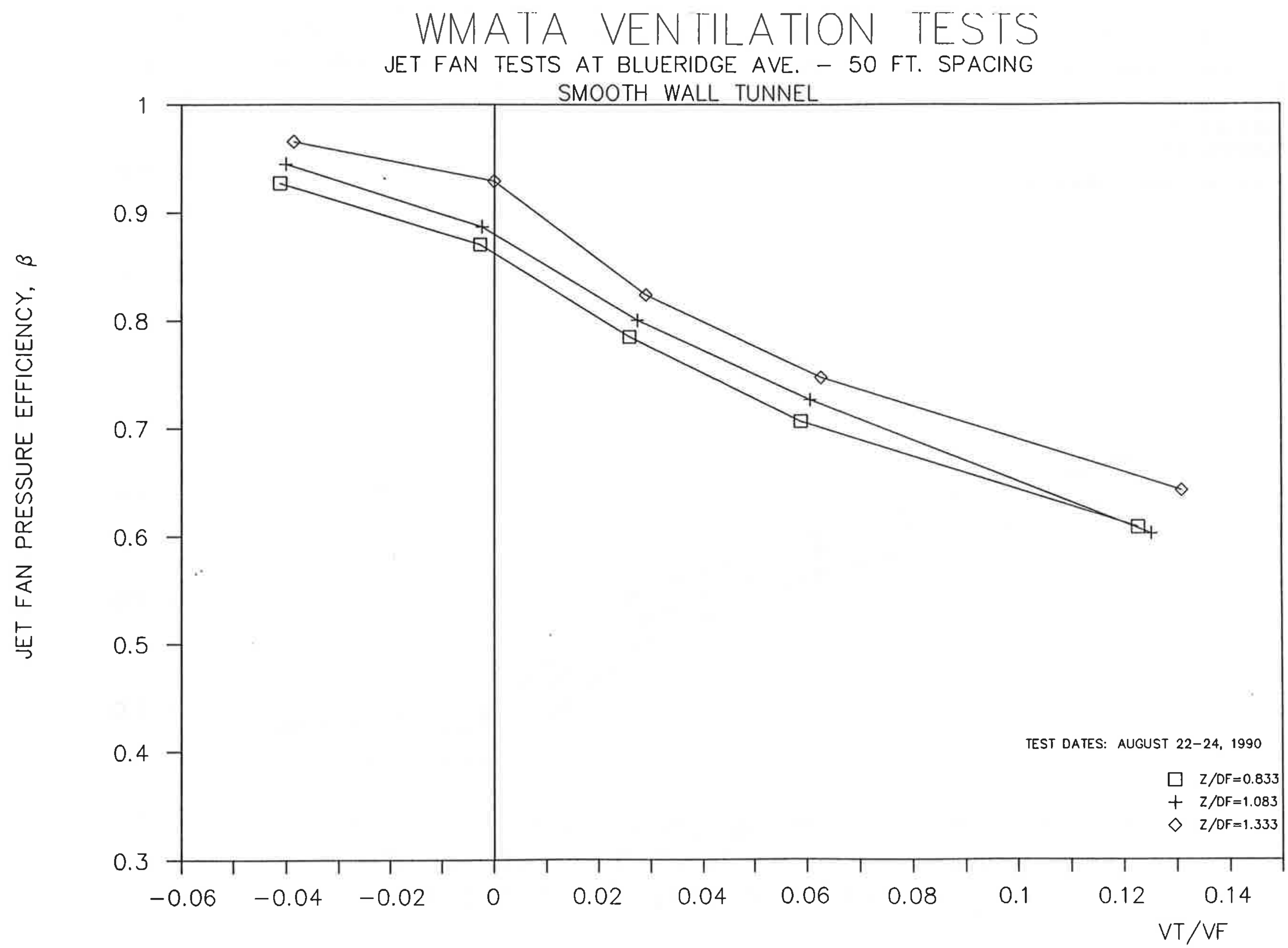

WMATA VENTILATION TESTS
JET FAN TESTS AT BLUERIDGE AVE. – 50 FT. SPACING
SMOOTH WALL TUNNEL
JET FAN PRESSURE EFFICIENCY, β
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
VT/VF
TEST DATES: AUGUST 22–24, 1990
Z/DF=0.833
Z/DF=1.083
Z/DF=1.333

FIGURE 3–14

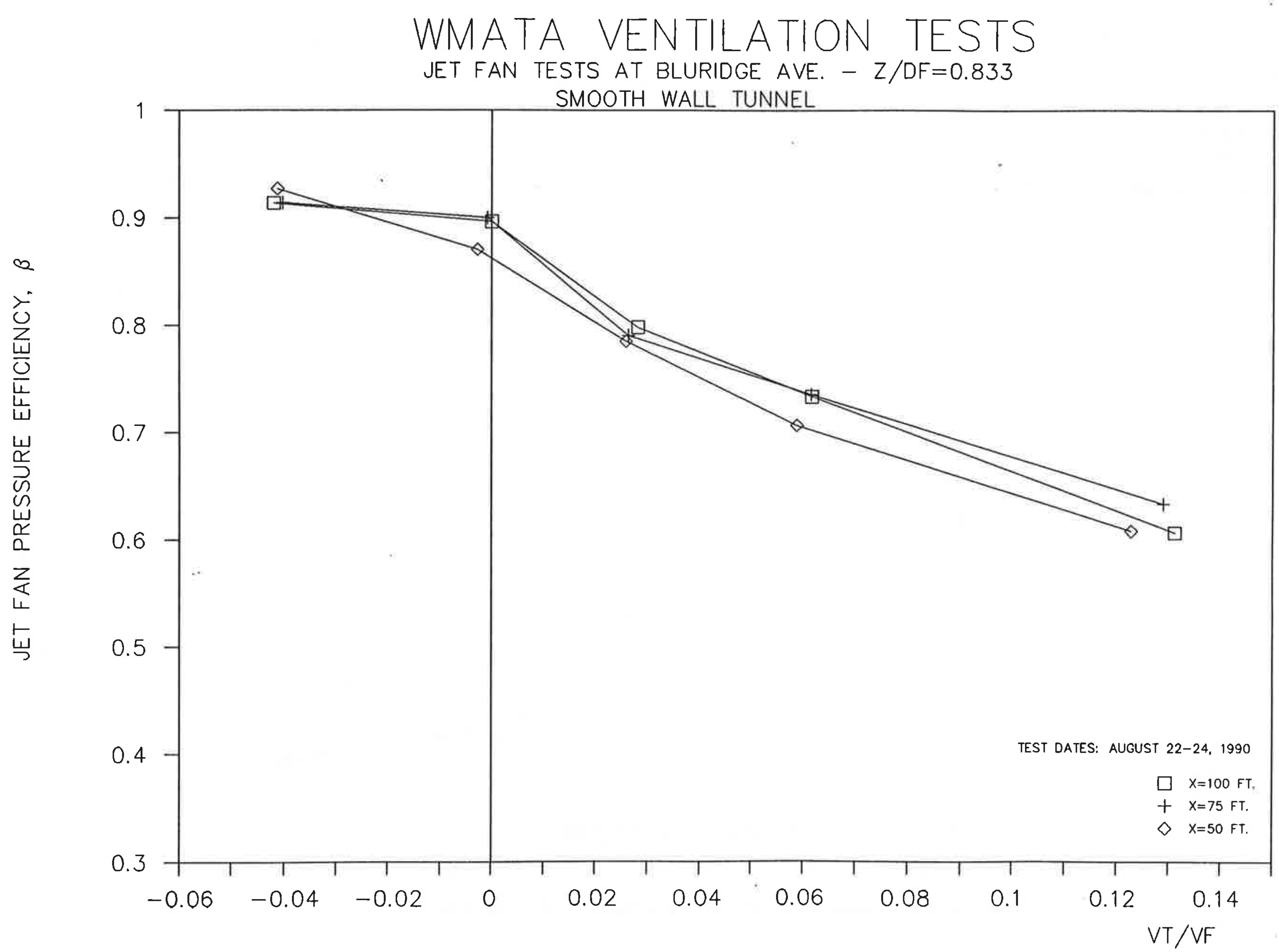

WMATA VENTILATION TESTS
JET FAN TESTS AT BLURIDGE AVE. – Z/DF=0.833
SMOOTH WALL TUNNEL
JET FAN PRESSURE EFFICIENCY, β
VT/VF
TEST DATES: AUGUST 22-24, 1990
X=100 FT.
X=75 FT.
X=50 FT.

FIGURE 3-15

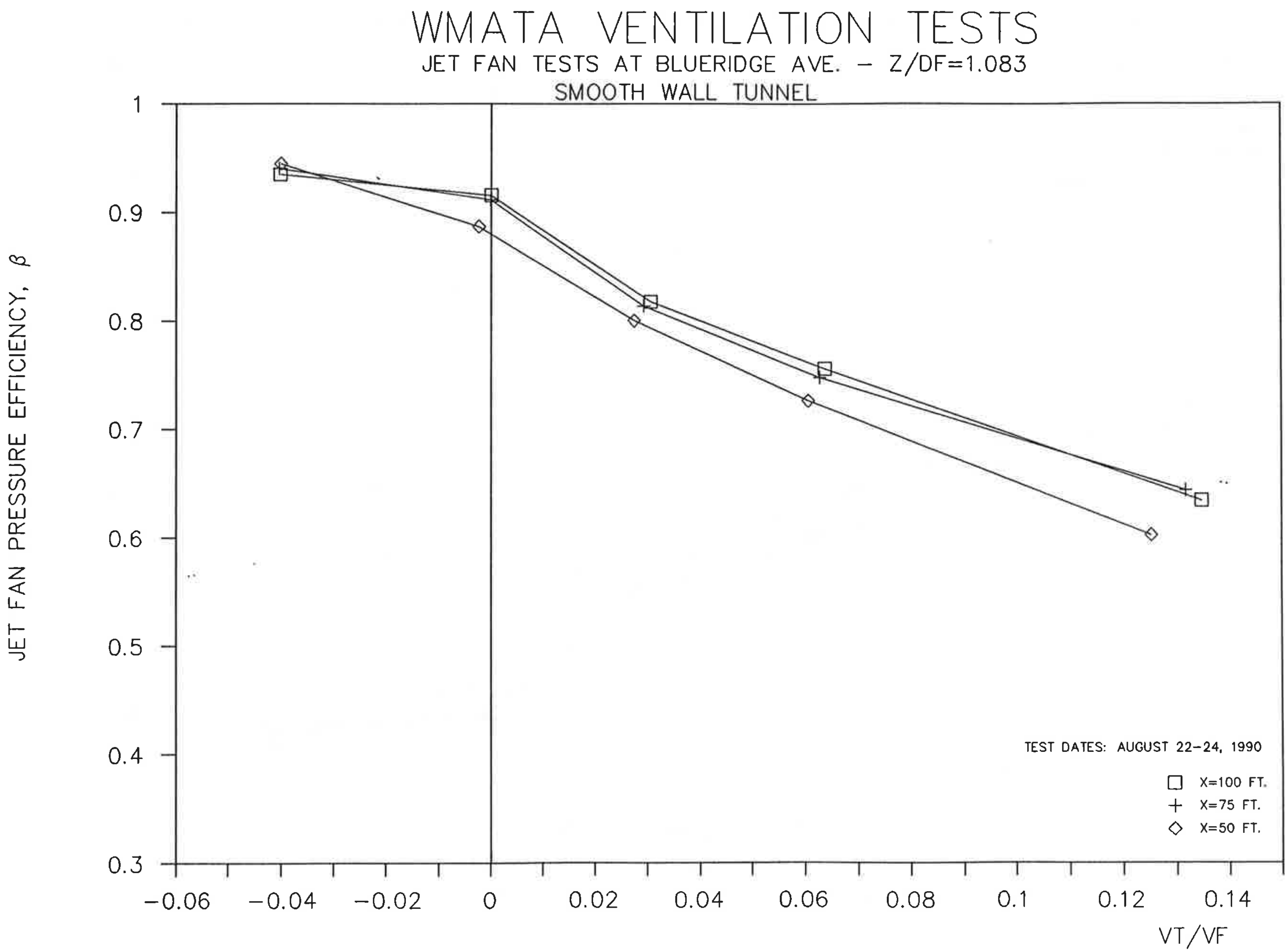

WMATA VENTILATION TESTS
JET FAN TESTS AT BLUERIDGE AVE. – Z/DF=1.083
SMOOTH WALL TUNNEL
JET FAN PRESSURE EFFICIENCY, β
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
VT/VF
TEST DATES: AUGUST 22–24, 1990
X=100 FT.
X=75 FT.
X=50 FT.

FIGURE 3–16

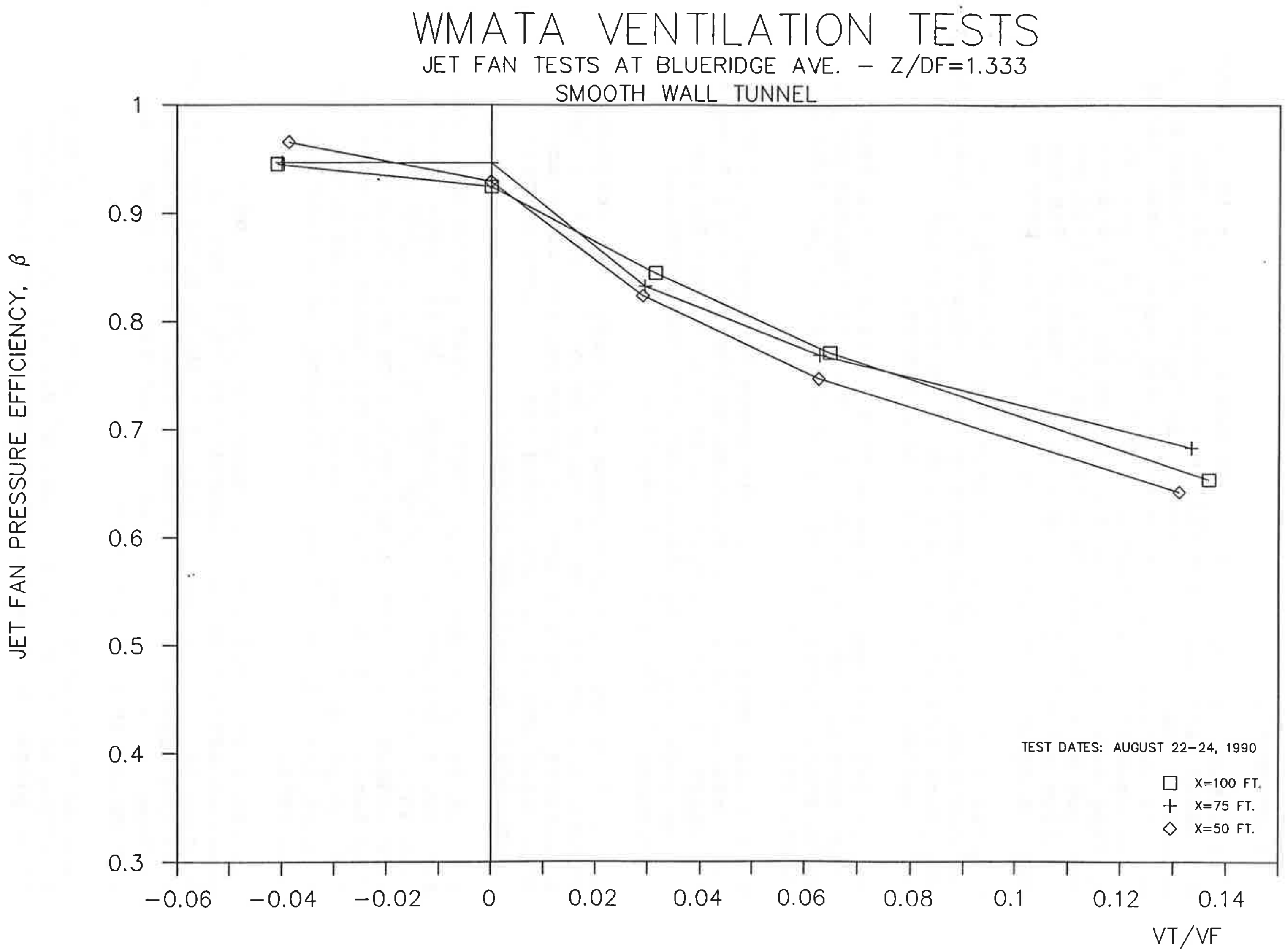

WMATA VENTILATION TESTS
JET FAN TESTS AT BLUERIDGE AVE. – Z/DF=1.333
SMOOTH WALL TUNNEL
JET FAN PRESSURE EFFICIENCY, β
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
–0.06
–0.04
–0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
VT/VF
TEST DATES: AUGUST 22–24, 1990
X=100 FT.
X=75 FT.
X=50 FT.

FIGURE 3–17

less than the estimated experimental error (plus or minus five percent).

In addition to the standard jet fan equation [8,10,13] both Meidinger [10] and Reale [11] have published jet fan equations. Meidinger's equation is Eq.38 in Appendix B and Reale's is Eq.39. Both have additional minor terms. Using these equations, the values of β for 100-foot jet fan spacing were recalculated to confirm that these minor terms were not affecting the results. The using of Meidinger's equation affected β by less than one percent. The use of Reale's equation affected β by less than five percent.

Figures 3-18, 3-19 and 3-20 show the smoothing of the reduced test data. This process used judgment to transform the point data to line data and to recognize that some tests were inherently more accurate than others.

Figure 3-21 assembles Figures 3-18, 3-19 and 3-21 into a graph that provides data suitable for SES computer program input and/or modifications for simulation of jet fans in smooth wall tunnels.

Ribbed Wall Tunnel. Table 3-10 shows the results of the jet fan tests in the tunnel adjacent to the 7th and I Streets fan shaft for jet fan spacings of 100, 75 and 50 feet, values obtained using the methodology and procedure referenced in the previous section.

The table shows some measurements of zero. As previously stated, the DAS assigns any value below 50 fpm to 0 fpm. A sensitivity study was done to determine the importance of this value and it was concluded that the test program recommendations were not affected.

The jet fan performance, β, varied greatly with the tunnel airflow, a phenomenon not documented in previous tests [8,9,10]. The values of QT/QF, VT/VF, X/DT, X/DF and Z/DF were computed as part of the effort to gain insight into this behavior. Since most of the references expressed the jet fan performance as a function of VT/VF, it was decided to plot the jet fan pressure efficiency as a function of this ratio.

Figures 3-22, 3-23 and 3-24 show the behavior of the jet fan pressure efficiency as a function of VT/VF for jet fan spacing of 100, 75 and 50 feet. The three plots per figure show the effect of varying the distance from the tunnel ceiling to the centerline of the jet fan. The plots show β increasing as Z is increased.

Figures 3-25, 3-26 and 3-27 show the behavior of β as a function of VT/VF for Z values of 20, 26 and 32 inches. The three plots per figure show the effect of varying the

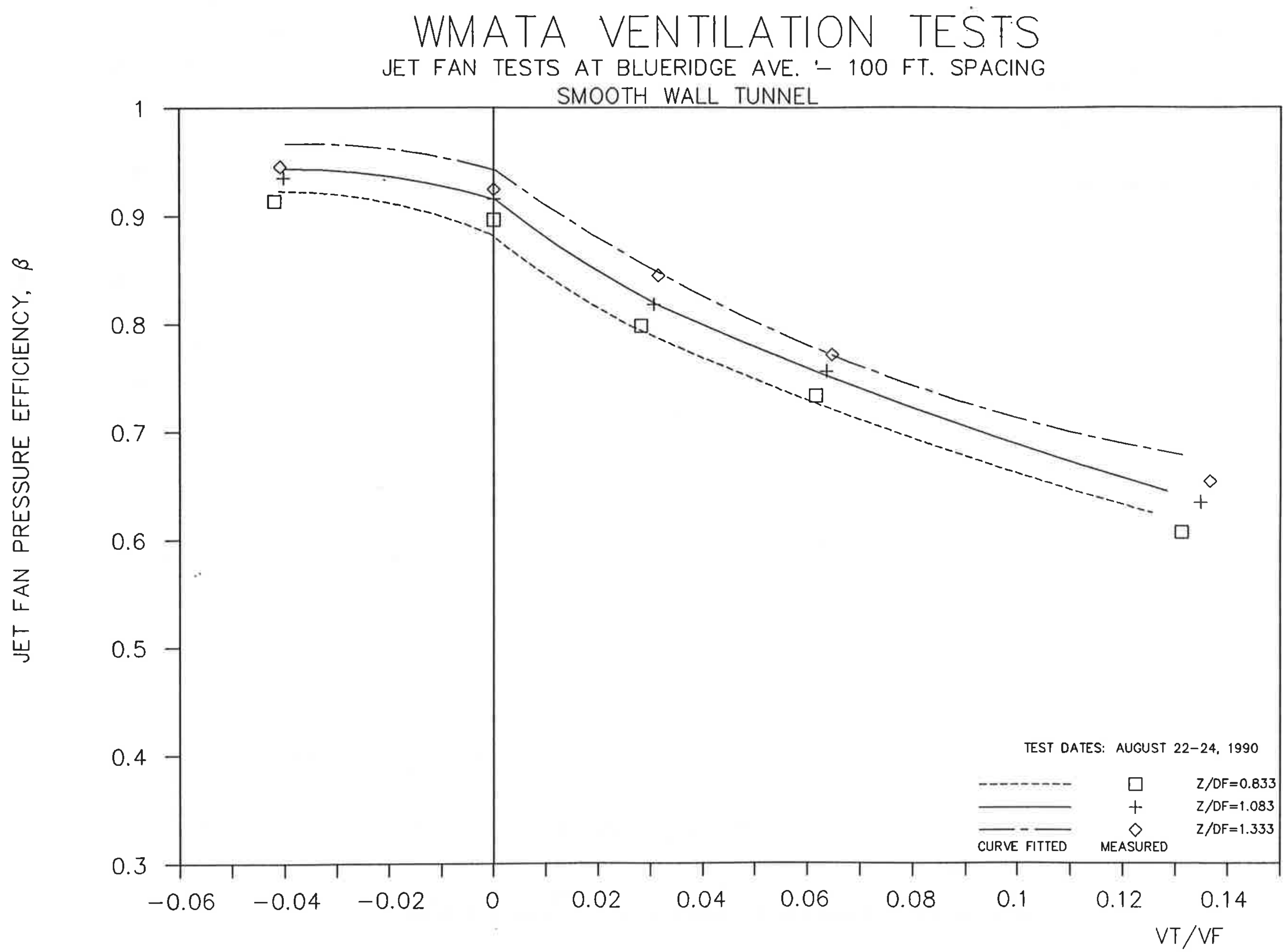

WMATA VENTILATION TESTS
JET FAN TESTS AT BLUERIDGE AVE. – 100 FT. SPACING
SMOOTH WALL TUNNEL
JET FAN PRESSURE EFFICIENCY, β
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
VT/VF
TEST DATES: AUGUST 22–24, 1990
Z/DF=0.833
Z/DF=1.083
Z/DF=1.333
CURVE FITTED
MEASURED

FIGURE 3–18

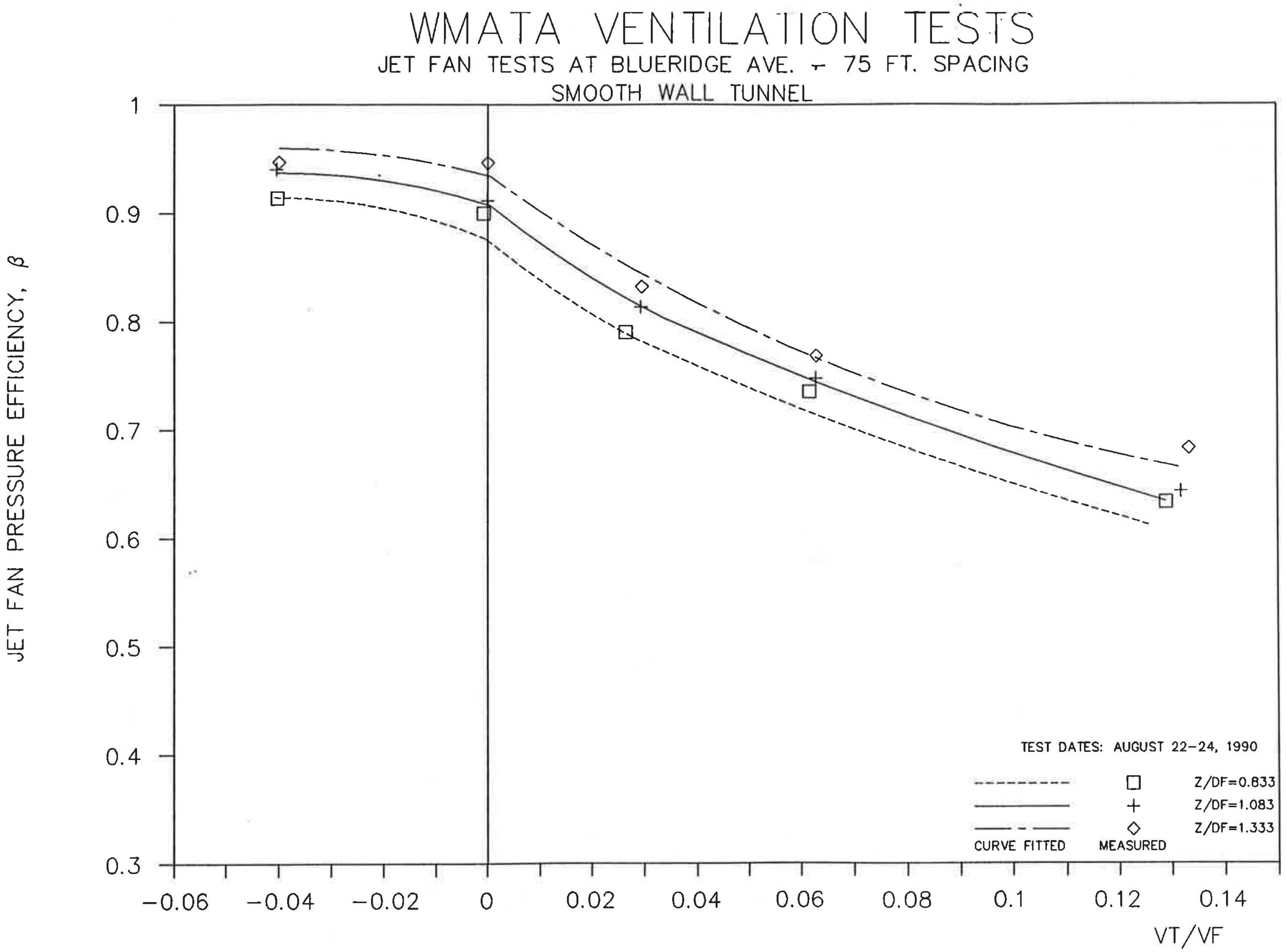

WMATA VENTILATION TESTS
JET FAN TESTS AT BLUERIDGE AVE. – 75 FT. SPACING
SMOOTH WALL TUNNEL
JET FAN PRESSURE EFFICIENCY, β
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
VT/VF
TEST DATES: AUGUST 22–24, 1990
Z/DF=0.833
Z/DF=1.083
Z/DF=1.333
CURVE FITTED
MEASURED

FIGURE 3–19

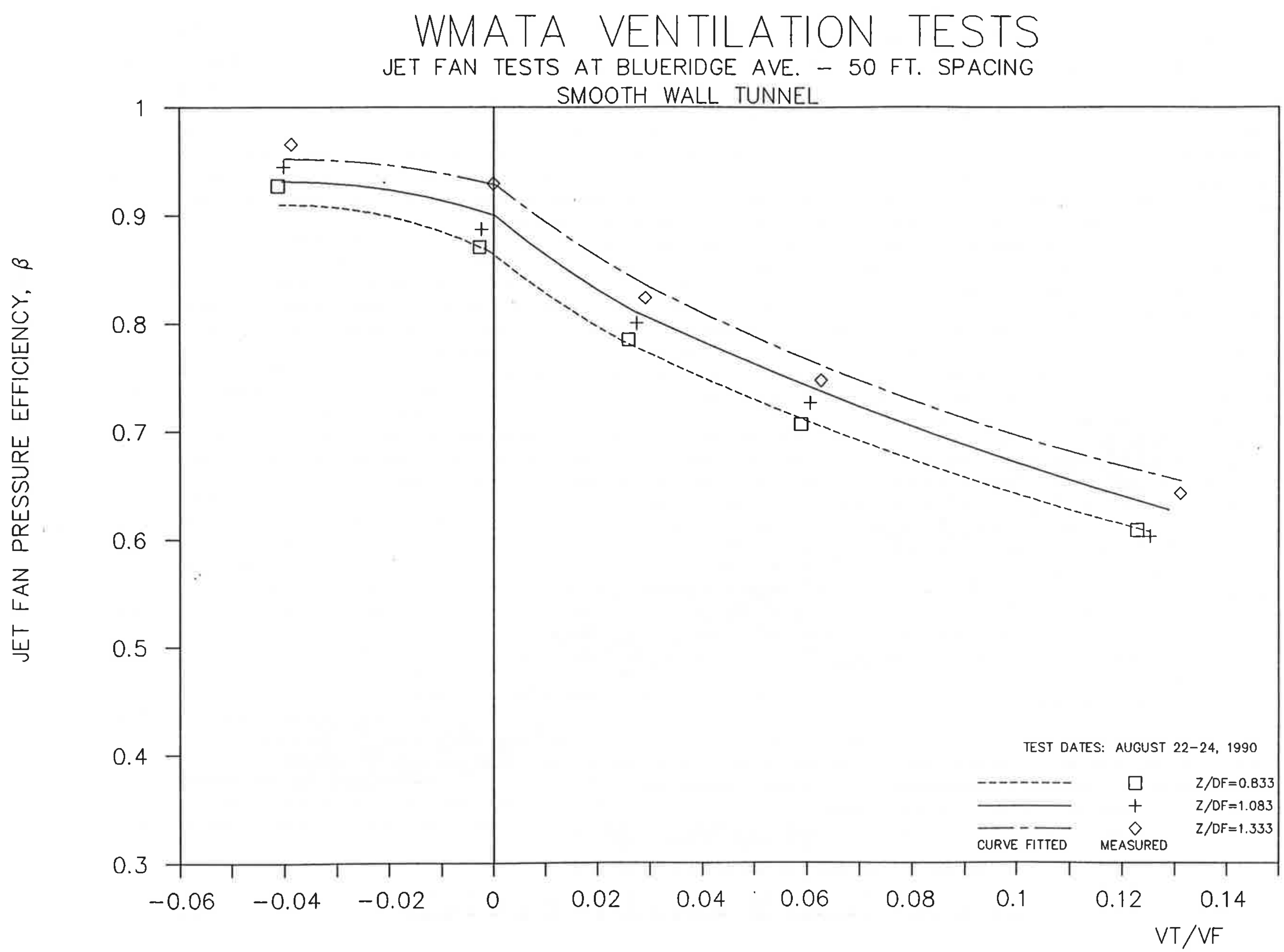

WMATA VENTILATION TESTS
JET FAN TESTS AT BLUERIDGE AVE. – 50 FT. SPACING
SMOOTH WALL TUNNEL
JET FAN PRESSURE EFFICIENCY, β
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
VT/VF
TEST DATES: AUGUST 22–24, 1990
Z/DF=0.833
Z/DF=1.083
Z/DF=1.333
CURVE FITTED
MEASURED

FIGURE 3–20

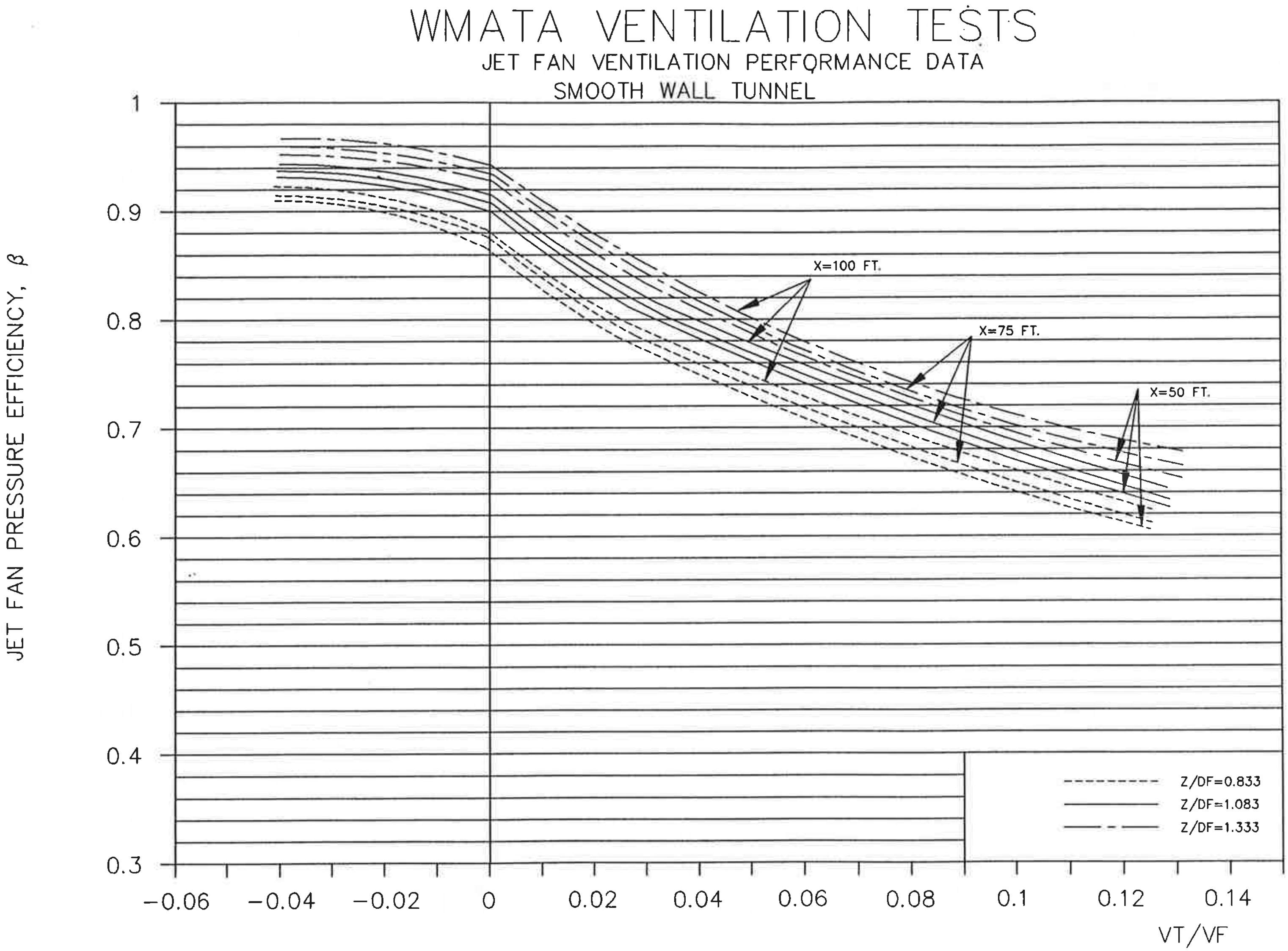

WMATA VENTILATION TESTS
JET FAN VENTILATION PERFORMANCE DATA
SMOOTH WALL TUNNEL
JET FAN PRESSURE EFFICIENCY, β
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
X=100 FT.
X=75 FT.
X=50 FT.
Z/DF=0.833
Z/DF=1.083
Z/DF=1.333
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
VT/VF

FIGURE 3−21

TABLE 3-10

WMATA VENTILATION TESTS — TEST DATES: AUG. 30-SEP. 6, 1990

JET FAN TESTS AT 7TH & I STREETS - 100 FOOT SPACING

RIBBED WALL TUNNEL

RUN NAME	No. FANS EXHAUST	JET FAN PRESSURE EFFICIENCY	TUNNEL AVERAGE VELOCITY (FPM)	TUNNEL AVERAGE AIRFLOW (CFM)	QT/QF	VT/VF	X (FT.)	X/DT	X/DF	Z (IN.)	Z/DF
7IJF100H4	4	0.7554	200.969	39197.2	-1.825	-0.029	100	6.622	50	20	0.833
7IJF100H3	3	0.6807	0.070	13.7	-0.001	-0.000	100	6.622	50	20	0.833
7IJF100H2	2	0.5273	-158.007	-30817.8	1.435	0.023	100	6.622	50	20	0.833
7IJF100H1	1	0.4359	-298.845	-58287.0	2.714	0.044	100	6.622	50	20	0.833
7IJF100H0	0	0.3443	-456.399	-89016.5	4.145	0.067	100	6.622	50	20	0.833
7IJF100M4	4	0.8109	138.765	27064.9	-1.260	-0.020	100	6.622	50	26	1.083
7IJF100M3	3	0.7175	5.552	1082.9	-0.050	-0.001	100	6.622	50	26	1.083
7IJF100M2	2	0.5830	-178.095	-34735.8	1.617	0.026	100	6.622	50	26	1.083
7IJF100M1	1	0.4860	-329.648	-64294.9	2.994	0.048	100	6.622	50	26	1.083
7IJF100M0	0	0.3929	-465.120	-90717.5	4.224	0.068	100	6.622	50	26	1.083
7IJF100L4	4	0.8516	119.208	23250.4	-1.083	-0.017	100	6.622	50	32	1.333
7IJF100L3	3	0.7396	47.679	9299.4	-0.433	-0.007	100	6.622	50	32	1.333
7IJF100L2	2	0.6036	-227.452	-44362.5	2.066	0.033	100	6.622	50	32	1.333
7IJF100L1	1	0.5220	-361.863	-70578.1	3.286	0.053	100	6.622	50	32	1.333
7IJF100L0	0	0.4238	-532.878	-103933.1	4.839	0.078	100	6.622	50	32	1.333

X=JET FAN SPACING.
Z= DISTANCE FROM TUNNEL WALL TO JET FAN CENTER LINE.
DT= TUNNEL HYDRAULIC DIAMETER, 15.1019 FT.
DF= JET FAN DISCHARGE DIAMETER, 24 IN. (2 FT.)
QT= AVERAGE TUNNEL AIRFLOW (CFM).
QF= AVERAGE JET FAN AIRFLOW CAPACITY (CFM)= -21477.
VT= AVERAGE TUNNEL AIR VELOCITY (FPM).
VF= AVERAGE JET FAN DISCHARGE VELOCITY (FPM)= -6836.34.

TABLE 3-10

WMATA VENTILATION TESTS TEST DATES: AUG. 30-SEP. 6, 1990

JET FAN TESTS AT 7TH & I STREETS – 75 FOOT SPACING

RIBBED WALL TUNNEL

RUN NAME	No. FANS EXHAUST	JET FAN PRESSURE EFFICIENCY	TUNNEL AVERAGE VELOCITY (FPM)	TUNNEL AVERAGE AIRFLOW (CFM)	QT/QF	VT/VF	X (FT.)	X/DT	X/DF	Z (IN.)	Z/DF
7IJF75H4	4	0.7224	177.480	34615.9	-1.612	-0.026	75	4.966	37.5	20	0.833
7IJF75H3	3	0.6639	0.000	0.0	0.000	0.000	75	4.966	37.5	20	0.833
7IJF75H2	2	0.5291	-166.260	-32427.5	1.510	0.024	75	4.966	37.5	20	0.833
7IJF75H1	1	0.4093	-312.601	-60970.0	2.839	0.046	75	4.966	37.5	20	0.833
7IJF75H0	0	0.3195	-463.958	-90490.8	4.213	0.068	75	4.966	37.5	20	0.833
7IJF75M4	4	0.7793	136.216	26567.7	-1.237	-0.020	75	4.966	37.5	26	1.083
7IJF75M3	3	0.6950	20.335	3966.2	-0.185	-0.003	75	4.966	37.5	26	1.083
7IJF75M2	2	0.5717	-198.397	-38695.5	1.802	0.029	75	4.966	37.5	26	1.083
7IJF75M1	1	0.4615	-333.211	-64989.8	3.026	0.049	75	4.966	37.5	26	1.083
7IJF75M0	0	0.3622	-484.561	-94509.3	4.400	0.071	75	4.966	37.5	26	1.083
7IJF75L4	4	0.8472	90.797	17709.1	-0.825	-0.013	75	4.966	37.5	32	1.333
7IJF75L3	3	0.7237	65.880	12849.3	-0.598	-0.010	75	4.966	37.5	32	1.333
7IJF75L2	2	0.6060	-225.456	-43973.2	2.047	0.033	75	4.966	37.5	32	1.333
7IJF75L1	1	0.5079	-359.620	-70140.6	3.266	0.053	75	4.966	37.5	32	1.333
7IJF75L0	0	0.4169	-533.547	-104063.5	4.845	0.078	75	4.966	37.5	32	1.333

X=JET FAN SPACING.
Z= DISTANCE FROM TUNNEL WALL TO JET FAN CENTER LINE.
DT= TUNNEL HYDRAULIC DIAMETER, 15.1019 FT.
DF= JET FAN DISCHARGE DIAMETER, 24 IN. (2 FT.)
QT= AVERAGE TUNNEL AIRFLOW (CFM).
QF= AVERAGE JET FAN AIRFLOW CAPACITY (CFM)= -21477.
VT= AVERAGE TUNNEL AIR VELOCITY (FPM).
VF= AVERAGE JET FAN DISCHARGE VELOCITY (FPM)= -6836.34.

TABLE 3-10

WMATA VENTILATION TESTS

TEST DATES: AUG. 30-SEP. 6, 1990

JET FAN TESTS AT 7TH & I STREETS - 50 FOOT SPACING

RIBBED WALL TUNNEL

RUN NAME	No. FANS EXHAUST	JET FAN PRESSURE EFFICIENCY	TUNNEL AVERAGE VELOCITY (FPM)	TUNNEL AVERAGE AIRFLOW (CFM)	QT/QF	VT/VF	X (FT.)	X/DT	X/DF	Z (IN.)	Z/DF
7IJF50H4	4	0.7269	176.036	34334.2	-1.599	-0.026	50	3.311	25	20	0.833
7IJF50H3	3	0.6740	0.639	124.6	-0.006	-0.000	50	3.311	25	20	0.833
7IJF50H2	2	0.4883	-149.279	-29115.5	1.356	0.022	50	3.311	25	20	0.833
7IJF50H1	1	0.3785	-274.651	-53568.2	2.494	0.040	50	3.311	25	20	0.833
7IJF50H0	0	0.2823	-450.396	-87845.7	4.090	0.066	50	3.311	25	20	0.833
7IJF50M4	4	0.7912	159.507	31110.4	-1.449	-0.023	50	3.311	25	26	1.083
7IJF50M3	3	0.7325	1.304	254.3	-0.012	-0.000	50	3.311	25	26	1.083
7IJF50M2	2	0.5417	-159.306	-31071.2	1.447	0.023	50	3.311	25	26	1.083
7IJF50M1	1	0.4216	-310.971	-60652.1	2.824	0.045	50	3.311	25	26	1.083
7IJF50M0	0	0.3277	-480.818	-93779.2	4.366	0.070	50	3.311	25	26	1.083
7IJF50L4	4	0.8458	121.272	23653.0	-1.101	-0.018	50	3.311	25	32	1.333
7IJF50L3	3	0.7425	44.830	8743.7	-0.407	-0.007	50	3.311	25	32	1.333
7IJF50L2	2	0.5840	-189.459	-36952.3	1.721	0.028	50	3.311	25	32	1.333
7IJF50L1	1	0.4930	-317.131	-61853.5	2.880	0.046	50	3.311	25	32	1.333
7IJF50L0	0	0.4130	-448.999	-87573.2	4.078	0.066	50	3.311	25	32	1.333

X=JET FAN SPACING.
Z= DISTANCE FROM TUNNEL WALL TO JET FAN CENTER LINE.
DT= TUNNEL HYDRAULIC DIAMETER, 15.1019 FT.
DF= JET FAN DISCHARGE DIAMETER, 24 IN. (2 FT.)
QT= AVERAGE TUNNEL AIRFLOW (CFM).
QF= AVERAGE JET FAN AIRFLOW CAPACITY (CFM)= -21477.
VT= AVERAGE TUNNEL AIR VELOCITY (FPM).
VF= AVERAGE JET FAN DISCHARGE VELOCITY (FPM)= -6836.34.

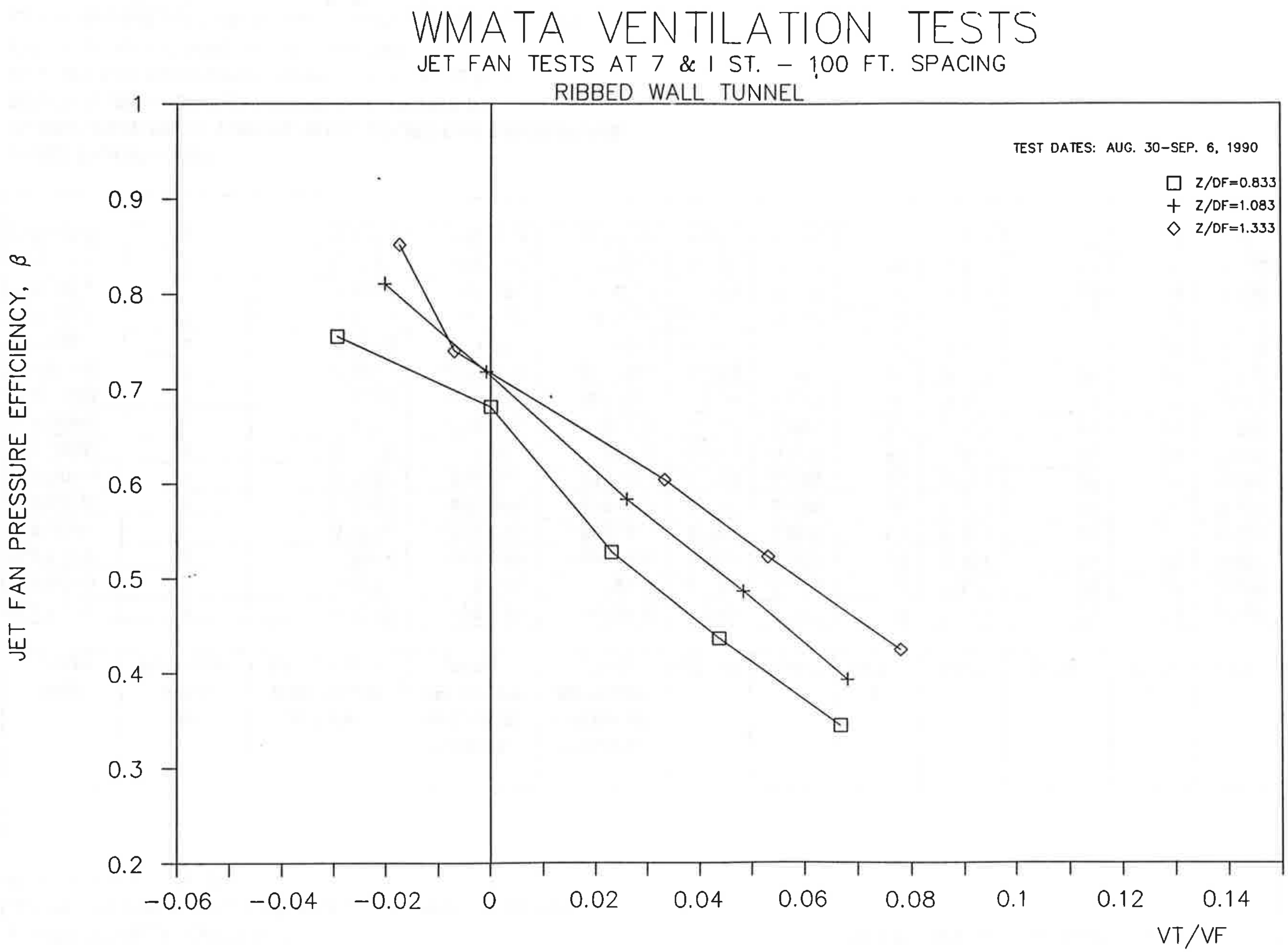

WMATA VENTILATION TESTS
JET FAN TESTS AT 7 & I ST. – 100 FT. SPACING
RIBBED WALL TUNNEL
TEST DATES: AUG. 30–SEP. 6, 1990
Z/DF=0.833
Z/DF=1.083
Z/DF=1.333
JET FAN PRESSURE EFFICIENCY, β
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
VT/VF

FIGURE 3–22

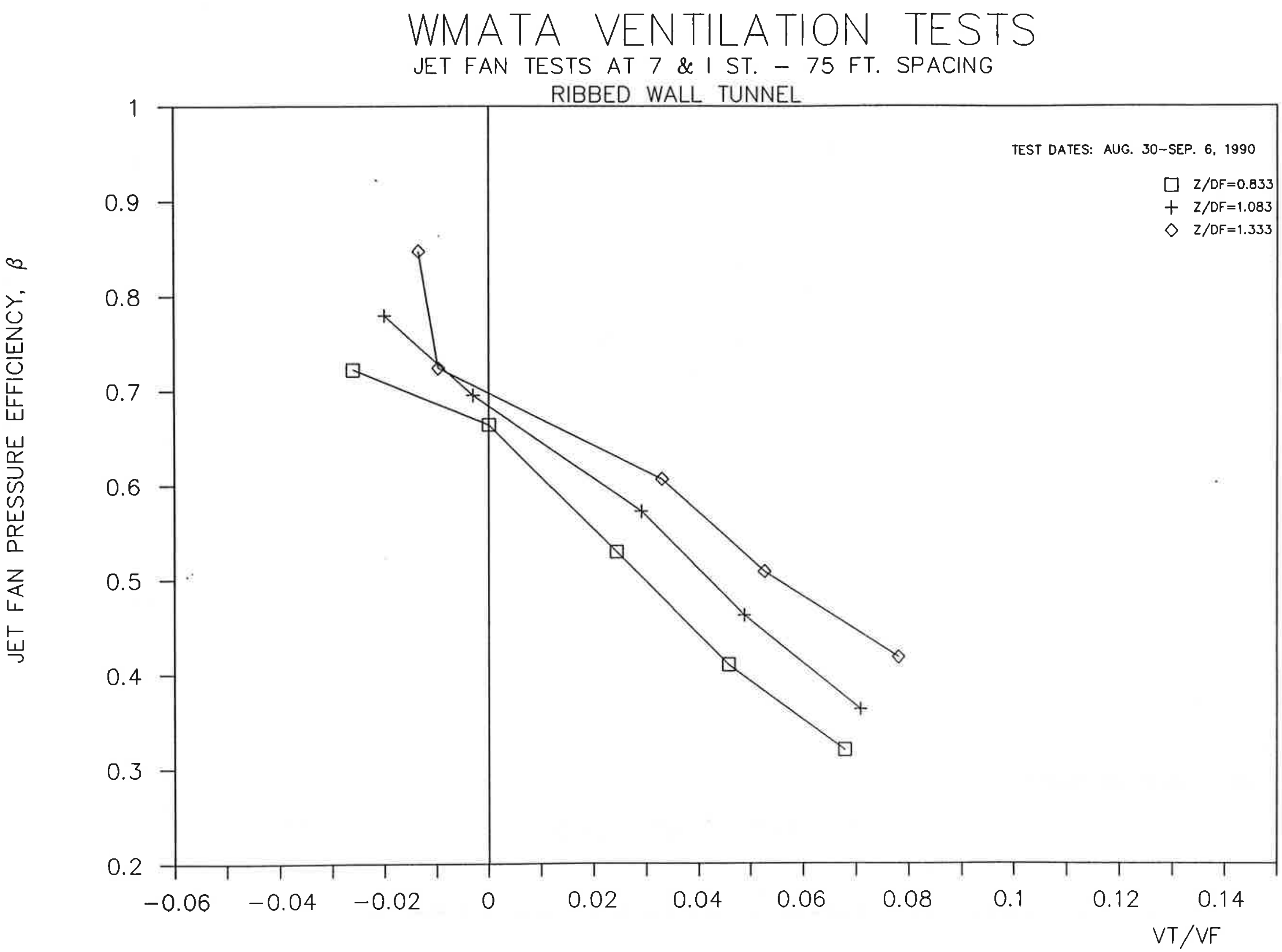

WMATA VENTILATION TESTS
JET FAN TESTS AT 7 & I ST. – 75 FT. SPACING
RIBBED WALL TUNNEL
TEST DATES: AUG. 30–SEP. 6, 1990
Z/DF=0.833
Z/DF=1.083
Z/DF=1.333
JET FAN PRESSURE EFFICIENCY, β
VT/VF
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
–0.06
–0.04
–0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14

FIGURE 3–23

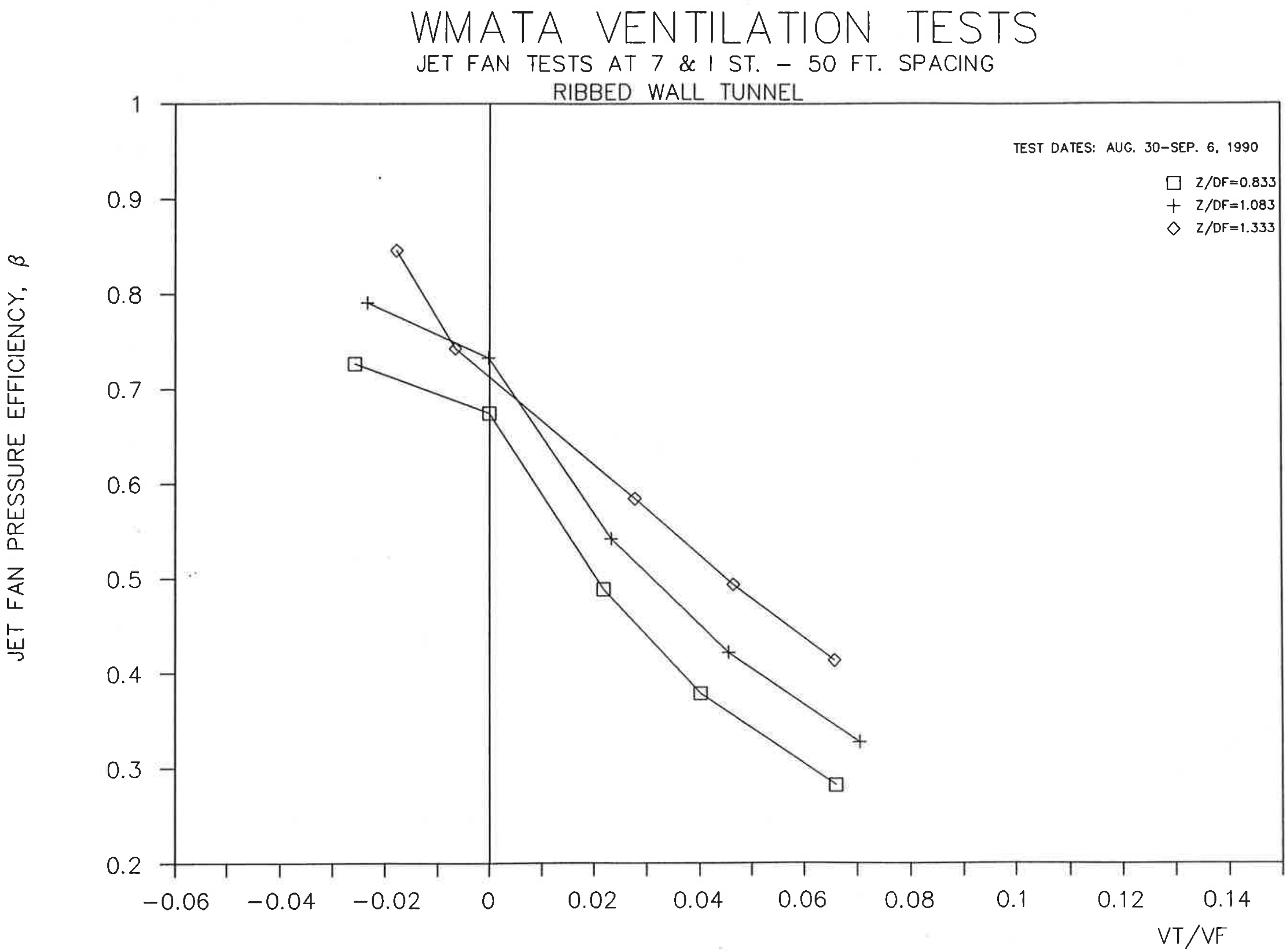

WMATA VENTILATION TESTS
JET FAN TESTS AT 7 & I ST. – 50 FT. SPACING
RIBBED WALL TUNNEL
TEST DATES: AUG. 30–SEP. 6, 1990
Z/DF=0.833
Z/DF=1.083
Z/DF=1.333
JET FAN PRESSURE EFFICIENCY, β
VT/VF
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14

FIGURE 3–24

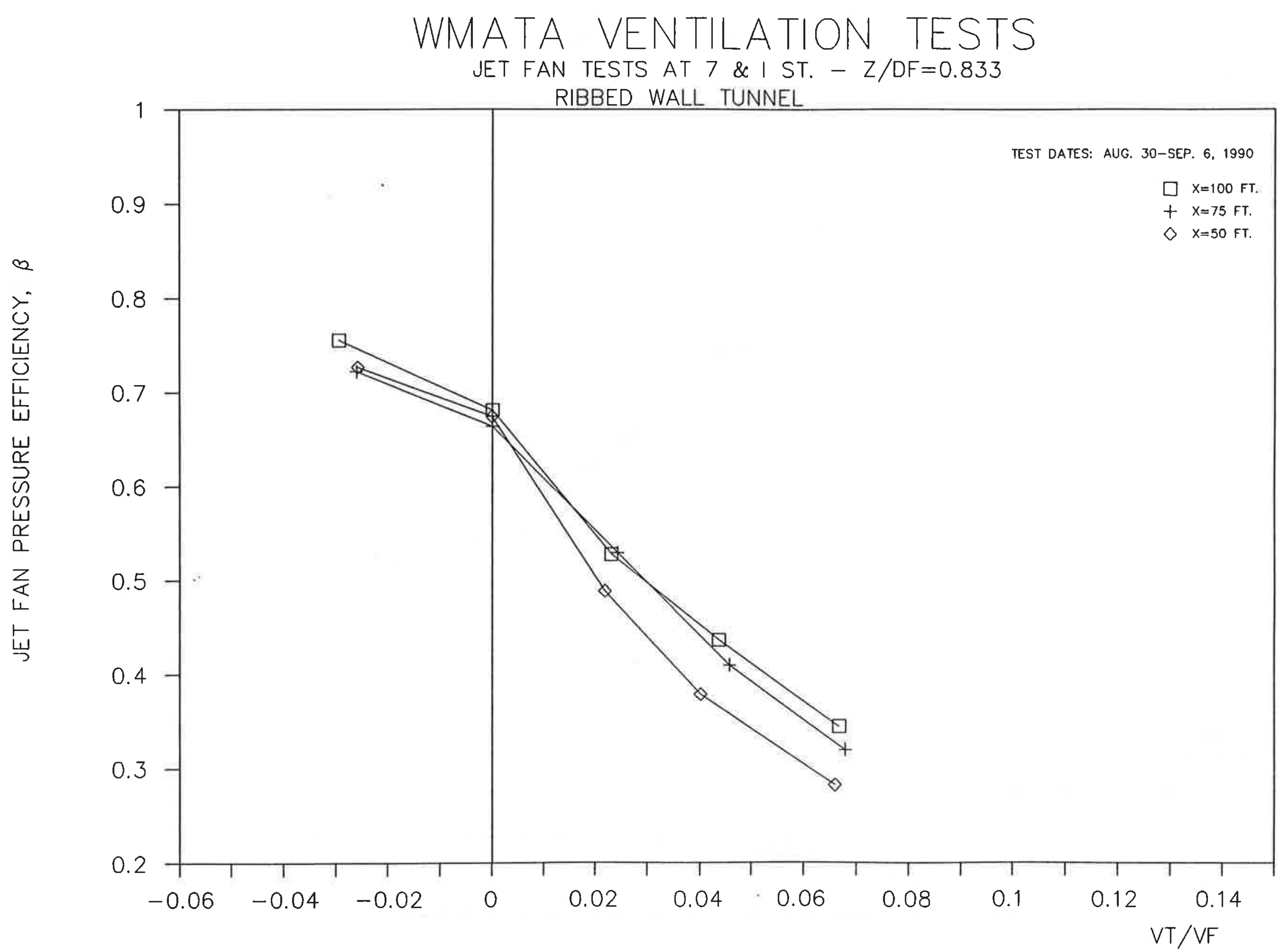

WMATA VENTILATION TESTS
JET FAN TESTS AT 7 & I ST. – Z/DF=0.833
RIBBED WALL TUNNEL
TEST DATES: AUG. 30–SEP. 6, 1990
X=100 FT.
X=75 FT.
X=50 FT.
JET FAN PRESSURE EFFICIENCY, β
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
VT/VF

FIGURE 3–25

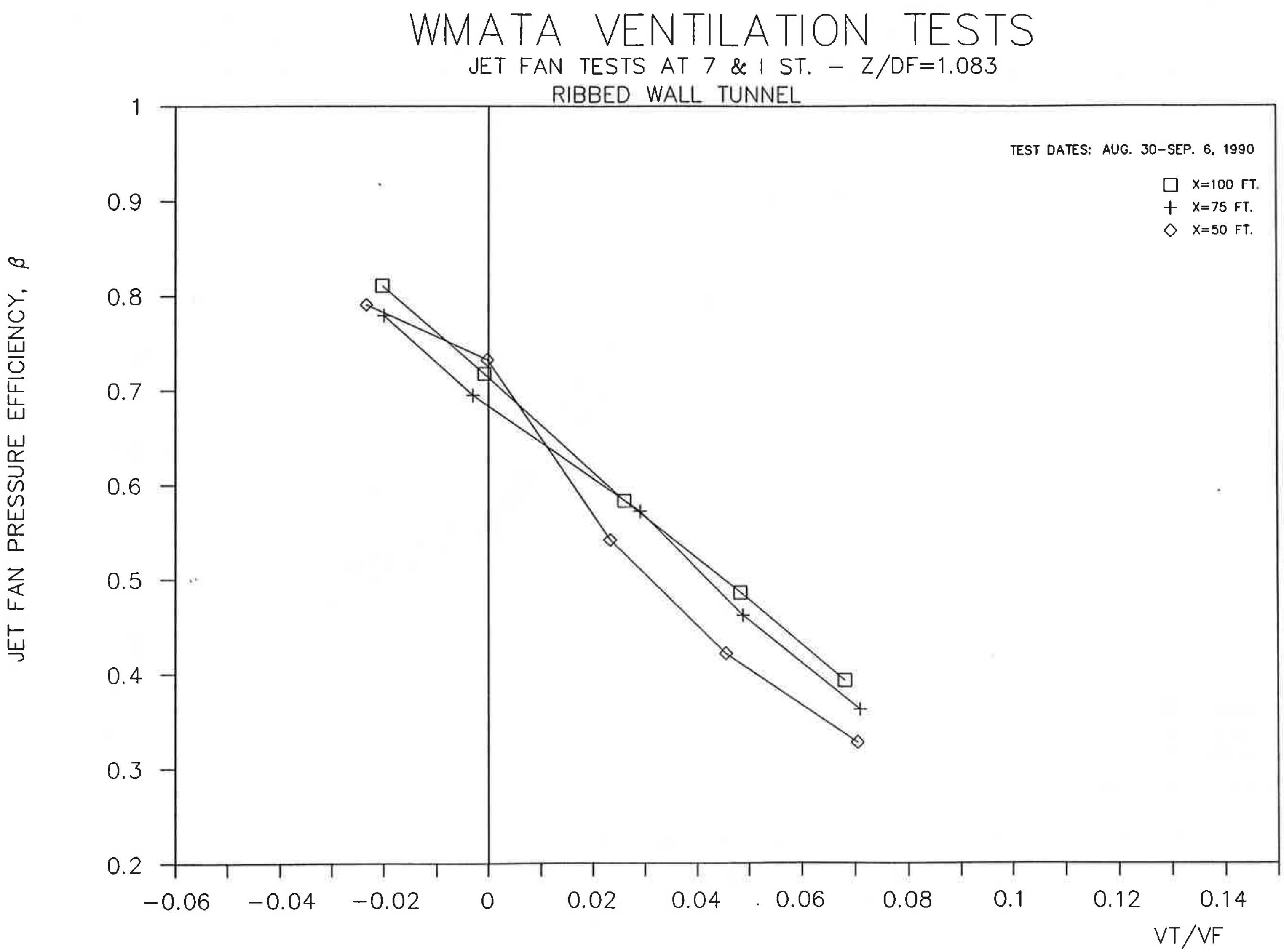

WMATA VENTILATION TESTS
JET FAN TESTS AT 7 & I ST. – Z/DF=1.083
RIBBED WALL TUNNEL
TEST DATES: AUG. 30–SEP. 6, 1990
X=100 FT.
X=75 FT.
X=50 FT.
JET FAN PRESSURE EFFICIENCY, β
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
–0.06
–0.04
–0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
VT/VF

FIGURE 3–26

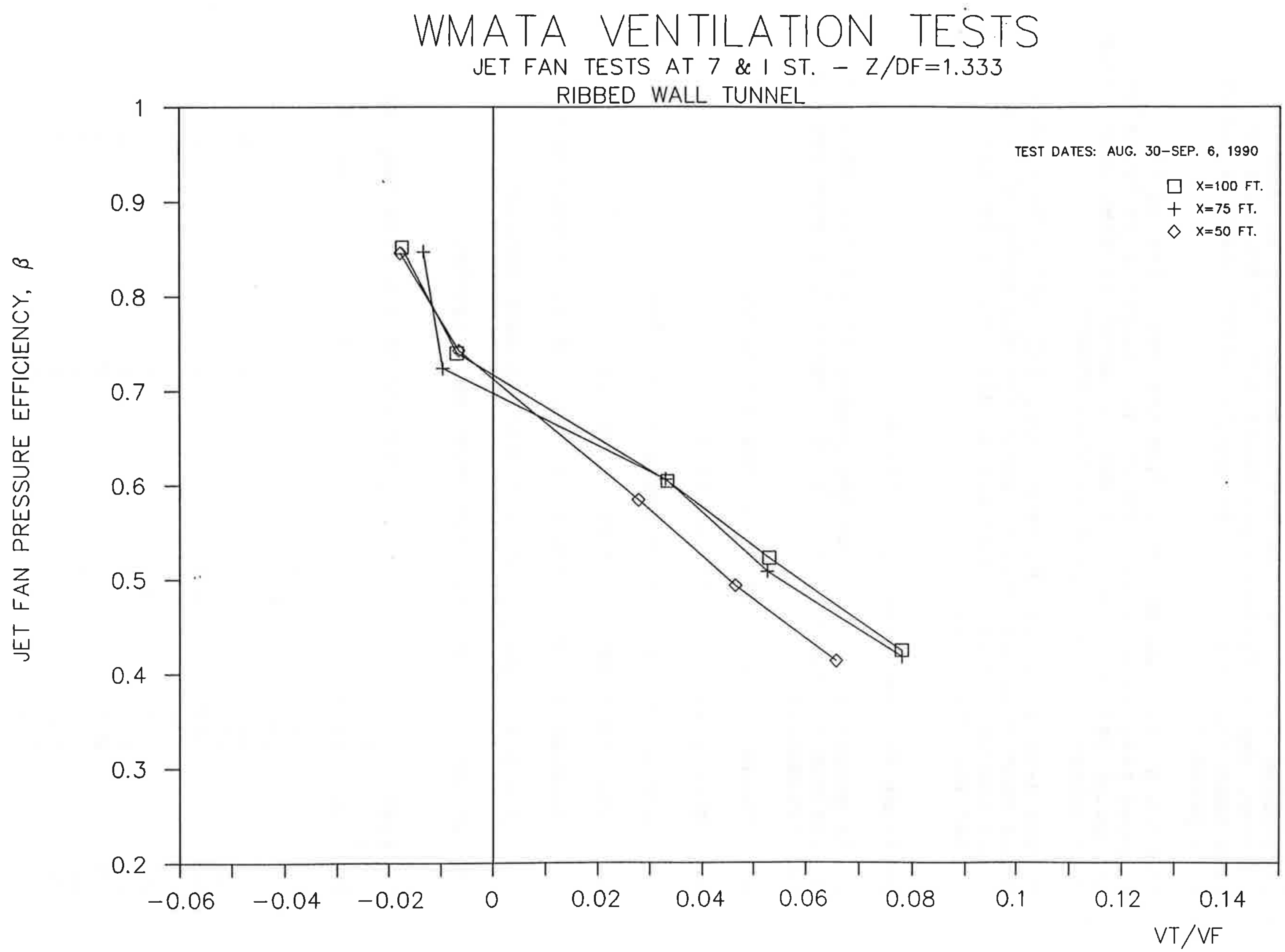

WMATA VENTILATION TESTS
JET FAN TESTS AT 7 & I ST. - Z/DF=1.333
RIBBED WALL TUNNEL
TEST DATES: AUG. 30-SEP. 6, 1990
X=100 FT.
X=75 FT.
X=50 FT.
JET FAN PRESSURE EFFICIENCY, β
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
VT/VF

FIGURE 3-27

distance between jet fans, X. The plots should show β increasing as X increases but sometimes they do not. However, the differences are small and for the most part less than the estimated experimental error (plus or minus five percent).

Figures 3-28, 3-29 and 3-30 show the smoothing of the reduced test data. This process used judgment to transform the point data to line data and to recognize that some tests were inherently more accurate than others.

Figure 3-31 assembles Figures 3-28, 3-29 and 3-30 into a graph that provides data suitable for SES computer program input and/or modifications for simulations of jet fans in ribbed wall tunnels.

Barriers vs. Jet Fans: A Comparison

It is possible to estimate the number of jet fans that are equivalent to one barrier. The following data were used for the estimates:

- Tunnel areas - 180, 240 and 300 sq ft
- Tunnel air velocity - 200 fpm
- Jet fan discharge velocity - 6000 fpm
- Jet fan diameters - 20 and 48 in.
- Barrier K - 86 (egress closed) and 40 (egress open)
- β - 0.9 (smooth) and 0.7 (ribbed wall tunnel)

The following shows the estimated equivalents.

Barrier K Desired	Tunnel Area	β	Number of Jet Fans Required	
			20 in.	48 in.
40	180	0.9	3	1
40	180	0.7	3	1
40	240	0.9	3	1
40	240	0.7	4	1
40	300	0.9	4	1
40	300	0.7	5	1
86	180	0.9	5	1
86	180	0.7	6	1
86	240	0.9	7	1
86	240	0.7	8	2
86	300	0.9	8	2
86	300	0.7	10	2

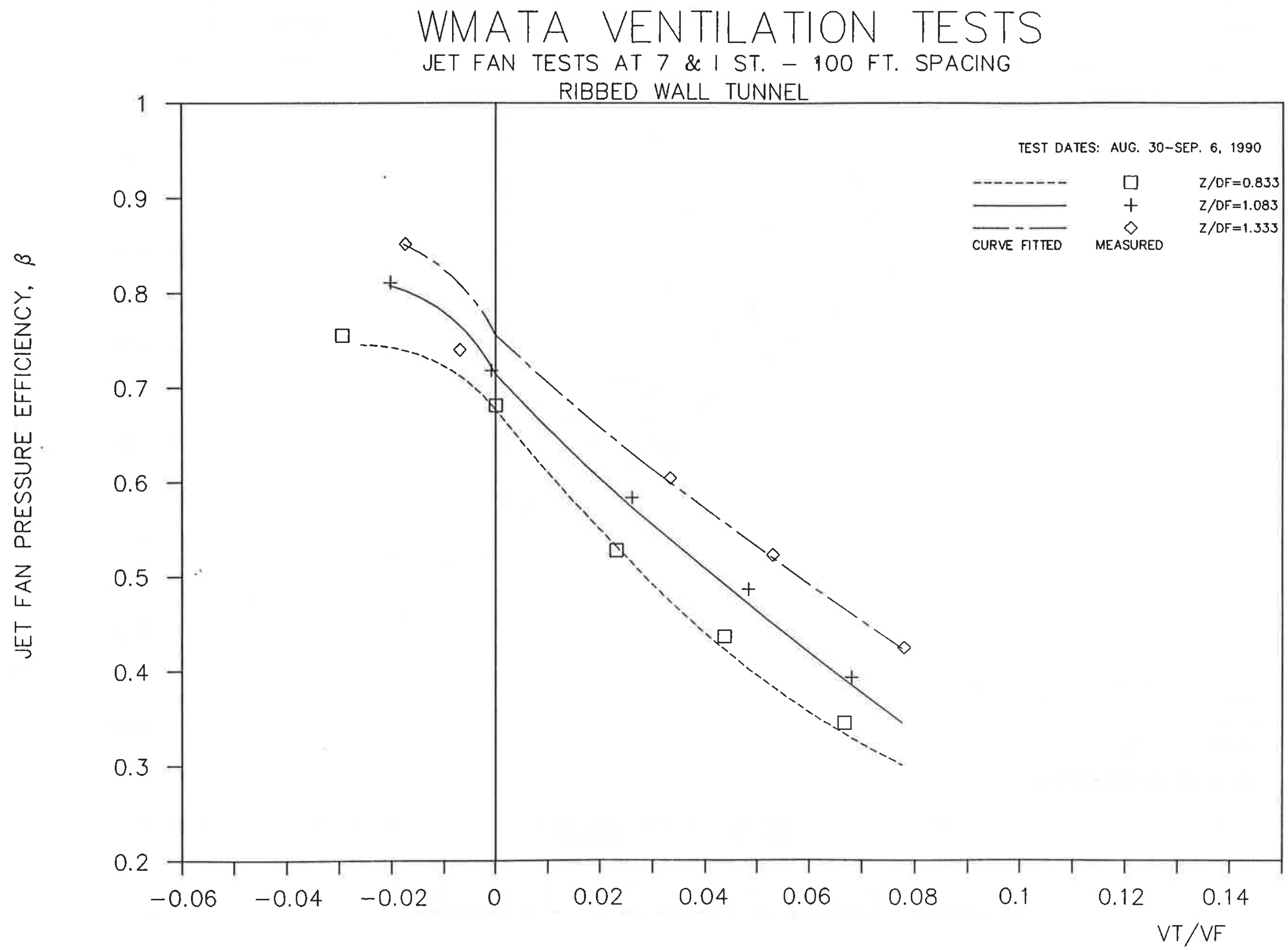

WMATA VENTILATION TESTS
JET FAN TESTS AT 7 & I ST. – 100 FT. SPACING
RIBBED WALL TUNNEL
TEST DATES: AUG. 30–SEP. 6, 1990
Z/DF=0.833
Z/DF=1.083
Z/DF=1.333
CURVE FITTED
MEASURED
JET FAN PRESSURE EFFICIENCY, β
VT/VF
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14

FIGURE 3–28

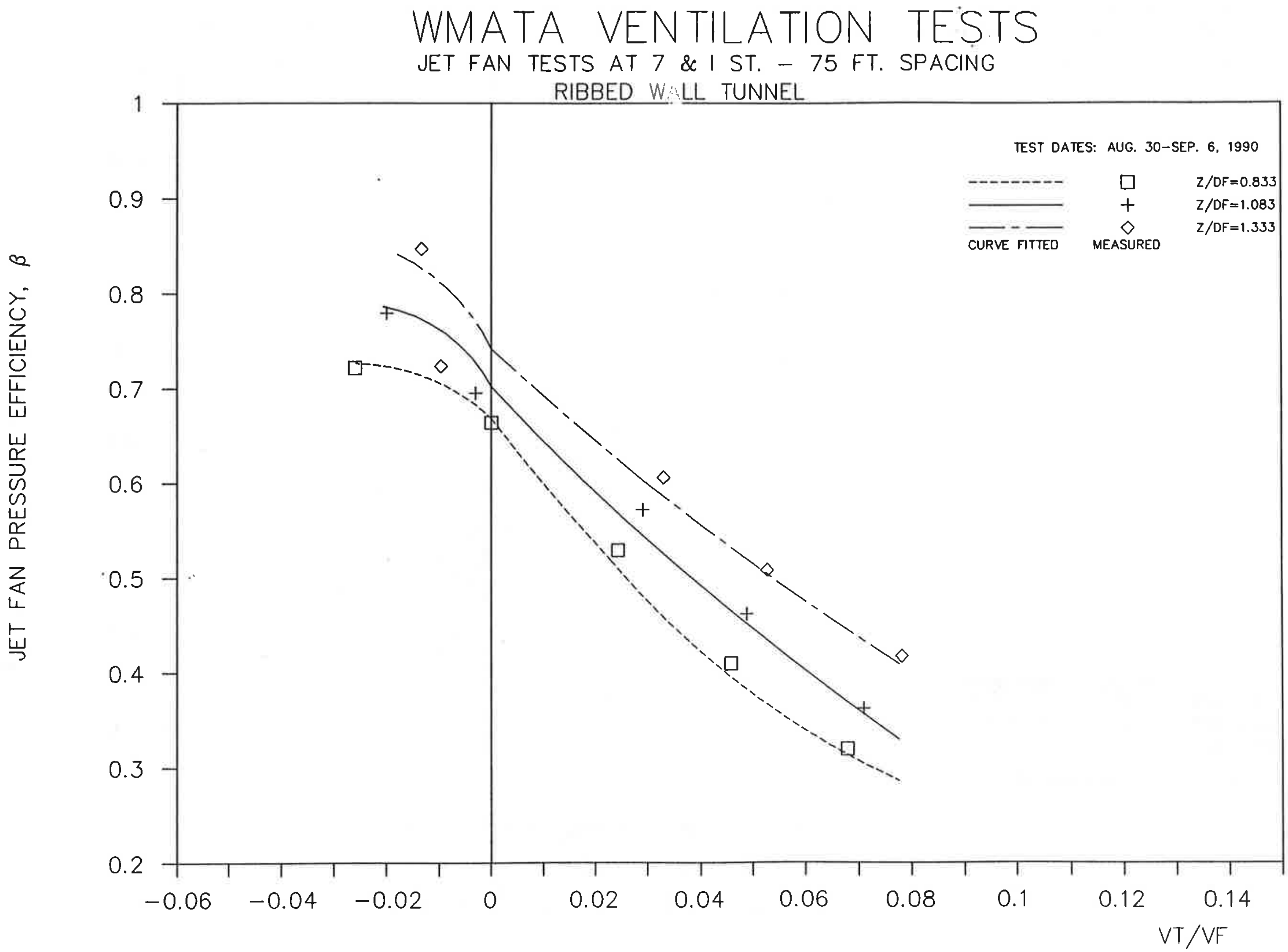

WMATA VENTILATION TESTS
JET FAN TESTS AT 7 & I ST. – 75 FT. SPACING
RIBBED WALL TUNNEL
TEST DATES: AUG. 30–SEP. 6, 1990
Z/DF=0.833
Z/DF=1.083
Z/DF=1.333
CURVE FITTED
MEASURED
JET FAN PRESSURE EFFICIENCY, β
VT/VF
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14

FIGURE 3–29

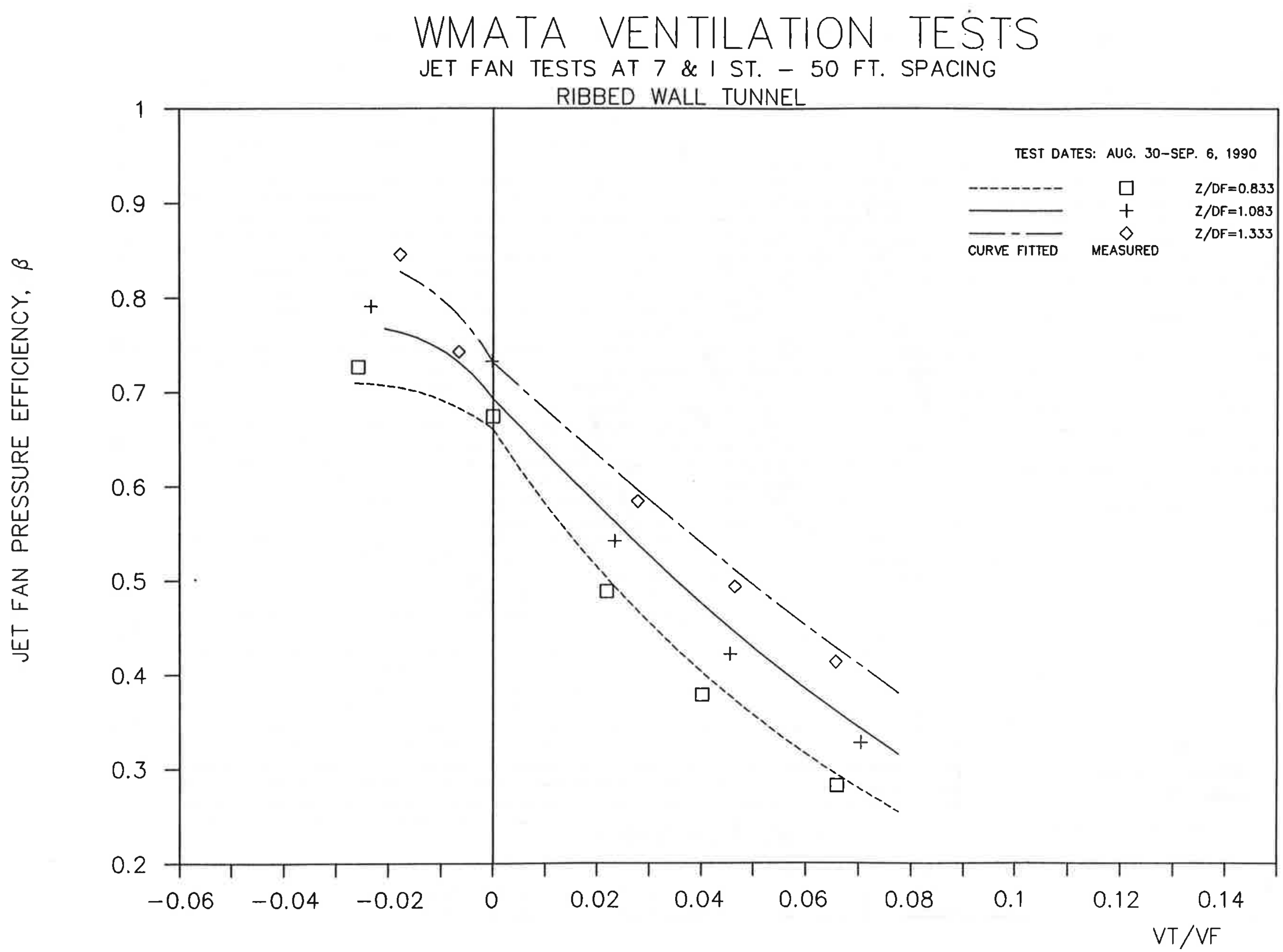

WMATA VENTILATION TESTS
JET FAN TESTS AT 7 & I ST. – 50 FT. SPACING
RIBBED WALL TUNNEL
TEST DATES: AUG. 30–SEP. 6, 1990
Z/DF=0.833
Z/DF=1.083
Z/DF=1.333
CURVE FITTED
MEASURED
JET FAN PRESSURE EFFICIENCY, β
VT/VF
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14

FIGURE 3–30

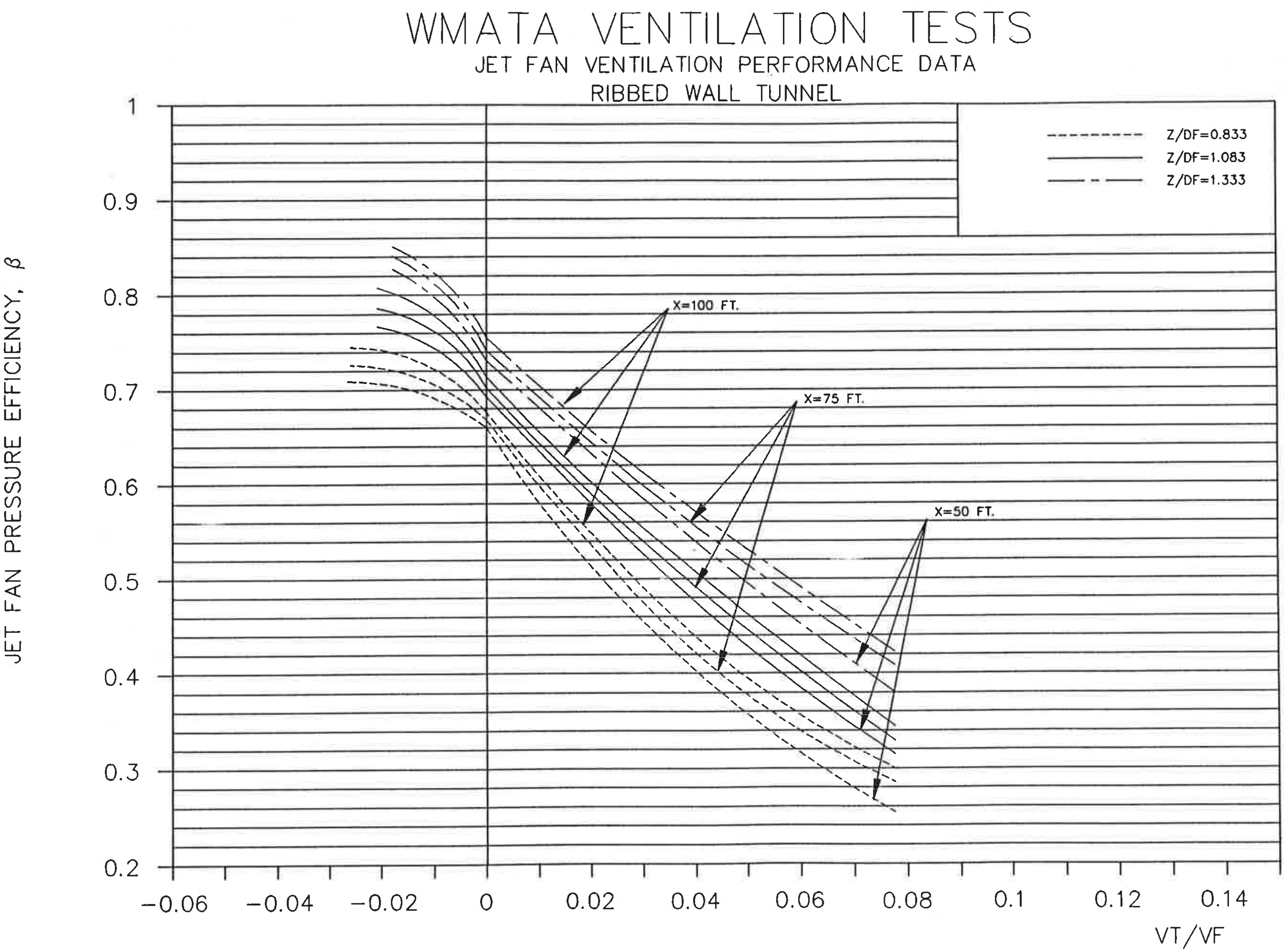

WMATA VENTILATION TESTS
JET FAN VENTILATION PERFORMANCE DATA
RIBBED WALL TUNNEL
Z/DF=0.833
Z/DF=1.083
Z/DF=1.333
X=100 FT.
X=75 FT.
X=50 FT.
JET FAN PRESSURE EFFICIENCY, β
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
VT/VF

FIGURE 3−31

These estimates indicate that:

- o Jet fans are not at all appropriate for tight, ribbed-wall tunnels having limited clearances such us those between Metro Center and McPherson Square Stations.
- o Jet fans are a solution for a large smooth wall tunnel having a shape that is too irregular for a barrier

It should be noted that these estimates are only a comparison for illustrative purposes and not indicative of any final-design requirement.

Commentary on Jet Fan Tests. The tests demonstrated that jet fans can be used to direct sufficient quantities of air past a stopped train during an emergency provided that space is available for their installation. The numerical range of design data developed indicates that jet fans would provide acceptable performance. The ventilation performance data in the form of the jet fan pressure efficiencies can be directly used for SES computer program input and/or modification during final design.

4. COMPUTER MODELING OF TUNNEL VENTILATION SYSTEMS

4.1 SUBWAY ENVIRONMENT SIMULATION COMPUTER PROGRAM

The performance of the emergency ventilation system during a tunnel fire is judged based on the ability of the ventilation system to produce forced air movement past the fire incident. The magnitude of the air velocity in the train annulus indicates whether the spread of smoke can be confined downstream of the fire site, thus protecting the upstream evacuation route, or whether the potential exists for smoke spreading into the upstream evacuation route, contrary to the forced ventilation (a phenomenon called back-layering).

Version 3 of the Subway Environment Simulation (SES) computer program [7] has been used to predict the tunnel airflows during fire conditions. This computer model, described in Appendix A, accounts for the "throttling" effects of a fire (i.e., increased pressure losses), the buoyant effects of the hot smoke which tends to flow "uphill", heat transfer to the tunnel walls by convection and radiation, and changes in fan performance while handling hot (i.e., less dense) gases.

The user's manual for the SES computer program [15] indicates that to prevent back-layering, the annular air velocity must be greater than a "critical" value. The magnitude of the critical value depends on various parameters including the fire heat release rate, the tunnel grade, the tunnel height, and the annular area. For the WMATA system, the critical velocity ranges from about 500 to about 650 fpm.

The SES computer program inputs include:

- o The ventilation performance data for the inflatable barriers
- o The ventilation performance data for the jet fans
- o The fire heat release rate.

Section 3 of this report documents the field tests that were conducted to establish the effectiveness of the barriers and the jet fans under varying tunnel conditions and the resulting ventilation data input to the SES computer program. Therefore, the next discussion focuses on the analysis used to estimate the peak heat release produced by a WMATA train fire. The results of this analysis are as follows:

- o A peak heat release rate of 69.7 MBtu/hr is recommended based on the current vehicle configuration which includes polycarbonate windows.

- o A peak heat release rate of 42.4 MBtu/hr would be recommended if all WMATA vehicles are retrofitted so that all windows are made from safety glass.

4.2 COMPUTER-BASED ESTIMATE OF FIRE HEAT RELEASE RATE

A computer-based study was conducted to estimate the heat release rate produced by a fire within a WMATA subway vehicle. This study, made under the direction of Parsons Brinckerhoff by Dr. Jonathan Barnett from the Center for Firesafety Studies at Worcester Polytechnic Institute, is presented in full in Appendix C.

The computer model used for this study was a slightly modified version of the COMPF2 computer program, developed by the Center for Fire Research, National Institute for Standards and Technology (formerly the National Bureau of Standards). The COMPF2 program is considered to be the most appropriate computer program for analyzing the peak heat release rate from a compartmentalized car fire because:

- o COMPF2 is the only post-flashover model available in the public domain. The peak heat release rate occurs during the post-flashover stage of burning when all of the interior combustibles are involved.

- o COMPF2 has been validated by comparison with experimental data.

- o The COMPF2 program has been shown to predict results comparable to the results from other computer programs.

Field models, such as TUNFIRE or JASMINE, may provide a reasonable approximation of fire parameters such as flame plume length within an enclosed environment and car-to-car flame transmission. However, they do not model the fire development within the compartment.

The physical characteristics of the Breda vehicle (i.e., the basic dimensions of the car and the thermal properties of the walls and ceiling) were used for the program input. A complete version of the inventory of combustible materials was not available, however for the Breda car. Therefore, the combustible data of the Rohr vehicle [16] was used.

Based on a combustible content of 59.25 MBtu for the above-floor materials only, the following results were predicted by the COMPF2 program for an above-floor fire involving a single WMATA vehicle:

- o Assuming a 65 percent burning pyrolysates fraction (BPF), a net heat of combustion of 9130 Btu/lb, and all windows open, a peak heat release rate of 34.3 MBtu/hr and a fire duration of 63 minutes were predicted.
- o Assuming a BPF of 65 percent, a net heat of combustion of 7420 Btu/lb, and all windows open, a peak heat release rate of 27.3 MBtu/hr and a fire duration of 78 minutes were predicted.
- o Assuming a BPF of 80 percent, a net heat of combustion of 7420 Btu/lb, and all windows open, a peak heat release rate of 33.7 MBtu/hr and a fire duration of 78 minutes were predicted.

It has been assumed that all windows are open because it is expected that the maximum fire temperature will result in failure of the polycarbonate windows.

Use of the heat release rate of 33.7 MBtu/hr was suggested by Barnett to account for the predictive accuracy of the COMPF2 program even though it was concluded that the heat release rate of 27.3 MBtu/hr was the most probable value. The suggested value is based on the heat content of the above-floor combustibles for a single WMATA vehicle. Therefore, the value needs to be adjusted to account for the heat content of the vehicle components located at floor level and below floor level, possible multiple car involvement, and a suitable factor of safety.

Modification of COMPF2 Results

Parsons Brinckerhoff has revised the results of the COMPF2 computer study in order to reflect historical observations of subway vehicle fires, advancements in the design and construction of subway vehicles, and specific physical characteristics of the Rohr and Breda vehicles used on the WMATA system. The following factors were considered:

Fire Hardening Activities. The total combustible content for the Rohr vehicle was slightly modified to reflect fire-hardening activities. Based on the Kaiser Engineers document "Metrorail Ventilation System Improvements and Vehicle Fire Hardening" [16] the revised breakout of material heat contents is as follows:

Interior & Exterior Materials, Above Floor Level:	48.0 MBtu
Floor Assembly:	12.3 MBtu
Undercar Materials:	8.3 MBtu
Total:	68.6 MBtu

Observations of Earlier Fires. Observations of BART and Toronto subway systems' fires (January 1979 and October 1976, respectively) indicated that:

- o Multiple cars were involved in both fire incidents.
- o Approximately 20 minutes after flashover the fire was transmitted to the adjacent car.
- o All combustibles above and below the car floor and less than one-half of the floor material were burned in the first car.
- o The fire was generally limited to the above-floor combustibles in the second and succeeding cars.

Advancement in Design and Constructions. The results of floor-assembly factory tests for vehicles such as the Miami/Baltimore car indicate that it is conservative to assume that about one-quarter of the floor combustibles would be consumed during a vehicle fire. This reduction in floor combustion may be attributed to the development of NFPA 130 in the early 1980's that led to the use of design and construction standards which limit the flammability and smoke emission characteristics for transit vehicle materials. All vehicles built to meet the NFPA 130 requirements or retrofitted as part of a vehicle fire-hardening program (including the WMATA vehicles) are much more resistant to the development and transmission of fire.

Direct Transmission of Fire. According to WMATA personnel, the ends of the WMATA vehicle consist of the following elements:

- o The cab end has an aluminum shell covered by a fiberglass cap plus windows made of safety glass.
- o The fiberglass itself does not support combustion; instead, the epoxy resin breaks down leaving the glass fibers in place.

- The butt-end of the cars is an aluminum shell (no fiberglass cap), and the only window is in the connecting door and is currently made of 3/8-inch polycarbonate.

Based on the above, direct transmission of the fire would be inhibited by the vehicle ends, and the most likely method of direct transmission would be through the butt-end polycarbonate window.

Indirect Transmission of Fire. The windows in the two types of cars using the WMATA system are made of different materials [17]. The original windows in the Rohr car are constructed of safety glass on the inside and ABS acrylic plastic on the outside. However, dual panel windows, consisting of clear tufax plastic on the outside and tinted polycarbonate on the inside, are being used as replacement windows for the Rohr cars. The Breda cars have polycarbonate side windows.

It is expected that the polycarbonate windows in the vehicles downstream of the fire site will fail when exposed to a temperature of about 600^{o}F. This is the nominal air temperature in the vicinity of the first vehicle downstream of the fire site based on a heat release rate of about 37 MBtu/hr. Therefore, the interior of the downstream vehicles would be exposed to the hot combustion gases, leading to potential ignition of these vehicles.

However, a vehicle retrofit program is currently being proposed to replace all of the polycarbonate windows with 1/4-inch safety glass. This retrofit would reduce the likelihood of indirect and direct fire transmission to the point where a vehicle fire should be contained within the compartment of origin.

Modification to Include Floor and Below Floor Combustibles. The COMPF2 results were first modified to reflect the revised inventory of combustibles and to account for the floor and below floor combustibles. Table 4-1 indicates the estimated peak heat release rate for the Breda Metro Red Line vehicle as a function of various burning percentage rates:

- Columns 1 through 3 give the results predicted by the COMPF2 computer program based on the combustible content of the above-floor materials only.
- Columns 4 through 9 show the basis for the estimated heat release rates for the floor and below-floor materials,
- Column 10 shows the total overall peak heat release rate.

Table 4-1: WMATA - Vehicle Peak Heat Release Rate
Modification of COMPF2 Computer Results

Floor Combustible Load: 12.245 MBtu

Below Floor Combustible Load: 8.342 MBtu

Case	COMPF2 Results			Calculated Results						Peak Heat Release Rate (MBtu/hr)
	BPF (%)	Qfire (MBtu/hr)	Duration (minutes)	BPF (%)		Duration of Burning (minutes)		Qfire (MBtu/hr)		
				Floor	Below Floor	Floor	Below Floor	Floor	Below Floor	
1	65	27.3	63	16.25	65	63	63	1.9	5.2	34.4
2	65	27.3	63	16.25	65	60	60	2.0	5.4	34.7
3	80	33.7	63	20	80	63	63	2.3	6.4	42.4
4	80	33.7	63	20	80	60	60	2.4	6.7	42.8
Column	1	2	3	4	5	6	7	8	9	10

Note: COMPF2 results are based on the combustible content of the above-floor materials only (48.009 MBtu).

Note that the duration of burning (Column 3) has been reduced to reflect the reduction in the above-floor combustible content (i.e., the burning rate would remain about the same but the fuel would be consumed more quickly) and that the BPF for the floor materials is adjusted to reflect the observation from factory tests that about one-quarter of the floor assembly would be consumed during a vehicle fire.

As stated earlier, the COMPF2 heat release rate of 27.3 MBtu/hr is considered to be the "most probable" value, but a heat release rate of 33.7 MBtu/hr was selected to provide a conservative basis of design. Case 3 was adopted as the scenario that most closely matches observed conditions of vehicle burning. A peak heat release rate of 42.4 MBtu/hr is estimated for a fire involving only one WMATA vehicle.

Fire Development Scenarios

To address the possibility of multiple car involvement, two scenarios were developed:

Scenario COMPF2-A:

Flashover Burning within a Single WMATA Vehicle - No Transmission to Adjacent Vehicles.

- The fire originates below the car floor, and after about 30 minutes it penetrates through the floor into the interior of the car, leading to flashover.
- At flashover, the fire burns at a constant rate until approximately 80 percent of the combustibles are consumed (see Appendix C). During this period, all combustibles above and below the car floor and one-quarter of the floor material are burned. The duration of this post-flashover period is based on a combination of the COMPF2 BPF's and on observations of the assumed burning percentage factor.

For this scenario, it has been assumed that the fire is not transmitted to the adjacent vehicles. This scenario would be recommended for the WMATA system if the polycarbonate windows were replaced by safety glass.

Flashover to succeeding cars should not occur if the amount of heat transmitted through the walls of the vehicle downstream of the fire is insufficient to cause ignition of the interior materials. This assumption should be justified by an analysis which accounts for the thermal resistance of the vehicle shell and the temperature of the smoke and hot gases in the vicinity of the first downstream vehicle.

Scenario COMPF2-B:

Flashover Burning within Multiple WMATA Vehicles - 30 Minute Flashover and Transmission to Adjacent Vehicles

This scenario is similar to the first scenario except that it is assumed that the fire is transmitted from car to car in approximately thirty-minute intervals. This scenario would be recommended for the design of the WMATA emergency ventilation system if the polycarbonate vehicle windows are not replaced.

Figures 4-1 and 4-2 show the profiles of the heat release rate as a function of time for Scenarios COMPF2-A and COMPF2-B respectively. Note that for Scenario COMPF2-B, the assumed values for flashover and car-to-car transmission have been modified slightly to eliminate spikes in the profiles which were considered unrealistic.

The peak heat release rate for each of these scenarios is as follows:

Scenario COMPF2-A (Single Car Fire):

$$Q_{max} = 42.4 \text{ MBtu/hr}$$

Scenario COMPF2-B (Multiple Car Fire, 30 Minute Flashover and Transmission Rate):

$$Q_{max} = 69.7 \text{ MBtu/hr}$$

Recommendation of a Design Heat Release Rate

As discussed above, the design and construction details of the WMATA vehicle have been reviewed in order to classify the vehicle according to the risk of flashover and car-to-car transmission. Observing that the fire-hardening efforts have produced vehicles which meet the NFPA-130 recommendations, the primary concern regarding fire development is the polycarbonate windows.

Given the current uncertainty regarding the potential replacement of the polycarbonate windows with safety glass, the two fire heat release rates, noted earlier, are recommended:

- A heat release rate of 69.7 MBtu/hr is recommended if the window replacement program is not pursued

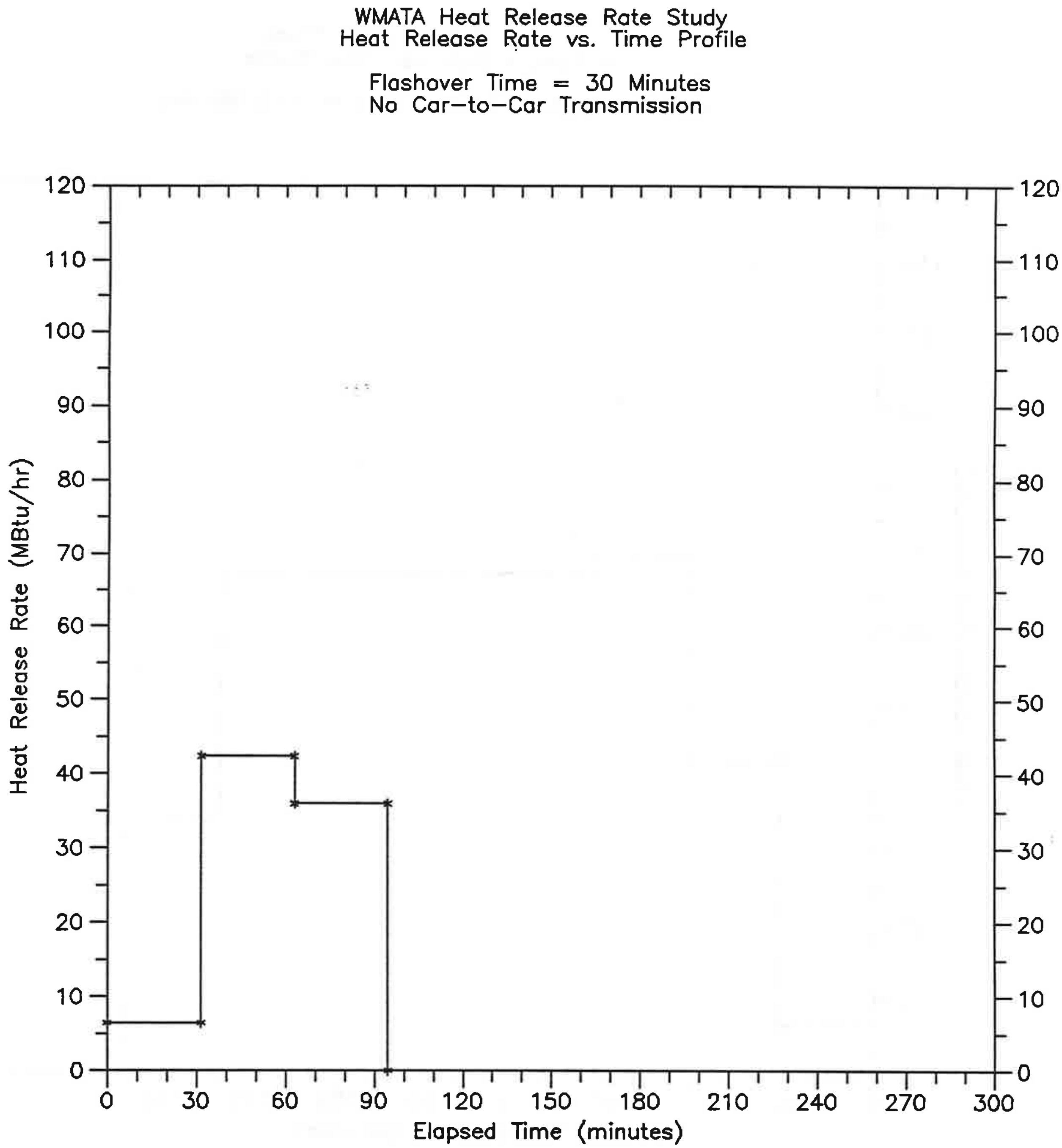


Figure 4–1: Scenario COMPF2–A

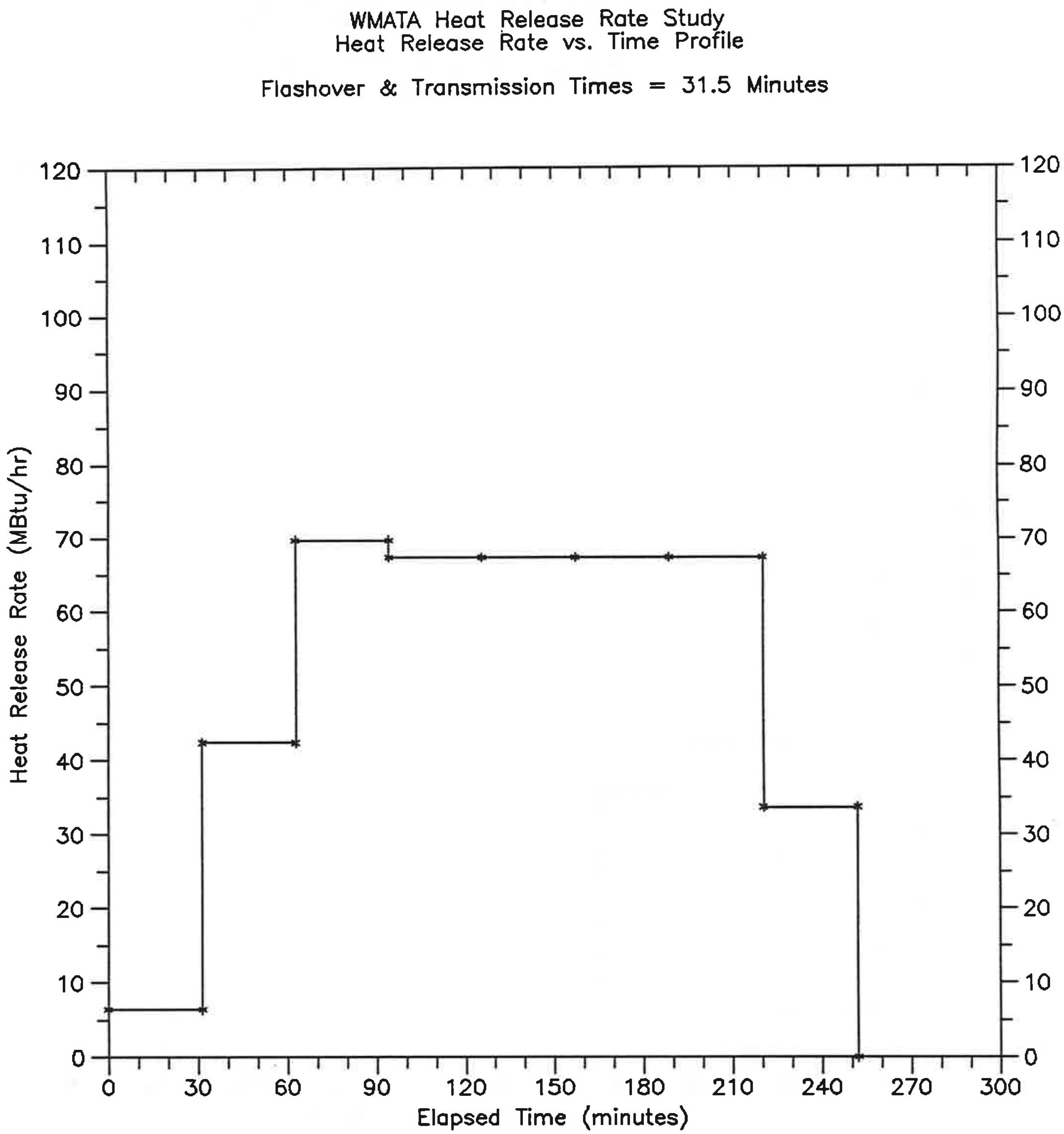


Figure 4–2: Scenario COMPF2–B

- A heat release rate of 42.4 MBtu/hr is recommended if all of the polycarbonate windows within the vehicle are replaced by safety glass.

4.3 SES ANALYSES

The SES computer program was used to predict emergency ventilation requirements in the tunnels between Metro Center and McPherson Square Stations. The simulations:

- Demonstrated the results of the ventilation test program on a typical portion of the system
- Developed sufficient data to enable a preliminary systemwide count of barriers and jet fans of sufficient accuracy for an input to a construction cost estimate for their implementation.

Simulation Elements

Critical Air Velocities. The train fire heat release rates of 42.4 and 69.7 MBtu/hr were used in the computer runs and in the calculation of the critical air velocities. The following critical air velocities were calculated using the data for the ribbed tunnel adjacent to the New York Avenue fan shaft.

FIRE HEAT RELEASE RATE MBtu/hr	TUNNEL GRADE (%)	CRITICAL AIRFLOW (cfm)	CRITICAL ANNULAR AIR VELOCITY (fpm)
69.7	-4.0	57,048	594
69.7	0.0	49,662	517
42.4	-4.0	52,590	547
42.4	0.0	46,047	479

Barriers. The simulations analyzed only barriers since they are preferred over jet fans. The numbers of jet fans, where required, can be estimated from the output of a barrier simulation. The input assumed the following:

- The barrier in the tunnel occupied by the train (but on the opposite side of the ventilation shaft) had its egress opening open.

o The barriers in the unaffected, empty tunnel parallel to the affected tunnel had their egress openings closed.

These assumptions were consistent with the assumption that egress would occur along the tunnel to the station past the fan shaft or up the fan shaft. The head loss coefficients input to the SES computer program were 40 for the open barrier and 86 for the closed barriers.

Simulation. Prior to the simulations the fan curve for the New York Avenue fan shaft was adjusted to produce SES-predicted "no fire" airflows which agreed with the June 1990 field measurements. This provided an assurance that the "as-built" conditions were being accurately simulated.

The simulations were made for the tunnel ventilation fans running in both supply (reverse direction) and exhaust (forward direction) modes. The results of each simulation were compared with the critical velocity to determine if the simulation was predicting the control of the direction of smoke spread or not. If the air velocity predicted during a fire was greater than the calculated critical air velocity, then it was concluded that the direction of smoke spread was being controlled.

Key Simulations

The following key simulations were made for the tunnels between Metro Center to McPherson Square Stations:

Simulation No.:	1	2	3
Fire Heat Release Rate (MBtu/hr):	69.7	69.7	69.7
Tunnel Ventilation Fan Mode:	Supply	Supply	Supply
Tunnel Ventilation Fan Reversibility (%):	70	70	90
Number of barriers per tunnel:	1	2	2
Incident Tunnel Airflow:			
Critical (cfm)	57,048	57,048	57,048
Actual (cfm)	51,515	55,216	65,166
Pass/Fail:	Fail	Fail	Pass

Simulation No.:	3	4
Fire Heat Release Rate (MBtu/hr):	69.7	42.4
Tunnel Ventilation Fan Mode:	Supply	Supply
Tunnel Ventilation Fan Reversibility (%):	90	70
Number of barriers per tunnel:	2	1
Incident Tunnel Airflow:		
Critical (cfm)	57,048	52,589
Actual (cfm)	65,166	53,197
Pass/Fail:	Pass	Pass

Results of Simulations

It was concluded that:

- Each of the tunnels adjacent to the New York Avenue fan shaft would have to have two barriers if the Metrorail trains were to remain as they currently are. However, if the trains were to be changed to glass windows, each of the tunnels would have to have only one barrier. Suitable locations for the barriers would be 50 feet for the first barrier and 150 feet for the second barrier measured from the edge of the fan shaft inlet to the tunnel.

- The fans in the New York Avenue fan shaft would have to be converted from 70 percent reversibility to 90 percent reversibility if the Metrorail trains were to remain as they are. However, the fans would not have to be changed if the trains were to be changed to glass windows.

It was recognized that the effects of the wall roughness and the tunnel grade were a near worst case at the New York Avenue Fan Shaft. It was therefore decided to use the same SES input data file to study the sensitivity of the above results in the wall roughness and the tunnel grade. A series of simulations produced the following results:

Wall Surface	Fire Heat Release Rate (MBtu/hr)	Tunnel Grade (%)	Number of Barriers Required per Tunnel	Required fan reversibility (%)
Rough	69.7	-4.0	2	90
Rough	69.7	0.0	2	70
Smooth	69.7	-4.0	2	70
Smooth	69.7	0.0	1	70
Rough	42.4	-4.0	1	70
Rough	42.4	0.0	1	70
Smooth	42.4	-4.0	1	70
Smooth	42.4	0.0	1	70

The simulations assumed that increasing the number of barriers per tunnel from one to two was less expensive than converting the tunnel ventilation fans from 70 to 90 percent reversibility.

Estimated Quantities of Equipment Needed to Upgrade the Metrorail Tunnel Ventilation System

The objective of the emergency ventilation system is to direct sufficient quantities of air past a stopped train during a fire emergency so that the direction of spread of smoke is controlled and a relatively smoke-free path of evacuation is maintained. Table 4-2 presents the estimated number of barriers and jet fans and the estimated number of tunnel ventilation fans that have to be 90 percent reversible to achieve this objective in the Metrorail System. These estimates were based on a train fire heat release rate of 69.7 MBtu/hr.

If the trains were retrofitted with glass windows, the fire heat release rate would decrease to 42.4 MBtu/hr and the estimated equipment quantities presented in Table 4-2 would be reduced by about 21 percent as presented in Table 4-3.

TABLE 4-2
ESTIMATED NUMBER OF BARRIERS AND JET FANS
ASSUMING A FIRE HEAT RELEASE RATE OF 69.7 MBTU/H
WMATA FAN SHAFT WALL CONFIGURATION

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FAN SHAFT No.	No. OF FANS @ 50,000 CFM	TUNNE TYPE: CIRCULAR	BOX	DOUBLE BOX	TRIPLE BOX	DOUBLE TRACK	WALL FINISH: SMOOTH	RIBBED	SEGMENTAL CONCRETE	TUNNEL GRADE BY THE FAN SHAFTS	BARRIERS	20 IN. DIAM. JET FANS	48 IN. DIAM. JET FANS	FAN SHAFT FANS 90% REVERS.
A-1	3			1			1			0.929%		20		
A-2	2	1					1			0.929%	4			
A-3	4	0.5			0.5		1			0.929%	2	15		
A-4	3					1	1			0.350%			2	
A-5	3					1	1			2.486%			4	
A-6	5	1					1			3.850%	8			
A-7	4	1					1			3.710%	8			
A-8	4	1					1			4.000%	8			
A-9	4	1					1			3.230%	8			
A-10	6	1					1			3.230%	8			
A-11	3	1					1			0.350%	4			
A-12	4	1					1			0.350%	4			
A-13	6	1					1			0.350%	4			
A-14	4	1					1			4.000%	8			
A-15	4			1			1			1.225%		20		
A-16	3			1			1			1.053%		20		
	62	10.5	0	3	0.5	2	16	0	0		66	75	6	0
B-1	2			1			1			0.350%		20		
B-2	3			1			1			0.994%		20		
B-3	3			1			1			4.000%		32		
B-4	3		1				1			4.000%		32		
B-5	6	1					1			3.302%	8			
B-6	4	1					1			0.350%	4			
B-7	4	1					1			4.000%	8			
B-8	4													
B-9	4													
	33	3	1	3	0	0	7	0	0		20	104	0	0
C-1	5	1						1		4.000%	8			5
C-2	4			1			1			2.000%		32		
C-3	6			1			1			1.609%		20		
C-4	4	1					1			3.902%	8			
C-5	6	1					1			4.000%	8			
C-6	4	1					1			1.658%	4			
C-7	4			1			1			0.035%		20		
C-8	4	1					1			0.804%	4			
C-9	5			1			1			0.350%		20		
C-10	2			1			1			0.390%		20		
C-11	2													
C-12	2													
	48	5	0	5	0	0	9	1	0		32	112	0	5

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TABLE 4-2
ESTIMATED NUMBER OF BARRIERS AND JET FANS
ASSUMING A FIRE HEAT RELEASE RATE OF 69.7 MBTU/H
WMATA FAN SHAFT WALL CONFIGURATION

FAN SHAFT No.	No. OF FANS @ 50,000 CFM	TUNNE TYPE CIRCULAR	BOX	DOUBLE BOX	TRIPLE BOX	DOUBLE TRACK	WALL FINISH SMOOTH	RIBBED	SEGMENTAL CONCRETE	TUNNEL GRADE BY THE FAN SHAFTS	BARRIERS	20 IN. DIAM. JET FANS	48 IN. DIAM. JET FANS	FAN SHAFT FANS 90% REVERS.
D-1	4	1						1		0.564%	8			
D-2	4			1			1			1.850%		20		
D-3	4	1						1		2.690%	8			4
D-4	4	1					1			0.365%	4			
D-5	5	1					1			2.700%	8			
D-6	5	1					1			2.130%	8			
D-7	5		1				1			0.350%		20		
D-8	6	1					1			0.360%	4			
D-9	3	1					1			3.980%	8			
	40	7	1	1	0	0	7	2	0		48	40	0	4
E-1	6	1							1	0.350%	4			
E-2	7				1		1			0.350%		30		
E-3	5	1							1	0.350%	4			
E-4	6													
E-5	3													
E-6	3													
E-7	6													
E-8	5													
E-9	3	0.5	0.5				0.5		0.5	0.499%	2	10		
E-10	4			1			1			0.000%		20		
E-11	2			1			1			0.350%		20		
E-12	2	1							1	4.000%	8			
E-13	2	1							1	0.910%	4			
	54	4.5	0.5	2	1	0	3.5	0	4.5		22	80	0	0
F-1	4	1					1			0.360%	4			
F-2	4	1					1			0.000%	4			
F-3	4	1						1		1.000%	8			
F-4	4	1							1	0.000%	4			
F-5	3	1							1	0.000%	4			
F-6	4		1				1			0.000%		20		
	23	5	1	0	0	0	3	1	2		24	20	0	0
G-1	4	1					1			2.038%	8			
G-2	2	1					1			0.350%	4			
G-3	2	1					1			0.300%	4			
G-4	2	1					1			2.635%	8			
	10	4	0	0	0	0	4	0	0		24	0	0	0

TABLE 4-2
ESTIMATED NUMBER OF BARRIERS AND JET FANS
ASSUMING A FIRE HEAT RELEASE RATE OF 69.7 MBTU/H
WMATA FAN SHAFT WALL CONFIGURATION

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FAN SHAFT No.	No. OF FANS @ 50,000 CFM	TUNNE TYPE: CIRCULAR	BOX	DOUBLE BOX	TRIPLE BOX	DOUBLE TRACK	WALL FINISH: SMOOTH	RIBBED	SEGMENTAL CONCRETE	TUNNEL GRADE BY THE FAN SHAFTS	BARRIERS	20 IN. DIAM. JET FANS	48 IN. DIAM. JET FANS	FAN SHAFT FANS 90% REVERS.
K-1	4	1					1			4.000%	8			
K-2	3			1			1			4.000%		32		
K-3	3			1			1			0.811%		20		
K-4	3			1			1			0.350%		20		
K-5	2			1			1			1.039%		20		
	15	1	0	4	0	0	5				8	92	0	0
L-1	2	0.5		0.5			0.5	0.5		0.000%	4	10		
L-2	2			1			1			3.000%		32		
	4	0.5	0	1.5	0	0	1.5	0.5	0		4	42	0	0
TOTALS	289	40.5	3.5	19.5	1.5	2	56	4.5	6.5		248	565	6	9

TOTAL NUMBER OF SHAFTS INVOLVED: 76
TOTAL NUMBER OF SHAFTS TO USED JET FANS: 28

NOTE: ALL FAN SHAFT FANS WILL REMAIN 70 PERCENT REVERSIBLE, EXCEPT FOR THOSE THAT ARE MARKED IN THIS TABULATION AS BEING CONVERTED TO 90 PERCENT REVERSIBLE.

TABLE 4-3
ESTIMATED NUMBER OF BARRIERS AND JET FANS
ASSUMING A FIRE HEAT RELEASE RATE OF 42.4 MBTU/H
WMATA FAN SHAFT WALL CONFIGURATION

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FAN SHAFT No.	No. OF FANS @ 50,000 CFM	TUNNE TYPE: CIRCULAR	TUNNE TYPE: BOX	TUNNE TYPE: DOUBLE BOX	TUNNE TYPE: TRIPLE BOX	TUNNE TYPE: DOUBLE TRACK	WALL FINISH: SMOOTH	WALL FINISH: RIBBED	WALL FINISH: SEGMENTAL CONCRETE	TUNNEL GRADE BY THE FAN SHAFTS	BARRIERS	20 IN. DIAM. JET FANS	48 IN. DIAM. JET FANS	FAN SHAFT FANS 90% REVERS.
A-1	3			1			1			0.929%		20		
A-2	2	1					1			0.929%	4			
A-3	4	0.5			0.5		1			0.929%	2	15		
A-4	3					1	1			0.350%			2	
A-5	3					1	1			2.486%			4	
A-6	5	1					1			3.850%	4			
A-7	4	1					1			3.710%	4			
A-8	4	1					1			4.000%	4			
A-9	4	1					1			3.230%	4			
A-10	6	1					1			3.230%	4			
A-11	3	1					1			0.350%	4			
A-12	4	1					1			0.350%	4			
A-13	6	1					1			0.350%	4			
A-14	4	1					1			4.000%	4			
A-15	4			1			1			1.225%		20		
A-16	3			1			1			1.053%		20		
	62	10.5	0	3	0.5	2	16	0	0		42	75	6	0
B-1	2			1			1			0.350%		20		
B-2	3			1			1			0.994%		20		
B-3	3			1			1			4.000%		20		
B-4	3		1				1			4.000%		20		
B-5	6	1					1			3.302%	4			
B-6	4	1					1			0.350%	4			
B-7	4	1					1			4.000%	4			
B-8	4													
B-9	4													
	33	3	1	3	0	0	7	0	0		12	80	0	0
C-1	5	1						1		4.000%	8			
C-2	4			1			1			2.000%		20		
C-3	6			1			1			1.609%		20		
C-4	4	1					1			3.902%	4			
C-5	6	1					1			4.000%	4			
C-6	4	1					1			1.658%	4			
C-7	4			1			1			0.035%		20		
C-8	4	1					1			0.804%	4			
C-9	5			1			1			0.350%		20		
C-10	2			1			1			0.390%		20		
C-11	2													
C-12	2													
	48	5	0	5	0	0	9	1	0		24	100	0	0

TABLE 4-3
ESTIMATED NUMBER OF BARRIERS AND JET FANS
ASSUMING A FIRE HEAT RELEASE RATE OF 42.4 MBTU/H
WMATA FAN SHAFT WALL CONFIGURATION

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FAN SHAFT No.	No. OF FANS @ 50,000 CFM	TUNNE TYPE: CIRCULAR	BOX	DOUBLE BOX	TRIPLE BOX	DOUBLE TRACK	WALL FINISH: SMOOTH	RIBBED	SEGMENTAL CONCRETE	TUNNEL GRADE BY THE FAN SHAFTS	BARRIERS	20 IN. DIAM. JET FANS	48 IN. DIAM. JET FANS	FAN SHAFT FANS 90% REVERS.
D-1	4	1						1		0.564%	4			
D-2	4			1			1			1.850%		20		
D-3	4	1						1		2.690%	8			
D-4	4	1					1			0.365%	4			
D-5	5	1					1			2.700%	4			
D-6	5	1					1			2.130%	4			
D-7	5		1				1			0.350%		20		
D-8	6	1					1			0.360%	4			
D-9	3	1					1			3.980%	4			
	40	7	1	1	0	0	7	2	0		32	40	0	0
E-1	6	1							1	0.350%	4			
E-2	7				1		1			0.350%		30		
E-3	5	1							1	0.350%	4			
E-4	6													
E-5	3													
E-6	3													
E-7	6													
E-8	5													
E-9	3	0.5	0.5				0.5		0.5	0.499%	2	10		
E-10	4			1			1			0.000%		20		
E-11	2			1			1			0.350%		20		
E-12	2	1							1	4.000%	4			
E-13	2	1							1	0.910%	4			
	54	4.5	0.5	2	1	0	3.5	0	4.5		18	80	0	0
F-1	4	1					1			0.360%	4			
F-2	4	1					1			0.000%	4			
F-3	4	1						1		1.000%	4			
F-4	4	1							1	0.000%	4			
F-5	3	1							1	0.000%	4			
F-6	4		1				1			0.000%		20		
	23	5	1	0	0	0	3	1	2		20	20	0	0
G-1	4	1					1			2.038%	4			
G-2	2	1					1			0.350%	4			
G-3	2	1					1			0.300%	4			
G-4	2	1					1			2.635%	4			
	10	4	0	0	0	0	4	0	0		16	0	0	0

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TABLE 4-3
ESTIMATED NUMBER OF BARRIERS AND JET FANS
ASSUMING A FIRE HEAT RELEASE RATE OF 42.4 MBTU/H
WMATA FAN SHAFT WALL CONFIGURATION

FAN SHAFT No.	No. OF FANS @ 50,000 CFM	TUNNE TYPE: CIRCULAR	BOX	DOUBLE BOX	TRIPLE BOX	DOUBLE TRACK	WALL FINISH: SMOOTH	RIBBED	SEGMENTAL CONCRETE	TUNNEL GRADE BY THE FAN SHAFTS	BARRIERS	20 IN. DIAM. JET FANS	48 IN. DIAM. JET FANS	FAN SHAFT FANS 90% REVERS.
K-1	4	1					1			4.000%	4			
K-2	3			1			1			4.000%		20		
K-3	3			1			1			0.811%		20		
K-4	3			1			1			0.350%		20		
K-5	2			1			1			1.039%		20		
	15	1	0	4	0	0	5				4	80	0	0
L-1	2	0.5		0.5			0.5	0.5		0.000%	4	10		
L-2	2			1			1			3.000%		20		
	4	0.5	0	1.5	0	0	1.5	0.5	0		4	30	0	0
TOTALS	289	40.5	3.5	19.5	1.5	2	56	4.5	6.5		172	505	6	0

TOTAL NUMBER OF SHAFTS INVOLVED: 76
TOTAL NUMBER OF SHAFTS TO USED JET FANS: 28

NOTE: ALL FAN SHAFT FANS WILL REMAIN 70 PERCENT REVERSIBLE, EXCEPT FOR THOSE THAT ARE MARKED IN THIS TABULATION AS BEING CONVERTED TO 90 PERCENT REVERSIBLE.

5. COST ESTIMATES FOR SYSTEMWIDE RETROFIT

The following estimates were made:

- Barriers and jet fans for a:
  - 42.4 MBtu/hr fire - $15,800,000
  - 69.7 MBtu/hr fire - $18,900,000
- Traditional approach - modification of existing station ventilation shafts - $585,000,000

Barriers
Each barrier assembly includes the fabric center with a closeable egress slit, a fabric inflatable torus, shroud lines extending about 20 feet in either direction mounted to the tunnel ceiling, a flexible casing mounted against the tunnel ceiling suitable for barrier storage, a pressurized nitrogen bottle for inflating the barrier and the barrier activation and release mechanisms. The cost of a barrier shipped to site, but not installed, is estimated to be $12,500. The cost of the barrier fabric alone is estimated to be $5,000 per barrier. It is recommended that a production configuration barrier be given a two-year service test. The cost of manufacturing and installing the service test barrier is estimated to be $100,000.

20-Inch Diameter Jet Fans
Each 20-inch diameter jet fan assembly includes a 100-percent reversible, 15 hp, axial-flow fan rated for 300^{o}F for one hour and a sound attenuator at each end. The cost of each 20-inch diameter jet fan shipped to site, but not installed, is estimated to be $5,000. This includes the routine factory testing that is done for all fans but does not include the manufacturer's shop drawing and calculation submittals, and the noise and performance testing that accompany the first fan. This effort is a one-time cost of $35,000. Each 20-inch diameter jet fan will require a 15 hp high-temperature reversing starter. The cost of these shipped to site, but not installed, is estimated to be $2,000 each. Each 20-inch diameter jet fan will require approximately 200 feet of high-temperature smokeless cable. The cost of this shipped to site, but not installed, is estimated to be $14.00 per foot or about $2,800 per jet fan. Each ventilation shaft modified for jet fans will require an additional 480 volt power supply. The cost of this shipped to site, but not installed, is estimated to be $35,000.

48-Inch Diameter Jet Fans

Each 48-inch diameter jet fan assembly includes a 100-percent reversible, 75 hp, axial-flow fan rated for 300^{o}F for one hour and a sound attenuator at each end. The cost of each 48-inch diameter jet fan shipped to site, but not installed, is estimated to be $25,000. This includes the routine factory testing that is done for all fans but does not include the manufacturer's shop drawing submittals and special factory testing that accompany the first fan. This effort is a one-time cost of $35,000. Each 48-inch diameter jet fan will require a 75 hp high-temperature reversing starter. The cost of these shipped to site, but not installed, is estimated to be $4,000 each. Each 48-inch diameter jet fan will require approximately 200 feet of high-temperature smokeless cable. The cost of this shipped to site, but not installed, is estimated to be $18.00 per foot or about $3,600 per jet fan. Each ventilation shaft modified for jet fans will require an additional 480 volt power supply. The cost of this shipped to site, but not installed, is estimated to be $35,000.

Conversion of Existing Fans to 90 Percent Reversibility

Discussions with manufacturers led to the conclusion it is appropriate to assume for the purposes of this estimate that the existing fans are replaced with 50,000 cfm, 90-percent reversible, axial-flow fans rated at 300^{o}F for at least one hour. The cost of these shipped to site, but not installed, is estimated to be $35,000 each.

Ventilation Equipment Monitoring and Central Control

A programmable logic controller (PLC) for the deployment of the barriers and/or the operation of the jet fans would have to be added to each ventilation shaft. The cost of each PLC shipped to site, but not installed, is estimated to be $4,000. It is further estimated that 10 subway station remote terminal units (RTUs) would have to be expanded. The cost of this is estimated at $60,000 each.

Installation

Installation is estimated to be 25 percent of all equipment costs, not including spares. This is deemed appropriate because it is imperative not to interfere with revenue service and very little, if any, structural modifications are required.

Non-Equipment Costs
Site adaption engineering including construction management services is estimated to be 20 percent of the equipment and installation costs, not including spares. An overall contingency of 10 percent has been estimated.

Systemwide Cost Estimate for a 69.7 Million Btu/hr Fire

Item		Estimate
1.	Barriers - 248 @ 12,500	3,100,000
2.	Spare Barriers - 20 @ 12,500 (Optional)	250,000
3.	Spare Barriers (Fabric Only) - 20 @ 5,000 (Optional)	100,000
4.	Barrier Installation - 0.25 x Item 1	775,000
5.	Service Test Barrier - 100,000 LS	100,000
6.	20-inch Diameter Jet Fans - 565 @ 5,000	2,825,000
7.	Starters for Item 6 - 565 @ 2,000	1,130,000
8.	Cabling for Item 6 - 565 @ 2,800	1,582,000
9.	Special Testing for Item 6 - 35,000 LS	35,000
10.	20-inch Diameter Jet Fan Installation 0.25 x Items 6, 7 and 8	1,384,250
11.	Spare 20-inch Diameter Jet Fans - 5 @ 5,000 (Optional)	25,000
12.	48-inch Diameter Jet Fans - 9 @ 25,000	225,000
13.	Starters for Item 12 - 9 @ 4,000	36,000
14.	Cabling for Item 12 - 9 @ 3,600	32,400
15.	Special Testing for Item 12 - 35,000 LS	35,000
16.	48-inch Diameter Jet Fan Installation 0.25 x Items 12, 13, 14	73,350
17.	Spare 48-inch Diameter Jet Fans - 2 @ 25,000 (Optional)	50,000
18.	90 Percent Reversing Fans - 9 @ 35,000	315,000
19.	90 Percent Reversing Fans Installation 0.25 x Item 18	78,750
20.	Additional 480 Volt Power Supplies - 28 @ 35,000	980,000
21.	Power Supply Installation - 0.25 x Item 20	245,000
22.	PLCs - 76 Ventilation Shafts @ 4,000 each	324,000
23.	Installation of PLCs - 0.25 x Item 22	76,000
24.	Additional RTUs - 10 @ 60,000	600,000
25.	Site Specific Engineering and CM Costs - 0.20 x Items 1, 4 through 16 and 18 through 24 - 0.20 x 13,956,750	2,791,350
26.	Contingency - 0.10 Items 1 through 25 - 0.10 x 17,148,100	1,714,810

TOTAL - Items 1 through 26	18,862,910
Say	18,900,000

Systemwide Cost Estimate for a 42.4 Million Btu/hr Fire

Item		Estimate
1.	Barriers - 172 @ 12,500	2,150,000
2.	Spare Barriers - 15 @ 12,500 (Optional)	187,500
3.	Spare Barriers (Fabric Only) - 15 @ 5,000 (Optional)	75,000
4.	Barrier Installation - 0.25 x Item 1	537,500
5.	Service Test Barrier - 100,000 LS	100,000
6.	20-inch Diameter Jet Fans - 505 @ 5,000	2,525,000
7.	Starters for Item 6 - 505 @ 2,000	1,010,000
8.	Cabling for Item 6 - 505 @ 2,800	1,414,000
9.	Special Testing for Item 6 - 35,000 LS	35,000
10.	20-inch Diameter Jet Fan Installation 0.25 x Items 6, 7 and 8	1,237,250
11.	Spare 20-inch Diameter Jet Fans - 5 @ 5,000 (Optional)	25,000
12.	48-inch Diameter Jet Fans - 9 @ 25,000	225,000
13.	Starters for Item 12 - 9 @ 4,000	36,000
14.	Cabling for Item 12 - 9 @ 3,600	32,400
15.	Special Testing for Item 12 - 35,000 LS	35,000
16.	48-inch Diameter Jet Fan Installation 0.25 x Items 12, 13, 14	73,350
17.	Spare 48-inch Diameter Jet Fans - 2 @ 25,000 (Optional)	50,000
18.	90 Percent Reversing Fans - 0 @ 35,000	0
19.	90 Percent Reversing Fans Installation 0.25 x Item 18	0
20.	Additional 480 Volt Power Supplies - 28 @ 35,000	980,000
21.	Power Supply Installation - 0.25 x Item 20	245,000
22.	PLCs - 76 Ventilation Shafts @ 4,000 each	304,000
23.	Installation of PLCs - 0.25 x Item 22	76,000
24.	Additional RTUs 10 @ 60,000	600,000
25.	Site Specific Engineering and CM Costs - 0.20 x Items 1, 4 through 16 and 18 through 24 - 0.20 x 11,640,500	2,328,100
26.	Contingency - 0.10 Items 1 through 25	

- 0.10 x 14,368,600 -		1,428,110
TOTAL - Items 1 through 26		15,709,210
	Say	15,800,000

Traditional Approach
An alternate approach to barriers and jet fans would be replacing the existing ventilation shafts at both ends of each station with fan ventilation shafts, dampered so that either one tunnel or the other is ventilated during emergency conditions. Each shaft would have a bypass damper for normal ventilation, two fans having a total capacity of about 250,000 to 350,000 cfm, a total fan horsepower of 250 to 500 and the necessary electrical power facilities. Each fan would have a shutoff damper and some sound attenuation depending on the location of the fan chamber. The space requirement would cause considerable structural modifications of the existing ventilation shafts at the station ends. It is estimated that each mid-tunnel ventilation shaft would require a fan shaft at the station ends; therefore, it appears that 152 modified ventilation shafts would be required.

Ventilation shafts similar to these are being installed in the Massachusetts Bay Transportation Authority's Red Line in Boston. The Red Line does not have mid-tunnel ventilation shafts and most of the tunnel geometry precludes the use of barriers similar to those tested in this study. The May 1991 low bid for Red Line shafts R13, R14 and R15 was $9,243,092. Adding 25 percent for engineering design and construction management results in a three shaft price of $11,553,865 or about $3,850,000 per shaft. Extrapolating this to 152 shafts provides an estimated cost of about $585,000,000.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 TRAIN FIRE HEAT RELEASE RATE

The analysis demonstrated that a train fire heat release rate of 69.7 MBtu/hr is appropriate for the currently-configured WMATA train which has polycarbonate windows. If the windows were changed to glass, then a reduction to 42.4 MBtu/hr is justified.

The following train fire heat release rates are recommended for design analysis:

- 69.7 MBtu/hr for trains having polycarbonate windows
- 42.4 MBtu/hr for trains having glass windows

A retrofit program is being proposed which would replace all the polycarbonate windows with safety glass. If it is decided to implement this proposal, the value of 42.4 MBtu/hr may be used. Otherwise, the more conservative value of 69.7 MBtu/hr should be used.

6.2 BARRIERS

The barrier deployment tests answered two fundamental questions about performance. The addition of the 180-degree air torus provided necessary stiffness to provide contact with the tunnel wall. The shrouds provided vertical alignment with airflow directed towards the shroud side of the barrier. Other design criteria - related to containment in the stored position, deployment time and geometry, release mechanism and storage latch reliability - were tested and found to be satisfactory. Some minor enhancements will be included in the production design.

The resistance to airflow caused by barriers is sufficient to redirect the tunnel airflows during emergencies, including fire, in the Metrorail. Figure 3-9, repeated here as Figure 6-1, provides the necessary data for the final design implementation SES analyses.

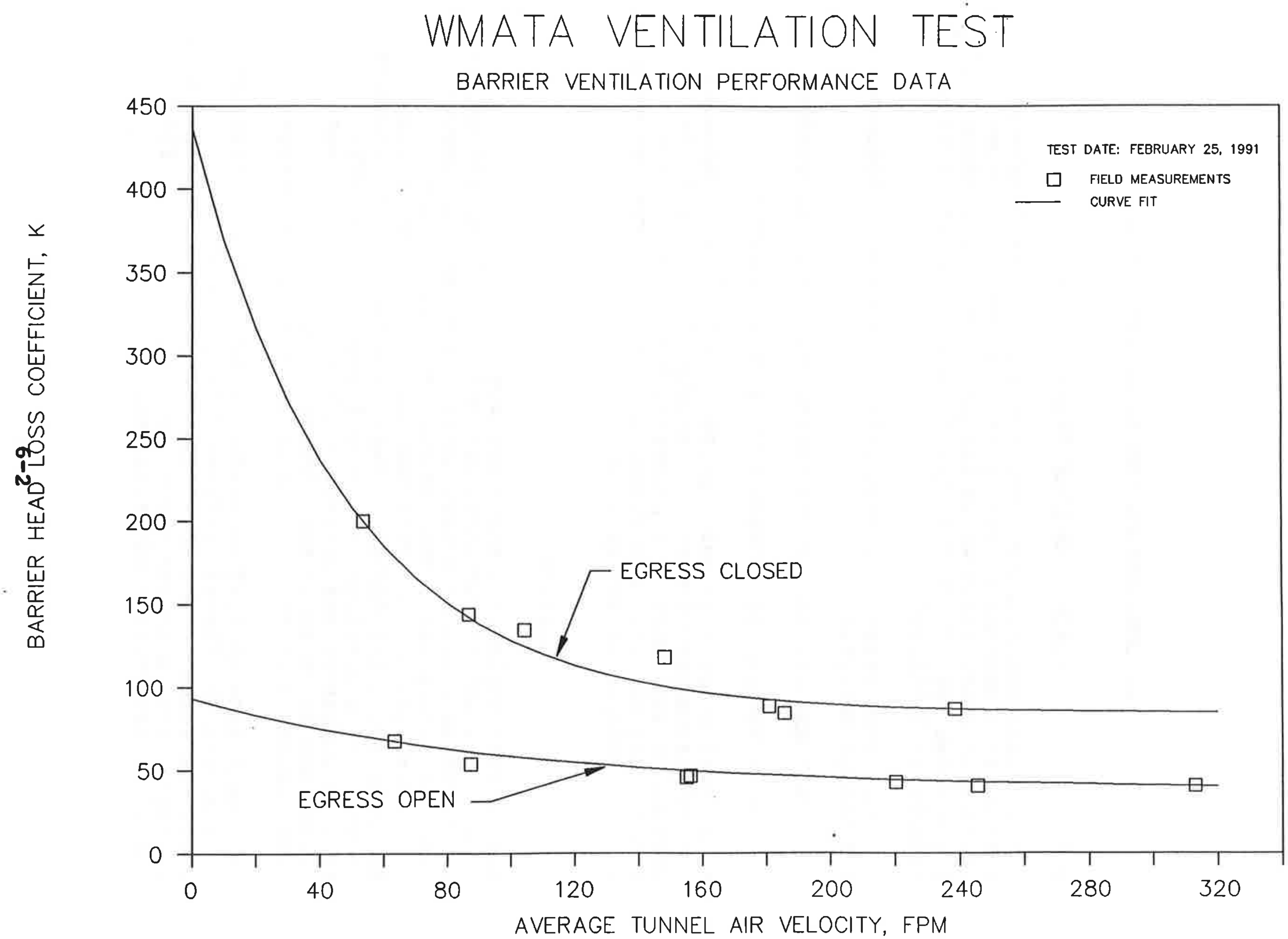
WMATA VENTILATION TEST
BARRIER VENTILATION PERFORMANCE DATA
TEST DATE: FEBRUARY 25, 1991
FIELD MEASUREMENTS
CURVE FIT
EGRESS CLOSED
EGRESS OPEN
BARRIER HEAD LOSS COEFFICIENT, K
AVERAGE TUNNEL AIR VELOCITY, FPM
0
50
100
150
200
250
300
350
400
450
0
40
80
120
160
200
240
280
320
6-2

FIGURE 6-1

Barriers are recommended as the preferred means of redirecting tunnel airflows during emergencies, including fire, in the Metrorail. The functional and ventilation tests support this recommendation.

6.3 JET FANS

The resistance to airflow caused by jet fans is sufficient to redirect the tunnel airflows during emergencies, including fire, in the Metrorail. Figures 3-21 and 3-31, repeated here as Figures 6-2 and 6-3, provide the necessary data for the final design implementation SES analyses.

Jet fans are recommended as an alternative means of redirecting tunnel airflows during emergencies, including fire, in the Metrorail. The ventilation tests support this recommendation.

It is further recommended that jet fans only be used in a portion of the system where the barrier cannot be installed because of space limitations. This recommendation is supported by the barriers being less expensive, not requiring power other than for control, and requiring fewer modifications to the central control system, etc.

6.4 EQUIPMENT RECOMMENDED TO UPGRADE THE METRORAIL TUNNEL VENTILATION SYSTEM

The estimate of the equipment was based on the following preferences:

- o Barriers are preferred over jet fans, except in portions of the system where barriers cannot be installed because of space limitations
- o Barriers are preferred over changing the current fan shaft capacities and/or reversibilities. A change in the fan shaft capacities and/or reversibilities is considered as the last alternative only when three or more barriers per tunnel adjacent to a fan shaft are required
- o The estimate was put together for two fire heat release rates - 69.7 MBtu/hr if the Metrorail trains were to remain as they currently are and 42.4 MBtu/hr if the

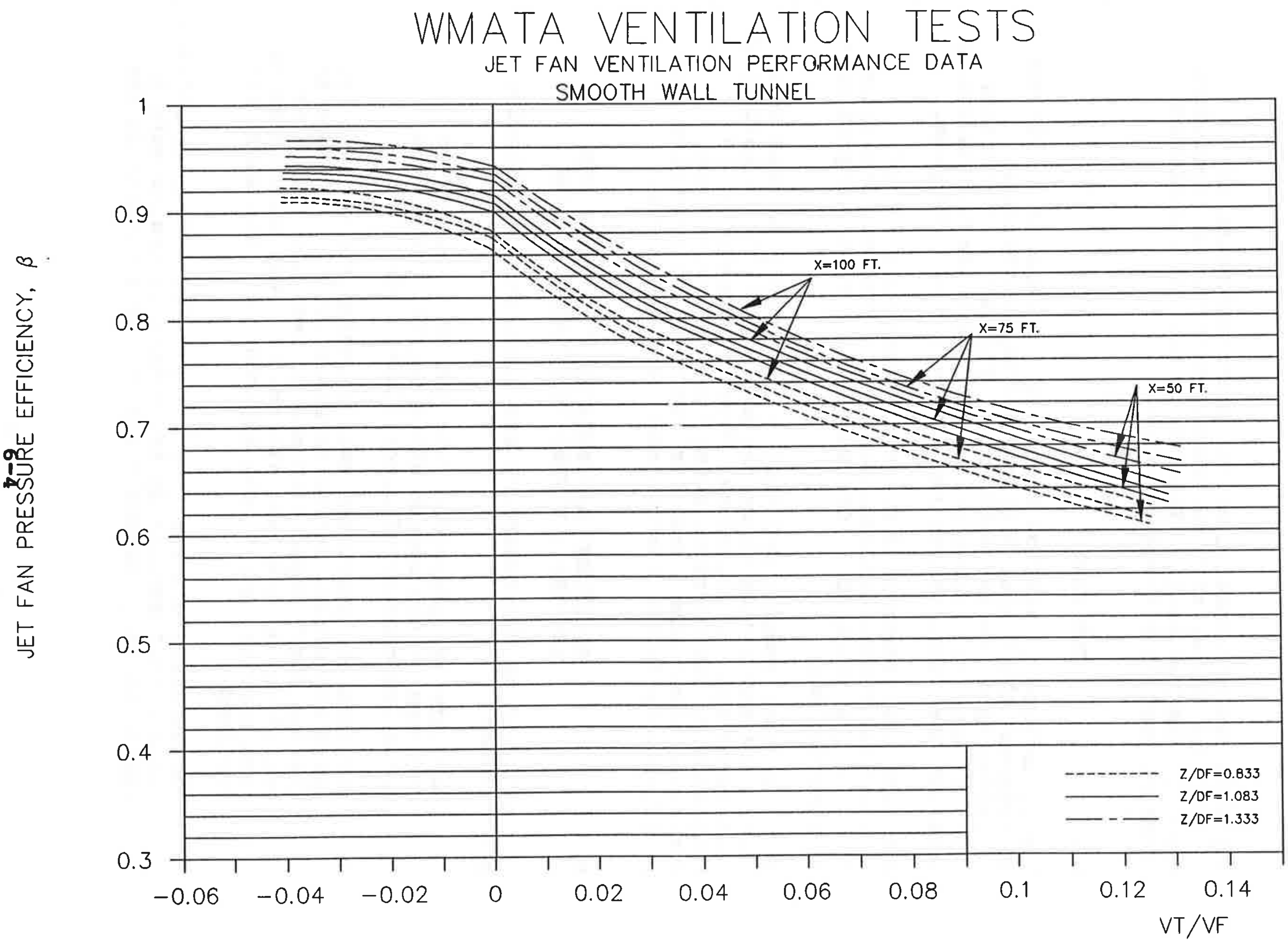
WMATA VENTILATION TESTS
JET FAN VENTILATION PERFORMANCE DATA
SMOOTH WALL TUNNEL
JET FAN PRESSURE EFFICIENCY, β
X=100 FT.
X=75 FT.
X=50 FT.
Z/DF=0.833
Z/DF=1.083
Z/DF=1.333
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
VT/VF

FIGURE 6−2

6-4

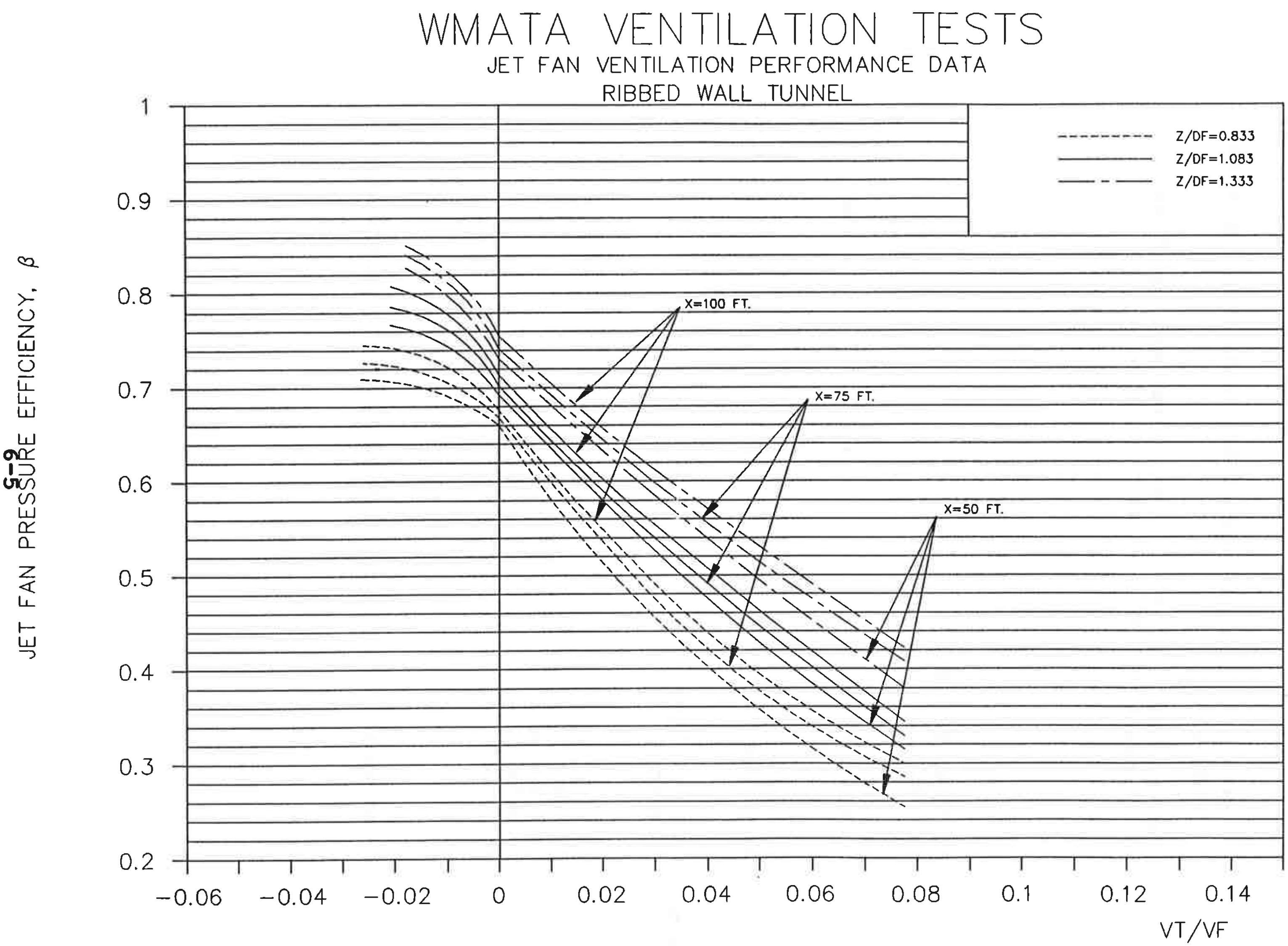
WMATA VENTILATION TESTS
JET FAN VENTILATION PERFORMANCE DATA
RIBBED WALL TUNNEL
Z/DF=0.833
Z/DF=1.083
Z/DF=1.333
X=100 FT.
X=75 FT.
X=50 FT.
JET FAN PRESSURE EFFICIENCY, β
VT/VF
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14

FIGURE 6−3

Metrorail trains were to be retrofitted to glass windows.

Based on these parameters, the final equipment count and cost is presented in a summary form below.

Fire Heat Release Rate (MBtu/hr):	42.4	69.7
Barriers: Required	172	248
20-in Jet Fans: Required	505	565
48-in Jet Fans: Required	6	6
Fan Shafts changed to 90 Percent Reversibility: Required	0	9
Estimated Cost	$15,800,000	$18,900,000

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APPENDIX A

DESCRIPTION OF

SUBWAY ENVIRONMENT SIMULATION

(SES)

COMPUTER PROGRAM

SUBWAY ENVIRONMENT SIMULATION COMPUTER PROGRAM

DESCRIPTION AND APPLICATION

1.0 INTRODUCTION

1.1 Background

The Subway Environment Simulation (SES) Computer Program is a designer-oriented tool which provides estimates of airflows, temperatures, and humidity, as well as air conditioning requirements, for both operating and proposed multiple-track subway systems.

The capabilities of the SES program are comprehensive, permitting the user to simulate a variety of train propulsion and braking systems; various systems of environmental control (including forced air ventilation, station air conditioning, and trackway exhaust); airflows in any given network of interconnected tunnels, stations and underground walkways; any desired sequence of train operation (including the mixing of trains with different operating characteristics and schedules); various steady-state and non-steady-state heat sources; emergency situations with trains stopped in tunnels and air movement solely by mechanical ventilation and buoyant forces; and a special feature to simulate the long-range thermal impact of the possible reduction in the heat-absorbing capacity of tunnel walls after many years of system operation.

The SES program was developed by Parsons Brinckerhoff under the aegis of the Transportation Systems Center of the United States Department of Transportation. The SES was field validated in Montreal and Toronto and has been applied to transit systems in Atlanta, Baltimore, Boston, Buffalo, Caracas, Chicago, Dallas, Hong Kong, Los Angeles, Minneapolis, Montreal, New Jersey, New York City, Philadelphia, Pittsburgh, San Francisco, Shanghai, Singapore, Taipei, and Washington, as well as to two rail systems in British Columbia and Amtrak's New York tunnels. Its tropical climate applications include Hong Kong and Singapore.

1.2 Design Applications

As indicated above, the SES program has been validated in model tests and in actual practice. It is applicable to a variety of subway operating and design configurations and has been demonstrated to be a cost-effective tool for evaluating the performance of all types of environmental control strategies. Examples of situations in which the program can provide important design information include the following engineering questions:

- What is the most effective size, configuration, spacing and location for ventilation shafts and/or fan shafts in the system in terms of overall system environmental conditions (temperatures, humidities, air velocities and the movement of smoke and gases during a fire emergency) and power requirements for environmental control?

- What are the impacts of various operating schedules, vehicle headways, vehicle velocities, and train sizes on system temperatures and vehicle power demand?

- What is the impact of vehicle air conditioning on overall heat rejection in the system and on the temperatures and humidities in stations and tunnels?

- What are the comparative impacts of various vehicle propulsion and braking systems on overall system temperature?

- What is the effect of track vertical alignment on system temperatures and power consumption? What are the long-term trade-offs between lowering track sections between stations and the costs of power for propulsion and environmental control?

- What are the energy consumption implications of vehicle air conditioning alone versus air conditioning the entire system?

- What are the long-term and short-term effects of heat-sink?

- What effect does evaporation from wetted walls have on the overall system temperatures and humidities?

- What are the effects of operating fans for mechanical ventilation simultaneously with scheduled train operation?

- What are the acceleration profiles of vehicles at various parts of the system? How much time is required for a vehicle to traverse the length of the system? What headways between vehicles are required to accommodate a given level of rider demand?

- What is the effect of emergency control procedures on subway environment? (For example, what are the purge times for smoke in the system?)

- What effect does the heat release from an emergency fire in the system have on the overall environmental conditions?

- What are the dynamic temperature and air flow conditions that prevail during a fire emergency?

- o What ventilation system capacity is adequate to control the spread of smoke and heat during a fire emergency?

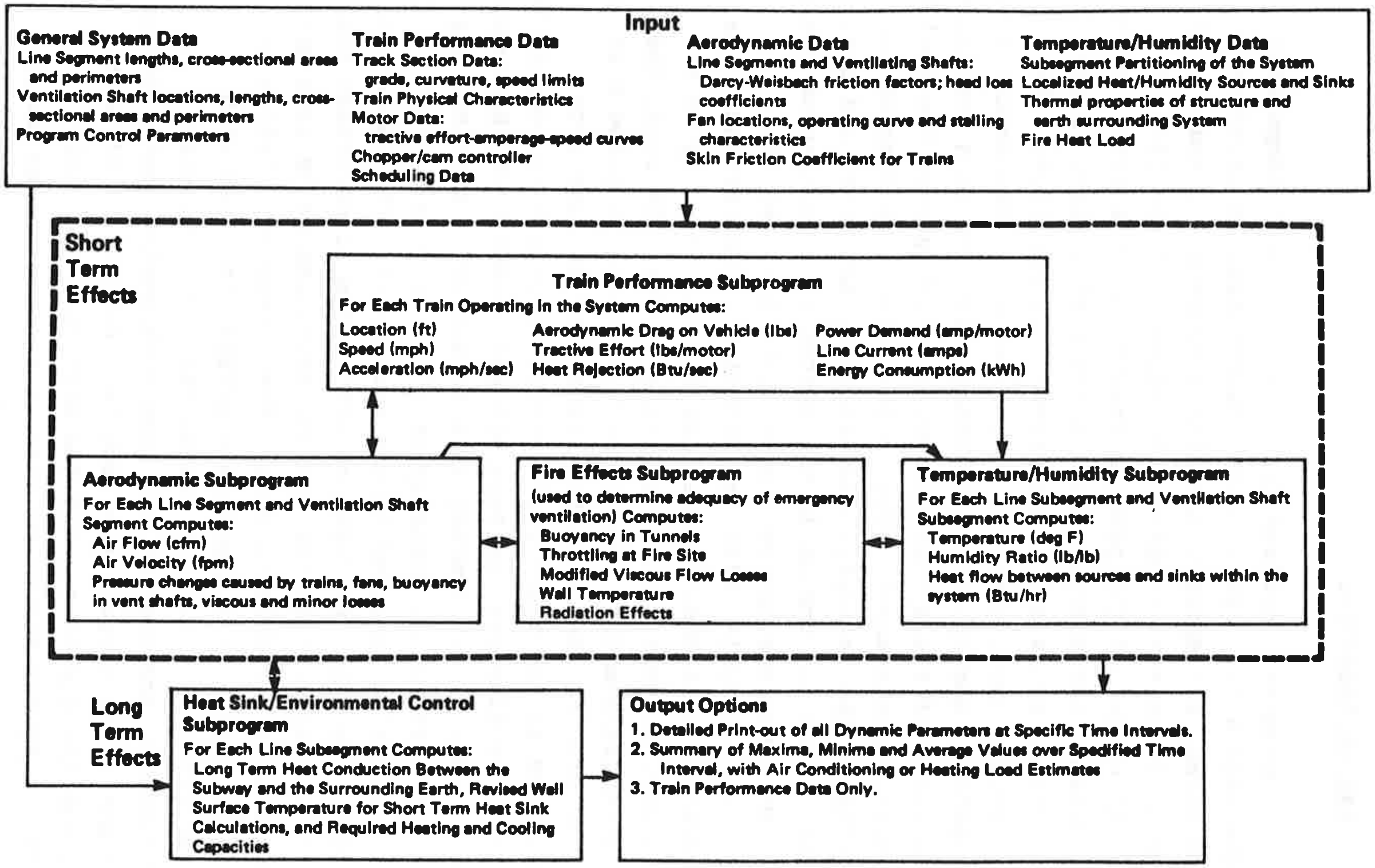
The above noted examples of program applications are by no means exhaustive. Indeed, the program is capable of estimating the environmental effects and implications of varying any or virtually all of the design parameters of a multi-track subway system.

2.0 SES DESCRIPTION

The SES computer model provides a dynamic simulation of the operation of multiple bi-directional trains in a multi-track subway and permits continuous reading of the air velocity, temperature, and humidity throughout any arrangement of stations, tunnels, ventilation shafts, and fan shafts. In addition, the program has been designed to provide readings of the maximum, minimum, and average values for system air velocities, temperatures, and humidities during any preset time interval. The program computes estimates of the station cooling and heating capacities necessary to satisfy any given environmental criteria, as well as the percentage of time during which any specified environmental criteria are exceeded. Although a simulation can extend over any period of subway operations, the primary focus of the SES is on short-term simulations, such as the peak rush hours, when there is often an extreme deterioration of the subway environment. Both the input/information required by the program and the output produced are tailored for the use of design engineers concerned with practical environmental problems.

2.1 Computation Sequences

The SES program comprises four interdependent computation sequences: a train performance subprogram, an aerodynamic subprogram, a temperature/humidity subprogram, and a heat sink/environmental control subprogram. In addition, a special option of the program enables the simulation of the aerodynamic and thermodynamic effects of a fire. Figure 1 provides an overview of the program organization. These subprograms use a mutually shared set of system descriptive parameters, and operating together they provide a continuous simulation of the dynamic phenomena which govern the quality of subway environment. The train performance subprogram determines the velocity, acceleration, position, and heat rejection of all trains in the system on a continuous basis. The aerodynamic subprogram uses these computed train parameters, coupled with the ventilation performance data, to compute continuous values for the air velocity in all stations, tunnels, and ventilation shafts. In turn, the temperature/humidity subprogram uses these computed airflow parameters together with the train heat release data generated in the train performance subprogram to compute the convective dispersal of sensible and latent heat throughout the system. It is thereby able to determine continuously the temperature and humidity at all locations. Finally, the air velocities computed in the aerodynamic subprogram are used by the train performance subprogram to determine the airflows adjacent to the trains, providing means to compute the vehicle aerodynamic drag. The subway ventilation and heat load data from these subprograms, together with information on daily and annual changes in outside conditions, are used by the heat sink/environmental control subprogram to compute the long-term conduction of heat between the subway air and the structure and soil surrounding the subway as well as the heating or cooling capacities required to satisfy design conditions in



PARAMETERS AND ORGANIZATION OF SUBWAY ENVIRONMENT SIMULATION (SES) COMPUTER PROGRAM specified areas of the subway. This integrated calculation procedure makes possible continuous simulation of the complex interactions among the dynamic phenomena operative in a subway system. In the following sections, the theoretical basis for each of the subprogram models is outlined and the fundamental logic for each of the four subprograms is described.

2.1.1 Train Performance Subprogram

The operation of trains provides a forcing function for the air movement in an underground transit system, and the heat dissipation from transit vehicles may account for as much as 90 percent of the heat released to the system. Consequently, a knowledge of the location, speed and acceleration of the trains within the subway system is essential to determine the rate and location of subway heat release as well as the system airflow regime.

The SES train performance subprogram provides the engineer with several options for simulating the operation of trains within a subway of which the most comprehensive is the implicit train performance. This option provides the engineer with a complete simulation of all aspects of train operation in the system. This option represents both the highest level of sophistication in the SES train performance computations and the greatest flexibility in evaluating trade-offs between train operations (headway, speed, etc.) and subway environment. The SES implicit train performance option differs from most conventional train performance computations in two important respects: (1) the SES subprogram has been designed specifically to accommodate accurate, continuous computation of the total heat released by trains, passengers and ancillary equipment such as air conditioning, and (2) the SES program permits the direct computation of the aerodynamic drag acting on each of the trains in the system, using continuously computed aerodynamic parameters. Conventional train performance programs are not ordinarily concerned with the continuous evaluation of vehicle heat release, and in evaluating vehicle aerodynamic drag these programs ordinarily settle for a semi-empirical relationship based on train velocity and blockage ratio (the ratio of the train frontal area to that of the tunnel cross section). The actual aerodynamic drag on a train fluctuates continuously as it encounters variable annular airflows resulting from changes in tunnel diameter, ventilation shaft location, mechanical ventilation, and the pressure caused by other trains.

The basic logic governing the computation of train acceleration capability requires computation of the train resistance, the available tractive effort, and the acceleration resistance. The train resistance is defined as the arithmetic sum of all the external forces which must be overcome in order to start, accelerate, and maintain the operating speed of a subway vehicle and consists of mechanical resistance, grade resistance, curve resistance, and air resistance. Train mechanical resistance is a summation of the journal friction (a function of train weight) and rolling friction (a function of speed and weight). Grade resistance (which may be either positive or negative) is determined from the slope of the track using an expression which includes the grade angle with the horizontal. Curve resistance is an additional friction term which represents the increased effort required to negotiate turns resulting from the increase in friction between the wheel flanges and the rails, and this term is computed as a function of track radius of curvature. The air resistance or aerodynamic drag is a function of the air velocity in the tunnel relative to the train, the train blockage ratio, tunnel wall friction, and the configuration of the cars. The available tractive effort for a given transit vehicle and the resulting acceleration and maximum velocity capability depends almost entirely upon the performance characteristics of the motor employed. Manufacturers of motors for rapid transit vehicles ordinarily provide standardized motor characteristic curves in which the tractive effort and speed are related to motor current for various values of motor field strength. Using data from these curves, the SES computes the precise tractive effort capabilities of vehicles powered by these motors as they travel through the system. The acceleration resistance is a combination of the forces required to accelerate the mass of the train and its equivalent mass of rotating parts, including wheels, axles, gears, and motor armatures. The implicit SES train performance option continuously computes values for the train resistance, the tractive effort, and the acceleration resistance of each vehicle in the system and from this determines the rate at which each train can accelerate, assuming no slippage at the wheel/rail interface.

The most important train-related heat release to the system can be traced to the vehicle braking cycle. For a train using a dynamic braking system, the speed reduction of the vehicles is brought about by using the motors as generators to produce electrical power which may be regenerated back into the traction power supply system, used to create stored energy (flywheels) or dissipated to a grid of undercar resistors. The rate at which energy is dissipated to these dynamic-braking resistor grids is approximately equal to the net rate of decrease in kinetic and potential energy of the braking train, corrected for the proportion that can be regenerated or absorbed by flywheels. This energy loss can be computed directly from the vehicle deceleration rate, velocity, total mass and the regeneration effectiveness or the flywheel characteristics. The implicit SES train performance option computes the instantaneous power dissipation to the braking resistors and the manner in which the resistors warm up and subsequently transfer the heat to the subway air. This computation directly accounts for the thermal inertia of the braking resistors, relating the heat storage and heat release to the surrounding air to the resistor thermal properties, weight and configuration, air turbulence and velocity, and resistor temperature.

In operation, the implicit train performance option first checks to see whether or not trains should be added or removed from the system (according to the train operating schedule specified by the user), after which it computes the individual train resistance for each train. The program then determines whether the train should accelerate, coast, decelerate, or maintain speed, using a brief computation which extrapolates the current operating mode of each train to determine if continuation of the train's current course will cause it to overrun a speed restriction or approach a stop too rapidly. If continued acceleration is indicated, the program computes the velocity-dependent tractive effort capabilities of the train and then calculates the acceleration which will occur over the preselected computation time interval.

Should a reduction in train speed be found necessary, the program computes a deceleration rate based on the user-specified braking rate. Finally, if the speed of the train exactly matches a system speed restriction, no acceleration occurs and the train uses only the power necessary to maintain this speed. When the train is on a downhill grade, the speed restriction is maintained by braking when necessary. The program next computes the heat energy being dissipated by the individual motors of each vehicle. For the case of a cam-controlled train, this consists of the motor current squared times the sum of the internal motor resistance and the external acceleration grid resistance.

For the case of a thyristor-controlled train this consists of the motor current squared times the internal resistance, plus the line current squared times the thyristor inefficiencies. The program provides a summation of traction and auxiliary energy requirements on a substation basis, which can be used for the preliminary design of the traction power supply system.

During the braking mode, energy is dissipated from both the change in train kinetic energy and the change in train potential energy (due to elevation). If regeneration or flywheels is being simulated, the energy dissipation is reduced accordingly. During station stops the SES continues the computation of heat release to the system from the passengers, equipment, and the warmed resistor grids. The program also computes the change in passenger loading at each station stop, thereby accounting for changes in total train weight and the corresponding effects in acceleration and braking energy dissipation, as well as changes in vehicle energy consumption and heat release from on board auxiliaries and passengers.

The computed values for the position, speed, and acceleration of all trains in the system as well as their individual rates of heat rejection are necessary for the operation of the aerodynamic and temperature/humidity subprograms. However, the train performance subprogram can also be operated independently to evaluate the comparative performance of transit vehicles, or propulsion motors, or both, by suppression of the computation and printing of environmentally related information. The airflows and air velocities of the aerodynamic subprogram would still be computed, of course, as these data would be necessary to compute aerodynamic drag for the train performance subprogram.

2.1.2 Aerodynamic Subprogram

The airflow through a subway system affects the comfort of subway patrons both directly and indirectly. Air movement is directly responsible for the convective transfer of heat and humidity through the system, and the cooling effects of moving air can directly influence the comfort of persons in non air-conditioned vehicles and in station areas. Furthermore, the buildup of excessive air pressures in stations from train piston effect has been known to constitute a separate operating problem, sometimes causing doors at entranceways to swing hazardously or become difficult to open. Airflow indirectly influences the heat content of subway air in two respects: (1) the aerodynamic drag on vehicles resulting from air motion relative to the trains affects the power consumption (and heat rejection) of the vehicle motors, and (2) the rate of heat transfer into the surrounding deep-heat sink is dependent upon the air velocity at the air-wall interface.

Airflow in a subway is generated by two primary sources: the piston effect of trains moving through confined tunnels and mechanical ventilation by fans. The mathematical model which has been developed to describe this flow for a subway assumes the flow to be unsteady, turbulent, incompressible, and effectively one-dimensional. The unsteady nature of airflow in subways precludes the use of approximate analyses based on the assumption of steady-state flow, because the air velocities generated by trains with arbitrary operating schedules moving through tunnels of varying shape and size must fluctuate continuously. Steady-state flows may only develop in the absence of train movements.

The present model includes consideration both of near-field phenomena (flow in the immediate vicinity of the train) and far field effects (flow at a distance far enough from the train that no transverse perturbations are present other than those ordinarily associated with normal turbulent inertial flow). Far-field flow is mathematically similar to typical inertia flows, whereas near-field flow must be described using formulations which include the aerodynamic drag acting on trains and the localized pressure rise which accompanies fan operation. As noted earlier, the computation of aerodynamic drag is an essential component of the subway simulation, because this factor determines both the air resistance that trains must overcome in order to accelerate and the amount of energy that is imparted by the moving trains to the surrounding air. In general, the drag experienced by a train in a single-track tunnel increases with train speed and decreases with frequency of train operation (shorter headway).

Using information describing the position, acceleration, and velocity of trains provided by the train performance subprogram, the location of each of the trains with respect to the subway is determined. The train operation information is then used to compute the net forcing function on the system airflows - the difference between energy added to the flow from train drag and fans and that removed due to the friction and minor losses. In this computation, the piston effect of each train is independently computed by evaluating the piston effect components on the system from the front, side, and rear of the train. The aerodynamic differential equations are then integrated forward in time using a modified version of the Runge-Kutta numerical integration technique. The standard output for the aerodynamic subprogram provides continuous readings for the aerodynamic drag on each train and for the air velocity (in feet per minute) and flow rates (in cubic feet per minute) in all tunnels, stations and ventilation shafts. Using the summary option, the subprogram can also provide output in the form of peak and average values of air velocity and total reading for airflow over any specified time interval.

2.1.3 Temperature/Humidity Subprogram

The temperature and humidity of the air throughout a subway system reflect the heat added or removed by underground equipment, trains, and patrons, as well as by the rate of heat exchange across the system walls and by mixing with external ambient air. An analytical treatment of this dynamic heat regime must provide a means to describe these phenomena mathematically in an operating system. The acceleration and braking of trains produces the main source of sensible heat in an operating subway system, but sensible and latent heat are also added by electrical equipment, patrons, and in certain instances, the surrounding earth. Heat is removed from the system mainly by the expulsion of warm system air through ventilation shafts and by heat conduction across the tunnel walls into the surrounding heat sink. Heat may also be added or removed by mechanical means such as heating and air conditioning.

In developing an analytical description of the heat regime, it was concluded that the system could be treated as one-dimensional, meaning that the air temperature and humidity can be considered uniform over any cross section. Axial conduction heat transfer in the system air was assumed to be negligibly small in comparison with the heat convected by moving air. The heat contributed by viscous dissipation resulting from air friction against the system walls, while usually small, can optionally be considered as a variable heat source.

Three fundamental processes can occur to alter the temperature and humidity in each of the subsegments: (1) sensible and latent heat can be directly added or removed by sources and sinks within the subsegment; (2) heat can be exchanged across the tunnel walls; and (3) there can be a net difference in the heat content between air flowing into the subsegment and air flowing out. An equation for the rate of change in temperature and humidity of each subsegment is therefore a combination of the analytical expressions for these three processes. The quantity of air flowing into each subsegment at any given time is computed by the aerodynamic subprogram and this airflow is used by the temperature/humidity subprogram together with values for subsegment temperature and humidity to compute the net difference between heat content of the air entering and leaving the subsegment. Rejection of heat from moving trains, computed simultaneously in the train performance program, is proportioned over the subsegments containing trains. Next the temperature/humidity subprogram sums the quantities of sensible and latent heat removed or added in each subsegment by patrons, auxiliary equipment, and station heating or air conditioning. Latent heat can be removed from or added to the system by condensation on, or evaporation from, system walls. In the case of simple condensation or evaporation, an equivalent amount of sensible heat is added to or removed from the system by the program. The heat transfer across the walls of the system is computed using the wall temperature and convective heat transfer coefficient which is a function of the subsegment air velocity, density, viscosity, thermal conductivity, and tunnel diameter. The value for subsegment wall temperature is computed in a separate operation using an analytical technique based on the diurnal and annual variation in outside ambient temperature, the deep heat sink temperature, and the degree of subway utilization. This analytical approach provides the wall surface temperature as a function of the time of the day and the time of the year. The heat transfer across the system walls has been found to have significant effect on the air temperature throughout the system.

The train locations, which were computed by the train performance subprogram, are used to determine the specific subsegments which contain some portion of each train. Each subsegment is then analyzed in detail, computing the rate of heat transfer to the tunnel walls, and, if trains are present, the amount of sensible or latent heat released into the subsegment by the trains. The airflows computed in the aerodynamic subprogram are used to determine those in each of the tunnel, station, and ventilation shaft subsegments. The values for heat flow across each subsegment boundary, for the sources and sinks of heat in each subsegment, and for the velocity-dependent coefficient of heat transfer across the system walls form a separate differential equation describing the rate of change of sensible and latent heat in each subsegment. These differential equations for the rate of change in air sensible and latent heat content are developed for each subsegment in the system, thus forming a system of equations which is integrated using a modified Runge-Kutta numerical integration technique resembling that used for the aerodynamic equations. This provides the time-dependent values for temperature and humidity throughout the stations, tunnels, and ventilation shafts of the system.

2.1.4 Heat Sink/Environmental Control Subprogram

There are three key independent factors which influence subway air temperature: system ventilation as determined by geometrical configuration, train operations and mechanical systems; system heat load, which relates directly to utilization of the subway; and outside ambient temperature. A fourth factor affecting subway air temperature is the heat transfer between the air and the surrounding structure and earth. In contrast with the first three factors, an interdependence exists between this heat transfer (commonly referred to as a "heat sink" effect) and the air temperature: the subway air temperatures directly influence the heat conduction history of the surrounding earth, since the rate of heat flux between the subway air and the walls is dependent on the convective heat transfer coefficient and the temperature difference between the air and the wall surfaces. One purpose of the heat sink/environmental control subprogram is the evaluation of this interdependent behavior.

During the relatively short-term simulation periods of the SES aerodynamic and temperature/humidity subprograms, the surface temperature of the subway structures is essentially constant. However, subway wall temperatures ordinarily experience daily and annual fluctuations because of variations in outside conditions and subway operating schedules. There may also occur a gradual increase in the average wall surface temperature over a period of years either as a result of prolonged internal temperatures above outside ambient conditions or because of increases in system utilization. Thus, to accomplish its purpose, the heat sink/environmental control subprogram must address not only the air-wall temperature interdependence, but also the conduction of heat in the earth as influenced by the daily, annual, and long-term variations in the subway air temperature. Whereas the short-term simulation evaluates subway airflows and temperature on a second-by-second basis, the heat/sink environmental control subprogram evaluates a phenomenon which is measured in terms of hours, days and years. Thus, this subprogram involves a shift in time scales and the link with the short-term simulation is accomplished through a process involving the averaging of short-term simulation results.

The heat sink computation scheme in this subprogram is geared to produce as output the wall surface temperature for each of the geometrical subsegments into which the subway tunnels and stations are partitioned, corresponding to the time of the day and year that the short-term simulation is intended. To perform this computation, the subprogram requires data on structure and earth thermal properties, earth temperature at a point far removed from the subway, and daily and annual variations in outside conditions. In addition, the subprogram requires detailed information on subway ventilation, heat loads, and areas of the system which are maintained at specified design temperatures with environmental control equipment. Thus, the use of the heat sink/environmental control subprogram requires that the aerodynamic and temperature/humidity subprograms first be applied in a short-term simulation. The SES is organized so that the required data transfer is accomplished internally in the program. The user can specify that the program execute a short-term simulation, transfer the required ventilation and heat load data to the heat sink/environmental control subprogram for the detailed wall surface temperature computations, and then transfer the calculated wall surface temperatures back to the short-term simulation portion of the program to continue the analysis.

The computation of the heating or cooling loads required to maintain design temperature and humidity conditions in specified areas of the system (such as stations) is an integral part of the heat sink/environmental control subprogram. The relationship between the heat sink and environmental control computation schemes is two-fold: first, many of the data requirements in terms of averaged short term SES computations of subway ventilation and heat loads are shared; and second, an interdependence exists because of the exchange of air between the controlled and uncontrolled areas of the system.

For user-specified areas within the subway where the temperature and humidity are to be maintained at design conditions, the environmental control computation scheme evaluates the heat which must be added or removed to achieve the desired conditions, on the average, during the design point operation addressed by the short-term simulation. This evaluation is performed for each of the geometrical subsegments into which the controlled area is partitioned, and includes calculations of sensible and latent heat gains from trains, sensible and latent heat gains from stationary sources (such as lighting, patrons, third rails, etc.), sensible heat transfer between the air and the structures (heat sink), and sensible and latent heat gains or losses attributable to the exchange of air between the subsegment and adjacent areas such as tunnels and stairways (convective load).

The interdependence with the heat sink computation for uncontrolled areas of the system is reflected by the evaluation of the convective load. The subprogram analyzes this interdependence by assuming that the airflow from controlled to uncontrolled areas of the system are at design temperature and humidity conditions. The heat sink computation scheme uses these airflow, temperature and humidity data in assessing the behavior of the heat sink in the uncontrolled areas of the system. In turn, the environmental control computation scheme is provided with a temperature for the air entering the controlled area from the uncontrolled area which reflects the estimated effects of the overall convective air and heat exchange process.

The SES organization is such that the computed heating or cooling load requirements can be transferred internally to the short-term simulation portion of the program to continue the analysis. By continuing the short-term simulation, the user can determine whether the computed loads satisfactorily achieve the desired design conditions in the controlled areas. A continuation of the simulation also provides data on the transient temperature and humidity excursions from the average design conditions caused by the unsteady nature of the airflows and heat loads throughout the subway.

2.2 Fire Model

The SES Program has the ability to model the effects of a subway fire. When the fire model is "turned on" as described below, the following aerodynamic and thermodynamic factors are considered by the program:

A fire in a tunnel has the effect of throttling the ventilating airflow. This effect is caused by the rapid expansion of the air flowing past the fire site. Also, as a consequence of the law of conservation of mass, the velocity of the hot gases downstream of the fire increases inversely proportional to the density (or equivalently, directly proportional to the absolute temperature of the gases), hence increasing the viscous pressure losses in this section of the tunnel. These pressure changes will reduce the tunnel airflow. The density differences between the hot gases and the ambient air give rise to pressure differentials which can either augment or retard the tunnel airflows, depending on the direction of ventilation (uphill or downhill). The elevated air temperatures produced by a fire cause the tunnel walls to heat up. This transient heating of the wall surface is an important factor in determining the conditions downwind of the fire. Allowing the wall surface temperature to respond properly improves the accuracy of the predicted air temperatures which are subsequently used to calculate the buoyant pressure differential.

The model treats the wall as a one-dimensional concrete slab of infinite thickness with uniform thermal properties and an arbitrary time-dependent heat flux at the wall surface. This approach is appropriate because (1) temperature changes resulting from heating at the wall surface will be confined to within a short distance of the wall surface, and (2) the wall surface temperature is of interest rather than the temperature at some depth below the surface.

The heat conduction equation is solved by using an approximate integral method. This method was chosen because it requires relatively little computation time and provides good accuracy (results range from three percent to nine percent of the theoretical value).

Heat is transferred to the wall by convection and radiation. Radiation will be the dominant mode of heat transfer at the fire site, while downwind of the fire, both modes will be nearly the same order of magnitude. At the site of the fire, heat is radiated uniformly from the interior of the burning vehicle through the windows and opened doors directly to the tunnel wall. The interior temperature of the vehicle is assumed to be at an "effective fire temperature". Both the effective fire temperature and the total area of the openings are input items. Downward of the fire site, the hot smoke is assumed to be radiating to the tunnel wall as a "black body" at a temperature equivalent to the "bulk" subsegment air temperature. Only radiation effects in the transverse direction from smoke to tunnel wall are considered.

The changes in air density associated with elevated temperatures degrade the performance characteristics (pressure vs. volume flow curve) of the exhaust fans. These effects have been accounted for in the model.

2.2.1 Application of Fire Model

The fire model is intended for use in a trial-and-error fashion to select the emergency ventilation system capacities. The interactions are between the tunnel air velocity (past the fire site) predicted by the SES Fire Model and a design air velocity criterion which precludes the backing of smoke against the ventilating air stream (back-layering). The air velocity criterion is a function of the fire heat release rate, the tunnel width, the average tunnel grade, and the temperature of the hot gases leaving the fire. A typical application of the fire model consists of the following steps:

1. Perform an SES simulation to predict the tunnel air velocity and the hot air temperature.

2. Determine the required air velocity using the methodology given in the users manual. (see Chapter 16)

3. If the predicted air velocity exceeds the required air velocity, the ventilation system is considered adequate.

4. If the predicted air velocity is less than the criterion, change the system and repeat the process.

Note that the SES is essentially a one-dimensional, incompressible, turbulent, slug-flow model. The throttling and buoyancy effects which are primarily caused by changes in density are conveniently accounted for by noting that changes in density are inversely proportional to changes in the absolute temperature of the gas (air), a quantity which is computed by the program. Therefore, the <u>effects</u> of density changes have been accounted for in the computations without actually converting computations in the program from an incompressible to a compressible flow model. As a result, the airflow quantities printed out by the program are "referenced" to the ambient air density. This notion of basing the computations on a reference air density has been used in mining ventilation computer programs and most recently in a program prepared at Michigan Tech for the U.S. Bureau of Mines.

The SES Fire Model has been designed with the ability to simulate the "overall" effects of a tunnel fire on the ventilation system. This level of detail is considered sufficient for evaluating the adequacy of an emergency ventilation system and is consistent with the state-of-the-art in mining ventilation programs with the capability of simulating fires. However, the model does have its limitations. As previously mentioned, the SES is a one-dimensional model. Therefore, the results of a fire simulation will indicate whether or not the ventilation air flows are sufficient to prevent back-layering, but not the extent of back-layering (a two-dimensional phenomena) if it is predicted to occur. In addition, the early stage of a fire, before the ventilation system is activated, generally cannot be simulated since this period is dominated by buoyant recirculating two-dimensional airflows.

APPENDIX B

DATA REDUCTION

B.1 MATHEMATICAL NOMENCLATURE

A = The area of the tunnel cross section in square feet (sqft)

A_a = The annulus tunnel cross sectional area in sqft

A_B = The area of the opening in the barrier in sqft

A_f = The jet fan discharge cross sectional area in sqft

a_i = The area of a sub-area of a cross section in sqft

C_d = Jet fan mounting head loss coefficient (for one unit)

ΔP = The static or total pressure change along the positive direction in inches of water gage

d = The hydraulic diameter of the cross section in feet (ft), $d = 4A/p$

F = Jet fan dynamic thrust in pound-force (lb_f)

f = The Darcy Weisbach friction factor

K = The barrier head loss coefficient

L = The length of the portion of the tunnel being studied in ft

$\ln$ = Natural logarithm

N = The number of jet fans

N_{Re} = The Reynolds Number of the airflow

n = The number of sub-areas in a cross section

P_a = The ambient pressure of air in inches of mercury

P_w = The partial pressure of water vapor in pound force per square inch (psi)

P_{ws} = The saturation pressure of water vapor over liquid water in psi

p = The perimeter of the tunnel in ft

Q = The airflow at a cross section in cubic feet per minute (cfm)

Q_a = The airflow at the annulus cross section in cfm

Q_f = The airflow discharged by a jet fan in cfm

Q_{fs} = The airflow through the fan shaft in cfm

Q_{tt} = The total airflow through the four tunnel legs in cfm

R = The gas constant for dry air, 53.352 ft-lbf/lbm-^oR

T = The dry bulb temperature in degrees Celsius

T_a = The dry bulb temperature in degrees Rankine

V = The average air velocity at a cross section using a single point measurement in feet per minute (fpm)

V_a = The average annular air velocity in fpm

V_f = The average air velocity of the jet fan discharge in fpm

V_ι = The air velocity measured for sub-area ι in fpm

V_m = The air velocity at a single point of measurement, measured at a point of convenience near the center of the cross section, in fpm

V_t = The average air velocity at a cross section using a traverse rig in fpm

W = The humidity ratio of moist air in mass of water per pound mass of dry air

α = The tunnel single point measurement factor

β = The overall jet fan pressure efficiency

γ = The air weight density in pound mass per cubic foot

δ = The fan shaft single point measurement factor in sqft

ϵ = The surface roughness of the cross section wall in ft

$\bar{\epsilon}$ = The relative roughness of the tunnel wall, ϵ/d

λ = Conversion factor to convert lb_f/sqft to inches of water gage (in. wg), 5.2 (lb_f/sqft)/in. wg.

μ = The absolute viscosity of air in pound force-second per square foot ((lb_f-sec)/sqft)

ρ = The air mass density in slugs per cubic foot

v = The specific volume of moist air in cubic feet per pound mass of dry air

Φ = The relative humidity of the air expressed as a percentage

B.2 AIR DENSITY

The air density can be calculated using the following procedure [3]:

Calculate the saturation pressure over liquid water for the temperature range of 32°F to 392°F with the following equations:

$$Ta = 1.8T+32+459.67 \quad \text{Eq.1}$$

$$\ln (P_{ws}) = C_1(Ta)^{-1}+C_2+C_3(Ta)+C_4(Ta)^2 +C_5(Ta)^3+C_6[\ln(Ta)] \quad \text{Eq.2}$$

where:

C_1 = -1.044039708E+04

C_2 = -1.12946496E+01

C_3 = -2.7022355E-02

C_4 = 1.2890360E-05

C_5 = -2.478068E-09

C_6 = 6.5459673

Calculate the partial pressure of water vapor with the equation:

$$P_w = \frac{\Phi P_{ws}}{100} \quad \text{Eq.3}$$

Calculate the humidity ratio with the equation:

$$W = \frac{0.62198P_w}{0.4912P_a-P_w} \quad \text{Eq.4}$$

Calculate the specific volume with the equation:

$$v = \frac{RT_a(1-1.607W)}{70.7328P_a} \qquad \text{Eq.5}$$

Calculate the air density with the equation:

$$\gamma = \frac{1+W}{v} \qquad \text{Eq.6}$$

Recalling that 1 slug = 32.174 lb_m, then

$$\rho = \gamma/32.174 \quad (slug/ft^3) \qquad \text{Eq.7}$$

Example:

For illustration purposes assume the following:

T = ambient dry bulb temperature = 26.666°C

Φ = relative humidity = 50%

P_a = ambient pressure = 29.92671 inches of mercury (1 atmosphere)

T_a = 539.669(°R)

R = 53.352 Ft-lb_f/(lb_m-°R)

Then:

$\ln(P_{ws}) = C_1/T_a+C_2+C_3*T_a+C_4*Ta^2+C_5*Ta^3+C_6*\ln(T_a)$

$\ln(P_{ws}) = -6.78546E-01$

$P_{ws} = e^{(-6.78546E-01)} = 5.073541E-01$

$$P_w = \frac{\Phi P_{ws}}{100} = 2.53677E-01$$

$$W = \frac{0.62198P_w}{0.4912P_a-P_w} = 1.092195E-02$$

$$v = \frac{RT_a(1-1.607W)}{70.7328P_a} = 1.336315E+01 \; (ft^3/lb_m)$$

$$\gamma = \frac{1+W}{v} = 7.564996E-02 \; (lb_m/ft^3)$$

$$\rho = \frac{7.546996E-2}{32.174} = 2.351276E-03 \text{ (slug/ft}^3\text{)}$$

B.3 ABSOLUTE VISCOSITY

The absolute viscosity of air is assumed to be a function of the ambient temperature of the air only. Linearly inter-polate the following table to solve for absolute viscosity [4]:

Dry Bulb Temperature (^oF)	Absolute Viscosity (lb_f - sec/ft^2)x10^7
0	3.45
5	3.50
10	3.55
15	3.60
20	3.65
25	3.68
30	3.70
35	3.75
40	3.80
45	3.83
50	3.85
55	3.88
60	3.90
65	3.95
70	3.98
75	4.00
80	4.01
85	4.02
90	4.03
95	4.05
100	4.08
105	4.10
110	4.13
115	4.18
120	4.20
125	4.23
130	4.25
135	4.28
140	4.32
145	4.35
150	4.37

B.4 TUNNEL SINGLE POINT MEASUREMENT FACTOR

The air velocity is not constant across the tunnel cross section. It varies with:

- The distance from the center of the cross section to the wall, being a maximum at the center and near-zero close to the wall.
- The average air velocity at the cross section.
- The additional turbulence caused by the close proximity of a train, ventilation shaft or portal upstream of the cross section.

This variation of the air velocity across the section is often called the velocity profile. The effect of a train, ventilation shaft or portal upstream can often persist for 200 feet. The single point measurement factor for the ventilation shaft is also influenced by its internal beams and struts. The effect of the average air velocity is such that the single point measurement factor varies from about 0.50 (slow, laminar flow) to about 0.98 (fast, fully developed, symmetrical turbulent flow).

Hence, the single point measurement factors must be determined for both directions of airflow for a wide range of air velocities, with and without a train or a ventilation shaft upstream.

The single point measurement factor is defined to be:

$$\alpha = \frac{Q}{AV_m} \qquad \text{Eq.8}$$

where:

$$Q = \sum_{\iota=1}^{\iota=n} a_\iota V_\iota \qquad \text{Eq.9}$$

Therefore,

$$\alpha = \frac{\sum_{\iota=1}^{\iota=n} a_\iota V_\iota}{AV_m} \qquad \text{Eq.10}$$

B.5 FAN SHAFT SINGLE POINT MEASUREMENT FACTOR

The fan shaft single point measurement factor correlates a single point velocity measurement with the actual airflow through the shaft. This factor is computed by measuring the airflow at the tunnel legs where the subscripts 1,2,3, and 4 represent the tunnel legs, and 5 the fan shaft.

$$Q_{tt} = (A_1V_1+A_2V_2+A_3V_3+A_4V_4) \qquad \text{Eq.11}$$

and dividing this quantity by the single point velocity measurement in the shaft:

$$\delta = \frac{Q_{tt}}{V_{m5}} \qquad \text{Eq.12}$$

but, since the areas of the tunnel legs are the same:

$$\delta = \frac{A(V_1+V_2+V_3+V_4)}{V_{m5}} \qquad \text{Eq.13}$$

B.6 AVERAGE TUNNEL VELOCITY

Once the tunnel single point measurement factor is computed, the average tunnel velocity is calculated by multiplying the single point measurement factor, α, by a single point velocity measurement V_m. V_m must be measured at the same tunnel cross section location as that of the V_m when computing the single point measurement factor.

$$V = \alpha V_m \qquad \text{Eq.14}$$

B.7 FAN SHAFT AIRFLOW

The fan shaft airflow is calculated by multiplying the single point velocity measurement in the shaft by the fan shaft single point measurement factor

$$Q_{fs} = \delta V_{m5} \qquad \text{Eq.15}$$

B.8 AVERAGE TRAVERSE VELOCITY

When traversing a cross section, the cross section is divided into n sub-sections. Each subsection will have a fan anemometer close to its center point. The average traverse velocity is calculated as follows:

$$V_t = \frac{Q}{A} \qquad \text{Eq.16}$$

Where:

$$Q = \sum_{\iota=1}^{\iota=n} a_\iota V_\iota \qquad \text{Eq.17}$$

Therefore,

$$V_t = \frac{\sum_{i=1}^{i=n} a_i V_i}{A} \qquad \text{Eq.18}$$

B.9 REYNOLDS NUMBER

The Reynolds number is defined by the following equation:

$$N_{Re} = \frac{\rho V d}{60\mu} \qquad \text{Eq.19}$$

B.10 FRICTION FACTOR

The tunnel pressure change caused by wall friction is defined by the equation:

$$\Delta P = - \frac{\rho f L |V| V}{7200 \lambda d} \qquad \text{Eq.20}$$

Therefore,

$$f = - \frac{7200 \lambda d \, \Delta P}{\rho L |V| V} \qquad \text{Eq.21}$$

Extensive experiments have shown that the friction factor, f, is a function of the Reynolds number, N_{Re}, and the relative roughness, ϵ/d.

B.11 JET FAN MOUNTING HEAD LOSS COEFFICIENT

When performing the jet fan ventilation tests there will be some losses due to the blockage of the jet fan mounting devices in addition to the friction losses due to the tunnel wall. These losses lead to the following pressure change equation when the jet fans are not running:

$$\Delta P = -\frac{\rho f L|V_t|V_t}{7200\lambda d} - \frac{N\rho C_d|V_t|V_t}{7200\lambda} \qquad \text{Eq.22}$$

After doing some rearrangement of the variables and solving for C_d, Eq.22 becomes:

$$C_d = -\frac{7200\lambda\Delta P}{N\rho|V_t|V_t} - \frac{fL}{Nd} \qquad \text{Eq.23}$$

B.12 BARRIER HEAD LOSS COEFFICIENT

The general equation to calculate the pressure change along a duct due to minor losses is:

$$\Delta P = -\frac{K\rho|V|V}{7200\lambda} \qquad \text{Eq.24}$$

Idelchik [2] has shown experimentally that, for a rigid, thin barrier in a duct,

$$K = \{A(1+[(A-A_B)/(2A)]^{1/2} -1)/A_B\}^2 \qquad \text{Eq.25}$$

The direct application of this equation to the Washington Metro barriers is made difficult by the following:

- A_B cannot be precisely measured for a barrier
- A_B varies as a function of the airflow through the barrier.

The barrier tends to balloon out parachute-style. The opening through the center of the barrier may increase as the air-flow increases; on the other hand, the edges of the barrier may be pressed more tightly against the tunnel wall thus effectively reducing A_B. Unfortunately, experimental data of this nature does not exist for the types of barriers that are contemplated for the Washington Metro. Therefore, K must experimentally be determined so that it can be accurately input into the design process.

Since the pressure differential will be measured for 100-foot tunnel section, it is necessary to include the losses caused by the tunnel wall friction. This leads to the pressure change equation:

$$\Delta P = -\frac{K\rho|V|V}{7200\lambda} - \frac{\rho fL|V|V}{7200\lambda d} \qquad \text{Eq.26}$$

Solving for K:

$$K = -\frac{7200\lambda\Delta P}{\rho|V|V} - \frac{fL}{d} \qquad \text{Eq.27}$$

Equation 25 can be used to provide data for the discussion of barrier performance as follows:

A_B/A	K	A_B/A	K
0.60	8.23	0.78	40.76
0.65	12.15	0.79	45.63
0.66	13.18	0.80	51.30
0.67	14.32	0.81	57.95
0.68	15.58	0.82	65.82
0.69	16.97	0.83	75.20
0.70	18.53	0.84	86.50
0.71	20.28	0.85	100.26
0.72	22.22	0.86	117.22
0.73	24.42	0.87	138.43
0.74	26.89	0.88	165.41
0.75	29.70	0.89	200.37
0.76	32.89	0.90	246.75
0.77	36.55	0.95	1074.79

where A_B/A is the fraction the duct is blocked.

B.13 JET FAN PRESSURE EFFICIENCY

The thrust equation for a jet fan is derived from the linear momentum equation. Assuming a frictionless and incompressible fluid under steady-state conditions [5]:

$$F = \frac{\rho Q_f (V_f - V_t)}{3600} = \lambda A \Delta P \qquad \text{Eq.28}$$

or:

$$\Delta P = \frac{\rho Q_f (V_f - V_t)}{3600 \lambda A} \qquad \text{Eq.29}$$

But, since there are losses in the system, the pressure change is multiplied by a factor, β, to account for them. Hence, Eq.29, $\Delta P_{theoretical}$, becomes:

$$\Delta P = \frac{\beta \rho Q_f (V_f - V_t)}{3600 \lambda A} \qquad \text{Eq.30}$$

β is defined to be the overall jet fan pressure efficiency:

$$\beta = \frac{\Delta P_{actual}}{\Delta P_{theoretical}} \qquad \text{Eq.31}$$

There will be N jet fans in the tunnel, therefore:

$$\Delta P = \frac{\beta \rho}{3600 \lambda A} \sum_{\iota=1}^{\iota=N} Q_{f\iota} (V_{f\iota} - V_t) \qquad \text{Eq.32}$$

Eq.32 does not include the losses due to the tunnel friction and the jet fan mounting devices. Including these losses, Eq.32 becomes:

$$\Delta P)_{total} = \Delta P)_{jf} + \Delta P)_{cd} + \Delta P)_{f} \qquad \text{Eq.33}$$

or:

$$\Delta P = \frac{\beta\rho}{3600\lambda A} \sum_{\iota=1}^{\iota=N} Q_{f\iota}(V_{f\iota}-V_t) - \frac{\rho N C_d|V_a|V_a}{7200\lambda} - \frac{\rho f L|V_t|V_t}{7200\lambda d} \qquad \text{Eq.34}$$

where Va is derived as follows:

$$Q_{tt}=Q_a+Q_f \qquad \text{Eq.35}$$

$$Q_a=Q_{tt}-Q_f \qquad \text{Eq.36}$$

$$V_aA_a=Q_{tt}-Q_f \qquad \text{Eq.37}$$

$$A_a=A-A_f \qquad \text{Eq.38}$$

$$V_a=\frac{Q_{tt}-Q_f}{A-A_f} \qquad \text{Eq.39}$$

Solving Eq.34 for β gives:

$$\beta = \frac{\Delta P + \dfrac{\rho N C_d|V_a|V_a}{7200\lambda} + \dfrac{\rho f L|V_t|V_t}{7200\lambda d}}{\dfrac{\rho}{3600\lambda A} \displaystyle\sum_{\iota=1}^{\iota=N} Q_{f\iota}(V_{f\iota}-V_t)} \qquad \text{Eq.40}$$

β is composed of other βs due to the entrance effect of the tunnel, the distance between the wall and the jet fan center line, and the distance separating the jet fans. It is also influenced by the tunnel wall roughness.

B.14 COLEBROOK'S FRICTION FACTOR EQUATION

Once the friction factor tests are completed, the measured friction factors need to be curve fitted to a smooth curve as presented in the Moody Chart for duct flow. The Moody Chart is plotted using the Colebrook's friction factor equation, Eq.36.

$$\frac{1}{f^{1/2}} = -2.0 \log_{10} \left(\frac{\epsilon/d}{3.7} + \frac{2.51}{N_{Re}\ f^{1/2}} \right) \qquad \text{Eq.41}$$

This equation is valid for computing the friction factor for N_{Re} higher than 2000, or in other words, for turbulent flow.

B.15 LAMINAR FLOW FRICTION FACTOR

When the value of N_{Re} falls in between about 2000 and 4000 , the flow may be either turbulent or laminar. For this circumstance Colebrook's equation can be used to estimate the friction factor since the flow is either very unstable laminar flow or turbulent. However, when the value of N_{Re} becomes lower than 2000, the flow is said to be a laminar. Theory predicts for laminar flow the friction factor given by the equation

$$f = \frac{64}{N_{Re}} \qquad \text{Eq.42}$$

B.16 OTHER JET FAN PRESSURE EQUATIONS

There have been several engineers who have performed experiments with jet fans and who have derived expressions to estimate the jet fan pressure. Among them are Meidinger [11] and Reale [10] who have presented technical papers in longitudinal ventilation of vehicle tunnels. Their equations to estimate the jet fan pressure are as follows:

- Meidinger's equation,

$$\Delta P = \beta\rho \sum_{\iota=1}^{\iota=N} \frac{(V_{f\iota})^2}{2}\left(2\varphi(1-\Psi_\iota) + \frac{\varphi^2(1-2\varphi+2\varphi\Psi_\iota-\Psi_\iota^2)}{(1-\varphi)^2} \right) \qquad \text{Eq.43}$$

- Reale's equation,

$$\Delta P = \beta\rho \sum_{\iota=1}^{\iota=N} \frac{(V_{f\iota})^2}{2} \frac{2\varphi(1-\Psi_\iota)^2}{(1-\varphi)} \qquad \text{Eq.44}$$

Where for both of the above equations,

$$\Psi_\iota = \frac{V_t}{V_{f\iota}} \qquad \text{Eq.45}$$

$$\varphi = \frac{A_f}{A} \qquad \text{Eq.46}$$

B.17 TUNNEL SINGLE POINT MEASUREMENT FACTOR TEST DATA REDUCTION

- Compute the air density, ρ, as described in section B.2.

- Compute the tunnel single point measurement factor as described in section B.4.

B.18 **FAN SHAFT SINGLE POINT MEASUREMENT FACTOR DATA REDUCTION**

- Compute the air density, ρ, as described in section B.2.
- Compute the fan shaft single point measurement factor as described in section B.5.

B.19 **TUNNEL WALL FRICTION FACTOR TEST DATA REDUCTION**

- Compute the air density, ρ, as described in section B.2.
- Compute, by linearly interpolating, the absolute viscosity, μ, as described in section B.3.
- Compute the average tunnel velocity, V, as described in section B.6.
- Compute the Reynolds number, N_{Re}, as described in section B.9.
- Measure the pressure change along the tunnel section.
- Compute the friction factor as described in section B.10.

B.20 **JET FAN MOUNTING HEAD LOSS TEST DATA REDUCTION**

- Compute the air density, ρ, as described in section B.2.
- Compute the average tunnel velocity, V, as described in section B.6.
- Measure the pressure change along the tunnel section.
- Compute the head loss coefficient, C_d, as described in section B.11.

B.21 JET FAN TEST DATA REDUCTION

- Compute the air density, ρ, as described in section B.2.
- Compute the average tunnel air velocity, V, as described in section B.6.
- Measure the pressure change along the tunnel section.
- Compute the overall jet fan pressure efficiency, β, as described in section B.13.

B.22 CIRCULAR OR RECTANGULAR BARRIER TEST DATA REDUCTION

- Compute the air density, ρ, as described in section B.2.
- Compute the average tunnel air velocity, V, as described in section B.6.
- Measure the pressure change across the barrier.
- Compute the barrier head loss coefficient, K, as described in section B.12.

B.23 DOUBLE TRACK TEST DATA REDUCTION

- Traverse the air velocity across the tunnel and compute the average air velocity as described in section B.8.

APPENDIX C

INVESTIGATION OF A POST-FLASHOVER COMPUTER MODEL TO ESTIMATE THE HEAT RELEASE RATE FOR A WMATA SUBWAY VEHICLE

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EXECUTIVE SUMMARY

The control of fires in the transit industry is an area of great interest and concern. This report focuses on fires in subway cars. There have been two major approaches to limiting damage and controlling fires in subway cars. The first is by limiting the amount and nature of combustible materials used in subway car construction. The other is through the successful operation of the emergency ventilation system to provide a smoke-free passenger evacuation route in the tunnel and to assist fire-fighting activities. A key parameter in the design of such systems is the magnitude of a post-flashover subway car fire. Fire magnitude, in this case, would be measured in terms of peak heat release rate (Btu/hour) which, in turn, governs the subway emergency ventilation system design.

The computer model used in this study is a slightly modified version of the computer program COMPF2, developed by the Center for Fire Research, National Institute for Standards and Technology (formerly the National Bureau of Standards). COMPF2 is a fire model which predicts the conditions in a space during a fully involved fire scenario. A fully involved fire is a fire which has spread to all of the combustibles in a space; this is also known as a post-flashover fire. This period of fire growth is of great concern as it is during this post-flashover period when the fire poses the greatest threat beyond the compartment of origin. It is also during this regime when the fire presents the greatest challenge to the emergency ventilation system.

This study involved the use of COMPF2 to predict the peak heat release rate in a subway car fire involving one rail car. The physical characteristics of the Breda vehicle (ie., the basic dimensions of the car and the thermal properties of the walls and ceiling) were used for the program input. However, a complete version of the inventory of combustible materials was not available for the Breda car. Therefore, the combustible data of the Rohr vehicle was used.

A sensitivity analysis of the impact of key parameters on the heat release rate of the fire was performed. The key parameters which were studied were the size of the openings in the car, the average net heat of combustion of the combustibles and the percent of volatiles which were actually burned in the fire. The model was used so that, for a given set of input parameters, the value of the rate of burning of the combustibles was internally adjusted by the model to predict the highest possible temperatures in the car. This fire scenario was assumed to be reasonably conservative for design purposes.

Based on a combustible content of 59,247,000 Btu for the above-floor materials only, the following results were predicted by the COMPF2 program for an above-floor fire involving a single WMATA vehicle:

- o Assuming a 65 percent burning efficiency (percent of volatiles burned), a net heat of combustion of 9130 Btu/lb, and all windows are open, a peak heat release rate of 34.3 million Btu/hr and a fire duration of 63 minutes were predicted.

- o Assuming a BPF of 65 percent, a net heat of combustion of 7420 Btu/lb, and all windows are open, a peak heat release rate of 27.3 million Btu/hr and a fire duration of 78 minutes were predicted.

o Assuming a BPF of 80 percent, a net heat of combustion of 7420 Btu/lb, and all windows are open, a peak heat release rate of 33.7 million Btu/hr and a fire duration of 78 minutes were predicted.

Use of the heat release rate of 33.7 million Btu/hr is suggested to account for the predictive accuracy of the COMPF2 program even though 27.3 million Btu/hr is the most probable value. As indicated above, the suggested value is based on the heat content of the above-floor combustibles for a single WMATA vehicle. Therefore, this value needs to be adjusted to account for the heat content of the vehicle components located at floor level and below floor level, potential multiple car involvement, and a suitable factor of safety.

1.0 INTRODUCTION

1.1 General

The control of fires in the transit industry has been an important element of design since the beginning of transit systems. There have been two major approaches to the task. The first is to control fires by the use of less combustible materials combined with fire resistant construction. The second is to provide an emergency ventilation system. The emergency ventilation system is needed to control smoke, to provide a smoke-free evacuation route for subway passengers, and to assist the fire department in their suppression activities.

1.2 Pre-Flashover Fire Hazard

The control of fires in limiting combustible materials is a very difficult task. As new materials such as plastics and second generation composites are used in the design of subway cars, unexpected fire hazards may be introduced. These hazards can be predicted through the use of small scale tests to determine the material properties of the combustibles, combined with the use of sophisticated pre-flashover computer models such as FIRST (Mitler 1987) or the specialized model developed at WPI (Barnett 1989a) or the approach developed by Smith (1981) at Ohio State University.

An alternative approach is by the use of full-scale or reduced scale testing. Reduced scale testing may give misleading results due to the difficulty in modeling both radiation heat transfer and air flow rates concurrently. Full-scale testing is much more reliable, but can test only one configuration at a time. In addition, full-scale testing is extremely expensive, particularly if several configurations need to be analyzed. Despite this, full-scale tests have been extensively used in the past. Their use has been to evaluate the hazards of specific furnishing constructions and arrangements. Examples of this include the studies conducted by the National Institute of Standards and Technology (formerly the National Bureau of Standards), studies conducted for the Washington Metropolitan Area Transit Authority (WMATA) in the late 1970's (Custer 1989) and the studies conducted by Williamson (Williamson, Fisher and Zickerman 1979).

Finally, although the pre-flashover fire is of concern in terms of time available for egress and time to flashover, the fire is still in its incipient stage and poses only a minor threat to spaces beyond the compartment of origin. Of greater concern is the fire's post-flashover regime.

1.3 Post-Flashover Fire Hazard

As described in Section 2.1 of this report, the post-flashover regime is where the fire poses the greatest threat beyond the compartment of origin. It is during this regime when the subway emergency ventilation system will be required to operate at peak capacity.

Predicting the post-flashover fire hazard is often an easier task than predicting the pre-flashover fire hazard as the fire is usually ventilation-controlled during the post-flashover regime. As a result, it is possible to model the post-flashover fire based on the current state-of-the-art in computer-based fire modeling (Barnett 1989b). This is the approach that has been taken in this study. The computer model COMPF2 has been used to model a fire in a subway car.

2.0 BASIC UNDERSTANDING OF COMPARTMENT FIRES

2.1 Introduction To A Compartment Fire

A natural, or "real" compartment fire, such as that which may occur in a subway car, may be divided into two regimes; the pre-flashover period and the post-flashover period. During the pre-flashover period, the fire proceeds from ignition to localized burning of one "fuel package". Toxic gas production is usually sufficient to render the environment uninhabitable. If sufficient fuel and ventilation are present, the end of this period is marked by a sudden jump in temperature and a change from localized burning to the burning of all of the combustibles in the compartment. This usually sudden event is called flashover. After flashover, the fire progresses into a stage called sustained burning, followed by a decay period when the fire slowly dies out. If there is inadequate ventilation or not enough fuel, flashover will not occur. In this case the fire will continue to burn locally until the fuel is exhausted or the fire is extinguished by manual suppression activities.

2.1.1 Post-Flashover Fires

The major portion of the post-flashover stage of compartment fire growth is the stage of sustained burning. This is one of the most important stages in a compartment fire's growth, as it is during this stage when a structure is threatened by the fire and when the fire is most likely to spread beyond the compartment of origin. In the case of a subway car, it is during this time when the fire's impact on the tunnel ventilation system is at its peak. During this period, all combustibles in the compartment have ignited and are contributing to the fire. Typically, the fire's growth is limited by the oxygen available for combustion; the fire is ventilation-controlled. The buoyant plumes rising above each of the burning objects interact with each other resulting in very turbulent air flows throughout the compartment. The swirling and mixing of the hot combustion gases result in a relatively homogeneous mixture throughout the compartment, although there is some evidence that more combustion occurs near openings where a greater supply of oxygen exists than elsewhere in the room (Harmathy 1972). The post-flashover period of the fire growth continues until the fire starts to decay due to a decrease in fuel contributing to the fire. Normally, at least eighty percent of a compartment's fuel is consumed prior to the decay period. During the start of the decay period, the fire often changes from the realm of ventilation-controlled to fuel-controlled (a fuel-controlled fire is limited by the availability of fuel rather than oxygen).

2.2 Gereral Model of A Post-Flashover Fire

A basic post-flashover model consists of a compartment with an opening in a wall. Heat is generated by a fire in the compartment. Heat flows through the boundaries and the opening. Fresh air also flows into the compartment through the opening. The opening may be a door, a window, cracks in the boundaries or any other passage which will permit air flow. Although only one opening is discussed, the compartment could have several openings. The atmosphere in the compartment consists of well-stirred combustion gases combined with fresh air entering the room. There are no individual plumes, per se. Instead, the plumes from each burning object are immediately dissipated into the swirling hot gases in the room. The following discussion, although general in nature, will focus on the description of a post-flashover model as implemented in the computer program COMPF2 (Babrauskas 1979) and modified for this study by Barnett.

A first law description of the post-flashover fire is as follows. The heat accumulated in the compartment is equal to the energy released by combustion of the fuel is a function of the type of fuel, its arrangement, shape, size and quantity. The heat losses from the compartment are equal to the net heat flow into the compartment's boundaries, the heat absorbed in gasification of the fuel, the convective heat loss due to gas flows through openings and the radiative heat loss through openings.

The heat accumulated in the compartment is that which is stored in the gas volume in the compartment. Because this is very small compared to the other terms, it is ignored in COMPF2.

2.2.1 The Combustion Model

During the post-flashover realm, the pyrolysis of the fuel proceeds at an almost constant rate. A reasonably complete model of the post-flashover combustion process is known only for liquid pool fires and experimental wooden crib fires. In general, the heat release rate of the fire is directly proportional to the burning rate (mass loss rate). For fuel-controlled fires, the burning rate is very difficult to determine. However, if a fire is ventilation-controlled, the burning rate is simply a function of the oxygen available for combustion. The oxygen available for combustion is equal to that in the compartment plus that entering the compartment through openings; the latter being the most important variable. The amount of air (oxygen) entering the compartment through a given opening is a function of the opening size, shape and location, as well as the pressure difference between the compartment and the adjoining space. This pressure difference is a function of the fire's buoyant driven air flows. In the case of subway car, this pressure difference is also a function of the pressure profile around the car caused by the tunnel ventilation system. However, this component has been estimated to be less than 0.2 in. wg, leading to the conclusion that the excess oxygen introduced by the tunnel ventilation system should not significantly increase the estimated heat release rate.

There are two basic methods available for predicting ventilation controlled burning rates. The first is based on the pioneering work by Kawagoe (1958), Babrauskas (1976), Pettersson et al (1976) and Harmathy (1972). They have suggested that for the ventilation-controlled regime, the burning rate may be modeled as a constant over time and as a function of the ventilation parameter. Kawagoe was the first to recognize that the ventilation parameter was a function of a constant, the product of the area of an opening times the square root of the height of the opening (Kawagoe 1958).

The theoretical basis for this relationship has been presented by Drysdale (1985) and is based on the following assumptions:

1. The compartment is modeled as a well-stirred combustion chamber.

2. The flow of hot gas in and out of the compartment is through one rectangular opening and is driven by buoyancy-induced forces with hot gas exiting above a neutral plane and cold air entering below.

3. There is no interaction between the hot gas flowing out and the cold air flowing into compartment.

4. Stoichiometric burning occurs within the compartment.

In reality, ventilation-controlled burning is more complex than suggested by this model. Ventilation-controlled burning is also a function of the heat losses through the compartment's boundary (Pettersson et al., 1976). However, it has been shown that the maximum compartment fire gas temperature occurs when the fire is just barely ventilation-controlled (Drysdale 1985). This may be intuitively expected as air in excess of that required for stoichiometric burning merely cools the fire compartment. Insufficient air prevents the complete combustion of the volatiles inside the compartment. As a result, not as much energy is released inside the compartment as when adequate air is provided.

A second approach to modeling the burning rate is to use a computer model such as COMPF2 to continually adjust the burning rate during each simulation so as to produce the maximum temperature in the fire compartment. This is the same result as predicted by Drysdale because the maximum temperature occurs during stoichiometric burning.

2.3 Heat Loss Terms

Of the heat losses described in Section 2.2, the heat absorbed in gasification of the fuel is ignored in COMPF2 because it is often included in the referenced heat of combustion. When this is not the case, the heat of combustion should be modified to include this term. The other terms are important and are accounted for in COMPF2: the heat flow into the boundaries, the heat loss due to radiation through the compartment's openings, and the heat loss due to radiation through the openings.

2.3.1 Heat Flow Into the Boundary

The simplest model for the heat transfer into the compartment's boundary assumes that the boundary is adiabatic. Of course, this is a very conservative approach and will result in predicted compartment post-flashover temperatures in excess of actual temperatures.

A more realistic approach is to assume that each of the bounding surfaces (the walls, floor and ceiling) are constructed of the same homogeneous material, with realistic values of conductivity, specific heat and density. The heat transfer through the boundary is still a very complex problem. A relatively simple solution may be obtained if one assumes that the heat flow is one-dimensional, normal to the inner surface (the surface of the boundary exposed to the fire), and that the boundary's thermal properties are constant with temperature. This last assumption is often used because of the lack of data for thermal properties of boundary materials as a function of temperature.

The solution of the one-dimensional heat equation as done in COMPF2 requires values of wall emissivity and convection coefficients. The differential equations are then solved using the Crank-Nicolson method.

2.3.2 Other Heat Loss Terms

COMPF2 calculates the radiant heat loss through the compartment's openings by modeling the compartment as a black body having a uniform gas temperature. The convective heat loss term is determined based on use of the chemical composition of the hot gas to calculate the enthalpy of the efflux. The value of the specific heat of the fire gas is assumed to be a constant, equal to the specific heat for the primary product of combustion (0.32 $Btu/lb_m{}^oF$). This assumption should not significantly affect the accuracy of the program results given the impact of the other assumptions and the modeling limitations inherent to this study.

3.0 USE OF COMPF2 IN THE ANALYSIS OF A FIRE ON A WMATA SUBWAY VEHICLE

3.1 Introduction To COMPF2

The focus of this study is on the post-flashover regime of burning. As discussed, this is the time period when the maximum heat release rate is reached and when the peak capacity of the subway emergency ventilation system is needed. COMPF2 is a computer model developed to predict the course of a post-flashover compartment fire (Babrauskas 1976). It is the only post-flashover computer model in the public domain. COMPF2 has been validated by comparison with experimental data (Babrauskas 1977) as indicated in the results shown in Figure 3. Barnett (1989b) showed that COMPF2 could be used to give comparable results with other computer models. The physical basis for the model is discussed in Section 2 of this report. An excellent derivation of the physical basis of the post-flashover fire regime is contained in Drysdale (1985). Appendix A contains a technical description of the COMPF2 program, including the program source code.

3.2 Use Of COMPF2

Successful use of COMPF2 is predicated upon the use of appropriate input variables. The input variables may be divided into three basic categories: geometric parameters, heat transfer properties and fuel parameters.

3.2.1 Geometric Parameters and Modifications to COMPF2

Only the surface area available for heat loss is of importance in defining the basic size of the compartment. Because the computer model can account for only one opening, multiple openings must be lumped together in such a way that

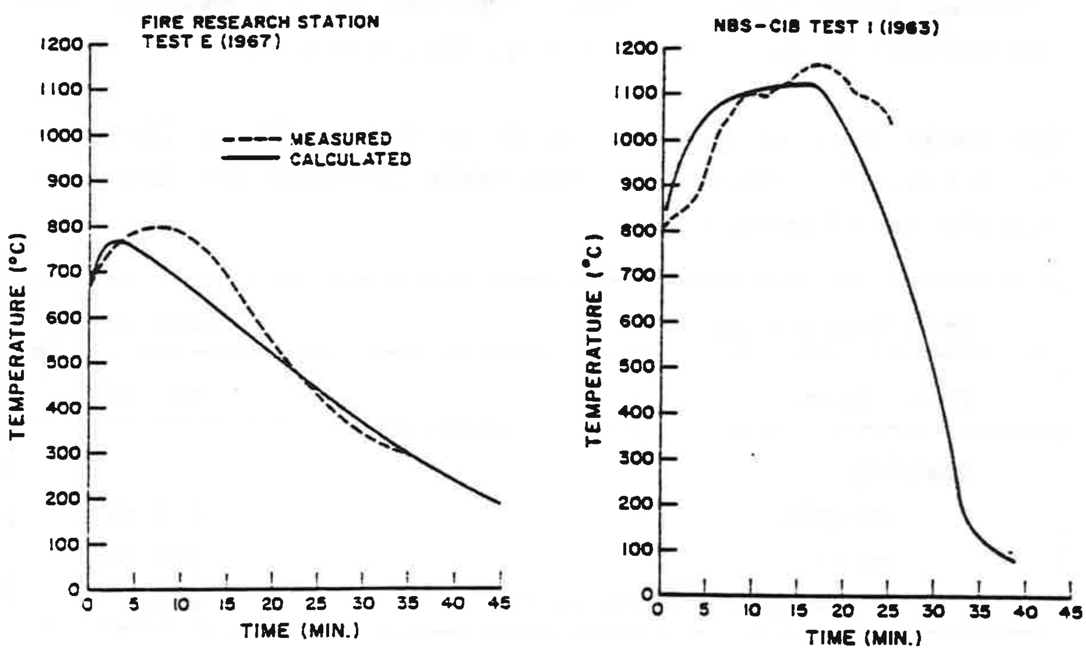

Figure 3.: COMPF2 Predictions Compared to Experimental Data

the airflows through them will be correctly modeled as airflow through one opening. This is a trivial exercise if the multiple openings are at the same elevation and have the same height. Otherwise, techniques such as that recommended by Pettersson et al (1976) must be used. For the purposes of this study, all of the windows are located at the same elevation and have the same height. All doors were assumed closed. For most of the computer analyses, the windows were assumed open. The latter assumption is made because the expected post-flashover fire temperatures are greater than the melting temperature of the glazing material.

The basic vehicle geometry used in the study is listed in Table 3.1. The data came from WMATA drawings for the Breda vehicle (see Appendix B).

Wall Surface Area	1558 sf
Floor Area	663 sf
Opening:	
height	3.1 ft
area	258 sf
discharge coefficient	0.68

Table 3.1: Geometric Parameters: Input to COMPF2

3.2.2 Heat Transfer Properties

A major method of heat loss from the compartment is by conduction through the walls. Thermal properties are strongly dependent upon temperature. However, since the temperature-dependent thermal properties for the walls of a subway car are not known, fixed values were used in the model. Although the partitions, doors and ceiling are constructed of different materials, each with a different thickness, only one value could be used in COMPF2. The values used were for a one-half-inch thick Rohacell. This was chosen as an area-weighted average representation of the vehicle boundary. The values are listed in Table 3.2.

Thickness	0.5	inches
Density	1.309	lb/(cu ft)
Conductivity	26	Btu/(hr-ft-^{o}F)
Specific Heat	0.0717	Btu/(lb-^{o}F)
Emissivity	0.9	

Table 3.2: Heat Transfer Properties of Vehicle Boundaries: Input to COMPF2

3.2.3 Fuel Parameters

For purposes of this study, the input fuel parameters used may be divided into two categories: those which were used for all computer runs, and those varied as a part of a sensitivity analysis.

3.2.3.1 Constant Fuel Properties

The COMPF2 program is not able to model more than one burning item. Therefore, the choice of material properties must account for the many different types of fuels present. The fire-resistant plastics typically specified within vehicle procurement contracts only act to retard pre-flashover burning. After vehicle flashover, the fire-resistant plastics exhibit material properties similar to those of a generic polycarbonate plastic. Since this study focuses on the post-flashover phase of burning, the material properties of a generic polycarbonate were used. The input parameters for the plastic fuel are listed in Table 3.3.

Molecular weight of unburnt pyrolysates	28.97 (Calc. by COMPF2)
Chemical composition	91.2 percent Carbon 7.7 percent Hydrogen
Stoichiometric air/fuel ratio	13.14 (Calc. by COMPF2)
Specific heat of pyrolysates	0.2198 Btu/(lb-^{o}F)
Flame emissivity	0.9

Table 3.3: Fuel Parameters: Input to COMPF2

3.2.3.2 Variable Fuel Properties

The area of the largest uncertainty in COMPF2 is the prediction of the rate of combustion of fuel. COMPF2 has several modes available for modeling a post-flashover fire's rate of burning. The program will predict the rate of burning for experimental wood cribs or for liquid pool fires. Alternatively, the user may specify the rate of burning as a function of time. Finally, the program has the ability to continuously adjust the rate of burning so as to produce the maximum fire temperature in the compartment. This option is the feature that has been used in this study.

The other parameters which have been varied are the maximum fraction of pyrolysates burned, the heat of combustion of the fuel, and the total weight of the fuel.

The maximum fraction of pyrolysates burned was varied from 50 percent to 80 percent. Experimental evidence has suggested that a value of 65 percent is most reasonable (Barnett 1989b).

Another parameter which was varied was the net heat of combustion. This was varied from 7,420 to 17,100 Btu/lb. The former is as suggested by Raymond K.E. (1983), the latter value for polystyrene. A value of 9,130 Btu/lb was also used, but unlike the 7,420 Btu/lb value, it was derived by calculating a weighted average for fuels which had a heat of combustion greater than 5,000 Btu/lb. Of these three values, the 7,420 Btu/lb value is considered to be the most realistic. The 9,130 Btu/lb value overestimates the heat of combustion but is considered to be a reasonable upper limit, and 17,100 Btu/lb is unrealistic for an average value. In all cases, the mass of the fuel was adjusted so that the total heat content of the fuel was 59,247,000 Btu. This is the heat content of the WMATA Rohr vehicle for interior combustibles above the floor level (see Appendix C). The Rohr combustible data was used because a complete inventory of combustible materials was not available for the WMATA Breda vehicle. It should be noted that a burning efficiency less than 1 means the fire within the subway car does not consume the theoretical amount of energy contained in the fuel. The left over energy content is typically in the form of either a residue char within the vehicle or as soot/smoke particles within the combustion gas stream.

3.3 Accuracy Of COMPF2

COMPF2 has been validated by comparison with experimental data and gives comparable results with other computer models. The best estimate of model reliability is based on the use of the model in predicting room fire behavior. For that purpose, the model is expected to be within 25 percent of reality. It is possible to modify the program so that additional factors, such as the relative location and type of different boundary materials, are internally modeled within the program. However, the most suitable means for improving the level of confidence in the calculated COMPF2 results appears to be through full-scale testing.

4.0 ANALYSIS OF RESULTS

4.1 General

The following is a basic analysis of the computer runs that were conducted as part of this study. Computer runs were conducted where the key variables which were varied as part of a sensitivity study were the burned pyrolysates fraction (BPF) and the heat of combustion of the fuel. Appendix D contains the computer input data and corresponding results for seven of the analyzed cases.

In addition to these computer runs, varying the amount of ventilation was also studied. For these runs, the fraction of pyrolysates burned was set equal to 0.65 and the heat of combustion was set equal to 17,100 Btu/lb.

4.2 Varying BPF and the Heat of Combustion

Table 4 summarizes the result for the values of the heat energy output of the fire (Q_{fire}), the corresponding gas temperature (Gas Temp.), influx air velocity (Airflow), and the fire duration as functions of the heat of combustion (H_c) and the BPF. These values are shown for the period of steady burning during the major portion of the post-flashover period. The results show that as the heat of combustion increases, the fire duration decreases. This is because the total heat content of the fuel was held constant at 59,247,000 Btu by adjusting the fuel's mass for the different values of the heat of combustion.

INPUT		OUTPUT			
H_c (Btu/lb)	BPF	Q_{fire} (MBtu/hr)	Gas Temp. (^oF)	Airflow (fpm)	Duration (minutes)
17,100	0.5	50.8	1433	293	34
17,100	0.6	60.5	1584	295	34
17,100	0.7	70.1	1717	296	34
17,100	0.8	79.6	1834	297	35
9,130	0.5	26.4	935	279	63
9,130	0.6	31.7	1060	283	63
9,130	0.7	36.9	1172	287	63
9,130	0.8	42.1	1274	289	63
7,420	0.5	20.9	794	271	78
7,420	0.6	25.2	906	277	78
7,420	0.7	29.4	1009	281	78
7,420	0.8	33.7	1103	284	78

Table 4.: Summary of the Effect of Varying The Burned Pyrolysates Fraction and The Heat of Combustion

Of particular interest is the value for the maximum heat release rate of the fire. Figure 4.1 shows the value of the maximum heat release rate as a function of the BPF for the three different values of the heat of combustion. It should be recognized that the maximum heat release rate is a function of the heat of combustion of the fuel, the BPF, and most importantly, the available oxygen which is a function of the opening size and shape. Also, the calculated heat release rate is internally adjusted within the COMPF2 program to result in the maximum fire gas temperature possible for the given set of conditions. This is the same as the case of stoichiometric combustion.

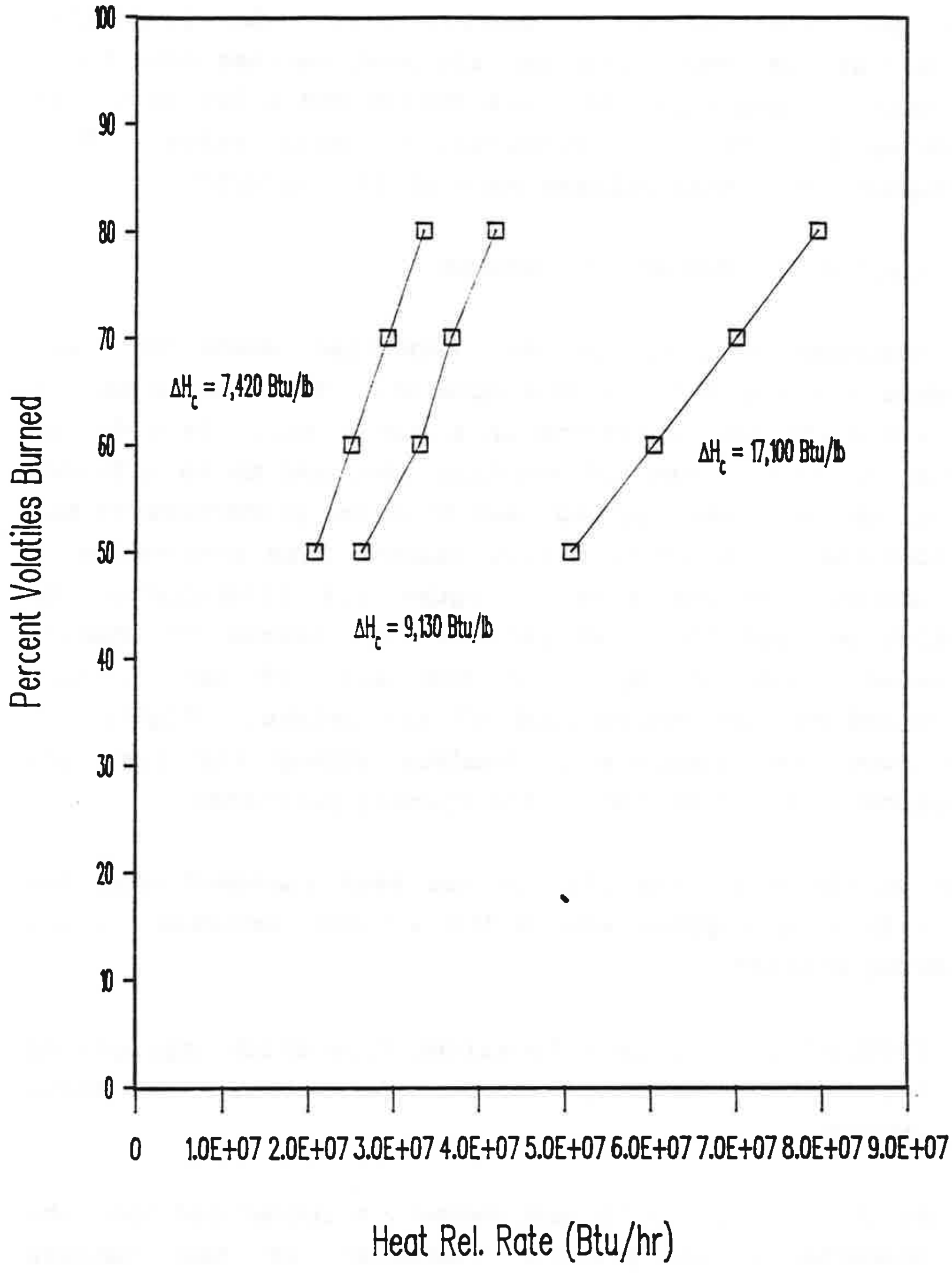

Figure 4.1: Maximum Heat Release Rate As a Function of BPF

A heat release rate of about 27.3 MBtu/hr (corresponding to H_C = 7,420 Btu/lb and BPF = 0.65) is considered to be the "most probable" value. However, given the predictive accuracy of the COMPF2 program, the heat release rate based on a heat of combustion of 7,420 Btu/lb and a BPF of 0.8 is suggested to provide a conservative design value. This corresponds to a heat release rate of 33.7 MBtu/hr.

4.3 Varying the Number of Openings

Nine computer simulations were conducted where the only variable was the size of the opening. This was meant to simulate different conditions in a subway car. In order to do this correctly, the wall/ceiling area had to be adjusted as well as the area-weighted heat transfer properties of the wall/ceiling. The maximum heat release rate occurred with the maximum opening size. Figure 4.2 illustrates the relation between the heat release rate versus an opening parameter which is equal to the area of the opening multiplied by the square root of the height. Figure 4.3 illustrates the increase in maximum subway car fire gas temperature as a function of the opening parameter.

Based on the above results, it has been reasoned that the design fire propagates within the vehicle interior in the following manner:

- Initially, there is a localized fire which impinges on two nearby windows, leading to failure of these windows.

- At this point, sufficient oxygen is introduced into the compartment to produce flashover of the vehicle interior, resulting in the failure of the remaining windows.

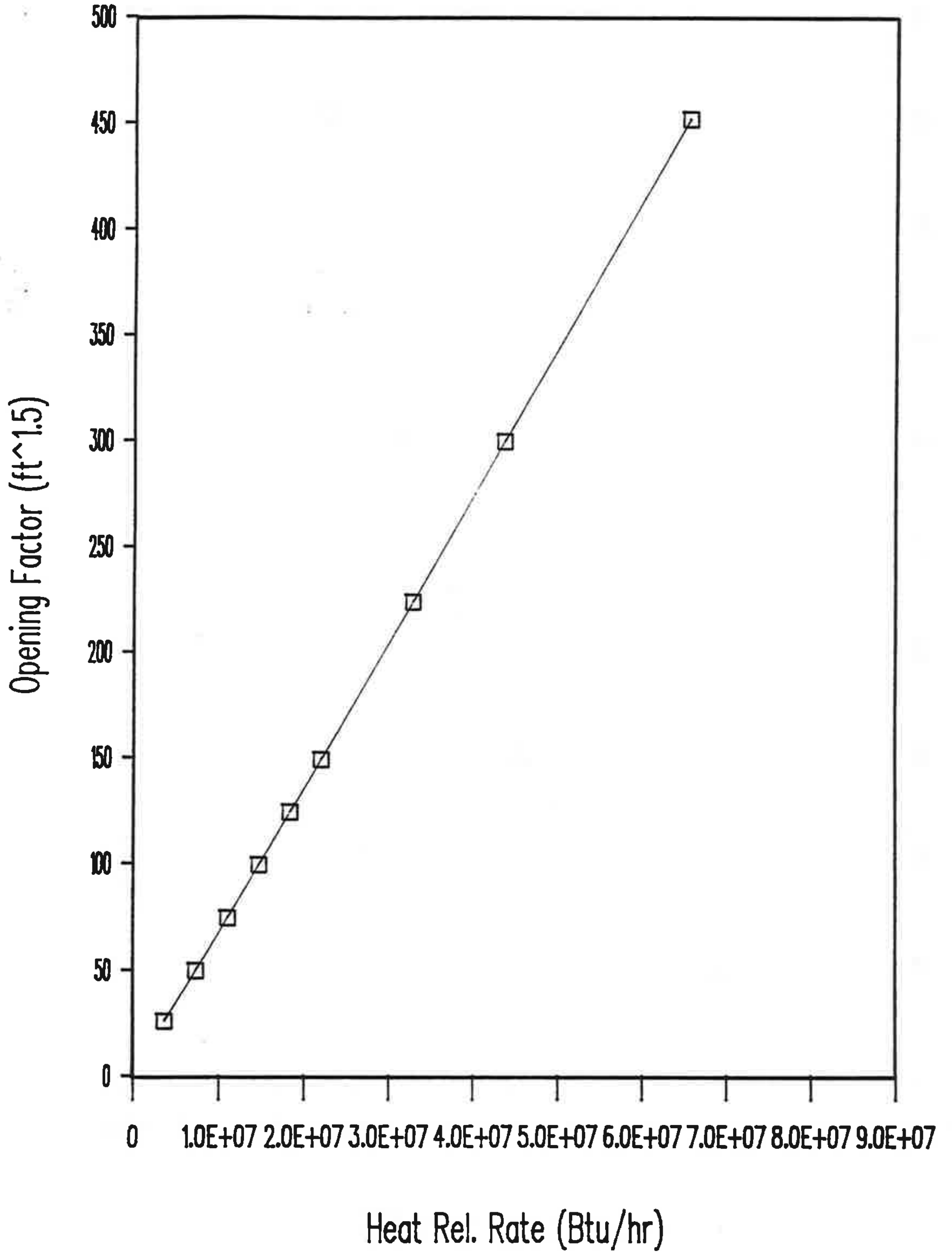

Figure 4.2: Maximum Heat Release Rate As A Function of the Opening Parameter

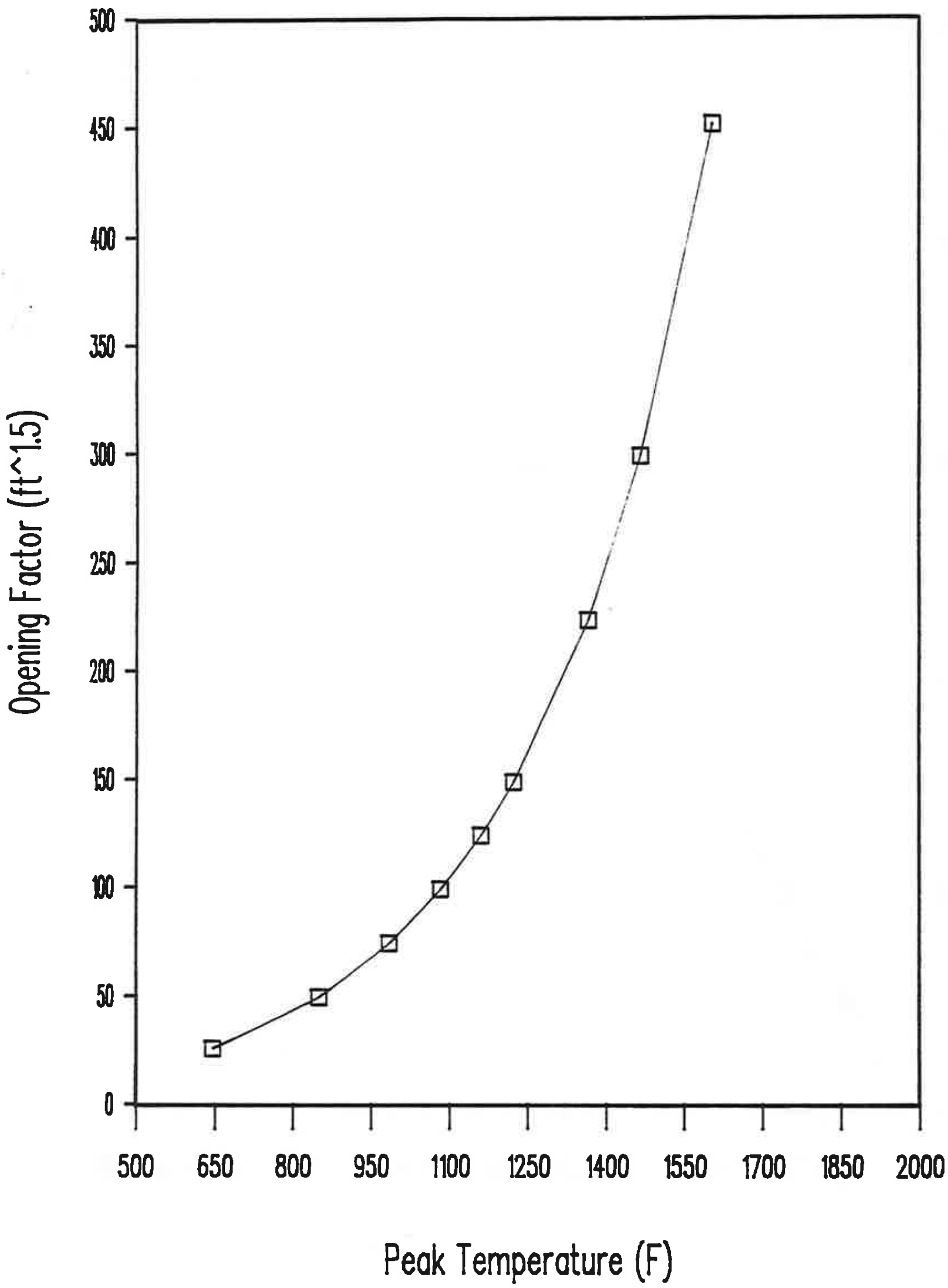

Figure 4.3: Peak Temperature As a Function of the Opening Parameter

- Additional air is then introduced into the compartment. It is at this point where the peak heat release rate occurs, and the fire continues to burn at this peak rate until all of the interior combustibles have been consumed.

5.0 CONCLUSION

A heat release rate of 27.3 MBtu/hr is estimated based on the "most probable" combination of input parameters. However, given the predictive accuracy of the COMPF2 program, a heat release rate of 33.7 MBtu/hr is suggested. Since this value is based on the combustible content of the above-floor combustibles for a single WMATA vehicle, this needs to be adjusted to account for the heat content of the vehicle components located at floor level and below floor level, potential multiple car involvement, and a suitable factor of safety.

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Appendix A

NATIONAL BUREAU OF STANDARDS TECHNICAL NOTE 991

COMPF2 - A PROGRAM FOR CALCULATING POST-FLASHOVER FIRE TEMPERATURES

NBS TECHNICAL NOTE 991

U.S. DEPARTMENT OF COMMERCE/National Bureau of Standards

COMPF2—A Program for Calculating Post-Flashover Fire Temperatures

COMPF2--A Program for Calculating Post-Flashover Fire Temperatures

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NOMENCLATURE

A	area (m^2)
b_p	combustion efficiency (-)
C_d	discharge coefficient (-)
c_p	heat capacity ($J\ kg^{-1}\ K^{-1}$)
D	smallest fuel dimension (m)
g	gravitational acceleration ($m\ s^{-1}$)
h	convective coefficient ($W\ m^{-2}\ K^{-1}$)
h	enthalpy (J)
h_c	combustion enthalpy (J)
Δh_c	calorific value ($J\ kg^{-1}$)
Δh_p	total heat of pyrolysis ($J\ kg^{-1}$)
k	thermal conductivity ($W\ m^{-1}\ K^{-1}$)
m	mass (kg)
M_o	initial fuel mass (kg)
q	heat (J)
Q	heat flow (W)
r	stoichiometric air/fuel ratio (-)
T	temperature (K)
v_p	regression velocity ($m\ s^{-1}$)
w	molecular weight ($kg\ mol^{-1}$)
x	thickness dimension (m)
ε	emissivity (-)
ρ	density ($kg\ m^{-3}$)
σ	Stefan-Boltzmann constant ($W\ m^{-2}\ K^{-4}$)

Subscripts

air	air
b	vaporization
ep	excess pyrolysate
f	hot gases; pool
o	ambient
p	pyrolysis
r	window radiation
v	ventilation, window
w	walls, including ceiling

Superscripts

	time rate
'''	per volume

COMPF2--A PROGRAM FOR CALCULATING POST-FLASHOVER FIRE TEMPERATURES

Vytenis Babrauskas

COMPF2 is a computer program for calculating the characteristics of a post-flashover fire in a single building compartment, based on fire-induced ventilation through a single door or window. It is intended both for performing design calculations and for the analysis of experimental burn data. Wood, thermoplastic, and liquid fuels can be treated. In addition to the capability of performing calculations for compartments with completely determined properties, routines are included for calculating fire behavior by an innovative variable abstraction method. A comprehensive output format is provided which gives gas temperatures, heat flow terms, and flow variables. The documentation includes input instructions, sample problems, and a listing of the program. The program is written in Fortran and constitutes an improved version of an earlier program, COMPF.

Key words: Computer programs--fire protection; fire protection; fire resistance; fire tests; fire walls; safety engineering--fires.

1. INTRODUCTION

With increasing efforts [1-4][1] towards rational methods of providing fire endurance for structural building components, it becomes highly desirable for both the designer and the researcher to have available computer programs for calculating expected fire temperatures and heat transfer through the building components. A fire is not considered as becoming a threat to a structure and its fire barriers until it reaches the flashover stage. Flashover of a room is defined as that fire stage when the bulk of the room volume becomes involved in flames. Operationally, this roughly coincides with flames coming out the door or window, or an upper gas space temperature of around 600° C, or a radiant heat flux at floor level of about 20 kW/m^2. For the purpose of designing for fire endurance, then, only post-flashover fires are considered. The present report describes a computer program for calculating the expected temperatures, heat and mass flows and other variables in post-flashover building fires. Different routines are incorporated for producing design time-temperature curves and for permitting comparative theoretical curves to be generated based on experimental mass loss rates.

2. HISTORY OF DEVELOPMENT

The first computer program for calculating post-flashover fire temperatures was developed by Kawagoe [5], in conjunction with his pioneering studies leading to a theoretical room fire model. This model was an adaptation of an earlier graphical technique. The main limitations of both the computer program

[1]Numbers in brackets refer to the literature references listed at the end of this paper.

and the theoretical model was the restriction to ventilation-limited fires. Fuel-limited fires could only be expressed in terms of an empirical temperature change rate. Magnusson and Thelandersson [6] studied heat release rates in more detail and produced a model. An unpublished computer program was used to implement that model. The normalized shape of the fire time-temperature curves was an input variable in this model; the shape was based on sets of typical measurements. Based on Magnusson and Thelandersson's theory, Fedock [7] published a similar computer program with emphasis on prestressed concrete structures. The first program to provide for theoretically based calculations of both ventilation-limited and fuel-limited burning was written by Tsuchiya [8]. It was restricted to fires starting in ventilation control and to fuel consisting of sparsely-packed wood sticks.

The predecessor to the present program, COMPF [9], was issued in 1975 and incorporated several new advances, including the ability to treat entirely fuel-limited fires, to allow for temperature-dependent wall properties, to permit the optional use of numerical input fuel weight loss rates, and to perform certain variable abstraction ("pessimization") calculations as an aid to design. (These techniques enable an input variable to be treated non-deterministically.) Program COMPF2 is intended to replace program COMPF and differs from it in the following main ways:

1. A subroutine has been added to allow treatment of fires where thermoplastic or liquid fuel exists in the form of a pool on the floor. The routine implements the theory discussed in reference [10] and outlined in section 4.1; examples of calculations are also given and discussed in that reference.

2. The deterministic wood fuel burning model has been extended to include the possibility of densely-packed cribs.

3. Both pool fire and densely-packed crib options have been incorporated into the pessimization routines.

4. In addition to performing transient calculations, the program can now also treat steady-state solutions, for both lossy and adiabatic walls.

5. The program is now in S.I. units throughout.

6. Certain corrections and improvements have been incorporated in the calculation routines. The method for the iterative solution of the heat balance equation has especially been improved.

3. THEORY

The post-flashover compartment fire theory has been given in some detail in reference [11], thus, only a brief summary will be given here. The main assumptions are:

- The compartment represents a well-stirred reactor, i.e., spatial temperature variations in the hot fire gases are ignored.
- The model is quasi-steady. Time variations in fuel release rate and in conduction losses are fully included. However, time rate of change terms in gas phase mass and energy balance are dropped.
- Air supply and gas outflow is through a single window in a vertical wall and is the result of fire-induced convection.
- The thermal discontinuity away from the window region is at a level below the bottom of the window. The volume below the discontinuity is occupied

by cold incoming air. In a flashed-over fire this discontinuity is close to the floor. Its exact location below the window bottom is immaterial [12].

- Burning is limited by rates of air or fuel supply rather than by gas phase chemical kinetics.
- Walls (including the ceiling) are modeled as portions of a homogeneous solid of finite thickness. Temperature-dependent material properties are allowed for.

The heat balance equation is:

$$\dot{h}_c - \dot{m}_f (h_{T_f} - h_{298}) - Q_w - Q_r - Q_{ep} = 0 \qquad (1)$$

where h denotes enthalpy and the definition of symbols is given in the Nomenclature section. The subscripts on the enthalpy terms denote the temperature at which they are evaluated. The window radiation loss is, simply

$$Q_r = A_v \sigma (T_f^4 - T_o^4) \qquad (2)$$

The wall loss term has a radiative and a convective component,

$$Q_w = A_w [\sigma \frac{1}{1/\varepsilon_f + 1/\varepsilon_w - 1} (T_f^4 - T_w^4) + h (T_f - T_w)] \qquad (3)$$

The convective coefficient h above is not well known since the exact flow conditions at the wall and ceiling surfaces in a post-flashover fire are not known in detail. The convective fraction is much less than the radiative fraction, permitting a rather simplified treatment. For turbulent-free convection flow over flat plates the value for h should depend [13] on $(T_f - T_w)^{1/3}$. A value of

$$h = 5.0 (T_f - T_w)^{1/3} \qquad (4)$$

was selected as being in reasonable agreement with data.

The analysis in [11] shows that for compartments greater than about 2 m on a side, a flame emissivity of $\varepsilon_f \approx 0.9$ may be used.

The enthalpy evolved from combustion, $\dot{h}_c$, must be evaluated as the lesser of

$$\dot{m}_p \Delta h_c b_p \qquad (5)$$

or

$$\dot{m}_{air} \frac{\Delta h_c}{r} b_p. \qquad (6)$$

When equation (5) is limiting, the combustion is known as "fuel-limited", while if equation (6) is smaller, combustion is "ventilation-limited". Here b_p represents the maximum combustion efficiency and is a largely unknown number. Since it represents, effectively, the "unmixedness" of the combustion, there may be a scale effect, with smaller compartment spaces showing less complete mixing. Experimental data can generally be correlated within a range of about $0.7 \le b_p \le 0.9$.

The value of $\dot{m}_{air}$ is obtained from the Bernoulli equation at the window and is

$$\dot{m}_{air} = \frac{2}{3} C_d \rho_o \left[2g \frac{1 - W_f T_o / W_o T_f}{[1 + (W_o T_f / W_f T_o [1 + (\dot{m}_p / \dot{m}_{air})]^2)^{1/3}]^3} \right]^{\frac{1}{2}} A_v \sqrt{h_v}. \quad (7)$$

The discharge coefficient has been determined by Prahl and Emmons [14] to be 0.68 for normal-shaped windows. This value does not hold in cases where the window takes up almost an entire wall. For such windows the flow patterns have not been studied, but data can be correlated by taking C_d at about one-half its normal value. The molecular weight of the products, W_f, is not exactly known since the composition of the gases, especially the unburned fuel gases (excess pyrolysates) is generally unknown. For simplicity their molecular weight has been assumed equal to that of nitrogen. The contribution of carbon monoxide and other minor combustion products is also ignored. The main dependence of $\dot{m}_{air}$ is on the window parameter $A_v \sqrt{h_v}$. For reasonable values of temperature the whole expression becomes approximately equal to

$$\dot{m}_{air} = (\ 0.45 \text{ to } 0.50\ )\ A_v \sqrt{h_v} \quad (8)$$

But this approximation has <u>not</u> been employed here.

Ventilation through multiple openings has not been provided for in this program. An approach for treating such problems is given in [11].

The heat of combustion, Δh_c, is taken as the net value since the hot gas outflow is above 100° C. The stoichiometric ratio, r, is a constant for a pure material; a tabulation of values is given in [15].

The rate of pyrolysis, $\dot{m}_p$, is one of the hardest quantities to determine. A discussion of available values is given in the next section.

The outflow mass rate, $\dot{m}_f$, is by mass conservation the sum of $\dot{m}_{air}$ and $\dot{m}_p$. The enthalpy of the outflow products, h_{T_f} and h_{298} is evaluated on the assumption that the combusted fuel goes to CO_2 and H_2O. No account is taken of CO for two reasons: because the effect on a mass basis would be very small, and because it was considered advisable not to introduce any reaction kinetics. Also, only elements C, H, O, and N have been considered for the fuel composition.

The excess pyrolysate term Q_{ep}, is the heat required to vaporize the excess pyrolysates. Note that with the conventional definition of heat of combustion, the loss for vaporization of combusted pyrolysates is already included in Δh_c.

The second major equation to be solved is for heat conduction through the wall.

$$\rho C_p \frac{\partial T_w}{\partial t} = \frac{\partial}{\partial x}(k \frac{\partial T_w}{\partial x}) + \dot{q}''' \tag{9}$$

The wall is initially at ambient temperature, T_o, and is subjected to boundary conditions at the fire side of:

$$-k \frac{\partial T_w}{\partial x} = h\ [T_f - T_w(o)] + \varepsilon\sigma\ [T_f^4 - T_w^4(o)] \tag{10}$$

and on the unexposed side (x = L),

$$-k \frac{\partial T_w}{\partial x} = h\ [T_w(L) - T_o] + \varepsilon\sigma\ [T_w^4\ (L) - T_o^4] \tag{11}$$

For the fire side the convective coefficient has been given above. For the unexposed side a value of

$$h = 1.87\ \ [T_o - T_w\ (L)]^{1/3} \tag{12}$$

was taken.

4. PYROLYSIS RATES

4.1 Liquid or Thermoplastic Pools

There is currently only one fuel arrangement where the pyrolysis rate may adequately be predicted from theory. It consists of a pool of thermoplastic or liquid fuel on the floor. The fuel is pyrolyzed solely by radiant flux and "sees" the compartment with a view factor of 1.0 and itself with a view factor of zero. In addition, the fuel must pyrolyze at a known surface temperature, T_b, and with a known heat of pyrolysis, Δh_p. Then:

$$\dot{m}_p = A_f \frac{\varepsilon\sigma\ (T_f^4 - T_b^4)}{\Delta h_p} \tag{13}$$

Tewarson and Pion [16] have measured heats of pyrolysis for numerous thermoplastic materials.

The above simple model is fully adequate for steady-state solutions. At the start of the fire, however, the radiation feedback is small from the hot gas volume but may be larger from the local plume above the pool itself. Thus, a plume term should be added in to model the starting transient. Very limited experimental data by Burgess [17] and by Modak [18] can be used to derive an empirical relationship for the plume pyrolysis rate as:

$$\dot{m} = A_f\ 0.0014 \frac{\Delta h_c}{\Delta h_p}\ \ (kg/s) \tag{14}$$

This relationship does not take into account differences in flame emissivities for various materials; as a result, it only provides a crude measure. In the present application, however, the contribution of this term is minor; therefore, an approximate expression is adequate. Also, as the room radiation increases, the effect of plume radiation on pyrolyzing the fuel decreases. For a radiatively black room, at high temperature, the plume term should properly be negligible. This interaction is crudely modeled by multiplying the plume term by a proportionality factor before adding to the far-field term. The proportionality factor, χ, has been set equal to

$$\chi = 1.0 - \frac{T_f^4 - T_b^4}{1700^4 - T_b^4} \qquad (15)$$

with $\chi \geq 0$.

4.2 Solid Fuels

Empirical data are available for the mass loss rates of wood planks in flashed-over fires. Because of the nature of wood combustion, these rates are not especially sensitive to room radiation and can be specified [11] using a regression velocity of 7-15 μm/s. This relationship is adequate to describe the burning of large, isolated wood panels. For pieces thin in two or three dimensions, yet still widely spaced, the following expression is suitable:

$$\frac{\dot{m}_p}{M_o} = \frac{F}{C}\left(\frac{m}{M_o}\right)^{1-1/F} \qquad (16)$$

Here M_o is the original mass, m is the mass at a given time, and F is a constant equal to 2 for cylinders or rectangular sticks and equal to 3 for spheres or cubes. C is given by

$$C = \frac{D}{2v_p}$$

with D being the smallest fuel dimension and v_p the regression velocity. For thin fuels v_p is approximately

$$v_p \approx 1.7 \times 10^{-6}\, D^{-0.6} \text{ (m/s)} \qquad (17)$$

The final arrangement for wood fuel for which data are available is a crib, or a regular stacked array. From the data of Nilsson [19] and Yamashika [20], a set of simplified relationships has been evolved for the three crib burning regimes.

<u>Fuel Surface Control</u>

$$\dot{m}_p = \frac{4}{D} v_p \left(\frac{m}{M_o}\right)^{1/2} M_o \quad \text{(kg/s)} \qquad (18)$$

$$v_p = 1.7 \times 10^{-6}\, D^{-0.6}$$

Crib Porosity Control

$$\dot{m}_p = 4.4 \times 10^{-4} \, (S/h_c) \, \frac{M_o}{D} \qquad (19)$$

S/h_c = ratio of stick clear spacing to crib height

Room Ventilation Control

$$\dot{m}_p = 0.12 \, A_v \sqrt{h_v} \qquad (20)$$

In calculations, each of the three rates above are determined and the lowest rate taken as governing.

5. DETAILS OF SUBROUTINES

The program routines are written in Fortran language. A complete listing is given in appendix B. The following are brief descriptions of the operation of each subroutine.

5.1 COMPF2

COMPF2 is the main program. It calls most of the calculational routines. A flow chart of COMPF2 is given in figure 1. The program starts with the initialization of certain constants and default values. The input title and namelist are then read in. If tabular data are specified, subroutine INC is called. ICONDS is then called in to set initial starting values. The input data are echoed in ECHOID. After that, the appropriate computational routine is called in. If no iteration failure has occurred the program then loops back to the start and goes to the next problem. In case of iteration failure, the program returns to the same problem, this time printing out additional intermediate calculation values. This intermediate output can also be forced to appear by specifying KTRACE=1.

5.2 CRIB

Subroutine CRIB calculates the burning of wood crib fires. A trial gas temperature value is assumed for the first time step. This value is preset, but may be overridden by specifying a value of TINPT. The flow quantities are computed, then the wall losses are determined by calling DESOLV. The heat balance is then determined. If the normalized residue is greater than 0.002, the iteration continues. The new temperature is normally determined by the Newton method. If divergence results, a scanning technique is used initially and a splitting of differences once a bounded oscillation results. After successful convergence a new wall temperature profile is established by calling RSTA. The calculation then proceeds to the next time step. Computation is terminated at the end of time MTIME, or when gas temperature drops to 353 K, or if errors or convergence failure is detected.

5.3 DEQNS

Subroutine DEQNS computes wall heat conduction using the Crank-Nicolson method [21]. DEQNS has two entry points: DESOLV and RSTA. The radiation boundary condition is linearized; updating every iteration rather than every time step ensures minimal error. An additional within-loop iteration is also used. DEQNS calls TRIDGF to solve the equation matrix.

5.4 ECHOID

Subroutine ECHOID echoes the input data. The complete data set is given for each run, rather than just the changed values. Care has been taken to give physical meaning for the variables printed.

5.5 ICONDS

Subroutine ICONDS initializes starting values and does some preliminary calculations on the input data. It also makes a few checks on the validity of the input data. The user, however, is cautioned that this checking is very rudimentary and in case of error exit or iteration failure the input data must be carefully examined.

5.6 INC

Subroutine INC is called in when tabular input data are to be read.

5.7 OUTPUT

Subroutine OUTPUT is the primary output routine. It writes at each time step a large number of variables to output files (logical units) 2 and 3. The temperatures, burning rates, and other primary variables are put on file 2, while the heat balance values and the mass fractions are written on file 3. OUTPUT also converts temperatures from Kelvin to degrees Celsius before printing them out.

5.8 PFLFIX

PFLFIX is a pessimization design routine. Fuel pyrolysis rate is calculated according to governing equations, but the ventilation is pessimized by instantaneously adjusting the window width to give the highest possible temperatures. Wood stick or wood crib fuel is assumed unless PLFUEL=T, in which case a pool fire is used. The window width is not allowed to exceed a maximum, as set by AWDOW/HWDOW. Calculations stop when the fuel, as specified by FLOAD, is exhausted, since the window width would be undefined beyond that point. Calculational procedures are similar to those in CRIB.

5.9 POOL

POOL is a pool fire burning routine. Computational details are similar to those as in CRIB. The pyrolysis rate is based on equations 13, 14, and 15. Three modes of subroutine operation are possible. If STOICH=T, the steady-state temperatures and pool area are determined for stoichiometric burning. If EISCAN=T, the steady-state solution is found for a given pool area greater than stoichiometric. The pool area is specified by use of the parameter EITA, defined as [10]

$$\eta = \frac{\dfrac{A_v \sqrt{h_v}}{A_f}}{\left(\dfrac{A_v \sqrt{h_v}}{A_f}\right)_{stoich}} \qquad (21)$$

For constant window size, this becomes simply a ratio of pool areas. No solutions are possible for $\eta \geq 1$. Finally, a transient calculation can be made, which proceeds similarly as in the other transient calculations. The user must make sure that the pool size given is sufficiently large so that $\eta \leq 1$.

5.10 PP

Subroutine PP is a plotting routine. Details are not given since plotting routines are dependent on the hardware used.

5.11 PVTFIX

PVTFIX is a pessimization routine, and is effectively the inverse of PFLFIX. In PVTFIX a fixed ventilation opening is specified. The fuel release rate is instantaneously varied to always result in the highest possible burning temperature. Temperatures drop after the fuel load is consumed. Computational details are similar to those in PFLFIX.

5.12 RPFIX

For comparison of measured data against numerical predictions a routine is needed which can accept $\dot{m}_p$ rates as an input tabular function of time. RPFIX provides for this type of checking calculation. The case of measured combustion rate input (as provided, for instance, by oxygen depletion measurements in the window outflow) can also be treated by dividing the measured rate by Δh_c (net) and setting $b_p = 1.0$.

5.13 STFLOW

Subroutine STFLOW is a wall heat conduction routine. It is similar to DEQNS, except that only the steady-state temperatures are determined.

5.14 TLU

Function TLU is a tabular data interpolating function used in several subroutines. If the independent variable entered is smaller than the smallest data point or larger than the largest data point, the output is set equal to the smallest, or largest dependent value, respectively.

5.15 TRIDGF

Subroutine TRIDGF uses a Gauss elimination procedure to solve a set of tri-diagonal matrix equations.

6. AGREEMENT WITH EXPERIMENT

A comparison of numerical predictions with experimental results has been given in [22] for the program COMPF. Similar agreement should hold for COMPF2, since COMPF2 is improved mainly in operational features, especially increased versatility, while retaining the same theoretical model as in COMPF. For pool fires useable full-scale experimental data are not available.

7. INPUT INSTRUCTIONS

7.1 Deck Set-up

The input is assigned to file 1. Each problem run consists of two or three card groups, as follows:

1. Title card (20A4). One card only. Card must be present. The identifying information from the title card is printed at the head of the output.

2. Namelist card(s). One or more cards. Details are given in the next section.

3. Tabular input (optional). This input group is contained only for the first run and for those ensuing runs where NEWPRP=T. If no tabular input is present, then blank cards must not be inserted. If tabular input is present, it is arranged as follows:

First card: NCN, NCP, NEM, NR, NQG (10I3). These are the number of points for the wall thermal conductivity, wall heat capacity, wall emissivity, mass pyrolysis rate, and wall heat generation rate, respectively. The number of points may be 0, 1, or greater than 1. If N=O, then the previous run value is unchanged. If N=1, then it is assumed the value is a constant, independent of temperature or time. If N≥1, then an array is inputted.

Ensuing card(s): These are in the format (8F10.0) and arranged in pairs (independent, dependent). For wall thermal properties, temperature is the independent variable, while for mass pyrolysis rate it is time. The order is: CNDA, CPW, EMSA, RPX, QGEN. First all the points (if any) for CNDA are read in, four pairs per card. Then a new card is started even if the last card is part-full, and CPW is read in. The process is continued for EMSA, RPX, QGEN. No blank cards may be inserted. If N=1 for an array, then the constant value is entered in columns 11-20.

After cards for one run are finished, the cards for the next one are stacked, again with no blank cards.

7.2 Namelist VARS

For all non-tabular data, the namelist format was adopted. This undeservedly obscure Fortran feature is highly advantageous for the present application. Its features include:

- Semi free-format input
- Variables may be in any order
- Unneeded variable values need not be specified
- Variables needed, but not specified in current run are automatically set equal to the prior given value.

The namelist card(s) must contain the following information: the first card must start with $VARS in columns 2-6, then a space, then the desired values, separated by commas. Input may be continued on continuation cards, each of which must have columns 1-2 blank. The stream is terminated by a $ after the last variable.

The user is cautioned to check the input carefully, since namelist format provides for only rudimentary error messages. The namelist VARS values are written to file 5 when read in. In normal operation file 5 can be rewound or discarded. If error failures occur, however, the VARS listing on file 5 may be useful in determining input errors.

Table 1 lists all the variables inputted in namelist VARS.

7.3 Modes of Program Operation

Time

Three possibilities are available: complete time-temperature curve calculation, calculation of steady-state temperature for a given wall, or the calculation of a steady-state temperature for adiabatic walls. To select adiabatic walls, set ADIA=TRUE. To select steady-state solution for real walls, set STEADY=TRUE. To obtain complete time-temperature curve, set ADIA and STEADY both FALSE. Note that for some fuel pyrolysis conditions below not all three possibilities are available.

Fuel Pyrolysis

The following modes of operations are available:

1) Pool fire
Set PLFUEL=TRUE.

a. Time-temperature curve for given ventilation and pool area. Specify SIZE. Set STOICH and EISCAN both FALSE.

b. Burning conditions at steady state for stoichiometric pool size, that is, determine values for EITA=1. Set STOICH=TRUE. Do not input SIZE. Do not set EISCAN=TRUE.

c. Burning conditions for any other EITA. Set EISCAN=TRUE. Specify EITA. This option must be preceded by the stoichiometric problem (option 1b, above). SIZE input is not used; if given, the value is disregarded.

2) Wood crib fire. This is the default option. Set FLSPEC, PLFUEL, RPSPEC, and VTSPEC all FALSE.

a. Simple stick burning. Must specify a value for REGRES greater than zero.

b. Nilsson's crib formulas for crib burning in three possible regimes. Specify REGRES=0. (default). Also specify SH.

3) Checking option when tabular input pyrolysis rates are given. Set RPSPEC=TRUE. Also must set NEWPRP=TRUE and give an appropriate array of RPX.

4) Pessimization over ventilation. Set FLSPEC=TRUE. Window width is automatically adjusted, but is no greater than determined by the inputted value of AWDOW/HWDOW. Program stops when fuel is exhausted.

a. Simple stick burning. Must specify a value for REGRES greater than zero and set PLFUEL=FALSE.

b. Nilsson's crib formulas for crib burning in three possible regimes. Set PFLUEL=FALSE and REGRES=0. Also specify SH.

c. Pool burning. Set PLFUEL=TRUE.

5) Pessimization over fuel pyrolysis rate. Set VTSPEC=TRUE. Fuel pyrolysis rate is automatically adjusted for pessimal burning conditions.

8. FILES USED

The Fortran file logical units must be declared as follows:

File 1 -- Input
File 2 -- Output (echoed input and main calculated variables)
File 3 -- Output (heat balance and mass fractions)
File 4 -- Output (intermediate tracing output - used only if KTRACE=1)
File 5 -- Output (listing of namelist VARS contents).

File 5 can be arranged to be rewound after each problem so that it will contain data only in case of error failure.

9. IMPLEMENTATION

Program COMPF2 has been successfully implemented on a UNIVAC 1108 computer The predecessor program, COMPF, was run on a CDC 6400 computer. The program uses, as much as possible, only standard Fortran expressions. Minor unavoidabl implementation differences exist, however, in commands associated with file usage.

10. LIST OF VARIABLES

Table 2 gives a list of all the major problem variables.

11. ACKNOWLEDGMENTS

Ulf Wickstrom (Lund Institute of Technology) assisted in program development; Richard Peacock (NBS) helped implement the program.

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Table 1. Variables specified in the input Namelist VARS

Variable	Default Values: First run	Default Values: Following run	Information
ADIA	FALSE	pv	if true, walls area adiabatic and only steady-state solution is sought
AFLOOR	none	pv	area of floor (m^2)
AWALL	none	pv	gross area of walls and ceiling (m^2)
AWDOW	none	pv	area of window (m^2)
BPF	none	pv	maximum fraction of pyrolyzed fuel burned to be ≤ 1.0
CD	0.68	pv	discharge coefficient
CFLPC	44.4	pv	percent, by weight, of carbon in fuel
CPPYR(2)	CPN2	pv	heat capacity of pyrolysis gases (J/kg-K)
CVGROS	none	pv	upper calorific value for dry fuel (J/kg)
DENSW	none	pv	wall density (kg/m^3)
DHP	none	pv	total heat of gasification for fuel (J/kg)
DTIME	none	pv	increment of time step (s)
EF	0.9	pv	gas emissivity, assumed gray
EISCAN	FALSE	FALSE	if true, solve steady-state problem in POOL for a given EITA
EITA	none	pv	normalized air-fuel parameter for pool burning
FLOAD	none	pv	fuel load (kg/m^2 floor area)
FLSPEC	FALSE	FALSE	if true, pessimize ventilation for a specified pyrolysis rate
HFLPC	5.4	pv	percent of hydrogen, by weight, in fuel
HWDOW	none	pv	window height (m)
IRUN	1	sequential	run problem number
IX	10	pv	number of wall slices, to be ≤ 10
KTRACE	0	0	print intermediate output if ≥ 1
MTIME	360.	pv	maximum fire time (s)
MWPYR	28.97	pv	molecular weight of pyrolysis gases (g/g-mole)
NEWPLT	FALSE	FALSE	if true, start new plot frame
NEWPRP	TRUE	FALSE	if true, new data arrays will be given
NFLPC	0.	pv	percent of nitrogen, by weight, in fuel
OFLPC	0.	pv	percent of oxygen, by weight, in fuel
PLFUEL	FALSE	FALSE	if true, fuel is a pool fire
PLOT	FALSE	pv	if true, plot time-temperature curve
PNCH	FALSE	pv	if true, punch time-temperature curve
PRNT	none	pv	interval at which results are to be printed (s)
REGRES	0.	pv	rate of fuel regression (m/s)
RPSPEC	FALSE	FALSE	if true, use tabular input fuel pyrolysis
SH	0	pv	ratio of clear spacing between sticks/crib height for crib
SHAPE	2.	pv	shape factor in pyrolysis equation for wood sticks
SIZE	none	pv	for cribs: smallest dimension of stick (m) for pools: pool area (m^2)
STEADY	FALSE	FALSE	if true, only steady-state solution is to be sought
STOICH	FALSE	FALSE	if true, EITA=1 solution is sought in POOL

Table 1. (continued)

TBOILC	0.	pv	fuel vaporization temperature for pools (C)
THICKW	none	pv	wall thickness (m)
TINPT	0.	0.	optional input iteration gas temperature (K)
VTSPEC	FALSE	FALSE	if true, pessimize pyrolysis rate for a specified ventilation
WFLPC	0.	pv	percent of water, by weight, in fuel

Note:

pv = previous value

Table 2. List of variables

ADIA	true if walls are adiabatic
AFLOOR	area of floor (m^2)
AWALL	gross area of walls and ceiling (m^2)
AWALLN	AWALL minus window area
AWDOW	area of window (m^2)
BPF	maximum fraction of pyrolyzed fuel burned
BWDOW	width of window (m)
BWORST	window width (.LE.BWDOW) which maximizes gas temperatures (m)
C	moles of carbon in fuel (mole/kg fuel)
CD	discharge coefficient
CFLPC	percent of carbon, by weight, in fuel
CND	conductivity of a given wall slice (W/m-K)
CNDA	conductivity of the wall, as a function of temperature (W/m-K)
CNG	average conductivity, next to higher numbered slice
CNL	average conductivity, next to lower numbered slice
CNV	numerical factor in heat transfer coefficient
CPA	heat capacity of ambient air (J/kg-K)
CPCO	heat capacity of CO, as a function of temperature (J/kg-K)
CPCO2	heat capacity of CO_2, as a function of temperature (J/kg-K)
CPH2	heat capacity of H_2, as a function of temperature (J/kg-K)
CPH20	heat capacity of H_2O, as a function of temperature (J/kg-K)
CPN2	heat capacity of N_2, as a function of temperature (J/kg-K)
CPO2	heat capacity of O_2, as a function of temperature (J/kg-K)
CPPYR	heat capacity of pyrolysis gases, as a function of temperature (J/kg-K)
CPW	wall heat capacity, as a function of temperature (J/kg-K)
CVGROS	upper calorific value for dry fuel (J/kg)
CVNET	lower calorific value for moist fuel (J/kg)
DENF	Biot Number/2--fire side
DENSA	ambient air density (kg/m^3)
DENSW	wall density (kg/m^3)
DENU	Biot Number/2--unexposed side
DERIV1	current derivative of heat balance remainder (W/K)
DERIV2	previous derivative of heat balance remainder (W/K)
DIF	temperature error in iteration (K)
DTGAS	increment in gas temperature (K)
DTIME	time increment (s)
DX	wall thickness increment (m)
EF	effective flame grey body emissivity
EISCAN	true if seeking contant EITA≠1 solution
EITA	dimensionless air/fuel parameter for pool burning
EMS	computed wall emissivity for parallel plane problem
EMSA	wall emissivity, as a function of temperature
FC	true if in fuel control
FLOAD	fuel load (kg/m^2 of floor area)
FLREM	mass of fuel remaining at a given time (kg)
FLSPEC	true if fuel pyrolysis rate is fixed and ventilation pessimized
FUELPC	percent of original fuel supply still remaining
F1	current heat balance error (W)
F2	previous heat balance error (W)
G	acceleration of gravity (m/s^2)
H	moles of hydrogen in fuel (mole/kg fuel)
HCP	variable in solving differential equation
HF	effective heat transfer coefficient, fire side (W/m^2-K)
HFLPC	percent of hydrogen, by weight, in fuel
HU	effective heat transfer coefficient, unexposed side (W/m^2-K)
HIN	height of neutral plane (m)
HRATIO	fractional height of neutral plan above window bottom
HWDOW	height of window (m)
ILINE	line number

Table 2. (continued)

IPG	page number
IRUN	run number
IX	number of wall slices
IXC	number of middle slice
IXL	number of penultimate slice
J	number of current time step
JM	maximum number of time steps
JPRINT	output to be printed every JPRINT time steps
K	number of trial iterations at any given time step
KD	number of iterations to converge differential equation
KITER	equals 0 for normal operation, equals 1 for convergence failure
KNTRL	parameter indicating exit status
KTRACE	print intermediate tracing output if KTRACE-1
MTIME	maximum time for fire simulation (s)
MWIN	molecular weight of ambient air (g/g-mole)
MWOUT	molecular weight of exhaust gases (g/g-mole)
MWPYR	molecular weight of pyrolysis gases (g/g-mole)
N	moles of nitrogen in fuel (mole/kg fuel)
NCND	number of points in CNDA table
NCPW	number of points in CPW table
NEMS	number of points in EMSA table
NEWPLT	true if start new plot frame (not overlay previous one)
NEWPRP	true if read in new set of tabular data
NFLPC	percent of nitrogen, by weight, in fuel
NQGEN	number of points in QGEN table
NRP	number of points in RPX table
O	moles of oxygen in fuel (mole/kg fuel)
OFLPC	percent of oxygen by weight, in fuel
OPENF	opening factor ration ($m^{2.5}$)
PLFUEL	true if pool fire configuration
PLOT	true if plot time-temperature curve
PNCH	true if punch time-temperature curve
PRNT	number of times per second output is to be printed
QCONW	heat transfered to walls by convection (W)
QFIRE	heat generated by combustion (W)
QFLOW	net flow enthalpy (exhaust minus inflow) (W)
QFUEL	heat lost in heating up unburned fuel fraction (W)
QGEN	wall heat generation, as a function of temp (W/m^3)
QRADO	heat radiated out the window (W)
QFLOW	new flow enthalpy (exhaust minus inflow) (W)
QFUEL	heat lost in heating up unburned fuel fraction (W)
QGEN	wall heat generation, as a function of temp (W/m^3)
QRADO	heat radiated out the window (W)
QRADW	heat transfered to walls by radiation (W)
QWLSUM	total heat removed from compartment and passing into the walls (J)
R	stoichiometric air/fuel mass ratio
RO	stoichiometric oxygen/fuel mass ratio
RC	rate of burning (kg/s)
REGRES	rate of fuel surface regression (m/s)
RMA	mass inflow rate of air (kg/s)
RMF	mass outflow rate of hot gases (kg/s)
RP	rate of pyrolysis (kg/s)
RPSPEC	true if rate of pyrolysis is prescribed as input
RPX	rate of pyrolysis, as a function of time (kg/s)
SCAN	true if search for solution by scanning temperatures
SH	ratio of clear spacing between sticks to crib height
SHAPE	contant indicating shape of fuel sticks
SIGMA	Stefan-Boltzmann constant (W/m^2-K^4)
SIZE	thickness of crib sticks (m)
	area of pool (m^2)
SIZE1	pool area for EITA=1 condition (m^2)

Table 2. (continued)

STEADY	true if only steady-state calculation to be made
STOICH	true if pool fire and EITA=1
TAMB	ambient temperature (K)
TGAS	gas temperature (K)
TGAS1	previous value of TGAS (K)
TGAS2	previous value of TGAS1 (K)
TGASC	gas temperature (C)
TGASN	closest gas temperature, lower than true (K)
TGASP	closest gas temperature, higher than true (K)
TGOLD	value of TGAS from prior time step (K)
THICKW	wall thickness (m)
TINPT	input trial starting gas temperature (K)
TITLE	title of this run
TSF	wall surface temperature, fire side (K)
TSU	wall surface temperature, unexposed side (K)
TTIME	total time (s)
T1	old wall temperature profile (K)
T2	new wall temperature profile (K)
T2C	wall temperature profile (C)
VAVGIN	average inflow velocity (m/s)
VTSPEC	true if ventilation is fixed and pyrolysis rate pessimized
W	moles of water in fuel (mole/kg fuel)
WA	format constant
WB	format constant
WFLPC	percent of water, by weight, in fuel
WTFUEL	initial total mass of fuel (kg)
YCO2	mass fraction of CO_2 in outflow
YH20	mass fraction of H_2O in outflow
YN2	mass fraction of N_2 in outflow
YO2	mass fraction of O_2 in outflow
YPYR	mass fraction of pyrolysates in outflow

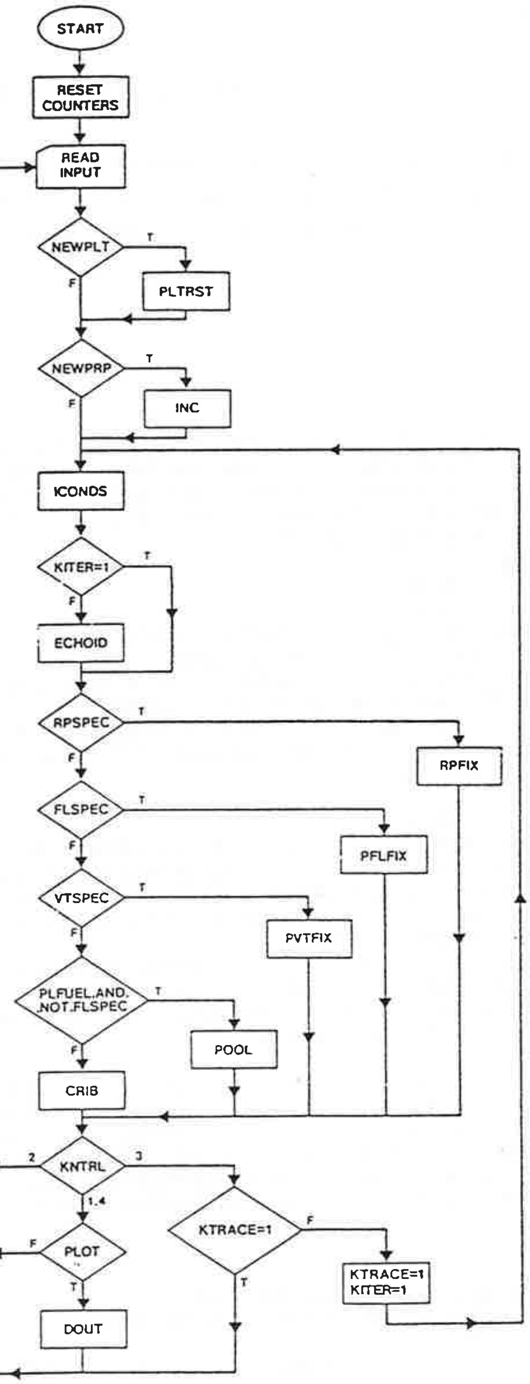

Figure 1. Flow chart for main program COMPF2

APPENDIX A -- SAMPLE PROBLEMS

Given below is a set of ten concatenated input problems. Each problem is intended to test out a subroutine or other feature of the program. The output for the problems is given following the input.

```
TEST PROGRAM FOR POOL FIRE, STEADY STATE, EITA=1.0
 $VARS AFLOOR=20.,AWALL=80.,AWDOW=4.,BPF=0.7,CD=0.68,CFLPC=85.7,
   CVGROS=46.5E6,DENSW=790.,DHP=2.4E6,EITA=1.0,FLOAD=20.,HFLPC=14.3,
   HWDOW=1.5,OFLPC=0.0,PLFUEL=T,STOICH=T,TBOILC=390.,
   THICKW=0.038,WFLPC=0.0$
001000001
           0.17
           0.5
TEST PROGRAM FOR POOL FIRE, STEADY STATE, EITA=0.01
 $VARS EISCAN=T,EITA=0.01,PLFUEL=T$
TEST PROGRAM WITH DELIBERATE ERROR TO CHECK KTRACE OPERATION
 $VARS EISCAN=T,PLFUEL=T,TBOILC=2000.$
TEST PROGRAM FOR POOL FIRE, TRANSIENT CASE, SIZE=7.5 M2
 $VARS DTIME=60.,MTIME=3600.,NEWPRP=T, PLFUEL=T, PRNT=60.,SIZE=7.5,
   TBOILC=390.$
000001
           840.
TEST PROGRAM FOR WOOD CRIB FIRE, REGRES SPECIFIED
 $VARS CFLPC=44.4,CVGROS=18.8E6,FLOAD=10.0,HFLPC=5.4,OFLPC=38.2,
   REGRES=1.5E-5,SHAPE=2.0,SIZE=0.05,WFLPC=12.0$
TEST PROGRAM 1 FOR WOOD CRIB FIRE, NILSSON'S FORMULAS
 $VARS REGRES=0.0,SH=0.10$
TEST PROGRAM 2 FOR WOOD CRIB FIRE, NILSSON'S FORMULAS
 $VARS FLOAD=20.,SH=0.20$
TEST PROGRAM FOR PVTFIX ROUTINE, VARIABLE WALL PROPERTIES
 $VARS NEWPRP=T,VTSPEC=T$
004008
273.       0.21       372.       0.21       373.       0.16       1073.      0.26
273.       1090.      372.       1090.      373.       47300.     383.       47300.
384.       5000.      413.       5000.      414.       840.       1073.      840.
TEST PROGRAM FOR PFLFIX ROUTINE, POOL OPTION
 $VARS AWDOW=10.,CFLPC=85.7,CVGROS=46.5E6,FLSPEC=T,HFLPC=14.3,NEWPRP=T,
   OFLPC=0.0,PLFUEL=T,SIZE=5.0,WFLPC=0.0$
001001
           0.17
           840.
TEST PROGRAM FOR RPFIX ROUTINE
 $VARS MTIME=1903.,NEWPRP=T,RPSPEC=T$
000000000003
0.0        0.12       120.       0.12       121.       0.25
```

TEST PROGRAM FOR POOL FIRE, STEADY STATE, EITA=1.0 COMPF2 VERSION 1.1 - RUN NO. 1

----GEOMETRY AND VENTILATION----

WALL SURFACE AREA = 80.0 M2
FLOOR AREA = 20.00 M2
WINDOW HEIGHT = 1.50 M
AREA = 4.00 M2
OPENING FACTOR = 4.899 M2.5
DISCHARGE COEFF.= .68

----FUEL LOAD PROPERTIES----

FIRE LOAD PER FLOOR AREA = 20.0 KG/M2
TOTAL ENTHALPY OF PYROLYSIS= 2.40+06 J/KG
BOILING TEMPERATURE= 390. DEG C

FUEL COMPOSITION
CARBON = 85.7 PERCENT BY WEIGHT
HYDROGEN = 14.3 PERCENT
OXYGEN = .0 PERCENT
NITROGEN = .0 PERCENT
WATER = .0 PERCENT
R = 14.78
RO= 3.43
HEAT OF COMBUSTION OF DRY FUEL = 46.50+06 J/KG
LOWER ACTUAL HEAT OF COMBUSTION = 43.36+06 J/KG
MOLECULAR WEIGHT OF UNBURNT PYROLYSATES = 28.97
CP OF PYROLYSIS GAS = (.1127*TGAS + 1010.) J/KG-K
MAXIMUM FRACTION OF PYROLYSATES BURNED = .70
GREY-GAS FLAME EMISSIVITY = .900

----WALL THERMAL PROPERTIES----

THICKNESS = .038 M
DENSITY = 790. KG/M3

THERMAL CONDUCTIVITY = .170 W/M-K

EMISSIVITY = .50

THERMOPLASTIC POOL FIRE PAGE NO. 1 RUN NO. 1

	TIME S	TEMP GAS,C	WALL TEMPS C			RP KG/S	RC KG/S	EXC.PYR. KG/S	FUEL PCT	AIR IN KG/S	N.P.	VELOCITY M/S	MOL.WT	FUEL CNTRL
1	0.	1169.	1157.	709.	262.	.153	.107	.046	100.0	2.26	.36	1.93	29.93	F

STOICHIOMETRIC FUEL SIZE= 1.741 M2

THERMOPLASTIC POOL FIRE PAGE NO. 1 RUN NO. 1

TIME	HEAT BALANCE GAS FLOW PCT	WND RAD PCT	WALL CNV PCT	WALL RAD PCT	Q-FIRE W	Q-WALL SUM J	YO2 PCT MASS	YN2 PCT MASS	YCO2 PCT MASS	YH2O PCT MASS	YPYR PCT MASS
0.	69.955	21.096	.229	6.331	4.639+06	0.000	.063	.721	.139	.057	.019

TEST PROGRAM FOR POOL FIRE, STEADY STATE, EITA=0.01 COMPF2 VERSION 1.1 - RUN NO. 2

----GEOMETRY AND VENTILATION----

WALL SURFACE AREA = 80.0 M2
FLOOR AREA = 20.00 M2
WINDOW HEIGHT = 1.50 M
AREA = 4.00 M2
OPENING FACTOR = 4.899 M2.5
DISCHARGE COEFF.= .68

----FUEL LOAD PROPERTIES----

FIRE LOAD PER FLOOR AREA = 20.0 KG/M2
TOTAL ENTHALPY OF PYROLYSIS= 2.40+06 J/KG
BOILING TEMPERATURE= 390. DEG C

FUEL COMPOSITION
CARBON = 85.7 PERCENT BY WEIGHT
HYDROGEN = 14.3 PERCENT
OXYGEN = .0 PERCENT
NITROGEN = .0 PERCENT
WATER = .0 PERCENT
R = 14.78
RO= 3.43
HEAT OF COMBUSTION OF DRY FUEL = 46.50+06 J/KG
LOWER ACTUAL HEAT OF COMBUSTION = 43.36+06 J/KG
MOLECULAR WEIGHT OF UNBURNT PYROLYSATES = 28.97
CP OF PYROLYSIS GAS = (.1127*TGAS + 1010.) J/KG-K
MAXIMUM FRACTION OF PYROLYSATES BURNED = .70
GREY-GAS FLAME EMISSIVITY = .900
FUEL AREA= 174.07 M2

----WALL THERMAL PROPERTIES----

THICKNESS = .038 M
DENSITY = 790. KG/M3

THERMAL CONDUCTIVITY = .170 W/M-K

EMISSIVITY = .50

THERMOPLASTIC POOL FIRE PAGE NO. 1 RUN NO. 2

	TIME S	TEMP GAS,C	WALL TEMPS ,C			RP KG/S	RC KG/S	EXC.PYR. KG/S	FUEL PCT	AIR IN KG/S	N.P.	VELOCITY M/S	MOL.WT	FUEL CNTRL
1	0.	525.	501.	327.	153.	.785	.097	.688	100.0	2.04	.37	1.72	29.71	F

THERMOPLASTIC POOL FIRE PAGE NO. 1 RUN NO. 2

TIME	HEAT BALANCE GAS FLOW PCT	WND RAD PCT	WALL CNV PCT	WALL RAD PCT	Q-FIRE W	Q-WALL SUM J	YO2 PCT MASS	YN2 PCT MASS	YCO2 PCT MASS	YH2O PCT MASS	YPYR PCT MASS
0.	37.526	2.152	.608	2.218	4.188+06	0.000	.049	.555	.107	.044	.245

```
TEST PROGRAM WITH DELIBERATE ERROR TO CHECK KTRACE OPERATION                    COMPF2 VERSION 1.1 - RUN NO.   3

-----GEOMETRY AND VENTILATION-----

WALL SURFACE AREA =      80.0 M2
FLOOR AREA =     20.00 M2
WINDOW HEIGHT =      1.50 M
          AREA =     4.00 M2
OPENING FACTOR =   4.899 M2.5
DISCHARGE COEFF.=  .68


-----FUEL LOAD PROPERTIES-----

FIRE LOAD PER FLOOR AREA =  20.0 KG/M2
TOTAL ENTHALPY OF PYROLYSIS=    2.40+06 J/KG
BOILING TEMPERATURE=2000. DEG C

FUEL COMPOSITION
CARBON    = 85.7 PERCENT BY WEIGHT
HYDROGEN = 14.3 PERCENT
OXYGEN   =   .0 PERCENT
NITROGEN =   .0 PERCENT
WATER    =   .0 PERCENT
R = 14.78
RO=  3.43
HEAT OF COMBUSTION OF DRY FUEL =   46.50+06 J/KG
LOWER ACTUAL HEAT OF COMBUSTION =   43.36+06 J/KG
MOLECULAR WEIGHT OF UNBURNT PYROLYSATES =  28.97
CP OF PYROLYSIS GAS = ( .1127*TGAS +  1010.) J/KG-K
MAXIMUM FRACTION OF PYROLYSATES BURNED =   .70
GREY-GAS FLAME EMISSIVITY =  .900
FUEL AREA=    174.07 M2

-----WALL THERMAL PROPERTIES-----

THICKNESS =  .038 M
DENSITY =   790. KG/M3

THERMAL CONDUCTIVITY =    .170 W/M-K

EMISSIVITY =  .50

            THERMOPLASTIC POOL FIRE                                             PAGE NO.  1    RUN NO.   3


        TIME   TEMP        WALL TEMPS      RP     RC    EXC.PYR.   FUEL    AIR IN     N.P.   VELOCITY  MOL.WT   FUEL
         S     GAS.C           C          KG/S   KG/S    KG/S      PCT     KG/S                M/S              CNTRL


---ITERATION FAILURE---
TGAS=          1890.00


TGAS.LT.TBOIL   TGAS=  1890.0   GO TO NEXT CASE


 RUN NO.   3

 TGAS1     TGAS2     F1       F2       DERIV1    K  KD  KH    J   T2(I)    TSF      QFIRE     QFLOW      QRADW       RP      RC

 1800.00      .00  2.43+08  0.00      1.35+05   1   3   0    1  1730.86  1791.43  4.026+05 -1.009+08  4.052+05-59.938   .009
 1810.00  1800.00  2.40+08  2.43+08 -2.93+05   2   3   0    1  1740.49  1801.51  2.891+04 -1.008+08  4.083+05-59.068   .001
 1900.00  1810.00  2.10+08  2.40+08 -3.33+05   3   3   0    1  1827.13  1892.16  2.405+03 -9.183+07  4.363+05-50.558   .000
```

TEST PROGRAM FOR POOL FIRE. TRANSIENT CASE. SIZE=7.5 M2

----GEOMETRY AND VENTILATION----

```
WALL SURFACE AREA =      80.0 M2
FLOOR AREA =     20.00 M2
WINDOW HEIGHT =      1.50 M
         AREA =      4.00 M2
OPENING FACTOR =    4.899 M2.5
DISCHARGE COEFF.=   .68
```

----FUEL LOAD PROPERTIES----

```
FIRE LOAD PER FLOOR AREA =   20.0 KG/M2
TOTAL ENTHALPY OF PYROLYSIS=     2.40+06 J/KG
BOILING TEMPERATURE= 390. DEG C

FUEL COMPOSITION
CARBON    = 85.7 PERCENT BY WEIGHT
HYDROGEN  = 14.3 PERCENT
OXYGEN    =   .0 PERCENT
NITROGEN  =   .0 PERCENT
WATER     =   .0 PERCENT
R = 14.78
R0=  3.43
HEAT OF COMBUSTION OF DRY FUEL =    46.50+06 J/KG
LOWER ACTUAL HEAT OF COMBUSTION =    43.36+06 J/KG
MOLECULAR WEIGHT OF UNBURNT PYROLYSATES =   28.97
CP OF PYROLYSIS GAS = ( .1127*TGAS +  1010.) J/KG-K
MAXIMUM FRACTION OF PYROLYSATES BURNED =    .70
GREY-GAS FLAME EMISSIVITY =  .900
FUEL AREA=       7.50 M2
```

----WALL THERMAL PROPERTIES----

```
THICKNESS =   .038 M
DENSITY =    790. KG/M3

THERMAL CONDUCTIVITY =     .170 W/M-K

HEAT CAPACITY =     840. J/KG-K

EMISSIVITY =   .50
```

THERMOPLASTIC POOL FIRE PAGE NO. 1 RUN NO. 4

	TIME S	TEMP GAS.C	WALL TEMPS C			RP KG/S	RC KG/S	EXC.PYR. KG/S	FUEL PCT	AIR IN KG/S	N.P.	VELOCITY M/S	MOL.WT	FUEL CNTRL
1	0.	739.	513.	26.	25.	.306	.108	.198	95.4	2.29	.38	1.86	29.87	F
2	60.	826.	712.	34.	25.	.362	.106	.256	90.0	2.23	.37	1.87	29.85	F
3	120.	852.	763.	53.	25.	.381	.105	.277	84.3	2.21	.37	1.87	29.85	F
4	180.	870.	798.	83.	26.	.396	.104	.292	78.3	2.20	.37	1.87	29.84	F
5	240.	882.	820.	117.	27.	.406	.104	.302	72.2	2.19	.36	1.87	29.84	F
6	300.	891.	836.	151.	30.	.413	.103	.310	66.0	2.18	.36	1.87	29.83	F
7	360.	898.	847.	183.	34.	.419	.103	.316	59.7	2.18	.36	1.87	29.83	F
8	420.	903.	857.	213.	39.	.424	.103	.321	53.4	2.17	.36	1.87	29.83	F
9	480.	907.	864.	240.	46.	.428	.103	.325	47.0	2.17	.36	1.87	29.83	F
10	540.	911.	871.	265.	53.	.431	.103	.328	40.5	2.17	.36	1.87	29.83	F
11	600.	914.	876.	288.	61.	.434	.102	.331	34.0	2.16	.36	1.87	29.82	F
12	660.	917.	881.	309.	69.	.436	.102	.334	27.5	2.16	.36	1.87	29.82	F
13	720.	919.	885.	329.	77.	.439	.102	.336	20.9	2.16	.36	1.87	29.82	F
14	780.	921.	888.	347.	85.	.440	.102	.338	14.3	2.16	.36	1.87	29.82	F
15	840.	923.	892.	364.	93.	.442	.102	.340	7.6	2.16	.36	1.87	29.82	F
16	900.	925.	894.	380.	101.	.444	.102	.342	1.0	2.15	.36	1.87	29.82	F
17	960.	926.	897.	394.	108.	.445	.102	.343	.0	2.15	.36	1.87	29.82	F
18	1020.	358.	534.	407.	115.	.000	.000	.000	.0	2.47	.43	1.78	26.90	T
19	1080.	255.	409.	414.	122.	.000	.000	.000	.0	2.39	.45	1.66	26.95	T
20	1140.	211.	350.	412.	128.	.000	.000	.000	.0	2.32	.45	1.59	26.94	T
21	1200.	184.	310.	402.	133.	.000	.000	.000	.0	2.26	.46	1.54	26.90	T
22	1260.	164.	280.	387.	137.	.000	.000	.000	.0	2.21	.46	1.49	26.87	T
23	1320.	149.	257.	371.	141.	.000	.000	.000	.0	2.16	.46	1.45	26.84	T
24	1380.	138.	238.	355.	143.	.000	.000	.000	.0	2.12	.47	1.42	26.80	T
25	1440.	129.	222.	339.	145.	.000	.000	.000	.0	2.09	.47	1.39	26.78	T
26	1500.	121.	209.	324.	145.	.000	.000	.000	.0	2.05	.47	1.36	26.75	T
27	1560.	114.	198.	310.	145.	.000	.000	.000	.0	2.02	.47	1.34	26.73	T
28	1620.	108.	188.	296.	144.	.000	.000	.000	.0	1.99	.47	1.31	26.70	T
29	1680.	103.	179.	284.	142.	.000	.000	.000	.0	1.97	.47	1.30	26.67	T
30	1740.	99.	171.	272.	140.	.000	.000	.000	.0	1.95	.47	1.28	26.64	T
31	1800.	95.	164.	261.	137.	.000	.000	.000	.0	1.92	.48	1.26	26.62	T
32	1860.	91.	157.	251.	135.	.000	.000	.000	.0	1.90	.48	1.24	26.60	T
33	1920.	88.	151.	241.	132.	.000	.000	.000	.0	1.88	.48	1.23	26.58	T
34	1980.	85.	146.	232.	129.	.000	.000	.000	.0	1.86	.48	1.22	26.56	T
35	2040.	82.	141.	223.	126.	.000	.000	.000	.0	1.85	.48	1.20	26.54	T
36	2100.	90.	136.	215.	123.	.000	.000	.000	.0	1.83	.48	1.19	26.52	T

THERMOPLASTIC POOL FIRE PAGE NO. 1 RUN NO. 4

TIME	HEAT BALANCE GAS FLOW PCT	WND RAD PCT	WALL CNV PCT	WALL RAD PCT	Q-FIRE W	Q-WALL SUM J	YO2 PCT MASS	YN2 PCT MASS	YCO2 PCT MASS	YH2O PCT MASS	YPYR PCT MASS
0.	44.886	5.022	11.092	28.910	4.694+06	1.127+08	.060	.679	.131	.054	.076
60.	51.859	7.174	4.559	22.952	4.582+06	1.883+08	.058	.663	.128	.052	.099
120.	54.089	7.950	3.297	20.091	4.543+06	2.520+08	.058	.657	.127	.052	.107
180.	55.726	8.546	2.523	17.707	4.514+06	3.068+08	.057	.652	.126	.052	.113
240.	56.787	8.943	2.091	16.097	4.496+06	3.559+08	.057	.650	.126	.051	.116
300.	57.586	9.250	1.787	14.794	4.481+06	4.005+08	.057	.647	.125	.051	.119
360.	58.196	9.486	1.574	13.785	4.470+06	4.417+08	.057	.646	.125	.051	.122
420.	58.693	9.681	1.411	12.954	4.461+06	4.801+08	.057	.644	.125	.051	.124
480.	59.095	9.840	1.283	12.252	4.453+06	5.163+08	.056	.643	.124	.051	.125
540.	59.440	9.978	1.180	11.659	4.447+06	5.505+08	.056	.642	.124	.051	.126
600.	59.737	10.097	1.094	11.144	4.442+06	5.832+08	.056	.641	.124	.051	.128
660.	59.996	10.201	1.022	10.691	4.437+06	6.143+08	.056	.641	.124	.051	.129
720.	60.224	10.294	.960	10.290	4.433+06	6.443+08	.056	.640	.124	.051	.130
780.	60.427	10.376	.907	9.929	4.429+06	6.731+08	.056	.639	.124	.051	.130
840.	60.610	10.451	.860	9.604	4.426+06	7.008+08	.056	.639	.123	.051	.131
900.	60.776	10.518	.818	9.308	4.423+06	7.277+08	.056	.638	.123	.051	.132
960.	60.927	10.580	.781	9.037	4.420+06	7.537+08	.056	.638	.123	.050	.132
1020.	96.257	3.743	-40.770	-59.079	0.000	7.537+08	.230	.770	.000	.000	.000
1080.	97.357	2.643	-52.654	-47.486	0.000	7.537+08	.230	.770	.000	.000	.000
1140.	97.717	2.283	-58.391	-41.795	0.000	7.537+08	.230	.770	.000	.000	.000
1200.	97.914	2.086	-62.064	-37.859	0.000	7.537+08	.230	.770	.000	.000	.000
1260.	98.036	1.964	-64.780	-35.129	0.000	7.537+08	.230	.770	.000	.000	.000
1320.	98.120	1.880	-67.042	-33.129	0.000	7.537+08	.230	.770	.000	.000	.000
1380.	98.180	1.820	-68.677	-31.505	0.000	7.537+08	.230	.770	.000	.000	.000
1440.	98.223	1.777	-69.805	-30.128	0.000	7.537+08	.230	.770	.000	.000	.000
1500.	98.258	1.742	-71.093	-29.103	0.000	7.537+08	.230	.770	.000	.000	.000
1560.	98.285	1.715	-71.919	-28.159	0.000	7.537+08	.230	.770	.000	.000	.000
1620.	98.306	1.694	-72.779	-27.407	0.000	7.537+08	.230	.770	.000	.000	.000
1680.	98.324	1.676	-73.334	-26.712	0.000	7.537+08	.230	.770	.000	.000	.000
1740.	98.338	1.662	-73.959	-26.146	0.000	7.537+08	.230	.770	.000	.000	.000
1800.	98.349	1.651	-74.362	-25.603	0.000	7.537+08	.230	.770	.000	.000	.000
1860.	98.359	1.641	-74.862	-25.162	0.000	7.537+08	.230	.770	.000	.000	.000
1920.	98.367	1.633	-75.260	-24.756	0.000	7.537+08	.230	.770	.000	.000	.000
1980.	98.374	1.626	-75.620	-24.394	0.000	7.537+08	.230	.770	.000	.000	.000
2040.	98.379	1.621	-75.777	-24.028	0.000	7.537+08	.230	.770	.000	.000	.000
2100.	98.384	1.616	-76.079	-23.735	0.000	7.537+08	.230	.770	.000	.000	.000

TEST PROGRAM FOR WOOD CRIB FIRE. REGRES SPECIFIED

----GEOMETRY AND VENTILATION----

WALL SURFACE AREA = 80.0 M2
FLOOR AREA = 20.00 M2
WINDOW HEIGHT = 1.50 M
AREA = 4.00 M2
OPENING FACTOR = 4.899 M2.5
DISCHARGE COEFF.= .68

-----FUEL LOAD PROPERTIES-----

FIRE LOAD PER FLOOR AREA = 10.0 KG/M2

FUEL COMPOSITION
CARBON = 44.4 PERCENT BY WEIGHT
HYDROGEN = 5.4 PERCENT
OXYGEN = 38.2 PERCENT
NITROGEN = .0 PERCENT
WATER = 12.0 PERCENT
R = 5.32
RO= 1.23
HEAT OF COMBUSTION OF DRY FUEL = 18.80+06 J/KG
LOWER ACTUAL HEAT OF COMBUSTION = 15.07+06 J/KG
MOLECULAR WEIGHT OF UNBURNT PYROLYSATES = 28.97
CP OF PYROLYSIS GAS = (.1127*TGAS + 1010.) J/KG-K
MAXIMUM FRACTION OF PYROLYSATES BURNED = .70
GREY-GAS FLAME EMISSIVITY = .900
RATE OF REGRESSION = 15.00-06 M/S
FUEL DIMENSION = .050 M
SHAPE FACTOR = 2.00

-----WALL THERMAL PROPERTIES-----

THICKNESS = .038 M
DENSITY = 790. KG/M3

THERMAL CONDUCTIVITY = .170 W/M-K

HEAT CAPACITY = 840. J/KG-K

EMISSIVITY = .50

CRIB FIRE

PAGE NO. 1 RUN NO. 5

	TIME S	TEMP GAS.C	WALL TEMPS C			RP KG/S	RC KG/S	EXC.PYR. KG/S	FUEL PCT	AIR IN KG/S	N.P.	VELOCITY M/S	MOL.WT	FUEL CNTRL
1	0.	510.	296.	26.	25.	.240	.168	.072	92.8	2.35	.41	1.80	29.90	T
2	60.	560.	422.	30.	25.	.231	.162	.069	85.9	2.35	.40	1.82	29.86	T
3	120.	572.	461.	41.	25.	.222	.156	.067	79.2	2.36	.40	1.83	29.83	T
4	180.	574.	482.	58.	25.	.214	.150	.064	72.8	2.36	.40	1.83	29.79	T
5	240.	571.	490.	78.	26.	.205	.143	.061	66.6	2.37	.40	1.83	29.76	T
6	300.	563.	492.	98.	28.	.196	.137	.059	60.8	2.37	.40	1.83	29.72	T
7	360.	553.	489.	117.	30.	.187	.131	.056	55.2	2.38	.41	1.83	29.69	T
8	420.	540.	483.	134.	33.	.178	.125	.053	49.8	2.38	.41	1.82	29.65	T
9	480.	526.	474.	149.	37.	.169	.119	.051	44.7	2.39	.41	1.82	29.62	T
10	540.	510.	463.	162.	42.	.161	.112	.048	39.9	2.39	.41	1.81	29.58	T
11	600.	494.	451.	174.	46.	.152	.106	.045	35.4	2.40	.41	1.81	29.55	T
12	660.	476.	437.	184.	51.	.143	.100	.043	31.1	2.40	.42	1.80	29.51	T
13	720.	457.	423.	192.	56.	.134	.094	.040	27.1	2.40	.42	1.79	29.48	T
14	780.	438.	408.	199.	61.	.125	.087	.037	23.3	2.40	.42	1.78	29.44	T
15	840.	417.	392.	204.	66.	.116	.081	.035	19.8	2.40	.42	1.76	29.41	T
16	900.	396.	375.	209.	70.	.107	.075	.032	16.6	2.40	.43	1.75	29.37	T
17	960.	374.	358.	212.	74.	.098	.069	.029	13.7	2.39	.43	1.73	29.33	T
18	1020.	352.	341.	214.	78.	.089	.062	.027	11.0	2.38	.43	1.71	29.30	T
19	1080.	328.	324.	216.	81.	.080	.056	.024	8.6	2.37	.44	1.69	29.26	T
20	1140.	304.	307.	216.	84.	.071	.049	.021	6.5	2.35	.44	1.66	29.23	T
21	1200.	279.	289.	216.	87.	.061	.043	.018	4.7	2.33	.45	1.63	29.19	T
22	1260.	253.	271.	214.	89.	.052	.036	.016	3.1	2.29	.45	1.59	29.15	T
23	1320.	226.	252.	213.	91.	.042	.030	.013	1.9	2.25	.45	1.54	29.12	T
24	1380.	199.	233.	210.	93.	.033	.023	.010	.9	2.19	.46	1.48	29.08	T
25	1440.	169.	213.	207.	94.	.022	.016	.007	.2	2.10	.47	1.40	29.03	T
26	1500.	134.	190.	203.	95.	.011	.008	.003	.0	1.96	.47	1.29	28.98	T
27	1560.	100.	166.	198.	96.	.000	.000	.000	.0	1.74	.48	1.13	28.92	T
28	1620.	92.	152.	193.	96.	.000	.000	.000	.0	1.68	.48	1.08	28.92	T
29	1680.	87.	143.	187.	96.	.000	.000	.000	.0	1.63	.48	1.05	28.92	T
30	1740.	83.	135.	181.	96.	.000	.000	.000	.0	1.59	.49	1.02	28.92	T
31	1800.	79.	129.	175.	95.	.000	.000	.000	.0	1.55	.49	.99	28.92	T

CRIB FIRE

PAGE NO. 1 RUN NO. 5

TIME	HEAT BALANCE GAS FLOW PCT	WND RAD PCT	WALL CNV PCT	WALL RAD PCT	Q-FIRE W	Q-WALL SUM J	YO2 PCT MASS	YN2 PCT MASS	YCO2 PCT MASS	YH2O PCT MASS	YPYR PCT MASS
0.	55.544	3.303	19.249	21.906	2.531+06	6.250+07	.129	.699	.106	.043	.028
60.	63.693	4.410	11.122	20.800	2.438+06	1.092+08	.132	.701	.102	.041	.027
120.	67.496	4.843	8.615	19.040	2.345+06	1.481+08	.136	.704	.098	.040	.026
180.	70.479	5.113	7.081	17.334	2.252+06	1.811+08	.139	.706	.094	.038	.025
240.	72.815	5.238	6.119	15.828	2.159+06	2.095+08	.143	.709	.091	.037	.024
300.	74.815	5.278	5.434	14.473	2.066+06	2.342+08	.147	.711	.087	.035	.023
360.	76.584	5.253	4.919	13.244	1.973+06	2.557+08	.150	.714	.083	.034	.022
420.	78.203	5.181	4.507	12.109	1.880+06	2.745+08	.154	.716	.079	.032	.021
480.	79.721	5.074	4.160	11.046	1.786+06	2.908+08	.158	.719	.075	.030	.020
540.	81.173	4.941	3.852	10.036	1.693+06	3.049+08	.161	.722	.072	.029	.019
600.	82.590	4.787	3.564	9.062	1.599+06	3.170+08	.165	.724	.068	.027	.018
660.	83.993	4.619	3.280	8.112	1.505+06	3.273+08	.169	.727	.064	.026	.017
720.	85.405	4.440	2.987	7.173	1.411+06	3.359+08	.172	.729	.060	.024	.016
780.	86.848	4.254	2.673	6.232	1.317+06	3.429+08	.176	.732	.056	.023	.015
840.	88.347	4.064	2.324	5.281	1.222+06	3.485+08	.180	.735	.052	.021	.014
900.	89.926	3.872	1.924	4.299	1.127+06	3.527+08	.183	.737	.049	.020	.013
960.	91.618	3.681	1.461	3.268	1.032+06	3.556+08	.187	.740	.045	.018	.012
1020.	93.446	3.492	.919	2.150	9.368+05	3.573+08	.191	.742	.041	.017	.011
1080.	95.478	3.308	.318	.902	8.407+05	3.580+08	.194	.745	.037	.015	.010
1140.	96.899	3.101	-.220	-.632	7.440+05	3.580+08	.198	.748	.033	.013	.009
1200.	97.133	2.867	-1.288	-2.188	6.465+05	3.580+08	.202	.750	.029	.012	.008
1260.	97.353	2.647	-3.035	-3.814	5.479+05	3.580+08	.206	.753	.025	.010	.007
1320.	97.559	2.441	-5.736	-5.614	4.476+05	3.580+08	.210	.756	.021	.009	.006
1380.	97.750	2.250	-10.041	-7.776	3.446+05	3.580+08	.214	.759	.017	.007	.004
1440.	97.922	2.078	-17.571	-10.734	2.366+05	3.580+08	.218	.762	.012	.005	.003
1500.	98.072	1.928	-34.791	-16.210	1.134+05	3.580+08	.224	.766	.006	.003	.002
1560.	98.139	1.861	-73.760	-26.340	0.000	3.580+08	.230	.770	.000	.000	.000
1620.	98.135	1.865	-74.639	-25.412	0.000	3.580+08	.230	.770	.000	.000	.000
1680.	98.127	1.873	-75.239	-24.810	0.000	3.580+08	.230	.770	.000	.000	.000
1740.	98.116	1.884	-75.698	-24.354	0.000	3.580+08	.230	.770	.000	.000	.000
1800.	98.104	1.896	-76.063	-23.994	0.000	3.580+08	.230	.770	.000	.000	.000

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TEST PROGRAM 1 FOR WOOD CRIB FIRE. NILSSON'S FORMULAS

----GEOMETRY AND VENTILATION----

WALL SURFACE AREA =       80.0 M2
FLOOR AREA =     20.00 M2
WINDOW HEIGHT =       1.50 M
         AREA =       4.00 M2
OPENING FACTOR =    4.899 M2.5
DISCHARGE COEFF.=   .68


----FUEL LOAD PROPERTIES----

FIRE LOAD PER FLOOR AREA =  10.0 KG/M2

FUEL COMPOSITION
CARBON   = 44.4 PERCENT BY WEIGHT
HYDROGEN =  5.4 PERCENT
OXYGEN   = 38.2 PERCENT
NITROGEN =   .0 PERCENT
WATER    = 12.0 PERCENT
R =  5.32
RO=  1.23
HEAT OF COMBUSTION OF DRY FUEL =   18.80+06 J/KG
LOWER ACTUAL HEAT OF COMBUSTION =   15.07+06 J/KG
MOLECULAR WEIGHT OF UNBURNT PYROLYSATES =  28.97
CP OF PYROLYSIS GAS = ( .1127*TGAS +  1010.) J/KG-K
MAXIMUM FRACTION OF PYROLYSATES BURNED =   .70
GREY-GAS FLAME EMISSIVITY =  .900
RATE OF REGRESSION =  00.00    M/S
FUEL DIMENSION =  .050 M
SHAPE FACTOR = 2.00

CRIB SPACING/HEIGHT RATIO=  .100

----WALL THERMAL PROPERTIES----

THICKNESS =  .038 M
DENSITY =   790. KG/M3

THERMAL CONDUCTIVITY =    .170 W/M-K

HEAT CAPACITY =    840. J/KG-K

EMISSIVITY =  .50
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CRIB FIRE PAGE NO. 1 RUN NO. 6

	TIME S	TEMP GAS.C	WALL TEMPS C			RP KG/S	RC KG/S	EXC.PYR. KG/S	FUEL PCT	AIR IN KG/S	N.P.	VELOCITY M/S	MOL.WT	FUEL CNTRL
1	0.	408.	217.	25.	25.	.175	.123	.053	94.7	2.36	.42	1.74	29.65	T
2	60.	452.	315.	28.	25.	.176	.123	.053	89.4	2.38	.42	1.78	29.65	T
3	120.	472.	357.	36.	25.	.175	.123	.353	84.2	2.38	.41	1.79	29.65	T
4	180.	487.	386.	49.	25.	.176	.123	.053	78.9	2.38	.41	1.80	29.65	T
5	240.	498.	408.	64.	26.	.176	.123	.053	73.6	2.38	.41	1.80	29.65	T
6	300.	506.	424.	80.	27.	.176	.123	.053	68.3	2.38	.41	1.81	29.65	T
7	360.	513.	438.	96.	29.	.176	.123	.053	63.0	2.38	.41	1.81	29.65	T
8	420.	519.	449.	111.	31.	.176	.123	.053	57.8	2.39	.41	1.81	29.65	T
9	480.	524.	458.	126.	34.	.176	.123	.053	52.5	2.39	.41	1.82	29.65	T
10	540.	524.	463.	139.	38.	.173	.121	.052	47.3	2.39	.41	1.82	29.64	T
11	600.	512.	458.	152.	42.	.165	.115	.049	42.3	2.39	.41	1.81	29.60	T
12	660.	497.	449.	164.	46.	.156	.109	.047	37.7	2.40	.41	1.81	29.56	T
13	720.	481.	438.	174.	51.	.147	.103	.044	33.3	2.40	.42	1.80	29.53	T
14	780.	464.	425.	183.	55.	.138	.097	.041	29.1	2.40	.42	1.79	29.49	T
15	840.	445.	411.	191.	60.	.129	.090	.039	25.2	2.40	.42	1.78	29.46	T
16	900.	425.	396.	198.	64.	.120	.084	.036	21.6	2.40	.42	1.77	29.42	T
17	960.	405.	381.	203.	68.	.111	.078	.033	18.3	2.40	.43	1.76	29.39	T
18	1020.	384.	364.	207.	72.	.102	.072	.031	15.2	2.39	.43	1.74	29.35	T
19	1080.	362.	348.	210.	76.	.093	.065	.028	12.4	2.39	.43	1.72	29.32	T
20	1140.	339.	330.	212.	79.	.084	.059	.025	9.9	2.38	.44	1.70	29.28	T
21	1200.	315.	313.	213.	82.	.375	.053	.323	7.6	2.36	.44	1.67	29.25	T
22	1260.	291.	296.	213.	85.	.066	.046	.020	5.6	2.34	.44	1.64	29.21	T
23	1320.	266.	279.	213.	87.	.057	.040	.017	3.9	2.31	.45	1.61	29.17	T
24	1380.	240.	261.	211.	90.	.047	.033	.014	2.5	2.27	.45	1.57	29.14	T
25	1440.	213.	242.	209.	91.	.038	.027	.011	1.4	2.22	.46	1.51	29.10	T
26	1500.	185.	222.	206.	93.	.328	.020	.008	.5	2.15	.46	1.45	29.06	T
27	1560.	154.	201.	203.	94.	.017	.012	.005	.0	2.04	.47	1.36	29.01	T
28	1620.	109.	175.	199.	94.	.002	.001	.001	.0	1.80	.48	1.17	23.93	T
29	1680.	95.	157.	194.	95.	.300	.000	.000	.3	1.70	.48	1.10	28.92	T
30	1740.	89.	146.	189.	95.	.300	.000	.000	.0	1.65	.48	1.06	28.92	T
31	1800.	84.	138.	183.	95.	.300	.000	.000	.0	1.60	.48	1.03	28.92	T
32	1860.	81.	131.	177.	95.	.003	.300	.000	.0	1.56	.49	1.00	28.92	T
33	1920.	77.	125.	171.	94.	.000	.000	.000	.0	1.53	.49	.98	28.92	T

CRIB FIRE PAGE NO. 1 RUN NO. 6

TIME	HEAT BALANCE GAS FLOW PCT	WND RAD PCT	WALL CNV PCT	WALL RAD PCT	Q-FIRE W	Q-WALL SUM J	YO2 PCT MASS	YN2 PCT MASS	YCO2 PCT MASS	YH2O PCT MASS	YPYR PCT MASS
0.	57.683	2.530	22.491	17.294	1.856+06	4.431+07	.154	.717	.079	.032	.021
60.	64.928	3.282	14.508	17.280	1.856+06	7.971+07	.155	.717	.079	.032	.021
120.	68.196	3.673	11.511	16.622	1.856+06	1.110+08	.155	.717	.078	.032	.321
180.	70.573	3.978	9.568	15.881	1.856+06	1.394+08	.155	.717	.078	.032	.021
240.	72.319	4.215	8.266	15.200	1.856+06	1.655+08	.155	.717	.078	.032	.321
300.	73.706	4.411	7.306	14.578	1.856+06	1.899+08	.155	.717	.078	.032	.321
360.	74.838	4.576	6.571	14.020	1.856+06	2.128+08	.155	.717	.078	.032	.021
420.	75.787	4.717	5.985	13.515	1.856+06	2.345+08	.155	.717	.078	.032	.021
480.	76.597	4.841	5.508	13.059	1.856+06	2.552+08	.155	.717	.078	.032	.321
540.	77.663	4.912	5.042	12.382	1.829+06	2.743+08	.156	.718	.077	.031	.020
600.	79.542	4.862	4.485	11.111	1.736+06	2.906+08	.160	.720	.073	.030	.019
660.	81.169	4.755	4.077	10.001	1.643+06	3.045+08	.163	.723	.070	.028	.018
720.	82.701	4.618	3.722	8.962	1.550+06	3.162+08	.167	.726	.066	.027	.017
780.	84.190	4.461	3.388	7.965	1.456+06	3.262+08	.171	.728	.062	.025	.016
840.	85.673	4.291	3.052	6.989	1.362+06	3.344+08	.174	.731	.058	.023	.015
900.	87.180	4.113	2.697	6.017	1.268+06	3.410+08	.178	.733	.054	.022	.014
960.	88.743	3.930	2.307	5.036	1.174+06	3.462+08	.181	.736	.051	.020	.013
1020.	90.393	3.745	1.864	4.022	1.080+06	3.500+08	.185	.738	.047	.019	.012
1080.	92.159	3.560	1.351	2.951	9.850+05	3.525+08	.189	.741	.043	.017	.011
1140.	94.085	3.378	.759	1.783	8.897+05	3.539+08	.193	.744	.039	.016	.010
1200.	96.227	3.200	.135	.453	7.938+05	3.542+08	.196	.746	.035	.014	.009
1260.	97.021	2.979	-.524	-1.158	6.973+05	3.542+08	.200	.749	.031	.013	.008
1320.	97.247	2.753	-1.857	-2.747	5.998+05	3.542+08	.204	.752	.327	.011	.007
1380.	97.458	2.542	-3.970	-4.448	5.009+05	3.542+08	.208	.754	.323	.009	.006
1440.	97.655	2.345	-7.264	-6.383	4.001+05	3.542+08	.212	.757	.019	.008	.005
1500.	97.836	2.164	-12.695	-8.823	2.958+05	3.542+08	.216	.760	.015	.006	.004
1560.	97.997	2.003	-23.094	-12.532	1.840+05	3.542+08	.221	.763	.310	.004	.003
1620.	98.133	1.867	-62.659	-23.888	2.191+04	3.542+08	.229	.769	.001	.001	.000
1680.	98.137	1.863	-74.329	-25.735	0.000	3.542+08	.230	.770	.000	.000	.000
1740.	98.130	1.870	-75.024	-25.025	0.000	3.542+08	.230	.770	.000	.000	.000
1800.	98.120	1.880	-75.537	-24.512	0.000	3.542+08	.230	.770	.000	.000	.000
1860.	98.108	1.892	-75.938	-24.116	0.000	3.542+08	.230	.770	.000	.000	.000
1920.	98.095	1.905	-76.262	-23.798	0.000	3.542+08	.230	.770	.000	.000	.000

TEST PROGRAM 2 FOR WOOD CRIB FIRE. NILSSON'S FORMULAS

-----GEOMETRY AND VENTILATION-----

WALL SURFACE AREA = 80.0 M2
FLOOR AREA = 20.00 M2
WINDOW HEIGHT = 1.50 M
AREA = 4.00 M2
OPENING FACTOR = 4.899 M2.5
DISCHARGE COEFF.= .68

-----FUEL LOAD PROPERTIES-----

FIRE LOAD PER FLOOR AREA = 20.0 KG/M2

FUEL COMPOSITION
CARBON = 44.4 PERCENT BY WEIGHT
HYDROGEN = 5.4 PERCENT
OXYGEN = 38.2 PERCENT
NITROGEN = .0 PERCENT
WATER = 12.0 PERCENT
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RO= 1.23
HEAT OF COMBUSTION OF DRY FUEL = 18.80+06 J/KG
LOWER ACTUAL HEAT OF COMBUSTION = 15.07+06 J/KG
MOLECULAR WEIGHT OF UNBURNT PYROLYSATES = 28.97
CP OF PYROLYSIS GAS = (.1127*TGAS + 1010.) J/KG-K
MAXIMUM FRACTION OF PYROLYSATES BURNED = .70
GREY-GAS FLAME EMISSIVITY = .900
RATE OF REGRESSION = 00.00 M/S
FUEL DIMENSION = .050 M
SHAPE FACTOR = 2.00

CRIB SPACING/HEIGHT RATIO= .200

-----WALL THERMAL PROPERTIES-----

THICKNESS = .038 M
DENSITY = 790. KG/M3

THERMAL CONDUCTIVITY = .170 W/M-K

HEAT CAPACITY = 840. J/KG-K

EMISSIVITY = .50

CRIB FIRE

PAGE NO. 1 RUN NO. 7

	TIME S	TEMP GAS.C	WALL TEMPS C			RP KG/S	RC KG/S	EXC.PYR. KG/S	FUEL PCT	AIR IN KG/S	N.P.	VELOCITY M/S	MOL.WT	FUEL CNTRL
1	0.	739.	514.	26.	25.	.479	.288	.191	92.8	2.19	.37	1.83	30.60	F
2	60.	858.	745.	34.	25.	.461	.286	.176	85.9	2.17	.36	1.85	30.60	F
3	120.	902.	815.	54.	25.	.444	.286	.158	79.2	2.17	.36	1.86	30.60	F
4	180.	936.	866.	95.	26.	.426	.286	.141	72.8	2.17	.36	1.87	30.59	F
5	240.	960.	900.	122.	27.	.409	.286	.123	66.7	2.17	.36	1.87	30.59	T
6	300.	955.	905.	159.	30.	.391	.274	.117	60.8	2.18	.36	1.88	30.52	T
7	360.	942.	897.	194.	34.	.374	.261	.112	55.2	2.20	.36	1.88	30.45	T
8	420.	924.	884.	227.	40.	.356	.249	.107	49.9	2.21	.37	1.88	30.38	T
9	480.	903.	866.	255.	47.	.338	.237	.101	44.8	2.23	.37	1.88	30.31	T
10	540.	879.	846.	281.	55.	.321	.224	.096	40.0	2.25	.37	1.88	30.24	T
11	600.	853.	822.	302.	63.	.303	.212	.091	35.5	2.26	.37	1.88	30.17	T
12	660.	824.	797.	321.	72.	.285	.200	.086	31.2	2.28	.38	1.88	30.09	T
13	720.	794.	769.	336.	80.	.267	.187	.080	27.2	2.30	.38	1.88	30.02	T
14	780.	762.	740.	349.	89.	.250	.175	.075	23.4	2.31	.38	1.88	29.95	T
15	840.	728.	709.	360.	97.	.232	.162	.070	20.0	2.33	.39	1.87	29.87	T
16	900.	693.	678.	368.	104.	.214	.150	.064	16.8	2.35	.39	1.87	29.80	T
17	960.	656.	644.	374.	111.	.196	.137	.059	13.8	2.37	.40	1.86	29.73	T
18	1020.	617.	610.	378.	117.	.178	.125	.053	11.1	2.38	.40	1.85	29.65	T
19	1080.	576.	575.	380.	122.	.160	.112	.048	8.7	2.39	.40	1.84	29.58	T
20	1140.	533.	540.	380.	127.	.142	.099	.042	6.6	2.41	.41	1.83	29.51	T
21	1200.	489.	504.	379.	131.	.123	.086	.037	4.8	2.41	.42	1.81	29.43	T
22	1260.	442.	467.	376.	134.	.105	.073	.031	3.2	2.42	.42	1.78	29.36	T
23	1320.	393.	429.	372.	137.	.086	.060	.026	1.9	2.41	.43	1.75	29.28	T
24	1380.	342.	390.	366.	139.	.066	.046	.020	.9	2.39	.44	1.71	29.21	T
25	1440.	286.	350.	359.	141.	.046	.032	.014	.2	2.35	.44	1.64	29.12	T
26	1500.	223.	307.	350.	142.	.023	.016	.007	.0	2.25	.46	1.54	29.03	T
27	1560.	155.	261.	341.	143.	.000	.000	.000	.0	2.06	.47	1.37	28.92	T
28	1620.	140.	236.	330.	143.	.060	.000	.000	.0	1.99	.47	1.31	28.92	T
29	1680.	129.	219.	318.	143.	.000	.000	.000	.0	1.94	.47	1.27	28.92	T
30	1740.	121.	205.	306.	142.	.000	.000	.000	.0	1.89	.48	1.24	28.92	T
31	1800.	115.	194.	294.	141.	.000	.000	.000	.0	1.85	.48	1.21	28.92	T
32	1860.	109.	184.	282.	139.	.000	.000	.300	.0	1.81	.48	1.18	28.92	T
33	1920.	105.	175.	270.	137.	.000	.000	.000	.0	1.78	.48	1.15	28.92	T
34	1980.	101.	168.	260.	135.	.000	.000	.000	.0	1.75	.48	1.13	28.92	T
35	2040.	97.	161.	250.	133.	.000	.000	.000	.0	1.72	.48	1.11	28.92	T
36	2100.	94.	155.	240.	130.	.000	.000	.000	.0	1.69	.48	1.09	28.92	T
37	2160.	91.	149.	231.	128.	.000	.000	.000	.0	1.66	.48	1.07	28.92	T
38	2220.	88.	144.	223.	125.	.000	.000	.000	.0	1.64	.48	1.05	28.92	T
39	2280.	85.	139.	214.	122.	.000	.000	.000	.0	1.61	.48	1.04	28.92	T
40	2340.	83.	135.	207.	119.	.000	.000	.000	.0	1.59	.49	1.02	28.92	T
41	2400.	81.	131.	199.	117.	.000	.000	.000	.0	1.56	.49	1.00	28.92	T
42	2460.	79.	127.	192.	114.	.000	.000	.000	.0	1.54	.49	.99	28.92	T

CRIB FIRE

PAGE NO. 1 RUN NO. 7

TIME	HEAT BALANCE GAS FLOW PCT	WND RAD PCT	WALL CNV PCT	WALL RAD PCT	Q-FIRE W	Q-WALL SUM J	YO2 PCT MASS	YN2 PCT MASS	YCO2 PCT MASS	YH2O PCT MASS	YPYR PCT MASS
0.	51.239	5.446	11.986	31.326	4.342+06	1.128+08	.055	.632	.176	.074	.071
60.	59.890	8.578	4.838	26.713	4.305+06	1.943+08	.056	.635	.177	.074	.067
120.	62.785	10.011	3.385	23.867	4.301+06	2.647+08	.056	.639	.178	.073	.061
180.	64.837	11.207	2.533	21.406	4.303+06	3.265+08	.057	.644	.179	.073	.054
240.	66.133	12.113	2.058	19.706	4.310+06	3.828+08	.057	.648	.180	.073	.047
300.	68.439	12.473	1.715	17.383	4.125+06	4.300+08	.064	.653	.173	.070	.046
360.	70.315	12.500	1.524	15.674	3.939+06	4.707+08	.071	.658	.166	.067	.044
420.	72.040	12.361	1.389	14.222	3.754+06	5.058+08	.078	.663	.158	.064	.042
480.	73.682	12.102	1.287	12.939	3.568+06	5.363+08	.086	.669	.150	.061	.040
540.	75.291	11.754	1.203	11.759	3.381+06	5.626+08	.093	.674	.142	.058	.037
600.	76.901	11.339	1.128	10.638	3.195+06	5.851+08	.101	.679	.135	.054	.035
660.	78.537	10.870	1.056	9.543	3.008+06	6.043+08	.108	.684	.127	.051	.033
720.	80.222	10.360	.978	8.444	2.821+06	6.202+08	.116	.690	.119	.048	.031
780.	81.979	9.818	.888	7.317	2.633+06	6.332+08	.123	.695	.111	.045	.029
840.	83.833	9.251	.778	6.136	2.445+06	6.433+08	.131	.700	.103	.042	.027
900.	85.814	8.668	.640	4.874	2.256+06	6.508+08	.139	.706	.095	.038	.025
960.	87.960	8.074	.464	3.496	2.067+06	6.557+08	.146	.711	.087	.035	.023
1020.	90.318	7.476	.243	1.956	1.877+06	6.582+08	.154	.716	.079	.032	.021
1080.	92.946	6.878	.010	.165	1.686+06	6.583+08	.162	.722	.071	.029	.019
1140.	93.846	6.154	-.314	-1.899	1.494+06	6.583+08	.169	.727	.063	.026	.017
1200.	94.558	5.442	-1.020	-4.049	1.300+06	6.583+08	.177	.733	.055	.022	.015
1260.	95.238	4.762	-2.239	-6.376	1.103+06	6.583+08	.185	.738	.047	.019	.012
1320.	95.883	4.117	-4.264	-8.925	9.040+05	6.583+08	.192	.744	.039	.016	.010
1380.	96.485	3.515	-7.700	-11.864	6.995+05	6.583+08	.200	.749	.031	.012	.008
1440.	97.049	2.951	-14.093	-15.688	4.853+05	6.583+08	.209	.755	.022	.009	.006
1500.	97.574	2.426	-28.573	-21.936	2.439+05	6.583+08	.219	.762	.012	.005	.003
1560.	97.982	2.018	-66.264	-33.909	0.000	6.583+08	.230	.770	.000	.000	.000
1620.	98.049	1.951	-68.413	-31.701	0.000	6.583+08	.230	.770	.000	.000	.000
1680.	98.085	1.915	-69.814	-30.274	0.000	6.583+08	.230	.770	.000	.000	.000
1740.	98.107	1.893	-70.898	-29.183	0.000	6.583+08	.230	.770	.000	.000	.000
1800.	98.122	1.878	-71.769	-28.312	0.000	6.583+08	.230	.770	.000	.000	.000
1860.	98.131	1.869	-72.495	-27.590	0.000	6.583+08	.230	.770	.000	.000	.000
1920.	98.136	1.864	-73.116	-26.981	0.000	6.583+08	.230	.770	.000	.000	.000
1980.	98.138	1.862	-73.665	-26.462	0.000	6.583+08	.230	.770	.000	.000	.000
2040.	98.138	1.862	-73.953	-25.954	0.000	6.583+08	.230	.770	.000	.000	.000
2100.	98.136	1.864	-74.573	-25.606	0.000	6.583+08	.230	.770	.000	.000	.000
2160.	98.133	1.867	-74.768	-25.201	0.000	6.583+08	.230	.770	.000	.000	.000
2220.	98.128	1.872	-75.114	-24.888	0.000	6.583+08	.230	.770	.000	.000	.000
2280.	98.123	1.877	-75.413	-24.604	0.000	6.583+08	.230	.770	.000	.000	.000
2340.	98.116	1.884	-75.679	-24.347	0.000	6.583+08	.230	.770	.000	.000	.000
2400.	98.109	1.891	-75.769	-24.079	0.000	6.583+08	.230	.770	.000	.000	.000
2460.	98.100	1.900	-75.979	-23.867	0.000	6.583+08	.230	.770	.000	.000	.000

TEST PROGRAM FOR PVTFIX ROUTINE. VARIABLE WALL PROPERTIES

-----GEOMETRY AND VENTILATION-----

```
WALL SURFACE AREA =      80.0 M2
FLOOR AREA =    20.00 M2
WINDOW HEIGHT =       1.50 M
         AREA =       4.00 M2
OPENING FACTOR =    4.899 M2.5
DISCHARGE COEFF.=   .68
```

----FUEL LOAD PROPERTIES----

```
FIRE LOAD PER FLOOR AREA =   20.0 KG/M2

FUEL COMPOSITION
CARBON    = 44.4 PERCENT BY WEIGHT
HYDROGEN =   5.4 PERCENT
OXYGEN    = 38.2 PERCENT
NITROGEN =    .0 PERCENT
WATER     = 12.0 PERCENT
R =   5.32
RO=   1.23
HEAT OF COMBUSTION OF DRY FUEL =   18.80+06 J/KG
LOWER ACTUAL HEAT OF COMBUSTION =   15.07+06 J/KG
MOLECULAR WEIGHT OF UNBURNT PYROLYSATES =   28.97
CP OF PYROLYSIS GAS = ( .1127*TGAS +  1010.) J/KG-K
MAXIMUM FRACTION OF PYROLYSATES BURNED =    .70
GREY-GAS FLAME EMISSIVITY =   .900
```

----WALL THERMAL PROPERTIES----

```
THICKNESS =   .038 M
DENSITY =   790. KG/M3
```

THERMAL CONDUCTIVITY ARRAY (W/M-K)

TEMPERATURE	CONDUCTIVITY
273.0	.210
372.0	.210
373.0	.160
1073.0	.260

HEAT CAPACITY ARRAY (J/KG-K)

TEMPERATURE	HEAT CAPACITY
273.0	1090.
372.0	1090.
373.0	47300.
383.0	47300.
384.0	5000.
413.0	5000.
414.0	840.
1073.0	840.

EMISSIVITY = .50

VENTILATION SPECIFIED. FUEL PYROLYSIS ADJUSTED FOR WORST CONDITIONS PAGE NO. 1 RUN NO.

	TIME S	TEMP GAS.C	WALL TEMPS C			RP KG/S	RC KG/S	EXC.PYR. KG/S	FUEL PCT	AIR IN KG/S	N.P.	VELOCITY M/S	MOL.WT	FUEL CNTRL
1	0.	720.	453.	26.	25.	.419	.293	.126	93.7	2.23	.38	1.84	30.59	F
2	60.	853.	729.	32.	25.	.414	.290	.124	87.5	2.20	.37	1.86	30.59	F
3	120.	887.	787.	48.	25.	.412	.289	.124	81.3	2.19	.37	1.87	30.59	F
4	180.	913.	829.	75.	26.	.411	.288	.123	75.2	2.19	.36	1.87	30.59	F
5	240.	933.	860.	96.	27.	.410	.287	.123	69.0	2.18	.36	1.87	30.59	F
6	300.	947.	881.	131.	29.	.409	.287	.123	62.9	2.18	.36	1.87	30.59	F
7	360.	959.	898.	146.	32.	.409	.286	.123	56.7	2.17	.36	1.87	30.59	F
8	420.	969.	914.	214.	36.	.408	.286	.122	50.6	2.17	.36	1.88	30.59	F
9	480.	978.	927.	252.	41.	.408	.285	.122	44.5	2.17	.36	1.88	30.59	F
10	540.	986.	938.	278.	47.	.407	.285	.122	38.4	2.17	.36	1.88	30.59	F
11	600.	992.	947.	312.	53.	.407	.285	.122	32.3	2.17	.36	1.88	30.59	F
12	660.	998.	955.	343.	57.	.407	.285	.122	26.2	2.16	.36	1.88	30.59	F
13	720.	1002.	961.	363.	61.	.407	.285	.122	20.1	2.16	.36	1.88	30.59	F
14	780.	1007.	967.	379.	64.	.406	.284	.122	14.0	2.16	.36	1.88	30.59	F
15	840.	1010.	972.	392.	67.	.406	.284	.122	7.9	2.16	.36	1.88	30.59	F
16	900.	1013.	976.	403.	69.	.406	.284	.122	1.8	2.16	.36	1.88	30.59	F
17	960.	1015.	980.	416.	72.	.406	.284	.122	.0	2.16	.36	1.88	30.59	F
18	1020.	426.	606.	428.	73.	.000	.000	.000	.0	2.47	.43	1.79	28.92	T
19	1080.	296.	459.	433.	74.	.000	.000	.000	.0	2.39	.45	1.67	28.92	T
20	1140.	239.	385.	419.	76.	.000	.000	.000	.0	2.30	.45	1.58	28.92	T
21	1200.	203.	335.	392.	77.	.000	.000	.000	.0	2.22	.46	1.50	28.92	T
22	1260.	178.	298.	364.	78.	.000	.000	.000	.0	2.15	.47	1.44	28.92	T
23	1320.	160.	269.	337.	79.	.000	.000	.000	.0	2.08	.47	1.38	28.92	T
24	1380.	145.	245.	312.	80.	.000	.000	.000	.0	2.02	.47	1.33	28.92	T
25	1440.	134.	226.	290.	81.	.000	.000	.000	.0	1.96	.47	1.29	28.92	T
26	1500.	124.	209.	271.	81.	.000	.000	.000	.0	1.91	.48	1.25	28.92	T
27	1560.	115.	194.	255.	82.	.000	.000	.000	.0	1.85	.48	1.21	28.92	T
28	1620.	108.	181.	240.	82.	.000	.000	.000	.0	1.80	.48	1.17	28.92	T
29	1680.	102.	170.	227.	82.	.000	.000	.000	.0	1.76	.48	1.14	28.92	T
30	1740.	96.	160.	216.	82.	.000	.000	.000	.0	1.71	.48	1.11	28.92	T
31	1800.	92.	152.	205.	83.	.000	.000	.000	.0	1.67	.48	1.08	28.92	T
32	1860.	87.	144.	190.	83.	.000	.000	.000	.0	1.63	.48	1.05	28.92	T
33	1920.	84.	137.	187.	83.	.000	.000	.000	.0	1.60	.48	1.03	28.92	T
34	1980.	80.	131.	179.	83.	.000	.000	.000	.0	1.56	.49	1.00	28.92	T
35	2040.	77.	125.	172.	83.	.000	.000	.000	.0	1.53	.49	.98	28.92	T

VENTILATION SPECIFIED. FUEL PYROLYSIS ADJUSTED FOR WORST CONDITIONS PAGE NO. 1 RUN NO. 8

TIME	HEAT BALANCE GAS FLOW PCT	WND RAD PCT	WALL CNV PCT	WALL RAD PCT	Q-FIRE W	Q-WALL SUM J	YO2 PCT MASS	YN2 PCT MASS	YCO2 PCT MASS	YH2O PCT MASS	YPYR PCT MASS
0.	48.339	4.946	14.745	32.022	4.419+06	1.240+08	.057	.648	.180	.073	.047
60.	58.154	8.318	5.410	28.134	4.363+06	2.118+08	.057	.648	.180	.073	.047
120.	60.694	9.415	4.060	25.768	4.347+06	2.896+08	.057	.648	.180	.073	.047
180.	62.608	10.308	3.244	23.808	4.334+06	3.599+08	.057	.648	.180	.073	.047
240.	64.103	11.047	2.695	22.137	4.324+06	4.244+08	.057	.648	.180	.073	.047
300.	65.155	11.590	2.344	20.860	4.317+06	4.845+08	.057	.648	.180	.073	.047
360.	66.052	12.068	2.081	19.804	4.310+06	5.411+08	.057	.648	.180	.073	.047
420.	66.825	12.493	1.862	18.807	4.305+06	5.945+08	.057	.648	.180	.073	.047
480.	67.492	12.868	1.686	17.929	4.301+06	6.451+08	.057	.648	.180	.073	.047
540.	68.080	13.204	1.545	17.190	4.296+06	6.934+08	.057	.648	.180	.073	.047
600.	68.577	13.494	1.429	16.529	4.293+06	7.396+08	.057	.648	.180	.073	.047
660.	68.996	13.741	1.335	15.963	4.290+06	7.841+08	.057	.648	.180	.073	.047
720.	69.354	13.956	1.254	15.443	4.288+06	8.271+08	.057	.648	.180	.073	.047
780.	69.673	14.149	1.187	15.000	4.285+06	8.687+08	.057	.648	.180	.073	.047
840.	69.940	14.313	1.132	14.625	4.284+06	9.092+08	.057	.648	.180	.073	.047
900.	70.160	14.448	1.088	14.315	4.282+06	9.488+08	.057	.648	.180	.073	.047
960.	70.342	14.561	1.052	14.056	4.281+06	9.876+08	.057	.648	.180	.073	.047
1020.	95.334	4.666	-34.635	-65.520	0.000	9.876+08	.230	.770	.000	.000	.000
1080.	96.914	3.086	-47.715	-52.475	0.000	9.876+08	.230	.770	.000	.000	.000
1140.	97.433	2.567	-54.773	-45.402	0.000	9.876+08	.230	.770	.000	.000	.000
1200.	97.701	2.299	-59.342	-40.481	0.000	9.876+08	.230	.770	.000	.000	.000
1260.	97.857	2.143	-62.819	-37.109	0.000	9.876+08	.230	.770	.000	.000	.000
1320.	97.958	2.042	-65.406	-34.512	0.000	9.876+08	.230	.770	.000	.000	.000
1380.	98.025	1.975	-67.489	-32.461	0.000	9.876+08	.230	.770	.000	.000	.000
1440.	98.071	1.929	-69.232	-30.849	0.000	9.876+08	.230	.770	.000	.000	.000
1500.	98.101	1.899	-70.589	-29.483	0.000	9.876+08	.230	.770	.000	.000	.000
1560.	98.121	1.879	-71.719	-28.347	0.000	9.876+08	.230	.770	.000	.000	.000
1620.	98.133	1.867	-72.665	-27.396	0.000	9.876+08	.230	.770	.000	.000	.000
1680.	98.138	1.862	-73.461	-26.598	0.000	9.876+08	.230	.770	.000	.000	.000
1740.	98.138	1.862	-74.133	-25.925	0.000	9.876+08	.230	.770	.000	.000	.000
1800.	98.135	1.865	-74.703	-25.355	0.000	9.876+08	.230	.770	.000	.000	.000
1860.	98.128	1.872	-75.188	-24.871	0.000	9.876+08	.230	.770	.000	.000	.000
1920.	98.119	1.881	-75.603	-24.459	0.000	9.876+08	.230	.770	.000	.000	.000
1980.	98.108	1.892	-75.960	-24.108	0.000	9.876+08	.230	.770	.000	.000	.000
2040.	98.095	1.905	-76.269	-23.809	0.000	9.876+08	.230	.770	.000	.000	.000

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TEST PROGRAM FOR PFLFIX ROUTINE. POOL OPTION

----GEOMETRY AND VENTILATION----

WALL SURFACE AREA =      80.0 M2
FLOOR AREA =     20.00 M2
WINDOW HEIGHT =      1.50 M
         AREA =     10.00 M2
OPENING FACTOR =  12.247 M2.5
DISCHARGE COEFF.=  .68


----FUEL LOAD PROPERTIES----

FIRE LOAD PER FLOOR AREA =  20.0 KG/M2
TOTAL ENTHALPY OF PYROLYSIS=    2.40+06 J/KG
BOILING TEMPERATURE= 390. DEG C

FUEL COMPOSITION
CARBON    = 85.7 PERCENT BY WEIGHT
HYDROGEN  = 14.3 PERCENT
OXYGEN    =   .0 PERCENT
NITROGEN  =   .0 PERCENT
WATER     =   .0 PERCENT
R = 14.78
RO=  3.43
HEAT OF COMBUSTION OF DRY FUEL =    46.50+06 J/KG
LOWER ACTUAL HEAT OF COMBUSTION =    43.36+06 J/KG
MOLECULAR WEIGHT OF UNBURNT PYROLYSATES =  28.97
CP OF PYROLYSIS GAS = ( .1127*TGAS +  1010.) J/KG-K
MAXIMUM FRACTION OF PYROLYSATES BURNED =    .70
GREY-GAS FLAME EMISSIVITY =  .900
FUEL AREA=       5.00 M2

----WALL THERMAL PROPERTIES----

THICKNESS =  .038 M
DENSITY =   790. KG/M3

THERMAL CONDUCTIVITY =    .170 W/M-K

HEAT CAPACITY =    840. J/KG-K

EMISSIVITY =  .50
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FUEL PYROLYSIS (POOL) SPECIFIED, VENTILATION ADJUSTED FOR WORST CONDITIONS PAGE NO. 1 RUN NO. 9

	TIME S	TEMP GAS,C	WALL TEMPS C			RP KG/S	RC KG/S	EXC.PYR. KG/S	FUEL PCT	AIR IN KG/S	N.P.	VELOCITY M/S	MOL.WT	FUEL CNTRL	WINDOW WIDTH
1	0.	1051.	866.	27.	25.	.380	.271	.116	94.2	5.73	.37	1.93	29.93	F	4.67
2	60.	1126.	1052.	39.	25.	.457	.267	.190	87.3	5.63	.36	1.93	29.92	F	6.67
3	120.	1140.	1079.	70.	25.	.471	.266	.205	80.3	5.61	.36	1.93	29.92	F	6.67
4	180.	1154.	1104.	115.	26.	.485	.265	.220	73.0	5.59	.36	1.93	29.91	F	6.67
5	240.	1161.	1118.	165.	28.	.493	.264	.228	65.6	5.58	.36	1.93	29.91	F	6.67
6	300.	1166.	1128.	211.	32.	.499	.264	.234	58.1	5.58	.36	1.93	29.91	F	6.67
7	360.	1170.	1135.	254.	38.	.503	.264	.239	50.6	5.57	.36	1.93	29.91	F	6.67
8	420.	1174.	1141.	293.	46.	.507	.264	.243	43.0	5.57	.36	1.93	29.91	F	6.67
9	480.	1176.	1146.	329.	55.	.510	.263	.246	35.3	5.56	.36	1.93	29.91	F	6.67
10	540.	1178.	1150.	361.	65.	.512	.263	.249	27.7	5.56	.36	1.93	29.91	F	6.67
11	600.	1180.	1154.	390.	76.	.514	.263	.251	19.9	5.56	.36	1.92	29.91	F	6.67
12	660.	1182.	1156.	417.	87.	.516	.263	.253	12.2	5.55	.36	1.92	29.91	F	6.67
13	720.	1183.	1159.	442.	97.	.518	.263	.255	4.4	5.55	.36	1.92	29.91	F	6.67
14	780.	1185.	1161.	464.	107.	.519	.263	.256	.0	5.55	.36	1.92	29.91	F	6.67

FUEL PYROLYSIS (POOL) SPECIFIED, VENTILATION ADJUSTED FOR WORST CONDITIONS PAGE NO. 1 RUN NO. 9

TIME	HEAT BALANCE GAS FLOW PCT	WND RAD PCT	WALL CNV PCT	WALL RAD PCT	Q-FIRE W	Q-WALL SUM J	YO2 PCT MASS	YN2 PCT MASS	YCO2 PCT MASS	YH2O PCT MASS	YPYR PCT MASS
0.	62.235	10.328	3.130	22.170	1.177+07	1.787+08	.063	.721	.139	.057	.019
60.	68.003	18.755	.948	12.241	1.157+07	2.702+08	.063	.712	.138	.056	.031
120.	69.104	19.586	.734	10.578	1.153+07	3.484+08	.062	.710	.137	.056	.034
180.	70.153	20.397	.551	8.900	1.149+07	4.136+08	.062	.709	.137	.056	.036
240.	70.729	20.849	.461	7.962	1.147+07	4.715+08	.062	.708	.137	.056	.037
300.	71.176	21.204	.396	7.225	1.145+07	5.239+08	.062	.707	.137	.056	.039
360.	71.507	21.469	.351	6.674	1.144+07	5.721+08	.062	.706	.136	.056	.039
420.	71.773	21.683	.316	6.229	1.143+07	6.170+08	.062	.706	.136	.056	.040
480.	71.990	21.859	.288	5.864	1.142+07	6.591+08	.062	.705	.136	.056	.040
540.	72.172	22.007	.266	5.556	1.142+07	6.990+08	.062	.705	.136	.056	.041
600.	72.327	22.134	.247	5.292	1.141+07	7.369+08	.062	.705	.136	.056	.041
660.	72.462	22.244	.231	5.062	1.140+07	7.731+08	.062	.705	.136	.056	.042
720.	72.581	22.342	.218	4.859	1.140+07	8.079+08	.062	.704	.136	.056	.042
780.	72.686	22.428	.206	4.679	1.140+07	8.413+08	.062	.704	.136	.056	.042

```
TEST PROGRAM FOR RPFIX ROUTINE

----GEOMETRY AND VENTILATION----

WALL SURFACE AREA =      80.0 M2
FLOOR AREA =     20.00 M2
WINDOW HEIGHT =      1.50 M
        AREA =     10.00 M2
OPENING FACTOR =   12.247 M2.5
DISCHARGE COEFF.=   .68


----FUEL LOAD PROPERTIES----

FIRE LOAD PER FLOOR AREA =   20.0 KG/M2

FUEL COMPOSITION
CARBON    = 85.7 PERCENT BY WEIGHT
HYDROGEN = 14.3 PERCENT
OXYGEN    =    .0 PERCENT
NITROGEN =    .0 PERCENT
WATER     =    .0 PERCENT
R = 14.78
R0=  3.43
HEAT OF COMBUSTION OF DRY FUEL =   46.50+06 J/KG
LOWER ACTUAL HEAT OF COMBUSTION =   43.36+06 J/KG
MOLECULAR WEIGHT OF UNBURNT PYROLYSATES =  28.97
CP OF PYROLYSIS GAS = ( .1127*TGAS +  1010.) J/KG-K
MAXIMUM FRACTION OF PYRCLYSATES BURNED =    .70
GREY-GAS FLAME EMISSIVITY =  .900

RATE OF PYROLYSIS  (KG/S)
   TIME        RP
     0.       .120
   120.       .120
   121.       .250


----WALL THERMAL PROPERTIES----

THICKNESS =   .038 M
DENSITY =   790. KG/M3

THERMAL CONDUCTIVITY =     .170 W/M-K

HEAT CAPACITY =     840. J/KG-K

EMISSIVITY =  .50
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INPUTTED VALUES OF RP ARE USED

PAGE NO. 1 RUN NO. 10

	TIME S	TEMP GAS.C	WALL TEMPS C			RP KG/S	RC KG/S	EXC.PYR. KG/S	FUEL PCT	AIR IN KG/S	N.P.	VELOCITY M/S	MOL.WT	FUEL CNTRL
1	0.	432.	234.	26.	25.	.120	.084	.036	98.2	6.11	.43	1.79	29.23	T
2	60.	457.	323.	29.	25.	.120	.084	.036	96.4	6.13	.42	1.80	29.23	T
3	120.	467.	355.	37.	25.	.120	.084	.036	94.6	6.13	.42	1.81	29.23	T
4	180.	805.	666.	51.	25.	.250	.175	.075	90.9	5.98	.39	1.91	29.56	T
5	240.	843.	756.	71.	26.	.250	.175	.075	87.1	5.95	.39	1.92	29.56	T
6	300.	856.	784.	97.	27.	.250	.175	.075	83.4	5.94	.39	1.92	29.56	T
7	360.	866.	804.	128.	29.	.250	.175	.075	79.6	5.94	.39	1.92	29.56	T
8	420.	872.	817.	160.	32.	.250	.175	.075	75.9	5.93	.38	1.92	29.57	T
9	480.	877.	827.	190.	37.	.250	.175	.075	72.1	5.93	.38	1.92	29.57	T
10	540.	881.	835.	218.	42.	.250	.175	.075	68.4	5.93	.38	1.92	29.57	T
11	600.	884.	841.	244.	49.	.250	.175	.075	64.6	5.92	.38	1.92	29.57	T
12	660.	887.	846.	267.	56.	.250	.175	.075	60.9	5.92	.38	1.92	29.57	T
13	720.	889.	851.	289.	64.	.250	.175	.075	57.1	5.92	.38	1.92	29.57	T
14	780.	891.	855.	309.	72.	.250	.175	.075	53.4	5.92	.38	1.92	29.57	T
15	840.	893.	858.	327.	80.	.250	.175	.075	49.6	5.92	.38	1.92	29.57	T
16	900.	894.	861.	344.	88.	.250	.175	.075	45.9	5.92	.38	1.92	29.57	T
17	960.	896.	864.	360.	95.	.250	.175	.075	42.1	5.92	.38	1.92	29.57	T
18	1020.	897.	866.	375.	102.	.250	.175	.075	38.4	5.91	.38	1.92	29.57	T
19	1080.	898.	868.	389.	109.	.250	.175	.075	34.6	5.91	.38	1.92	29.57	T
20	1140.	899.	870.	401.	116.	.250	.175	.075	30.9	5.91	.38	1.92	29.57	T
21	1200.	900.	872.	413.	122.	.250	.175	.075	27.1	5.91	.38	1.92	29.57	T
22	1260.	901.	874.	425.	127.	.250	.175	.075	23.4	5.91	.38	1.93	29.57	T
23	1320.	902.	876.	435.	133.	.250	.175	.075	19.6	5.91	.38	1.93	29.57	T
24	1380.	903.	877.	445.	138.	.250	.175	.075	15.9	5.91	.38	1.93	29.57	T
25	1440.	904.	878.	454.	142.	.250	.175	.075	12.1	5.91	.38	1.93	29.57	T
26	1500.	904.	880.	463.	147.	.250	.175	.075	8.4	5.91	.38	1.93	29.57	T
27	1560.	905.	881.	471.	151.	.250	.175	.075	4.6	5.91	.38	1.93	29.57	T
28	1620.	905.	882.	478.	154.	.250	.175	.075	.9	5.91	.38	1.93	29.57	T
29	1680.	906.	883.	485.	158.	.250	.175	.075	.0	5.91	.38	1.93	29.57	T
30	1740.	206.	476.	491.	161.	.000	.000	.000	.0	5.58	.46	1.51	28.92	T
31	1800.	148.	357.	491.	164.	.000	.000	.000	.0	5.08	.47	1.34	28.92	T
32	1860.	126.	307.	481.	167.	.000	.000	.000	.0	4.80	.48	1.26	28.92	T
33	1920.	112.	272.	464.	169.	.000	.000	.000	.0	4.58	.48	1.19	28.92	T

INPUTTED VALUES OF RP ARE USED

PAGE NO. 1 RUN NO. 10

TIME	HEAT BALANCE GAS FLOW PCT	WND RAD PCT	WALL CNV PCT	WALL RAD PCT	Q-FIRE W	Q-WALL SUM J	YO2 PCT MASS	YN2 PCT MASS	YCO2 PCT MASS	YH2O PCT MASS	YPYR PCT MASS
0.	75.919	3.719	11.044	9.317	3.642+06	4.450+07	.179	.755	.042	.017	.006
60.	80.960	4.296	6.596	8.147	3.642+06	7.672+07	.179	.755	.042	.017	.006
120.	82.877	4.533	5.171	7.419	3.642+06	1.042+08	.180	.755	.042	.017	.006
180.	72.523	10.016	3.312	14.154	7.588+06	1.837+08	.124	.739	.088	.036	.012
240.	76.015	11.532	1.779	10.659	7.588+06	2.404+08	.124	.739	.089	.036	.012
300.	77.201	12.086	1.379	9.318	7.588+06	2.891+08	.124	.739	.089	.036	.012
360.	78.063	12.502	1.122	8.308	7.588+06	3.320+08	.124	.739	.089	.036	.012
420.	78.650	12.792	.963	7.606	7.588+06	3.710+08	.124	.739	.089	.036	.012
480.	79.090	13.013	.848	7.049	7.588+06	4.070+08	.124	.739	.089	.036	.012
540.	79.441	13.191	.762	6.606	7.588+06	4.405+08	.124	.739	.089	.036	.012
600.	79.729	13.339	.694	6.239	7.588+06	4.721+08	.123	.739	.089	.036	.012
660.	79.970	13.464	.639	5.927	7.588+06	5.020+08	.123	.739	.089	.036	.012
720.	80.176	13.571	.594	5.659	7.588+06	5.305+08	.123	.739	.089	.037	.012
780.	80.355	13.665	.556	5.424	7.588+06	5.577+08	.123	.739	.089	.037	.012
840.	80.513	13.748	.523	5.217	7.588+06	5.838+08	.123	.739	.089	.037	.012
900.	80.653	13.822	.494	5.031	7.588+06	6.090+08	.123	.739	.089	.037	.012
960.	80.778	13.889	.469	4.864	7.588+06	6.332+08	.123	.739	.089	.037	.012
1020.	80.892	13.949	.447	4.712	7.588+06	6.567+08	.123	.739	.089	.037	.012
1080.	80.996	14.005	.427	4.573	7.588+06	6.795+08	.123	.739	.089	.037	.012
1140.	81.090	14.055	.409	4.445	7.588+06	7.016+08	.123	.739	.089	.037	.012
1200.	81.178	14.102	.393	4.328	7.588+06	7.231+08	.123	.739	.089	.037	.012
1260.	81.258	14.140	.378	4.219	7.588+06	7.440+08	.123	.739	.089	.037	.012
1320.	81.333	14.186	.364	4.117	7.588+06	7.644+08	.123	.739	.089	.037	.012
1380.	81.402	14.224	.352	4.023	7.588+06	7.843+08	.123	.739	.089	.037	.012
1440.	81.466	14.258	.340	3.935	7.588+06	8.038+08	.123	.739	.089	.037	.012
1500.	81.526	14.291	.330	3.853	7.588+06	8.228+08	.123	.739	.089	.037	.012
1560.	81.582	14.322	.320	3.776	7.588+06	8.415+08	.123	.739	.089	.037	.012
1620.	81.635	14.350	.311	3.704	7.588+06	8.598+08	.123	.739	.089	.037	.012
1680.	81.683	14.377	.303	3.637	7.588+06	8.777+08	.123	.739	.089	.037	.012
1740.	97.678	2.322	-55.416	-44.732	0.000	8.777+08	.230	.770	.000	.000	.000
1800.	98.014	1.986	-64.641	-35.282	0.000	8.777+08	.230	.770	.000	.000	.000
1860.	98.094	1.906	-68.298	-31.506	0.000	8.777+08	.230	.770	.000	.000	.000
1920.	98.127	1.873	-70.817	-29.066	0.000	8.777+08	.230	.770	.000	.000	.000

APPENDIX B -- PROGRAM LISTING

```
C
C        COMPF2--MAIN PROGRAM
C        CONSTITUTES REVISION OF PROGRAM COMPF
C        COMPF2 VERSION 1.0 PROGRAMMED 1 MARCH 1978 BY V. BABRAUSKAS
C        VERSION 1.1  MINOR REVISIONS  18 AUG 1978
C
      COMMON /CNSTS/  AWALLN,BWDOW,DENSA,G,GASCNT,KTRACE,MTIME
      COMMON /CP/     CPA,CPCO(2),CPCO2(2),CPH2(2),CPH2O(2),CPN2(2),
     1  CPO2(2),CPPYR(2)
      COMMON /FUEL/   C,CFLPC,CVGROS,CVNET,H,HFLPC,MWPYR,N,NFLPC,O,
     1  OFLPC,R,RO,REGRES,SH,SHAPE,SIZE,W,WFLPC,WTFUEL
      COMMON /GP/     AWDOW,BPF,CD,CNV,DTIME,EMS(2),HWDOW,IX,IXC,IXL,
     1  J,JM,JP,JPRINT,K,KD,KH,KITER,KNTRL,MWIN,MWOUT,RC,RP,SIGMA
      COMMON /LOGIC/  FC,FLSPEC,KRIT,NEWPLT,NEWPRP,PLFUEL,PLOT,PNCH,
     1  RPSPEC,VTSPEC
      COMMON /PLAST/ TBOILC,DHP,STOICH,SIZE1,EITA,EISCAN
      COMMON /PRBLM/  ADIA,AFLOOR,AWALL,DENSW,FLOAD,IRUN,OPENF,
     1  PRNT,STEADY,THICKW
      COMMON /TEMP/   DENF,DENU,TAMB,TGAS,TINPT,T1(20),T2(20),TSF,TSU
      COMMON /THERML/ CNDA(2,10),CPW(2,10),DX,EF,EMSA(2,10),
     1  NCND,NCPW,NEMS,NQGEN,NRP,QGEN(2,10),RPX(2,50)
      COMMON /TITLE/  TITLE(14)
      COMMON /CPLOT/  BUFX(500),BUFY(500),SCALX,SCALY,SPECS(30)
      INTEGER TITLE
      LOGICAL ADIA,EISCAN,FC,FLSPEC,KRIT,NEWPLT,NEWPRP, PLFUEL,
     1  PLOT,PNCH,RPSPEC,STEADY,STOICH,VTSPEC
      REAL MWIN,MWOUT,MWPYR,MTIME,N,NFLPC
C
      DATA ADIA,CD,CFLPC,CNV,CPA,DENSA,EF,G
     1  /.FALSE.,0.68,44.4,5.0,1005.,1.18,0.9,9.8/,
     2  HFLPC,IRUN,IX,MTIME,MWPYR,NEWPRP
     3  /5.4,0,10,360.,28.97,.TRUE./,
     4  NFLPC,OFLPC,PLOT,PNCH,REGRES,SH,SHAPE
     5  /0.0, 38.2, .FALSE.,.FALSE.,0.0,0.0,2./,
     6  SIGMA,SIZE1,STEADY,TINPT,WFLPC
     7  /5.6697E-8,-10.,.FALSE.,0.0,12.0/
C       HEAT CAPACITIES ARE GIVEN IN THE FORM  CP(1)*TEMP+CP(2)
      DATA  CPCO   /0.1185, 1018./,
     1      CPCO2  /0.2114, 931./,
     2      CPH2O  /0.3549, 1814./,
     3      CPH2   /0.6862, 13966./,
     4      CPO2   /0.3704, 931./,
     5      CPN2   /0.1127, 1010./,
     6      CPPYR  /0.1127, 1010./
C       PROPERTIES OF PYROLYSIS GASES ARE ASSUMED SAME AS FOR NITROGEN
C
      NAMELIST /VARS/ ADIA,AFLOOR,AWALL,AWDOW,BPF,CD,CFLPC,CPPYR,CVGROS,
     1  DENSW,DHP,DTIME,EF,EISCAN,EITA,FLOAD,FLSPEC,HFLPC,HWDOW,
     2  IRUN,IX,KTRACE,MTIME,MWPYR,NEWPLT,NEWPRP,NFLPC,OFLPC,PLFUEL,
     3  PLOT,PNCH,PRNT,REGRES,RPSPEC,SH,SHAPE,SIZE,STEADY,STOICH,
     4  TINPT,THICKW,TBOILC,VTSPEC,WFLPC,  SCALX,SCALY
   10 READ (1,900,END=150) TITLE
  900 FORMAT (13A6,A2)
      WRITE(2,910) TITLE
  910 FORMAT(1H1,13A6,A2)
      EISCAN=.FALSE.
      STOICH=.FALSE.
```

```
      STEADY=.FALSE.
      KITER= 0
      TINPT= 0.
      KNTRL= 1
      KTRACE= 0
      NEWPLT= .FALSE.
      RPSPEC= .FALSE.
      FLSPEC= .FALSE.
      VTSPEC= .FALSE.
      PLFUEL= .FALSE.
      IRUN= IRUN+1
   20 READ (1,VARS)
      WRITE (5,VARS)
      IF(ADIA.OR.EISCAN.OR.STOICH) STEADY=.TRUE.
      IF (PNCH) PUNCH 900, TITLE
      IF (NEWPLT.AND.PLOT) CALL PLTRST
      IF (NEWPRP) CALL INC
      NEWPRP= .FALSE.
   30 CALL ICONDS
      IF (KNTRL.EQ.2) GOTO 10
      IF (KTRACE.NE.1)GOTO 50
   40 WRITE (4,901) IRUN
  901 FORMAT ('1 RUN NO.',I4//
     1   '  TGAS1     TGAS2      F1         F2         DERIV1     K KD '
     2   'KH      J   T2(1)     TSF        QFIRE      QFLOW       QRADW    '
     3   '   RP       RC   '/)
   50 IF (KITER.EQ.1) GO TO 60
      CALL ECHOID
   60 IF (RPSPEC) GOTO 70
      IF (FLSPEC) GOTO 80
      IF (VTSPEC) GOTO 90
      IF (PLFUEL.AND..NOT.FLSPEC) GOTO 100
      CALL CRIB
      GOTO 110
   70 CALL RPFIX
      GOTO 110
   80 CALL PFLFIX
      GOTO 110
   90 CALL PVTFIX
      GOTO 110
  100 CALL POOL
  110 GO TO (120,10,130,120),KNTRL
C         KNTRL= 1 INITIAL VALUE
C         KNTRL= 2 INPUT ERROR DETECTED, PROCEED TO NEW RUN
C         KNTRL= 3 ITERATION FAILURE--PRINT OUT STEPS EVEN IF KTRACE= 0.
C         KNTRL= 4 SIMULATION TIME LIMIT EXCEEDED
  120 CONTINUE
C          INSERT HERE ANY REWIND COMMAND TO BE DONE IF NO ERROR
      IF (PLOT.OR.PNCH) CALL DOUT
      GO TO 10
  130 IF (KTRACE.EQ.1) GOTO 10
  140 KTRACE= 1
      KITER= 1
      WRITE (2.903) TGAS
  903 FORMAT ('0---ITERATION FAILURE---'/' TGAS=',F16.2)
      GO TO 30
  150 CONTINUE
C     ENDFILE 5
      STOP
      END
```

```
      SUBROUTINE CRIB
C
C         CRIB FIRE ROUTINE
C         EQUATIONS FOLLOW NILSSON'S DATA FOR WOOD CRIBS.
C         OTHER FUEL CRIBS CAN BE TREATED IF PYROLYSIS CONSTANTS
C         ARE KNOWN.
C
      COMMON /CNSTS/  AWALLN,BWDOW,DENSA,G,GASCNT,KTRACE,MTIME
      COMMON /CP/     CPA,CPCO(2),CPCO2(2),CPH2(2),CPH2O(2),CPN2(2),
     1   CPO2(2),CPPYR(2)
      COMMON /FUEL/   C,CFLPC,CVGROS,CVNET,H,HFLPC,MWPYR,N,NFLPC,O,
     1   OFLPC,R,RO,REGRES,SH,SHAPE,SIZE,W,WFLPC,WTFUEL
      COMMON /GP/     AWDOW,BPF,CD,CNV,DTIME,EMS(2),HWDOW,IX,IXC,IXL,
     1   J,JM,JP,JPRINT,K,KD,KH,KITER,KNTRL,MWIN,MWOUT,RC,RP,SIGMA
      COMMON /LOGIC/  FC,FLSPEC,KRIT,NEWPLT,NEWPRP,PLFUEL,PLOT,PNCH,
     1   RPSPEC,VTSPEC
      COMMON /PLAST/ TBOILC,DHP,STOICH,SIZE1,EITA,EISCAN
      COMMON /PRBLM/  ADIA,AFLOOR,AWALL,DENSW,FLOAD,IRUN,OPENF,
     1   PRNT,STEADY,THICKW
      COMMON /QS/     QCONW,QFIRE,QFLOW,QRADO,QRADW,QWLSUM
      COMMON /TEMP/   DENF,DENU,TAMB,TGAS,TINPT,T1(20),T2(20),TSF,TSU
      COMMON /THERML/ CNDA(2,10),CPW(2,10),DX,EF,EMSA(2,10),
     1   NCND,NCPW,NEMS,NQGEN,NRP,QGEN(2,10),RPX(2,50)
      COMMON /WOUT/   BWORST,FLREM,HRATIO,RMA,RMF,TTIME,VAVGIN,
     1   WA,WB,YCO2,YH2O,YN2,YO2,YPYR
      LOGICAL ADIA,EISCAN,FC,FLSPEC,KRIT,NEWPRP,PLFUEL,
     1   PLOT,PNCH,RPSPEC,SCAN,STEADY,STOICH,VTSPEC
      REAL MWIN,MWOUT,MWPYR,MTIME,N,NFLPC
      IF (STEADY) GOTO 190
      FC= .FALSE.
      SCAN= .FALSE.
      QRADW=0.
      QCONW= 0.
      F2=0.
      F1=0.
      DTGAS=10.
      CALL HEADNG
C         START TIME LOOP
      DO 170 J=1,JM
      KH= 0
      DERIV1= 1.
      TGAS2= 0.
      TGAS1= 0.
      TGASP= 2000.
      TGASN= TAMB
   20 CONTINUE
      K= 0
   30 CONTINUE
      IF (FLREM.GT.0.) GOTO 40
      RC= 0.
      RP= 0.
      GO TO 50
   40 IF (REGRES.LE.0.0) GOTO 45
C         USE THIS FORMULA IF INPUT REGRES IS SPECIFIED
      RP= REGRES*2.*SHAPE/SIZE*FLREM**(1.-1./SHAPE)*WTFUEL**(1./SHAPE)
      GO TO 50
   45 CONTINUE
```

```
C       .  FUEL SURFACE CONTROL
C          ASSUME CRIB STICK DENSITY RHOCR= 500 KG/M**3
      RHOCR= 500.
      REGREN= 1.24E-3/RHOCR*SIZE**-0.6
      RP1= REGREN*2.*SHAPE/SIZE*FLREM**(1.-1./SHAPE)*WTFUEL**(1./SHAPE)
C          CRIB POROSITY CONTROL
      RP2= 0.22*WTFUEL/(RHOCR*SIZE)*SH
C          ROOM VENTILATION CONTROL
      RP3= 0.120*AWDOW*SQRT(HWDOW)
      RP= AMIN1 (RP1,RP2,RP3)
   50 RMF= RMA+RP
      YCO2= 3.66667*CFLPC*RC/100./RMF
      YH2O= (WFLPC*RP+9.0*HFLPC*RC)/100./RMF
      YO2= (0.23*RMA-R0*RC)/RMF
      YN2= 0.77*RMA/RMF +NFLPC*RP/100./RMF
      YPYR= (RP-RC)/RMF
      IF(YPYR.LT..0) YPYR= 0.
      MWOUT= 44.*YCO2+18.*YH2O+28.*YN2+32.*YO2+MWPYR*YPYR
      HRATIO= 1./(1.+((TGAS/TAMB)*(MWIN/MWOUT)*(1.+RP/RMA)**2)
     1    **0.3333333333)
C          NOTE HIN IS TAKEN AS POSITIVE
      HIN= HWDOW* HRATIO
      ZW=1.-MWOUT*TAMB/MWIN/TGAS
      IF(ZW)195,55,55
   55 VAVGIN= 0.666667*SQRT(2.*G*HIN*ZW)
      RMA= CD*VAVGIN*HIN*BWDOW*DENSA
      RMF= RMA+RP
      IF (RMA/R-RP) 60,60,65
   60 RC= BPF*RMA/R
      GO TO 70
   65 RC= BPF*RP
      FC= .TRUE.
   70 CONTINUE
      QFLOW= RMF*(YCO2*(TGAS*(0.5*CPCO2(1)*TGAS+CPCO2(2))-TAMB*(0.5*
     1    CPCO2(1)*TAMB+CPCO2(2))) +YH2O*(TGAS*(0.5*CPH2O(1)*TGAS+
     2    CPH2O(2))-TAMB*(0.5*CPH2O(1)*TAMB+CPH2O(2))) +YO2*(TGAS*(
     3    0.5*CPO2(1)*TGAS+CPO2(2))-TAMB*(0.5*CPO2(1)*TAMB+CPO2(2)))
     4    +YN2*(TGAS*(0.5*CPN2(1)*TGAS+CPN2(2))-TAMB*(0.5*CPN2(1)*
     5    TAMB+CPN2(2))) +YPYR*(TGAS*(0.5*CPPYR(1)*TGAS+CPPYR(2))
     6    -TAMB*(0.5*CPPYR(1)*TAMB+CPPYR(2))))
      QFIRE= RC*CVNET
      IF (ADIA) GOTO 90
      CALL DESOLV
      QRADW= AWALLN*EMS(1)*SIGMA*(TGAS**4.-TSF**4.)
      QCONW= AWALLN*(TGAS-TSF)*CNV*((TGAS-TSF)*(TGAS-TSF))**0.16666667
   90 CONTINUE
      QRADO= AWDOW*SIGMA*(TGAS**4.-TAMB**4.)
      K= K+1
      F3=F2
      F2=F1
      F1= QFIRE-QFLOW-QRADO-QRADW-QCONW
      TGAS3=TGAS2
      TGAS2=TGAS1
      TGAS1=TGAS
      IF (F1.LT.0..AND.TGAS.LT.TGASP) TGASP=TGAS
      IF (F1.GT.0..AND.TGAS.GT.TGASN) TGASN=TGAS
      DERIV2= DERIV1
      IF (TGAS1.EQ.TGAS2) GOTO 130
```

```
      DERIV1=(F1-F2)/(TGAS1-TGAS2)
      IF (KTRACE.GT.0) WRITE (4,99) TGAS1,TGAS2,F1,F2,DERIV1,K,KD,
     1   KH,J,T2(1),TSF,QFIRE,QFLOW,QRADW,RP,RC
  99  FORMAT(2F9.2,3(1PE9.2),3I3,I5,2(0PF9.2),3(1PE10.3),2(0PF7.3))
      IF (.NOT.SCAN) GOTO 95
      IF (F1/F2.GE.0.0) GOTO 93
      SCAN= .FALSE.
      GOTO 100
  93  TGAS= TGAS-DTGAS
      IF (TGAS.LT.TAMB) GOTO 200
      GOTO 120
  95  IF (DERIV1.LT..0.AND.ABS(F2).GT..0001)GOTO 100
      IF(DERIV2.LT..0.AND.J.GT.2) GOTO 100
      TGAS= TGAS1+DTGAS/5.
      GOTO 120
 100  DIF= ABS(F1/QFLOW)
      IF (DIF.LT.0.002.AND.ABS(TGAS2-TGAS1).LT.2.) GOTO 130
      TGAS=(F1*TGAS2-F2*TGAS1)/(F1-F2)
      IF (K.GT.10.AND.F1.LT.0..AND.TGAS.GT.TGASP) GOTO 105
      IF (K.GT.10.AND.F1.GT.0..AND.TGAS.LT.TGASN) GOTO 105
      IF (K.EQ.1.AND.KH.EQ.0) TGAS= TGAS1 +10.
      IF (TGAS.GT.2000.) GOTO 110
      IF (TGAS.LT.(TAMB+30.)) GOTO 110
      GOTO 120
 105  TGAS= (TGASN+TGASP)/2.
      GOTO 120
 110  SCAN= .TRUE.
      TGAS= 1900.
 120  CONTINUE
      IF (K-200) 30,30,200
 130  CONTINUE
      CALL RSTA
      FLREM= FLREM-RP*DTIME
      IF(FLREM.LT.0.) FLREM=0.
      IF (QCONW.GT.0.) QWLSUM= QWLSUM+(QRADW+QCONW)*DTIME
      IF (TTIME .GE. MTIME) GO TO 210
      IF (TGAS.LE.353..AND.J.GE.10) GO TO 210
      IF (J.EQ.1) GO TO 150
      IF (JP.LT.JPRINT) GO TO 160
      JP= 0
 150  CALL OUTPUT
 160  JP= JP+1
      TTIME= TTIME+DTIME
 170  CONTINUE
C        END TIME STEP DO-LOOP
 180  CONTINUE
 185  CALL OUTPUT
      RETURN
C          ERROR IN INPUT
 190  CONTINUE
      KNTRL= 2
      WRITE (2,910)
 910  FORMAT (///' CRIB ROUTINE DOES NOT ACCEPT STEADY-STATE CASE')
      RETURN
C         SQUARE ROOT ERROR
 195  CONTINUE
      IF(KTRACE.EQ.1) WRITE(2,930) TGAS,RC,RP,YPYR,ZW,RMA,MWOUT
 930  FORMAT (/' TGAS=',F5.0,' RC=',E10.4,' RP=',E10.4,
```

```
     1  ' YPYR=',E10.4,' ZW=',F6.4,' RMA=',E10.4,' MWOUT=',F6.1)
C         FAIL TO CONVERGE, ERROR EXIT
  200 CONTINUE
      KNTRL=3
      RETURN
C         FIRE IS OVER (TRANSIENT CASE)
  210 CONTINUE
      CALL OUTPUT
      RETURN
      END
```

```
      SUBROUTINE DEQNS
C
C        DIFFERENTIAL EQUATION SOLVER BASED ON  CRANK-NICOLSON METHOD.
C
      COMMON /GP/      AWDOW,BPF,CD,CNV,DTIME,EMS(2),HWDOW,IX,IXC,IXL,
     1   J,JM,JP,JPRINT,K,KD,KH,KITER,KNTRL,MWIN,MWOUT,RC,RP,SIGMA
      COMMON /PRBLM/   ADIA,AFLOOR,AWALL,DENSW,FLOAD,IRUN,OPENF,
     1   PRNT,STEADY,THICKW
      COMMON /TEMP/    DENF,DENU,TAMB,TGAS,TINPT,T1(20),T2(20),TSF,TSU
      COMMON /THERML/ CNDA(2,10),CPW(2,10),DX,EF,EMSA(2,10),
     1   NCND,NCPW,NEMS,NQGEN,NRP,QGEN(2,10),RPX(2,50)
      DIMENSION A(20),B(20),C(20),CND(20),D(20),HCP(20)
C
      ENTRY RSTA
C
C        ENTER HERE WHEN READY FOR NEW TIME STEP (FINISHED ITERATING)
C
      DO 10 I=1,IX
      T1(I)= T2(I)
   10 CONTINUE
      TGOLD= TGAS
      IF (J.EQ.0) TGOLD=TAMB
      RETURN
C
      ENTRY DESOLV
C
C        SOLVE DIFFERENTIAL EQUATION
C
      KD= 1
      DX1= DX
      DO 20 I=1,IX
      CND(I)= TLU(CNDA,NCND,T1(I))
   20 HCP(I)= DENSW*DX/DTIME*TLU(CPW,NCPW,T1(I))
      EMS(1)= 1./(1./TLU(EMSA,NEMS,TSF) +1./EF -1.)
      EMS(2)= TLU(EMSA,NEMS,TSU)
      DO 50 I=2,IXL
      CNL= 1./(DX/CND(I-1)+DX/CND(I))
      IF (I.EQ.2 ) CNL= 1./(DX1/CND(1)+DX/CND(2))
      CNG= 1./(DX/CND(I)+DX/CND(I+1))
      A(I)= -CNL
      B(I)= HCP(I)+CNL+CNG
      C(I)= -CNG
      D(I)= (HCP(I)-CNL-CNG)*T1(I)+CNL*T1(I-1)+CNG*T1(I+1)
   50 IF (NQGEN.GT.0) D(I)= D(I)+DX*TLU(QGEN,NQGEN,T1(I))
      CNG= 1./(DX1/CND(1)+DX/CND(2))
      C(1)= -CNG
      CNL= 1./(DX/CND(IXL)+DX/CND(IX))
      A(IX)= -CNL
C
C        ENTER HERE WHEN KD.GT.1 SINCE PRIOR EXPRESSIONS DO NOT CHANGE
C
   30 TSFOLD= TSF
      ZRF= TGAS*(TGAS*(TGAS+TSF)+TSF*TSF)+TSF*TSF*TSF
      ZCF= CNV*((TGAS-TSF)*(TGAS-TSF))**0.1666666667
      HF= ZCF+SIGMA*EMS(1)*ZRF
      DENF= HF*DX1/2./CND(1)
      ZF= HF/2./(DENF+1.)
```

```
      B(1)= HCP(1)+ZF+CNG
      D(1)= (HCP(1)-ZF-CNG)*T1(1)+ZF*(TGAS+TGOLD)+CNG*T1(2)
      IF (NQGEN.GT.0) D(1)= D(1)+DX*TLU(QGEN,NQGEN,T1(1))
      ZRU= TAMB*(TAMB*(TAMB+TSU)+TSU*TSU)+TSU*TSU*TSU
      ZCU= 1.87*((TAMB-TSU)*(TAMB-TSU))**0.1666666667
      HU= ZCU+SIGMA*EMS(2)*ZRU
      DENU= HU*DX/2./CND(IX)
      ZU= HU/2./(DENU+1.)
      B(IX)= HCP(IX)+ZU+CNL
      D(IX)= (HCP(IX)-ZU-CNL)*T1(IX)+ZU*2.*TAMB+CNL*T1(IXL)
      IF (NQGEN.GT.0) D(IX)= D(IX)+DX*TLU(QGEN,NQGEN,T1(IX))
      CALL TRIDGF (A,B,C,D,T2,IX)
      TSF= (DENF*TGAS+T2(1))/(DENF+1.)
      TSU= (DENU*TAMB+T2(IX))/(DENU+1.)
      KD= KD+1
      IF (ABS(TSF-TSFOLD).LT.4) RETURN
      IF (KD.LE.6) GO TO 30
      WRITE (2,100) TSF,TSFOLD
100   FORMAT ('0    FAIL TO CONVERGE D.E.   TSF=',F7.2,'    TSFOLD=' F7.2)
      IF (KD.LE.30) GO TO 30
      RETURN
      END
```

```
      SUBROUTINE ECHOID
C
C         SUBROUTINE TO ECHO INPUT DATA
C
      COMMON /CP/     CPA,CPCO(2),CPCO2(2),CPH2(2),CPH2O(2),CPN2(2),
     1   CPO2(2),CPPYR(2)
      COMMON /FUEL/   C,CFLPC,CVGROS,CVNET,H,HFLPC,MWPYR,N,NFLPC,O,
     1   CFLPC,R,RO,REGRES,SH,SHAPE,SIZE,W,WFLPC,WTFUEL
      COMMON /GP/     AWDOW,BPF,CD,CNV,DTIME,EMS(2),HWDOW,IX,IXC,IXL,
     1   J,JM,JP,JPRINT,K,KD,KH,KITER,KNTRL,MWIN,MWOUT,RC,RP,SIGMA
      COMMON /LOGIC/  FC,FLSPEC,KRIT,NEWPLT,NEWPRP,PLFUEL,PLOT,PNCH,
     1   RPSPEC,VTSPEC
      COMMON /PLAST/ TBOILC,DHP,STOICH,SIZE1,EITA,EISCAN
      COMMON /PRBLM/  ADIA,AFLOOR,AWALL,DENSW,FLOAD,IRUN,OPENF,
     1   PRNT,STEADY,THICKW
      COMMON /THERML/ CNDA(2,10),CPW(2,10),DX,EF,EMSA(2,10),
     1   NCND,NCPW,NEMS,NQGEN,NRP,QGEN(2,10),RPX(2,50)
      LOGICAL ADIA,EISCAN,FC,FLSPEC,KRIT,NEWPRP,PLFUEL,
     1   PLOT,PNCH,RPSPEC,STEADY,STOICH,VTSPEC
      REAL MWIN,MWOUT,MWPYR,N,NFLPC
      WRITE (2,90) IRUN
      WRITE (2,91) AWALL, AFLOOR, HWDOW, AWDOW, OPENF, CD
      WRITE (2,92) FLOAD
      IF (PLFUEL) WRITE (2,93) DHP,TBOILC
      WRITE (2,94)  CFLPC,HFLPC,OFLPC,NFLPC,WFLPC,R,RO
      WRITE (2,95) CVGROS,CVNET,MWPYR,CPPYR,BPF,EF
      IF (.NOT.(PLFUEL.OR.VTSPEC.OR.RPSPEC)) WRITE (2,96) REGRES,SIZE,
     1   SHAPE
      IF (PLFUEL.AND..NOT.STOICH) WRITE (2,97) SIZE
      IF (.NOT.(PLFUEL.OR.VTSPEC.OR.RPSPEC).AND.SH.GT.0.0) WRITE (2,908)
     1   SH
      IF (RPSPEC.AND.NRP.EQ.1) WRITE (2,913) RPX(2,1)
      IF (RPSPEC.AND.NRP.NE.1) WRITE (2,914) ((RPX(I,J),I=1,2),J=1,NRP)
      IF(ADIA) GOTO 200
      WRITE (2,98) THICKW,DENSW
      IF (NCND.EQ.1) WRITE (2,900) CNDA(2,1)
      IF (NCND.GT.1) WRITE (2,901)((CNDA(I,J),I=1,2),J=1,NCND)
      IF (NCPW.EQ.1) WRITE (2,904) CPW(2,1)
      IF (NCPW.GT.1) WRITE (2,905)((CPW(I,J),I=1,2),J=1,NCPW)
      IF (NEMS.EQ.1) WRITE (2,902) EMSA(2,1)
      IF (NEMS.NE.1) WRITE (2,903)((EMSA(I,J),I=1,2),J=1,NEMS)
      IF (NQGEN.EQ.1) WRITE (2,906) QGEN(2,1)
      IF (NQGEN.GT.1) WRITE (2,907)((QGEN(I,J),I=1,2),J=1,NQGEN)
  200 IF(ADIA) WRITE(2,909)
      RETURN
   90 FORMAT (1H+, T86,'COMPF2 VERSION 1.1 - RUN NO.',I4)
   91 FORMAT ('0----GEOMETRY AND VENTILATION----'//
     1   ' WALL SURFACE AREA = ',F8.1,' M2'/
     2   ' FLOOR AREA = ',F8.2,' M2'/
     3   ' WINDOW HEIGHT = ',F8.2,' M'/
     4   '         AREA = ',F8.2,' M2'/
     5   ' OPENING FACTOR = ',F7.3,' M2.5'/
     6   ' DISCHARGE COEFF.= ',F4.2/)
   92 FORMAT ('0----FUEL LOAD PROPERTIES----'//
     1   ' FIRE LOAD PER FLOOR AREA =',F6.1,' KG/M2')
  913 FORMAT ('ORATE OF PYROLYSIS =',F7.2,' KG/S')
  914 FORMAT ('ORATE OF PYROLYSIS  (KG/S)'/'    TIME      RP'
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    1    50(/3X,F5.0,F9.3))
 93 FORMAT (' TOTAL ENTHALPY OF PYROLYSIS= '
    1     ,1PE10.2,' J/KG'/' BOILING TEMPERATURE=',0PF5.0,' DEG C')
 94 FORMAT ('0FUEL COMPOSITION'/
    1    ' CARBON    = ',F4.1,' PERCENT BY WEIGHT'/
    2    ' HYDROGEN  = ',F4.1,' PERCENT'/
    3    ' OXYGEN    = ',F4.1,' PERCENT'/
    4    ' NITROGEN  = ',F4.1,' PERCENT'/
    5    ' WATER     = ',F4.1,' PERCENT'/
    6    ' R = ',F5.2/
    7    ' R0= ',F5.2)
 95 FORMAT  ( ' HEAT OF COMBUSTION OF DRY FUEL = ',2PE10.2,' J/KG'/
    1    ' LOWER ACTUAL HEAT OF COMBUSTION = ',E10.2,' J/KG'/
    2    ' MOLECULAR WEIGHT OF UNBURNT PYROLYSATES = ',0PF6.2/
    3    ' CP OF PYROLYSIS GAS = (',F6.4,'*TGAS + ',F6.0,
    4    ') J/KG-K'/
    5    ' MAXIMUM FRACTION OF PYROLYSATES BURNED = ',F5.2/
    6    ' GREY-GAS FLAME EMISSIVITY = 'F5.3)
 96 FORMAT (' RATE OF REGRESSION = ',2PE9.2,' M/S'/
    1    ' FUEL DIMENSION = ',0PF5.3,' M'/
    2    ' SHAPE FACTOR = ',F4.2 /)
 97 FORMAT (' FUEL AREA=',F10.2,' M2')
908 FORMAT (' CRIB SPACING/HEIGHT RATIO=',F6.3)
 98 FORMAT ('0----WALL THERMAL PROPERTIES----'//
    1    ' THICKNESS = ',F5.3,' M'/
    2    ' DENSITY = ',F6.0,' KG/M3')
909 FORMAT ('0----WALL THERMAL PROPERTIES----'//
    1       ' ADIABATIC WALL'//)
900 FORMAT ('0THERMAL CONDUCTIVITY = ',F7.3,' W/M-K')
901 FORMAT ('0THERMAL CONDUCTIVITY ARRAY (W/M-K)'/
    1    ' TEMPERATURE   CONDUCTIVITY', 10(/3X,F7.1,4X,F10.3))
902 FORMAT ('0EMISSIVITY = ',F4.2)
903 FORMAT ('0EMISSIVITY ARRAY'/' TEMPERATURE   EMISSIVITY'
    1    10(/3X,F7.1,4X,F10.3))
904 FORMAT ('0HEAT CAPACITY = ',F7.0,' J/KG-K')
905 FORMAT  ('0HEAT CAPACITY ARRAY (J/KG-K)'/
    1    ' TEMPERATURE   HEAT CAPACITY', 10(/3X,F7.1,4X,F10.0))
906 FORMAT ('0WALL HEAT GENERATED = ',F9.3,' W/M3')
907 FORMAT ('0WALL HEAT GENERATED ARRAY (W/M3)'/
    1    ' TEMPERATURE   QGEN',  10(/3X,F7.1,4X,F10.3))
    END
```

```
      SUBROUTINE ICONDS
C
C         SET INITIAL CONDITIONS AND CONSTANTS
C
      COMMON /CNSTS/  AWALLN,BWDOW,DENSA,G,GASCNT,KTRACE,MTIME
      COMMON /CP/     CPA,CPCO(2),CPCO2(2),CPH2(2),CPH2O(2),CPN2(2),
     1   CPO2(2),CPPYR(2)
      COMMON /FUEL/   C,CFLPC,CVGROS,CVNET,H,HFLPC,MWPYR,N,NFLPC,O,
     1   OFLPC,R,RO,REGRES,SH,SHAPE,SIZE,W,WFLPC,WTFUEL
      COMMON /GP/     AWDOW,BPF,CD,CNV,DTIME,EMS(2),HWDOW,IX,IXC,IXL,
     1   J,JM,JP,JPRINT,K,KD,KH,KITER,KNTRL,MWIN,MWOUT,RC,RP,SIGMA
      COMMON /LOGIC/  FC,FLSPEC,KRIT,NEWPLT,NEWPRP,PLFUEL,PLOT,PNCH,
     1   RPSPEC,VTSPEC
      COMMON /PLAST/ TBOILC,DHP,STOICH,SIZE1,EITA,EISCAN
      COMMON /PRBLM/  ADIA,AFLOOR,AWALL,DENSW,FLOAD,IRUN,OPENF,
     1   PRNT,STEADY,THICKW
      COMMON /QS/     QCONW,QFIRE,QFLOW,QRADO,QRADW,QWLSUM
      COMMON /TEMP/   DENF,DENU,TAMB,TGAS,TINPT,T1(20),T2(20),TSF,TSU
      COMMON /THERML/ CNDA(2,10),CPW(2,10),DX,EF,EMSA(2,10),
     1   NCND,NCPW,NEMS,NQGEN,NRP,QGEN(2,10),RPX(2,50)
      COMMON /WOUT/   BWORST,FLREM,HRATIO,RMA,RMF,TTIME,VAVGIN,
     1   WA,WB,YCO2,YH2O,YN2,YO2,YPYR
      LOGICAL ADIA,EISCAN,FC,FLSPEC,KRIT,NEWPRP,PLFUEL,
     1   PLOT,PNCH,RPSPEC,STEADY,STOICH
      REAL MWIN,MWOUT,MWPYR,MTIME,N,NFLPC
      FC= .FALSE.
      KNTRL= 1
      AWALLN= AWALL-AWDOW
      BWDOW= AWDOW/HWDOW
      WTFUEL= FLOAD*AFLOOR
      OPENF= AWDOW*SQRT(HWDOW)
      MWIN= 28.97
      MWOUT= MWIN
      TAMB= 298.
      TGAS= 1800.
      IF (TINPT.GT.0.) TGAS= TINPT
      IXL= IX-1
      IXC= IX/2
      TSF= TAMB
      TSU= TAMB
      DENF= 0.
      DENU= 0.
      WA= 6H
      WB= 5H
      IF (.NOT.FLSPEC) GO TO 10
      WA= 6HWINDOW
      WB= 5HWIDTH
   10 JP= 0
      IF (.NOT.STEADY) JPRINT= PRNT/DTIME + (1.0-1.E-6)
      IF (STEADY) GOTO 20
      IF (DTIME.GT.0.00001) GOTO 15
      WRITE (2,95)
      KNTRL= 2
      RETURN
   95 FORMAT (///' FOR NON-STEADY PROBLEMS MUST SPECIFY DTIME ',
     1    'GREATER THAN ZERO')
   15 IF (MTIME.GT.DTIME) GOTO 20
```

```
      WRITE (2,92)
   92 FORMAT (///' FOR NON-STEADY PROBLEMS MUST SPECIFY MTIME ',
     1    'GREATER THAN DTIME')
      KNTRL= 2
      RETURN
   20 CONTINUE
      IF (.NOT.STEADY) JM= MTIME/DTIME +2
      IF (STEADY) JM= 2
      DX= THICKW/IX
      FLREM= WTFUEL
      TTIME= 0.
      EMS(1)= 1./(1./TLU(EMSA,NEMS,TAMB) +1./EF -1.)
      QWLSUM= 0.
      DO 60 I=1,IX
   60 T2(I)= TAMB
      J= 0
      CALL RSTA
      TOTAL= CFLPC+HFLPC+OFLPC+NFLPC+WFLPC
      IF (TOTAL.LT.101.1.AND.TOTAL.GT.98.9) GOTO 70
C          CHECK FOR ERRORS IN FUEL COMPOSITION
      KNTRL= 2
      WRITE (2,90)
   90 FORMAT (///' SUM OF FUEL COMPOSITION INPUT IS INCORRECT')
      RETURN
   70 C= CFLPC*(10./12.)
      H= HFLPC*10.
      O= OFLPC*(10./16.)
      W= WFLPC*(10./18.)
      N= NFLPC*(10./14.)
      RO= (C+H/4.-O/2.)*32./1000.
      R= RO/0.232
      CVNET= CVGROS*(1.-WFLPC/100.)-(WFLPC+9.0*HFLPC)/100.*2440.E+3
C        LATENT HEAT OF H2O EVAPORATION= 2440E+3 J/KG AT 25 C
      RMA= 0.16*AWDOW*DENSA*SQRT(G*HWDOW)
      RMF= RMA
      RC= BPF*RMA/R
      YO2= 0.10
      IF (STOICH) EITA= 1.
      IF (EISCAN) SIZE= SIZE1/EITA
      RETURN
      END
```

```
      SUBROUTINE INC
C
C        ROUTINE TO INPUT ALL CONSTANTS NOT GIVEN IN NAMELIST -VARS-
C
      COMMON /THERML/ CNDA(2,10),CPW(2,10),DX,EF,EMSA(2,10),
     1   NCND,NCPW,NEMS,NQGEN,NRP,QGEN(2,10),RPX(2,50)
      NQGEN= 0
      READ (1,91) NCN,NCP,NEM,NR,NQG
      IF (NCN.EQ.0) GO TO 10
      NCND= NCN
      READ (1,90) (CNDA(1,I),CNDA(2,I),I=1,NCND)
   10 IF (NCP.EQ.0) GO TO 20
      NCPW= NCP
      READ (1,90) (CPW(1,I),CPW(2,I),I=1,NCPW)
   20 IF (NEM.EQ.0) GO TO 30
      NEMS= NEM
      READ (1,90) (EMSA(1,I),EMSA(2,I),I=1,NEMS)
   30 IF (NR.EQ.0) GO TO 40
      NRP= NR
      READ (1,90) (RPX(1,I),RPX(2,I),I=1,NRP)
      NQGEN= NQG
   40 IF (NQG.EQ.0) GO TO 50
      READ (1,90) (QGEN(1,I),QGEN(2,I),I=1,NQGEN)
   50 RETURN
   90 FORMAT (8F10.0)
   91 FORMAT (10I3)
      END
```

```
      SUBROUTINE OUTPUT
C
C          PRINTS OUTPUT DATA
C
      COMMON /FUEL/    C,CFLPC,CVGROS,CVNET,H,HFLPC,MWPYR,N,NFLPC,O,
     1    OFLPC,R,RO,REGRES,SH,SHAPE,SIZE,W,WFLPC,WTFUEL
      COMMON /GP/       AWDOW,BPF,CD,CNV,DTIME,EMS(2),HWDOW,IX,IXC,IXL,
     1    J,JM,JP,JPRINT,K,KD,KH,KITER,KNTRL,MWIN,MWOUT,RC,RP,SIGMA
      COMMON /LOGIC/   FC,FLSPEC,KRIT,NEWPLT,NEWPRP,PLFUEL,PLOT,PNCH,
     1    RPSPEC,VTSPEC
      COMMON /PLAST/ TBOILC,DHP,STOICH,SIZE1,EITA,EISCAN
      COMMON /PRBLM/   ADIA,AFLOOR,AWALL,DENSW,FLOAD,IRUN,OPENF,
     1    PRNT,STEADY,THICKW
      COMMON /QS/       QCONW,QFIRE,QFLOW,QRADO,QRADW,QWLSUM
      COMMON /TEMP/     DENF,DENU,TAMB,TGAS,TINPT,T1(20),T2(20),TSF,TSU
      COMMON /WOUT/     BWORST,FLREM,HRATIO,RMA,RMF,TTIME,VAVGIN,
     1    WA,WB,YCO2,YH2O,YN2,YO2,YPYR
      LOGICAL ADIA,EISCAN,FC,FLSPEC,KRIT,NEWPRP,PLFUEL,
     1    PLOT,PNCH,RPSPEC,STEADY,STOICH,VTSPEC
      REAL MWIN,MWOUT,MWPYR,N,NFLPC
      LOGICAL DATPRT
      DIMENSION T2C(3)
      DATA DATPRT /.FALSE./
      IF (KITER.EQ.1) RETURN
      IF (PLOT.OR.PNCH) CALL DSTO     (TTIME,TGAS)
      IF (ILINE.LE.47) GO TO 50
      DATPRT= .TRUE.
      GO TO 300
   50 TGASC= TGAS-273.
      T2C(1)= TSF-273.
      T2C(2)= T2(IXC)-273.
      T2C(3)= TSU-273.
      FUELPC= FLREM/WTFUEL*100.
      QNORM= QFIRE/100.
      IF (QCONW.LT.0) QNORM= (QFLOW+QRADO)/100.
      ZFLOW= QFLOW/QNORM
      ZRADO= QRADO/QNORM
      ZCONW= QCONW/QNORM
      ZRADW= QRADW/QNORM
      EXCESS= RP-RC
      ILINE = ILINE+1
      WRITE (2,90) J,TTIME,TGASC,T2C,RP,RC,EXCESS,FUELPC,RMA,HRATIO,
     1    VAVGIN,MWOUT,FC
      IF (FLSPEC) WRITE (2,91) BWORST
      WRITE (3,92) TTIME,ZFLOW,ZRADO,ZCONW,ZRADW,QFIRE,QWLSUM,
     1    YO2,YN2,YCO2,YH2O,YPYR
      IF (STOICH) WRITE (2,901) SIZE1
      RETURN
C
      ENTRY HEADNG
C          START NEW PAGE
      IF (KITER.EQ.1) RETURN
      IPG = 1
  300 CONTINUE
      ILINE = 0
      IF (.NOT.RPSPEC) GOTO 315
      WRITE (2,94) IPG,IRUN
```

```
      WRITE (3,94) IPG,IRUN
      GO TO 400
315   IF (.NOT.FLSPEC) GOTO 325
      IF (.NOT.PLFUEL) WRITE (2,95) IPG,IRUN
      IF (.NOT.PLFUEL) WRITE (3,95) IPG,IRUN
      IF (PLFUEL) WRITE (2,905) IPG,IRUN
      IF (PLFUEL) WRITE (3,905) IPG,IRUN
      GO TO 400
325   IF (.NOT.VTSPEC) GOTO 335
      WRITE (2,96) IPG,IRUN
      WRITE (3,96) IPG,IRUN
      GO TO 400
335   IF (.NOT.PLFUEL) GO TO 345
      WRITE (2,97) IPG,IRUN
      WRITE (3,97) IPG,IRUN
      GO TO 400
345   WRITE (2,98) IPG,IRUN
      WRITE (3,98) IPG,IRUN
400   IPG = IPG+1
      WRITE (2,99) WA,WB
      WRITE (3,900)
      IF (.NOT.DATPRT) RETURN
      DATPRT= .FALSE.
      GO TO 50
 90   FORMAT (1H ,I4,T6,F8.0,T15,F7.0,T25,3F6.0,T44,F6.3,T51,F6.3,
     1   T60,F6.3,T69,F5.1,T79,F4.2,T87,F7.2,T96,F9.2,T109,F6.2,5X,L1)
 91   FORMAT (1H+, T124, F6.2)
 92   FORMAT (1H ,F7.0,4F11.3,1PE15.3,E15.3,1X,0P(5F8.3))
 94   FORMAT (1H1,T14,' INPUTTED VALUES OF RP ARE USED'
     1   T100,'PAGE NO.',I3,T115,'RUN NO.',I4//)
 95   FORMAT (1H1,T14, ' FUEL PYROLYSIS (CRIB) SPECIFIED, VENTILATION '
     1   ' ADJUSTED FOR WORST CONDITIONS', T100,'PAGE NO.',I3,T115,
     2   'RUN NO.',I4//)
 96   FORMAT (1H1,T14,' VENTILATION SPECIFIED, FUEL PYROLYSIS ADJUSTED'
     1   ' FOR WORST CONDITIONS',T100,'PAGE NO.',I3,T115,'RUN NO.',I4/
     2   /)
 97   FORMAT (1H1,T14,' THERMOPLASTIC POOL FIRE',T100,'PAGE NO.'
     1   I3,T115,'RUN NO.', I4//)
 98   FORMAT (1H1,T14,'CRIB FIRE',T100,'PAGE NO.',I3,
     1   T115,'RUN NO.',I4/)
 99   FORMAT (1H0,T10,'TIME',T17,'TEMP',T30,'WALL TEMPS',T47,'RP',
     1   T54,'RC',T59,'EXC.PYR.',T70,'FUEL',T78,'AIR IN',T90,'N.P.',
     2   T98,'VELOCITY',T109,'MOL.WT',T118,'FUEL',T124,A6/
     3   T11,'S',T17,'GAS,C',T34,'C',T46,'KG/S',T53,'KG/S',T61,
     4   'KG/S',T71,'PCT',T79,'KG/S',T101,'M/S',T108,
     5   T118,'CNTRL',T124,A5/)
900   FORMAT (T5,'TIME',T24,'HEAT BALANCE',T75,'Q-WALL',T88,'YO2',T96,
     2   'YN2',T104,'YCO2',T112,'YH2O',T120,'YPYR'/
     2   T13,'GAS FLOW',T25,'WND RAD',T36,'WALL CNV',T47,'WALL RAD',
     3   T60,'Q-FIRE',T76,'SUM',T88,'PCT',T96,'PCT',T104,'PCT',T112,
     4   'PCT',T120,'PCT'/
     5   T16,'PCT',T27,'PCT',T39,'PCT',T49,'PCT',T62,'W',T77,
     6   'J',T88,'MASS',T96,'MASS',T104,'MASS',T112,'MASS',
     7   T120,'MASS'/)
901   FORMAT (//' STOICHIOMETRIC FUEL SIZE= ',F8.3,' M2')
905   FORMAT (1H1,T14, ' FUEL PYROLYSIS (POOL) SPECIFIED, VENTILATION'
     1   ' ADJUSTED FOR WORST CONDITIONS', T100,'PAGE NO.',I3,T115,
     2   'RUN NO.',I4//)
      END
```

```
      SUBROUTINE PFLFIX
C
C
C          PESSIMIZATION ROUTINE
C          FIXED FUEL PYROLYSIS, WINDOW WIDTH VARIED FOR WORST
C          BURNING CONDITIONS.
C          EITHER CRIB OR POOL FUELS ACCEPTED
C          FOR POOL FUELS, MUST ALSO SET PLFUEL=.TRUE.
C
      COMMON /CNSTS/  AWALLN,BWDOW,DENSA,G,GASCNT,KTRACE,MTIME
      COMMON /CP/     CPA,CPCO(2),CPCO2(2),CPH2(2),CPH2O(2),CPN2(2),
     1   CPO2(2),CPPYR(2)
      COMMON /FUEL/   C,CFLPC,CVGROS,CVNET,H,HFLPC,MWPYR,N,NFLPC,O,
     1   OFLPC,R,RO,REGRES,SH,SHAPE,SIZE,W,WFLPC,WTFUEL
      COMMON /GP/     AWDOW,BPF,CD,CNV,DTIME,EMS(2),HWDOW,IX,IXC,IXL,
     1   J,JM,JP,JPRINT,K,KD,KH,KITER,KNTRL,MWIN,MWOUT,RC,RP,SIGMA
      COMMON /LOGIC/  FC,FLSPEC,KRIT,NEWPLT,NEWPRP,PLFUEL,PLOT,PNCH,
     1   RPSPEC,VTSPEC
      COMMON /PLAST/ TBOILC,DHP,STOICH,SIZE1,EITA,EISCAN
      COMMON /PRBLM/  ADIA,AFLOOR,AWALL,DENSW,FLOAD,IRUN,OPENF,
     1   PRNT,STEADY,THICKW
      COMMON /QS/     QCONW,QFIRE,QFLOW,QRADO,QRADW,QWLSUM
      COMMON /TEMP/   DENF,DENU,TAMB,TGAS,TINPT,T1(20),T2(20),TSF,TSU
      COMMON /THERML/ CNDA(2,10),CPW(2,10),DX,EF,EMSA(2,10),
     1   NCND,NCPW,NEMS,NQGEN,NRP,QGEN(2,10),RPX(2,50)
      COMMON /WOUT/   BWORST,FLREM,HRATIO,RMA,RMF,TTIME,VAVGIN,
     1   WA,WB,YCO2,YH2O,YN2,YO2,YPYR
      LOGICAL ADIA,EISCAN,FC,FLSPEC,KRIT,NEWPRP,PLFUEL,
     1   PLOT,PNCH,RPSPEC,SCAN,STEADY,STOICH,VTSPEC
      REAL MWIN,MWOUT,MWPYR,MTIME,N,NFLPC
      IF (STEADY) GOTO 190
      FC= .FALSE.
      SCAN= .FALSE.
      QRADW=0.
      QCONW= 0.
      F2=0.
      F1=0.
      DTGAS=10.
      TBOIL=TBOILC+273.
      CALL HEADNG
C          START TIME LOOP
      DO 170 J=1,JM
      KH= 0
      DERIV1= 1.
      TGAS2= 0.
      TGAS1= 0.
      TGASP= 2000.
      TGASN= TAMB
   20 CONTINUE
      K= 0
   30 CONTINUE
      KR= 0
      RMA= 0.666667*CD*0.5*AWDOW*DENSA*SQRT(G*HWDOW*(1.-TAMB/TGAS))
      IF (FLREM) 220,220,35
C          AS SOON AS FUEL IS EXHAUSTED PROGRAM MUST STOP,
C          SINCE WINDOW SIZE WOULD NOT BE WELL DEFINED.
   35 IF (.NOT.PLFUEL) GOTO 40
```

```
      RP= SIZE*EF*SIGMA*(TGAS**4.-TBOIL**4.)/DHP
      PLUME= SIZE*0.0014*CVNET/DHP
      PROP= 1.-(TGAS**4.-TBOIL**4.)/(1700.**4.-TBOIL**4.)
      IF (PROP.LT.0.) PROP= 0.
      RP= RP+PROP*PLUME
      GO TO 50
   40 IF (REGRES.LE.0.0) GOTO 45
C        USE THIS FORMULA IF INPUT REGRES IS SPECIFIED
      RP= REGRES*2.*SHAPE/SIZE*FLREM**(1.-1./SHAPE)*WTFUEL**(1./SHAPE)
      GO TO 50
   45 CONTINUE
C        FUEL SURFACE CONTROL
C        ASSUME CRIB STICK DENSITY RHOCR= 500 KG/M**3
      RHOCR= 500.
      REGREN= 1.24E-3/RHOCR*SIZE**-0.6
      RP1= REGREN*2.*SHAPE/SIZE*FLREM**(1.-1./SHAPE)*WTFUEL**(1./SHAPE)
C        CRIB POROSITY CONTROL
      RP2= 0.22*WTFUEL/(RHOCR*SIZE)*SH
      RP= AMIN1 (RP1,RP2)
   50 RMF= RMA+ RP
      YCO2= 3.66667*CFLPC*RC/100./RMF
      YH2O= (WFLPC*RP+9.0*HFLPC*RC)/100./RMF
      YO2= (0.23*RMA-RO*RC)/RMF
      YN2= 0.77*RMA/RMF +NFLPC*RP/100./RMF
      YPYR= (RP-RC)/RMF
      IF(YPYR.LT..0) YPYR= 0.
      MWOUT= 44.*YCO2+18.*YH2O+28.*YN2+32.*YO2+MWPYR*YPYR
      HRATIO= 1./(1.+((TGAS/TAMB)*(MWIN/MWOUT)*(1.+RP/RMA)**2)
     1  **0.3333333333)
C        NOTE HIN IS TAKEN AS POSITIVE
      HIN= HWDOW* HRATIO
      ZW=1.-MWOUT*TAMB/MWIN/TGAS
      IF(ZW)195,55,55
   55 VAVGIN= 0.666667*SQRT(2.*G*HIN*ZW)
      RMA= CD*VAVGIN*HIN*BWDOW*DENSA
      IF (RP-RMA/R) 60,60,65
   60 RC= RP*BPF
      BWORST= BWDOW*RC*R/RMA
      RMA= RC*R/BPF
      GO TO 70
   65 RC= BPF*RMA/R
      BWORST= BWDOW
C        RECALCULATE Y- VALUES SINCE RP,RC HAVE BEEN CHANGED
   70 KR= KR+1
      IF (KR-3) 50,75,75
   75 CONTINUE
      QFLOW= RMF*(YCO2*(TGAS*(0.5*CPCO2(1)*TGAS+CPCO2(2))-TAMB*(0.5*
     1   CPCO2(1)*TAMB+CPCO2(2))) +YH2O*(TGAS*(0.5*CPH2O(1)*TGAS+
     2   CPH2O(2))-TAMB*(0.5*CPH2O(1)*TAMB+CPH2O(2))) +YO2*(TGAS*(
     3   0.5*CPO2(1)*TGAS+CPO2(2))-TAMB*(0.5*CPO2(1)*TAMB+CPO2(2)))
     4   +YN2*(TGAS*(0.5*CPN2(1)*TGAS+CPN2(2))-TAMB*(0.5*CPN2(1)*
     5   TAMB+CPN2(2))) +YPYR*(TGAS*(0.5*CPPYR(1)*TGAS+CPPYR(2))
     6   -TAMB*(0.5*CPPYR(1)*TAMB+CPPYR(2))))
      QFIRE= RC*CVNET
      IF (ADIA) GOTO 90
      CALL DESOLV
      QRADW= AWALLN*EMS(1)*SIGMA*(TGAS**4.-TSF**4.)
      QCONW= AWALLN*(TGAS-TSF)*CNV*((TGAS-TSF)*(TGAS-TSF))**0.16666667
```

```
90 CONTINUE
   QRADO= HWDOW*BWORST*SIGMA*(TGAS**4.-TAMB**4.)
   K= K+1
   F3=F2
   F2=F1
   F1= QFIRE-QFLOW-QRADO-QRADW-QCONW
   TGAS3=TGAS2
   TGAS2=TGAS1
   TGAS1=TGAS
   IF (F1.LT.0..AND.TGAS.LT.TGASP) TGASP=TGAS
   IF (F1.GT.0..AND.TGAS.GT.TGASN) TGASN=TGAS
   DERIV2= DERIV1
   IF (TGAS1.EQ.TGAS2) GOTO 130
   DERIV1=(F1-F2)/(TGAS1-TGAS2)
   IF (KTRACE.GT.0) WRITE (4,99) TGAS1,TGAS2,F1,F2,DERIV1,K,KD,
  1    KH,J,T2(1),TSF,QFIRE,QFLOW,QRADW,RP,RC
99 FORMAT(2F9.2,3(1PE9.2),3I3,I5,2(0PF9.2),3(1PE10.3),2(0PF7.3))
   IF (.NOT.SCAN) GOTO 95
   IF (F1/F2.GE.0.0) GOTO 93
   SCAN= .FALSE.
   GOTO 100
93 TGAS= TGAS-DTGAS
   IF ((PLFUEL.AND.(TGAS.LT.TBOIL)).OR.(TGAS.LT.TAMB)) GOTO 200
   GOTO 120
95 IF (DERIV2.LT..0.AND.ABS(F2).GT..0001)GOTO 100
   IF(DERIV2.LT..0.AND.J.GT.2) GOTO 100
   TGAS= TGAS1+DTGAS
   GOTO 120
100 DIF= ABS(F1/QFLOW)
   IF (DIF.LT.0.002.AND.ABS(TGAS2-TGAS1).LT.2.) GOTO 130
   TGAS=(F1*TGAS2-F2*TGAS1)/(F1-F2)
   IF (K.GT.10.AND.F1.LT.0..AND.TGAS.GT.TGASP) GOTO 105
   IF (K.GT.10.AND.F1.GT.0..AND.TGAS.LT.TGASN) GOTO 105
   IF (TGAS.GT.TGASP.OR.TGAS.LT.TGASN) TGAS=(TGASP+TGASN)/2.
   IF (K.EQ.1.AND.KH.EQ.0) TGAS= TGAS1+10.
   IF (TGAS.GT.2000.) GOTO 110
   IF (TGAS.LT.(TAMB+30.)) GOTO 110
   IF (PLFUEL.AND.TGAS.LT.TBOIL) GOTO 110
   GOTO 120
105 TGAS= (TGASN+TGASP)/2.
   GOTO 120
110 SCAN= .TRUE.
   TGAS= 1900.
120 CONTINUE
   IF (K-200) 30,30,200
130 CONTINUE
   CALL RSTA
   FLREM= FLREM-RP*DTIME
   IF(FLREM.LT.0) FLREM=0.
   IF (QCONW.GT.0.) QWLSUM= QWLSUM+(QRADW+QCONW)*DTIME
   IF (TTIME .GE. MTIME) GO TO 210
   IF (TGAS.LE.353..AND.J.GE.10) GO TO 210
   IF (J.EQ.1) GO TO 150
   IF (JP.LT.JPRINT) GO TO 160
   JP= 0
150 CALL OUTPUT
160 JP= JP+1
   TTIME= TTIME+DTIME
```

```
 170 CONTINUE
C        END TIME STEP DO-LOOP
     RETURN
C        ERROR IN INPUT
 190 CONTINUE
     KNTRL= 2
     WRITE (2,910)
 910 FORMAT (///' PFLFIX ROUTINE DOES NOT ACCEPT STEADY-STATE CASE')
 195 CONTINUE
     IF(KTRACE.EQ.1) WRITE(2,930) TGAS,RC,RP,YPYR,ZW,RMA,MWOUT
 930 FORMAT (/' TGAS=',F5.0,' RC=',E10.4,' RP=',E10.4,
    1  ' YPYR=',E10.4,' ZW=',F6.4,' RMA=',E10.4,' MWOUT=',F6.1)
C        FAIL TO CONVERGE. ERROR EXIT
 200 CONTINUE
     KNTRL=3
     RETURN
C        FIRE IS OVER (TRANSIENT CASE)
 210 CONTINUE
     CALL OUTPUT
 220 CONTINUE
     RETURN
     END
```

```
      SUBROUTINE POOL
C
C           PLASTIC FUEL (POOL FIRE) ROUTINE
C           FUEL 'SEES' ONLY COMPARTMENT AND NOT ITSELF
C
      COMMON /CNSTS/   AWALLN,BWDOW,DENSA,G,GASCNT,KTRACE,MTIME
      COMMON /CP/      CPA,CPCO(2),CPCO2(2),CPH2(2),CPH2O(2),CPN2(2),
     1    CPO2(2),CPPYR(2)
      COMMON /FUEL/    C,CFLPC,CVGROS,CVNET,H,HFLPC,MWPYR,N,NFLPC,O,
     1    OFLPC,R,RO,REGRES,SH,SHAPE,SIZE,W,WFLPC,WTFUEL
      COMMON /GP/      AWDOW,BPF,CD,CNV,DTIME,EMS(2),HWDOW,IX,IXC,IXL,
     1    J,JM,JP,JPRINT,K,KD,KH,KITER,KNTRL,MWIN,MWOUT,RC,RP,SIGMA
      COMMON /LOGIC/   FC,FLSPEC,KRIT,NEWPLT,NEWPRP,PLFUEL,PLOT,PNCH,
     1    RPSPEC,VTSPEC
      COMMON /PLAST/ TBOILC,DHP,STOICH,SIZE1,EITA,EISCAN
      COMMON /PRBLM/   ADIA,AFLOOR,AWALL,DENSW,FLOAD,IRUN,OPENF,
     1    PRNT,STEADY,THICKW
      COMMON /QS/      QCONW,QFIRE,QFLOW,QRADO,QRADW,QWLSUM
      COMMON /TEMP/    DENF,DENU,TAMB,TGAS,TINPT,T1(20),T2(20),TSF,TSU
      COMMON /THERML/ CNDA(2,10),CPW(2,10),DX,EF,EMSA(2,10),
     1    NCND,NCPW,NEMS,NQGEN,NRP,QGEN(2,10),RPX(2,50)           --- EF=0.9
      COMMON /WOUT/    BWORST,FLREM,HRATIO,RMA,RMF,TTIME,VAVGIN,
     1    WA,WB,YCO2,YH2O,YN2,YO2,YPYR
      LOGICAL ADIA,EISCAN,FC,FLSPEC,KRIT,NEWPRP,PLFUEL,
     1    PLOT,PNCH,RPSPEC,SCAN,STEADY,STOICH,VTSPEC
      REAL MWIN,MWOUT,MWPYR,MTIME,N,NFLPC
C           Y- DENOTE MASS FRACTIONS OF OUTFLOW
C           RMA= MASS INFLOW RATE
C           RMF= MASS OUTFLOW RATE
C           R= STOICHIOMETRIC AIR/FUEL MASS RATIO
C           RO= STOICHIOMETRIC OXYGEN/FUEL RATIO
      SCAN= .FALSE.
C         INITIALIZES STOICHIOMETRIC CASE
      IF (STOICH) EITA =1.
      QRADW=0.
      QCONW= 0.
      F2=0.
      F1=0.
      DTGAS=10.
      TBOIL=TBOILC+273.
      FC= .FALSE.
      CALL HEADNG
      TF2= TGAS
C         START TIME STEP
      DO 170 J=I,JM
      KH= 0
      DERIV1= 1.
      TGAS2= 0.
      TGAS1= 0.
      TGASP= 2000.
      TGASN= TAMB
   20 CONTINUE
      K= 0
   30 CONTINUE
      IF (STOICH) GOTO 34
   32 RP= SIZE*EF*SIGMA*(TGAS**4.-TBOIL**4.)/DHP
      IF (STEADY) GOTO 33
```

```
      PLUME= SIZE*0.0014*CVNET/DHP
      PROP= 1.-(TGAS**4.-TBOIL**4.)/(1700.**4.-TBOIL**4.)
      IF (PROP.LT.0.) PROP= 0.
      RP= RP+PROP*PLUME
   33 CONTINUE
      RMF= RMA+RP
      IF(FLREM.LE.0)RP=0.
   34 YCO2= 3.66667*CFLPC*RC/100./RMF
      YH2O= (WFLPC*RP+9.0*HFLPC*RC)/100./RMF
      YO2= (0.23*RMA-RO*RC)/RMF
      YN2= 0.77*RMA/RMF +NFLPC*RP/100./RMF
      YPYR= (RP-RC)/RMF
      IF(YPYR.LT..0) YPYR= 0.
      QFUEL= (RP-RC)*DHP
      MWOUT= 44.*YCO2+18.*YH2O+28.*YN2+32.*YO2+MWPYR*YPYR
      HRATIO= 1./(1.+((TGAS/TAMB)*(MWIN/MWOUT)*(1.+RP/RMA)**2)
     1    **0.3333333333)
C         NOTE HIN IS TAKEN AS POSITIVE
      HIN= HWDOW* HRATIO
      ZW=1.-MWOUT*TAMB/MWIN/TGAS
      IF(ZW)195,35,35
   35 VAVGIN= 0.666667*SQRT(2.*G*HIN*ZW)
      RMA= CD*VAVGIN*HIN*BWDOW*DENSA
      RMF= RMA+RP
      RC= BPF*RMA/R
      IF (STOICH) RP= RC/BPF
      IF ((EISCAN.AND.EITA.LT.1.).OR.STOICH) GOTO 37
   36 IF (RC.GT.RP*BPF) GOTO 40
   37 FC= .FALSE.
      GO TO 45
   40 FC= .TRUE.
      RC= RP*BPF
C         RECALCULATE VALUES IF IN FUEL CONTROL REGIME.
      YCO2= 3.66667*CFLPC*RC/100./RMF
      YH2O= (WFLPC*RP+9.0*HFLPC*RC)/100./RMF
      YO2= (0.23*RMA-RO*RC)/RMF
      YN2= 0.77*RMA/RMF +NFLPC*RP/100./RMF
      YPYR= (RP-RC)/RMF
   45 CONTINUE
      QFLOW= RMF*(YCO2*(TGAS*(0.5*CPCO2(1)*TGAS+CPCO2(2))-TAMB*(0.5*
     1    CPCO2(1)*TAMB+CPCO2(2))) +YH2O*(TGAS*(0.5*CPH2O(1)*TGAS+
     2    CPH2O(2))-TAMB*(0.5*CPH2O(1)*TAMB+CPH2O(2))) +YO2*(TGAS*(
     3    0.5*CPO2(1)*TGAS+CPO2(2))-TAMB*(0.5*CPO2(1)*TAMB+CPO2(2)))
     4    +YN2*(TGAS*(0.5*CPN2(1)*TGAS+CPN2(2))-TAMB*(0.5*CPN2(1)*
     5    TAMB+CPN2(2))) +YPYR*(TGAS*(0.5*CPPYR(1)*TGAS+CPPYR(2))
     6    -TAMB*(0.5*CPPYR(1)*TAMB+CPPYR(2))))
      QFIRE= RC*CVNET
      IF (ADIA) GOTO 90
      IF (.NOT.STEADY) CALL DESOLV
      IF (STEADY) CALL STFLOW
      QRADW= AWALLN*EMS(1)*SIGMA*(TGAS**4.-TSF**4.)
      QCONW= AWALLN*(TGAS-TSF)*CNV*((TGAS-TSF)*(TGAS-TSF))**0.16666667
   90 CONTINUE
      QRADO= AWDOW*SIGMA*(TGAS**4.-TAMB**4.)
      K= K+1
      F3=F2
      F2=F1
      F1= QFIRE-QFLOW-QFUEL-QRADO-QRADW-QCONW
```

```
      TGAS3=TGAS2
      TGAS2=TGAS1
      TGAS1=TGAS
      IF (F1.LT.0..AND.TGAS.LT.TGASP) TGASP=TGAS
      IF (F1.GT.0..AND.TGAS.GT.TGASN) TGASN=TGAS
      DERIV2= DERIV1
      IF (TGAS1.EQ.TGAS2) GOTO 130
      DERIV1=(F1-F2)/(TGAS1-TGAS2)
      IF (KTRACE.GT.0) WRITE (4,99) TGAS1,TGAS2,F1,F2,DERIV1,K,KD,
     1   KH,J,T2(1),TSF,QFIRE,QFLOW,QRADW,RP,RC
   99 FORMAT(2F9.2,3(1PE9.2),3I3,I5,2(0PF9.2),3(1PE10.3),2(0PF7.3))
      IF (.NOT.SCAN) GOTO 95
      IF (F1/F2.GE.0.0) GOTO 93
      SCAN= .FALSE.
      GOTO 100
   93 TGAS= TGAS-DTGAS
      IF (TGAS.LT.TAMB) GOTO 200
      IF (TGAS.LT.TBOIL.AND.(FLREM.GT.0.0)) GOTO 190
      GOTO 120
   95 IF (DERIV1.LT..0.AND.ABS(F2).GT..0001)GOTO 100
      IF(DERIV2.LT..0.AND.J.GT.2) GOTO 100
      TGAS= TGAS1+DTGAS
      GOTO 120
  100 DIF= ABS(F1/QFLOW)
      IF (DIF.LT.0.002.AND.ABS(TGAS2-TGAS1).LT.2.) GOTO 130
      TGAS=(F1*TGAS2-F2*TGAS1)/(F1-F2)
      IF (K.GT.10.AND.F1.LT.0..AND.TGAS.GT.TGASP) GOTO 105
      IF (K.GT.10.AND.F1.GT.0..AND.TGAS.LT.TGASN) GOTO 105
      IF (K.EQ.1.AND.KH.EQ.0) TGAS= TGAS1+10.
      IF (TGAS.GT.2000.) GOTO 110
      IF (TGAS.LT.(TAMB+30.)) GOTO 110
      IF (TGAS.LT.TBOIL.AND.(FLREM.GT.0.0)) GOTO 110
      GOTO 120
  105 TGAS= (TGASN+TGASP)/2.
      GOTO 120
  110 SCAN= .TRUE.
      TGAS= 1900.
  120 CONTINUE
      IF (STEADY.AND..NOT.ADIA) CALL STFLOW
      IF (K-200) 30,30,200
  130 IF (STEADY) GOTO 180
      CALL RSTA
      FLREM= FLREM-RP*DTIME
      IF(FLREM.LT.0) FLREM=0.
      IF (QCONW.GT.0.) QWLSUM= QWLSUM+(QRADW+QCONW)*DTIME
      IF (TTIME .GE. MTIME) GO TO 210
      IF (TGAS.LE.353..AND.J.GE.10) GO TO 210
      IF (J.EQ.1) GO TO 150
      IF (JP.LT.JPRINT) GO TO 160
      JP= 0
  150 CALL OUTPUT
  160 JP= JP+1
      TTIME= TTIME+DTIME
  170 CONTINUE
C          END TIME STEP DO-LOOP
  180 CONTINUE
      IF(.NOT.STOICH) GOTO 185
C          FIND STOICHIOMETRIC FUEL SIZE
```

```
      SIZE1= RP/(EF*SIGMA*(TGAS**4.-TBOIL**4.)/DHP)
  185 CALL OUTPUT
C        NORMAL EXIT WHEN STEADY.EQ.T
      RETURN
C        ERROR EXIT
  190 CONTINUE
      IF (KTRACE.EQ.1) WRITE (2,910) TGAS.
  910 FORMAT(///' TGAS.LT.TBOIL   TGAS=',F8.1,'   GO TO NEXT CASE'///)
      GOTO 200
C        SQUARE ROOT ERROR
  195 CONTINUE
      IF(KTRACE.EQ.1) WRITE(2,930) TGAS,RC,RP,YPYR,ZW,RMA,MWOUT
  930 FORMAT (/' TGAS=',F5.0,' RC=',E10.4,' RP=',E10.4,
     1  ' YPYR=',E10.4,' ZW=',F6.4,' RMA=',E10.4,' MWOUT=',F6.1)
C        FAIL TO CONVERGE, ERROR EXIT
  200 CONTINUE
      KNTRL=3
      RETURN
C        FIRE IS OVER (TRANSIENT CASE)
  210 CONTINUE
      CALL OUTPUT
      RETURN
      END
```

```
      SUBROUTINE PP
C
C        PLOTTING SUBROUTINE
C        THIS ROUTINE IS LEFT BLANK SINCE IT IS MACHINE-DEPENDENT
C
      ENTRY PLTRST
C        THIS ENTRY SETS UP THE INIALIZATION OF PLOTTING
      ENTRY DSTO
C        THIS ENTRY IS CALLED EACH TIME TO STORE A DATA POINT
      ENTRY DOUT
C        THIS IS THE LAST ENTRY FOR A GIVEN RUN
      RETURN
      END
```

```
      SUBROUTINE PVTFIX
C
C         PESSIMIZATION ROUTINE
C         FIXED VENTILATION,WORST POSSIBLE FUEL PYROLYSIS RATE.
C
      COMMON /CNSTS/  AWALLN,BWDOW,DENSA,G,GASCNT,KTRACE,MTIME
      COMMON /CP/     CPA,CPCO(2),CPCO2(2),CPH2(2),CPH2O(2),CPN2(2),
     1   CPO2(2),CPPYR(2)
      COMMON /FUEL/   C,CFLPC,CVGROS,CVNET,H,HFLPC,MWPYR,N,NFLPC,O,
     1   OFLPC,R,RO,REGRES,SH,SHAPE,SIZE,W,WFLPC,WTFUEL
      COMMON /GP/     AWDOW,BPF,CD,CNV,DTIME,EMS(2),HWDOW,IX,IXC,IXL,
     1   J,JM,JP,JPRINT,K,KD,KH,KITER,KNTRL,MWIN,MWOUT,RC,RP,SIGMA
      COMMON /LOGIC/  FC,FLSPEC,KRIT,NEWPLT,NEWPRP,PLFUEL,PLOT,PNCH,
     1   RPSPEC,VTSPEC
      COMMON /PLAST/ TBOILC,DHP,STOICH,SIZE1,EITA,EISCAN
      COMMON /PRBLM/  ADIA,AFLOOR,AWALL,DENSW,FLOAD,IRUN,OPENF,
     1   PRNT,STEADY,THICKW
      COMMON /QS/     QCONW,QFIRE,QFLOW,QRADO,QRADW,QWLSUM
      COMMON /TEMP/   DENF,DENU,TAMB,TGAS,TINPT,T1(20),T2(20),TSF,TSU
      COMMON /THERML/ CNDA(2,10),CPW(2,10),DX,EF,EMSA(2,10),
     1   NCND,NCPW,NEMS,NQGEN,NRP,QGEN(2,10),RPX(2,50)
      COMMON /WOUT/   BWORST,FLREM,HRATIO,RMA,RMF,TTIME,VAVGIN,
     1   WA,WB,YCO2,YH2O,YN2,YO2,YPYR
      LOGICAL ADIA,EISCAN,FC,FLSPEC,KRIT,NEWPRP,PLFUEL,
     1   PLOT,PNCH,RPSPEC,SCAN,STEADY,STOICH,VTSPEC
      REAL MWIN,MWOUT,MWPYR,MTIME,N,NFLPC
      IF (STEADY) GOTO 190
      FC= .FALSE.
      SCAN= .FALSE.
      QRADW=0.
      QCONW= 0.
      F2=0.
      F1=0.
      DTGAS=10.
      CALL HEADNG
C          START TIME LOOP
      DO 170 J=1,JM
      KH= 0
      DERIV1= 1.
      TGAS2= 0.
      TGAS1= 0.
      TGASP= 2000.
      TGASN= TAMB
   20 CONTINUE
      K= 0
   30 CONTINUE
      IF (FLREM.GT.0.) GOTO 32
      RC= 0.
      RP= 0.
      FC= .TRUE.
   32 RMF= RMA+RP
      YCO2= 3.66667*CFLPC*RC/100./RMF
      YH2O= (WFLPC*RP+9.0*HFLPC*RC)/100./RMF
      YO2= (0.23*RMA-RO*RC)/RMF
      YN2= 0.77*RMA/RMF +NFLPC*RP/100./RMF
      YPYR= (RP-RC)/RMF
      IF(YPYR.LT..0) YPYR= 0.
```

```
      MWOUT= 44.*YCO2+18.*YH2O+28.*YN2+32.*YO2+MWPYR*YPYR
      HRATIO= 1./(1.+((TGAS/TAMB)*(MWIN/MWOUT)*(1.+RP/RMA)**2)
     1   **0.3333333333)
C          NOTE HIN IS TAKEN AS POSITIVE
      HIN= HWDOW* HRATIO
      ZW=1.-MWOUT*TAMB/MWIN/TGAS
      IF(ZW)195,35,35
   35 VAVGIN= 0.666667*SQRT(2.*G*HIN*ZW)
      RMA= CD*VAVGIN*HIN*BWDOW*DENSA
      RMF= RMA+RP
      IF (.NOT.FC) RC= BPF*RMA/R
      IF (.NOT.FC) RP= RC/BPF
   45 CONTINUE
      QFLOW= RMF*(YCO2*(TGAS*(0.5*CPCO2(1)*TGAS+CPCO2(2))-TAMB*(0.5*
     1   CPCO2(1)*TAMB+CPCO2(2))) +YH2O*(TGAS*(0.5*CPH2O(1)*TGAS+
     2   CPH2O(2))-TAMB*(0.5*CPH2O(1)*TAMB+CPH2O(2))) +YO2*(TGAS*(
     3   0.5*CPO2(1)*TGAS+CPO2(2))-TAMB*(0.5*CPO2(1)*TAMB+CPO2(2)))
     4   +YN2*(TGAS*(0.5*CPN2(1)*TGAS+CPN2(2))-TAMB*(0.5*CPN2(1)*
     5   TAMB+CPN2(2))) +YPYR*(TGAS*(0.5*CPPYR(1)*TGAS+CPPYR(2))
     6   -TAMB*(0.5*CPPYR(1)*TAMB+CPPYR(2))))
      QFIRE= RC*CVNET
      IF (ADIA) GOTO 90
      CALL DESOLV
      QRADW= AWALLN*EMS(1)*SIGMA*(TGAS**4.-TSF**4.)
      QCONW= AWALLN*(TGAS-TSF)*CNV*((TGAS-TSF)*(TGAS-TSF))**0.16666667
   90 CONTINUE
      QRADO= AWDOW*SIGMA*(TGAS**4.-TAMB**4.)
      K= K+1
      F3=F2
      F2=F1
      F1= QFIRE-QFLOW-QRADO-QRADW-QCONW
      TGAS3=TGAS2
      TGAS2=TGAS1
      TGAS1=TGAS
      IF (F1.LT.0..AND.TGAS.LT.TGASP) TGASP=TGAS
      IF (F1.GT.0..AND.TGAS.GT.TGASN) TGASN=TGAS
      DERIV2= DERIV1
      IF (TGAS1.EQ.TGAS2) GOTO 130
      DERIV1=(F1-F2)/(TGAS1-TGAS2)
      IF (KTRACE.GT.0) WRITE (4,99) TGAS1,TGAS2,F1,F2,DERIV1,K,KD,
     1   KH,J,T2(1),TSF,QFIRE,QFLOW,QRADW,RP,RC
   99 FORMAT(2F9.2,3(1PE9.2),3I3,I5,2(0PF9.2),3(1PE10.3),2(0PF7.3))
      IF (.NOT.SCAN) GOTO 95
      IF (F1/F2.GE.0.0) GOTO 93
      SCAN= .FALSE.
      GOTO 100
   93 TGAS= TGAS-DTGAS
      IF (TGAS.LT.TAMB) GOTO 200
      GOTO 120
   95 IF (DERIV1.LT..0.AND.ABS(F2).GT..0001)GOTO 100
      IF(DERIV2.LT..0.AND.J.GT.2) GOTO 100
      TGAS= TGAS1+DTGAS
      GOTO 120
  100 DIF= ABS(F1/QFLOW)
      IF (DIF.LT.0.002.AND.ABS(TGAS2-TGAS1).LT.2.) GOTO 130
      TGAS=(F1*TGAS2-F2*TGAS1)/(F1-F2)
      IF (K.GT.10.AND.F1.LT.0..AND.TGAS.GT.TGASP) GOTO 105
      IF (K.GT.10.AND.F1.GT.0..AND.TGAS.LT.TGASN) GOTO 105
```

```
      IF (K.EQ.1.AND.KH.EQ.0) TGAS= TGAS1 +10.
      IF (TGAS.GT.2000.) GOTO 110
      IF (TGAS.LT.(TAMB+30.)) GOTO 110
      GOTO 120
  105 TGAS= (TGASN+TGASP)/2.
      GOTO 120
  110 SCAN= .TRUE.
      TGAS= 1900.
  120 CONTINUE
      IF (K-200) 30,30,200
  130 CONTINUE
      CALL RSTA
      FLREM= FLREM-RP*DTIME
      IF(FLREM.LT.0) FLREM=0.
      IF (QCONW.GT.0.) QWLSUM= QWLSUM+(QRADW+QCCNW)*DTIME
      IF (TTIME .GE. MTIME) GO TO 210
      IF (TGAS.LE.353..AND.J.GE.10) GO TO 210
      IF (J.EQ.1) GO TO 150
      IF (JP.LT.JPRINT) GO TO 160
      JP= 0
  150 CALL OUTPUT
  160 JP= JP+1
      TTIME= TTIME+DTIME
  170 CONTINUE
C        END TIME STEP DO-LOOP
      RETURN
C       ,ERROR IN INPUT
  190 CONTINUE
      KNTRL= 2
      WRITE (2,910)
  910 FORMAT (///' PVTFIX ROUTINE DOES NOT ACCEPT STEADY-STATE CASE')
      RETURN
C        SQUARE ROOT ERROR
  195 CONTINUE
      IF(KTRACE.EQ.1) WRITE(2,930) TGAS,RC,RP,YPYR,ZW,RMA,MWOUT
  930 FORMAT (/' TGAS=',F5.0,' RC=',E10.4,' RP=',E10.4,
     1  ' YPYR=',E10.4,' ZW=',F6.4,' RMA=',E10.4,' MWOUT=',F6.1)
C        FAIL TO CONVERGE, ERROR EXIT
  200 CONTINUE
      KNTRL=3
      RETURN
C        FIRE IS OVER (TRANSIENT CASE)
  210 CONTINUE
      CALL OUTPUT
      RETURN
      END
```

```
      SUBROUTINE RPFIX
C
C
C          TABULAR FUEL PYROLYSIS ROUTINE
C          FUEL PYROLYSIS RATE IS AN INPUT VARIABLE.
C
      COMMON /CNSTS/  AWALLN,BWDOW,DENSA,G,GASCNT,KTRACE,MTIME
      COMMON /CP/     CPA,CPCO(2),CPCO2(2),CPH2(2),CPH2O(2),CPN2(2),
     1    CPO2(2),CPPYR(2)
      COMMON /FUEL/   C,CFLPC,CVGROS,CVNET,H,HFLPC,MWPYR,N,NFLPC,O,
     1    OFLPC,R,RO,REGRES,SH,SHAPE,SIZE,W,WFLPC,WTFUEL
      COMMON /GP/     AWDOW,BPF,CD,CNV,DTIME,EMS(2),HWDOW,IX,IXC,IXL,
     1    J,JM,JP,JPRINT,K,KD,KH,KITER,KNTRL,MWIN,MWOUT,RC,RP,SIGMA
      COMMON /LOGIC/  FC,FLSPEC,KRIT,NEWPLT,NEWPRP,PLFUEL,PLOT,PNCH,
     1    RPSPEC,VTSPEC
      COMMON /PLAST/ TBOILC,DHP,STOICH,SIZE1,EITA,EISCAN
      COMMON /PRBLM/  ADIA,AFLOOR,AWALL,DENSW,FLOAD,IRUN,OPENF,
     1    PRNT,STEADY,THICKW
      COMMON /QS/     QCONW,QFIRE,QFLOW,QRADO,QRADW,QWLSUM
      COMMON /TEMP/   DENF,DENU,TAMB,TGAS,TINPT,T1(20),T2(20),TSF,TSU
      COMMON /THERML/ CNDA(2,10),CPW(2,10),DX,EF,EMSA(2,10),
     1    NCND,NCPW,NEMS,NQGEN,NRP,QGEN(2,10),RPX(2,50)
      COMMON /WOUT/   BWORST,FLREM,HRATIO,RMA,RMF,TTIME,VAVGIN,
     1    WA,WB,YCO2,YH2O,YN2,YO2,YPYR
      LOGICAL ADIA,EISCAN,FC,FLSPEC,KRIT,NEWPRP,PLFUEL,
     1    PLOT,PNCH,RPSPEC,SCAN,STEADY,STOICH,VTSPEC
      REAL MWIN,MWOUT,MWPYR,MTIME,N,NFLPC
      SCAN= .FALSE.
      QRADW=0.
      QCONW= 0.
      F2=0.
      F1=0.
      DTGAS=10.
      CALL HEADNG
C           START TIME LOOP
      DO 170 J=1,JM
      KH= 0
      DERIV1= 1.
      TGAS2= 0.
      TGAS1= 0.
      TGASP= 2000.
      TGASN= TAMB
   20 CONTINUE
      K= 0
   30 CONTINUE
      FC= .FALSE.
      IF (FLREM.GT.0.) RP= TLU(RPX,NRP,TTIME)
      IF (FLREM.LE.0.) RP= 0.
      RMF= RMA+RP
      YCO2= 3.66667*CFLPC*RC/100./RMF
      YH2O= (WFLPC*RP+9.0*HFLPC*RC)/100./RMF
      YO2= (0.23*RMA-RO*RC)/RMF
      YN2= 0.77*RMA/RMF +NFLPC*RP/100./RMF
      YPYR= (RP-RC)/RMF
      IF(YPYR.LT..0) YPYR= 0.
      MWOUT= 44.*YCO2+18.*YH2O+28.*YN2+32.*YO2+MWPYR*YPYR
      HRATIO= 1./(1.+((TGAS/TAMB)*(MWIN/MWOUT)*(1.+RP/RMA)**2)
```

```
     1    **0.3333333333)
C         NOTE HIN IS TAKEN AS POSITIVE
      HIN= HWDOW* HRATIO
      ZW=1.-MWOUT*TAMB/MWIN/TGAS
      IF(ZW)195,35,35
   35 VAVGIN= 0.666667*SQRT(2.*G*HIN*ZW)
      RMA= CD*VAVGIN*HIN*BWDOW*DENSA
      RMF= RMA+RP
      IF (RMA/R-RP) 40,40,45
   40 RC= BPF*RMA/R
      GO TO 50
   45 RC= BPF*RP
      FC= .TRUE.
   50 CONTINUE
      QFLOW= RMF*(YCO2*(TGAS*(0.5*CPCO2(1)*TGAS+CPCO2(2))-TAMB*(0.5*
     1    CPCO2(1)*TAMB+CPCO2(2))) +YH2O*(TGAS*(0.5*CPH2O(1)*TGAS+
     2    CPH2O(2))-TAMB*(0.5*CPH2O(1)*TAMB+CPH2O(2))) +YO2*(TGAS*(
     3    0.5*CPO2(1)*TGAS+CPO2(2))-TAMB*(0.5*CPO2(1)*TAMB+CPO2(2)))
     4    +YN2*(TGAS*(0.5*CPN2(1)*TGAS+CPN2(2))-TAMB*(0.5*CPN2(1)*
     5    TAMB+CPN2(2))) +YPYR*(TGAS*(0.5*CPPYR(1)*TGAS+CPPYR(2))
     6    -TAMB*(0.5*CPPYR(1)*TAMB+CPPYR(2))))
      QFIRE= RC*CVNET
      IF (ADIA) GOTO 90
      IF (.NOT.STEADY) CALL DESOLV
      IF (STEADY) CALL STFLOW
      QRADW= AWALLN*EMS(1)*SIGMA*(TGAS**4.-TSF**4.)
      QCONW= AWALLN*(TGAS-TSF)*CNV*((TGAS-TSF)*(TGAS-TSF))**0.16666667
   90 CONTINUE
      QRADO= AWDOW*SIGMA*(TGAS**4.-TAMB**4.)
      K= K+1
      F3=F2
      F2=F1
      F1= QFIRE-QFLOW-QRADO-QRADW-QCONW
      TGAS3=TGAS2
      TGAS2=TGAS1
      TGAS1=TGAS
      IF (F1.LT.0..AND.TGAS.LT.TGASP) TGASP=TGAS
      IF (F1.GT.0..AND.TGAS.GT.TGASN) TGASN=TGAS
      DERIV2= DERIV1
      IF (TGAS1.EQ.TGAS2) GOTO 130
      DERIV1=(F1-F2)/(TGAS1-TGAS2)
      IF (KTRACE.GT.0) WRITE (4,99) TGAS1,TGAS2,F1,F2,DERIV1,K,KD,
     1    KH,J,T2(1),TSF,QFIRE,QFLOW,QRADW,RP,RC
   99 FORMAT(2F9.2,3(1PE9.2),3I3,I5,2(0PF9.2),3(1PE10.3),2(0PF7.3))
      IF (.NOT.SCAN) GOTO 95
      IF (F1/F2.GE.0.0) GOTO 93
      SCAN= .FALSE.
      GOTO 100
   93 TGAS= TGAS-DTGAS
      IF (TGAS.LT.TAMB) GOTO 200
      GOTO 120
   95 IF (DERIV1.LT..0.AND.ABS(F2).GT..0001)GOTO 100
      IF(DERIV2.LT..0.AND.J.GT.2) GOTO 100
      TGAS= TGAS1+DTGAS
      GOTO 120
  100 DIF= ABS(F1/QFLOW)
      IF (DIF.LT.0.002.AND.ABS(TGAS2-TGAS1).LT.2.) GOTO 130
      TGAS=(F1*TGAS2-F2*TGAS1)/(F1-F2)
```

```
      IF (K.GT.10.AND.F1.LT.0..AND.TGAS.GT.TGASP) GOTO 105
      IF (K.GT.10.AND.F1.GT.0..AND.TGAS.LT.TGASN) GOTO 105
      IF (K.EQ.1.AND.KH.EQ.0) TGAS= TGAS1+10.
      IF (TGAS.GT.2000.) GOTO 110
      IF (TGAS.LT.(TAMB+30.)) GOTO 110
      GOTO 120
  105 TGAS= (TGASN+TGASP)/2.
      GOTO 120
  110 SCAN= .TRUE.
      TGAS= 1900.
  120 CONTINUE
      IF (STEADY.AND..NOT.ADIA) CALL STFLOW
      IF (K-200) 30,30,200
  130 CONTINUE
      IF (STEADY) GOTO 180
      CALL RSTA
      FLREM= FLREM-RP*DTIME
      IF(FLREM.LT.0.) FLREM=0.
      IF (QCONW.GT.0.) QWLSUM= QWLSUM+(QRADW+QCONW)*DTIME
      IF (TTIME .GE. MTIME) GO TO 210
      IF (TGAS.LE.353..AND.J.GE.10) GO TO 210
      IF (J.EQ.1) GO TO 150
      IF (JP.LT.JPRINT) GO TO 160
      JP= 0
  150 CALL OUTPUT
  160 JP= JP+1
      TTIME= TTIME+DTIME
  170 CONTINUE
C        END TIME STEP DO-LOOP
  180 CONTINUE
  185 CALL OUTPUT
C        NORMAL EXIT WHEN STEADY.EQ.T
      RETURN
C        SQUARE ROOT ERROR
  195 CONTINUE
      IF(KTRACE.EQ.1) WRITE(2,930) TGAS,RC,RP,YPYR,ZW,RMA,MWOUT
  930 FORMAT (/' TGAS=',F5.0,' RC=',E10.4,' RP=',E10.4,
     1  ' YPYR=',E10.4,' ZW=',F6.4,' RMA=',E10.4,' MWOUT=',F6.1)
C        FAIL TO CONVERGE, ERROR EXIT
  200 CONTINUE
      KNTRL=3
      RETURN
C        FIRE IS OVER (TRANSIENT CASE)
  210 CONTINUE
      CALL OUTPUT
      RETURN
      END
```

```
      SUBROUTINE STFLOW
C
C           CALCULATES WALL HEAT CONDUCTION WHEN STEADY-STATE
C           CONDITION ONLY IS NEEDED.
C
      COMMON /GP/      AWDOW,BPF,CD,CNV,DTIME,EMS(2),HWDOW,IX,IXC,IXL,
     1   J,JM,JP,JPRINT,K,KD,KH,KITER,KNTRL,MWIN,MWOUT,RC,RP,SIGMA
      COMMON /PRBLM/  ADIA,AFLOOR,AWALL,DENSW,FLOAD,IRUN,OPENF,
     1   PRNT,STEADY,THICKW
      COMMON /TEMP/   DENF,DENU,TAMB,TGAS,TINPT,T1(20),T2(20),TSF,TSU
      COMMON /THERML/ CNDA(2,10),CPW(2,10),DX,EF,EMSA(2,10),
     1   NCND,NCPW,NEMS,NQGEN,NRP,QGEN(2,10),RPX(2,50)
C        BIOT= BIOT NUMBER
      KD= 0
      TSF= TGAS -30.
      TSU= TAMB +30.
   10 CONTINUE
      TSFOLD= TSF
      TSUOLD= TSU
      EMS(1)= 1./(1./TLU(EMSA,NEMS,TSF) +1./EF -1.)
      EMS(2)= TLU(EMSA,NEMS,TSU)
      TAVG= (TGAS+TAMB)/2.
      CND= TLU(CNDA,NCND,TAVG)
      ZRF= TGAS*(TGAS*(TGAS+TSF)+TSF*TSF)+TSF*TSF*TSF
      ZCF= CNV*((TGAS-TSF)*(TGAS-TSF))**0.16666667
      HF= ZCF+EMS(1)*SIGMA*ZRF
      BIOTF= HF*THICKW/CND
      ZRU= TAMB*(TAMB*(TAMB+TSU)+TSU*TSU)+TSU*TSU*TSU
      ZCU= 1.31*((TAMB-TSU)*(TAMB-TSU))**0.16666667
      HU= ZCU+EMS(2)*SIGMA*ZRU
      BIOTU= HU*THICKW/CND
      TSF= ((BIOTF+HF/HU)*TGAS+TAMB)/(1.+BIOTF+HF/HU)
      TSU= ((BIOTU+HU/HF)*TAMB+TGAS)/(1.+BIOTU+HU/HF)
      T2(1)= TSF- (TSF-TSU)*DX/THICKW/2.
      T2(IXC)= (TSF+TSU)/2.
      IF ((ABS(TSF-TSFOLD).LT.3.).AND.(ABS(TSU-TSUOLD).LT.3.))
     1   RETURN
      KD= KD+1
      TSU= (TSU+TSUOLD)/2.
      IF (KD.LT.20) GOTO 10
      WRITE (2,90) TSF,TSFOLD
   90 FORMAT (//' **UNSUCCESSFUL ITERATION IN STFLOW'/
     1   '     TSF=',F15.2,'  TSFOLD=',F15.2)
      RETURN
      END
```

```
      FUNCTION TLU (ARRAY,NUM,VALIN)
C        TABULAR LOOK-UP INTERPOLATING ROUTINE
C
      DIMENSION ARRAY(2,NUM)
C        ARRAY(1,I)= INDEPENDENT VARIABLE
C        ARRAY(2,I)= DEPENDENT VARIABLE
C        INTERPOLATES LINEARLY WITHIN GIVEN DOMAIN.  SETS EQUAL TO
C        SMALLEST OR LARGEST VALUE IF OUTSIDE THE DOMAIN.
      IF (NUM.NE.1) GO TO 10
      TLU= ARRAY(2,1)
      RETURN
   10 IF (NUM.NE.2) GO TO 20
      I= 2
      GO TO 50
   20 IF (VALIN.GT.ARRAY(1,1)) GO TO 30
      TLU= ARRAY(2,1)
      RETURN
   30 DO 40 I=2,NUM
      IF (VALIN.LE.ARRAY(1,I)) GO TO 50
   40 CONTINUE
      TLU= ARRAY(2,NUM)
      RETURN
   50 TLU= ARRAY(2,I-1) + (VALIN - ARRAY(1,I-1))*
     1    ((ARRAY(2,I) - ARRAY(2,I-1)) / (ARRAY(1,I) - ARRAY(1,I-1)))
      RETURN
      END


      SUBROUTINE TRIDGF (A,B,C,D,E,IX)
C
C        TRIDIAGONAL GAUSS ELIMINATION PROCEDURE FOR UNSYMMETRIC
C        MATRICES.
C        A=LEFT OF DIAGONAL, B=DIAGONAL, C=RIGHT OF DIAGONAL,
C        D= CONSTANT VECTOR, E= SOLUTION VECTOR, IX= SIZE OF MATRIX.
C
      DIMENSION A(20),B(20),C(20),D(20),E(20),CP(20)
      CP(1)= C(1)/B(1)
      E(1)= D(1)/B(1)
      C(IX)= 0.
      IXL= IX-1
      DO 10 I=2,IX
      J= I-1
      BX= B(I)-CP(J)*A(I)
      CP(I)= C(I)/BX
      E(I)= (D(I)-E(J)*A(I))/BX
   10 CONTINUE
      DO 20 I=1,IXL
      J= IX-I
      E(J)= E(J)-E(J+1)*CP(J)
   20 CONTINUE
      RETURN
      END
```

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15. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

COMPF2 is a computer program for calculating the characteristics of a post-flashover fire in a single building compartment, based on fire-induced ventilation through a single door or window. It is intended both for performing design calculations and for the analysis of experimental burn data. Wood, thermoplastic, and liquid fuels can be treated. In addition to the capability of performing calculations for compartments with completely determined properties, routines are included for calculating fire behavior by an innovative variable abstraction method. A comprehensive output format is provided which gives gas temperatures, heat flow terms, and flow variables. The documentation includes input instructions, sample problems, and a listing of the program. The program is written in Fortran and constitutes an improved version of an earlier program, COMPF.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Computer programs—fire protection; fire protection; fire resistance; fire tests; fire walls; safety engineering—fires.

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Appendix B

Vehicle Drawings Used for COMPF2 Study

Drawing Number	Drawing Title
M349-01	Side Elevation & Floor Plan
M349-02	Car Body Cross Section Normal Ceiling Area
M349-03	Cross Section - "F" End Low Ceiling Area
M349-04	Car Body Cross Section at Center Door
M349-05	Car End Elevation and Contour
M349-06	Non-Cab End
M349-07	Reflected Ceiling Plan
M349-08	Operator's Cab
M349-09	Operator's Console Control Panel
M349-10	Operator's Console Indicator Panel
M349-11	Operator's Auxiliary Control Panel
M349-12	Operator's Circuit Breaker Panel
M349-13	Trainline Circuit Breaker Panel
M349-14	Operator's Seat
M349-15	Two-Passenger Seat
M349-16	Back-To-Back Passenger Seat
M349-17	Speaker Grilles
M349-18	Dynamic Outline

Appendix C

WMATA ROHR VEHICLE

FIRE LOADING DATA AND CALCULATION

TABLE 4.3-1

ROHR VEHICLE HARDENING STUDY
COMBUSTIBLE MATERIALS INVENTORY

FUNCTION	MATERIAL	MANUFACTURER	WEIGHT (LB)	LOW HEATING VALUE (BTU/LB)	FUEL LOAD x 10^{-6} (BTU/CAR)
A. Interior					
1. Roof					
a. Insulation	Fiberglass	Johns-Mansville	363	0	0
b. Liner	PVC-Acrylic (DKE450)	Dupont	1,486	7,700	11,442
c. Cleating	Phenolic FG		40	7,750	310
	Epoxy		40	6,000	240
d. Trim	PVC-Acrylic (DKE450)	Rubbercraft	16	7,700	23
e. Light Fixture Lens	Polycarbonate (Lexan)	General Electric	45	11,100	500
f. Electrical Insulation	Hypalon		79	11,100	877
	Teflon		8	2,000	16
SUBTOTAL			2,077		13,508
2. Walls					
a. Insulation	Fiberglass	Johns-Mansville	91	0	0
b. Liner	PVC-Acrylic (DKE450)	Dupont	780	7,700	6,006
c. Cleating	Phenolic FG		20	7,700	154
	Epoxy FG		20	6,000	120
d. Windscreens, Cabs, Partitions	Melamine Wood	Champion Int.	175	4,000	700
e. Grilles, Trim	PVC		37	7,700	285
f. Window					
. Glazing Strips	Neoprene	Champion Int.	188	8,500	1,598
. Panes	Acrylic	Kirkhill	350	11,500	4,025
. Interlayer	PV Butral		6	7,700	46
. Seal	GRS Rubber		34	8,500	289
g. Destination	Polyester Film	Deanton	7.5	13,000	98
SUBTOTAL			1,708		13,321

TABLE 4.3-1 (CONT)

VEHICLE HARDENING STUDY
COMBUSTIBLE MATERIALS INVENTORY

FUNCTION	MATERIAL	MANUFACTURER	WEIGHT (LB)	LOW HEATING VALUE (BTU/LB)	FUEL LOAD x 10^{-6} (BTU/CAR)
A. Interior (continued)					
3. Seats					
a. Back and Frame	Acrylic-PVC		150	7,700	2,495
b. Cushions	RP Neoprene	Toyad	1,725	8,500	10,880
c. Upholstery	Vinyl	Tepperman	120	11,000	1,320
d. Arm Rests	Polycarbonate (Lexan)	General Electric	12	11,100	133
e. Equipment Panels	Plymetal	Westholt	8	4,000	32
(under seat)	Wood		16	7,900	126
SUBTOTAL			2,031		14,986
4. Floor & Carpet					
a. Floor Assembly	Plymetal (Aluminum)	Champion	2,347		
	Plywood		1,550	7,900	12,245
b. Carpet	4 plywool	Bigelow-Sanford	280	8,000	2,240
c. Carpet Pad	Rubber Foam	Bigelow-Sanford	210	8,500	1,785
SUBTOTAL			2,040		16,270
5. Miscellaneous					
a. Emergency Ladder	Wood	Montclair	12	3,000	96
b. Paddles	Wood				
SUBTOTAL			12		96
B. Cab					
a. Vibration isolators	Polyurethane		10	18,000	180
b. Shell	Epoxy FRP	Nordam	303	6,000	1,698
c. Floor Covering	RCA Rubber Tile	RCA	4	6,000	24
d. Seat Cushion	RP Neoprene Foam	Tepperman	3	8,500	25
e. Seat Upholstery	Vinyl	Tepperman	1	11,000	11
f. Curtain	Polyester Film	Deanton	1.1	10,000	11
g. Shield	Acrylic	Edwards	10.8	11,500	124
SUBTOTAL			333		2,073
TOTAL ABOVE FLOOR			8,201		60,254

TABLE 4.3-1 (CONT)

VEHICLE HARDENING STUDY
COMBUSTIBLE MATERIALS INVENTORY

FUNCITON	MATERIAL	MANUFACTURER	WEIGHT (LB)	LOW HEATING VALUE (BTU/LB)	FUEL LOAD x 10^{-6} (BTU/CAR)
TOTAL ABOVE FLOOR (carried forward from previous page)			8,201		60,254
C. Undercar					
a. Paint	Acrylic		80	11,000	80
b. Electrical Insulation	Hypalon		343	11,000	3,807
	Tefzel	Prestolite	8	2,150	17
c. Sealant	Polysuphide		115	11,000	1,265
	Epoxy aluminum		40	11,000	440
d. Air ducting	Acrylic PVC		30	7,700	231
e. Refrigerant	Freon 22		30	1,400	42
f. Hydr. Fluid	Oil		35	20,000	700
g. HVAC Duct	Glasscloth	Trane	2		0
H. Air Springs	Rubber/Neoprene		160	6,000	960
TOTAL UNDERCAR			843		8,342
TOTAL CAR			9,044		68,596

Appendix D

COMPF2 COMPUTER PRINTOUTS

INPUT DATA AND CORRESPONDING RESULTS

SUBWAY3001 - bpf = 50%, cvgross=21.2 load=52.2________ irun=1 COMPF2 VERSION 1.1 - RUN NO. 1

----GEOMETRY AND VENTILATION----

WALL SURFACE AREA = 1557.5 sq. ft.
FLOOR AREA = 662.6 sq. ft.
WINDOW HEIGHT = 3.1 ft.
AREA = 250.3 sq. ft.
OPENING FACTOR = 451.230 ft. ^1.5
DISCHARGE COEFF.= 0.68

----FUEL LOAD PROPERTIES----

FIRE LOAD PER FLOOR AREA = 10.7 lbs/sq.ft.

FUEL COMPOSITION
CARBON = 91.2 PERCENT BY WEIGHT
HYDROGEN = 7.7 PERCENT
OXYGEN = 0. PERCENT
NITROGEN = 0. PERCENT
WATER = 0. PERCENT
R = 13.14
RO= 3.05
HEAT OF COMBUSTION OF DRY FUEL = 91.3E+02 btu/lb
LOWER ACTUAL HEAT OF COMBUSTION = 84.0E+02 btu/lb
MOLECULAR WEIGHT OF UNBURNT PYROLYSATES = 28.97
CP OF PYROLYSIS GAS = (0. *TGAS + 0.3198) btu/lb-F
MAXIMUM FRACTION OF PYROLYSATES BURN = 0.50
GREY-GAS FLAME EMISSIVITY = 0.900

----WALL THERMAL PROPERTIES----

THICKNESS = 0.0 ft.
DENSITY = 1.309 lbs/cu. ft.

THERMAL CONDUCTIVITY = 26. btu/hr-ft-F

HEAT CAPACITY = 0.0717 btu/lb-F

EMISSIVITY = 0.90

VENTILATION SPECIFIED, FUEL PYROLYSIS ADJUSTED FOR WORST CONDITIONS PAGE NO. 1 RUN NO. 1

	TIME S	TEMP GAS,F	WALL TEMPS F			RP LBS/S	RC LBS/S	EXC.PYR. LBS/S	FUEL PCT	AIR IN LBS/S	N.P.	VELOCITY FT/M	MOL.WT	FUEL CNTRL
1	0.	791.	151.	148.	145.	0.848	0.424	0.424	99.97	24.59	0.42	270.70	30.09	F
31	30.	935.	693.	691.	687.	0.855	0.428	0.428	99.18	24.79	0.41	278.76	30.09	F
61	60.	935.	693.	691.	686.	0.855	0.428	0.428	98.38	24.79	0.41	278.77	30.09	F
91	90.	935.	693.	691.	686.	0.855	0.428	0.428	97.58	24.79	0.41	278.77	30.09	F
121	120.	935.	693.	691.	686.	0.855	0.428	0.428	96.78	24.79	0.41	278.77	30.09	F
151	150.	935.	693.	691.	686.	0.855	0.428	0.428	95.98	24.79	0.41	278.77	30.09	F
181	180.	935.	693.	691.	686.	0.855	0.428	0.428	95.18	24.79	0.41	278.77	30.09	F
211	210.	935.	693.	691.	686.	0.855	0.428	0.428	94.39	24.79	0.41	278.77	30.09	F
241	240.	935.	693.	691.	686.	0.855	0.428	0.428	93.59	24.79	0.41	278.77	30.09	F
271	270.	935.	693.	691.	686.	0.855	0.428	0.428	92.79	24.79	0.41	278.77	30.09	F
301	300.	935.	693.	691.	686.	0.855	0.428	0.428	91.99	24.79	0.41	278.77	30.09	F
331	330.	935.	693.	691.	686.	0.855	0.428	0.428	91.19	24.79	0.41	278.77	30.09	F
361	360.	935.	693.	691.	686.	0.855	0.428	0.428	90.39	24.79	0.41	278.77	30.09	F
391	390.	935.	693.	691.	686.	0.855	0.428	0.428	89.59	24.79	0.41	278.77	30.09	F
421	420.	935.	693.	691.	686.	0.855	0.428	0.428	88.80	24.79	0.41	278.77	30.09	F
451	450.	935.	693.	691.	686.	0.855	0.428	0.428	88.00	24.79	0.41	278.77	30.09	F
481	480.	935.	693.	691.	686.	0.855	0.428	0.428	87.20	24.79	0.41	278.77	30.09	F
511	510.	935.	693.	691.	686.	0.855	0.428	0.428	86.40	24.79	0.41	278.77	30.09	F
541	540.	935.	693.	691.	686.	0.855	0.428	0.428	85.60	24.79	0.41	278.77	30.09	F
571	570.	935.	693.	691.	686.	0.855	0.428	0.428	84.80	24.79	0.41	278.77	30.09	F
601	600.	935.	693.	691.	686.	0.855	0.428	0.428	84.01	24.79	0.41	278.77	30.09	F
631	630.	935.	693.	691.	686.	0.855	0.428	0.428	83.21	24.79	0.41	278.77	30.09	F
661	660.	935.	693.	691.	686.	0.855	0.428	0.428	82.41	24.79	0.41	278.77	30.09	F
691	690.	935.	693.	691.	686.	0.855	0.428	0.428	81.61	24.79	0.41	278.77	30.09	F
721	720.	935.	693.	691.	686.	0.855	0.428	0.428	80.81	24.79	0.41	278.77	30.09	F
751	750.	935.	693.	691.	686.	0.855	0.428	0.428	80.01	24.79	0.41	278.77	30.09	F
781	780.	935.	693.	691.	686.	0.855	0.428	0.428	79.22	24.79	0.41	278.77	30.09	F
811	810.	935.	693.	691.	686.	0.855	0.428	0.428	78.42	24.79	0.41	278.77	30.09	F
841	840.	935.	693.	691.	686.	0.855	0.428	0.428	77.62	24.79	0.41	278.77	30.09	F
871	870.	935.	693.	691.	686.	0.855	0.428	0.428	76.82	24.79	0.41	278.77	30.09	F
901	900.	935.	693.	691.	686.	0.855	0.428	0.428	76.02	24.79	0.41	278.77	30.09	F
931	930.	935.	693.	691.	686.	0.855	0.428	0.428	75.22	24.79	0.41	278.77	30.09	F
961	960.	935.	693.	691.	686.	0.855	0.428	0.428	74.42	24.79	0.41	278.77	30.09	F
991	990.	935.	693.	691.	686.	0.855	0.428	0.428	73.63	24.79	0.41	278.77	30.09	F
1021	1020.	935.	693.	691.	686.	0.855	0.428	0.428	72.83	24.79	0.41	278.77	30.09	F
1051	1050.	935.	693.	691.	686.	0.855	0.428	0.428	72.03	24.79	0.41	278.77	30.09	F
1081	1080.	935.	693.	691.	686.	0.855	0.428	0.428	71.23	24.79	0.41	278.77	30.09	F
1111	1110.	935.	693.	691.	686.	0.855	0.428	0.428	70.43	24.79	0.41	278.77	30.09	F
1141	1140.	935.	693.	691.	686.	0.855	0.428	0.428	69.63	24.79	0.41	278.77	30.09	F
1171	1170.	935.	693.	691.	686.	0.855	0.428	0.428	68.84	24.79	0.41	278.77	30.09	F
1201	1200.	935.	693.	691.	686.	0.855	0.428	0.428	68.04	24.79	0.41	278.77	30.09	F
1231	1230.	935.	693.	691.	686.	0.855	0.428	0.428	67.24	24.79	0.41	278.77	30.09	F
1261	1260.	935.	693.	691.	686.	0.855	0.428	0.428	66.44	24.79	0.41	278.77	30.09	F
1291	1290.	935.	693.	691.	686.	0.855	0.428	0.428	65.64	24.79	0.41	278.77	30.09	F
1321	1320.	935.	693.	691.	686.	0.855	0.428	0.428	64.84	24.79	0.41	278.77	30.09	F
1351	1350.	935.	693.	691.	686.	0.855	0.428	0.428	64.05	24.79	0.41	278.77	30.09	F
1381	1380.	935.	693.	691.	686.	0.855	0.428	0.428	63.25	24.79	0.41	278.77	30.09	F
1411	1410.	935.	693.	691.	686.	0.855	0.428	0.428	62.45	24.79	0.41	278.77	30.09	F
1441	1440.	935.	693.	691.	686.	0.855	0.428	0.428	61.65	24.79	0.41	278.77	30.09	F
1471	1470.	935.	693.	691.	686.	0.855	0.428	0.428	60.85	24.79	0.41	278.77	30.09	F
1501	1500.	935.	693.	691.	686.	0.855	0.428	0.428	60.05	24.79	0.41	278.77	30.09	F
1531	1530.	935.	693.	691.	686.	0.855	0.428	0.428	59.25	24.79	0.41	278.77	30.09	F
1561	1560.	935.	693.	691.	686.	0.855	0.428	0.428	58.46	24.79	0.41	278.77	30.09	F
1591	1590.	935.	693.	691.	686.	0.855	0.428	0.428	57.66	24.79	0.41	278.77	30.09	F
1621	1620.	935.	693.	691.	686.	0.855	0.428	0.428	56.86	24.79	0.41	278.77	30.09	F
1651	1650.	935.	693.	691.	686.	0.855	0.428	0.428	56.06	24.79	0.41	278.77	30.09	F
1681	1680.	935.	693.	691.	686.	0.855	0.428	0.428	55.26	24.79	0.41	278.77	30.09	F
1711	1710.	935.	693.	691.	686.	0.855	0.428	0.428	54.46	24.79	0.41	278.77	30.09	F
1741	1740.	935.	693.	691.	686.	0.855	0.428	0.428	53.67	24.79	0.41	278.77	30.09	F

1771	1770.	935.	693.	691.	686.	0.855	0.428	0.428	52.87	24.79	0.41	278.77	30.09	F
1801	1800.	935.	693.	691.	686.	0.855	0.428	0.428	52.07	24.79	0.41	278.77	30.09	F
1831	1830.	935.	693.	691.	686.	0.855	0.428	0.428	51.27	24.79	0.41	278.77	30.09	F
1861	1860.	935.	693.	691.	686.	0.855	0.428	0.428	50.47	24.79	0.41	278.77	30.09	F
1891	1890.	935.	693.	691.	686.	0.855	0.428	0.428	49.67	24.79	0.41	278.77	30.09	F
1921	1920.	935.	693.	691.	686.	0.855	0.428	0.428	48.88	24.79	0.41	278.77	30.09	F
1951	1950.	935.	693.	691.	686.	0.855	0.428	0.428	48.08	24.79	0.41	278.77	30.09	F
1981	1980.	935.	693.	691.	686.	0.855	0.428	0.428	47.28	24.79	0.41	278.77	30.09	F
2011	2010.	935.	693.	691.	686.	0.855	0.428	0.428	46.48	24.79	0.41	278.77	30.09	F
2041	2040.	935.	693.	691.	686.	0.855	0.428	0.428	45.68	24.79	0.41	278.77	30.09	F
2071	2070.	935.	693.	691.	686.	0.855	0.428	0.428	44.88	24.79	0.41	278.77	30.09	F
2101	2100.	935.	693.	691.	686.	0.855	0.428	0.428	44.08	24.79	0.41	278.77	30.09	F
2131	2130.	935.	693.	691.	686.	0.855	0.428	0.428	43.29	24.79	0.41	278.77	30.09	F
2161	2160.	935.	693.	691.	686.	0.855	0.428	0.428	42.49	24.79	0.41	278.77	30.09	F
2191	2190.	935.	693.	691.	686.	0.855	0.428	0.428	41.69	24.79	0.41	278.77	30.09	F
2221	2220.	935.	693.	691.	686.	0.855	0.428	0.428	40.89	24.79	0.41	278.77	30.09	F
2251	2250.	935.	693.	691.	686.	0.855	0.428	0.428	40.09	24.79	0.41	278.77	30.09	F
2281	2280.	935.	693.	691.	686.	0.855	0.428	0.428	39.29	24.79	0.41	278.77	30.09	F
2311	2310.	935.	693.	691.	686.	0.855	0.428	0.428	38.50	24.79	0.41	278.77	30.09	F
2341	2340.	935.	693.	691.	686.	0.855	0.428	0.428	37.70	24.79	0.41	278.77	30.09	F
2371	2370.	935.	693.	691.	686.	0.855	0.428	0.428	36.90	24.79	0.41	278.77	30.09	F
2401	2400.	935.	693.	691.	686.	0.855	0.428	0.428	36.10	24.79	0.41	278.77	30.09	F
2431	2430.	935.	693.	691.	686.	0.855	0.428	0.428	35.30	24.79	0.41	278.77	30.09	F
2461	2460.	935.	693.	691.	686.	0.855	0.428	0.428	34.50	24.79	0.41	278.77	30.09	F
2491	2490.	935.	693.	691.	686.	0.855	0.428	0.428	33.71	24.79	0.41	278.77	30.09	F
2521	2520.	935.	693.	691.	686.	0.855	0.428	0.428	32.91	24.79	0.41	278.77	30.09	F
2551	2550.	935.	693.	691.	686.	0.855	0.428	0.428	32.11	24.79	0.41	278.77	30.09	F
2581	2580.	935.	693.	691.	686.	0.855	0.428	0.428	31.31	24.79	0.41	278.77	30.09	F
2611	2610.	935.	693.	691.	686.	0.855	0.428	0.428	30.51	24.79	0.41	278.77	30.09	F
2641	2640.	935.	693.	691.	686.	0.855	0.428	0.428	29.71	24.79	0.41	278.77	30.09	F
2671	2670.	935.	693.	691.	686.	0.855	0.428	0.428	28.91	24.79	0.41	278.77	30.09	F
2701	2700.	935.	693.	691.	686.	0.855	0.428	0.428	28.12	24.79	0.41	278.77	30.09	F
2731	2730.	935.	693.	691.	686.	0.855	0.428	0.428	27.32	24.79	0.41	278.77	30.09	F
2761	2760.	935.	693.	691.	686.	0.855	0.428	0.428	26.52	24.79	0.41	278.77	30.09	F
2791	2790.	935.	693.	691.	686.	0.855	0.428	0.428	25.72	24.79	0.41	278.77	30.09	F
2821	2820.	935.	693.	691.	686.	0.855	0.428	0.428	24.92	24.79	0.41	278.77	30.09	F
2851	2850.	935.	693.	691.	686.	0.855	0.428	0.428	24.12	24.79	0.41	278.77	30.09	F
2881	2880.	935.	693.	691.	686.	0.855	0.428	0.428	23.32	24.79	0.41	278.77	30.09	F
2911	2910.	935.	693.	691.	686.	0.855	0.428	0.428	22.53	24.79	0.41	278.77	30.09	F
2941	2940.	935.	693.	691.	686.	0.855	0.428	0.428	21.73	24.79	0.41	278.77	30.09	F
2971	2970.	935.	693.	691.	686.	0.855	0.428	0.428	20.93	24.79	0.41	278.77	30.09	F
3001	3000.	935.	693.	691.	686.	0.855	0.428	0.428	20.13	24.79	0.41	278.77	30.09	F
3031	3030.	935.	693.	691.	686.	0.855	0.428	0.428	19.33	24.79	0.41	278.77	30.09	F
3061	3060.	935.	693.	691.	686.	0.855	0.428	0.428	18.53	24.79	0.41	278.77	30.09	F
3091	3090.	935.	693.	691.	686.	0.855	0.428	0.428	17.74	24.79	0.41	278.77	30.09	F
3121	3120.	935.	693.	691.	686.	0.855	0.428	0.428	16.94	24.79	0.41	278.77	30.09	F
3151	3150.	935.	693.	691.	686.	0.855	0.428	0.428	16.14	24.79	0.41	278.77	30.09	F
3181	3180.	935.	693.	691.	686.	0.855	0.428	0.428	15.34	24.79	0.41	278.77	30.09	F
3211	3210.	935.	693.	691.	686.	0.855	0.428	0.428	14.54	24.79	0.41	278.77	30.09	F
3241	3240.	935.	693.	691.	686.	0.855	0.428	0.428	13.74	24.79	0.41	278.77	30.09	F
3271	3270.	935.	693.	691.	686.	0.855	0.428	0.428	12.94	24.79	0.41	278.77	30.09	F
3301	3300.	935.	693.	691.	686.	0.855	0.428	0.428	12.15	24.79	0.41	278.77	30.09	F
3331	3330.	935.	693.	691.	686.	0.855	0.428	0.428	11.35	24.79	0.41	278.77	30.09	F
3361	3360.	935.	693.	691.	686.	0.855	0.428	0.428	10.55	24.79	0.41	278.77	30.09	F
3391	3390.	935.	693.	691.	686.	0.855	0.428	0.428	9.75	24.79	0.41	278.77	30.09	F
3421	3420.	935.	693.	691.	686.	0.855	0.428	0.428	8.95	24.79	0.41	278.77	30.09	F
3451	3450.	935.	693.	691.	686.	0.855	0.428	0.428	8.15	24.79	0.41	278.77	30.09	F
3481	3480.	935.	693.	691.	686.	0.855	0.428	0.428	7.36	24.79	0.41	278.77	30.09	F
3511	3510.	935.	693.	691.	686.	0.855	0.428	0.428	6.56	24.79	0.41	278.77	30.09	F
3541	3540.	935.	693.	691.	686.	0.855	0.428	0.428	5.76	24.79	0.41	278.77	30.09	F
3571	3570.	935.	693.	691.	686.	0.855	0.428	0.428	4.96	24.79	0.41	278.77	30.09	F
3601	3600.	935.	693.	691.	686.	0.855	0.428	0.428	4.16	24.79	0.41	278.77	30.09	F
3631	3630.	935.	693.	691.	686.	0.855	0.428	0.428	3.36	24.79	0.41	278.77	30.09	F
3661	3660.	935.	693.	691.	686.	0.855	0.428	0.428	2.56	24.79	0.41	278.77	30.09	F
3691	3690.	935.	693.	691.	686.	0.855	0.428	0.428	1.77	24.79	0.41	278.77	30.09	F
3721	3720.	935.	693.	691.	686.	0.855	0.428	0.428	0.97	24.79	0.41	278.77	30.09	F

3751	3750.	935.	693.	691.	686.	0.855	0.428	0.428	0.17	24.79	0.41	278.77	30.09	F
3763	3762.	171.	345.	346.	346.	0.	0.	0.	0.	15.92	0.49	151.80	28.92	T

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VENTILATION SPECIFIED, FUEL PYROLYSIS ADJUSTED FOR WORST CONDITIONS PAGE NO. 1 RUN NO. 1

TIME	HEAT BALANCE GAS FLOW PCT	WND RAD PCT	WALL CNV PCT	WALL RAD PCT	Q-FIRE BTU/HR	Q-WALL SUM BTU	YO2 PCT MASS	YN2 PCT MASS	YCO2 PCT MASS	YH2O PCT MASS	YPYR PCT MASS
0.	63.140	3.692	18.333	14.832	2.614E+07	2.605E+03	0.106	0.716	0.118	0.025	0.035
30.	76.340	5.742	4.991	12.908	2.635E+07	4.603E+04	0.106	0.716	0.118	0.025	0.035
60.	76.341	5.742	4.991	12.907	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
90.	76.341	5.742	4.991	12.907	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
120.	76.341	5.742	4.991	12.907	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
150.	76.341	5.742	4.990	12.907	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
180.	76.342	5.742	4.991	12.907	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
210.	76.342	5.742	4.990	12.907	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
240.	76.342	5.742	4.990	12.907	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
270.	76.342	5.742	4.990	12.907	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
300.	76.342	5.742	4.990	12.907	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
330.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
360.	76.342	5.742	4.990	12.907	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
390.	76.342	5.742	4.990	12.907	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
420.	76.342	5.742	4.991	12.907	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
450.	76.342	5.742	4.990	12.907	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
480.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
510.	76.342	5.742	4.990	12.907	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
540.	76.342	5.742	4.990	12.907	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
570.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
600.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
630.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
660.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
690.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
720.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
750.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
780.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
810.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
840.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
870.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
900.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
930.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
960.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
990.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1020.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1050.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1080.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1110.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1140.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1170.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1200.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1230.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1260.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1290.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1320.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1350.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1380.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1410.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1440.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1470.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1500.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1530.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1560.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1590.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1620.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1650.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1680.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1710.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1740.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035

1770.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1800.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1830.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1860.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1890.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1920.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1950.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
1980.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2010.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2040.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2070.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2100.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2130.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2160.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2190.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2220.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2250.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2280.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2310.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2340.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2370.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2400.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2430.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2460.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2490.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2520.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2550.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2580.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2610.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2640.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2670.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2700.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2730.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2760.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2790.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2820.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2850.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2880.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2910.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2940.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
2970.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3000.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3030.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3060.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3090.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3120.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3150.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3180.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3210.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3240.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3270.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3300.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3330.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3360.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3390.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3420.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3450.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3480.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3510.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3540.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3570.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3600.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3630.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3660.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3690.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3720.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035

3750.	76.342	5.742	4.990	12.906	2.635E+07	4.256E+04	0.106	0.716	0.118	0.025	0.035
3762.	97.593	2.407	-65.857	-34.243	0.000E+00	9.962E+03	0.230	0.770	0.	0.	0.

SUBWAY3002 - bpf = 60%, cvgross=21.2 load=52.2___________ lrun=1 COMPF2 VERSION 1.1 - RUN NO. 1

----GEOMETRY AND VENTILATION----

WALL SURFACE AREA = 1557.5 sq. ft.
FLOOR AREA = 662.6 sq. ft.
WINDOW HEIGHT = 3.1 ft.
AREA = 258.3 sq. ft.
OPENING FACTOR = 451.230 ft. ^1.5
DISCHARGE COEFF.= 0.68

----FUEL LOAD PROPERTIES----

FIRE LOAD PER FLOOR AREA = 10.7 lbs/sq.ft.

FUEL COMPOSITION
CARBON = 91.2 PERCENT BY WEIGHT
HYDROGEN = 7.7 PERCENT
OXYGEN = 0. PERCENT
NITROGEN = 0. PERCENT
WATER = 0. PERCENT
R = 13.14
RO= 3.05
HEAT OF COMBUSTION OF DRY FUEL = 91.3E+02 btu/lb
LOWER ACTUAL HEAT OF COMBUSTION = 84.0E+02 btu/lb
MOLECULAR WEIGHT OF UNBURNT PYROLYSATES = 28.97
CP OF PYROLYSIS GAS = (0. *TGAS + 0.3198) btu/lb-F
MAXIMUM FRACTION OF PYROLYSATES BURN = 0.60
GREY-GAS FLAME EMISSIVITY = 0.900

----WALL THERMAL PROPERTIES----

THICKNESS = 0.0 ft.
DENSITY = 1.309 lbs/cu. ft.

THERMAL CONDUCTIVITY = 26. btu/hr-ft-F

HEAT CAPACITY = 0.0717 btu/lb-F

EMISSIVITY = 0.90

VENTILATION SPECIFIED, FUEL PYROLYSIS ADJUSTED FOR WORST CONDITIONS

	TIME S	TEMP GAS,F	WALL TEMPS F			RP LBS/S	RC LBS/S	EXC.PYR. LBS/S	FUEL PCT	AIR IN LBS/S	N.P.	VELOCITY FT/M	MOL.WT	FUEL CNTRL
1	0.	896.	172.	168.	164.	0.854	0.512	0.341	99.97	24.74	0.42	276.30	30.33	F
31	30.	1060.	793.	790.	784.	0.856	0.514	0.343	99.17	24.82	0.41	283.44	30.33	F
61	60.	1060.	793.	790.	784.	0.856	0.514	0.343	98.37	24.82	0.41	283.44	30.33	F
91	90.	1060.	793.	790.	784.	0.856	0.514	0.343	97.57	24.82	0.41	283.44	30.33	F
121	120.	1060.	793.	790.	784.	0.856	0.514	0.343	96.78	24.82	0.41	283.44	30.33	F
151	150.	1060.	793.	790.	784.	0.856	0.514	0.343	95.98	24.82	0.41	283.44	30.33	F
181	180.	1060.	793.	790.	784.	0.856	0.514	0.343	95.18	24.82	0.41	283.44	30.33	F
211	210.	1060.	793.	790.	784.	0.856	0.514	0.343	94.38	24.82	0.41	283.44	30.33	F
241	240.	1060.	793.	790.	784.	0.856	0.514	0.343	93.58	24.82	0.41	283.44	30.33	F
271	270.	1060.	793.	790.	784.	0.856	0.514	0.343	92.78	24.82	0.41	283.44	30.33	F
301	300.	1060.	793.	790.	784.	0.856	0.514	0.343	91.98	24.82	0.41	283.44	30.33	F
331	330.	1060.	793.	790.	784.	0.856	0.514	0.343	91.18	24.82	0.41	283.44	30.33	F
361	360.	1060.	793.	790.	784.	0.856	0.514	0.343	90.38	24.82	0.41	283.44	30.33	F
391	390.	1060.	793.	790.	784.	0.856	0.514	0.343	89.58	24.82	0.41	283.44	30.33	F
421	420.	1060.	793.	790.	784.	0.856	0.514	0.343	88.78	24.82	0.41	283.44	30.33	F
451	450.	1060.	793.	790.	784.	0.856	0.514	0.343	87.98	24.82	0.41	283.44	30.33	F
481	480.	1060.	793.	790.	784.	0.856	0.514	0.343	87.18	24.82	0.41	283.44	30.33	F
511	510.	1060.	793.	790.	784.	0.856	0.514	0.343	86.38	24.82	0.41	283.44	30.33	F
541	540.	1060.	793.	790.	784.	0.856	0.514	0.343	85.58	24.82	0.41	283.44	30.33	F
571	570.	1060.	793.	790.	784.	0.856	0.514	0.343	84.78	24.82	0.41	283.44	30.33	F
601	600.	1060.	793.	790.	784.	0.856	0.514	0.343	83.98	24.82	0.41	283.44	30.33	F
631	630.	1060.	793.	790.	784.	0.856	0.514	0.343	83.18	24.82	0.41	283.44	30.33	F
661	660.	1060.	793.	790.	784.	0.856	0.514	0.343	82.38	24.82	0.41	283.44	30.33	F
691	690.	1060.	793.	790.	784.	0.856	0.514	0.343	81.58	24.82	0.41	283.44	30.33	F
721	720.	1060.	793.	790.	784.	0.856	0.514	0.343	80.78	24.82	0.41	283.44	30.33	F
751	750.	1060.	793.	790.	784.	0.856	0.514	0.343	79.98	24.82	0.41	283.44	30.33	F
781	780.	1060.	793.	790.	784.	0.856	0.514	0.343	79.18	24.82	0.41	283.44	30.33	F
811	810.	1060.	793.	790.	784.	0.856	0.514	0.343	78.39	24.82	0.41	283.44	30.33	F
841	840.	1060.	793.	790.	784.	0.856	0.514	0.343	77.59	24.82	0.41	283.44	30.33	F
871	870.	1060.	793.	790.	784.	0.856	0.514	0.343	76.79	24.82	0.41	283.44	30.33	F
901	900.	1060.	793.	790.	784.	0.856	0.514	0.343	75.99	24.82	0.41	283.44	30.33	F
931	930.	1060.	793.	790.	784.	0.856	0.514	0.343	75.19	24.82	0.41	283.44	30.33	F
961	960.	1060.	793.	790.	784.	0.856	0.514	0.343	74.39	24.82	0.41	283.44	30.33	F
991	990.	1060.	793.	790.	784.	0.856	0.514	0.343	73.59	24.82	0.41	283.44	30.33	F
1021	1020.	1060.	793.	790.	784.	0.856	0.514	0.343	72.79	24.82	0.41	283.44	30.33	F
1051	1050.	1060.	793.	790.	784.	0.856	0.514	0.343	71.99	24.82	0.41	283.44	30.33	F
1081	1080.	1060.	793.	790.	784.	0.856	0.514	0.343	71.19	24.82	0.41	283.44	30.33	F
1111	1110.	1060.	793.	790.	784.	0.856	0.514	0.343	70.39	24.82	0.41	283.44	30.33	F
1141	1140.	1060.	793.	790.	784.	0.856	0.514	0.343	69.59	24.82	0.41	283.44	30.33	F
1171	1170.	1060.	793.	790.	784.	0.856	0.514	0.343	68.79	24.82	0.41	283.44	30.33	F
1201	1200.	1060.	793.	790.	784.	0.856	0.514	0.343	67.99	24.82	0.41	283.44	30.33	F
1231	1230.	1060.	793.	790.	784.	0.856	0.514	0.343	67.19	24.82	0.41	283.44	30.33	F
1261	1260.	1060.	793.	790.	784.	0.856	0.514	0.343	66.39	24.82	0.41	283.44	30.33	F
1291	1290.	1060.	793.	790.	784.	0.856	0.514	0.343	65.59	24.82	0.41	283.44	30.33	F
1321	1320.	1060.	793.	790.	784.	0.856	0.514	0.343	64.79	24.82	0.41	283.44	30.33	F
1351	1350.	1060.	793.	790.	784.	0.856	0.514	0.343	63.99	24.82	0.41	283.44	30.33	F
1381	1380.	1060.	793.	790.	784.	0.856	0.514	0.343	63.19	24.82	0.41	283.44	30.33	F
1411	1410.	1060.	793.	790.	784.	0.856	0.514	0.343	62.39	24.82	0.41	283.44	30.33	F
1441	1440.	1060.	793.	790.	784.	0.856	0.514	0.343	61.59	24.82	0.41	283.44	30.33	F
1471	1470.	1060.	793.	790.	784.	0.856	0.514	0.343	60.80	24.82	0.41	283.44	30.33	F
1501	1500.	1060.	793.	790.	784.	0.856	0.514	0.343	60.00	24.82	0.41	283.44	30.33	F
1531	1530.	1060.	793.	790.	784.	0.856	0.514	0.343	59.20	24.82	0.41	283.44	30.33	F
1561	1560.	1060.	793.	790.	784.	0.856	0.514	0.343	58.40	24.82	0.41	283.44	30.33	F
1591	1590.	1060.	793.	790.	784.	0.856	0.514	0.343	57.60	24.82	0.41	283.44	30.33	F
1621	1620.	1060.	793.	790.	784.	0.856	0.514	0.343	56.80	24.82	0.41	283.44	30.33	F
1651	1650.	1060.	793.	790.	784.	0.856	0.514	0.343	56.00	24.82	0.41	283.44	30.33	F
1681	1680.	1060.	793.	790.	784.	0.856	0.514	0.343	55.20	24.82	0.41	283.44	30.33	F
1711	1710.	1060.	793.	790.	784.	0.856	0.514	0.343	54.40	24.82	0.41	283.44	30.33	F
1741	1740.	1060.	793.	790.	784.	0.856	0.514	0.343	53.60	24.82	0.41	283.44	30.33	F

1771	1770.	1060.	793.	790.	784.	0.856	0.514	0.343	52.80	24.82	0.41	283.44	30.33	F
1801	1800.	1060.	793.	790.	784.	0.856	0.514	0.343	52.00	24.82	0.41	283.44	30.33	F
1831	1830.	1060.	793.	790.	784.	0.856	0.514	0.343	51.20	24.82	0.41	283.44	30.33	F
1861	1860.	1060.	793.	790.	784.	0.856	0.514	0.343	50.40	24.82	0.41	283.44	30.33	F
1891	1890.	1060.	793.	790.	784.	0.856	0.514	0.343	49.60	24.82	0.41	283.44	30.33	F
1921	1920.	1060.	793.	790.	784.	0.856	0.514	0.343	48.80	24.82	0.41	283.44	30.33	F
1951	1950.	1060.	793.	790.	784.	0.856	0.514	0.343	48.00	24.82	0.41	283.44	30.33	F
1981	1980.	1060.	793.	790.	784.	0.856	0.514	0.343	47.20	24.82	0.41	283.44	30.33	F
2011	2010.	1060.	793.	790.	784.	0.856	0.514	0.343	46.40	24.82	0.41	283.44	30.33	F
2041	2040.	1060.	793.	790.	784.	0.856	0.514	0.343	45.60	24.82	0.41	283.44	30.33	F
2071	2070.	1060.	793.	790.	784.	0.856	0.514	0.343	44.80	24.82	0.41	283.44	30.33	F
2101	2100.	1060.	793.	790.	784.	0.856	0.514	0.343	44.00	24.82	0.41	283.44	30.33	F
2131	2130.	1060.	793.	790.	784.	0.856	0.514	0.343	43.20	24.82	0.41	283.44	30.33	F
2161	2160.	1060.	793.	790.	784.	0.856	0.514	0.343	42.41	24.82	0.41	283.44	30.33	F
2191	2190.	1060.	793.	790.	784.	0.856	0.514	0.343	41.61	24.82	0.41	283.44	30.33	F
2221	2220.	1060.	793.	790.	784.	0.856	0.514	0.343	40.81	24.82	0.41	283.44	30.33	F
2251	2250.	1060.	793.	790.	784.	0.856	0.514	0.343	40.01	24.82	0.41	283.44	30.33	F
2281	2280.	1060.	793.	790.	784.	0.856	0.514	0.343	39.21	24.82	0.41	283.44	30.33	F
2311	2310.	1060.	793.	790.	784.	0.856	0.514	0.343	38.41	24.82	0.41	283.44	30.33	F
2341	2340.	1060.	793.	790.	784.	0.856	0.514	0.343	37.61	24.82	0.41	283.44	30.33	F
2371	2370.	1060.	793.	790.	784.	0.856	0.514	0.343	36.81	24.82	0.41	283.44	30.33	F
2401	2400.	1060.	793.	790.	784.	0.856	0.514	0.343	36.01	24.82	0.41	283.44	30.33	F
2431	2430.	1060.	793.	790.	784.	0.856	0.514	0.343	35.21	24.82	0.41	283.44	30.33	F
2461	2460.	1060.	793.	790.	784.	0.856	0.514	0.343	34.41	24.82	0.41	283.44	30.33	F
2491	2490.	1060.	793.	790.	784.	0.856	0.514	0.343	33.61	24.82	0.41	283.44	30.33	F
2521	2520.	1060.	793.	790.	784.	0.856	0.514	0.343	32.81	24.82	0.41	283.44	30.33	F
2551	2550.	1060.	793.	790.	784.	0.856	0.514	0.343	32.01	24.82	0.41	283.44	30.33	F
2581	2580.	1060.	793.	790.	784.	0.856	0.514	0.343	31.21	24.82	0.41	283.44	30.33	F
2611	2610.	1060.	793.	790.	784.	0.856	0.514	0.343	30.41	24.82	0.41	283.44	30.33	F
2641	2640.	1060.	793.	790.	784.	0.856	0.514	0.343	29.61	24.82	0.41	283.44	30.33	F
2671	2670.	1060.	793.	790.	784.	0.856	0.514	0.343	28.81	24.82	0.41	283.44	30.33	F
2701	2700.	1060.	793.	790.	784.	0.856	0.514	0.343	28.01	24.82	0.41	283.44	30.33	F
2731	2730.	1060.	793.	790.	784.	0.856	0.514	0.343	27.21	24.82	0.41	283.44	30.33	F
2761	2760.	1060.	793.	790.	784.	0.856	0.514	0.343	26.41	24.82	0.41	283.44	30.33	F
2791	2790.	1060.	793.	790.	784.	0.856	0.514	0.343	25.61	24.82	0.41	283.44	30.33	F
2821	2820.	1060.	793.	790.	784.	0.856	0.514	0.343	24.82	24.82	0.41	283.44	30.33	F
2851	2850.	1060.	793.	790.	784.	0.856	0.514	0.343	24.02	24.82	0.41	283.44	30.33	F
2881	2880.	1060.	793.	790.	784.	0.856	0.514	0.343	23.22	24.82	0.41	283.44	30.33	F
2911	2910.	1060.	793.	790.	784.	0.856	0.514	0.343	22.42	24.82	0.41	283.44	30.33	F
2941	2940.	1060.	793.	790.	784.	0.856	0.514	0.343	21.62	24.82	0.41	283.44	30.33	F
2971	2970.	1060.	793.	790.	784.	0.856	0.514	0.343	20.82	24.82	0.41	283.44	30.33	F
3001	3000.	1060.	793.	790.	784.	0.856	0.514	0.343	20.02	24.82	0.41	283.44	30.33	F
3031	3030.	1060.	793.	790.	784.	0.856	0.514	0.343	19.22	24.82	0.41	283.44	30.33	F
3061	3060.	1060.	793.	790.	784.	0.856	0.514	0.343	18.42	24.82	0.41	283.44	30.33	F
3091	3090.	1060.	793.	790.	784.	0.856	0.514	0.343	17.62	24.82	0.41	283.44	30.33	F
3121	3120.	1060.	793.	790.	784.	0.856	0.514	0.343	16.82	24.82	0.41	283.44	30.33	F
3151	3150.	1060.	793.	790.	784.	0.856	0.514	0.343	16.02	24.82	0.41	283.44	30.33	F
3181	3180.	1060.	793.	790.	784.	0.856	0.514	0.343	15.22	24.82	0.41	283.44	30.33	F
3211	3210.	1060.	793.	790.	784.	0.856	0.514	0.343	14.42	24.82	0.41	283.44	30.33	F
3241	3240.	1060.	793.	790.	784.	0.856	0.514	0.343	13.62	24.82	0.41	283.44	30.33	F
3271	3270.	1060.	793.	790.	784.	0.856	0.514	0.343	12.82	24.82	0.41	283.44	30.33	F
3301	3300.	1060.	793.	790.	784.	0.856	0.514	0.343	12.02	24.82	0.41	283.44	30.33	F
3331	3330.	1060.	793.	790.	784.	0.856	0.514	0.343	11.22	24.82	0.41	283.44	30.33	F
3361	3360.	1060.	793.	790.	784.	0.856	0.514	0.343	10.42	24.82	0.41	283.44	30.33	F
3391	3390.	1060.	793.	790.	784.	0.856	0.514	0.343	9.62	24.82	0.41	283.44	30.33	F
3421	3420.	1060.	793.	790.	784.	0.856	0.514	0.343	8.83	24.82	0.41	283.44	30.33	F
3451	3450.	1060.	793.	790.	784.	0.856	0.514	0.343	8.03	24.82	0.41	283.44	30.33	F
3481	3480.	1060.	793.	790.	784.	0.856	0.514	0.343	7.23	24.82	0.41	283.44	30.33	F
3511	3510.	1060.	793.	790.	784.	0.856	0.514	0.343	6.43	24.82	0.41	283.44	30.33	F
3541	3540.	1060.	793.	790.	784.	0.856	0.514	0.343	5.63	24.82	0.41	283.44	30.33	F
3571	3570.	1060.	793.	790.	784.	0.856	0.514	0.343	4.83	24.82	0.41	283.44	30.33	F
3601	3600.	1060.	793.	790.	784.	0.856	0.514	0.343	4.03	24.82	0.41	283.44	30.33	F
3631	3630.	1060.	793.	790.	784.	0.856	0.514	0.343	3.23	24.82	0.41	283.44	30.33	F
3661	3660.	1060.	793.	790.	784.	0.856	0.514	0.343	2.43	24.82	0.41	283.44	30.33	F
3691	3690.	1060.	793.	790.	784.	0.856	0.514	0.343	1.63	24.82	0.41	283.44	30.33	F
3721	3720.	1060.	793.	790.	784.	0.856	0.514	0.343	0.83	24.82	0.41	283.44	30.33	F

3751	3750.	1060.	793.	790.	784.	0.856	0.514	0.343	0.03	24.82	0.41	283.44	30.33	F
3759	3753.	166.	332.	331.	330.	0.	0.	0.	0.	15.60	0.49	148.52	28.92	T

VENTILATION SPECIFIED, FUEL PYROLYSIS ADJUSTED FOR WORST CONDITIONS PAGE NO. 1 RUN NO. 1

TIME	GAS FLOW PCT	HEAT BALANCE WND RAD PCT	WALL CNV PCT	WALL RAD PCT	Q-FIRE BTU/HR	Q-WALL SUM BTU	YO2 PCT MASS	YN2 PCT MASS	YCO2 PCT MASS	YH2O PCT MASS	YPYR PCT MASS
0.	60.661	4.266	17.924	17.149	3.156E+07	3.327E+03	0.084	0.716	0.142	0.029	0.028
30.	73.238	6.771	4.724	15.245	3.166E+07	6.066E+04	0.084	0.716	0.142	0.029	0.028
60.	73.240	6.771	4.723	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
90.	73.241	6.772	4.723	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
120.	73.241	6.772	4.723	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
150.	73.241	6.772	4.723	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
180.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
210.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
240.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
270.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
300.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
330.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
360.	73.241	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
390.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
420.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
450.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
480.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
510.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
540.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
570.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
600.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
630.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
660.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
690.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
720.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
750.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
780.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
810.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
840.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
870.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
900.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
930.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
960.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
990.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
1020.	73.242	6.772	4.722	15.243	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1050.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
1080.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1110.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
1140.	73.242	6.772	4.722	15.243	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1170.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1200.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1230.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1260.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1290.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
1320.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1350.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
1380.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1410.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1440.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1470.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1500.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1530.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
1560.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
1590.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1620.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1650.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1680.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
1710.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1740.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028

1770.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1800.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
1830.	73.242	6.772	4.722	15.243	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1860.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
1890.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
1920.	73.242	6.772	4.722	15.243	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
1950.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
1980.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
2010.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2040.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2070.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2100.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
2130.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2160.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
2190.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2220.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2250.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2280.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2310.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2340.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2370.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
2400.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2430.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2460.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
2490.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
2520.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2550.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2580.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2610.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2640.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
2670.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
2700.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2730.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2760.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
2790.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2820.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
2850.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2880.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2910.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
2940.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
2970.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3000.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3030.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3060.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3090.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3120.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3150.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3180.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3210.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3240.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3270.	73.242	6.772	4.722	15.243	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3300.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
3330.	73.242	6.772	4.722	15.243	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3360.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3390.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3420.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3450.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
3480.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
3510.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3540.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
3570.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3600.	73.242	6.772	4.722	15.243	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
3630.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3660.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3690.	73.242	6.772	4.722	15.242	3.166E+07	5.705E+04	0.084	0.716	0.142	0.029	0.028
3720.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028

3750.	73.242	6.772	4.722	15.242	3.166E+07	5.704E+04	0.084	0.716	0.142	0.029	0.028
3758.	97.575	2.425	-66.365	-33.729	0.000E+00	3.854E+03	0.230	0.770	0.	0.	0.

SUBW1Y3003 -- bpf = 70%, cvgross=21.2 load=52.2__________ lrun=1 COMPF2 VERSION 1.1 - RUN NO. 1

----GEOMETRY AND VENTILATION----

WALL SURFACE AREA = 1557.5 sq. ft.
FLOOR AREA = 662.6 sq. ft.
WINDOW HEIGHT = 3.1 ft.
AREA = 258.3 sq. ft.
OPENING FACTOR = 451.230 ft. ^1.5
DISCHARGE COEFF.= 0.68

----FUEL LOAD PROPERTIES----

FIRE LOAD PER FLOOR AREA = 10.7 lbs/sq.ft.

FUEL COMPOSITION
CARBON = 91.2 PERCENT BY WEIGHT
HYDROGEN = 7.7 PERCENT
OXYGEN = 0. PERCENT
NITROGEN = 0. PERCENT
WATER = 0. PERCENT
R = 13.14
RO= 3.05
HEAT OF COMBUSTION OF DRY FUEL = 91.3E+02 btu/lb
LOWER ACTUAL HEAT OF COMBUSTION = 84.0E+02 btu/lb
MOLECULAR WEIGHT OF UNBURNT PYROLYSATES = 28.97
CP OF PYROLYSIS GAS = (0. *TGAS + 0.3198) btu/lb-F
MAXIMUM FRACTION OF PYROLYSATES BURN = 0.70
GREY-GAS FLAME EMISSIVITY = 0.900

----WALL THERMAL PROPERTIES----

THICKNESS = 0.0 ft.
DENSITY = 1.309 lbs/cu. ft.

THERMAL CONDUCTIVITY = 26. btu/hr-ft-F

HEAT CAPACITY = 0.0717 btu/lb-F

EMISSIVITY = 0.90

VENTILATION SPECIFIED, FUEL PYROLYSIS ADJUSTED FOR WORST CONDITIONS

PAGE NO. 1 RUN NO. 1

	TIME S	TEMP GAS,F	WALL TEMPS F			RP LBS/S	RC LBS/S	EXC.PYR. LBS/S	FUEL PCT	AIR IN LBS/S	N.P.	VELOCITY FT/M	MOL.WT	FUEL CNTRL
1	0.	992.	193.	188.	184.	0.856	0.599	0.257	99.97	24.80	0.41	280.32	30.56	F
31	30.	1172.	884.	881.	874.	0.855	0.599	0.257	99.17	24.79	0.40	286.70	30.56	F
61	60.	1172.	884.	881.	874.	0.855	0.599	0.257	98.38	24.79	0.40	286.70	30.56	F
91	90.	1172.	884.	881.	874.	0.855	0.599	0.257	97.58	24.79	0.40	286.70	30.56	F
121	120.	1172.	884.	881.	874.	0.855	0.599	0.257	96.78	24.79	0.40	286.70	30.56	F
151	150.	1172.	884.	881.	874.	0.855	0.599	0.257	95.98	24.79	0.40	286.70	30.56	F
181	180.	1172.	884.	881.	874.	0.855	0.599	0.257	95.18	24.79	0.40	286.70	30.56	F
211	210.	1172.	884.	881.	874.	0.855	0.599	0.257	94.38	24.79	0.40	286.70	30.56	F
241	240.	1172.	884.	881.	874.	0.855	0.599	0.257	93.59	24.79	0.40	286.70	30.56	F
271	270.	1172.	884.	881.	874.	0.855	0.599	0.257	92.79	24.79	0.40	286.70	30.56	F
301	300.	1172.	884.	881.	874.	0.855	0.599	0.257	91.99	24.79	0.40	286.70	30.56	F
331	330.	1172.	884.	881.	874.	0.855	0.599	0.257	91.19	24.79	0.40	286.70	30.56	F
361	360.	1172.	884.	881.	874.	0.855	0.599	0.257	90.39	24.79	0.40	286.70	30.56	F
391	390.	1172.	884.	881.	874.	0.855	0.599	0.257	89.59	24.79	0.40	286.70	30.56	F
421	420.	1172.	884.	881.	874.	0.855	0.599	0.257	88.80	24.79	0.40	286.70	30.56	F
451	450.	1172.	884.	881.	874.	0.855	0.599	0.257	88.00	24.79	0.40	286.70	30.56	F
481	480.	1172.	884.	881.	874.	0.855	0.599	0.257	87.20	24.79	0.40	286.70	30.56	F
511	510.	1172.	884.	881.	874.	0.855	0.599	0.257	86.40	24.79	0.40	286.70	30.56	F
541	540.	1172.	884.	881.	874.	0.855	0.599	0.257	85.60	24.79	0.40	286.70	30.56	F
571	570.	1172.	884.	881.	874.	0.855	0.599	0.257	84.80	24.79	0.40	286.70	30.56	F
601	600.	1172.	884.	881.	874.	0.855	0.599	0.257	84.00	24.79	0.40	286.70	30.56	F
631	630.	1172.	884.	881.	874.	0.855	0.599	0.257	83.21	24.79	0.40	286.70	30.56	F
661	660.	1172.	884.	881.	874.	0.855	0.599	0.257	82.41	24.79	0.40	286.70	30.56	F
691	690.	1172.	884.	881.	874.	0.855	0.599	0.257	81.61	24.79	0.40	286.70	30.56	F
721	720.	1172.	884.	881.	874.	0.855	0.599	0.257	80.81	24.79	0.40	286.70	30.56	F
751	750.	1172.	884.	881.	874.	0.855	0.599	0.257	80.01	24.79	0.40	286.70	30.56	F
781	780.	1172.	884.	881.	874.	0.855	0.599	0.257	79.21	24.79	0.40	286.70	30.56	F
811	810.	1172.	884.	881.	874.	0.855	0.599	0.257	78.42	24.79	0.40	286.70	30.56	F
841	840.	1172.	884.	881.	874.	0.855	0.599	0.257	77.62	24.79	0.40	286.70	30.56	F
871	870.	1172.	884.	881.	874.	0.855	0.599	0.257	76.82	24.79	0.40	286.70	30.56	F
901	900.	1172.	884.	881.	874.	0.855	0.599	0.257	76.02	24.79	0.40	286.70	30.56	F
931	930.	1172.	884.	881.	874.	0.855	0.599	0.257	75.22	24.79	0.40	286.70	30.56	F
961	960.	1172.	884.	881.	874.	0.855	0.599	0.257	74.42	24.79	0.40	286.70	30.56	F
991	990.	1172.	884.	881.	874.	0.855	0.599	0.257	73.63	24.79	0.40	286.70	30.56	F
1021	1020.	1172.	884.	881.	874.	0.855	0.599	0.257	72.83	24.79	0.40	286.70	30.56	F
1051	1050.	1172.	884.	881.	874.	0.855	0.599	0.257	72.03	24.79	0.40	286.70	30.56	F
1081	1080.	1172.	884.	881.	874.	0.855	0.599	0.257	71.23	24.79	0.40	286.70	30.56	F
1111	1110.	1172.	884.	881.	874.	0.855	0.599	0.257	70.43	24.79	0.40	286.70	30.56	F
1141	1140.	1172.	884.	881.	874.	0.855	0.599	0.257	69.63	24.79	0.40	286.70	30.56	F
1171	1170.	1172.	884.	881.	874.	0.855	0.599	0.257	68.83	24.79	0.40	286.70	30.56	F
1201	1200.	1172.	884.	881.	874.	0.855	0.599	0.257	68.04	24.79	0.40	286.70	30.56	F
1231	1230.	1172.	884.	881.	874.	0.855	0.599	0.257	67.24	24.79	0.40	286.70	30.56	F
1261	1260.	1172.	884.	881.	874.	0.855	0.599	0.257	66.44	24.79	0.40	286.70	30.56	F
1291	1290.	1172.	884.	881.	874.	0.855	0.599	0.257	65.64	24.79	0.40	286.70	30.56	F
1321	1320.	1172.	884.	881.	874.	0.855	0.599	0.257	64.84	24.79	0.40	286.70	30.56	F
1351	1350.	1172.	884.	881.	874.	0.855	0.599	0.257	64.04	24.79	0.40	286.70	30.56	F
1381	1380.	1172.	884.	881.	874.	0.855	0.599	0.257	63.25	24.79	0.40	286.70	30.56	F
1411	1410.	1172.	884.	881.	874.	0.855	0.599	0.257	62.45	24.79	0.40	286.70	30.56	F
1441	1440.	1172.	884.	881.	874.	0.855	0.599	0.257	61.65	24.79	0.40	286.70	30.56	F
1471	1470.	1172.	884.	881.	874.	0.855	0.599	0.257	60.85	24.79	0.40	286.70	30.56	F
1501	1500.	1172.	884.	881.	874.	0.855	0.599	0.257	60.05	24.79	0.40	286.70	30.56	F
1531	1530.	1172.	884.	881.	874.	0.855	0.599	0.257	59.25	24.79	0.40	286.70	30.56	F
1561	1560.	1172.	884.	881.	874.	0.855	0.599	0.257	58.45	24.79	0.40	286.70	30.56	F
1591	1590.	1172.	884.	881.	874.	0.855	0.599	0.257	57.66	24.79	0.40	286.70	30.56	F
1621	1620.	1172.	884.	881.	874.	0.855	0.599	0.257	56.86	24.79	0.40	286.70	30.56	F
1651	1650.	1172.	884.	881.	874.	0.855	0.599	0.257	56.06	24.79	0.40	286.70	30.56	F
1681	1680.	1172.	884.	881.	874.	0.855	0.599	0.257	55.26	24.79	0.40	286.70	30.56	F
1711	1710.	1172.	884.	881.	874.	0.855	0.599	0.257	54.46	24.79	0.40	286.70	30.56	F
1741	1740.	1172.	884.	881.	874.	0.855	0.599	0.257	53.66	24.79	0.40	286.70	30.56	F

1771	1770.	1172.	884.	881.	874.	0.855	0.599	0.257	52.86	24.79	0.40	286.70	30.56	F
1801	1800.	1172.	884.	881.	874.	0.855	0.599	0.257	52.07	24.79	0.40	286.70	30.56	F
1831	1830.	1172.	884.	881.	874.	0.855	0.599	0.257	51.27	24.79	0.40	286.70	30.56	F
1861	1860.	1172.	884.	881.	874.	0.855	0.599	0.257	50.47	24.79	0.40	286.70	30.56	F
1891	1890.	1172.	884.	881.	874.	0.855	0.599	0.257	49.67	24.79	0.40	286.70	30.56	F
1921	1920.	1172.	884.	881.	874.	0.855	0.599	0.257	48.87	24.79	0.40	286.70	30.56	F
1951	1950.	1172.	884.	881.	874.	0.855	0.599	0.257	48.07	24.79	0.40	286.70	30.56	F
1981	1980.	1172.	884.	881.	874.	0.855	0.599	0.257	47.27	24.79	0.40	286.70	30.56	F
2011	2010.	1172.	884.	881.	874.	0.855	0.599	0.257	46.48	24.79	0.40	286.70	30.56	F
2041	2040.	1172.	884.	881.	874.	0.855	0.599	0.257	45.68	24.79	0.40	286.70	30.56	F
2071	2070.	1172.	884.	881.	874.	0.855	0.599	0.257	44.88	24.79	0.40	286.70	30.56	F
2101	2100.	1172.	884.	881.	874.	0.855	0.599	0.257	44.08	24.79	0.40	286.70	30.56	F
2131	2130.	1172.	884.	881.	874.	0.855	0.599	0.257	43.28	24.79	0.40	286.70	30.56	F
2161	2160.	1172.	884.	881.	874.	0.855	0.599	0.257	42.48	24.79	0.40	286.70	30.56	F
2191	2190.	1172.	884.	881.	874.	0.855	0.599	0.257	41.69	24.79	0.40	286.70	30.56	F
2221	2220.	1172.	884.	881.	874.	0.855	0.599	0.257	40.89	24.79	0.40	286.70	30.56	F
2251	2250.	1172.	884.	881.	874.	0.855	0.599	0.257	40.09	24.79	0.40	286.70	30.56	F
2281	2280.	1172.	884.	881.	874.	0.855	0.599	0.257	39.29	24.79	0.40	286.70	30.56	F
2311	2310.	1172.	884.	881.	874.	0.855	0.599	0.257	38.49	24.79	0.40	286.70	30.56	F
2341	2340.	1172.	884.	881.	874.	0.855	0.599	0.257	37.69	24.79	0.40	286.70	30.56	F
2371	2370.	1172.	884.	881.	874.	0.855	0.599	0.257	36.89	24.79	0.40	286.70	30.56	F
2401	2400.	1172.	884.	881.	874.	0.855	0.599	0.257	36.10	24.79	0.40	286.70	30.56	F
2431	2430.	1172.	884.	881.	874.	0.855	0.599	0.257	35.30	24.79	0.40	286.70	30.56	F
2461	2460.	1172.	884.	881.	874.	0.855	0.599	0.257	34.50	24.79	0.40	286.70	30.56	F
2491	2490.	1172.	884.	881.	874.	0.855	0.599	0.257	33.70	24.79	0.40	286.70	30.56	F
2521	2520.	1172.	884.	881.	874.	0.855	0.599	0.257	32.90	24.79	0.40	286.70	30.56	F
2551	2550.	1172.	884.	881.	874.	0.855	0.599	0.257	32.10	24.79	0.40	286.70	30.56	F
2581	2580.	1172.	884.	881.	874.	0.855	0.599	0.257	31.30	24.79	0.40	286.70	30.56	F
2611	2610.	1172.	884.	881.	874.	0.855	0.599	0.257	30.51	24.79	0.40	286.70	30.56	F
2641	2640.	1172.	884.	881.	874.	0.855	0.599	0.257	29.71	24.79	0.40	286.70	30.56	F
2671	2670.	1172.	884.	881.	874.	0.855	0.599	0.257	28.91	24.79	0.40	286.70	30.56	F
2701	2700.	1172.	884.	881.	874.	0.855	0.599	0.257	28.11	24.79	0.40	286.70	30.56	F
2731	2730.	1172.	884.	881.	874.	0.855	0.599	0.257	27.31	24.79	0.40	286.70	30.56	F
2761	2760.	1172.	884.	881.	874.	0.855	0.599	0.257	26.51	24.79	0.40	286.70	30.56	F
2791	2790.	1172.	884.	881.	874.	0.855	0.599	0.257	25.71	24.79	0.40	286.70	30.56	F
2821	2820.	1172.	884.	881.	874.	0.855	0.599	0.257	24.92	24.79	0.40	286.70	30.56	F
2851	2850.	1172.	884.	881.	874.	0.855	0.599	0.257	24.12	24.79	0.40	286.70	30.56	F
2881	2880.	1172.	884.	881.	874.	0.855	0.599	0.257	23.32	24.79	0.40	286.70	30.56	F
2911	2910.	1172.	884.	881.	874.	0.855	0.599	0.257	22.52	24.79	0.40	286.70	30.56	F
2941	2940.	1172.	884.	881.	874.	0.855	0.599	0.257	21.72	24.79	0.40	286.70	30.56	F
2971	2970.	1172.	884.	881.	874.	0.855	0.599	0.257	20.92	24.79	0.40	286.70	30.56	F
3001	3000.	1172.	884.	881.	874.	0.855	0.599	0.257	20.12	24.79	0.40	286.70	30.56	F
3031	3030.	1172.	884.	881.	874.	0.855	0.599	0.257	19.33	24.79	0.40	286.70	30.56	F
3061	3060.	1172.	884.	881.	874.	0.855	0.599	0.257	18.53	24.79	0.40	286.70	30.56	F
3091	3090.	1172.	884.	881.	874.	0.855	0.599	0.257	17.73	24.79	0.40	286.70	30.56	F
3121	3120.	1172.	884.	881.	874.	0.855	0.599	0.257	16.93	24.79	0.40	286.70	30.56	F
3151	3150.	1172.	884.	881.	874.	0.855	0.599	0.257	16.13	24.79	0.40	286.70	30.56	F
3181	3180.	1172.	884.	881.	874.	0.855	0.599	0.257	15.33	24.79	0.40	286.70	30.56	F
3211	3210.	1172.	884.	881.	874.	0.855	0.599	0.257	14.54	24.79	0.40	286.70	30.56	F
3241	3240.	1172.	884.	881.	874.	0.855	0.599	0.257	13.74	24.79	0.40	286.70	30.56	F
3271	3270.	1172.	884.	881.	874.	0.855	0.599	0.257	12.94	24.79	0.40	286.70	30.56	F
3301	3300.	1172.	884.	881.	874.	0.855	0.599	0.257	12.14	24.79	0.40	286.70	30.56	F
3331	3330.	1172.	884.	881.	874.	0.855	0.599	0.257	11.34	24.79	0.40	286.70	30.56	F
3361	3360.	1172.	884.	881.	874.	0.855	0.599	0.257	10.54	24.79	0.40	286.70	30.56	F
3391	3390.	1172.	884.	881.	874.	0.855	0.599	0.257	9.74	24.79	0.40	286.70	30.56	F
3421	3420.	1172.	884.	881.	874.	0.855	0.599	0.257	8.95	24.79	0.40	286.70	30.56	F
3451	3450.	1172.	884.	881.	874.	0.855	0.599	0.257	8.15	24.79	0.40	286.70	30.56	F
3481	3480.	1172.	884.	881.	874.	0.855	0.599	0.257	7.35	24.79	0.40	286.70	30.56	F
3511	3510.	1172.	884.	881.	874.	0.855	0.599	0.257	6.55	24.79	0.40	286.70	30.56	F
3541	3540.	1172.	884.	881.	874.	0.855	0.599	0.257	5.75	24.79	0.40	286.70	30.56	F
3571	3570.	1172.	884.	881.	874.	0.855	0.599	0.257	4.95	24.79	0.40	286.70	30.56	F
3601	3600.	1172.	884.	881.	874.	0.855	0.599	0.257	4.15	24.79	0.40	286.70	30.56	F
3631	3630.	1172.	884.	881.	874.	0.855	0.599	0.257	3.36	24.79	0.40	286.70	30.56	F
3661	3660.	1172.	884.	881.	874.	0.855	0.599	0.257	2.56	24.79	0.40	286.70	30.56	F
3691	3690.	1172.	884.	881.	874.	0.855	0.599	0.257	1.76	24.79	0.40	286.70	30.56	F
3721	3720.	1172.	884.	881.	874.	0.855	0.599	0.257	0.96	24.79	0.40	286.70	30.56	F

3751	3750.	1172.	884.	881.	874.	0.855	0.599	0.257	0.16	24.79	0.40	286.70	30.56	F
3764	3763.	173.	349.	348.	347.	0.	0.	0.	0.	16.01	0.49	152.72	28.92	T

VENTILATION SPECIFIED; FUEL PYROLYSIS ADJUSTED FOR WORST CONDITIONS PAGE NO. 1 RUN NO. 1

TIME	HEAT BALANCE GAS FLOW PCT	WND RAD PCT	WALL CNV PCT	WALL RAD PCT	Q-FIRE BTU/HR	Q-WALL SUM BTU	YO2 PCT MASS	YN2 PCT MASS	YCO2 PCT MASS	YH2O PCT MASS	YPYR PCT MASS
0.	58.333	4.823	17.457	19.396	3.692E+07	4.089E+03	0.063	0.716	0.166	0.034	0.021
30.	70.289	7.760	4.479	17.446	3.689E+07	7.665E+04	0.063	0.716	0.166	0.034	0.021
60.	70.291	7.760	4.478	17.445	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
90.	70.292	7.761	4.477	17.444	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
120.	70.292	7.761	4.477	17.444	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
150.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
180.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
210.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
240.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
270.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
300.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
330.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
360.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
390.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
420.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
450.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
480.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
510.	70.293	7.761	4.476	17.442	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
540.	70.293	7.761	4.476	17.442	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
570.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
600.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
630.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
660.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
690.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
720.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
750.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
780.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
810.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
840.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
870.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
900.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
930.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
960.	70.293	7.761	4.476	17.442	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
990.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1020.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1050.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1080.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1110.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1140.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1170.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1200.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1230.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1260.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1290.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1320.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1350.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1380.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1410.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1440.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1470.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1500.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1530.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1560.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1590.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1620.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1650.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1680.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1710.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1740.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021

1770.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1800.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1830.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1860.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1890.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1920.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1950.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
1980.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2010.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2040.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2070.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2100.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2130.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2160.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2190.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2220.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2250.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2280.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2310.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2340.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2370.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2400.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2430.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2460.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2490.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2520.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2550.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2580.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2610.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2640.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2670.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2700.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2730.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2760.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2790.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2820.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2850.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2880.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2910.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2940.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
2970.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3000.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3030.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3060.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3090.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3120.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3150.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3180.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3210.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3240.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3270.	70.293	7.761	4.476	17.442	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3300.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3330.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3360.	70.293	7.761	4.476	17.442	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3390.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3420.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3450.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3480.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3510.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3540.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3570.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3600.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3630.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3660.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3690.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3720.	70.293	7.761	4.477	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021

3750.	70.293	7.761	4.476	17.443	3.689E+07	7.298E+04	0.063	0.716	0.166	0.034	0.021
3763.	97.597	2.403	-65.706	-34.392	0.000E+00	1.708E+04	0.230	0.770	0.	0.	0.

SUDWAY3004 - hp = 80%, cvgross=21.2 load=52.2________ lrun=1 COMPF2 VERSION 1.1 - RUN NO. 1

--- GEOMETRY AND VENTILATION---

WALL SURFACE AREA = 1557.5 sq. ft.
FLOOR AREA = 662.6 sq. ft.
WINDOW HEIGHT = 3.1 ft.
AREA = 258.3 sq. ft.
OPENING FACTOR = 451.230 ft. ^1.5
DISCHARGE COEFF. = 0.68

-----FUEL LOAD PROPERTIES----

FIRE LOAD PER FLOOR AREA = 10.7 lbs/sq.ft.

FUEL COMPOSITION
CARBON = 91.2 PERCENT BY WEIGHT
HYDROGEN = 7.7 PERCENT
OXYGEN = 0. PERCENT
NITROGEN = 0. PERCENT
WATER = 0. PERCENT
R = 13.14
RO= 3.05
HEAT OF COMBUSTION OF DRY FUEL = 91.3E+02 btu/lb
LOWER ACTUAL HEAT OF COMBUSTION = 84.0E+02 btu/lb
MOLECULAR WEIGHT OF UNBURNT PYROLYSATES = 28.97
CP OF PYROLYSIS GAS = (0. *TGAS + 0.3198) btu/lb-F
MAXIMUM FRACTION OF PYROLYSATES BURN = 0.80
GREY-GAS FLAME EMISSIVITY = 0.900

----WALL THERMAL PROPERTIES----

THICKNESS = 0.0 ft.
DENSITY = 1.309 lbs/cu. ft.

THERMAL CONDUCTIVITY = 26. btu/hr-ft-F

HEAT CAPACITY = 0.0717 btu/lb-F

EMISSIVITY = 0.90

VENTILATION SPECIFIED, FUEL PYROLYSIS ADJUSTED FOR WORST CONDITIONS PAGE NO. 1 RUN NO. 1

	TIME S	TEMP GAS,F	WALL TEMPS F			RP LBS/S	RC LBS/S	EXC.PYR. LBS/S	FUEL PCT	AIR IN LBS/S	N.P.	VELOCITY FT/M	MOL.WT	FUEL CNTRL
1	0.	1080.	215.	210.	204.	0.856	0.685	0.171	99.97	24.82	0.41	283.32	30.80	F
31	30.	1274.	968.	965.	955.	0.853	0.683	0.171	99.18	24.73	0.40	289.06	30.80	F
61	60.	1274.	968.	965.	955.	0.853	0.683	0.171	98.38	24.73	0.40	289.06	30.80	F
91	90.	1274.	968.	965.	955.	0.853	0.683	0.171	97.58	24.73	0.40	289.06	30.80	F
121	120.	1274.	969.	965.	955.	0.853	0.683	0.171	96.79	24.73	0.40	289.06	30.80	F
151	150.	1274.	969.	965.	955.	0.853	0.683	0.171	95.99	24.73	0.40	289.06	30.80	F
181	180.	1274.	969.	965.	955.	0.853	0.683	0.171	95.19	24.73	0.40	289.06	30.80	F
211	210.	1274.	969.	965.	955.	0.853	0.683	0.171	94.40	24.73	0.40	289.06	30.80	F
241	240.	1274.	969.	965.	955.	0.853	0.683	0.171	93.60	24.73	0.40	289.06	30.80	F
271	270.	1274.	969.	965.	955.	0.853	0.683	0.171	92.80	24.73	0.40	289.06	30.80	F
301	300.	1274.	969.	965.	955.	0.853	0.683	0.171	92.01	24.73	0.40	289.06	30.80	F
331	330.	1274.	969.	965.	955.	0.853	0.683	0.171	91.21	24.73	0.40	289.06	30.80	F
361	360.	1274.	969.	965.	955.	0.853	0.683	0.171	90.41	24.73	0.40	289.06	30.80	F
391	390.	1274.	969.	965.	955.	0.853	0.683	0.171	89.62	24.73	0.40	289.06	30.80	F
421	420.	1274.	969.	965.	955.	0.853	0.683	0.171	88.82	24.73	0.40	289.06	30.80	F
451	450.	1274.	969.	965.	955.	0.853	0.683	0.171	88.02	24.73	0.40	289.06	30.80	F
481	480.	1274.	969.	965.	955.	0.853	0.683	0.171	87.23	24.73	0.40	289.06	30.80	F
511	510.	1274.	969.	965.	955.	0.853	0.683	0.171	86.43	24.73	0.40	289.06	30.80	F
541	540.	1274.	969.	965.	955.	0.853	0.683	0.171	85.63	24.73	0.40	289.06	30.80	F
571	570.	1274.	969.	965.	955.	0.853	0.683	0.171	84.84	24.73	0.40	289.06	30.80	F
601	600.	1274.	969.	965.	955.	0.853	0.683	0.171	84.04	24.73	0.40	289.06	30.80	F
631	630.	1274.	969.	965.	955.	0.853	0.683	0.171	83.24	24.73	0.40	289.06	30.80	F
661	660.	1274.	969.	965.	955.	0.853	0.683	0.171	82.45	24.73	0.40	289.06	30.80	F
691	690.	1274.	969.	965.	955.	0.853	0.683	0.171	81.65	24.73	0.40	289.06	30.80	F
721	720.	1274.	969.	965.	955.	0.853	0.683	0.171	80.85	24.73	0.40	289.06	30.80	F
751	750.	1274.	969.	965.	955.	0.853	0.683	0.171	80.06	24.73	0.40	289.06	30.80	F
781	780.	1274.	969.	965.	955.	0.853	0.683	0.171	79.26	24.73	0.40	289.06	30.80	F
811	810.	1274.	969.	965.	955.	0.853	0.683	0.171	78.46	24.73	0.40	289.06	30.80	F
841	840.	1274.	969.	965.	955.	0.853	0.683	0.171	77.67	24.73	0.40	289.06	30.80	F
871	870.	1274.	969.	965.	955.	0.853	0.683	0.171	76.87	24.73	0.40	289.06	30.80	F
901	900.	1274.	969.	965.	955.	0.853	0.683	0.171	76.08	24.73	0.40	289.06	30.80	F
931	930.	1274.	969.	965.	955.	0.853	0.683	0.171	75.28	24.73	0.40	289.06	30.80	F
961	960.	1274.	969.	965.	955.	0.853	0.683	0.171	74.48	24.73	0.40	289.06	30.80	F
991	990.	1274.	969.	965.	955.	0.853	0.683	0.171	73.69	24.73	0.40	289.06	30.80	F
1021	1020.	1274.	969.	965.	955.	0.853	0.683	0.171	72.89	24.73	0.40	289.06	30.80	F
1051	1050.	1274.	969.	965.	955.	0.853	0.683	0.171	72.09	24.73	0.40	289.06	30.80	F
1081	1080.	1274.	969.	965.	955.	0.853	0.683	0.171	71.30	24.73	0.40	289.06	30.80	F
1111	1110.	1274.	969.	965.	955.	0.853	0.683	0.171	70.50	24.73	0.40	289.06	30.80	F
1141	1140.	1274.	969.	965.	955.	0.853	0.683	0.171	69.70	24.73	0.40	289.06	30.80	F
1171	1170.	1274.	969.	965.	955.	0.853	0.683	0.171	68.91	24.73	0.40	289.06	30.80	F
1201	1200.	1274.	969.	965.	955.	0.853	0.683	0.171	68.11	24.73	0.40	289.06	30.80	F
1231	1230.	1274.	969.	965.	955.	0.853	0.683	0.171	67.31	24.73	0.40	289.06	30.80	F
1261	1260.	1274.	969.	965.	955.	0.853	0.683	0.171	66.52	24.73	0.40	289.06	30.80	F
1291	1290.	1274.	969.	965.	955.	0.853	0.683	0.171	65.72	24.73	0.40	289.06	30.80	F
1321	1320.	1274.	969.	965.	955.	0.853	0.683	0.171	64.92	24.73	0.40	289.06	30.80	F
1351	1350.	1274.	969.	965.	955.	0.853	0.683	0.171	64.13	24.73	0.40	289.06	30.80	F
1381	1380.	1274.	969.	965.	955.	0.853	0.683	0.171	63.33	24.73	0.40	289.06	30.80	F
1411	1410.	1274.	969.	965.	955.	0.853	0.683	0.171	62.53	24.73	0.40	289.06	30.80	F
1441	1440.	1274.	969.	965.	955.	0.853	0.683	0.171	61.74	24.73	0.40	289.06	30.80	F
1471	1470.	1274.	969.	965.	955.	0.853	0.683	0.171	60.94	24.73	0.40	289.06	30.80	F
1501	1500.	1274.	969.	965.	955.	0.853	0.683	0.171	60.14	24.73	0.40	289.06	30.80	F
1531	1530.	1274.	969.	965.	955.	0.853	0.683	0.171	59.35	24.73	0.40	289.06	30.80	F
1561	1560.	1274.	969.	965.	955.	0.853	0.683	0.171	58.55	24.73	0.40	289.06	30.80	F
1591	1590.	1274.	969.	965.	955.	0.853	0.683	0.171	57.75	24.73	0.40	289.06	30.80	F
1621	1620.	1274.	969.	965.	955.	0.853	0.683	0.171	56.96	24.73	0.40	289.06	30.80	F
1651	1650.	1274.	969.	965.	955.	0.853	0.683	0.171	56.16	24.73	0.40	289.06	30.80	F
1681	1680.	1274.	969.	965.	955.	0.853	0.683	0.171	55.36	24.73	0.40	289.06	30.80	F
1711	1710.	1274.	969.	965.	955.	0.853	0.683	0.171	54.57	24.73	0.40	289.06	30.80	F
1741	1740.	1274.	969.	965.	955.	0.853	0.683	0.171	53.77	24.73	0.40	289.06	30.80	F

1771	1770.	1274.	969.	965.	955.	0.853	0.683	0.171	52.97	24.73	0.40	289.06	30.80	F
1801	1800.	1274.	969.	965.	955.	0.853	0.683	0.171	52.18	24.73	0.40	289.06	30.80	F
1831	1830.	1274.	969.	965.	955.	0.853	0.683	0.171	51.38	24.73	0.40	289.06	30.80	F
1861	1860.	1274.	969.	965.	955.	0.853	0.683	0.171	50.58	24.73	0.40	289.06	30.80	F
1891	1890.	1274.	969.	965.	955.	0.853	0.683	0.171	49.79	24.73	0.40	289.06	30.80	F
1921	1920.	1274.	969.	965.	955.	0.853	0.683	0.171	48.99	24.73	0.40	289.06	30.80	F
1951	1950.	1274.	969.	965.	955.	0.853	0.683	0.171	48.19	24.73	0.40	289.06	30.80	F
1981	1980.	1274.	969.	965.	955.	0.853	0.683	0.171	47.40	24.73	0.40	289.06	30.80	F
2011	2010.	1274.	969.	965.	955.	0.853	0.683	0.171	46.60	24.73	0.40	289.06	30.80	F
2041	2040.	1274.	969.	965.	955.	0.853	0.683	0.171	45.80	24.73	0.40	289.06	30.80	F
2071	2070.	1274.	969.	965.	955.	0.853	0.683	0.171	45.01	24.73	0.40	289.06	30.80	F
2101	2100.	1274.	969.	965.	955.	0.853	0.683	0.171	44.21	24.73	0.40	289.06	30.80	F
2131	2130.	1274.	969.	965.	955.	0.853	0.683	0.171	43.41	24.73	0.40	289.06	30.80	F
2161	2160.	1274.	969.	965.	955.	0.853	0.683	0.171	42.62	24.73	0.40	289.06	30.80	F
2191	2190.	1274.	969.	965.	955.	0.853	0.683	0.171	41.82	24.73	0.40	289.06	30.80	F
2221	2220.	1274.	969.	965.	955.	0.853	0.683	0.171	41.02	24.73	0.40	289.06	30.80	F
2251	2250.	1274.	969.	965.	955.	0.853	0.683	0.171	40.23	24.73	0.40	289.06	30.80	F
2281	2280.	1274.	969.	965.	955.	0.853	0.683	0.171	39.43	24.73	0.40	289.06	30.80	F
2311	2310.	1274.	969.	965.	955.	0.853	0.683	0.171	38.64	24.73	0.40	289.06	30.80	F
2341	2340.	1274.	969.	965.	955.	0.853	0.683	0.171	37.84	24.73	0.40	289.06	30.80	F
2371	2370.	1274.	969.	965.	955.	0.853	0.683	0.171	37.04	24.73	0.40	289.06	30.80	F
2401	2400.	1274.	969.	965.	955.	0.853	0.683	0.171	36.25	24.73	0.40	289.06	30.80	F
2431	2430.	1274.	969.	965.	955.	0.853	0.683	0.171	35.45	24.73	0.40	289.06	30.80	F
2461	2460.	1274.	969.	965.	955.	0.853	0.683	0.171	34.65	24.73	0.40	289.06	30.80	F
2491	2490.	1274.	969.	965.	955.	0.853	0.683	0.171	33.86	24.73	0.40	289.06	30.80	F
2521	2520.	1274.	969.	965.	955.	0.853	0.683	0.171	33.06	24.73	0.40	289.06	30.80	F
2551	2550.	1274.	969.	965.	955.	0.853	0.683	0.171	32.26	24.73	0.40	289.06	30.80	F
2581	2580.	1274.	969.	965.	955.	0.853	0.683	0.171	31.47	24.73	0.40	289.06	30.80	F
2611	2610.	1274.	969.	965.	955.	0.853	0.683	0.171	30.67	24.73	0.40	289.06	30.80	F
2641	2640.	1274.	969.	965.	955.	0.853	0.683	0.171	29.87	24.73	0.40	289.06	30.80	F
2671	2670.	1274.	969.	965.	955.	0.853	0.683	0.171	29.08	24.73	0.40	289.06	30.80	F
2701	2700.	1274.	969.	965.	955.	0.853	0.683	0.171	28.28	24.73	0.40	289.06	30.80	F
2731	2730.	1274.	969.	965.	955.	0.853	0.683	0.171	27.48	24.73	0.40	289.06	30.80	F
2761	2760.	1274.	969.	965.	955.	0.853	0.683	0.171	26.69	24.73	0.40	289.06	30.80	F
2791	2790.	1274.	969.	965.	955.	0.853	0.683	0.171	25.89	24.73	0.40	289.06	30.80	F
2821	2820.	1274.	969.	965.	955.	0.853	0.683	0.171	25.09	24.73	0.40	289.06	30.80	F
2851	2850.	1274.	969.	965.	955.	0.853	0.683	0.171	24.30	24.73	0.40	289.06	30.80	F
2881	2880.	1274.	969.	965.	955.	0.853	0.683	0.171	23.50	24.73	0.40	289.06	30.80	F
2911	2910.	1274.	969.	965.	955.	0.853	0.683	0.171	22.70	24.73	0.40	289.06	30.80	F
2941	2940.	1274.	969.	965.	955.	0.853	0.683	0.171	21.91	24.73	0.40	289.06	30.80	F
2971	2970.	1274.	969.	965.	955.	0.853	0.683	0.171	21.11	24.73	0.40	289.06	30.80	F
3001	3000.	1274.	969.	965.	955.	0.853	0.683	0.171	20.31	24.73	0.40	289.06	30.80	F
3031	3030.	1274.	969.	965.	955.	0.853	0.683	0.171	19.52	24.73	0.40	289.06	30.80	F
3061	3060.	1274.	969.	965.	955.	0.853	0.683	0.171	18.72	24.73	0.40	289.06	30.80	F
3091	3090.	1274.	969.	965.	955.	0.853	0.683	0.171	17.92	24.73	0.40	289.06	30.80	F
3121	3120.	1274.	969.	965.	955.	0.853	0.683	0.171	17.13	24.73	0.40	289.06	30.80	F
3151	3150.	1274.	969.	965.	955.	0.853	0.683	0.171	16.33	24.73	0.40	289.06	30.80	F
3181	3180.	1274.	969.	965.	955.	0.853	0.683	0.171	15.53	24.73	0.40	289.06	30.80	F
3211	3210.	1274.	969.	965.	955.	0.853	0.683	0.171	14.74	24.73	0.40	289.06	30.80	F
3241	3240.	1274.	969.	965.	955.	0.853	0.683	0.171	13.94	24.73	0.40	289.06	30.80	F
3271	3270.	1274.	969.	965.	955.	0.853	0.683	0.171	13.14	24.73	0.40	289.06	30.80	F
3301	3300.	1274.	969.	965.	955.	0.853	0.683	0.171	12.35	24.73	0.40	289.06	30.80	F
3331	3330.	1274.	969.	965.	955.	0.853	0.683	0.171	11.55	24.73	0.40	289.06	30.80	F
3361	3360.	1274.	969.	965.	955.	0.853	0.683	0.171	10.75	24.73	0.40	289.06	30.80	F
3391	3390.	1274.	969.	965.	955.	0.853	0.683	0.171	9.96	24.73	0.40	289.06	30.80	F
3421	3420.	1274.	969.	965.	955.	0.853	0.683	0.171	9.16	24.73	0.40	289.06	30.80	F
3451	3450.	1274.	969.	965.	955.	0.853	0.683	0.171	8.36	24.73	0.40	289.06	30.80	F
3481	3480.	1274.	969.	965.	955.	0.853	0.683	0.171	7.57	24.73	0.40	289.06	30.80	F
3511	3510.	1274.	969.	965.	955.	0.853	0.683	0.171	6.77	24.73	0.40	289.06	30.80	F
3541	3540.	1274.	969.	965.	955.	0.853	0.683	0.171	5.97	24.73	0.40	289.06	30.80	F
3571	3570.	1274.	969.	965.	955.	0.853	0.683	0.171	5.18	24.73	0.40	289.06	30.80	F
3601	3600.	1274.	969.	965.	955.	0.853	0.683	0.171	4.38	24.73	0.40	289.06	30.80	F
3631	3630.	1274.	969.	965.	955.	0.853	0.683	0.171	3.58	24.73	0.40	289.06	30.80	F
3661	3660.	1274.	969.	965.	955.	0.853	0.683	0.171	2.79	24.73	0.40	289.06	30.80	F
3691	3690.	1274.	969.	965.	955.	0.853	0.683	0.171	1.99	24.73	0.40	289.06	30.80	F
3721	3720.	1274.	969.	965.	955.	0.853	0.683	0.171	1.19	24.73	0.40	289.06	30.80	F

3751	3750.	1274.	969.	965.	955.	0.853	0.683	0.171	0.40	24.73	0.40	289.06	30.80	F
3773	3772.	162.	321.	323.	324.	0.	0.	0.	0.	15.33	0.49	145.82	28.92	T

VENTILATION SPECIFIED, FUEL PYROLYSIS ADJUSTED FOR WORST CONDITIONS

TIME	HEAT BALANCE GAS FLOW PCT	WND RAD PCT	WALL CNV PCT	WALL RAD PCT	Q-FIRE BTU/HR	Q-WALL SUM BTU	YO2 PCT MASS	YN2 PCT MASS	YCO2 PCT MASS	YH2O PCT MASS	YPYR PCT MASS
0.	54.156	5.355	16.955	21.539	4.222E+07	4.884E+03	0.041	0.716	0.189	0.039	0.014
30.	67.520	8.695	4.257	19.494	4.206E+07	9.379E+04	0.041	0.716	0.189	0.039	0.014
60.	67.523	8.696	4.256	19.492	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
90.	67.524	8.697	4.255	19.491	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
120.	67.525	8.697	4.254	19.491	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
150.	67.525	8.697	4.254	19.491	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
180.	67.525	8.697	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
210.	67.526	8.697	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
240.	67.526	8.697	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
270.	67.526	8.697	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
300.	67.527	8.697	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
330.	67.527	8.697	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
360.	67.527	8.697	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
390.	67.527	8.697	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
420.	67.527	8.697	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
450.	67.527	8.697	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
480.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
510.	67.527	8.697	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
540.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
570.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
600.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
630.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
660.	67.527	8.698	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
690.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
720.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
750.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
780.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
810.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
840.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
870.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
900.	67.527	8.698	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
930.	67.527	8.697	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
960.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
990.	67.527	8.697	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1020.	67.527	8.698	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1050.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1080.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1110.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1140.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1170.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1200.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1230.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1260.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1290.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1320.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1350.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1380.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1410.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1440.	67.527	8.698	4.253	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1470.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1500.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1530.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1560.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1590.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1620.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1650.	67.527	8.698	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1680.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1710.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1740.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014

1770.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1800.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1830.	67.527	8.697	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1860.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1890.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1920.	67.527	8.698	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1950.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
1980.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2010.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2040.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2070.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2100.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2130.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2160.	67.527	8.697	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2190.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2220.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2250.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2280.	67.527	8.697	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2310.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2340.	67.527	8.699	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2370.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2400.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2430.	67.527	8.698	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2460.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2490.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2520.	67.527	8.697	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2550.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2580.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2610.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2640.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2670.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2700.	67.527	8.698	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2730.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2760.	67.527	8.698	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2790.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2820.	67.527	8.698	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2850.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2880.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2910.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2940.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
2970.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3000.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3030.	67.527	8.697	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3060.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3090.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3120.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3150.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3180.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3210.	67.527	8.697	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3240.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3270.	67.527	8.698	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3300.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3330.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3360.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3390.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3420.	67.527	8.698	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3450.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3480.	67.527	8.698	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3510.	67.527	8.698	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3540.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3570.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3600.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3630.	67.527	8.698	4.254	19.490	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3660.	67.527	8.697	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3690.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3720.	67.527	8.698	4.254	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014

3750.	67.527	8.698	4.253	19.489	4.206E+07	9.013E+04	0.041	0.716	0.189	0.039	0.014
3772.	97.558	2.442	-66.757	-33.330	0.000E+00	4.511E+04	0.230	0.770	0.	0.	0.

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SUBWAY2002 - hpf = 60%, cvgross=17.3, fload=64.8___________ Irun=1          COMPF2 VERSION 1.1 - RUN NO.   1

----GEOMETRY AND VENTILATION----

WALL SURFACE AREA =    1557.5 sq. ft.
FLOOR AREA :     662.6 sq. ft.
WINDOW HEIGHT =       3.1 ft.
          AREA =    258.3 sq. ft.
OPENING FACTOR = 451.230 ft. ^1.5
DISCHARGE COEFF.= 0.68

----FUEL LOAD PROPERTIES----

FIRE LOAD PER FLOOR AREA =  13.3 lbs/sq.ft.

FUEL COMPOSITION
CARBON    = 91.2 PERCENT BY WEIGHT
HYDROGEN =  7.7 PERCENT
OXYGEN    =  0.  PERCENT
NITROGEN =  0.  PERCENT
WATER     =  0.  PERCENT
R = 13.14
RO=  3.05
HEAT OF COMBUSTION OF DRY FUEL =   74.2E+02 btu/lb
LOWER ACTUAL HEAT OF COMBUSTION =   67.0E+02 btu/lb
MOLECULAR WEIGHT OF UNBURNT PYROLYSATES =  28.97
CP OF PYROLYSIS GAS = (0.     *TGAS + 0.3198) btu/lb-F
MAXIMUM FRACTION OF PYROLYSATES BURN =  0.60
GREY-GAS FLAME EMISSIVITY = 0.900

----WALL THERMAL PROPERTIES----

THICKNESS =   0.0 ft.
DENSITY =  1.309 lbs/cu. ft.

THERMAL CONDUCTIVITY =     26. btu/hr-ft-F

HEAT CAPACITY =  0.0717 btu/lb-F

EMISSIVITY = 0.90
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VENTILATION SPECIFIED, FUEL PYROLYSIS ADJUSTED FOR WORST CONDITIONS

PAGE NO. 1 RUN NO. 1

	TIME S	TEMP GAS,F	WALL TEMPS F			RF LBS/S	RC LBS/S	EXC.PYR. LBS/S	FUEL PCT	AIR IN LBS/S	N.P.	VELOCITY FT/M	MOL.WT	FUEL CNTRL
1	0.	766.	147.	144.	141.	0.845	0.507	0.338	99.98	24.50	0.42	269.34	30.33	F
31	30.	906.	670.	668.	664.	0.854	0.512	0.342	99.34	24.75	0.41	276.81	30.33	F
61	60.	906.	670.	668.	664.	0.854	0.512	0.342	98.69	24.75	0.41	276.81	30.33	F
91	90.	906.	670.	668.	664.	0.854	0.512	0.342	98.05	24.75	0.41	276.81	30.33	F
121	120.	906.	670.	668.	664.	0.854	0.512	0.342	97.41	24.75	0.41	276.81	30.33	F
151	150.	906.	670.	668.	664.	0.854	0.512	0.342	96.77	24.75	0.41	276.81	30.33	F
181	180.	906.	670.	668.	664.	0.854	0.512	0.342	96.13	24.75	0.41	276.81	30.33	F
211	210.	906.	670.	668.	664.	0.854	0.512	0.342	95.48	24.75	0.41	276.81	30.33	F
241	240.	906.	670.	668.	664.	0.854	0.512	0.342	94.84	24.75	0.41	276.81	30.33	F
271	270.	906.	670.	668.	664.	0.854	0.512	0.342	94.20	24.75	0.41	276.81	30.33	F
301	300.	906.	670.	668.	664.	0.854	0.512	0.342	93.56	24.75	0.41	276.81	30.33	F
331	330.	906.	670.	668.	664.	0.854	0.512	0.342	92.91	24.75	0.41	276.81	30.33	F
361	360.	906.	670.	668.	664.	0.854	0.512	0.342	92.27	24.75	0.41	276.81	30.33	F
391	390.	906.	670.	668.	664.	0.854	0.512	0.342	91.63	24.75	0.41	276.81	30.33	F
421	420.	906.	670.	668.	664.	0.854	0.512	0.342	90.99	24.75	0.41	276.81	30.33	F
451	450.	906.	670.	668.	664.	0.854	0.512	0.342	90.35	24.75	0.41	276.81	30.33	F
481	480.	906.	670.	668.	664.	0.854	0.512	0.342	89.70	24.75	0.41	276.81	30.33	F
511	510.	906.	670.	668.	664.	0.854	0.512	0.342	89.06	24.75	0.41	276.81	30.33	F
541	540.	906.	670.	668.	664.	0.854	0.512	0.342	88.42	24.75	0.41	276.81	30.33	F
571	570.	906.	670.	668.	664.	0.854	0.512	0.342	87.78	24.75	0.41	276.81	30.33	F
601	600.	906.	670.	668.	664.	0.854	0.512	0.342	87.13	24.75	0.41	276.81	30.33	F
631	630.	906.	670.	668.	664.	0.854	0.512	0.342	86.49	24.75	0.41	276.81	30.33	F
661	660.	906.	670.	668.	664.	0.854	0.512	0.342	85.85	24.75	0.41	276.81	30.33	F
691	690.	906.	670.	668.	664.	0.854	0.512	0.342	85.21	24.75	0.41	276.81	30.33	F
721	720.	906.	670.	668.	664.	0.854	0.512	0.342	84.57	24.75	0.41	276.81	30.33	F
751	750.	906.	670.	668.	664.	0.854	0.512	0.342	83.92	24.75	0.41	276.81	30.33	F
781	780.	906.	670.	668.	664.	0.854	0.512	0.342	83.28	24.75	0.41	276.81	30.33	F
811	810.	906.	670.	668.	664.	0.854	0.512	0.342	82.64	24.75	0.41	276.81	30.33	F
841	840.	906.	670.	668.	664.	0.854	0.512	0.342	82.00	24.75	0.41	276.81	30.33	F
871	870.	906.	670.	668.	664.	0.854	0.512	0.342	81.35	24.75	0.41	276.81	30.33	F
901	900.	906.	670.	668.	664.	0.854	0.512	0.342	80.71	24.75	0.41	276.81	30.33	F
931	930.	906.	670.	668.	664.	0.854	0.512	0.342	80.07	24.75	0.41	276.81	30.33	F
961	960.	906.	670.	668.	664.	0.854	0.512	0.342	79.43	24.75	0.41	276.81	30.33	F
991	990.	906.	670.	668.	664.	0.854	0.512	0.342	78.78	24.75	0.41	276.81	30.33	F
1021	1020.	906.	670.	668.	664.	0.854	0.512	0.342	78.14	24.75	0.41	276.81	30.33	F
1051	1050.	906.	670.	668.	664.	0.854	0.512	0.342	77.50	24.75	0.41	276.81	30.33	F
1081	1080.	906.	670.	668.	664.	0.854	0.512	0.342	76.86	24.75	0.41	276.81	30.33	F
1111	1110.	906.	670.	668.	664.	0.854	0.512	0.342	76.22	24.75	0.41	276.81	30.33	F
1141	1140.	906.	670.	668.	664.	0.854	0.512	0.342	75.57	24.75	0.41	276.81	30.33	F
1171	1170.	906.	670.	668.	664.	0.854	0.512	0.342	74.93	24.75	0.41	276.81	30.33	F
1201	1200.	906.	670.	668.	664.	0.854	0.512	0.342	74.29	24.75	0.41	276.81	30.33	F
1231	1230.	906.	670.	668.	664.	0.854	0.512	0.342	73.65	24.75	0.41	276.81	30.33	F
1261	1260.	906.	670.	668.	664.	0.854	0.512	0.342	73.00	24.75	0.41	276.81	30.33	F
1291	1290.	906.	670.	668.	664.	0.854	0.512	0.342	72.36	24.75	0.41	276.81	30.33	F
1321	1320.	906.	670.	668.	664.	0.854	0.512	0.342	71.72	24.75	0.41	276.81	30.33	F
1351	1350.	906.	670.	668.	664.	0.854	0.512	0.342	71.08	24.75	0.41	276.81	30.33	F
1381	1380.	906.	670.	668.	664.	0.854	0.512	0.342	70.44	24.75	0.41	276.81	30.33	F
1411	1410.	906.	670.	668.	664.	0.854	0.512	0.342	69.79	24.75	0.41	276.81	30.33	F
1441	1440.	906.	670.	668.	664.	0.854	0.512	0.342	69.15	24.75	0.41	276.81	30.33	F
1471	1470.	906.	670.	668.	664.	0.854	0.512	0.342	68.51	24.75	0.41	276.81	30.33	F
1501	1500.	906.	670.	668.	664.	0.854	0.512	0.342	67.87	24.75	0.41	276.81	30.33	F
1531	1530.	906.	670.	668.	664.	0.854	0.512	0.342	67.22	24.75	0.41	276.81	30.33	F
1561	1560.	906.	670.	668.	664.	0.854	0.512	0.342	66.58	24.75	0.41	276.81	30.33	F
1591	1590.	906.	670.	668.	664.	0.854	0.512	0.342	65.94	24.75	0.41	276.81	30.33	F
1621	1620.	906.	670.	668.	664.	0.854	0.512	0.342	65.30	24.75	0.41	276.81	30.33	F
1651	1650.	906.	670.	668.	664.	0.854	0.512	0.342	64.66	24.75	0.41	276.81	30.33	F
1681	1680.	906.	670.	668.	664.	0.854	0.512	0.342	64.01	24.75	0.41	276.81	30.33	F
1711	1710.	906.	670.	668.	664.	0.854	0.512	0.342	63.37	24.75	0.41	276.81	30.33	F
1741	1740.	906.	670.	668.	664.	0.854	0.512	0.342	62.73	24.75	0.41	276.81	30.33	F

1771	1770.	906.	670.	668.	664.	0.854	0.512	0.342	62.09	24.75	0.41	276.81	30.33	F
1801	1800.	906.	670.	668.	664.	0.854	0.512	0.342	61.44	24.75	0.41	276.81	30.33	F
1831	1830.	906.	670.	668.	664.	0.854	0.512	0.342	60.80	24.75	0.41	276.81	30.33	F
1861	1860.	906.	670.	668.	664.	0.854	0.512	0.342	60.16	24.75	0.41	276.81	30.33	F
1891	1890.	906.	670.	668.	664.	0.854	0.512	0.342	59.52	24.75	0.41	276.81	30.33	F
1921	1920.	906.	670.	668.	664.	0.854	0.512	0.342	58.87	24.75	0.41	276.81	30.33	F
1951	1950.	906.	670.	668.	664.	0.854	0.512	0.342	58.23	24.75	0.41	276.81	30.33	F
1981	1980.	906.	670.	668.	664.	0.854	0.512	0.342	57.59	24.75	0.41	276.81	30.33	F
2011	2010.	906.	670.	668.	664.	0.854	0.512	0.342	56.95	24.75	0.41	276.81	30.33	F
2041	2040.	906.	670.	668.	664.	0.854	0.512	0.342	56.31	24.75	0.41	276.81	30.33	F
2071	2070.	906.	670.	668.	664.	0.854	0.512	0.342	55.66	24.75	0.41	276.81	30.33	F
2101	2100.	906.	670.	668.	664.	0.854	0.512	0.342	55.02	24.75	0.41	276.81	30.33	F
2131	2130.	906.	670.	668.	664.	0.854	0.512	0.342	54.38	24.75	0.41	276.81	30.33	F
2161	2160.	906.	670.	668.	664.	0.854	0.512	0.342	53.74	24.75	0.41	276.81	30.33	F
2191	2190.	906.	670.	668.	664.	0.854	0.512	0.342	53.09	24.75	0.41	276.81	30.33	F
2221	2220.	906.	670.	668.	664.	0.854	0.512	0.342	52.45	24.75	0.41	276.81	30.33	F
2251	2250.	906.	670.	668.	664.	0.854	0.512	0.342	51.81	24.75	0.41	276.81	30.33	F
2281	2280.	906.	670.	668.	664.	0.854	0.512	0.342	51.17	24.75	0.41	276.81	30.33	F
2311	2310.	906.	670.	668.	664.	0.854	0.512	0.342	50.53	24.75	0.41	276.81	30.33	F
2341	2340.	906.	670.	668.	664.	0.854	0.512	0.342	49.88	24.75	0.41	276.81	30.33	F
2371	2370.	906.	670.	668.	664.	0.854	0.512	0.342	49.24	24.75	0.41	276.81	30.33	F
2401	2400.	906.	670.	668.	664.	0.854	0.512	0.342	48.60	24.75	0.41	276.81	30.33	F
2431	2430.	906.	670.	668.	664.	0.854	0.512	0.342	47.96	24.75	0.41	276.81	30.33	F
2461	2460.	906.	670.	668.	664.	0.854	0.512	0.342	47.31	24.75	0.41	276.81	30.33	F
2491	2490.	906.	670.	668.	664.	0.854	0.512	0.342	46.67	24.75	0.41	276.81	30.33	F
2521	2520.	906.	670.	668.	664.	0.854	0.512	0.342	46.03	24.75	0.41	276.81	30.33	F
2551	2550.	906.	670.	668.	664.	0.854	0.512	0.342	45.39	24.75	0.41	276.81	30.33	F
2581	2580.	906.	670.	668.	664.	0.854	0.512	0.342	44.74	24.75	0.41	276.81	30.33	F
2611	2610.	906.	670.	668.	664.	0.854	0.512	0.342	44.10	24.75	0.41	276.81	30.33	F
2641	2640.	906.	670.	668.	664.	0.854	0.512	0.342	43.46	24.75	0.41	276.81	30.33	F
2671	2670.	906.	670.	668.	664.	0.854	0.512	0.342	42.82	24.75	0.41	276.81	30.33	F
2701	2700.	906.	670.	668.	664.	0.854	0.512	0.342	42.17	24.75	0.41	276.81	30.33	F
2731	2730.	906.	670.	668.	664.	0.854	0.512	0.342	41.53	24.75	0.41	276.81	30.33	F
2761	2760.	906.	670.	668.	664.	0.854	0.512	0.342	40.89	24.75	0.41	276.81	30.33	F
2791	2790.	906.	670.	668.	664.	0.854	0.512	0.342	40.25	24.75	0.41	276.81	30.33	F
2821	2820.	906.	670.	668.	664.	0.854	0.512	0.342	39.61	24.75	0.41	276.81	30.33	F
2851	2850.	906.	670.	668.	664.	0.854	0.512	0.342	38.96	24.75	0.41	276.81	30.33	F
2881	2880.	906.	670.	668.	664.	0.854	0.512	0.342	38.32	24.75	0.41	276.81	30.33	F
2911	2910.	906.	670.	668.	664.	0.854	0.512	0.342	37.68	24.75	0.41	276.81	30.33	F
2941	2940.	906.	670.	668.	664.	0.854	0.512	0.342	37.04	24.75	0.41	276.81	30.33	F
2971	2970.	906.	670.	668.	664.	0.854	0.512	0.342	36.39	24.75	0.41	276.81	30.33	F
3001	3000.	906.	670.	668.	664.	0.854	0.512	0.342	35.75	24.75	0.41	276.81	30.33	F
3031	3030.	906.	670.	668.	664.	0.854	0.512	0.342	35.11	24.75	0.41	276.81	30.33	F
3061	3060.	906.	670.	668.	664.	0.854	0.512	0.342	34.47	24.75	0.41	276.81	30.33	F
3091	3090.	906.	670.	668.	664.	0.854	0.512	0.342	33.82	24.75	0.41	276.81	30.33	F
3121	3120.	906.	670.	668.	664.	0.854	0.512	0.342	33.18	24.75	0.41	276.81	30.33	F
3151	3150.	906.	670.	668.	664.	0.854	0.512	0.342	32.54	24.75	0.41	276.81	30.33	F
3181	3180.	906.	670.	668.	664.	0.854	0.512	0.342	31.90	24.75	0.41	276.81	30.33	F
3211	3210.	906.	670.	668.	664.	0.854	0.512	0.342	31.26	24.75	0.41	276.81	30.33	F
3241	3240.	906.	670.	668.	664.	0.854	0.512	0.342	30.61	24.75	0.41	276.81	30.33	F
3271	3270.	906.	670.	668.	664.	0.854	0.512	0.342	29.97	24.75	0.41	276.81	30.33	F
3301	3300.	906.	670.	668.	664.	0.854	0.512	0.342	29.33	24.75	0.41	276.81	30.33	F
3331	3330.	906.	670.	668.	664.	0.854	0.512	0.342	28.69	24.75	0.41	276.81	30.33	F
3361	3360.	906.	670.	668.	664.	0.854	0.512	0.342	28.04	24.75	0.41	276.81	30.33	F
3391	3390.	906.	670.	668.	664.	0.854	0.512	0.342	27.40	24.75	0.41	276.81	30.33	F
3421	3420.	906.	670.	668.	664.	0.854	0.512	0.342	26.76	24.75	0.41	276.81	30.33	F
3451	3450.	906.	670.	668.	664.	0.854	0.512	0.342	26.12	24.75	0.41	276.81	30.33	F
3481	3480.	906.	670.	668.	664.	0.854	0.512	0.342	25.47	24.75	0.41	276.81	30.33	F
3511	3510.	906.	670.	668.	664.	0.854	0.512	0.342	24.83	24.75	0.41	276.81	30.33	F
3541	3540.	906.	670.	668.	664.	0.854	0.512	0.342	24.19	24.75	0.41	276.81	30.33	F
3571	3570.	906.	670.	668.	664.	0.854	0.512	0.342	23.55	24.75	0.41	276.81	30.33	F
3601	3600.	906.	670.	668.	664.	0.854	0.512	0.342	22.90	24.75	0.41	276.81	30.33	F
3631	3630.	906.	670.	668.	664.	0.854	0.512	0.342	22.26	24.75	0.41	276.81	30.33	F
3661	3660.	906.	670.	668.	664.	0.854	0.512	0.342	21.62	24.75	0.41	276.81	30.33	F
3691	3690.	906.	670.	668.	664.	0.854	0.512	0.342	20.98	24.75	0.41	276.81	30.33	F
3721	3720.	906.	670.	668.	664.	0.854	0.512	0.342	20.34	24.75	0.41	276.81	30.33	F

3751	3750.	906.	670.	668.	664.	0.854	0.512	0.342	19.69	24.75	0.41	276.81	30.33	F
3781	3780.	906.	670.	668.	664.	0.854	0.512	0.342	19.05	24.75	0.41	276.81	30.33	F
3811	3810.	906.	670.	668.	664.	0.854	0.512	0.342	18.41	24.75	0.41	276.81	30.33	F
3841	3840.	906.	670.	668.	664.	0.854	0.512	0.342	17.77	24.75	0.41	276.81	30.33	F
3871	3870	906.	670.	668.	664.	0.854	0.512	0.342	17.12	24.75	0.41	276.81	30.33	F
3901	3900.	906.	670.	668.	664.	0.854	0.512	0.342	16.48	24.75	0.41	276.81	30.33	F
3931	3930.	906.	670.	668.	664.	0.854	0.512	0.342	15.84	24.75	0.41	276.81	30.33	F
3961	3960.	906.	670.	668.	664.	0.854	0.512	0.342	15.20	24.75	0.41	276.81	30.33	F
3991	3990.	906.	670.	668.	664.	0.854	0.512	0.342	14.55	24.75	0.41	276.81	30.33	F
4021	4020.	906.	670.	668.	664.	0.854	0.512	0.342	13.91	24.75	0.41	276.81	30.33	F
4051	4050.	906.	670.	668.	664.	0.854	0.512	0.342	13.27	24.75	0.41	276.81	30.33	F
4081	4080.	906.	670.	668.	664.	0.854	0.512	0.342	12.63	24.75	0.41	276.81	30.33	F
4111	4110.	906.	670.	668.	664.	0.854	0.512	0.342	11.99	24.75	0.41	276.81	30.33	F
4141	4140.	906.	670.	668.	664.	0.854	0.512	0.342	11.34	24.75	0.41	276.81	30.33	F
4171	4170.	906.	670.	668.	664.	0.854	0.512	0.342	10.70	24.75	0.41	276.81	30.33	F
4201	4200.	906.	670.	668.	664.	0.854	0.512	0.342	10.06	24.75	0.41	276.81	30.33	F
4231	4230.	906.	670.	668.	664.	0.854	0.512	0.342	9.42	24.75	0.41	276.81	30.33	F
4261	4260.	906.	670.	668.	664.	0.854	0.512	0.342	8.77	24.75	0.41	276.81	30.33	F
4291	4290.	906.	670.	668.	664.	0.854	0.512	0.342	8.13	24.75	0.41	276.81	30.33	F
4321	4320.	906.	670.	668.	664.	0.854	0.512	0.342	7.49	24.75	0.41	276.81	30.33	F
4351	4350.	906.	670.	668.	664.	0.854	0.512	0.342	6.85	24.75	0.41	276.81	30.33	F
4381	4380.	906.	670.	668.	664.	0.854	0.512	0.342	6.20	24.75	0.41	276.81	30.33	F
4411	4410.	906.	670.	668.	664.	0.854	0.512	0.342	5.56	24.75	0.41	276.81	30.33	F
4441	4440.	906.	670.	668.	664.	0.854	0.512	0.342	4.92	24.75	0.41	276.81	30.33	F
4471	4470.	906.	670.	668.	664.	0.854	0.512	0.342	4.28	24.75	0.41	276.81	30.33	F
4501	4500.	906.	670.	668.	664.	0.854	0.512	0.342	3.64	24.75	0.41	276.81	30.33	F
4531	4530.	906.	670.	668.	664.	0.854	0.512	0.342	2.99	24.75	0.41	276.81	30.33	F
4561	4560.	906.	670.	668.	664.	0.854	0.512	0.342	2.35	24.75	0.41	276.81	30.33	F
4591	4590.	906.	670.	668.	664.	0.854	0.512	0.342	1.71	24.75	0.41	276.81	30.33	F
4621	4620.	906.	670.	668.	664.	0.854	0.512	0.342	1.07	24.75	0.41	276.81	30.33	F
4651	4650.	906.	670.	668.	664.	0.854	0.512	0.342	0.42	24.75	0.41	276.81	30.33	F
4676	4675.	169.	339.	339.	340.	0.	0.	0.	0.	15.77	0.49	150.24	28.92	T

VENTILATION SPECIFIED, FUEL PYROLYSIS ADJUSTED FOR WORST CONDITIONS PAGE NO. 1 RUN NO. 1

TIME	GAS FLOW PCT	HEAT BALANCE WND RAD PCT	WALL CNV PCT	WALL RAD PCT	Q-FIRE BTU/HR	Q-WALL SUM BTU	YO2 PCT MASS	YN2 PCT MASS	YCO2 PCT MASS	YH2O PCT MASS	YPYR PCT MASS
0.	63.096	3.565	18.417	14.318	2.492E+07	2.452E+03	0.084	0.716	0.142	0.029	0.028
30.	77.040	5.511	5.052	12.377	2.518E+07	4.302E+04	0.084	0.716	0.142	0.029	0.028
60.	77.041	5.512	5.051	12.377	2.518E+07	3.960E+04	0.084	0.716	0.142	0.029	0.028
90.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
120.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
150.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
180.	77.042	5.512	5.050	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
210.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
240.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
270.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
300.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
330.	77.042	5.512	5.051	12.376	2.518E+07	3.960E+04	0.084	0.716	0.142	0.029	0.028
360.	77.041	5.512	5.051	12.376	2.518E+07	3.960E+04	0.084	0.716	0.142	0.029	0.028
390.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
420.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
450.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
480.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
510.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
540.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
570.	77.042	5.512	5.050	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
600.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
630.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
660.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
690.	77.042	5.512	5.050	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
720.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
750.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
780.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
810.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
840.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
870.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
900.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
930.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
960.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
990.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1020.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1050.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1080.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1110.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1140.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1170.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1200.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1230.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1260.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1290.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1320.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1350.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1380.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1410.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1440.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1470.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1500.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1530.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1560.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1590.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1620.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1650.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1680.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1710.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1740.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028

1770.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1800.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1830.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1860.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1890.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1920.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1950.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
1980.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2010.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2040.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2070.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2100.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2130.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2160.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2190.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2220.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2250.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2280.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2310.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2340.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2370.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2400.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2430.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2460.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2490.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2520.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2550.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2580.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2610.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2640.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2670.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2700.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2730.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2760.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2790.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2820.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2850.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2880.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2910.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2940.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
2970.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3000.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3030.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3060.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3090.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3120.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3150.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3180.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3210.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3240.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3270.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3300.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3330.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3360.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3390.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3420.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3450.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3480.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3510.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3540.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3570.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3600.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3630.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3660.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3690.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3720.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028

3750.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3780.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3810.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3840.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3870.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3900.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3930.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3960.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
3990.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4020.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4050.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4080.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4110.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4140.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4170.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4200.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4230.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4260.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4290.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4320.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4350.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4380.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4410.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4440.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4470.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4500.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4530.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4560.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4590.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4620.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4650.	77.042	5.512	5.051	12.376	2.518E+07	3.959E+04	0.084	0.716	0.142	0.029	0.028
4675.	97.585	2.415	-66.101	-33.996	0.000E+00	2.641E+04	0.230	0.770	0.	0.	0.

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SUBWAY2003   bpf = 70%, cvgross=17.3, fload=64.8__________ irun=1          COMPF2 VERSION 1.1 - RUN NO.   1

----GEOMETRY AND VENTILATION----

WALL SURFACE AREA =    1557.5 sq. ft.
FLOOR AREA =     662.6 sq. ft.
WINDOW HEIGHT =        3.1 ft.
          AREA =     253.3 sq. ft.
OPENING FACTOR = 451.230 ft. ^1.5
DISCHARGE COEFF.= 0.68

----FUEL LOAD PROPERTIES----

FIRE LOAD PER FLOOR AREA =  13.3 lbs/sq.ft.

FUEL COMPOSITION
CARBON   = 91.2 PERCENT BY WEIGHT
HYDROGEN =  7.7 PERCENT
OXYGEN   =  0.  PERCENT
NITROGEN =  0.  PERCENT
WATER    =  0.  PERCENT
R = 13.14
RO=  3.05
HEAT OF COMBUSTION OF DRY FUEL =    74.2E+02 btu/lb
LOWER ACTUAL HEAT OF COMBUSTION =    67.0E+02 btu/lb
MOLECULAR WEIGHT OF UNBURNT PYROLYSATES =  28.97
CP OF PYROLYSIS GAS = (0.     *TGAS + 0.3198) btu/lb-F
MAXIMUM FRACTION OF PYROLYSATES BURN =  0.70
GREY-GAS FLAME EMISSIVITY = 0.900

----WALL THERMAL PROPERTIES----

THICKNESS =    0.0 ft.
DENSITY =  1.309 lbs/cu. ft.

THERMAL CONDUCTIVITY =      26. btu/hr-ft-F

HEAT CAPACITY =  0.0717 btu/lb-F

EMISSIVITY = 0.90
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VENTILATION SPECIFIED, FUEL PYROLYSIS ADJUSTED FOR WORST CONDITIONS

PAGE NO. 1 RUN NO. 1

	TIME S	TEMP GAS,F	WALL TEMPS F			RP LBS/S	RC LBS/S	EXC.PYR. LBS/S	FUEL PCT	AIR IN LBS/S	N.P.	VELOCITY FT/M	MOL.WT	FUEL CNTRL
1	0.	853.	163.	159.	156.	0.851	0.596	0.255	99.98	24.67	0.42	273.32	30.56	F
31	30.	1009.	751.	749.	744.	0.856	0.599	0.257	99.33	24.81	0.41	281.02	30.56	F
61	60.	1009.	752.	749.	744.	0.856	0.599	0.257	98.69	24.81	0.41	281.02	30.56	F
91	90.	1009.	752.	749.	744.	0.856	0.599	0.257	98.05	24.81	0.41	281.02	30.56	F
121	120.	1009.	752.	749.	744.	0.856	0.599	0.257	97.40	24.81	0.41	281.02	30.56	F
151	150.	1009.	752.	749.	744.	0.856	0.599	0.257	96.76	24.81	0.41	281.02	30.56	F
181	180.	1009.	752.	749.	744.	0.856	0.599	0.257	96.12	24.81	0.41	281.02	30.56	F
211	210.	1009.	752.	749.	744.	0.856	0.599	0.257	95.47	24.81	0.41	281.02	30.56	F
241	240.	1009.	752.	749.	744.	0.856	0.599	0.257	94.83	24.81	0.41	281.02	30.56	F
271	270.	1009.	752.	749.	744.	0.856	0.599	0.257	94.18	24.81	0.41	281.02	30.56	F
301	300.	1009.	752.	749.	744.	0.856	0.599	0.257	93.54	24.81	0.41	281.02	30.56	F
331	330.	1009.	752.	749.	744.	0.856	0.599	0.257	92.90	24.81	0.41	281.02	30.56	F
361	360.	1009.	752.	749.	744.	0.856	0.599	0.257	92.25	24.81	0.41	281.02	30.56	F
391	390.	1009.	752.	749.	744.	0.856	0.599	0.257	91.61	24.81	0.41	281.02	30.56	F
421	420.	1009.	752.	749.	744.	0.856	0.599	0.257	90.96	24.81	0.41	281.02	30.56	F
451	450.	1009.	752.	749.	744.	0.856	0.599	0.257	90.32	24.81	0.41	281.02	30.56	F
481	480.	1009.	752.	749.	744.	0.856	0.599	0.257	89.68	24.81	0.41	281.02	30.56	F
511	510.	1009.	752.	749.	744.	0.856	0.599	0.257	89.03	24.81	0.41	281.02	30.56	F
541	540.	1009.	752.	749.	744.	0.856	0.599	0.257	88.39	24.81	0.41	281.02	30.56	F
571	570.	1009.	752.	749.	744.	0.856	0.599	0.257	87.74	24.81	0.41	281.02	30.56	F
601	600.	1009.	752.	749.	744.	0.856	0.599	0.257	87.10	24.81	0.41	281.02	30.56	F
631	630.	1009.	752.	749.	744.	0.856	0.599	0.257	86.46	24.81	0.41	281.02	30.56	F
661	660.	1009.	752.	749.	744.	0.856	0.599	0.257	85.81	24.81	0.41	281.02	30.56	F
691	690.	1009.	752.	749.	744.	0.856	0.599	0.257	85.17	24.81	0.41	281.02	30.56	F
721	720.	1009.	752.	749.	744.	0.856	0.599	0.257	84.53	24.81	0.41	281.02	30.56	F
751	750.	1009.	752.	749.	744.	0.856	0.599	0.257	83.88	24.81	0.41	281.02	30.56	F
781	780.	1009.	752.	749.	744.	0.856	0.599	0.257	83.24	24.81	0.41	281.02	30.56	F
811	810.	1009.	752.	749.	744.	0.856	0.599	0.257	82.59	24.81	0.41	281.02	30.56	F
841	840.	1009.	752.	749.	744.	0.856	0.599	0.257	81.95	24.81	0.41	281.02	30.56	F
871	870.	1009.	752.	749.	744.	0.856	0.599	0.257	81.31	24.81	0.41	281.02	30.56	F
901	900.	1009.	752.	749.	744.	0.856	0.599	0.257	80.66	24.81	0.41	281.02	30.56	F
931	930.	1009.	752.	749.	744.	0.856	0.599	0.257	80.02	24.81	0.41	281.02	30.56	F
961	960.	1009.	752.	749.	744.	0.856	0.599	0.257	79.37	24.81	0.41	281.02	30.56	F
991	990.	1009.	752.	749.	744.	0.856	0.599	0.257	78.73	24.81	0.41	281.02	30.56	F
1021	1020.	1009.	752.	749.	744.	0.856	0.599	0.257	78.09	24.81	0.41	281.02	30.56	F
1051	1050.	1009.	752.	749.	744.	0.856	0.599	0.257	77.44	24.81	0.41	281.02	30.56	F
1081	1080.	1009.	752.	749.	744.	0.856	0.599	0.257	76.80	24.81	0.41	281.02	30.56	F
1111	1110.	1009.	752.	749.	744.	0.856	0.599	0.257	76.15	24.81	0.41	281.02	30.56	F
1141	1140.	1009.	752.	749.	744.	0.856	0.599	0.257	75.51	24.81	0.41	281.02	30.56	F
1171	1170.	1009.	752.	749.	744.	0.856	0.599	0.257	74.87	24.81	0.41	281.02	30.56	F
1201	1200.	1009.	752.	749.	744.	0.856	0.599	0.257	74.22	24.81	0.41	281.02	30.56	F
1231	1230.	1009.	752.	749.	744.	0.856	0.599	0.257	73.58	24.81	0.41	281.02	30.56	F
1261	1260.	1009.	752.	749.	744.	0.856	0.599	0.257	72.93	24.81	0.41	281.02	30.56	F
1291	1290.	1009.	752.	749.	744.	0.856	0.599	0.257	72.29	24.81	0.41	281.02	30.56	F
1321	1320.	1009.	752.	749.	744.	0.856	0.599	0.257	71.65	24.81	0.41	281.02	30.56	F
1351	1350.	1009.	752.	749.	744.	0.856	0.599	0.257	71.00	24.81	0.41	281.02	30.56	F
1381	1380.	1009.	752.	749.	744.	0.856	0.599	0.257	70.36	24.81	0.41	281.02	30.56	F
1411	1410.	1009.	752.	749.	744.	0.856	0.599	0.257	69.72	24.81	0.41	281.02	30.56	F
1441	1440.	1009.	752.	749.	744.	0.856	0.599	0.257	69.07	24.81	0.41	281.02	30.56	F
1471	1470.	1009.	752.	749.	744.	0.856	0.599	0.257	68.43	24.81	0.41	281.02	30.56	F
1501	1500.	1009.	752.	749.	744.	0.856	0.599	0.257	67.78	24.81	0.41	281.02	30.56	F
1531	1530.	1009.	752.	749.	744.	0.856	0.599	0.257	67.14	24.81	0.41	281.02	30.56	F
1561	1560.	1009.	752.	749.	744.	0.856	0.599	0.257	66.50	24.81	0.41	281.02	30.56	F
1591	1590.	1009.	752.	749.	744.	0.856	0.599	0.257	65.85	24.81	0.41	281.02	30.56	F
1621	1620.	1009.	752.	749.	744.	0.856	0.599	0.257	65.21	24.81	0.41	281.02	30.56	F
1651	1650.	1009.	752.	749.	744.	0.856	0.599	0.257	64.56	24.81	0.41	281.02	30.56	F
1681	1680.	1009.	752.	749.	744.	0.856	0.599	0.257	63.92	24.81	0.41	281.02	30.56	F
1711	1710.	1009.	752.	749.	744.	0.856	0.599	0.257	63.28	24.81	0.41	281.02	30.56	F
1741	1740.	1009.	752.	749.	744.	0.856	0.599	0.257	62.63	24.81	0.41	281.02	30.56	F

1771	1770.	1009.	752.	749.	744.	0.856	0.599	0.257	61.99	24.81	0.41	281.02	30.56	F
1801	1800	1009.	752.	749.	744.	0.856	0.599	0.257	61.34	24.81	0.41	281.02	30.56	F
1831	1830.	1009.	752.	749.	744.	0.856	0.599	0.257	60.70	24.81	0.41	281.02	30.56	F
1861	1860.	1009.	752.	749.	744.	0.856	0.599	0.257	60.06	24.81	0.41	281.02	30.56	F
1891	1890.	1009.	752.	749.	744.	0.856	0.599	0.257	59.41	24.81	0.41	281.02	30.56	F
1921	1920.	1009.	752.	749.	744.	0.856	0.599	0.257	58.77	24.81	0.41	281.02	30.56	F
1951	1950.	1009.	752.	749.	744.	0.856	0.599	0.257	58.12	24.81	0.41	281.02	30.56	F
1981	1980.	1009.	752.	749.	744.	0.856	0.599	0.257	57.48	24.81	0.41	281.02	30.56	F
2011	2010.	1009.	752.	749.	744.	0.856	0.599	0.257	56.84	24.81	0.41	281.02	30.56	F
2041	2040.	1009.	752.	749.	744.	0.856	0.599	0.257	56.19	24.81	0.41	281.02	30.56	F
2071	2070.	1009.	752.	749.	744.	0.856	0.599	0.257	55.55	24.81	0.41	281.02	30.56	F
2101	2100.	1009.	752.	749.	744.	0.856	0.599	0.257	54.91	24.81	0.41	281.02	30.56	F
2131	2130.	1009.	752.	749.	744.	0.856	0.599	0.257	54.26	24.81	0.41	281.02	30.56	F
2161	2160.	1009.	752.	749.	744.	0.856	0.599	0.257	53.62	24.81	0.41	281.02	30.56	F
2191	2190.	1009.	752.	749.	744.	0.856	0.599	0.257	52.97	24.81	0.41	281.02	30.56	F
2221	2220.	1009.	752.	749.	744.	0.856	0.599	0.257	52.33	24.81	0.41	281.02	30.56	F
2251	2250.	1009.	752.	749.	744.	0.856	0.599	0.257	51.69	24.81	0.41	281.02	30.56	F
2281	2280.	1009.	752.	749.	744.	0.856	0.599	0.257	51.04	24.81	0.41	281.02	30.56	F
2311	2310.	1009.	752.	749.	744.	0.856	0.599	0.257	50.40	24.81	0.41	281.02	30.56	F
2341	2340.	1009.	752.	749.	744.	0.856	0.599	0.257	49.75	24.81	0.41	281.02	30.56	F
2371	2370.	1009.	752.	749.	744.	0.856	0.599	0.257	49.11	24.81	0.41	281.02	30.56	F
2401	2400.	1009.	752.	749.	744.	0.856	0.599	0.257	48.47	24.81	0.41	281.02	30.56	F
2431	2430.	1009.	752.	749.	744.	0.856	0.599	0.257	47.82	24.81	0.41	281.02	30.56	F
2461	2460.	1009.	752.	749.	744.	0.856	0.599	0.257	47.18	24.81	0.41	281.02	30.56	F
2491	2490.	1009.	752.	749.	744.	0.856	0.599	0.257	46.54	24.81	0.41	281.02	30.56	F
2521	2520.	1009.	752.	749.	744.	0.856	0.599	0.257	45.89	24.81	0.41	281.02	30.56	F
2551	2550.	1009.	752.	749.	744.	0.856	0.599	0.257	45.25	24.81	0.41	281.02	30.56	F
2581	2580.	1009.	752.	749.	744.	0.856	0.599	0.257	44.60	24.81	0.41	281.02	30.56	F
2611	2610.	1009.	752.	749.	744.	0.856	0.599	0.257	43.96	24.81	0.41	281.02	30.56	F
2641	2640.	1009.	752.	749.	744.	0.856	0.599	0.257	43.32	24.81	0.41	281.02	30.56	F
2671	2670.	1009.	752.	749.	744.	0.856	0.599	0.257	42.67	24.81	0.41	281.02	30.56	F
2701	2700.	1009.	752.	749.	744.	0.856	0.599	0.257	42.03	24.81	0.41	281.02	30.56	F
2731	2730.	1009.	752.	749.	744.	0.856	0.599	0.257	41.38	24.81	0.41	281.02	30.56	F
2761	2760.	1009.	752.	749.	744.	0.856	0.599	0.257	40.74	24.81	0.41	281.02	30.56	F
2791	2790.	1009.	752.	749.	744.	0.856	0.599	0.257	40.10	24.81	0.41	281.02	30.56	F
2821	2820.	1009.	752.	749.	744.	0.856	0.599	0.257	39.45	24.81	0.41	281.02	30.56	F
2851	2850.	1009.	752.	749.	744.	0.856	0.599	0.257	38.81	24.81	0.41	281.02	30.56	F
2881	2880.	1009.	752.	749.	744.	0.856	0.599	0.257	38.17	24.81	0.41	281.02	30.56	F
2911	2910.	1009.	752.	749.	744.	0.856	0.599	0.257	37.52	24.81	0.41	281.02	30.56	F
2941	2940.	1009.	752.	749.	744.	0.856	0.599	0.257	36.88	24.81	0.41	281.02	30.56	F
2971	2970.	1009.	752.	749.	744.	0.856	0.599	0.257	36.23	24.81	0.41	281.02	30.56	F
3001	3000.	1009.	752.	749.	744.	0.856	0.599	0.257	35.59	24.81	0.41	281.02	30.56	F
3031	3030.	1009.	752.	749.	744.	0.856	0.599	0.257	34.95	24.81	0.41	281.02	30.56	F
3061	3060.	1009.	752.	749.	744.	0.856	0.599	0.257	34.30	24.81	0.41	281.02	30.56	F
3091	3090.	1009.	752.	749.	744.	0.856	0.599	0.257	33.66	24.81	0.41	281.02	30.56	F
3121	3120.	1009.	752.	749.	744.	0.856	0.599	0.257	33.02	24.81	0.41	281.02	30.56	F
3151	3150.	1009.	752.	749.	744.	0.856	0.599	0.257	32.37	24.81	0.41	281.02	30.56	F
3181	3180.	1009.	752.	749.	744.	0.856	0.599	0.257	31.73	24.81	0.41	281.02	30.56	F
3211	3210.	1009.	752.	749.	744.	0.856	0.599	0.257	31.08	24.81	0.41	281.02	30.56	F
3241	3240.	1009.	752.	749.	744.	0.856	0.599	0.257	30.44	24.81	0.41	281.02	30.56	F
3271	3270.	1009.	752.	749.	744.	0.856	0.599	0.257	29.80	24.81	0.41	281.02	30.56	F
3301	3300.	1009.	752.	749.	744.	0.856	0.599	0.257	29.15	24.81	0.41	281.02	30.56	F
3331	3330.	1009.	752.	749.	744.	0.856	0.599	0.257	28.51	24.81	0.41	281.02	30.56	F
3361	3360.	1009.	752.	749.	744.	0.856	0.599	0.257	27.86	24.81	0.41	281.02	30.56	F
3391	3390.	1009.	752.	749.	744.	0.856	0.599	0.257	27.22	24.81	0.41	281.02	30.56	F
3421	3420.	1009.	752.	749.	744.	0.856	0.599	0.257	26.58	24.81	0.41	281.02	30.56	F
3451	3450.	1009.	752.	749.	744.	0.856	0.599	0.257	25.93	24.81	0.41	281.02	30.56	F
3481	3480.	1009.	752.	749.	744.	0.856	0.599	0.257	25.29	24.81	0.41	281.02	30.56	F
3511	3510.	1009.	752.	749.	744.	0.856	0.599	0.257	24.65	24.81	0.41	281.02	30.56	F
3541	3540.	1009.	752.	749.	744.	0.856	0.599	0.257	24.00	24.81	0.41	281.02	30.56	F
3571	3570.	1009.	752.	749.	744.	0.856	0.599	0.257	23.36	24.81	0.41	281.02	30.56	F
3601	3600.	1009.	752.	749.	744.	0.856	0.599	0.257	22.71	24.81	0.41	281.02	30.56	F
3631	3630.	1009.	752.	749.	744.	0.856	0.599	0.257	22.07	24.81	0.41	281.02	30.56	F
3661	3660.	1009.	752.	749.	744.	0.856	0.599	0.257	21.43	24.81	0.41	281.02	30.56	F
3691	3690.	1009.	752.	749.	744.	0.856	0.599	0.257	20.78	24.81	0.41	281.02	30.56	F
3721	3720.	1009.	752.	749.	744.	0.856	0.599	0.257	20.14	24.81	0.41	281.02	30.56	F

3751	3750.	1009.	752.	749.	744.	0.856	0.599	0.257	19.49	24.81	0.41	281.02	30.56	F
3781	3780.	1009.	752.	749.	744.	0.856	0.599	0.257	18.85	24.81	0.41	281.02	30.56	F
3811	3810.	1009.	752.	749.	744.	0.856	0.599	0.257	18.21	24.81	0.41	281.02	30.56	F
3841	3840.	1009.	752.	749.	744.	0.856	0.599	0.257	17.56	24.81	0.41	281.02	30.56	F
3871	3870.	1009.	752.	749.	744.	0.856	0.599	0.257	16.92	24.81	0.41	281.02	30.56	F
3901	3900.	1009.	752.	749.	744.	0.856	0.599	0.257	16.28	24.81	0.41	281.02	30.56	F
3931	3930.	1009.	752.	749.	744.	0.856	0.599	0.257	15.63	24.81	0.41	281.02	30.56	F
3961	3960.	1009.	752.	749.	744.	0.856	0.599	0.257	14.99	24.81	0.41	281.02	30.56	F
3991	3990.	1009.	752.	749.	744.	0.856	0.599	0.257	14.34	24.81	0.41	281.02	30.56	F
4021	4020.	1009.	752.	749.	744.	0.856	0.599	0.257	13.70	24.81	0.41	281.02	30.56	F
4051	4050.	1009.	752.	749.	744.	0.856	0.599	0.257	13.06	24.81	0.41	281.02	30.56	F
4081	4080.	1009.	752.	749.	744.	0.856	0.599	0.257	12.41	24.81	0.41	281.02	30.56	F
4111	4110.	1009.	752.	749.	744.	0.856	0.599	0.257	11.77	24.81	0.41	281.02	30.56	F
4141	4140.	1009.	752.	749.	744.	0.856	0.599	0.257	11.12	24.81	0.41	281.02	30.56	F
4171	4170.	1009.	752.	749.	744.	0.856	0.599	0.257	10.48	24.81	0.41	281.02	30.56	F
4201	4200.	1009.	752.	749.	744.	0.856	0.599	0.257	9.84	24.81	0.41	281.02	30.56	F
4231	4230.	1009.	752.	749.	744.	0.856	0.599	0.257	9.19	24.81	0.41	281.02	30.56	F
4261	4260.	1009.	752.	749.	744.	0.856	0.599	0.257	8.55	24.81	0.41	281.02	30.56	F
4291	4290.	1009.	752.	749.	744.	0.856	0.599	0.257	7.91	24.81	0.41	281.02	30.56	F
4321	4320.	1009.	752.	749.	744.	0.856	0.599	0.257	7.26	24.81	0.41	281.02	30.56	F
4351	4350.	1009.	752.	749.	744.	0.856	0.599	0.257	6.62	24.81	0.41	281.02	30.56	F
4381	4380.	1009.	752.	749.	744.	0.856	0.599	0.257	5.97	24.81	0.41	281.02	30.56	F
4411	4410.	1009.	752.	749.	744.	0.856	0.599	0.257	5.33	24.81	0.41	281.02	30.56	F
4441	4440.	1009.	752.	749.	744.	0.856	0.599	0.257	4.69	24.81	0.41	281.02	30.56	F
4471	4470.	1009.	752.	749.	744.	0.856	0.599	0.257	4.04	24.81	0.41	281.02	30.56	F
4501	4500.	1009.	752.	749.	744.	0.856	0.599	0.257	3.40	24.81	0.41	281.02	30.56	F
4531	4530.	1009.	752.	749.	744.	0.856	0.599	0.257	2.75	24.81	0.41	281.02	30.56	F
4561	4560.	1009.	752.	749.	744.	0.856	0.599	0.257	2.11	24.81	0.41	281.02	30.56	F
4591	4590.	1009.	752.	749.	744.	0.856	0.599	0.257	1.47	24.81	0.41	281.02	30.56	F
4621	4620.	1009.	752.	749.	744.	0.856	0.599	0.257	0.82	24.81	0.41	281.02	30.56	F
4651	4650.	1009.	752.	749.	744.	0.856	0.599	0.257	0.18	24.81	0.41	281.02	30.56	F
4666	4665.	163.	323.	323.	322.	0.	0.	0.	0.	15.39	0.49	146.40	29.92	T

VENTILATION SPECIFIED, FUEL PYROLYSIS ADJUSTED FOR WORST CONDITIONS PAGE NO. 1 RUN NO. 1

TIME	HEAT BALANCE GAS FLOW PCT	WND RAD PCT	WALL CNV PCT	WALL RAD PCT	Q-FIRE BTU/HR	Q-WALL SUM BTU	YO2 PCT MASS	YN2 PCT MASS	YCO2 PCT MASS	YH2O PCT MASS	YPYR PCT MASS
0.	61.696	4.034	18.106	16.173	2.927E+07	3.016E+03	0.063	0.716	0.166	0.034	0.021
30.	74.547	6.336	4.832	14.264	2.944E+07	5.430E+04	0.063	0.716	0.166	0.034	0.021
60.	74.549	6.337	4.831	14.263	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
90.	74.549	6.337	4.831	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
120.	74.550	6.337	4.831	14.263	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
150.	74.549	6.337	4.831	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
180.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
210.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
240.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
270.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
300.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
330.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
360.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
390.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
420.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
450.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
480.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
510.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
540.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
570.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
600.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
630.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
660.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
690.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
720.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
750.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
780.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
810.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
840.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
870.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
900.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
930.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
960.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
990.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1020.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1050.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1080.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1110.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1140.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1170.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1200.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1230.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1260.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1290.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1320.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1350.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1380.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1410.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1440.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1470.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1500.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1530.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1560.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1590.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1620.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1650.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1680.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1710.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1740.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021

1770.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1800.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1830.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1860.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1890.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1920.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1950.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
1980.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2010.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2040.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2070.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2100.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2130.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2160.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2190.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2220.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2250.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2280.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2310.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2340.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2370.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2400.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2430.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2460.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2490.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2520.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2550.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2580.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2610.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2640.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2670.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2700.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2730.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2760.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2790.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2820.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2850.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2880.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2910.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2940.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
2970.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3000.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3030.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3060.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3090.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3120.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3150.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3180.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3210.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3240.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3270.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3300.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3330.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3360.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3390.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3420.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3450.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3480.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3510.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3540.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3570.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3600.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3630.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3660.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3690.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3720.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021

3750.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3780.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3810.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3840.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3870.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3900.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3930.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3960.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
3990.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4020.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4050.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4080.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4110.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4140.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4170.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4200.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4230.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4260.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4290.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4320.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4350.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4380.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4410.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4440.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4470.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4500.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4530.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4560.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4590.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4620.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4650.	74.550	6.337	4.830	14.262	2.944E+07	5.073E+04	0.063	0.716	0.166	0.034	0.021
4665.	97.562	2.438	-66.673	-33.413	0.000E+00	1.525E+04	0.230	0.770	0.	0.	0.

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SUBWAY2004 - hp? = 80%, cvgross=17.3, fload=64.8 irun=1          COMPF2 VERSION 1.1 - RUN NO.  1

---- GEOMETRY AND VENTILATION----

WALL SURFACE AREA =    1557.5 sq. ft.
FLOOR AREA =     662.6 sq. ft.
WINDOW HEIGHT =         [illegible].1 ft.
             AREA =      [illegible]58.3 sq. ft.
OPENING FACTOR   451.[illegible]30 ft. ^1.5
DISCHARGE COEFF = 0.6[illegible]

----FUEL LOAD PROPERTIES----

FIRE LOAD PER FLOOR AREA =  13.3 lbs/sq.ft.

FUEL COMPOSITION
CARBON     = [illegible] PERCENT BY WEIGHT
HYDROGEN  =  7.7  PERCENT
OXYGEN    =  0.   PERCENT
NITROGEN =  0.   PERCENT
WATER     =  0.   PERCENT
R = 13.14
RO=  3.05
HEAT OF COMBUSTION OF DRY FUEL =   74.2E+02 btu/lb
LOWER ACTUAL HEAT OF COMBUSTION =   67.0E+02 btu/lb
MOLECULAR WEIGHT OF UNBURNT PYROLYSATES =  28.97
CP OF PYROLYSIS GAS = (0.     *TGAS + 0.3198) btu/lb-F
MAXIMUM FRACTION OF PYROLYSATES BURN =  0.80
GREY GAS FLAME EMISSIVITY = 0.900

----WALL THERMAL PROPERTIES----

THICKNESS =    0.0 ft.
DENSITY =  [illegible].309 lbs/cu. ft.

THERMAL CONDUCTIVITY =      26. btu/hr-ft-F

HEAT CAPACITY =  0.0717 btu/lb-F

EMISSIVITY = 0.[illegible]0
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VENTILATION [illegible], FUEL PYROLYSIS ADJUSTED FOR HURST CONDITIONS PAGE NO. 1 RUN NO. 1

	TIME S	TEMP GAS F	WALL TEMPS F			RP LBS/S	RC LBS/S	EXC.PYR. LBS/S	FUEL PCT	AIR IN LBS/S	N.P.	VELOCITY FT/M	MOL.WT	FUEL CNTRL
1	0.	903.	179.	175.	171.	0.854	0.683	0.171	99.98	24.76	0.41	277.10	30.80	F
31	30.	1103.	828.	825.	819.	0.856	0.685	0.171	99.33	24.82	0.40	284.14	30.80	F
61	60.	1103.	828.	825.	819.	0.856	0.685	0.171	98.69	24.82	0.40	284.14	30.80	F
91	90.	1103.	828.	825.	819.	0.856	0.685	0.171	98.05	24.82	0.40	284.14	30.80	F
121	120.	1103.	828.	825.	819.	0.856	0.685	0.171	97.40	24.82	0.40	284.14	30.80	F
151	150.	1103.	828.	825.	819.	0.856	0.685	0.171	96.76	24.82	0.40	284.14	30.80	F
181	180.	1103.	828.	825.	819.	0.856	0.685	0.171	96.12	24.82	0.40	284.14	30.80	F
211	210.	1103.	828.	825.	819.	0.856	0.685	0.171	95.47	24.82	0.40	284.14	30.80	F
241	240.	1103.	828.	825.	819.	0.856	0.685	0.171	94.83	24.82	0.40	284.14	30.80	F
271	270.	1103.	828.	825.	819.	0.856	0.685	0.171	94.18	24.82	0.40	284.14	30.80	F
301	300.	1103.	828.	825.	819.	0.856	0.685	0.171	93.54	24.82	0.40	284.14	30.80	F
331	330.	1103.	828.	825.	819.	0.856	0.685	0.171	92.90	24.82	0.40	284.14	30.80	F
361	360.	1103.	828.	825.	819.	0.856	0.685	0.171	92.25	24.82	0.40	284.14	30.80	F
391	390.	1103.	828.	825.	819.	0.856	0.685	0.171	91.61	24.82	0.40	284.14	30.80	F
421	420.	1103.	828.	825.	819.	0.856	0.685	0.171	90.96	24.82	0.40	284.14	30.80	F
451	450.	1103.	828.	825.	819.	0.856	0.685	0.171	90.32	24.82	0.40	284.14	30.80	F
481	480.	1103.	828.	825.	819.	0.856	0.685	0.171	89.68	24.82	0.40	284.14	30.80	F
511	510.	1103.	828.	825.	819.	0.856	0.685	0.171	89.03	24.82	0.40	284.14	30.80	F
541	540.	1103.	828.	825.	819.	0.856	0.685	0.171	88.39	24.82	0.40	284.14	30.80	F
571	570.	1103.	828.	825.	819.	0.856	0.685	0.171	87.74	24.82	0.40	284.14	30.80	F
601	600.	1103.	828.	825.	819.	0.856	0.685	0.171	87.10	24.82	0.40	284.14	30.80	F
631	630.	1103.	828.	825.	819.	0.856	0.685	0.171	86.46	24.82	0.40	284.14	30.80	F
661	660.	1103.	828.	825.	819.	0.856	0.685	0.171	85.81	24.82	0.40	284.14	30.80	F
691	690.	1103.	828.	825.	819.	0.856	0.685	0.171	85.17	24.82	0.40	284.14	30.80	F
721	720.	1103.	828.	825.	819.	0.856	0.685	0.171	84.52	24.82	0.40	284.14	30.80	F
751	750.	1103.	828.	825.	819.	0.856	0.685	0.171	83.88	24.82	0.40	284.14	30.80	F
781	780.	1103.	828.	825.	819.	0.856	0.685	0.171	83.24	24.82	0.40	284.14	30.80	F
811	810.	1103.	828.	825.	819.	0.856	0.685	0.171	82.59	24.82	0.40	284.14	30.80	F
841	840.	1103.	828.	825.	819.	0.856	0.685	0.171	81.95	24.82	0.40	284.14	30.80	F
871	870.	1103.	828.	825.	819.	0.856	0.685	0.171	81.31	24.82	0.40	284.14	30.80	F
901	900.	1103.	828.	825.	819.	0.856	0.685	0.171	80.66	24.82	0.40	284.14	30.80	F
931	930.	1103.	828.	825.	819.	0.856	0.685	0.171	80.02	24.82	0.40	284.14	30.80	F
961	960.	1103.	828.	825.	819.	0.856	0.685	0.171	79.37	24.82	0.40	284.14	30.80	F
991	990.	1103.	828.	825.	819.	0.856	0.685	0.171	78.73	24.82	0.40	284.14	30.80	F
1021	1020.	1103.	828.	825.	819.	0.856	0.685	0.171	78.09	24.82	0.40	284.14	30.80	F
1051	1050.	1103.	828.	825.	819.	0.856	0.685	0.171	77.44	24.82	0.40	284.14	30.80	F
1081	1080.	1103.	828.	825.	819.	0.856	0.685	0.171	76.80	24.82	0.40	284.14	30.80	F
1111	1110.	1103.	828.	825.	819.	0.856	0.685	0.171	76.15	24.82	0.40	284.14	30.80	F
1141	1140.	1103.	828.	825.	819.	0.856	0.685	0.171	75.51	24.82	0.40	284.14	30.80	F
1171	1170	1103.	828.	825.	819.	0.856	0.685	0.171	74.87	24.82	0.40	284.14	30.80	F
1201	1200.	1103.	828.	825.	819.	0.856	0.685	0.171	74.22	24.82	0.40	284.14	30.80	F
1231	1230.	1103.	828.	825.	819.	0.856	0.685	0.171	73.58	24.82	0.40	284.14	30.80	F
1261	1260.	1103.	828.	825.	819.	0.856	0.685	0.171	72.93	24.82	0.40	284.14	30.80	F
1291	1290.	1103.	828.	825.	819.	0.856	0.685	0.171	72.29	24.82	0.40	284.14	30.80	F
1321	1320.	1103.	828.	825.	819.	0.856	0.685	0.171	71.65	24.82	0.40	284.14	30.80	F
1351	1350.	1103.	828.	825.	819.	0.856	0.685	0.171	71.00	24.82	0.40	284.14	30.80	F
1381	1380.	1103.	828.	825.	819.	0.856	0.685	0.171	70.36	24.82	0.40	284.14	30.80	F
1411	1410.	1103.	828.	825.	819.	0.856	0.685	0.171	69.71	24.82	0.40	284.14	30.80	F
1441	1440.	1103.	828.	825.	819.	0.856	0.685	0.171	69.07	24.82	0.40	284.14	30.80	F
1471	1470.	1103.	828.	825.	819.	0.856	0.685	0.171	68.43	24.82	0.40	284.14	30.80	F
1501	1500.	1103.	828.	825.	819.	0.856	0.685	0.171	67.78	24.82	0.40	284.14	30.80	F
1531	1530.	1103.	828.	825.	819.	0.856	0.685	0.171	67.14	24.82	0.40	284.14	30.80	F
1561	1560.	1103.	828.	825.	819.	0.856	0.685	0.171	66.50	24.82	0.40	284.14	30.80	F
1591	1590.	1103.	828.	825.	819.	0.856	0.685	0.171	65.85	24.82	0.40	284.14	30.80	F
1621	1620.	1103.	828.	825.	819.	0.856	0.685	0.171	65.21	24.82	0.40	284.14	30.80	F
1651	1650.	1103.	828.	825.	819.	0.856	0.685	0.171	64.56	24.82	0.40	284.14	30.80	F
1681	1680.	1103.	828.	825.	819.	0.856	0.685	0.171	63.92	24.82	0.40	284.14	30.80	F
1711	1710.	1103.	828.	825.	819.	0.856	0.685	0.171	63.28	24.82	0.40	284.14	30.80	F
1741	1740.	1103.	828.	825.	819.	0.856	0.685	0.171	62.63	24.82	0.40	284.14	30.80	F

1771	1770.	1103.	828.	825.	819.	0.856	0.685	0.171	61.99	24.82	0.40	284.14	30.80	F
1801	1800.	1103.	828.	825.	819.	0.856	0.685	0.171	61.34	24.82	0.40	284.14	30.80	F
1831	1830.	1103.	828.	825.	819.	0.856	0.685	0.171	60.70	24.82	0.40	284.14	30.80	F
1861	1860.	1103.	828.	825.	819.	0.856	0.685	0.171	60.06	24.82	0.40	284.14	30.80	F
1891	1890.	1103.	828.	825.	819.	0.856	0.685	0.171	59.41	24.82	0.40	284.14	30.80	F
1921	1920.	1103.	828.	825.	819.	0.856	0.685	0.171	58.77	24.82	0.40	284.14	30.80	F
1951	1950.	1103.	828.	825.	819.	0.856	0.685	0.171	58.12	24.82	0.40	284.14	30.80	F
1981	1980.	1103.	828.	825.	819.	0.856	0.685	0.171	57.48	24.82	0.40	284.14	30.80	F
2011	2010.	1103.	828.	825.	819.	0.856	0.685	0.171	56.84	24.82	0.40	284.14	30.80	F
2041	2040.	1103.	828.	825.	819.	0.856	0.685	0.171	56.19	24.82	0.40	284.14	30.80	F
2071	2070.	1103.	828.	825.	819.	0.856	0.685	0.171	55.55	24.82	0.40	284.14	30.80	F
2101	2100.	1103.	828.	825.	819.	0.856	0.685	0.171	54.91	24.82	0.40	284.14	30.80	F
2131	2130.	1103.	828.	825.	819.	0.856	0.685	0.171	54.26	24.82	0.40	284.14	30.80	F
2161	2160.	1103.	828.	825.	819.	0.856	0.685	0.171	53.62	24.82	0.40	284.14	30.80	F
2191	2190.	1103.	828.	825.	819.	0.856	0.685	0.171	52.97	24.82	0.40	284.14	30.80	F
2221	2220.	1103.	828.	825.	819.	0.856	0.685	0.171	52.33	24.82	0.40	284.14	30.80	F
2251	2250.	1103.	828.	825.	819.	0.856	0.685	0.171	51.69	24.82	0.40	284.14	30.80	F
2281	2280.	1103.	828.	825.	819.	0.856	0.685	0.171	51.04	24.82	0.40	284.14	30.80	F
2311	2310.	1103.	828.	825.	819.	0.856	0.685	0.171	50.40	24.82	0.40	284.14	30.80	F
2341	2340.	1103.	828.	825.	819.	0.856	0.685	0.171	49.75	24.82	0.40	284.14	30.80	F
2371	2370.	1103.	828.	825.	819.	0.856	0.685	0.171	49.11	24.82	0.40	284.14	30.80	F
2401	2400.	1103.	828.	825.	819.	0.856	0.685	0.171	48.47	24.82	0.40	284.14	30.80	F
2431	2430.	1103.	828.	825.	819.	0.856	0.685	0.171	47.82	24.82	0.40	284.14	30.80	F
2461	2460.	1103.	828.	825.	819.	0.856	0.685	0.171	47.18	24.82	0.40	284.14	30.80	F
2491	2490.	1103.	828.	825.	819.	0.856	0.685	0.171	46.53	24.82	0.40	284.14	30.80	F
2521	2520.	1103.	828.	825.	819.	0.856	0.685	0.171	45.89	24.82	0.40	284.14	30.80	F
2551	2550.	1103.	828.	825.	819.	0.856	0.685	0.171	45.25	24.82	0.40	284.14	30.80	F
2581	2580.	1103.	828.	825.	819.	0.856	0.685	0.171	44.60	24.82	0.40	284.14	30.80	F
2611	2610.	1103.	828.	825.	819.	0.856	0.685	0.171	43.96	24.82	0.40	284.14	30.80	F
2641	2640.	1103.	828.	825.	819.	0.856	0.685	0.171	43.31	24.82	0.40	284.14	30.80	F
2671	2670.	1103.	828.	825.	819.	0.856	0.685	0.171	42.67	24.82	0.40	284.14	30.80	F
2701	2700.	1103.	828.	825.	819.	0.856	0.685	0.171	42.03	24.82	0.40	284.14	30.80	F
2731	2730.	1103.	828.	825.	819.	0.856	0.685	0.171	41.38	24.82	0.40	284.14	30.80	F
2761	2760.	1103.	828.	825.	819.	0.856	0.685	0.171	40.74	24.82	0.40	284.14	30.80	F
2791	2790.	1103.	828.	825.	819.	0.856	0.685	0.171	40.09	24.82	0.40	284.14	30.80	F
2821	2820.	1103.	828.	825.	819.	0.856	0.685	0.171	39.45	24.82	0.40	284.14	30.80	F
2851	2850.	1103.	828.	825.	819.	0.856	0.685	0.171	38.81	24.82	0.40	284.14	30.80	F
2881	2880.	1103.	828.	825.	819.	0.856	0.685	0.171	38.16	24.82	0.40	284.14	30.80	F
2911	2910.	1103.	828.	825.	819.	0.856	0.685	0.171	37.52	24.82	0.40	284.14	30.80	F
2941	2940.	1103.	828.	825.	819.	0.856	0.685	0.171	36.87	24.82	0.40	284.14	30.80	F
2971	2970.	1103.	828.	825.	819.	0.856	0.685	0.171	36.23	24.82	0.40	284.14	30.80	F
3001	3000.	1103.	828.	825.	819.	0.856	0.685	0.171	35.59	24.82	0.40	284.14	30.80	F
3031	3030.	1103.	828.	825.	819.	0.856	0.685	0.171	34.94	24.82	0.40	284.14	30.80	F
3061	3060.	1103.	828.	825.	819.	0.856	0.685	0.171	34.30	24.82	0.40	284.14	30.80	F
3091	3090.	1103.	828.	825.	819.	0.856	0.685	0.171	33.65	24.82	0.40	284.14	30.80	F
3121	3120.	1103.	828.	825.	819.	0.856	0.685	0.171	33.01	24.82	0.40	284.14	30.80	F
3151	3150.	1103.	828.	825.	819.	0.856	0.685	0.171	32.37	24.82	0.40	284.14	30.80	F
3181	3180.	1103.	828.	825.	819.	0.856	0.685	0.171	31.72	24.82	0.40	284.14	30.80	F
3211	3210.	1103.	828.	825.	819.	0.856	0.685	0.171	31.08	24.82	0.40	284.14	30.80	F
3241	3240.	1103.	828.	825.	819.	0.856	0.685	0.171	30.43	24.82	0.40	284.14	30.80	F
3271	3270.	1103.	828.	825.	819.	0.856	0.685	0.171	29.79	24.82	0.40	284.14	30.80	F
3301	3300.	1103.	828.	825.	819.	0.856	0.685	0.171	29.15	24.82	0.40	284.14	30.80	F
3331	3330.	1103.	828.	825.	819.	0.856	0.685	0.171	28.50	24.82	0.40	284.14	30.80	F
3361	3360.	1103.	828.	825.	819.	0.856	0.685	0.171	27.86	24.82	0.40	284.14	30.80	F
3391	3390.	1103.	828.	825.	819.	0.856	0.685	0.171	27.21	24.82	0.40	284.14	30.80	F
3421	3420.	1103.	828.	825.	819.	0.856	0.685	0.171	26.57	24.82	0.40	284.14	30.80	F
3451	3450.	1103.	828.	825.	819.	0.856	0.685	0.171	25.93	24.82	0.40	284.14	30.80	F
3481	3480.	1103.	828.	825.	819.	0.856	0.685	0.171	25.28	24.82	0.40	284.14	30.80	F
3511	3510.	1103.	828.	825.	819.	0.856	0.685	0.171	24.64	24.82	0.40	284.14	30.80	F
3541	3540.	1103.	828.	825.	819.	0.856	0.685	0.171	23.99	24.82	0.40	284.14	30.80	F
3571	3570.	1103.	828.	825.	819.	0.856	0.685	0.171	23.35	24.82	0.40	284.14	30.80	F
3601	3600.	1103.	828.	825.	819.	0.856	0.685	0.171	22.71	24.82	0.40	284.14	30.80	F
3631	3630.	1103.	828.	825.	819.	0.856	0.685	0.171	22.06	24.82	0.40	284.14	30.80	F
3661	3660.	1103.	828.	825.	819.	0.856	0.685	0.171	21.42	24.82	0.40	284.14	30.80	F
3691	3690.	1103.	828.	825.	819.	0.856	0.685	0.171	20.77	24.82	0.40	284.14	30.80	F
3721	3720.	1103.	828.	825.	819.	0.856	0.685	0.171	20.13	24.82	0.40	284.14	30.80	F

3751	3750.	1103.	828.	825.	819.	0.856	0.685	0.171	19.49	24.82	0.40	284.14	30.80	F
3781	3780.	1103.	828.	825.	819.	0.856	0.685	0.171	18.84	24.82	0.40	284.14	30.80	F
3811	3810.	1103.	828.	825.	819.	0.856	0.685	0.171	18.20	24.82	0.40	284.14	30.80	F
3841	3840.	1103.	828.	825.	819.	0.856	0.685	0.171	17.55	24.82	0.40	284.14	30.80	F
3871	3870.	1103.	828.	825.	819.	0.856	0.685	0.171	16.91	24.82	0.40	284.14	30.80	F
3901	3900.	1103.	828.	825.	819.	0.856	0.685	0.171	16.27	24.82	0.40	284.14	30.80	F
3931	3930.	1103.	828.	825.	819.	0.856	0.685	0.171	15.62	24.82	0.40	284.14	30.80	F
3961	3960.	1103.	828.	825.	819.	0.856	0.685	0.171	14.98	24.82	0.40	284.14	30.80	F
3991	3990.	1103.	828.	825.	819.	0.856	0.685	0.171	14.33	24.82	0.40	284.14	30.80	F
4021	4020.	1103.	828.	825.	819.	0.856	0.685	0.171	13.69	24.82	0.40	284.14	30.80	F
4051	4050.	1103.	828.	825.	819.	0.856	0.685	0.171	13.05	24.82	0.40	284.14	30.80	F
4081	4080.	1103.	828.	825.	819.	0.856	0.685	0.171	12.40	24.82	0.40	284.14	30.80	F
4111	4110	1103.	828.	825.	819.	0.856	0.685	0.171	11.76	24.82	0.40	284.14	30.80	F
4141	4140	1103.	828.	825.	819.	0.856	0.685	0.171	11.11	24.82	0.40	284.14	30.80	F
4171	4170.	1103.	828.	825.	819.	0.856	0.685	0.171	10.47	24.82	0.40	284.14	30.80	F
4201	4200.	1103.	828.	825.	819.	0.856	0.685	0.171	9.83	24.82	0.40	284.14	30.80	F
4231	4230.	1103.	828.	825.	819.	0.856	0.685	0.171	9.18	24.82	0.40	284.14	30.80	F
4261	4260.	1103.	828.	825.	819.	0.856	0.685	0.171	8.54	24.82	0.40	284.14	30.80	F
4291	4290.	1103.	828.	825.	819.	0.856	0.685	0.171	7.89	24.82	0.40	284.14	30.80	F
4321	4320.	1103.	828.	825.	819.	0.856	0.685	0.171	7.25	24.82	0.40	284.14	30.80	F
4351	4350.	1103.	828.	825.	819.	0.856	0.685	0.171	6.61	24.82	0.40	284.14	30.80	F
4381	4380.	1103.	828.	825.	819.	0.856	0.685	0.171	5.96	24.82	0.40	284.14	30.80	F
4411	4410.	1103.	828.	825.	819.	0.856	0.685	0.171	5.32	24.82	0.40	284.14	30.80	F
4441	4440.	1103.	828.	825.	819.	0.856	0.685	0.171	4.67	24.82	0.40	284.14	30.80	F
4471	4470.	1103.	828.	825.	819.	0.856	0.685	0.171	4.03	24.82	0.40	284.14	30.80	F
4501	4500.	1103.	828.	825.	819.	0.856	0.685	0.171	3.39	24.82	0.40	284.14	30.80	F
4531	4530.	1103.	828.	825.	819.	0.856	0.685	0.171	2.74	24.82	0.40	284.14	30.80	F
4561	4560.	1103.	828.	825.	819.	0.856	0.685	0.171	2.10	24.82	0.40	284.14	30.80	F
4591	4590.	1103.	828.	825.	819.	0.856	0.685	0.171	1.45	24.82	0.40	284.14	30.80	F
4621	4620.	1103.	828.	825.	819.	0.856	0.685	0.171	0.81	24.82	0.40	284.14	30.80	F
4651	4650.	1103.	828.	825.	819.	0.856	0.685	0.171	0.17	24.82	0.40	284.14	30.80	F
4665	4664.	169.	339.	338.	337.	0.	0.	0.	0.	15.77	0.49	150.21	28.92	T

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VENTILATION SPECIFIED, FUEL PYROLYSIS ADJUSTED FOR WORST CONDITIONS PAGE NO. 1 RUN NO. 1

TIME	GAS FLOW PCT	HEAT BALANCE WND RAD PCT	WALL CNV PCT	WALL RAD PCT	Q-FIRE BTU/HR	Q-WALL SUM BTU	YO2 PCT MASS	YN2 PCT MASS	YCO2 PCT MASS	YH2O PCT MASS	YPYR PCT MASS
0.	59.109	4.475	17.752	17.995	3.358E+07	3.607E+03	0.041	0.716	0.189	0.039	0.014
30.	72.136	7.141	4.626	16.073	3.366E+07	6.650E+04	0.041	0.716	0.189	0.039	0.014
60.	72.138	7.141	4.625	16.072	3.366E+07	6.286E+04	0.041	0.716	0.189	0.039	0.014
90.	72.139	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
120.	72.139	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
150.	72.139	7.142	4.624	16.071	3.366E+07	6.286E+04	0.041	0.716	0.189	0.039	0.014
180.	72.140	7.142	4.624	16.071	3.366E+07	6.286E+04	0.041	0.716	0.189	0.039	0.014
210.	72.140	7.142	4.624	16.071	3.366E+07	6.286E+04	0.041	0.716	0.189	0.039	0.014
240.	72.140	7.142	4.624	16.071	3.366E+07	6.286E+04	0.041	0.716	0.189	0.039	0.014
270.	72.140	7.142	4.624	16.071	3.366E+07	6.286E+04	0.041	0.716	0.189	0.039	0.014
300.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
330.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
360.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
390.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
420.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
450.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
480.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
510.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
540.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
570.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
600.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
630.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
660.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
690.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
720.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
750.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
780.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
810.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
840.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
870.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
900.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
930.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
960.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
990.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1020.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1050.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1080.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1110.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1140.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1170.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1200.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1230.	72.141	7.142	4.623	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1260.	72.141	7.142	4.623	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1290.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1320.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1350.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1380.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1410.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1440.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1470.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1500.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1530.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1560.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1590.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1620.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1650.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1680.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1710.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1740.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014

1770.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1800.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1830.	72.141	7.142	4.623	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1860.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1890.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1920.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1950.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
1980.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2010.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2040.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2070.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2100.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2130.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2160.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2190.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2220.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2250.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2280.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2310.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2340.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2370.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2400.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2430.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2460.	72.140	7.142	4.623	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2490.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2520.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2550.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2580.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2610.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2640.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2670.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2700.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2730.	72.141	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2760.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2790.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2820.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2850.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2880.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2910.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2940.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
2970.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3000.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3030.	72.140	7.142	4.623	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3060.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3090.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3120.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3150.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3180.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3210.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3240.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3270.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3300.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3330.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3360.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3390.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3420.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3450.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3480.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3510.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3540.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3570.	72.141	7.142	4.623	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3600.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3630.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3660.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3690.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3720.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014

3750.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3780.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3810.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3840.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3870.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3900.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3930.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3960.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
3990.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4020.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4050.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4080.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4110.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4140.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4170.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4200.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4230.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4260.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4290.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4320.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4350.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4380.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4410.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4440.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4470.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4500.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4530.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4560.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4590.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4620.	72.140	7.142	4.624	16.070	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4650.	72.140	7.142	4.624	16.071	3.366E+07	6.285E+04	0.041	0.716	0.189	0.039	0.014
4664.	97.504	2.416	-66.106	-33.990	0.000E+00						
1.681E+04	0.230	0.770	0.	0.	0.						

APPENDIX D

DATA ACQUISITION HARDWARE

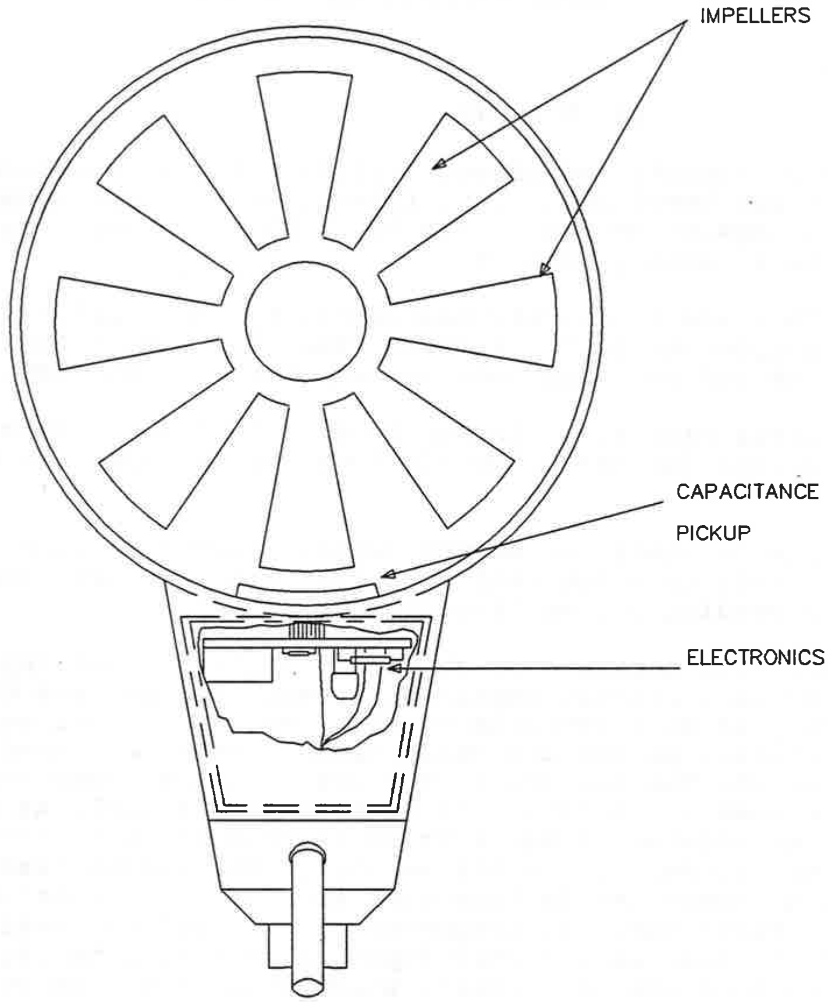
D.1 AIR VELOCITY

The air velocity measurements utilize fan anemometers built by Airflow Development Inc. (Figure D-1). These anemometers have an operating range from 50 to 2000 fpm and were used for the following reasons:

- They are relatively unaffected by the swirling components of the airflow. That is, they detect only the desired longitudinal component of the flow.
- Their size (four inches in diameter) makes them well suited for measuring airflows over a large cross section.
- Due to their mechanical nature, they have long-time constants which tend to filter the readings, thereby providing better time-average trends.

The fan anemometers consist of a stainless steel impeller mounted in a plastic assembly. Encased in the base of the assembly is an electronic circuit and capacitance sensor. As the impeller passes the capacitance sensor the capacitance is changed. The electronic circuit monitors these changes and creates a 100 millivolt peak-to-peak signal. As the impeller rotates, a pulse train is created whose frequency is proportional to the air velocity. The signal created by the fan anemometer is then sent to a signal conditioning module which converts frequency into a voltage level signal which can then be directly input to an analog to digital conversion board (A/D board) which resides on the bus of the microprocessor.

The signal conditioning modules chosen for this application are the 3B45 series made by Analog Devices. The 3B45 is an isolated frequency input module. To increase the resolution of the 3B45, custom ranging modules (resistor networks) were developed by KLD. The input signal is then compared to a threshold voltage selected by the resistor network, and the comparitor's frequency is finally converted to a voltage. This signal is then amplified and filtered to give an output in the range of 0-10 Vdc. The resistor network was designed such that a value of zero Vdc corresponds to an air velocity of zero fpm and 10 Vdc corresponds to a velocity of 2000 fpm. All fan anemometers were calibrated for both directions, over this range with KLD's open jet wind tunnel facility.



AIRFLOW DEVELOPMENTS FAN ANEMOMETER

FIGURE D-1

D.2 STATIC PRESSURE MEASUREMENT

The measurement of static pressure involves a static pressure tip and a differential pressure transducer. The static pressure tip built by United Sensor is designed so that only the static pressure component of the total pressure in a flow is sensed. The probe used for this program was constructed of 1/16-inch stainless steel tubing. The end of the tube is aerodynamically sealed shut. Approximately 4.2 diameters from the closed end of the probe, small holes are bored into the tube. It is these small holes that sense the static pressure. At 14 diameters (7/8 of an inch) from the closed end the tube is bent at a 90 degree angle. A length of polyethylene tubing connects the tip to a differential pressure transducer. To provide the accurate measurement of static pressure, a Setra model # 239 low range differential pressure transducer was selected. The operating range of the transducer is from 0 to 0.5 in. wg with a respective output range of 0 - 5 Vdc. Since a 12 bit D/A connector was used, a resolution of 0.00024 in. wg was achieved. The Setra pressure transducer is a variable capacitance device. A stainless steel diaphragm and a fixed isolated electrode form a variable capacitance. As the pressure changes so does the capacitance which is detected and converted to a high level signal. To provide the accuracy of these devices a remote zeroing capability was added. This allows each device to be zeroed before a given test. Since the Setra transducer created a linear high level signal, there was no need to use separate signal conditioning modules. Signals from the transducers were directly output to the A/D board in the microprocessor.

D.3 HUMIDITY AND TEMPERATURE MEASUREMENT

Measurement of temperature and humidity were both performed with a Vaisala HMD 30YB. This device is capable of measuring temperature from -20 degrees Celsius (-4 degrees Fahrenheit) to +80 degrees Celsius (+176 degrees Fahrenheit), and the humidity spanned the full range of zero to 100 percent relative humidity.

D.4 BAROMETRIC PRESSURE MEASUREMENT

The barometric pressure (BP) instrument is the only handheld measurement device. Before a test run, the BP was measured with the handheld barometer, then manually entered into data acquisition software. The handheld barometer is made by Taylor Instrument Company. This barometer, Model #2075C, has a chrome-finished brass case, measures three inches in diameter, and weighs approximately one pound. This instrument has the capability of measuring barometric pressures in the range from 24.86 to 31.00 inches of mercury, in gradations of two-hundredths of an inch.

D.5 COMPUTER HARDWARE CONFIGURATION

All digitization, data storage and analysis is accomplished on a NEC386S "portable" personal computer (PC) running at 20 Megahertz. The digitization is performed via a National Instruments AT-MIO-16 data acquisition board which resides on the NEC386S' ATbus. The AT-MIO-16 is a high performance, multi-function analog, digital and timing I/O board for the PC. This board interfaces with two (2) National Instruments AMUX-64 boards which provide the ability to sample and acquire up to 64 differential channels of analog information. Each channel could be attached to either a pressure, air velocity, temperature or humidity sensor.

In order to provide the flexibility required at the test site(s), two PCs are used, a "host" and a "remote". The host PC would execute the DAS test software. The remote PC would control the host through use of a remote access program ("PC Anywhere III", DMA Associates, Inc.). This access software allows the host PC to execute in the required proximity of the test equipment, with remote PC "mirroring" the host's execution and providing remote control of the host's functions. This software is used with Black Box short haul modems; the actual distance between the two computers could be several thousand feet. This configuration allows the operator to work in an environment more conducive to doing analysis than in a tunnel test section. In addition, the presence of personnel in the test section would disrupt the airflow.

An Epson FX800 parallel printer provides the ability to output disk-based reports.

D.6 SUPPORT EQUIPMENT AND COMMUNICATION PATHWAYS

The number of transducers for a given test series could range from 37 to 47. To support these transducers, four rakes were built. Of these four rakes, two were designed for a ribbed tunnel section (Figure D-2) and two for a box tunnel section (Figure D-3). The positioning of the instruments allowed each rake to be designed according to standard techniques for monitoring air flow through ducts. The circular tunnel rake is constructed of 1/8-inch aluminum two-inch square channel. The square tunnel rake was built of both square channel and two-inch angle aluminum. The circular rake has a total of 19 fan anemometers while the square rake has 17. Each transducer is attached to the rake with a 3/8-inch bolt. All interconnections on a rake are terminated with connectors to facilitate installation and replacement of equipment. Each rake is interconnected to its

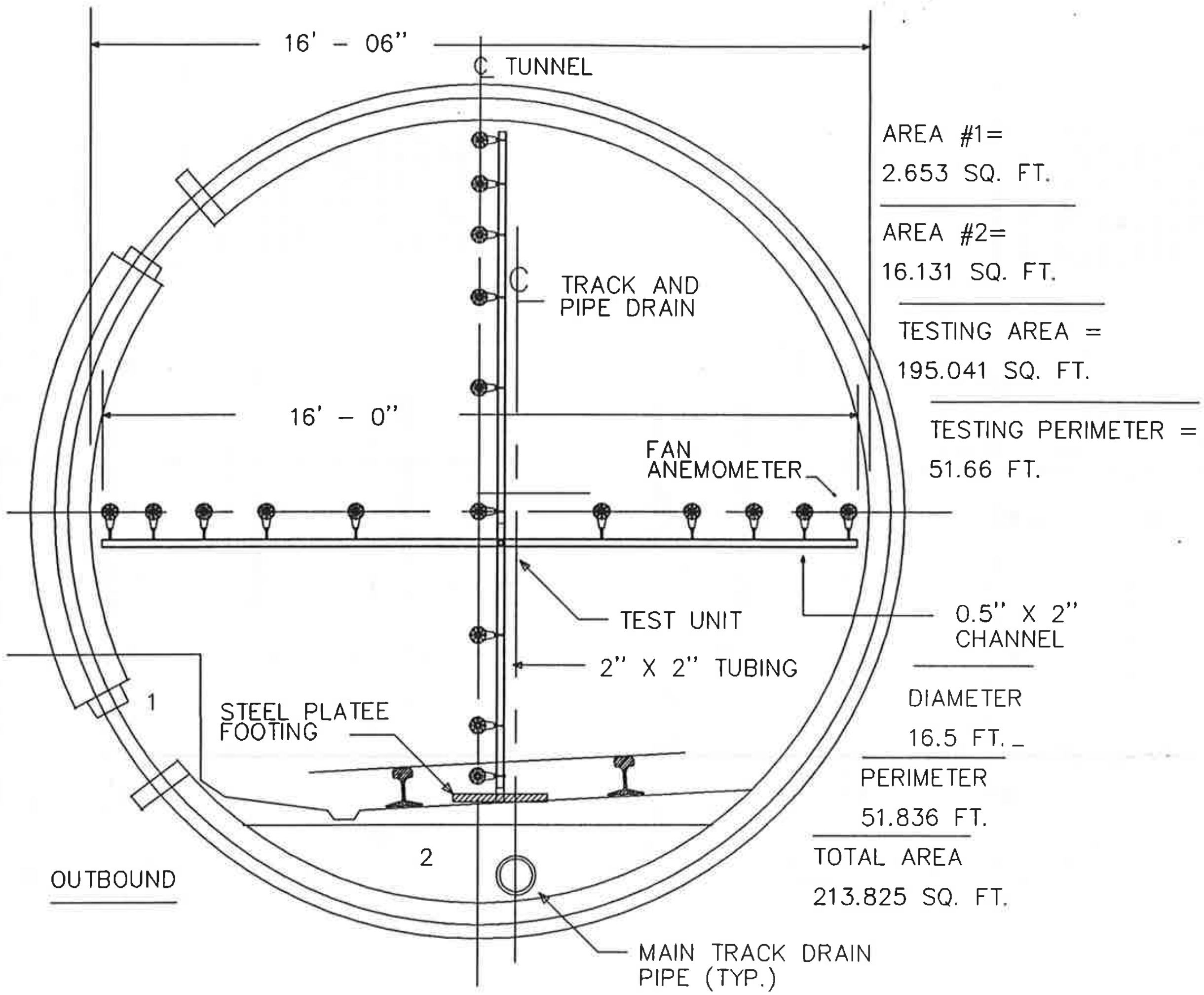
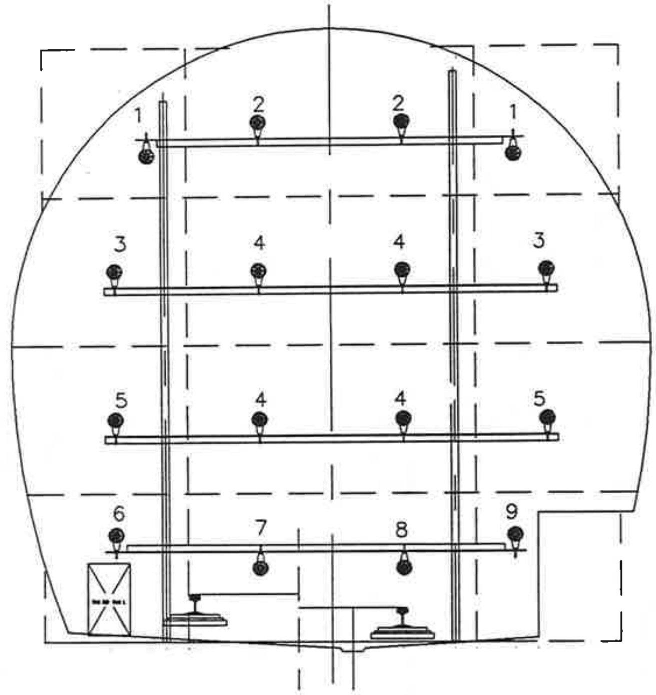

16' – 06"
℄ TUNNEL
AREA #1=
2.653 SQ. FT.
AREA #2=
16.131 SQ. FT.
TESTING AREA =
195.041 SQ. FT.
TESTING PERIMETER =
51.66 FT.
℄ TRACK AND PIPE DRAIN
16' – 0"
FAN ANEMOMETER
TEST UNIT
0.5" X 2" CHANNEL
2" X 2" TUBING
DIAMETER
16.5 FT.
PERIMETER
51.836 FT.
TOTAL AREA
213.825 SQ. FT.
1
STEEL PLATEE FOOTING
2
OUTBOUND
MAIN TRACK DRAIN PIPE (TYP.)

FIGURE D-2

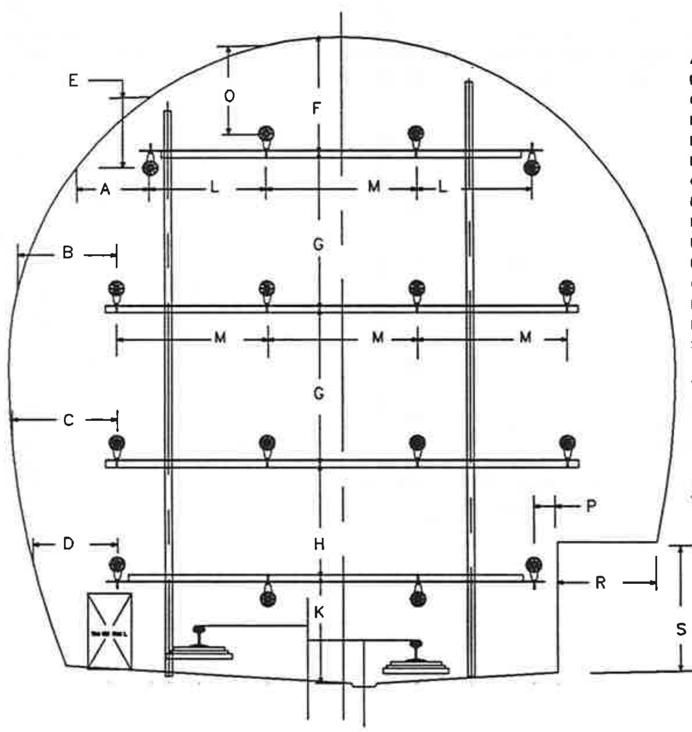


AREA #1 = 6. 288 SQ. FT
AREA #2 = 12. 832 SQ. FT
AREA #3 = 13. 845 SQ. FT
AREA #4 = 12. 246 SQ. FT
AREA #5 = 14. 534 SQ. FT
AREA #6 = 9. 598 SQ. FT
AREA #7 = 11. 808 SQ. FT
AREA #8 = 11. 939 SQ. FT
AREA #9 = 6. 326 SQ. FT

TOTAL AREA = 183.653 SQ. FT.

PERIMETER = 51 FT. 8.0401 IN.

BLURIDGE



A= 1 FT. 8.407 IN.
B= 2 FT. 2.913 IN.
C= 2 FT. 4.648 IN.
D= 1 FT. 11.009 IN.
E= 1 FT. 7.670 IN.
F= 2 FT. 8.438 IN.
G= 3 FT. 6.750 IN.
H= 2 FT. 7.374 IN.
K= 2 FT. 5.000 IN.
L= 2 FT. 7.875 IN.
M= 3 FT. 5.250 IN.
O= 2 FT. 0.345 IN.
P= 0 FT. 6.500 IN.
R= 2 FT. 3.237 IN.
S= 3 FT.

TUNNEL RADIUS= 7 FT. 7.500 IN.

BLUERIDGE

FIGURE D-3

corresponding signal conditioning rack. The signal conditioning rack (SCR) is a standard 19-inch electronics rack that houses a sub-rack containing a power supply backplane and the individual signal conditioning modules. The SCRs also have an interface panel where interconnections from the velocity rakes are provided. Each SCR is interconnected to a multiplexer rack via two cables which are terminated with DB25 connectors. The multiplexer rack contains the two National Instruments AMUX-64 boards which multiplex the channels into the A/D board. The multiplexer rack also acts as an interface for the signals from the static pressure, temperature and humidity transducers. The static pressure, humidity and temperature transducer stands are all constructed in a similar manner. These stands consist of cement-filled buckets and an imbedded aluminum upright (Figure D-4). This configuration was found to provide the needed stability for these stands.

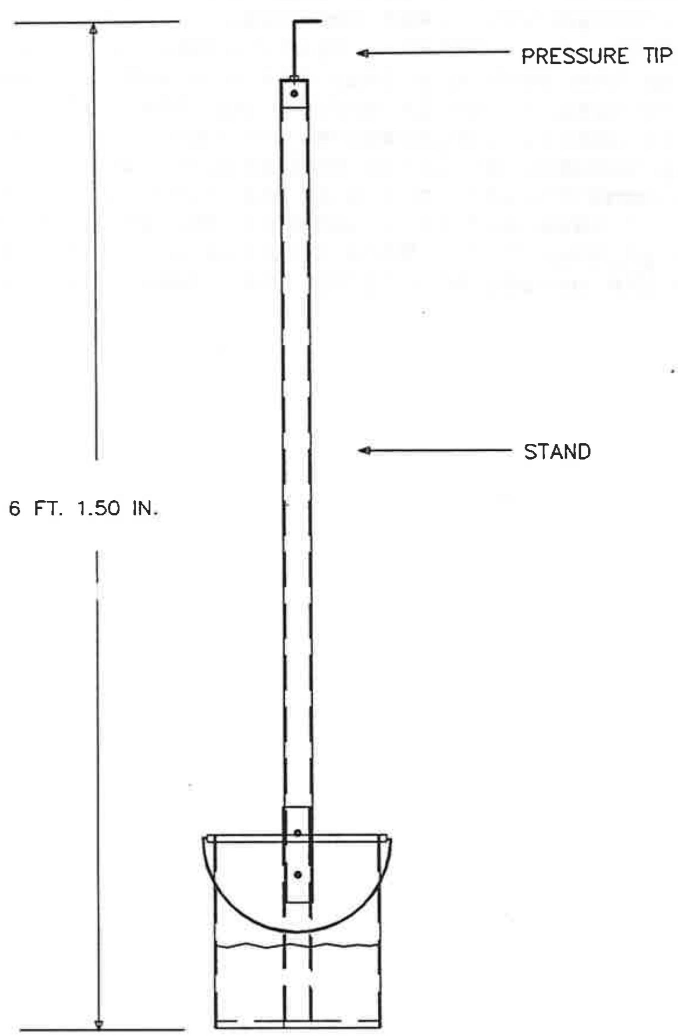


FIGURE D-4

APPENDIX E

TEST NOMENCLATURE

E.1 GENERAL

Each test or run was given a name that provided identification of the test location, the type of test, whether fan shaft dampers were being used or not, the number of fan shaft fans being operated, etc.

For all tests, the first two characters of the test name identified the test location:

MC - Tunnel between Metro Center Station and the New York Avenue fan shaft.

BR - Tunnel adjacent to the Blueridge Avenue fan shaft.

7I - Tunnel adjacent to the 7th and I Streets SW fan shaft.

E.2 FRICTION FACTOR TESTS

Five or six character test names were used. The first two characters identified the test site.

The third and fourth characters, FF, identified the test as a friction factor test.

If used, the fifth character, D, indicated the test included the use of a damper to direct the fan shaft airflow through two tunnel legs.

The last character was the number of fan shaft fans operating.

E.3 BARRIER VENTILATION TESTS

Five, six or seven character test names were used. The first two characters identified the test site.

The third character, B, identified the test as a barrier test.

The fourth character was indicating the number of fan shaft fans operating.

The remaining characters were:

DT - The test used a damper to direct the fan shaft air through two tunnel legs and a train was present in the third tunnel leg.

T - A damper was not used. A train was present in the third tunnel leg.

DTR - DT tests repeated.

E.4 JET FAN MOUNTING HEAD LOSS COEFFICIENT TESTS

Five or six character test names were used. The first two characters identified the test site.

The third character, D, identified the test as a jet fan mounting head loss coefficient test. The use of the D occurred because the tests were originally described as "drag" tests.

The remaining characters were the numbers 50, 75 or 100 identifying the distance between jet fans.

E.5 JET FAN PRESSURE EFFICIENCY TESTS

Eight or nine character test names were used. The first two characters identified the test site.

The third and fourth characters, JF, identified the test as a jet fan pressure efficiency test.

The next two or three characters were the numbers 50, 75 or 100 identifying the distance between jet fans.

The penultimate character identified the elevation of the jet fan.

H - The lift table was in the high position such that the distance from the centerline of the jet fan to the tunnel wall was 20 inches.

M - The lift table was in the medium position such that the distance from the centerline of the jet fan to the tunnel wall was 26 inches.

L - The lift table was in the low position such that the distance from the centerline of the jet fan to the tunnel wall was 32 inches.

The last character was the number of fan shaft fans operating.

APPENDIX F

TEST DESCRIPTIONS

F.1 INITIAL TESTS AT METRO CENTER STATION/NEW YORK AVENUE FAN SHAFT

The first series of tests of the test program involved the establishing of the Single Point Measurement Factors for Ribbed Wall Tunnel without a train.tl These tests were conducted in the tunnel between Metro Center and McPherson Station on the morning of 10 June 1990.

The tests involved 10 flow conditions (5 with the damper open and 5 with the damper closed) and the fan shaft fans operating from all 5 decreasing to 1.

Each test took about five to ten minutes. This included the time to adjust the number of fans operating, the time for the airflows to reach quasi-steady-state, the time to initialize the individual test disk file and 60 to 80 seconds to record the data for averaging purposes. While the airflows were approaching quasi-steady-state, fluctuations of about plus or minus 20 percent were observed. These decreased to about plus or minus five percent prior to recording. The time to reach quasi-steady- state increased as the number of fans operating decreased. The barometric pressure was measured three times during the test period and manually input to each test. The air temperature and humidity were updated every second during the observations and recordings. Figure F-1 shows the results.

The results were not as anticipated. It was expected that the single point measurement factor would be about 0.95 with five fans operating and would decrease as the number of fans operating decreased.

The following hypotheses were advanced as causes for the unanticipated results:

1. An error in the data reduction computer program.

2 A mechanical or electrical instrument problem.

3. The horizontal curvature of the tunnel distorting the airflow.

4. The inlet effect of the ventilation shaft distorting the airflow upstream of the ventilation shaft.

5. The location of the anemometers in proximity to the tunnel walls.

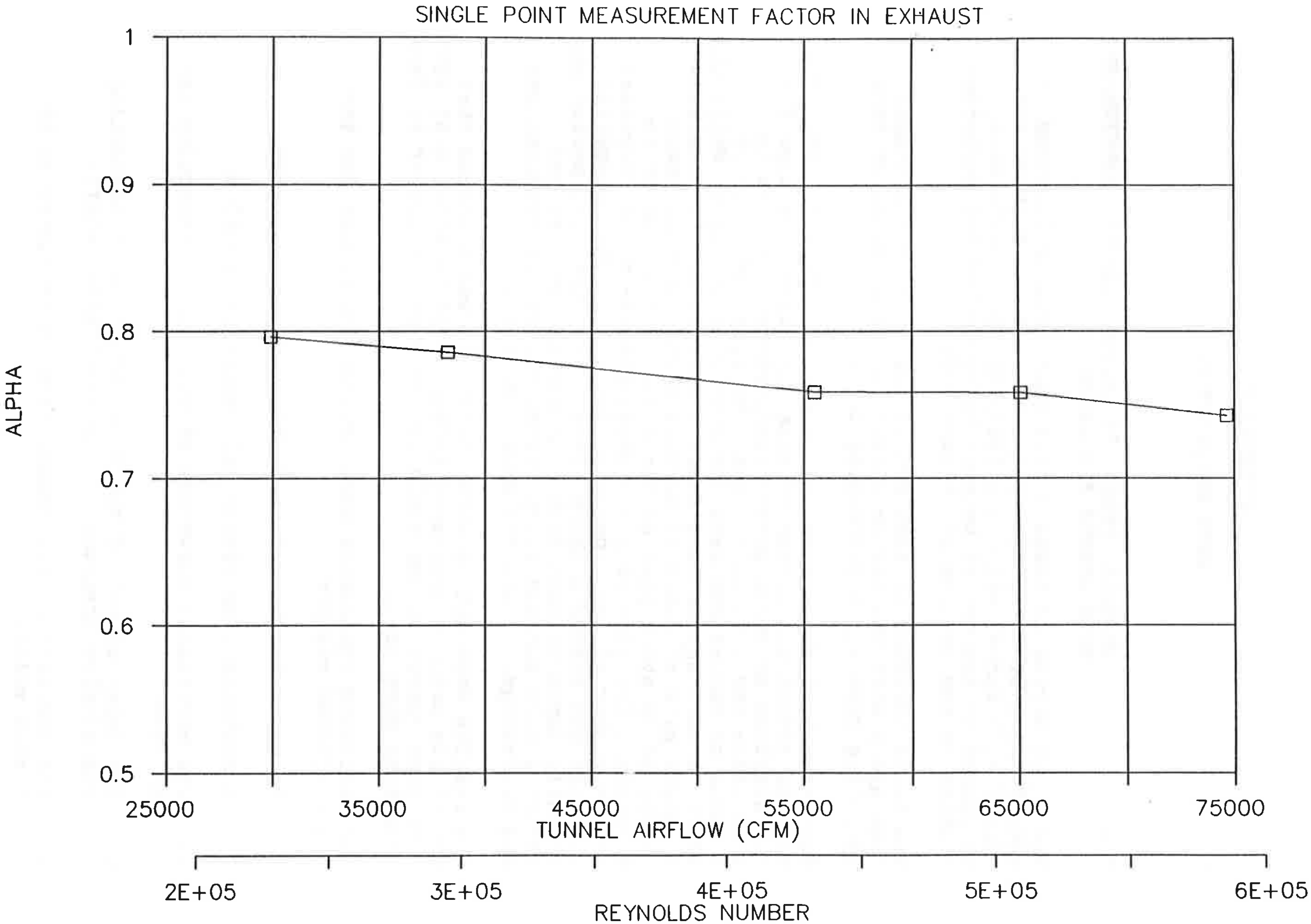

SINGLE POINT MEASUREMENT FACTOR IN EXHAUST
ALPHA
1
0.9
0.8
0.7
0.6
0.5
25000
35000
45000
55000
65000
75000
TUNNEL AIRFLOW (CFM)
2E+05
3E+05
4E+05
5E+05
6E+05
REYNOLDS NUMBER

FIGURE F-1

6. An unknown effect caused by the ribbed tunnel.

7. The instrumentation error changing from reading higher than actual (plus error) to reading lower than actual (minus error) as the number fans operating, and therefore the tunnel air velocities, increased.

It was therefore decided to plot the horizontal and vertical velocity profiles shown in Figures F-2 and F-3. This was initially done using the data reduction computer program.

A separate computer program was written to calculate the average airflows and the single point measurement factors and to plot the air velocities shown in the following graphs. This separate computer program was hand checked. It was concluded that Hypothesis 1 was unlikely, since these results agreed with the direct plots from the data reduction computer program. After a review of the plots, it was concluded that Hypotheses 2 and 5 were unlikely.

Hypothesis 7 was reviewed and the instrument calibration logs were checked. It was concluded that Hypothesis 7 was unlikely since the maximum error was less than two percent and did not change sign over the range of airflows tested.

Hypotheses 3, 4 and 6 remained. Since insufficient data was available to further evaluate them, it was decided to make a number of traverses in the horizontal plane at various stations along Tracks 1 and 2. It was anticipated that measuring horizontally along the tunnel would provide insight to Hypothesis 5 and that measuring in Track 2 would provide insight to Hypothesis 3. It was decided to do these measurements at the beginning of the 16 June test program.

Special ventilation tests were conducted in the tunnels between Metro Center and McPherson Stations on the morning of 16 June 1990.

Air velocity measurements were made in the Track 1 and 2 tunnels between Metro Center Station and the New York Avenue Ventilation Shaft (FSC-1). The air velocity measurements consisted of horizontal traverses made at six locations along Track 1 and two locations along Track 2. For each traverse, the instrument pole was located next to the walkway (about two feet from the tunnel wall), outside the rail nearest the walkway, centered between the rails, outside the rail away from the walkway, outside the third rail, and near the opposite wall (about 15 inches from the fire line). The instrument was an Airflow DVA-30 Anemometer having a four-inch head assembly mounted on top of a square aluminum pole such that the center of the anemometer was about 73.5 inches from the ground. The instrument was factory calibrated in April 1990. The five FSC-1 fans were operated in the exhaust. Four readings were taken at each

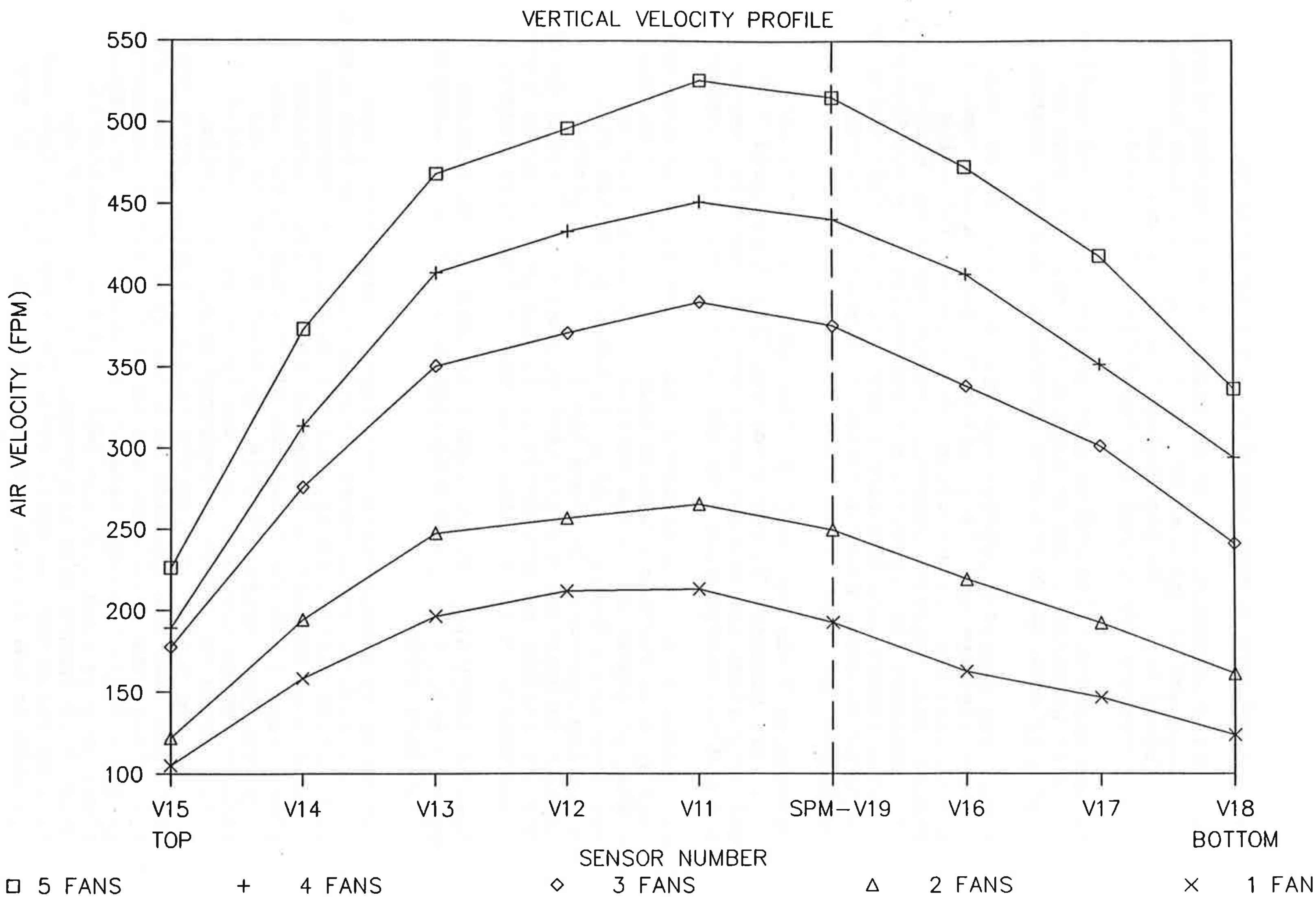

VERTICAL VELOCITY PROFILE
AIR VELOCITY (FPM)
550
500
450
400
350
300
250
200
150
100
V15
TOP
V14
V13
V12
V11
SPM-V19
V16
V17
V18
BOTTOM
SENSOR NUMBER
5 FANS
4 FANS
3 FANS
2 FANS
1 FAN

FIGURE F-2

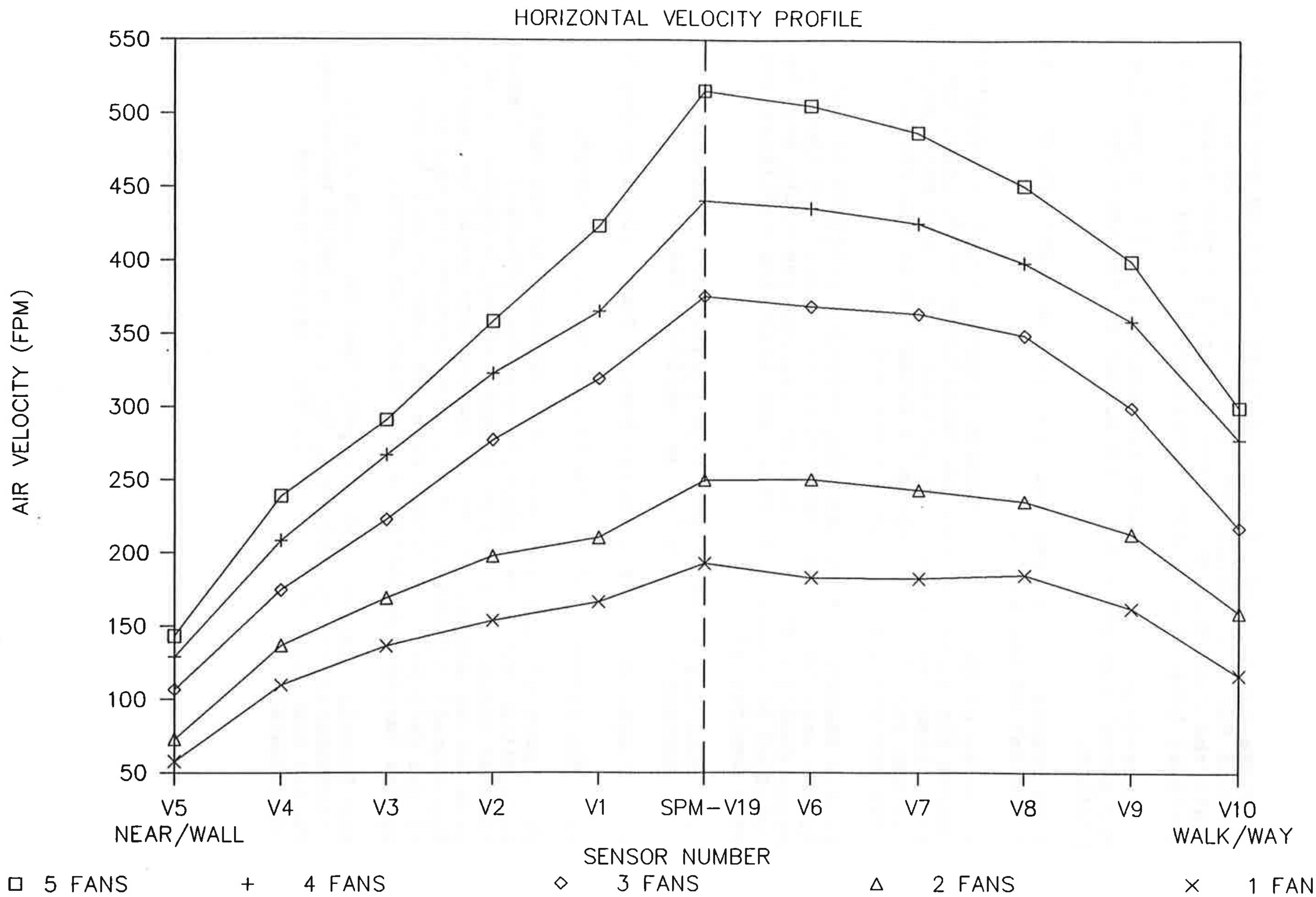

HORIZONTAL VELOCITY PROFILE
550
500
450
400
350
300
250
200
150
100
50
AIR VELOCITY (FPM)
V5
NEAR/WALL
V4
V3
V2
V1
SPM-V19
V6
V7
V8
V9
V10
WALK/WAY
SENSOR NUMBER
5 FANS
4 FANS
3 FANS
2 FANS
1 FAN

FIGURE F-3

traverse point about 20 seconds apart. The time averaging allowed for each reading was about 10 seconds. Table F-1 lists the readings and Figures F-4 and F-5 plot their averages transversely and longitudinally along the tunnel.

A comparison of the results for Tracks 1 and 2 showed the horizontal curvature had some effect on the velocity profile.

Both graphs showed some shifting to the right, which is the "outside" of the curve.

A review of the Track 1 figures (traverse and longitudinal) showed the distance from the ventilation shaft inlet had some effect on the velocity profile. There was some tendency for the profile to become more symmetric as the distance from the ventilation shaft increased.

It was therefore concluded the velocity profiles in the tunnel were not as anticipated in the tunnel and that the Metro Center/McPherson Station test program would have to be modified to account for this. The following modifications were decided upon:

1. Full traverses rather than single point measurement factors were used in the remaining tests.

2. Single Point Measurement Factor Tests would be deleted.

3. All future tests would be done using one track.

The impact of this was some reprogramming of the data acquisition and data reduction computer programs and some loss of convenience during testing at Metro Center since more set-up and take-down of instruments would be required. The overall objectives of the test program and the accuracy of the data being acquired were not compromised in any way by the issues and modifications discussed above.

One friction factor test was performed to check out the instrumentation and software. The single point measurement factor was assumed to be 0.75. The results were as anticipated.

VELOCITY TRAVERSED BY HAND

TRACK #1							TRACK #2						
STATION	NEAR WALL	OUTSIDE THIRD RAIL	OUTSIDE LEFT RAIL	CENTER RAIL	OUTSIDE RIGHT RAIL	WALK WAY	STATION	NEAR WALL	OUTSIDE THIRD RAIL	OUTSIDE LEFT RAIL	CENTER RAIL	OUTSIDE RIGHT RAIL	WALK WAY
7+70	239.00	300.00	407.00	467.00	491.00	477.00	7+50	390.00	435.00	554.00	518.00	483.00	444.00
A	208.00	290.00	392.00	462.00	493.00	451.00	A	374.00	470.00	577.00	544.00	503.00	401.00
	240.00	308.00	400.00	455.00	480.00	456.00		390.00	425.00	555.00	520.00	488.00	412.00
	210.00	297.00	391.00	455.00	491.00	473.00		380.00	435.00	546.00	525.00	486.00	396.00
AVG	224.25	298.75	397.50	459.75	488.75	464.25	AVG	383.50	441.25	553.00	526.75	490.00	413.25
STD	15.27	6.46	6.50	5.07	5.12	10.99	STD	6.84	17.09	4.18	10.28	7.71	18.67
7+20	226.00	300.00	427.00	495.00	519.00	478.00	6+50	395.00	470.00	544.00	546.00	500.00	358.00
B	206.00	274.00	424.00	495.00	513.00	470.00	B	389.00	470.00	580.00	547.00	503.00	358.00
	260.00	300.00	442.00	471.00	512.00	474.00		370.00	452.00	581.00	531.00	510.00	359.00
	185.00	283.00	424.00	497.00	501.00	478.00		396.00	471.00	580.00	551.00	523.00	364.00
AVG	219.25	289.25	429.25	489.50	511.25	475.00	AVG	387.50	465.75	571.25	543.75	515.75	359.75
STD	27.63	11.21	7.46	10.71	6.50	3.32	STD	10.45	7.95	15.74	7.60	11.58	2.49
6+70	229.00	274.00	410.00	463.00	480.00	472.00		N/W	OTR	OLR	C	ORR	W/W
C	220.00	289.00	416.00	481.00	476.00	434.00							
	230.00	293.00	409.00	468.00	488.00	431.00							
	241.00	296.00	417.00	458.00	493.00	463.00							
AVG	230.00	288.00	413.00	467.50	484.25	450.00							
STD	18.47	22.48	12.28	8.61	6.89	21.35							
5+70	263.00	324.00	411.00	477.00	514.00	414.00							
E	244.00	314.00	388.00	486.00	500.00	441.00							
	240.00	284.00	408.00	489.00	488.00	442.00							
	253.00	324.00	388.00	478.00	496.00	438.00							
AVG	250.00	311.50	398.75	482.50	499.50	433.75							
STD	8.86	16.39	10.80	5.12	9.42	11.50							
3+60		365.00	431.00	447.00	424.00	400.00							
F		398.00	453.00	450.00	461.00	375.00							
		346.00	453.00	454.00	431.00	358.00							
		306.00	442.00	445.00	449.00	404.00							
AVG		353.75	444.75	449.00	441.25	384.25							
STD		33.26	9.12	3.39	14.60	18.79							
	N/W	OTR	OLR	C	ORR	W/W							

TABLE F-1

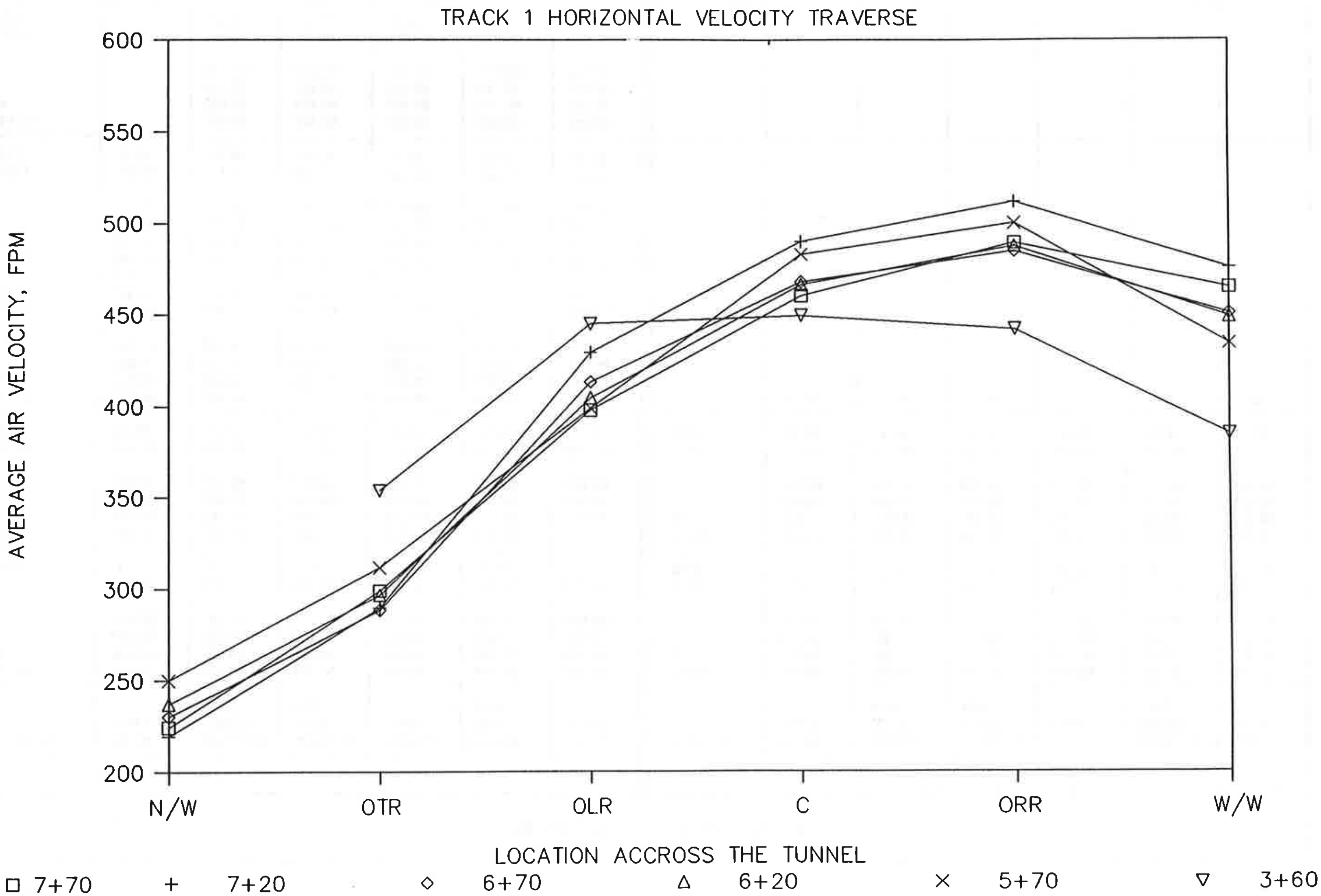

TRACK 1 HORIZONTAL VELOCITY TRAVERSE
AVERAGE AIR VELOCITY, FPM
600
550
500
450
400
350
300
250
200
N/W
OTR
OLR
C
ORR
W/W
LOCATION ACCROSS THE TUNNEL
□ 7+70
+ 7+20
◇ 6+70
△ 6+20
× 5+70
▽ 3+60

FIGURE F-4

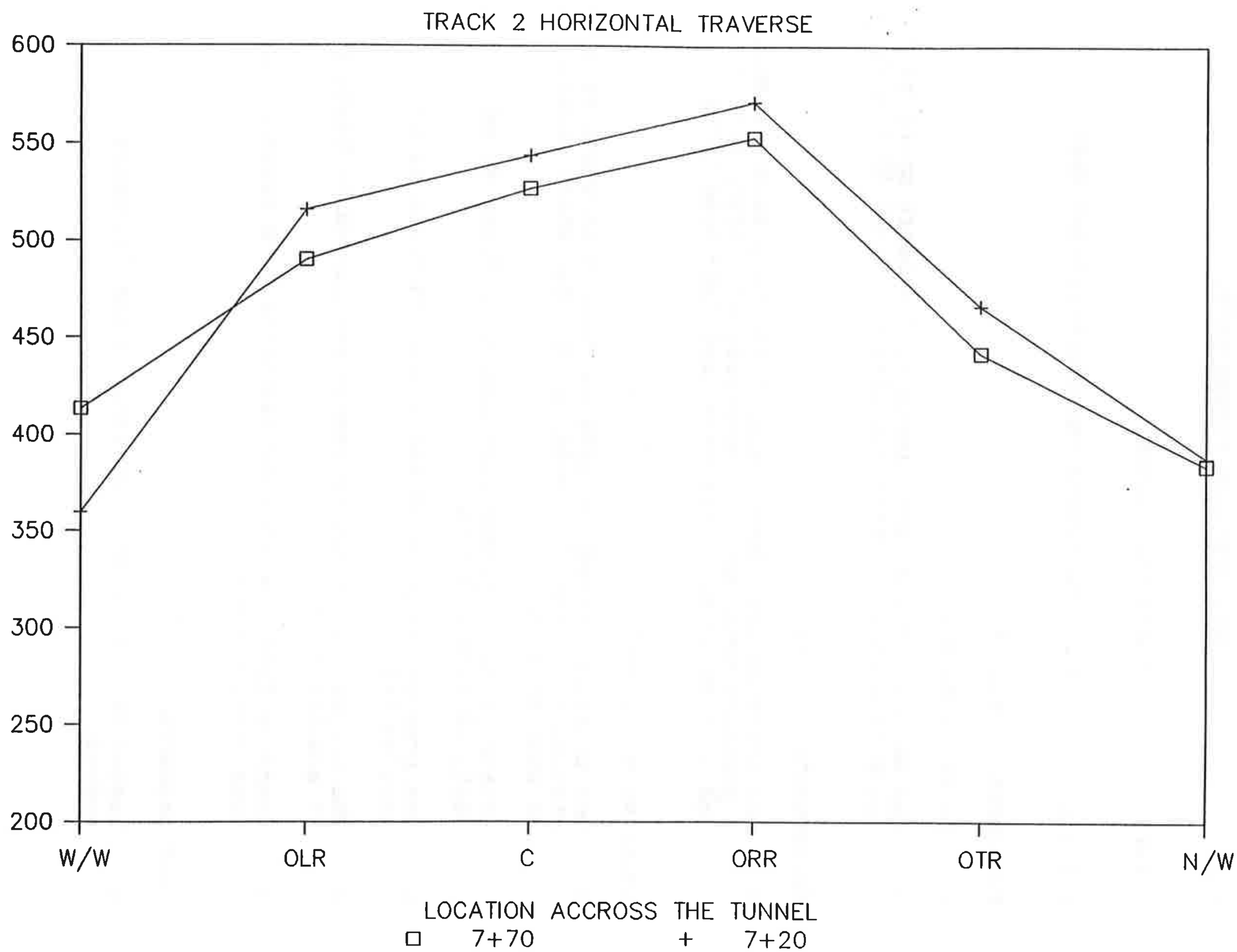

TRACK 2 HORIZONTAL TRAVERSE
AVERAGE AIR VELOCITY, FPM
600
550
500
450
400
350
300
250
200
W/W
OLR
C
ORR
OTR
N/W
LOCATION ACCROSS THE TUNNEL
□ 7+70
+ 7+20

FIGURE F-5

F.2 TUNNEL FRICTION FACTOR TESTS

F.2.1 Ribbed Wall Tunnel

F.2.1.1 New York Avenue Fan Shaft-Exhaust Mode

Equipment Locations

- o Refer to Figure F-6.
- o Two wooden dampers were placed at fan shaft openings on Track #2 side completely blocking off Track #2 tunnel.

Instrumentation Used

- o One traverse transducer rake, 2 static pressure probes, 1 pressure transducer, 1 temperature/humidity sensor, and 1 handheld barometer were used for these tests.

Location of Sensors

- o One traverse transducer rake was placed on Track #1 at station 6+20 with the center of the fan shaft located at station 8+35.
- o Static pressure probes were placed on Track #1 at stations 7+70 and 4+70.
- o One pressure transducer was placed on Track #1 at station 6+20.
- o The temperature/humidity sensor was placed on Track #1 at station 5+70.
- o Readings from the handheld barometer were taken at or near station 5+00.

Test Sequence

- o Tested for ten flow conditions in the following sequence:

Friction Factor Set-Up:
New York Avenue Fan Shaft Test Site

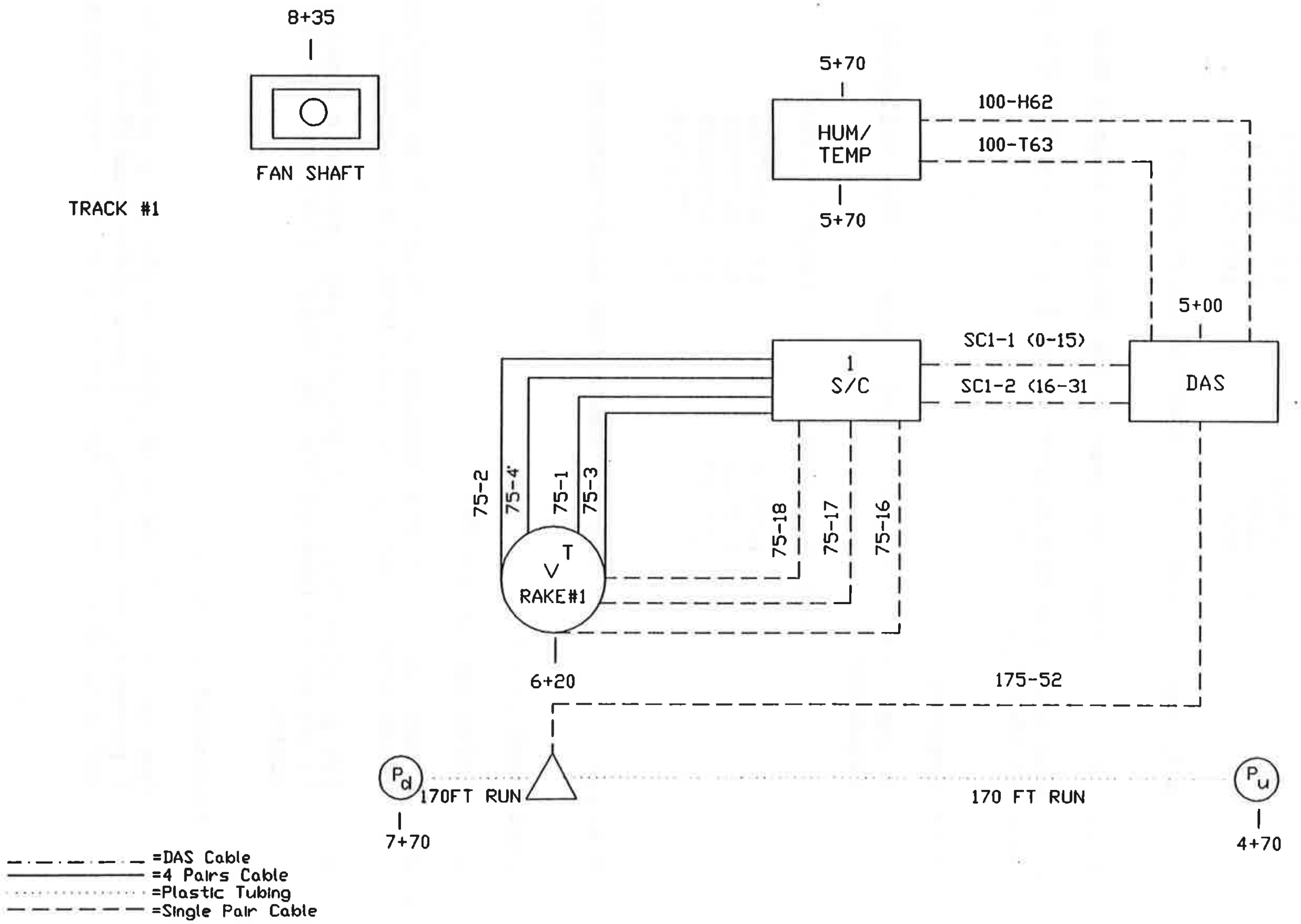


FIGURE F-6

Damper Opened	Damper Closed
1) MCFF5	6) MCFFD5
2) MCFF4	7) MCFFD4
3) MCFF3	8) MCFFD3
4) MCFF2	9) MCFFD2
5) MCFF1	10) MCFFD1

The test nomenclature is presented in Appendix E

F.2.1.2 **New York Avenue Fan Shaft - Supply Mode**

Followed the same procedures as in F.2.1.1 except the fans were in the supply mode.

Test Sequence

o Tested for seven flow conditions in the following sequence:

Damper Opened	Damper Closed
1) MCFF5S	4) MCFFD5S
2) MCFF4S	5) MCFFD4S
3) MCFF3S	6) MCFFD3S
	7) MCFFD2S

F.2.1.3 **7th and I Streets Fan Shaft-Exhaust Mode**

Equipment Location

o Refer to Figure F-7.

o A one-car train was located on Track #2 at station 70+40 approximately 100 feet from fan shaft inlet.

o Two plastic tarpaulin dampers were placed across Track #1 on both sides of the fan shaft blocking off Track #1 tunnel.

Instrumentation Used

o One traverse transducer rake, 2 static pressure probes, 1 pressure transducer, 1 temperature/humidity sensor, and 1 handheld barometer were used for these tests.

Friction Factor Site Set-Up: 7th & I Streets Fan Shaft Test Site

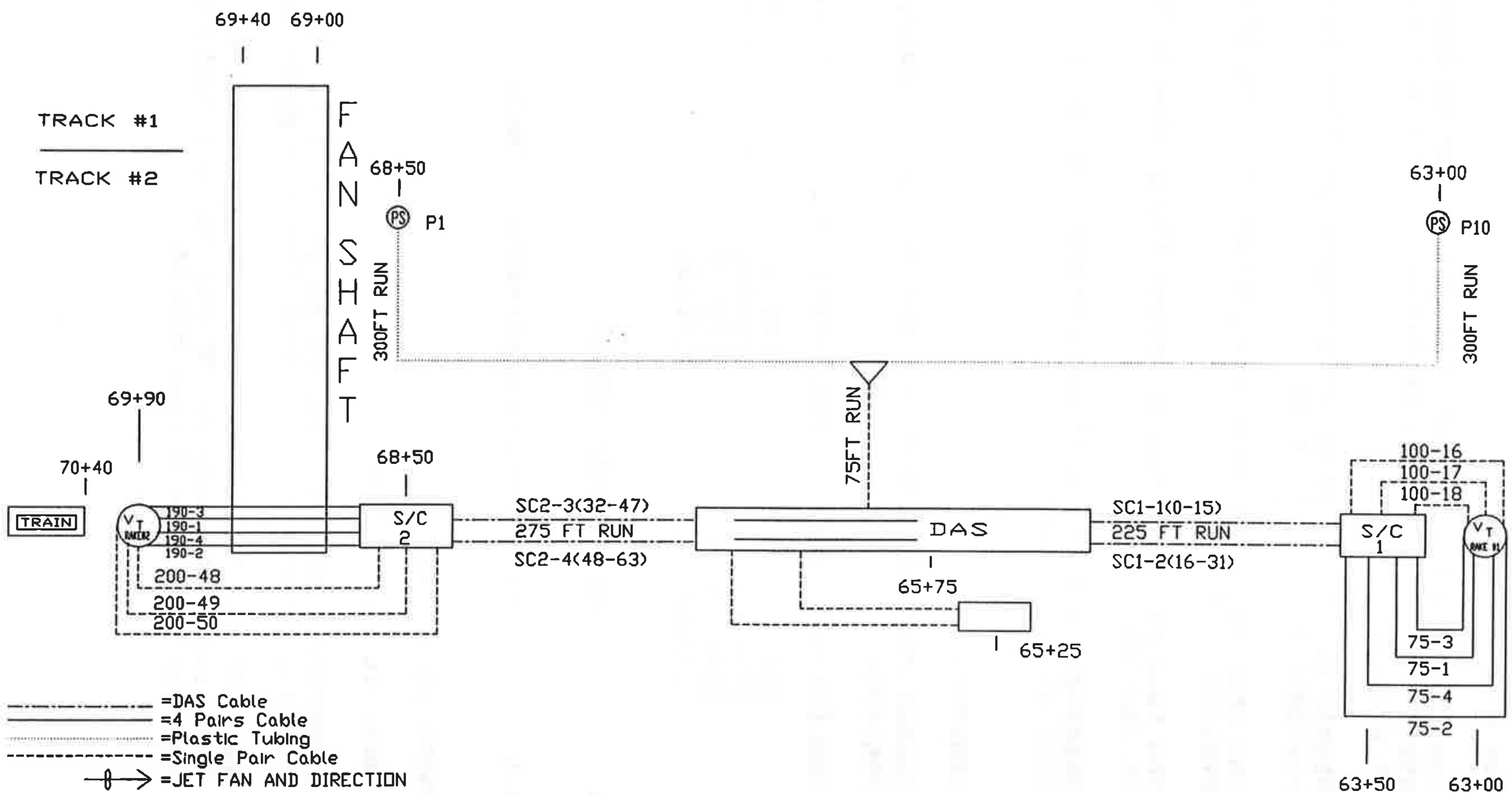


FIGURE F-7

Location of Sensors

- o One traverse transducer rake was placed on Track #2 at station 63+00 with the center of the fan shaft located at station 69+90.
- o Static pressure probes were placed on Track #2 at stations 63+00 and 68+50.
- o One pressure transducer was placed on Track #2 at station 65+75.
- o The temperature/humidity sensor was placed on Track #2 at station 65+25.
- o Readings from the handheld barometer were taken at or near station 65+75.

Test Sequence

- o Tested for ten flow conditions in the following sequence:

Two Dampers Closed	One Damper Closed	No Damper
7IFF2D4	7IFF1D4	7IFF0D4
7IFF2D3	7IFF1D3	7IFF0D3
7IFF2D2	7IFF1D2	
7IFF2D1	7IFF1D1	

F.2.2 Smooth Wall Tunnel

F.2.2.1 Blueridge Fan Shaft-Exhaust Mode

Equipment Locations

- o Refer to Figure F-8.
- o A one-car train was located on Track #2 at station 653+00 approximately 100 feet from fan shaft inlet.
- o The dead-end tunnel provided the equivalent of a fan shaft isolation damper. Therefore, all tests were performed with the damper closed.

Friction Factor Site Set-Up:
Blueridge Avenue Fan Shaft Test Site

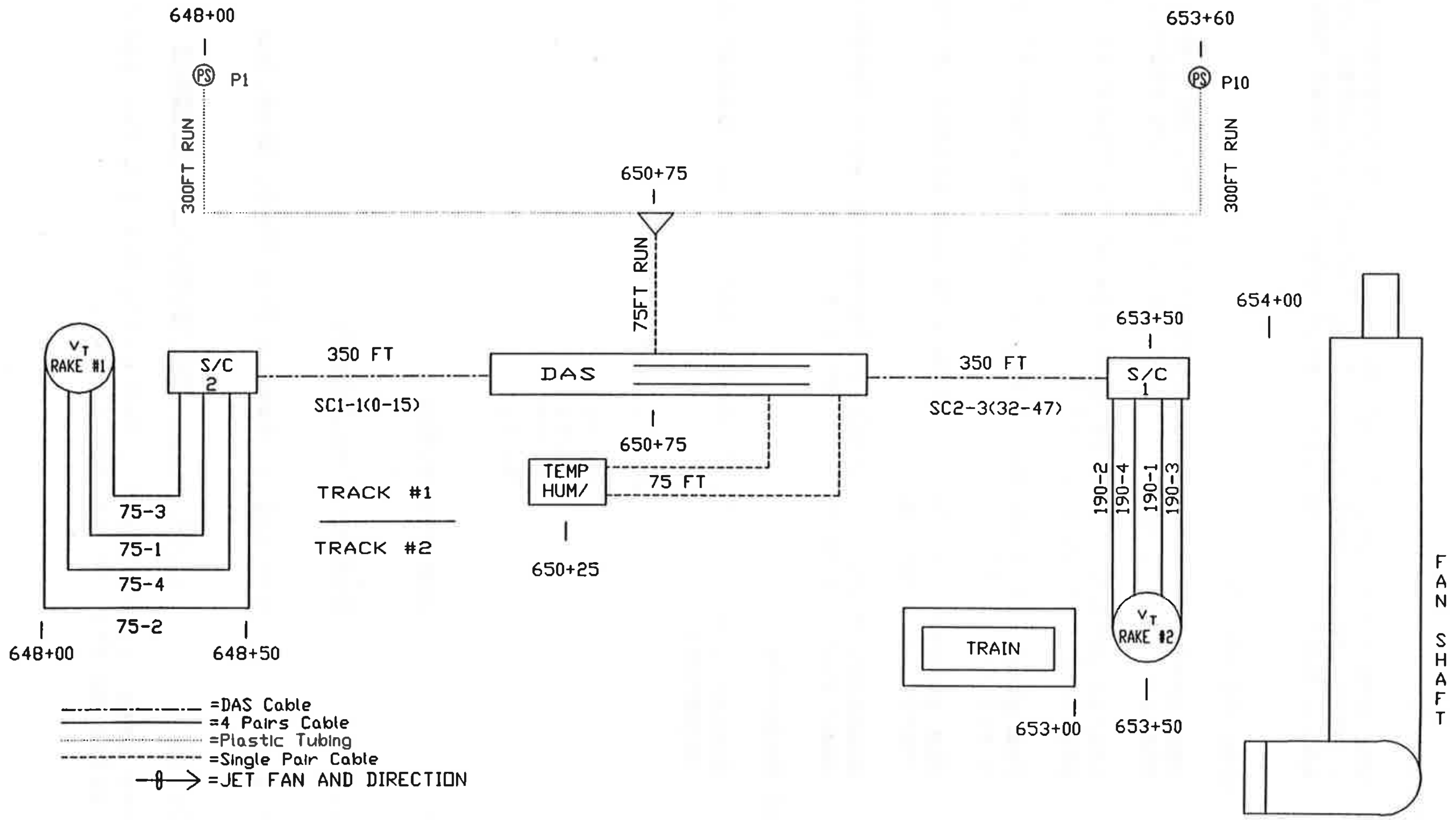


FIGURE F-8

Instrumentation Used

- One traverse transducer rake, 2 static pressure probes 1 pressure transducer, 1 temperature/humidity sensor, and 1 handheld barometer were used for these tests.

Location of Sensors

- One traverse transducer rake was placed on Track #1 at station 648+00 and on Track #2 at station 653+50.
- Static pressure probes were placed on Track #1 at stations 648+00 and 653+50.
- One pressure transducer was placed on Track #1 at station 650+75.
- The temperature/humidity sensor was placed at station 650+25 on Track #1.
- Readings from the handheld barometer were taken at or near station 650+75 on Track #1.

Test Sequence

- Tested for four flow conditions in the following sequence:

Damper Closed

BRFF4
BRFF3
BRFF2
BRFF1

F.3 JET FAN TESTS

F.3.1 <u>Ribbed Wall Tunnel</u>

F.3.1.1 7th and I Streets Fan Shaft Location

F.3.1.1.1 <u>100-Foot Jet Fan Spacing With Train</u>

These tests were repeated for different jet fan locations relative to the top of the tunnel.

F.3.1.1.1.1 Exhaust Mode, Distance From Top of Tunnel: 20 Inches

Equipment Locations

- Refer to Figure F-9.
- A one-car train was located on Track #2 at station 70+40 approximately 100 feet from fan shaft inlet.
- Four jet fans were placed at the center of the tunnel on Track #2. Fan 1, fan 2, fan 3 and fan 4 were located at stations 67+25, 66+25, 65+25, 64+25 respectively. When testing in the exhaust mode the output of the jet fans were in a direction away from the fan shaft.
- Two plastic tarpaulin dampers were placed across Track #1 on both sides of the fan shaft blocking off Track #1 tunnel.

Instrumentation Used

- Two (2) traverse transducer rakes, 10 static pressure probes, 5 pressure transducers, 1 temperature/humidity sensor, and 1 handheld barometer were used for these tests.

Location of Sensors

- The traverse transducer rakes were placed on Track #1 at stations 69+90 and 63+00.
- A static pressure probe was placed 25 feet from either side of each jet fan. Two additional static pressure probes were placed on Track #2 at stations 68+50 and 63+00.
- A pressure transducer was placed at the following 5 stations 67+25, 66+25, 65+75, 65+25, and 64+25.
- The temperature/humidity sensor was placed at station 65+25 on Track #1.
- Readings from the handheld barometer were taken at or near station 65+75 on Track #1.

Test Sequence

- Tested for five flow conditions in the following sequence:

Jet Fan Site Set-Up: 100-ft. Spacing
7th & I Strrets Fan Shaft Test Site

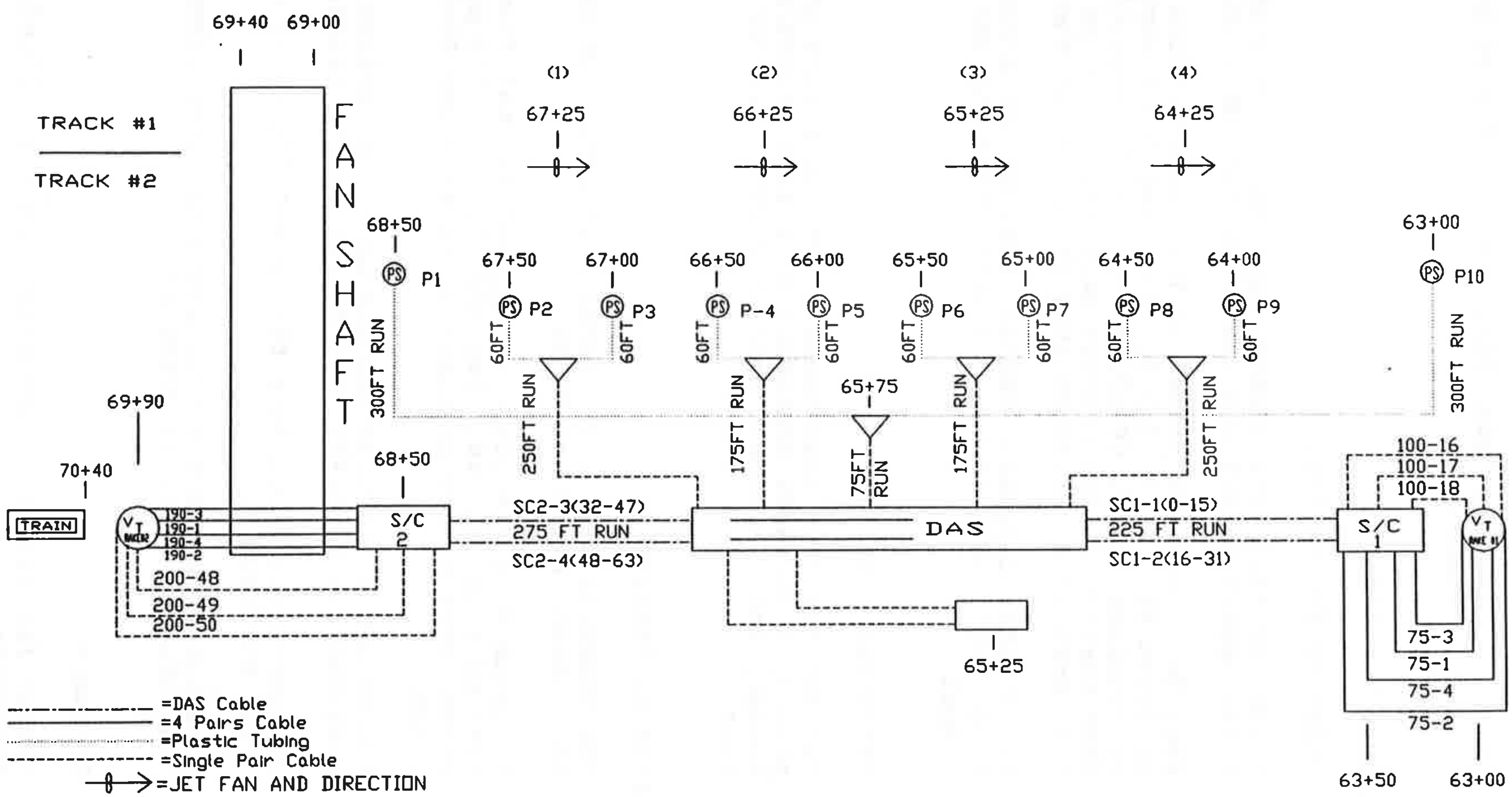


FIGURE F-9

Damper Closed

1) 7IJ100H4
2) 7IJ100H3
3) 7IJ100H2
4) 7IJ100H1
5) 7IJ100H0

F.3.1.1.1.2 Exhaust Mode, Distance From Top of Tunnel: 26 Inches

Followed the same procedure as in F.3.1.1.1.1 except the center of the jet fans was lowered to a distance of 26 inches from top of the tunnel.

Test Sequence

- Tested for five flow conditions in the following sequence:

Damper Closed

1) 7IJ100M4
2) 7IJ100M3
3) 7IJ100M2
4) 7IJ100M1
5) 7IJ100M0

F.3.1.1.1.3 Exhaust Mode, Distance From Top of Tunnel: 32 Inches

Followed the same procedure as in F.3.1.1.1.1 except the center of the jet fans was lowered to a distance of 32 inches from the top of the tunnel.

Test Sequence

- Tested for five flow conditions in the following sequence:

Damper Closed

1) 7IJ100L4
2) 7IJ100L3
3) 7IJ100L2
4) 7IJ100L1
5) 7IJ100L0

F.3.1.1.2 <u>75-Foot Jet Fan Spacing With Train</u>

These tests were repeated for different jet fan locations relative to the top of the tunnel.

F.3.1.1.2.1 Exhaust Mode, Distance From Top of Tunnel: 20 Inches

Equipment Locations

o Refer to Figure F-10.

o A one-car train was located on Track #2 at station 70+40 approximately 100 feet from the fan shaft inlet.

o Four jet fans were placed at center of the tunnel on Track #2. Fan 1, fan 2, and fan 3 and fan 4 were located at stations 66+87.5, 66+12.5, 65+37.5, and 64+62.5 respectively. When testing in this exhaust mode the output of the jet fans were in a direction away from the fan shaft.

o Two plastic tarpaulin dampers were placed across Track #1 on both sides of the fan shaft blocking off Track #1 tunnel.

Instrumentation Used

o Two traverse transducer rakes, 10 static pressure probes, 5 pressure transducers, 1 temperature/humidity sensor, and 1 handheld barometer were used for these tests.

Location of Sensors

o The traverse transducer rakes were placed on Track #2 at stations 69+90 and 63+00.

o A static pressure probe was placed 19 feet from either end of each jet fan. Two additional static pressure

Jet Fan Site Set-Up: 75-ft. Spacing
8th & I Streets Fan Shaft Test Site

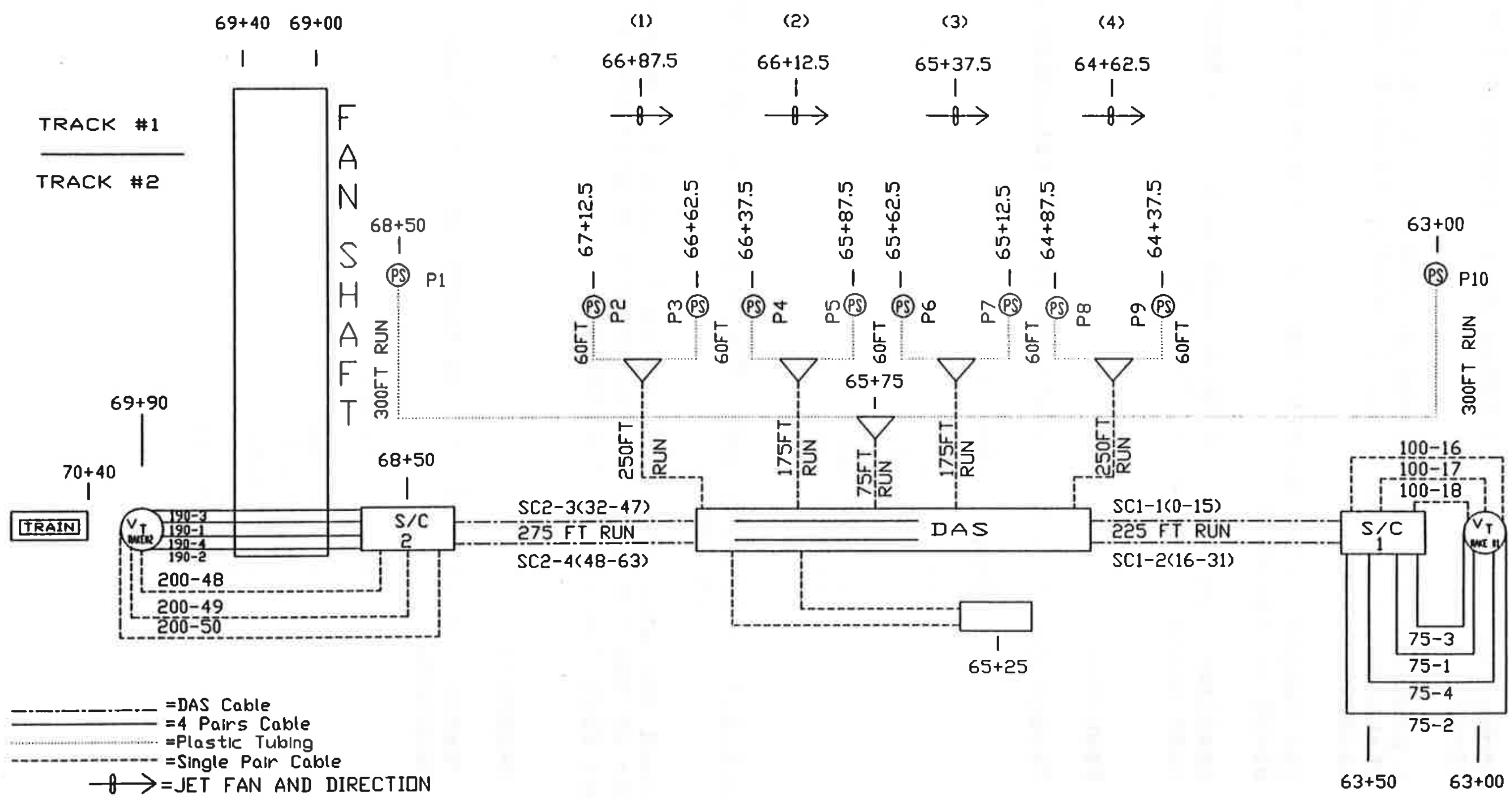


FIGURE F-10

probes were placed on Track #2 at stations 68+50 and 63+00.

- A pressure transducer was placed at the following 5 stations: 66+87.5, 66+12.5, 65+75, 65+37.5, and 64+62.5.
- The temperature/humidity sensor was placed at station 65+25 on Track #2.
- Readings from the handheld barometer were taken at or near station 65+75 on Track #2.

Test Sequence

- Tested for 5 flow conditions in the following sequence:

  Damper Closed

  1) 7IJ75H4
  2) 7IJ75H3
  3) 7IJ75H2
  4) 7IJ75H1
  5) 7IJ75H0

F.3.1.1.2.2 Exhaust Mode, Distance from Top of Tunnel: 26 Inches

Followed the same procedure as in F.3.1.1.2.1 except the center of the jet fans was lowered to a distance of 26 inches from the top of the tunnel.

Test Sequence

- Tested for five flow conditions in the following sequence:

  Damper Closed

  1) 7IJ75M4
  2) 7IJ75M3
  3) 7IJ75M2
  4) 7IJ75M1
  5) 7IJ75M0

F.3.1.1.2.3 Exhaust Mode, Distance From Top of Tunnel: 32 Inches

Followed the same procedure as in F.3.1.1.2.1 except the center of the jet fans were lowered to a distance of 32 inches from the top of the tunnel.

Test Sequence

o Tested for five flow conditions in the following sequence:

Damper Closed

1) 7IJ75L4
2) 7IJ75L3
3) 7IJ75L2
4) 7IJ75L1
5) 7IJ75L0

F.3.1.1.3 <u>50-Foot Jet Fan Spacing With Train</u>

These tests were repeated for different jet fan locations relative to the top of the tunnel.

F.3.1.1.3.1 Exhaust Mode, Distance From Top of Tunnel: 20 Inches

Equipment Locations

o Refer to Figure F-11.

o A one-car train was located on Track #2 at station 70+40 approximately 100 feet from the fan shaft inlet.

o Four jet fans were placed at the center of the tunnel on Track #2. Fan 1, fan 2, fan 3, and fan 4 were located at stations 66+50, 66+00, 65+50, and 65+00 respectively. When testing in the exhaust mode the output of the jet fans was in a direction away from the fan shaft.

o Two dampers in the form of circular plastic tarpaulins were installed on Track #1 at each side of the fan shaft, blocking off Track #1 tunnel.

Jet Fan Site Set-Up: 50-ft. Spacing
7th & I Streets Fan Shaft Test Site

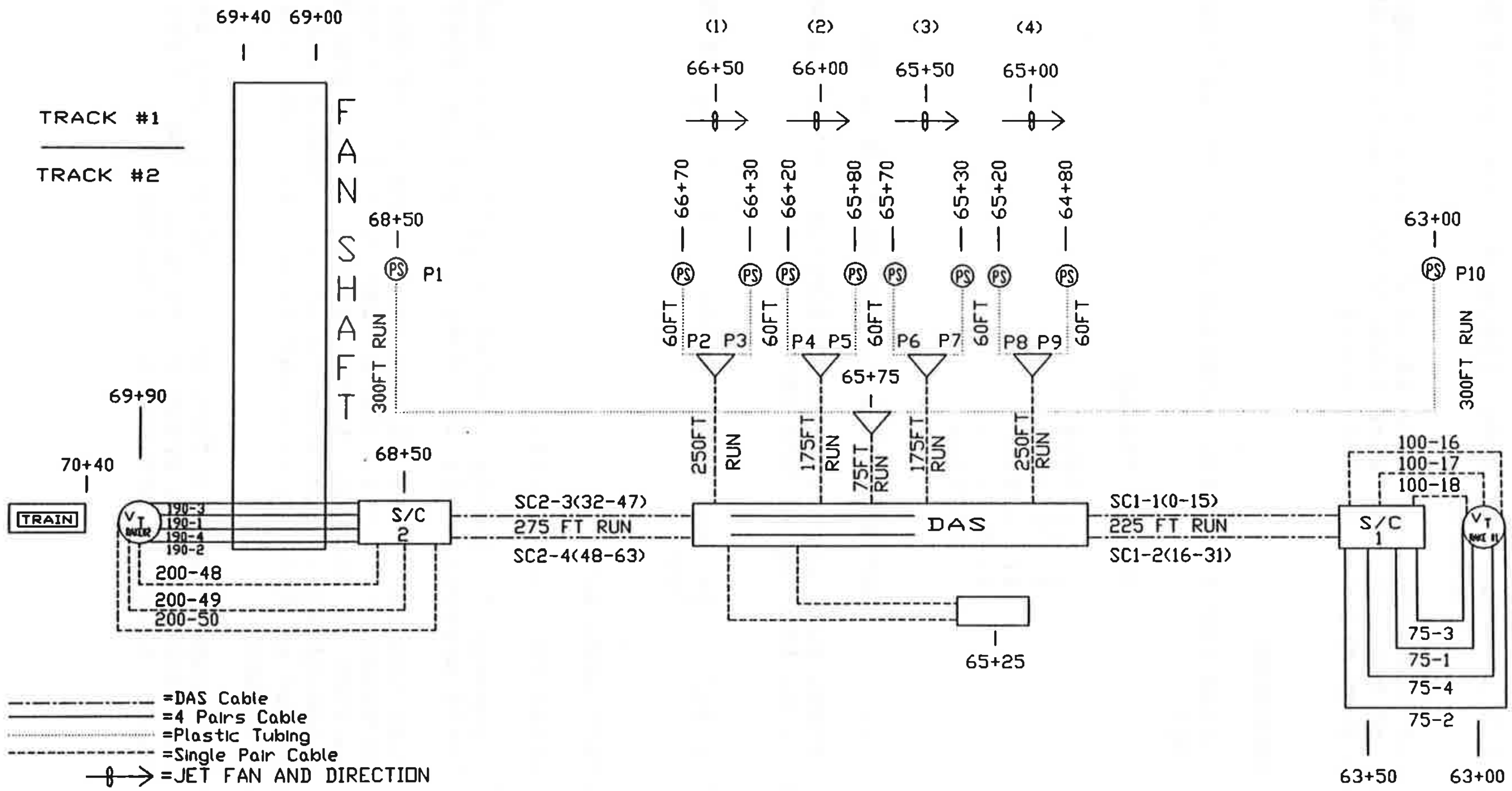


FIGURE F-11

Instrumentation Used

- o Two traverse transducer rakes, 10 static pressure probes, 5 pressure transducers, 1 temperature/humidity sensor, and 1 handheld barometer were used for these tests.

Location of Sensors

- o The traverse transducer rakes were placed on Track #2 at stations 69+90 and 63+00.
- o A static pressure probe was placed 13 feet from either end of each jet fan. Two additional static pressure probes were placed on Track #2 at stations 68+50 and 63+00.
- o A pressure transducer was placed at the following 5 stations: 66+50, 66+00, 65+75, 65+50, and 65+00.
- o The temperature/humidity sensor was placed at station 65+25 on Track #2.
- o Readings from the handheld barometer were taken at or near station 65+75 on Track #2.

Test Sequence

- o Tested for five flow conditions in the following sequence:

Damper Closed

1) 7IJ50H4
2) 7IJ50H3
3) 7IJ50H2
4) 7IJ50H1
5) 7IJ50H0

F.3.1.1.3.2 Exhaust Mode, Distance from Top of Tunnel: 26 Inches

Followed the same procedure as in F.3.1.1.3.1 except the center of the jet fans was lowered to a distance of 26 inches from the top of the tunnel.

Test Sequence

o Tested for five flow conditions in the following sequence:

Damper Closed

1) 7IJ50M4
2) 7IJ50M3
3) 7IJ50M2
4) 7IJ50M1
5) 7IJ50M0

F.3.1.1.3.3 Exhaust Mode, Distance From Top of Tunnel: 32 Inches

Followed the same procedure as in F.3.1.1.3.1 except the center of the jet fans were lowered to a distance of 32 inches from the top of the tunnel.

Test Sequence

o Tested for five flow conditions in the following sequence:

Damper Closed

1) 7IJ50L4
2) 7IJ50L3
3) 7IJ50L2
4) 7IJ50L1
5) 7IJ50L0

F.3.2 **Smooth Wall Tunnel**

F.3.2.1 **Blueridge Avenue Fan Shaft Location**

F.3.2.1.1 100-Foot Jet Fan Spacing With Train

These tests were repeated for different jet fan locations relative to the top of the tunnel.

F.3.2.1.1.1 Exhaust Mode, Distance From Top of Tunnel: 20 Inches

Equipment Locations

o Refer to Figure F-12.

o Located a one-car train on Track #2 at station 653+00 approximately 100 feet from the fan shaft inlet.

Jet Fan Site Set-Up: 100-ft. Spacing
Blueridge Avenue Fan Shaft Test Site

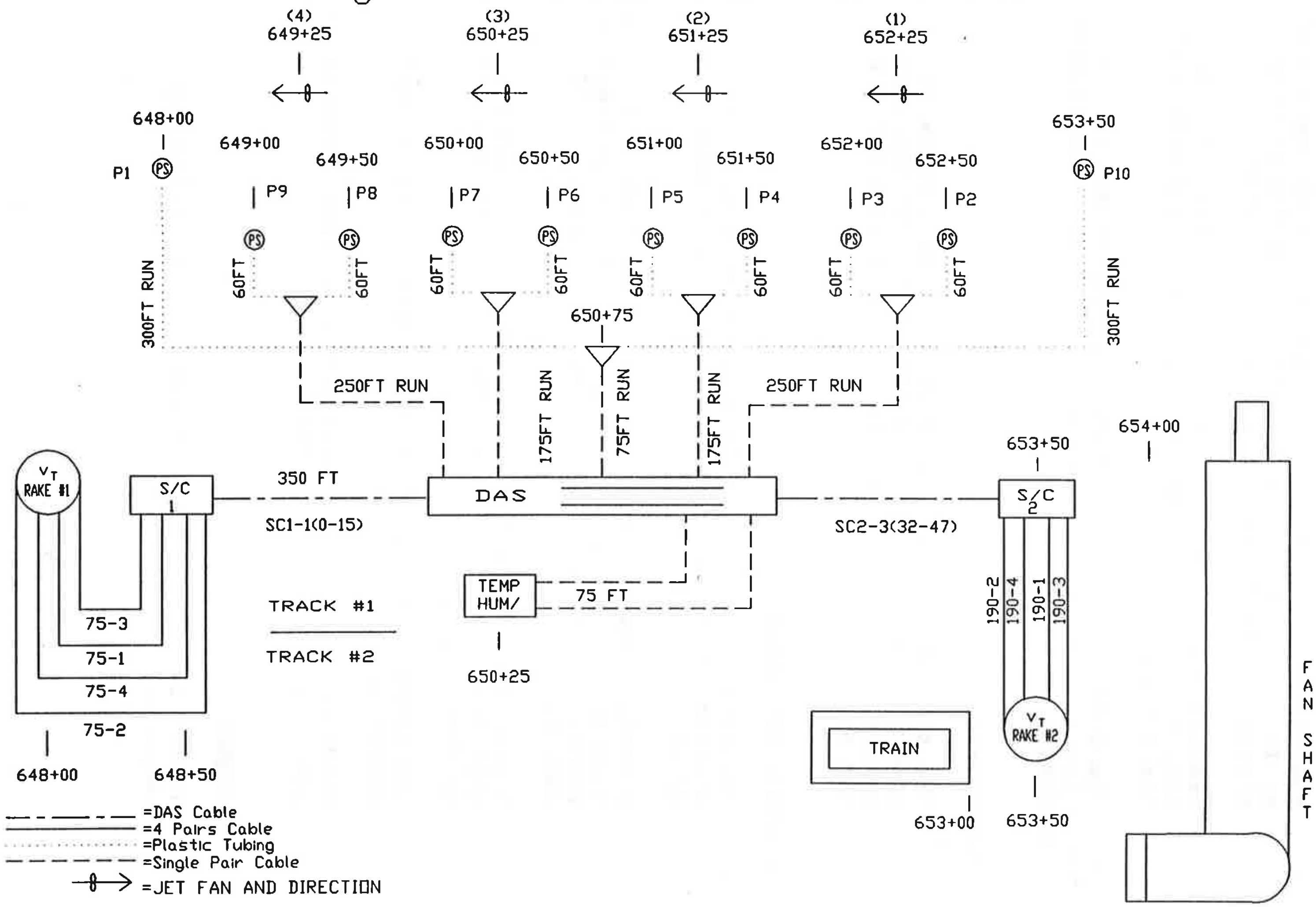


FIGURE F-12

- Four jet fans were placed at the center of the tunnel on Track #1. Fan 1, fan 2, fan 3, and fan 4--were at stations 649+12, 650+25, 651+25, and 652+25,

  respectively. When testing in the exhaust mode the output of the jet fans were in a direction away from the fan shaft.

- The dead-end tunnel provided the equivalent of a fan shaft isolation damper. Therefore, all tests were performed with damper closed.

Instrumentation Used

- Two traverse transducer rakes, 10 static pressure probes, 5 pressure transducers, 1 temperature/humidity sensor, and 1 handheld barometer were used for these tests.

Location of Sensors

- Placed 1 traverse transducer rake on Track #1 at station 648+00 and 1 traverse transducer rake on Track #2 at station 653+50.
- A static pressure probe was placed 25 feet from either side of each jet fan. Two additional static pressure probes were placed on Track #1 at stations 648+00 and 653+50.
- A pressure transducer was placed at the following 5 stations: 649+25, 650+25, 650+75, 651+25, and 652+25 on Track #1.
- The temperature/humidity sensor was placed at station 650+25 on Track #1.
- Readings from the handheld barometer were taken at or near station 650+75 on Track #1.

Test Sequence

- Tested for five flow conditions in the following sequence:

Damper Closed

1) BRJ100H4
2) BRJ1003
3) BRJ100H2
4) BRJ100H1
5) BRJ100H0

F.3.2.1.1.2 Exhaust Mode, Distance From Top of Tunnel: 26 Inches

Followed the same procedure as in F.3.2.1.1.1 except the center of the jet fans was lowered to a distance of 26 inches from the top of the tunnel.

Test Sequence

o Tested for five flow conditions in the following sequence:

Damper Closed

1) BRJ100M4
2) BRJ100M3
3) BRJ100M2
4) BRJ100M1
5) BRJ100M0

F.3.2.1.1.3 Exhaust Mode, Distance From Top of Tunnel: 32 Inches

Followed the same procedure as in F.3.2.1.1.1 except the center of the jet fans was lowered to a distance of 32 inches from the top of the tunnel.

Test Sequence

o Tested for five flow conditions in the following sequence:

Damper Closed

1) BRJ100L4
2) BRJ100L3
3) BRJ100L2
4) BRJ100L1
5) BRJ100L0

F.3.2.1.2 75-Foot Jet Fan Spacing With Train

These tests were repeated for different jet fan locations relative to the top of the tunnel.

F.3.2.1.2.1 Exhaust Mode, Distance From Top of Tunnel: 20 Inches

Equipment Locations

- Refer to Figure F-13.
- Located a one-car train on Track #2 at station 653+00 approximately 100 feet from fan shaft inlet.
- Four jet fans were placed at the center of the tunnel on Track #1. Fan 1, fan 2, fan 3 and fan 4 were located at stations 649+12.5, 649+87.5, 650+62.5 and 651+37.5 respectively. When testing in the exhaust mode the output of the jet fans must be in a direction away from the fan shaft.

  The dead-end tunnel provided the equivalent of a fan shaft isolation damper. Therefore, all tests were performed with damper closed.

Instrumentation Used

- Provided 2 traverse transducer rakes, 10 static pressure probes, five pressure transducers, 1 temperature/humidity sensor, and 1 handheld barometer.

Location of Sensors

- Placed one traverse transducer rake on Track #1 at station 648+00 and 1 traverse transducer rake on Track #2 at station 653+50.
- Placed a static pressure probe 19 feet from either side of each jet fan. Two additional static pressure probes were placed on Track #1 at stations 648+00 and 653+50.
- Placed a pressure transducer at the following 5 stations on Track #1: 649+12.5, 649+87.5, 650+62.5, 651+37.5, and 651+87.5.
- Placed temperature/humidity sensor at station 650+25 on Track #1.

Jet Fan Site Set-Up: 75-ft. Spacing
Blueridge Avenue Fan Shaft Test Site

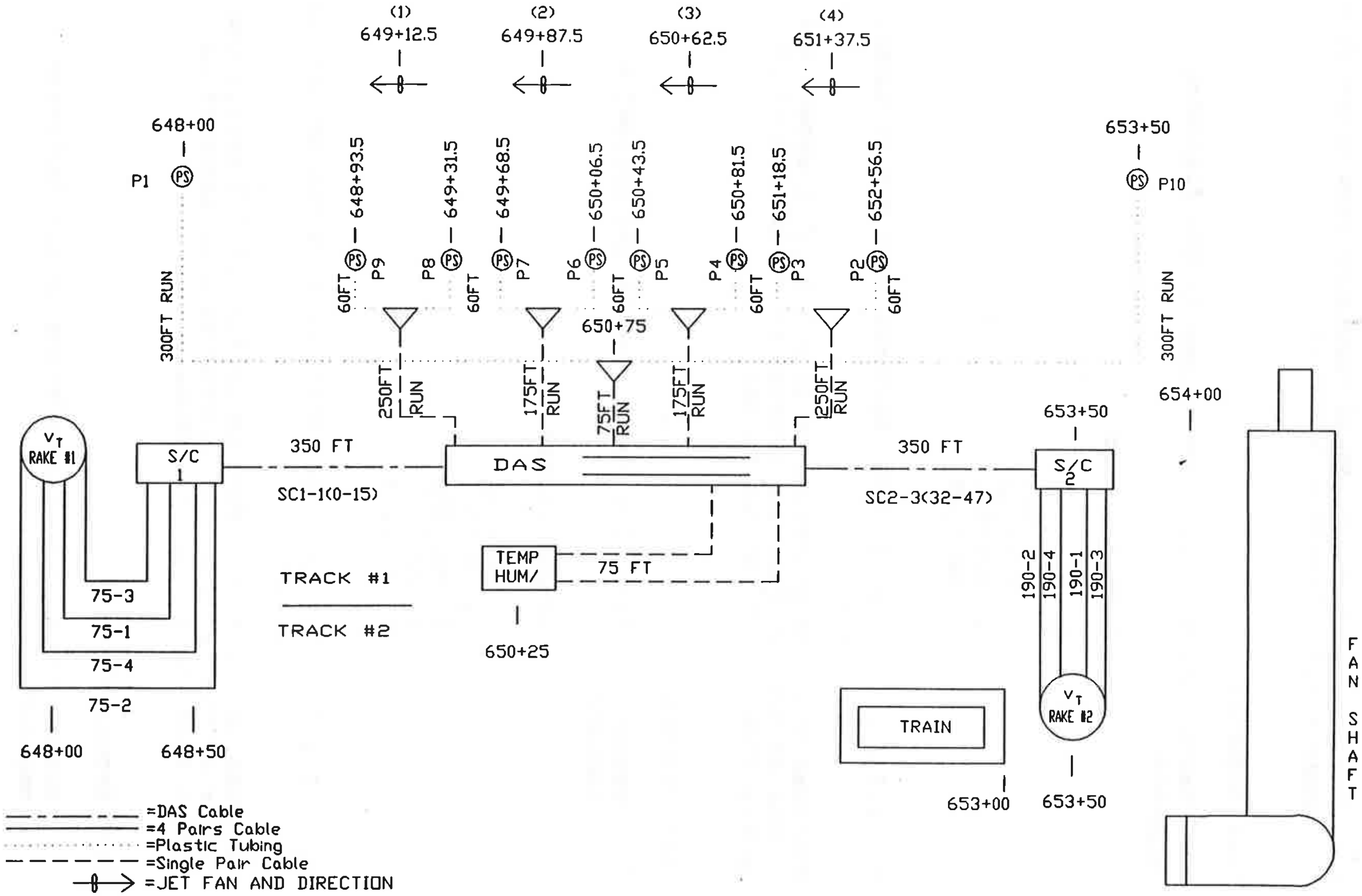


FIGURE F-13

- o Readings from the handheld barometer were taken at or near station 650+75 on Track #1.

Test Sequence

- o Tested for five flow conditions in the following sequence:

Damper Closed

1) BRJ75H4
2) BRJ75H3
3) BRJ75H2
4) BRJ75H1
5) BRJ75H0

F.3.2.1.2.2 Exhaust Mode, Distance From Top of Tunnel: 26 Inches

Followed the same procedure as in F.3.2.1.2.1 except the center of the jet fans was lowered to a distance of 26 inches from the top of the tunnel.

Test Sequence

- o Tested for five flow conditions in the following sequence:

Damper Closed

1) BRJ75M4
2) BRJ75M3
3) BRJ75M2
4) BRJ75M1
5) BRJ75M0

F.3.2.1.2.3 Exhaust Mode, Distance From Top of Tunnel: 32 Inches

Followed the same procedure as in F.3.2.1.2.1 except the center of the jet fans was lowered to a distance of 32 inches from the top of the tunnel.

Test Sequence

- o Tested for five flow conditions in the following sequence:

Damper Closed

1) BRJ75L4
2) BRJ75L3
3) BRJ75L2
4) BRJ75L1
5) BRJ75L0

F.3.2.1.3 <u>50-Foot Jet Fan Spacing With Train</u>

These tests were repeated for different jet fan locations relative to the top of the tunnel.

F.3.2.1.3.1 Exhaust Mode, Distance From Top of Tunnel: 20 Inches

Equipment Locations

- o Refer to Figure F-14.
- o Located a one-car train on Track #2 at station 653+00 approximately 100 feet from the fan shaft inlet.
- o Four jet fans were placed at the center of the tunnel on Track #1. Fan 1, fan 2, fan 3, and fan 4 were located at stations 650+00, 650+50, 651+00, and 651+50, respectively. When testing in the exhaust mode the output of the jet fans must be in a direction away from the fan shaft.
- o The dead-end tunnel provided the equivalent of a fan shaft isolation damper. Therefore, all tests were performed with damper closed.

Instrumentation Used

- o Provided 2 traverse transducer rakes, 10 static pressure probes, 5 pressure transducers, 1 temperature/humidity sensor, and 1 handheld barometer.

Location of Sensors

- o Placed 1 traverse transducer rake on Track #1 at station 648+00 and 1 traverse transducer rake on Track #2 at station 653+50.
- o Placed a static pressure probe 12 feet from either side of each jet fan. Two additional static pressure probes were placed on Track #1 at stations 648+00 and 653+50.

Jet Fan Site Set-Up: 50-ft. Spacing
Blueridge Avenue Fan Shaft Test Site

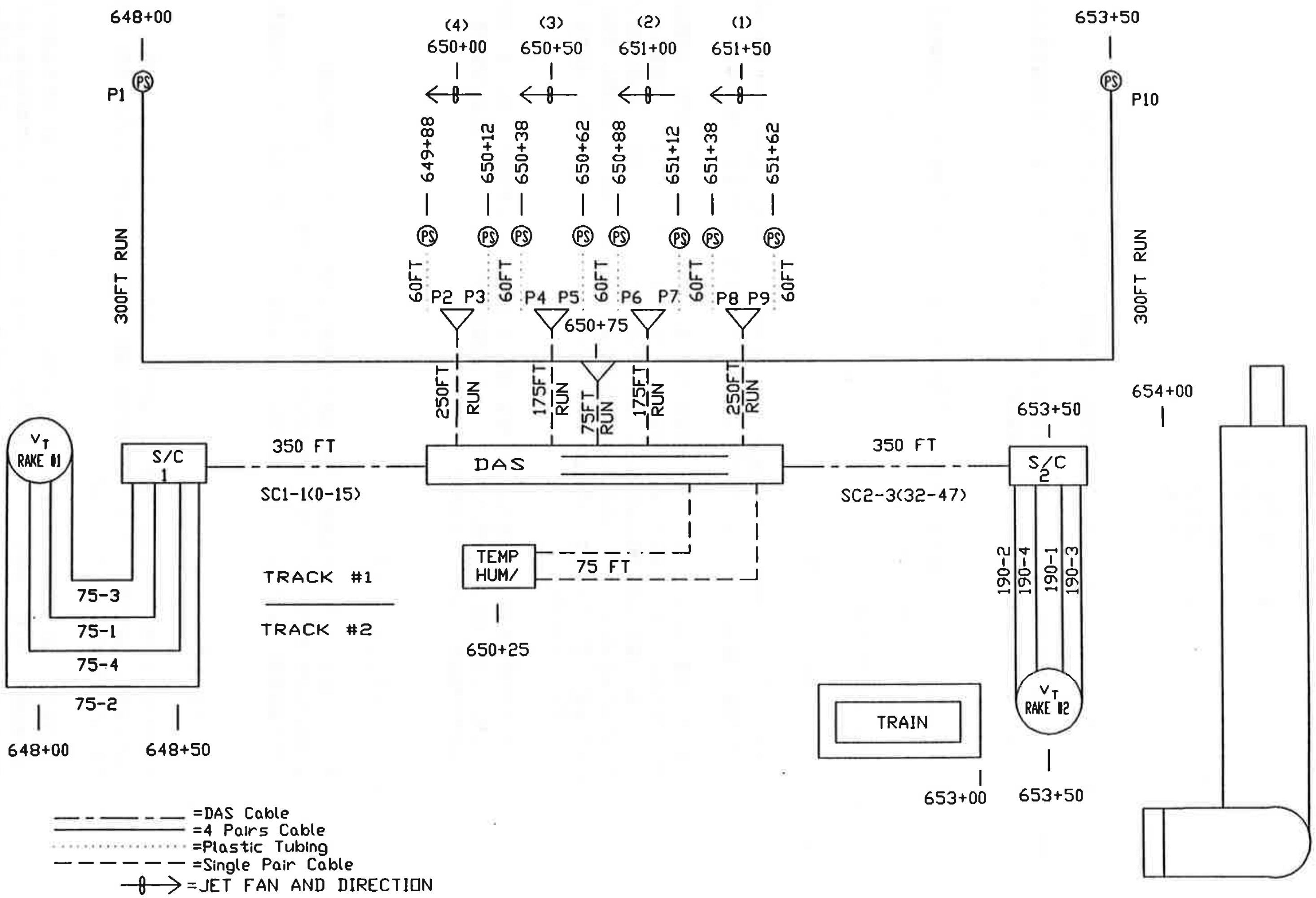


FIGURE F-14

- Placed a pressure transducer at the following 5 stations on Track #1: 650+00, 650+50, 650+75, 651+00, and 651+50.
- The humidity/temperature sensor was placed at station 650+25 on Track #1.
- Readings from the handheld barometer were taken at or near 650+75 on Track #1.

Test Sequence

- Tested for five flow conditions in the following sequence:

Damper Closed

1) BRJ50H4
2) BRJ50H3
3) BRJ50H2
4) BRJ50H1
5) BRJ50H0

F.3.2.1.3.2 Exhaust Mode, Distance From Top of Tunnel: 26 Inches

Followed the same procedure as in F.3.2.1.3.1 except the center of the jet fans was lowered to a distance of 26 inches from the top of the tunnel.

Test Sequence

- Tested for five flow conditions in the following sequence:

Damper Closed

1) BRJ50M4
2) BRJ50M3
3) BRJ50M2
4) BRJ50M1
5) BRJ50M0

F.3.2.1.3.3 Exhaust Mode, Distance From Top of Tunnel: 32 Inches

Followed the same procedure as in F.3.2.1.3.1 except the center of the jet fans was lowered to a distance of 32 inches from the top of the tunnel.

Test Sequence

o Tested for five flow conditions in the following sequence:

Damper Closed

1) BRJ50L4
2) BRJ50L3
3) BRJ50L2
4) BRJ50L1
5) BRJ50L0

F.4 BARRIER TESTS

F.4.1 New York Avenue Fan Shaft Location

These tests were made to measure the deployment characteristics of the barrier. The time necessary for full deployment, the ability to conform to the shape of the tunnel, the special fitting problems around the third rail, walkway, other intrusions into the tunnel, and the personnel access opening were monitored closely. Data were collected to determine the barrier head loss coefficient, pressure differential through the barrier, and air velocities in the tunnel with the barrier and the adjacent tunnel.

Equipment Locations

o Refer to Figure F-15.

o Scaffolding covered by nylon-reinforced tarp was erected across Track #1 to simulate the presence of a train. Scaffolding was erected at station 9+55.

o The barrier was placed on Track #1 at station 7+20.

Instrumentation Used

o Two traverse transducer rakes, 2 static pressure probes, 1 pressure transducer, 1 temperature/humidity sensor, and 1 handheld barometer were used.

Location of Sensors

o The traverse transducer rakes were placed on Track #1 at stations 6+20 and 9+05.

Circular Barrier Set-Up:
New York Avenue Fan Shaft Test Site

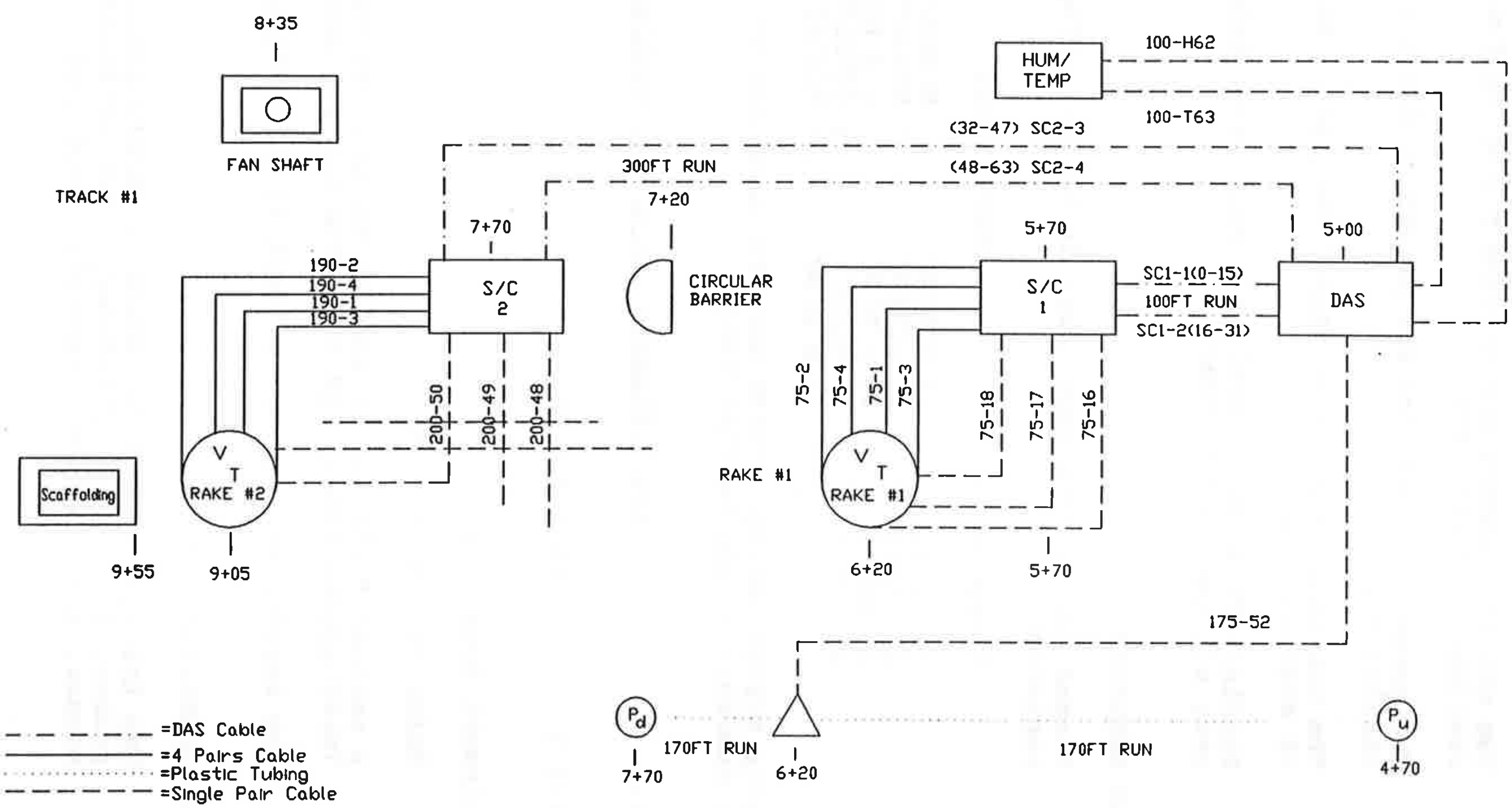


FIGURE F-15

- Two static pressure probes were placed on Track #1 at stations 4+70 and 7+70.
- The pressure transducer was placed on Track #1 at station 6+15.
- The temperature/humidity sensor was placed on Track #1 at station 5+70.
- Readings from the handheld barometer were taken at or near station 5+00 on Track #1.

Test Sequence

- Tested for 14 flow conditions in the following sequence:

Damper Open	Damper Closed	
1) MCB5T	1) MCB5DT	6) MCB5DTR*
2) MCB4T	2) MCB4DT	7) MCB4DTR
3) MCB3T	3) MCB3DT	8) MCB3DTR
4) MCB2T	4) MCB2DT	9) MCB2DTR
	5) MCB1DT	10) MCB1DTR

*Tests MCB5DT through MCB1DT were repeated due to loss of air pressure in the barrier torus.

F.4.2 7th and I Streets Fan Shaft Location

F.4.2.1 Exhaust Mode

Equipment Locations

- Refer to Figure F-16.
- A one-car train was located on Track #2 at station 70+40 approximately 100 feet from the fan shaft inlet.
- The barrier was placed on Track #2 at station 68+00.

Instrumentation Used

- Two traverse transducer rakes, 2 static pressure probes, 1 pressure transducer, 1 temperature/humidity sensor, and 1 handheld barometer were used.

Circular Barrier Set-Up:
7th & I Streets Fan Shaft Test Site

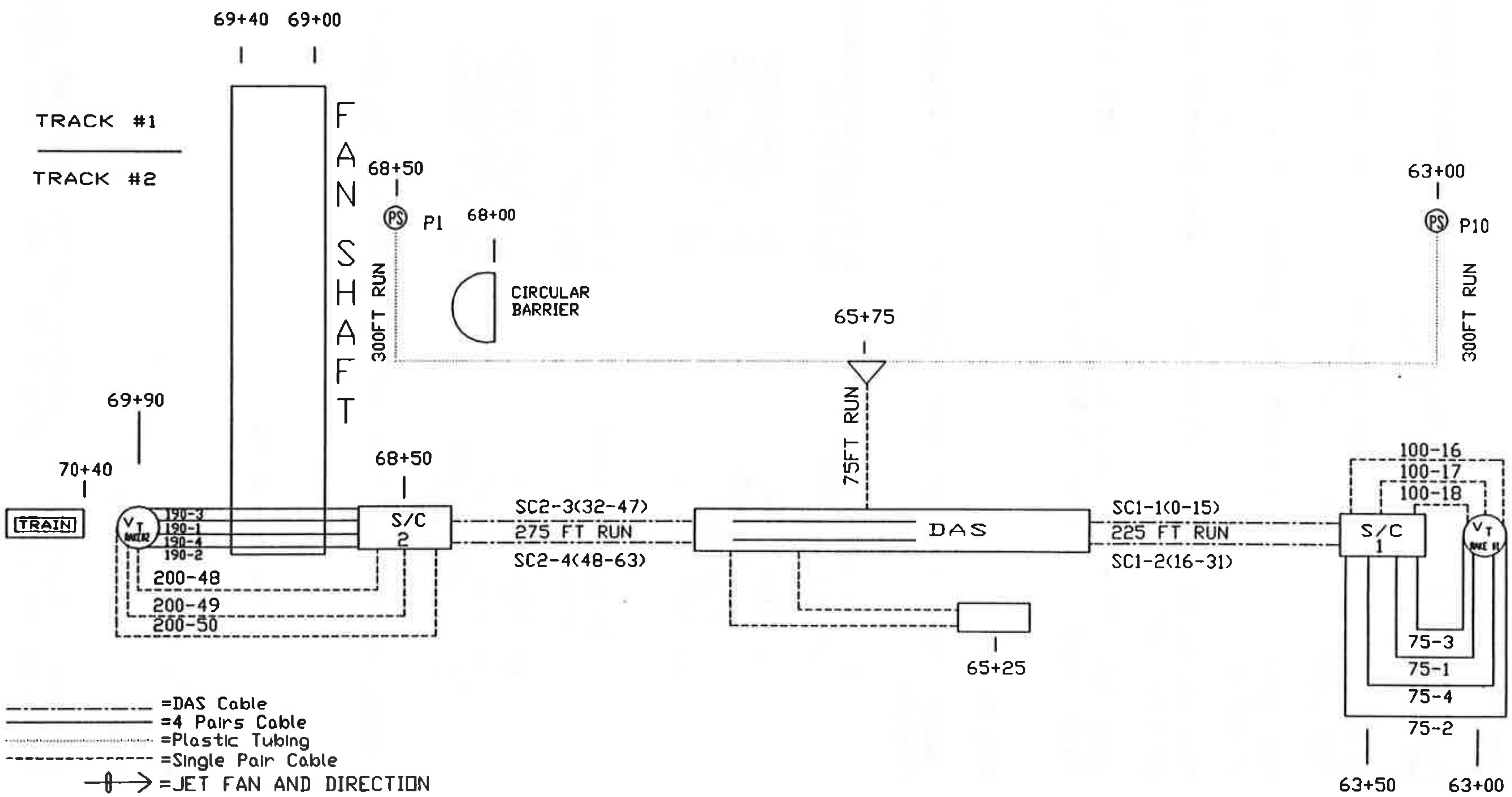


FIGURE F-16

Location of Sensors

- The traverse transducer rakes were placed on Track #2 at stations 69+90 and 63+00.
- Two static pressure probes were placed on Track #2 at stations 68+50 and 63+00.
- The pressure transducer was placed on Track #2 at station 65+75.
- The temperature/humidity sensor was placed on Track #2 at station 67+75.
- Readings from the handheld barometer were taken at or near station 65+25 on Track #2.

Test Sequence

- Tested for 15 flow conditions in the following sequence:

2 Dampers Closed Egress Closed	2 Dampers Closed Egress Open
1) 7IB4D2TEC	5) 7IB4D2TEO
2) 7IB3D2TEC	6) 7IB3D2TEO
3) 7IB2D2TEC	7) 7IB2D2TEO
4) 7IB1D2TEC	8) 7IB1D2TEO
1 Damper Closed Egress Closed	**1 Damper Closed Egress Open**
9) 7IB4D1TEC	13) 7IB4D1TEO
10) 7IB3D1TEC	14) 7IB3D1TEO
11) 7IB3D1TECR*	15) 7IB2D1TEO
12) 7IB2D1TEC	

*Test repeated due to loss of air pressure in the barrier torus.

F.4.2.2 **Supply Mode**

Equipment Locations

- Refer to Figure F-16.
- A one-car train was located on Track #2 at station 70+40 approximately 100 feet from the fan shaft inlet.

- The barrier was placed on Track #2 at station 68+00.

Instrumentation Used

- Two traverse transducer rakes, 2 static pressure probes, 1 pressure transducer, 1 temperature/humidity sensor, and 1 handheld barometer were used.

Location of Sensors

- The traverse transducer rakes were placed on Track #2 at stations 69+90 and 63+00.
- Two static pressure probes were placed on Track #2 at stations 68+50 and 63+00.
- The pressure transducer was placed on Track #2 at station 65+75.
- The temperature/humidity sensor was placed on Track #2 at station 5+70.
- Readings from the handheld barometer were taken at or near station 65+25 on Track #2.

Test Sequence

- Tested for 6 flow conditions in the following sequence:

2 Dampers Closed Egress Closed	2 Dampers Closed Egress Open
1) 7IB4D2TSC	4) 7IB4D2TSO
2) 7IB3D2TSC	5) 7IB3D2TSO
3) 7IB2D2TSC	6) 7IB2D2TSO

F.5 JET FAN MOUNTING HEAD LOSS COEFFICIENT TESTS

These tests were made to measure the impediment to airflow caused by the jet fan mounting equipment used to transport and raise/lower the jet fans. These data were collected by measuring the pressure drop over a tunnel length containing the jet fans. These tests were performed in both smooth wall and ribbed wall tunnels.

The jet fan mounting head loss coefficient tests were performed with the jet fans mounted.

F.5.1 Ribbed Wall Tunnel - 7th and I Streets Fan Shaft Location

F.5.1.1 Exhaust Mode With Train - 100-Foot Jet Fan Spacing

Equipment Locations

- o Refer to Figure F-17.
- o A one-car train was located on Track #2 at station 70+40 approximately 100 feet from fan shaft inlet.
- o Four jet fans were placed at the center of the tunnel on Track #2. Fan 1, fan 2, fan 3 and fan 4 were located at stations 67+25, 66+25, 65+25, 64+25, respectively. During this test the jet fans were not operating.
- o Two dampers in the form of circular plastic tarpaulins were installed on Track #1 at each side of the fan shaft, blocking off Track #1 tunnel.

Instrumentation Used

- o Two traverse transducer rakes, 2 static pressure probes, 1 pressure transducer, 1 temperature/humidity sensor, and 1 handheld barometer were used.

Location of Sensors

- o The traverse transducer rakes were placed on Track #1 at stations 69+90 and 63+00.
- o The static pressure probes were placed on Track #1 at stations 68+50 and 63+00.
- o The transducer was placed on Track #1 at station 65+75.
- o The temperature/humidity sensor was placed on Track #1 at station 65+25.
- o Readings from the handheld barometer were taken at or near 65+75 on Track #1.

Test Sequence

- o Tested for one flow condition, four fan shaft fans operating in the exhaust mode.

Jet Fan Mounting Head Loss Coefficient Set-Up
100-ft. Spacing
7th & I Streets Fan Shaft Test Site

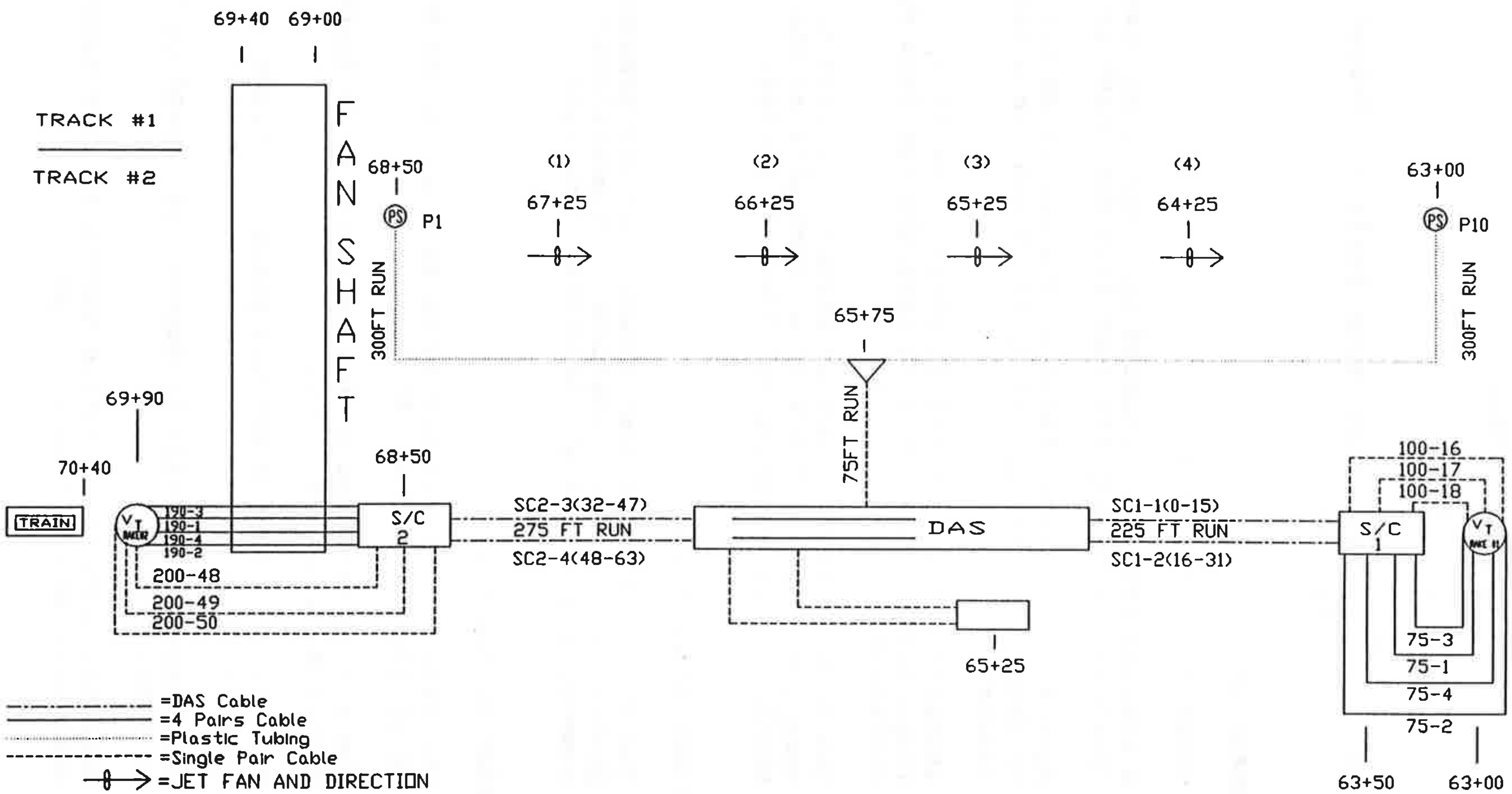


FIGURE F-17

Damper Closed

1) 7ID100

F.5.1.2 **Exhaust Mode With Train - 75-Foot Jet Fan Spacing**

Equipment Locations

- o Refer to Figure F-18.
- o A one-car train was located on Track #2 at station 70+40 approximately 100 feet from fan shaft inlet.
- o Five jet fans were placed at the center of the tunnel on Track #2. Fan 1, fan 2, fan 3 and fan 4 were located at
- o stations 66+87.5, 66+12.5, 65+37.5, 64+62.5, respectively. During this test the jet fans were not operating.
- o Two dampers in the form of circular plastic tarpaulins were installed on Track #1 at each side of the fan shaft opening blocking off Track #1 tunnel.

Instrumentation Used

- o Two traverse transducer rakes, 2 static pressure probes, 1 pressure transducer, 1 temperature/humidity sensor, and 1 handheld barometer were used.

Location of Sensors

- o The traverse transducer rakes were placed on Track #2 at stations 69+90 and 63+00.
- o The static pressure probes were placed on Track #2 at stations 68+50 and 63+00.
- o The pressure transducer was placed on Track #2 at station 65+75.
- o The temperature/humidity sensor was placed on Track #2 at station 65+25.
- o Readings from the handheld barometer were taken at or near station 65+75 on Track #2.

Jet Fan Mounting Head Loss Coefficient Set-Up
75-ft. Spacing
7th & I Streets Fan Shaft Test Site

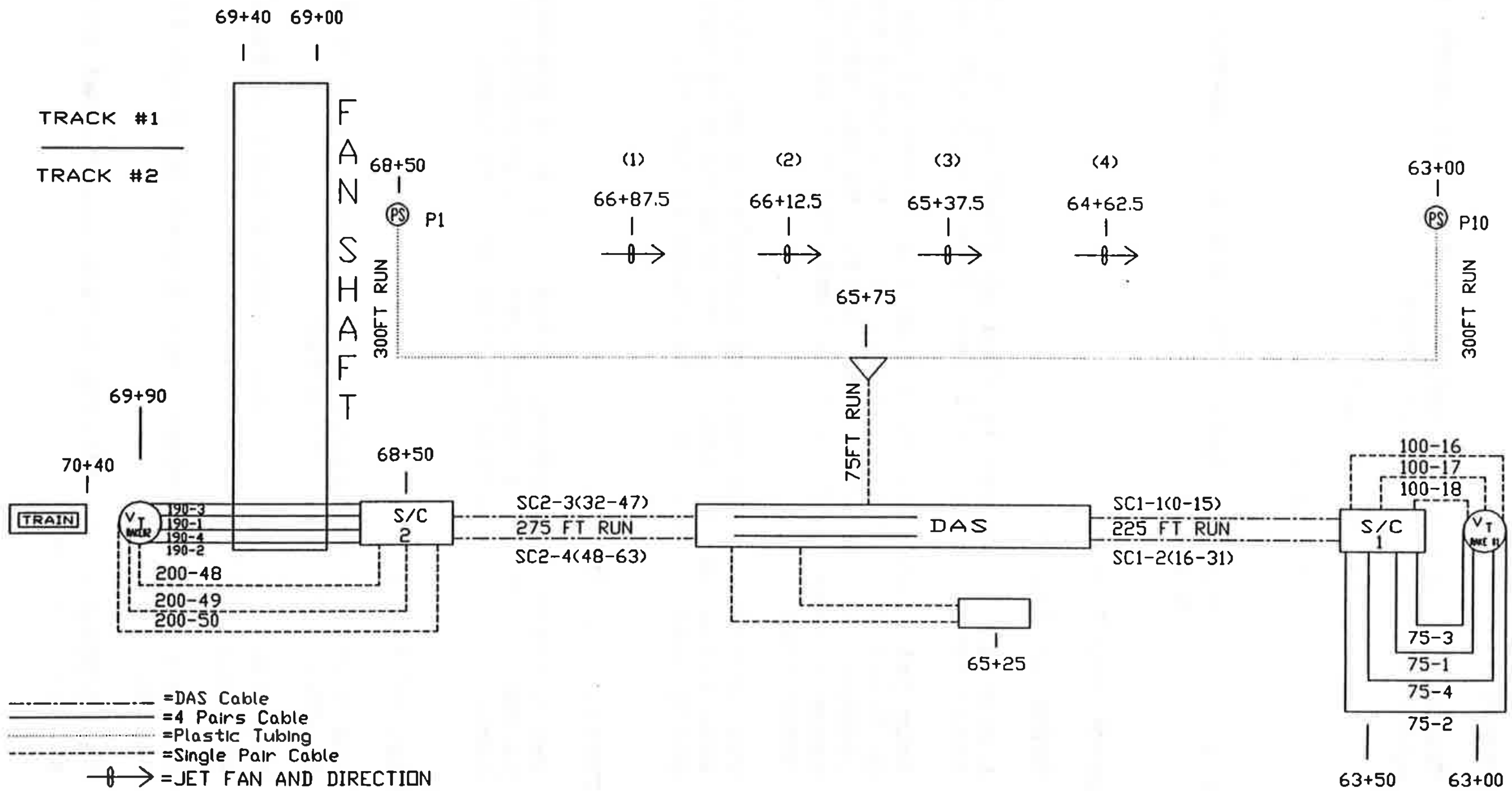


FIGURE F-18

Test Sequence

- o Tested for one flow condition, four fan shaft fans operating in the exhaust mode.

  Damper Closed

  1) 7ID75

F.5.1.3 Exhaust Mode With Train - 50-Foot Jet Fan Spacing

Equipment Locations

- o Refer to Figure F-19.
- o A one-car train was located on Track #2 at station 70+40 approximately 100 feet from fan shaft inlet.
- o Four jet fans were placed at the center of the tunnel on Track #2. Fan 1, fan 2, fan 3 and fan 4 were located at stations 66+50, 66+00, 65+50, 65+00, respectively. During this test the jet fans were not operating.
- o Two dampers in the form of circular plastic tarpaulins were installed on Track #1 at each side of the fan shaft opening blocking off Track #1 tunnel.

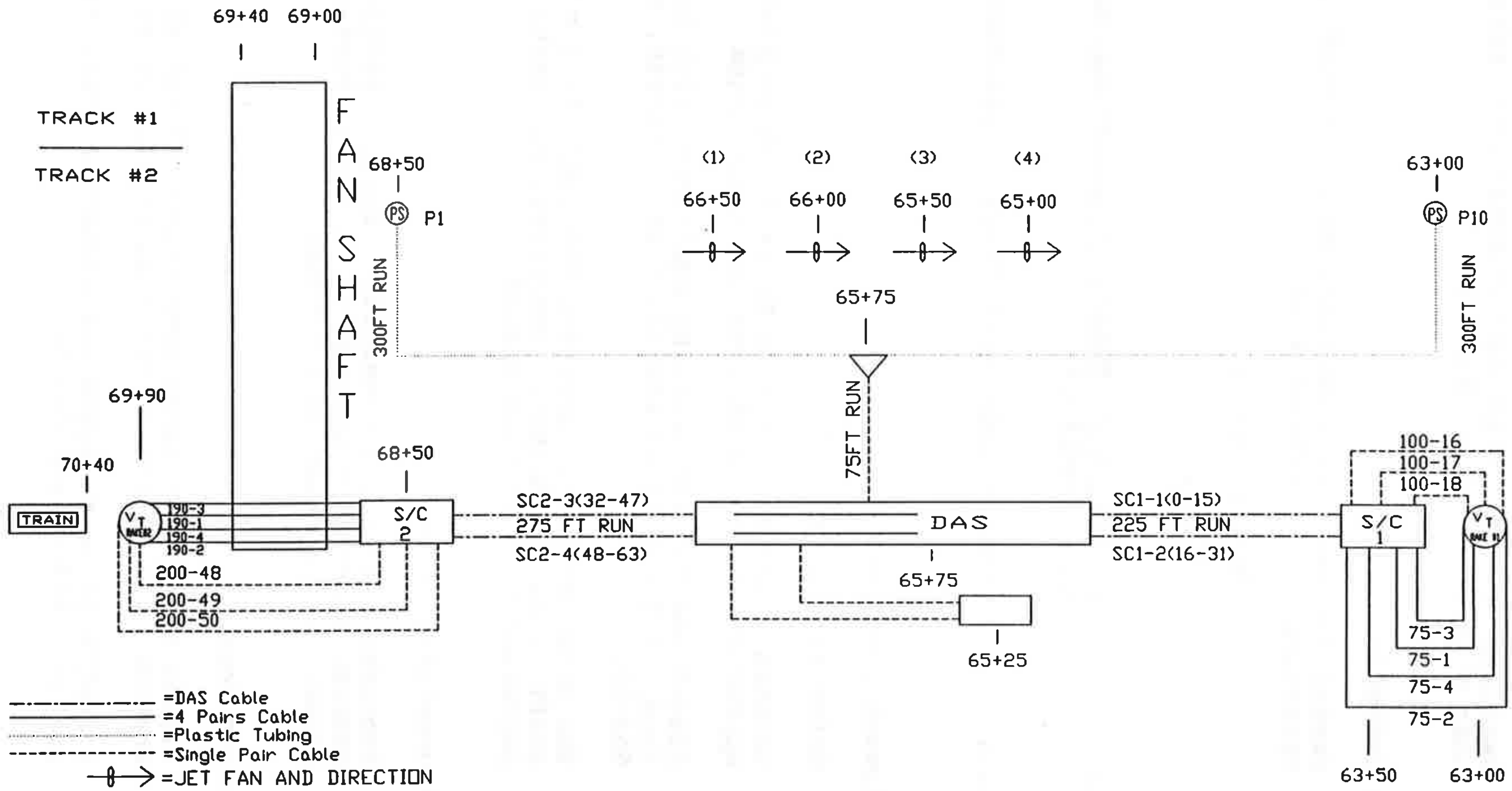
Instrumentation Used

- o Two traverse transducer rakes, 2 static pressure probes, 1 pressure transducer, 1 temperature/humidity sensor, and 1 handheld barometer were used.

Location of Sensors

- o The traverse transducer rakes were placed on Track #2 at stations 69+90 and 63+00.
- o The static pressure probes were placed on Track #2 at stations 68+50 and 63+00.
- o The pressure transducer was placed on Track #2 at station 65+75.
- o The temperature/humidity sensor was placed on Track #2 at station 65+25.

Jet Fan Mounting Head Loss Coefficient Set-Up
50-ft. Spacing
7th & I Streets Fan Shaft Test Site



F-47

FIGURE F-19

o Readings from the handheld barometer were taken at or near station 65+25 on Track #2.

Test Sequence

o Tested for one flow condition, four fan shaft fans operating in the exhaust mode.

Damper Closed

1) 7ID50

F.5.2 **Smooth Wall Tunnel - Blueridge Avenue Fan Shaft Location**

F.5.2.1 **Exhaust Mode With Train - 100-Foot Jet Fan Spacing**

Equipment Locations

o Refer to Figure F-20.

o Located a one-car train on Track #2 at station 653+00, approximately 100 feet from the shaft inlet.

o Placed the jet fan mounting equipment, with the jet fans, on Track #1 at station 649+25, 650+25, 651+25 and 652+25.

o The dead-end tunnel provided the equivalent of a fan shaft isolation damper. Therefore, all tests were performed with dampers closed.

Instrumentation Used

o Provided 2 traverse transducer rakes, 2 static pressure probes, 1 pressure transducer, 1 temperature/humidity sensor, and 1 handheld barometer.

Location Sensors

o Placed a traverse transducer rake on Track #2 at stations 653+50 and on Track #1 at station 648+00.

o A static pressure probe was placed on Track #1 at stations 648+00 and 653+50.

Jet Fan Mounting Head Loss Coefficient Set-Up
100-ft. Spacing
Blueridge Avenue Fan Shaft Test Site

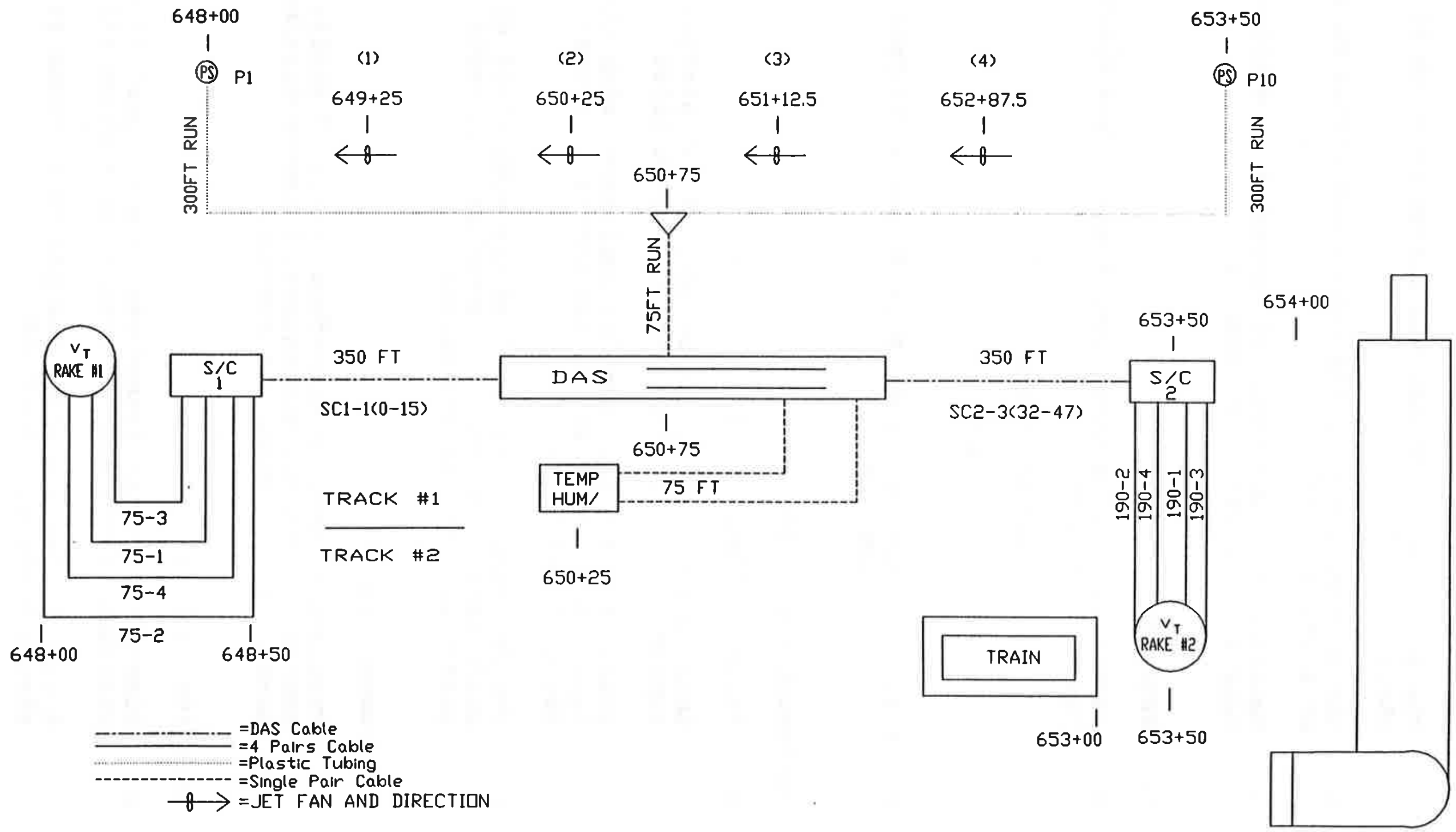


FIGURE F-20

- The pressure transducer was placed on Track #1 at station 650+75.
- The temperature/humidity sensor was placed on Track #1 at station 650+25.
- Readings from the handheld barometer were taken at or near station 650+75 on Track #1.

Test Sequence

- Tested for 1 flow condition, 4 shaft fans operating in the exhaust mode.

Damper Closed

1) BRD100

F.5.2.2. Exhaust Mode With Train - 75-Foot Jet Fan Spacing

Equipment Locations

- Refer to Figure F-21.
- Located a one-car train on Track #2 at station 653+00, approximately 100 feet from the shaft inlet.
- Placed the jet fan mounting equipment, with the jet fans, on Track #1 at station 649+12.5, 649+87.5, 650+62.5 and 652+37.5.
- The dead-end tunnel provided the equivalent of a fan shaft isolation damper. Therefore, all tests were performed with dampers closed.

Instrumentation Used

- Provided 2 traverse transducer rakes, 2 static pressure probes, 1 pressure transducer, 1 temperature/humidity sensor, and 1 handheld barometer.

Location Sensors

- Placed a traverse transducer rake on Track #2 at stations 653+50 and on Track #1 at station 648+00.
- A static pressure probe was placed on Track #1 at stations 648+00 and 653+50.

Jet Fan Mounting Head Loss Coefficient Set-Up
75-ft. Spacing
Blueridge Avenue Fan Shaft Test Site

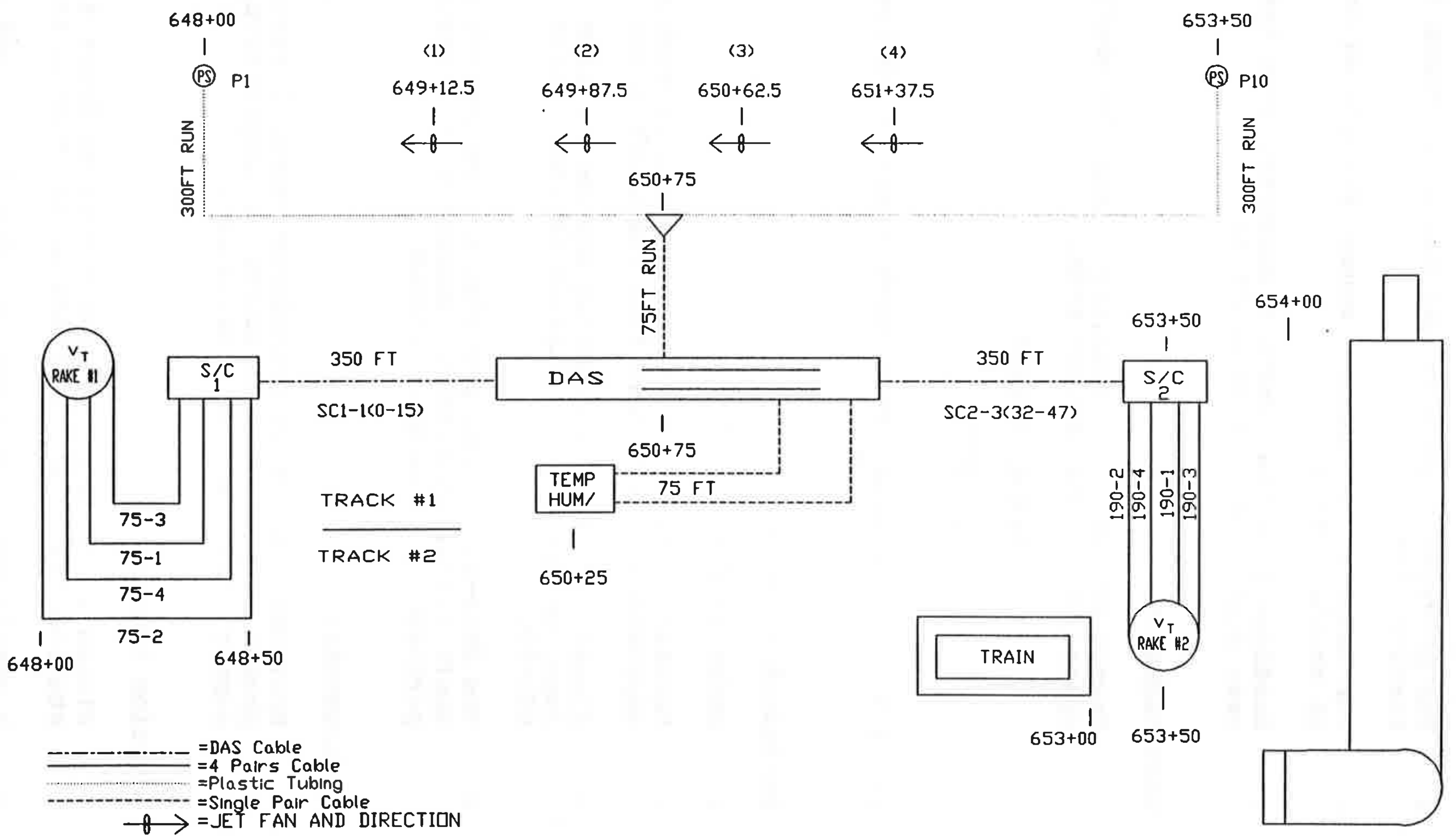


FIGURE F-21

- The pressure transducer was placed on Track #1 at station 650+75.
- The temperature/humidity sensor was placed on Track #1 at station 650+25.
- Readings from the handheld barometer were taken at or near station 650+75 on Track #1.

Test Sequence

- Tested for one flow condition, four fan shaft fans operating in the exhaust mode.

  Damper Closed

  1) BRD75

F.5.2.3 Exhaust Mode With Train - 50-Foot Jet Fan Spacing

Equipment Locations

- Refer to Figure F-22.
- Located a one-car train on Track #2 at station 653+00, approximately 100 feet from the shaft inlet.
- Placed the jet fan mounting equipment, with the jet fans, on Track #1 at station 650+00, 650+50, 651+00 and 651+50.
- The dead-end tunnel provided the equivalent of a fan shaft isolation damper. Therefore, all tests were performed with dampers closed.

Instrumentation Used

- Provided 2 traverse transducer rakes, 2 static pressure probes, 1 pressure transducer, 1 temperature/humidity sensor, and 1 handheld barometer.

Location Sensors

- Placed a traverse transducer rake on Track #2 at station 653+50 and on Track #1 at Station 648+00.
- A static pressure probe was placed on Track #1 at stations 648+00 and 653+50.

Jet Fan Mounting Head Loss Coefficient Set-Up
50-ft. Spacing
Blueridge Avenue Fan Shaft Test Site

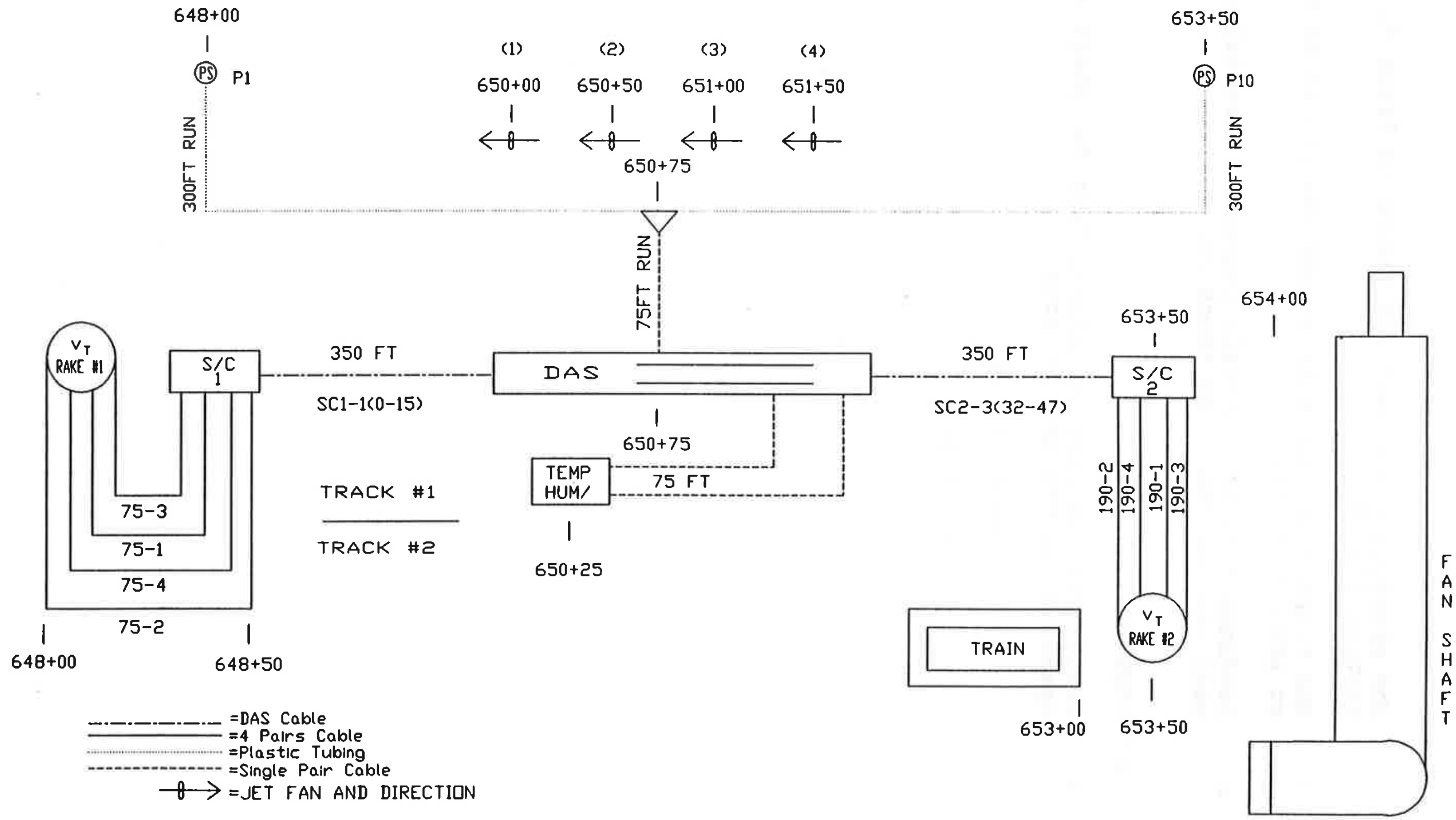


FIGURE F-22

- The pressure transducer was placed on Track #1 at station 650+75.
- The temperature/humidity sensor was placed on Track #1 at station 650+25.
- Readings from the handheld barometer were taken at or near station 650+75 on Track #1.

Test Sequence

- Tested for one flow condition, four fan shaft fans operating in the exhaust mode.

Damper Closed

1) BRD50