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Test Plan: Fire and Thermal Characteristics of Mayport 19F Trainers

Robert S. Levine
William Rinkinen

U.S. DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
(Formerly National Bureau of Standards)
National Engineering Laboratory
Center for Fire Research
Gaithersburg, MD 20899

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Sponsored by:
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Abstract

Equipment and procedures are described for taking data during hot fire tests of prototype Navy Fire Fighter Trainers at the Mayport Naval Station, Jacksonville, Florida. Gas and wall temperatures, radiant fluxes, ventilation flow velocities, and gas composition will be measured. The data will be used to validate or improve a mathematical model which can be used as a design tool for future facilities.

Key words: Compartment modeling; fire trainers; Mayport; Navy trainers; test plan.

1. Scope and Goal

Reference [1] states that the Center for Fire Research will perform a series of engineering research calculations and investigations of relevant fire phenomena important to the design, operation, safety, and reliability of the U.S. Navy's new generation of firefighting trainers - 19F Series.

The goal of this effort is to provide fire science support for the design, acceptance and safe operation of firefighting trainers and facilities.

2. Objectives

Tasks, including those below, will be selected in consonance with engineering personnel at the Naval Training System Center (NTSC), Orlando, Florida. This work statement will be continually evaluated and may be modified as indicated by intermediate results.

A. Measure temperatures, radiant fluxes, oxygen concentrations, and possibly other environmental parameters during acceptance tests and early operation (as needed to acquire the data) of the 19F Series of Trainers at the Fleet Training Center, Mayport Naval Station, Mayport, Florida.

B. Analyze the results of Task A, and furnish a report on those results, with conclusions of their meaning with regard to providing a realistic and safe training experience for the trainees.

C. Improve and modify as necessary relevant NIST-CFR predictive computer programs so that they can accurately reproduce the measurements in Task A. These programs will then be used to:

1. Fill in temperatures, radiant fluxes, and other environment conditions in areas of the trainers that are not accessible to measurement.

2. Provide the Navy with validated tools (computer programs) that can be used for future designs.

D. Accompany Navy personnel, at their request, to firefighting facilities and to technical meetings as a technical consultant.

3. Introduction

The 19F series of Naval firefighting trainees are designed not only to give the trainers an opportunity to learn, under realistic fire conditions, the identification and extinguishment of Class A, B, and C fires, but also to provide safety if they make a mistake. This is accomplished by burning propane gas in the specially designed "fireplaces" in the facility, and controlling the flow of fuel either automatically, responding to the trainees' actions; or by the instructional staff, if necessary, to prevent injury. Since propane fires do not create smoke, realistic smoke obscuration is created (total obscuration at 1 meter) by smoke generators.

Currently installed at the Mayport, Florida, Navy Base are prototypes of the 19F1A Advanced Trainer, and the 19F3 Basic Firefighting Trainer. Measurements and analysis described in this report will be performed on these trainers.

The 19F1A trainer (Figure 1) simulates a bilge fire, a bilge-oil spray fire, a deep fat fryer/stack hood fire, electrical panel, clothes dryer, vent duct, trash can, mattress, storage room, metal storage locker, motor/generator, and wire bundle fires.

The 19F3 trainer consists of four buildings designed for training basic fire fighting techniques, and so the compartments are larger than in the 19F1A to accommodate more students/class.

The 19F3-B1 building (Figure 2) simulates a bilge fire situation with two fire locations (bilge burning in two areas) separated by obstructions. One bilge "fireplace" contains an oil-spray fire. The 19F3-B2 building (Figure 3) simulates mattress, metal storage locker, deep fat fryer, cable way, and electrical panel fires. The 19F3-B3 and B4 (Figure 4) are very large compartments simulating a pit fire (15 ft x 15 ft) with 12 ft high flames. The pit fires are not duplicated on the 19F1A.

In each of these trainers two things must be established in each compartment. We want to make certain that foreseeable accidents, such as a trainee losing his breathing apparatus, will not cause severe injury to him; we want to collect data to evaluate and improve the validity of mathematical compartment fire models that will be useful to NTSC for future trainer designs. We welcome NTSC's comments and suggestions for improvement of this test plan.

4. Overview of Compartment Fire Models

Currently two computer compartment fire models exist at the NIST, Center for Fire Research, that are likely to be useful to NTSC. Both are available on floppy disks that will run on IBM-compatible personal computers. These are FIRST6X, a growth model of the Harvard 5 Single Room Fire Code, (developed at Harvard University under grant from NIST-CFR), and FAST 18 (developed at NIST-CFR).

Input data required for the models are:

- Dimensions of the compartment.

- Propane gas flow rate (vs. time) to the burner(s).

- Heat of combustion of the gas.

- Stoichiometry of the combustion (to calculate oxygen content)

- CO fraction in the burned gases.

- Sizes and location of all vents (doors, windows, etc.).

- Forced ventilation flow rate.

- Physical details of the walls, ceiling, floor.

- Materials of the walls, ceiling, etc.

  (These latest versions of both programs will calculate time-dependent temperatures of multi-layer walls).

- FIRST will calculate the temperatures (and ignition, if flammable) of up to 5 other objects in the room. These objects are called "Targets". The dominant mode of heating of these objects is thermal radiation from the fire, the plume, hot walls, and hot ceiling layer gas.

- FAST 18 calculates a radiant flux to the floor, that can be integrated to determine when an object (target) on the floor reaches ignition temperature.

Both programs assume a two-layer atmosphere in the compartment. There is a cold lower layer, and a hot upper layer formed by the hot fire gases and the air entrained with them in the fire plume. The boundary between these two layers is assumed sharp. Each layer is a "zone", or "thermodynamic control volume", and the program solves heat, momentum, and mass transfer equations between all zones.

This sharp transition from a cold lower layer to a hot ceiling layer is probably not realistic for the trainer compartments. With high ventilation rates, there will be a transitional boundary layer between the layers. In previous work in real facilities we have found the calculated layer height usually corresponds to the height at which we measure a temperature increase of 10 to 15% of the maximum temperature (upper to lower) difference. Knowledge of this "boundary layer," its height, gradient, and gas composition are crucial to the evaluation of hazard in the trainers. If we calculate a ceiling layer height as 5 ft above the floor, it does not mean a 6 ft tall trainee breathing the gas would be quickly overcome if the calculated ceiling layer gas has hazardous CO and temperature. He could be safe if the increase at that level were significantly less than the upper layer conditions. It will be necessary to establish what these conditions are.

Therefore, the following data will have to be measured in each applicable compartment.

- Gas temperature at a number of distances between the floor and the ceiling (say 10 levels).

- Gas composition (O_2 and CO content) at nose height.

- Thermal radiation fluxes at locations that would be occupied by trainees.

- Wall temperatures and structure temperatures, where significant for structural considerations, or for injury to the trainees.

- Ventilation flow rates. (The calculations will be sensitive to these.) It cannot be assumed that actual flows will be those stated on the fan nameplate since flows are affected by the ducting and the fan installation. Hence, duct flow rates will have to be measured.

The model calculations will automatically give radiant fluxes to targets, and the radiometer results will be compared to these.

5. Test Equipment[1]

A "step van" vehicle has been outfitted with shock mounted racks for instruments, equipment, storage for tools, wire, sensing tubing, other end-item instruments, and a workbench. The van will be driven to Mayport.

Most data will be collected and initial calculations performed by a Hewlett Packard 3497A Data Acquisition/control unit (commonly called a scanner). The HP instrument will be controlled by an IBM PC-XT computer which will perform the initial calculations. Data will be recorded in the hard disk (or floppy) of the PC, and printed out by a printer in the van.

[1] Certain commercial equipment or instruments are identified in this paper. This does not imply recommendation or endorsement by NIST, nor does it imply that the equipment identified is necessarily the best available for the purpose.

Another IBM PC-XT computer will be carried in the van as a spare, and to run the FIRST 6X and FAST 18 programs for a first-look comparison of experimental data with calculated data. It is possible that the existing computer programs will match adequately the experimental data, but in our experience this is not likely. This "quick look" check, however, will make certain that there are no "holes" in the data when we later modify the computer programs so that they give dependable answers.

Figures 5, 6, and 7 show the HP3497A and the interior of the van. Figures 8, 9 and 10 show typical data.

6. Cold Ventilation Flow Measurements

As previously mentioned, the ventilation flows must be accurately measured to achieve accurate compartment fire modeling. We understand it is not unusual for the actual volumetric flow rate to differ from the nameplate rates by 20%. It would be best, of course, to make this measurement during a hot test but this is impossible. The reason is that the flow velocity will need to be measured at a number of places in the duct to account for the flow profile in the duct, and it is impractical to install a set of rakes of velocity and temperature probes needed to get all the data in a 5 minute hot test.

Instead we measure the velocity profile in each facility cold, then take advantage of the fact that centrifugal blowers tend to be nearly constant volume flow devices. Since in cold flow, we have adequate time, we use a single pitot tube at an array of positions inside each duct. Typically we made 5 traverses, 5 points per traverse (25 readings) per duct.

The sensing device is a precision water manometer, Figure 11, (precision water level readouts) fabricated at the NIST instrument shop for this kind of use. The use of this instrument avoids calibration and drift problems with electrical ΔP gages and possible electromagnetic interference from the large radar set nearby at Mayport.

The location for flow measurements on the 19F1A trainer is shown in Figure 12, the 19F3-B1 building in Figures 13A and B and the 19F3-B3 and B4 building in Figures 14A and B. Insertion of the "bidirectional" probe (Reference 3) is shown in Figures 15A and B.

From a survey at Mayport, September 9, 1988, a 5 ft shank on the bidirectional probe was determined to be long enough for all measurements. Holes had to be drilled in the ducts (5 each duct) to insert the pitot tube. The holes were plugged with commercially obtainable fittings after the test as a permanent repair.

These flow data were obtained in 3 days of running, using two CFR-NIST personnel with support, when needed, by Navy personnel.

7. Hot Test Data

A. Thermocouples

The bulk of the data obtained will be air and surface temperatures using thermocouples. We will use a standard Chromel-Alumel wire (30 ga. size) with no other wire in the circuit back to special thermocouple connectors into a terminal board in the instrument van. The terminal board is permanently wired to the scanner.

From one to four thermocouple "trees" will be used in each compartment. Each tree will consist of 10 or more thermocouples. Vertical spacing between thermocouples will be adjusted to obtain detailed data at the heights of interest for training, i.e., 7 of the thermocouples spaced 6 in apart from 3.0 to 6.0 ft above the deck. Test locations are listed in the Appendix.

We will also obtain at least one air temperature at the fan inlet for each run. Combined with volumetric flow data obtained earlier, this will enable us to calculate mass flow rates.

Where necessary, the concrete structure walls and ceilings of the trainers are protected by steel plates. We will use thermocouples to measure the steel temperature (vs. time) at typical locations.

Thermocouple wires generally will pass through the crawl spaces of the trainer, and up into the compartments through the floor grating. This will avoid damage that would be caused if they were walked on, and avoid interference with Navy training operations.

B. Gas Analysis

The instrument van will include (Figure 5) gas pumps, dryers, filters, and other hardware, along with oxygen meters and carbon dioxide/carbon monoxide meters. These will sense gas at the 5 ft level in each trainer compartment, as well as monitoring gas concentration in the vents (if possible). The gas samples will be ducted through copper and plastic tubing (depending on gas temperature). We want to determine whether, at that height, there are severe oxygen deficiencies, or significant amounts of carbon monoxide. We do not expect CO from the propane burners or the smoke generator but will make certain of this from measurement. The data will feed into the scanner, and be recorded by the computer. Data analysis should include comparisons with data collected using the analyzer built into the control system of the trainer.

C. Radiometers

Medtherm wide angle radiometers will be used to measure the radiant flux that will impinge on the trainees at locations they are likely to occupy during training. These devices are water cooled, and the output signal is affected by water temperature. Therefore, the cooling water (a small flow) will be supplied from a pressurized water tank in the instrument van. The (thermopile) output, again, will be fed to the scanner and hence to the computer. Low level heat flux transducers of the Schmidt-Boelter (SB) thermopile type will be used for lower level radiant feedback. For monitoring higher level heat fluxes the SB will be replaced with the Gardon type heat flux sensor.

D. Readout

Following a test the accumulated data will be recorded on a floppy disk for future analysis, and printed on a printer in the van after raw data has been reduced to useable information. Selected data will be plotted at Mayport to determine whether it is reasonable and also whether it agrees with computer printouts of the same variables from FIRST6X. The floppy disks, one for each test, will be the primary data for future analysis.

E. EMI Interference

Data will be taken in the shadow of large radar at Mayport. Although it is not likely that there will be a pickup problem in the low impedance (balanced ground) thermocouple wires, there is a chance for EMI interference with the instruments in the van.

To obviate this, the metal walls of the van will be grounded at the facility. If necessary aluminum foil sheets will be used to augment the shielding at windows and doors of the van. It may also be necessary to wrap the bundles of thermocouple wire with aluminum foil, and connect it to the guard lead of the scanner.

8. Documentation

Measurements and results will be documented in a report of the test (or separate reports for each trainer if NTSC so desires). Duplicate floppy disks of the data will also be provided to NTSC, along with floppy disks with validated compartment fire model software.

9. Schedule

The following schedule is tentative because of uncertainties in the hot test timing:

A. Cold duct flow measurements

October 12-14, 1988 at Mayport.

B. Hot Measurements

During Navy acceptance tests at Mayport. Date to be determined, but likely, February 1989.

C. Data analysis

Proceed promptly following the hot tests. Figure 8, temperature vs. time; Figure 9, heat flux; Figure 10, gas concentrations will be typical of the reduced data plots of test that have been completed for each training compartment.

D. Reports

Monthly progress reports starting November 1, 1988. Final report at the conclusion of data analysis (approximately 60 days after final test).

10. Summary

We have described, in outline, the data to be obtained, and how that data will satisfy the input requirements for the two existing compartment fire models. The data will also be adequate to validate the calculations of the models (or improvements to the models), and will also be useful to NTSC to assure realism and safety.

The final, validated model (or models) will be operable on IBM-PC computers, and will be delivered to NTSC for possible use as design tools. The Center for Fire Research recognizes an obligation to work with NTSC in benefitting from the models, and hopefully continuing to be of service to NTSC in this important fire fighter trainer program.

11. References

1. (MIPR N6133988MP80009) dated January 29, 1988 from Commanding Officer, Naval Training Systems Center, Code 5, Orlando, Florida 32813-7100.

2. Fire Fighting School Facilities Criteria, Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia, March 1987.

3. McCaffrey, B. J., and Heskestad, G., "A Robust Bidirectional Low Velocity Probe for flame and Fire Application," Combustion and flame, Vol. 26, 125-7 (1976).

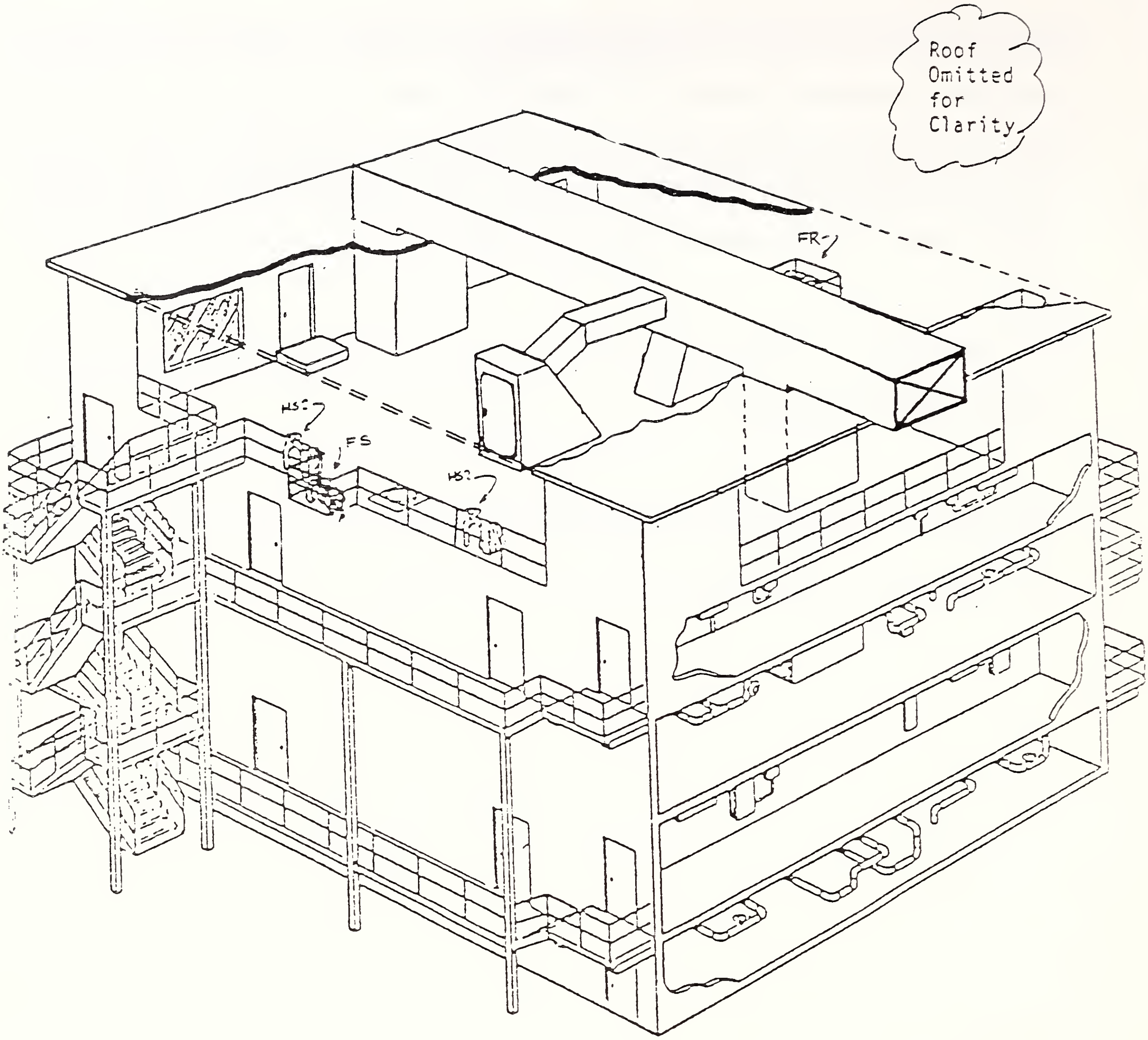

Figure 1. The 19F1A Training Structure

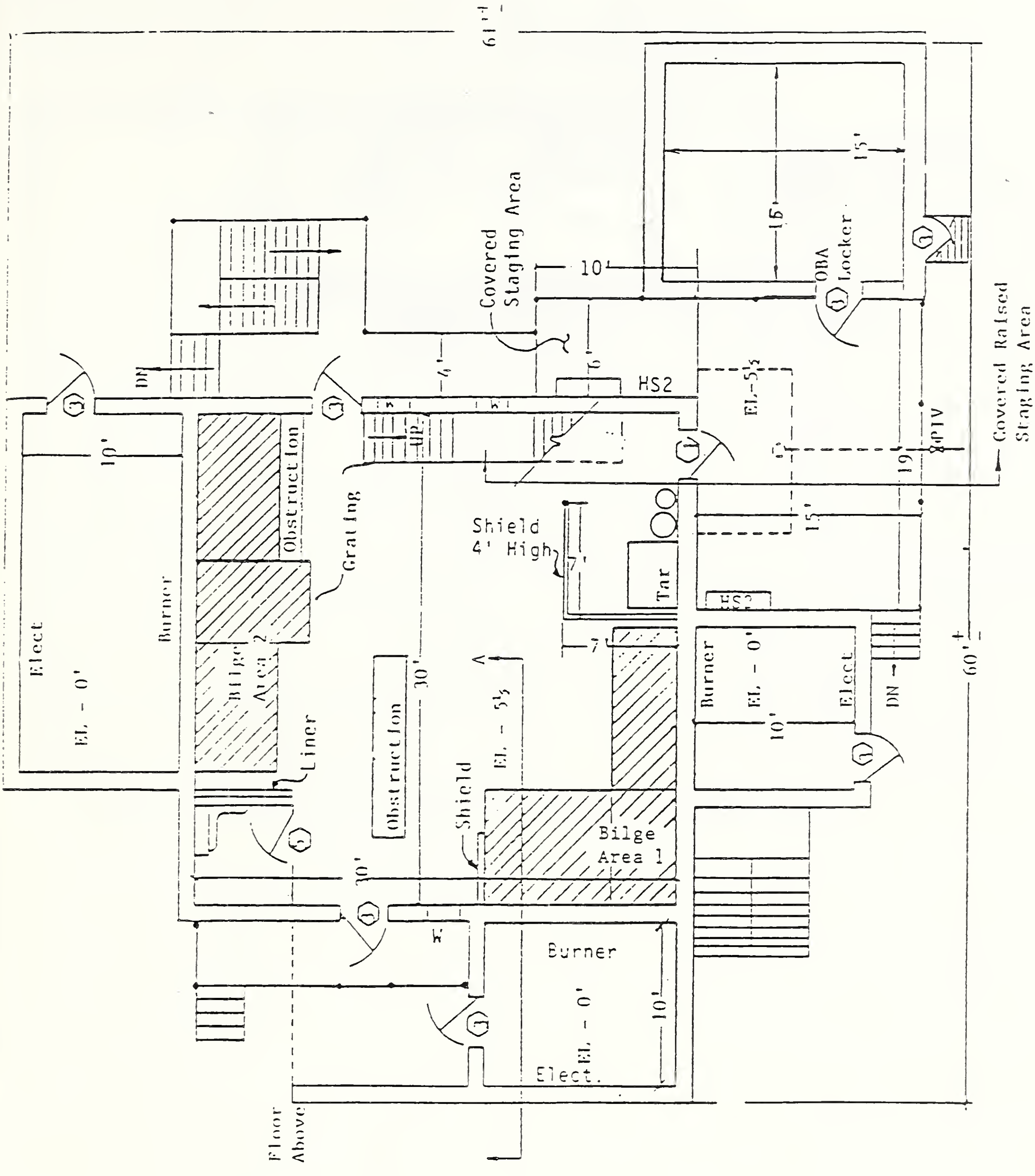

Figure 2. The 19F3-B1 Training Structure
Lower Level Floor Plan

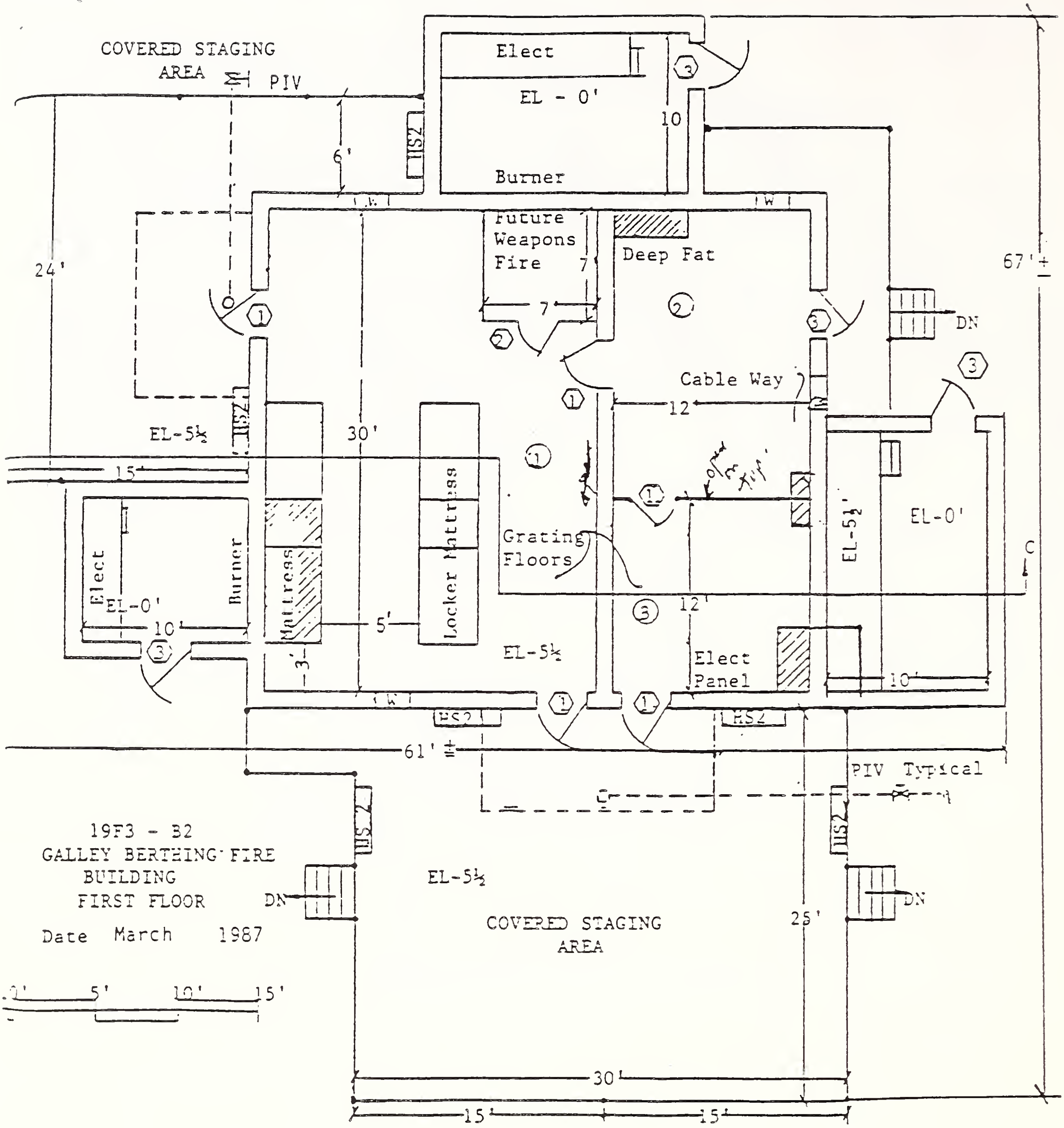

Figure 3. The 19F3-B2 Training Structure First Floor Plan

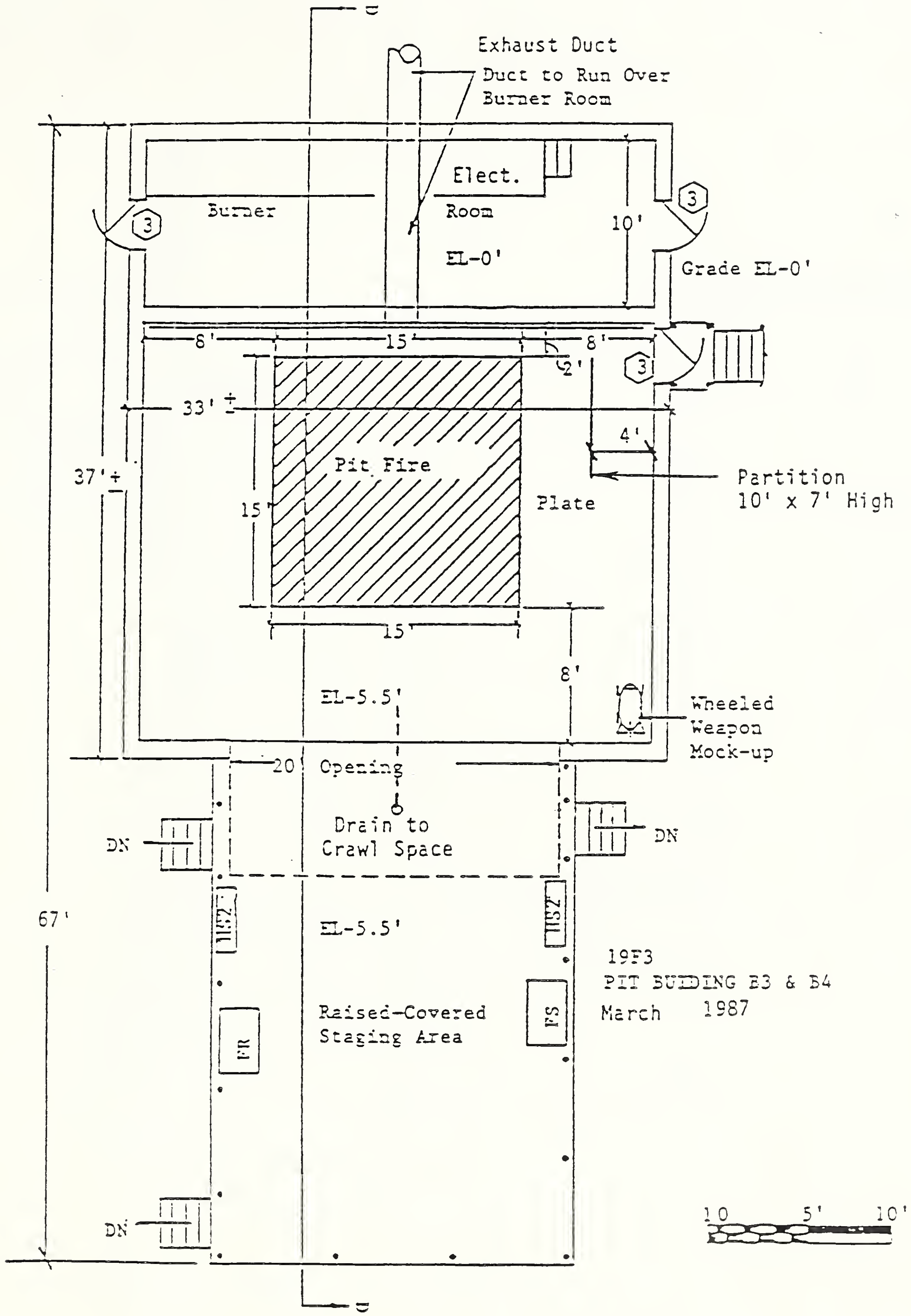

Figure 4. The 19F3-B3 & B4 Training Structure
Pit Building Floor Plan

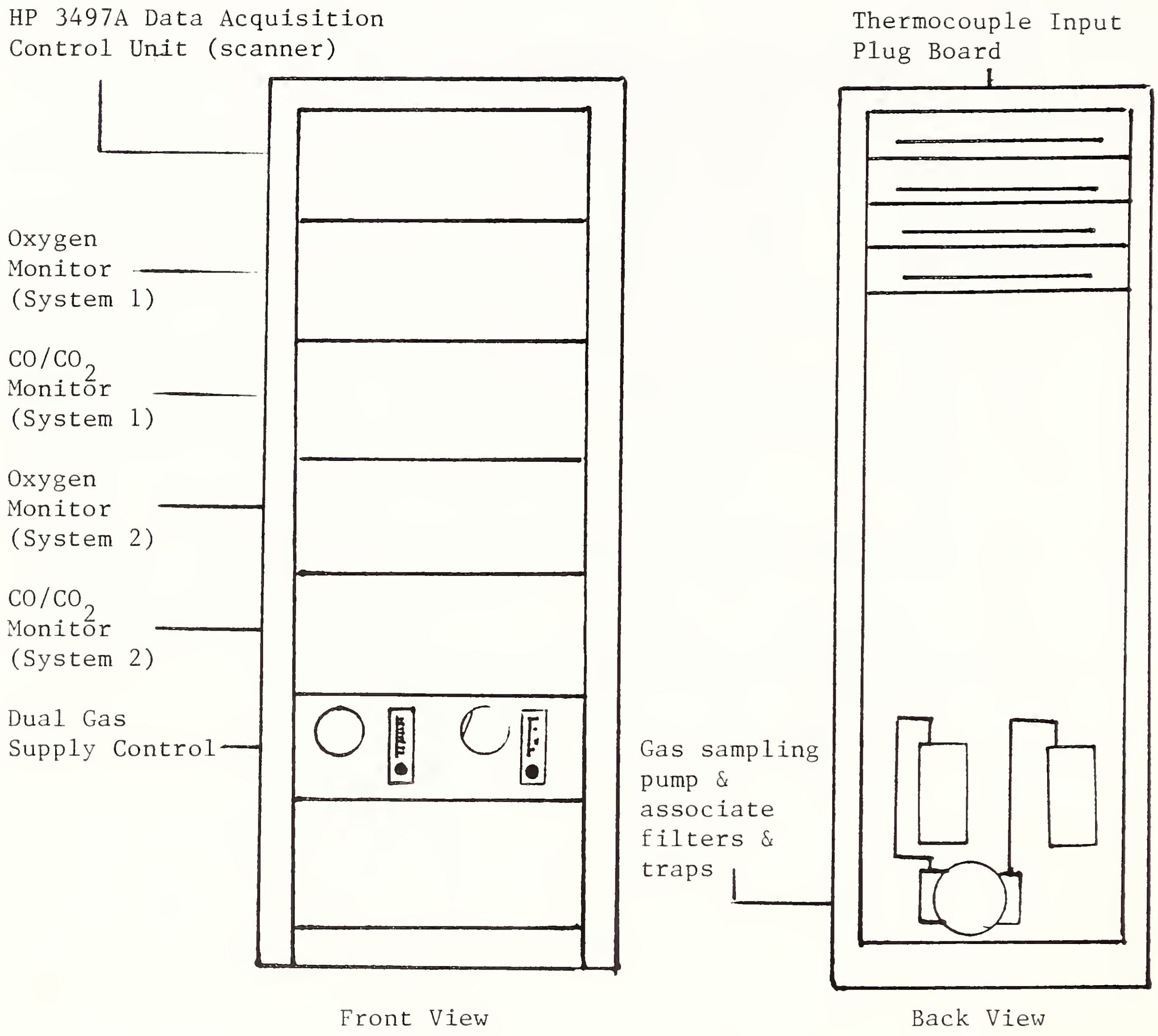

Figure 5. Instrumentation Rack (shock mounted)

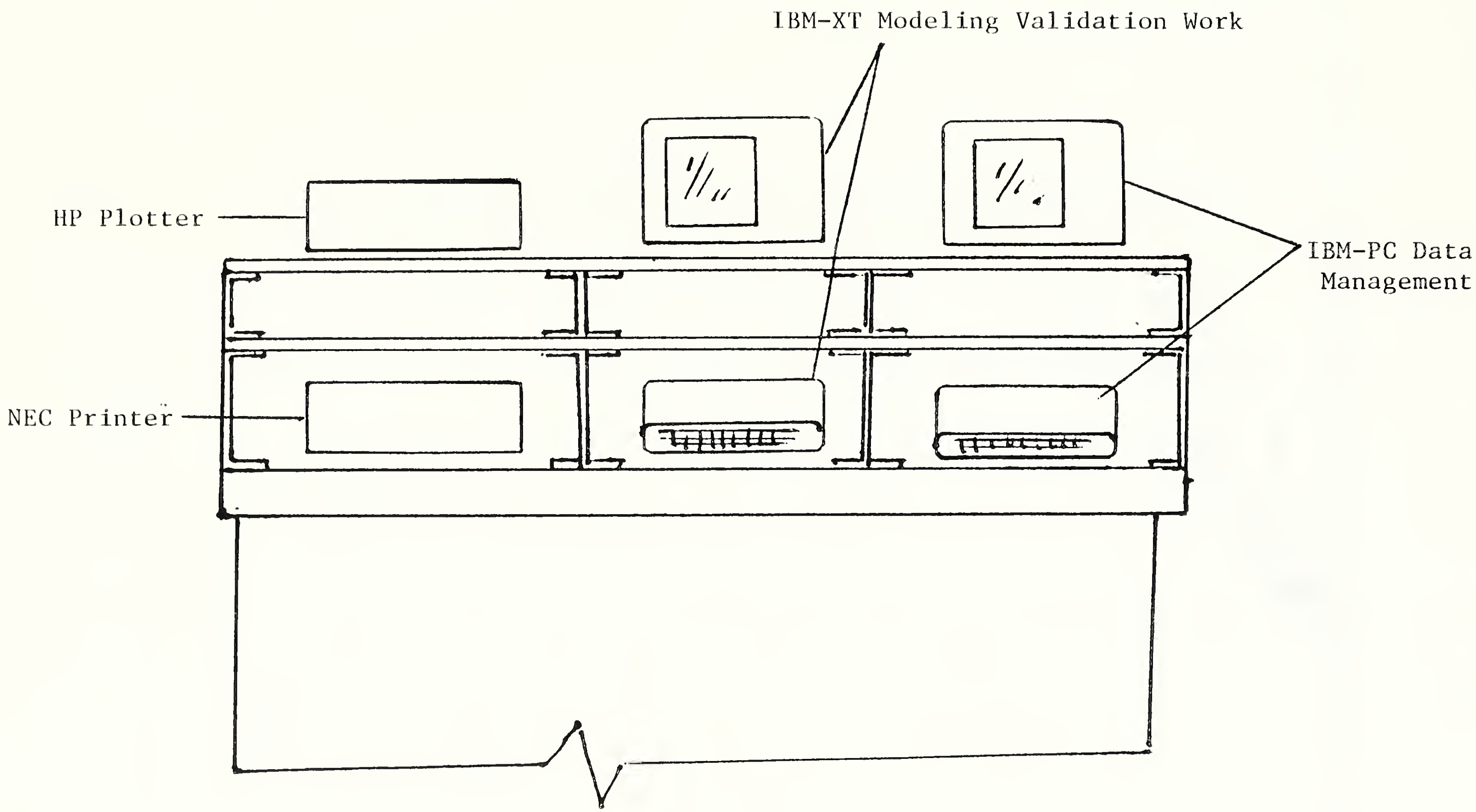

Figure 6. Left Side Van Data Management Control Area (shock mounted)

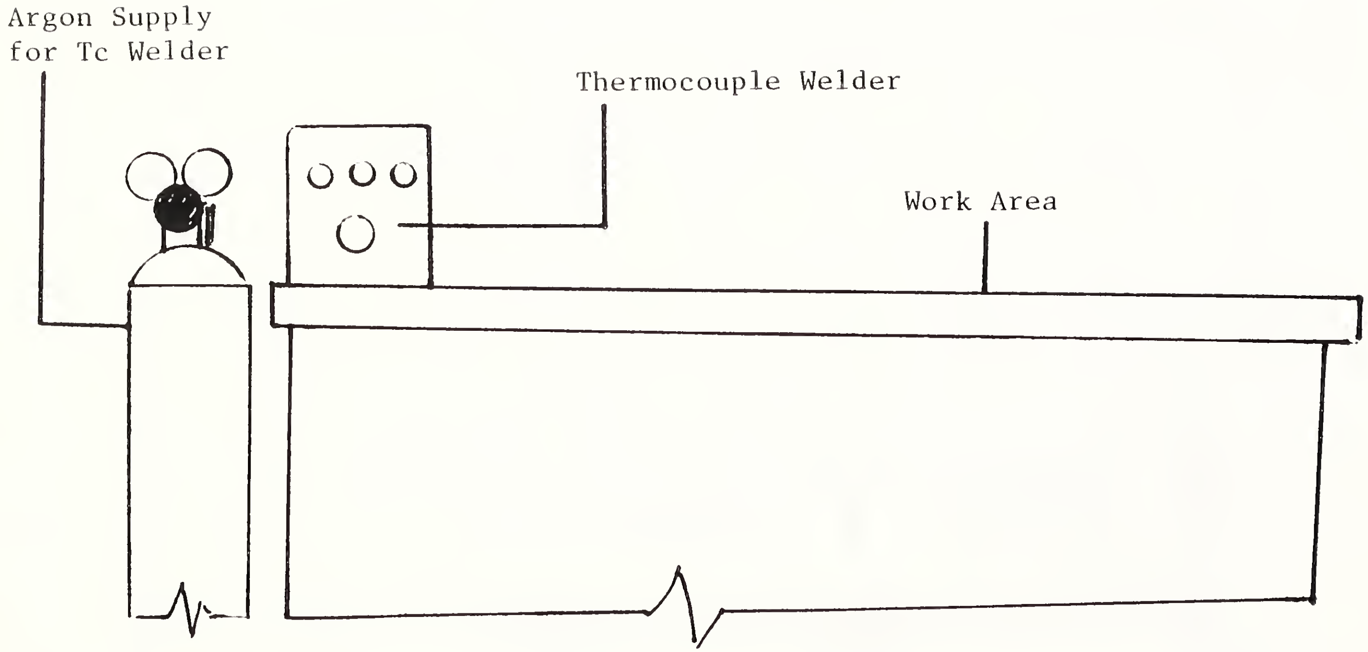

Figure 7. Right Side Van Instrumentation Fabrication Location

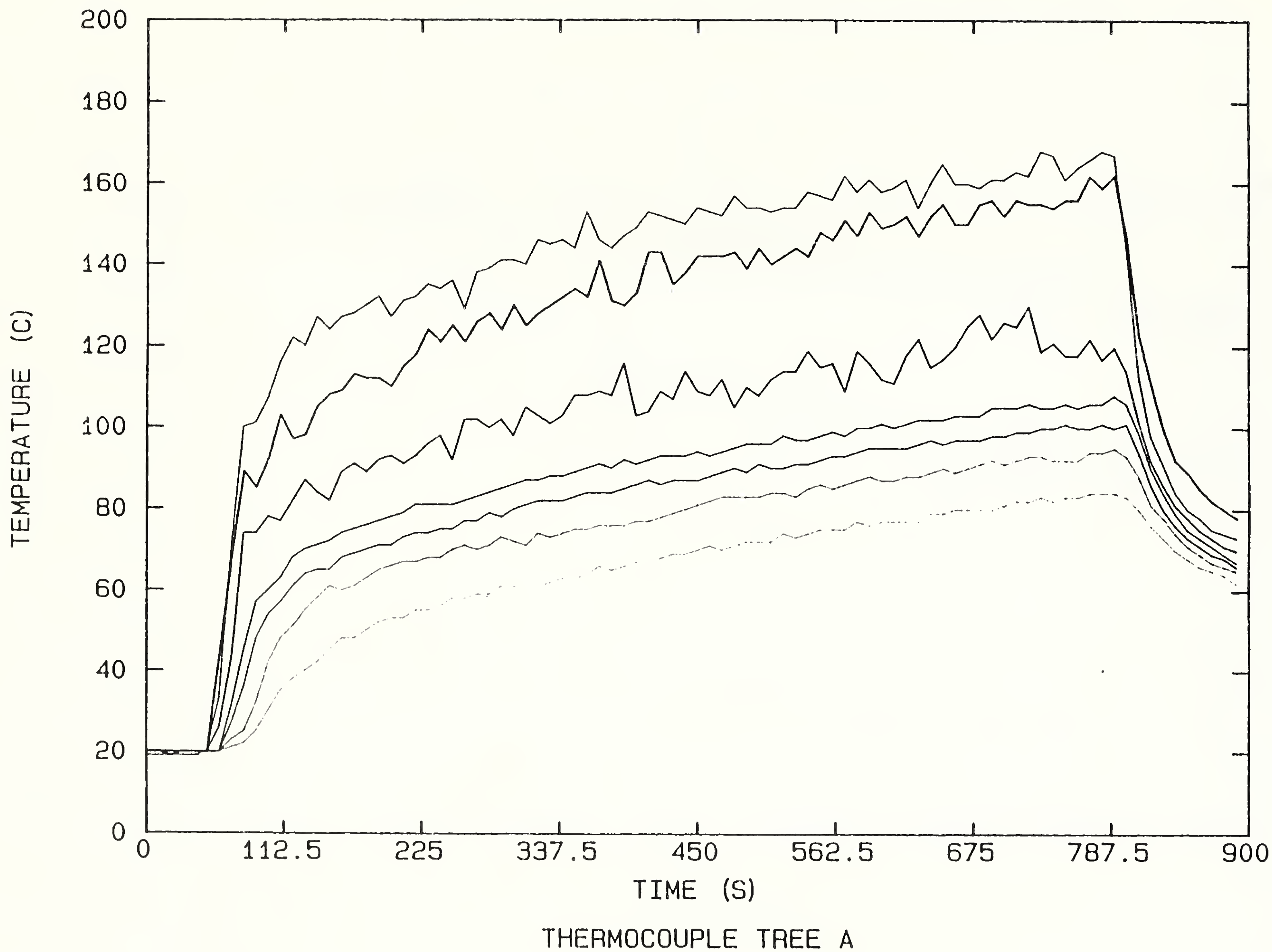

Figure 8. Typical Plot of Temperature vs. Time for a Seven Thermocouple Tree

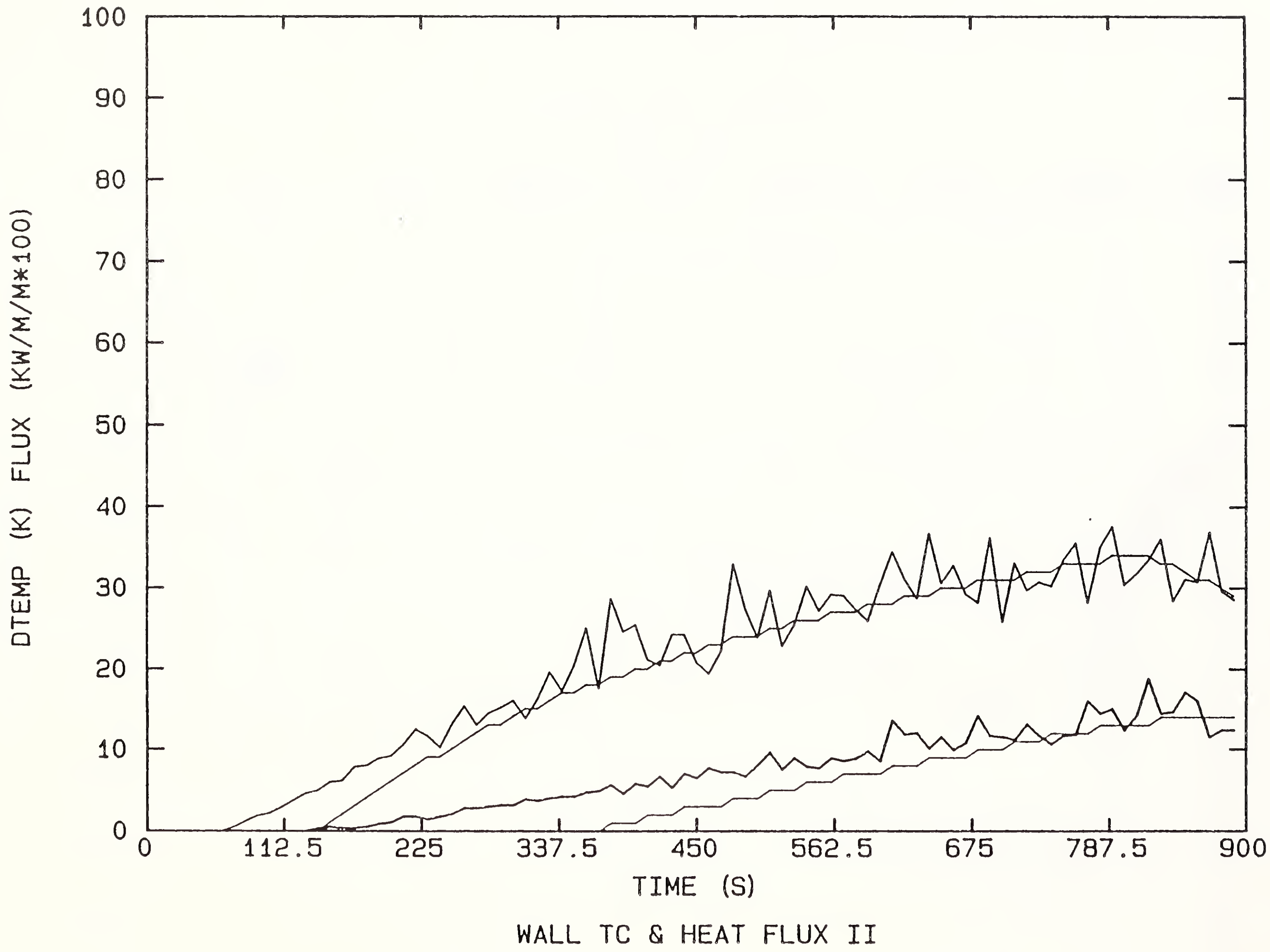

Figure 9. Typical Plot of Wall Thermocouple and Heat Flux (Temperature may be placed on a different plot for clarity)

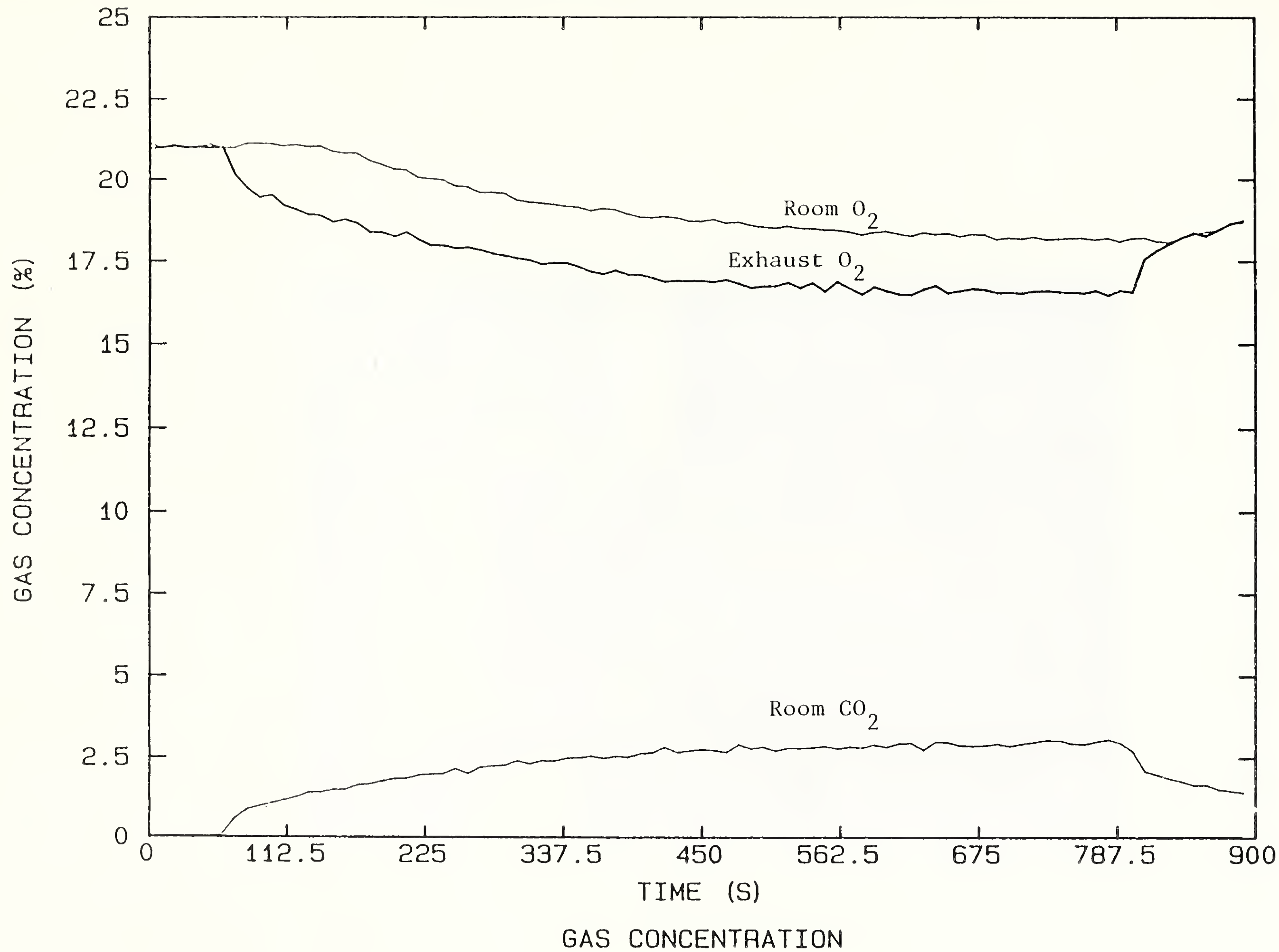

Figure 10. Typical Gas Concentration Plot

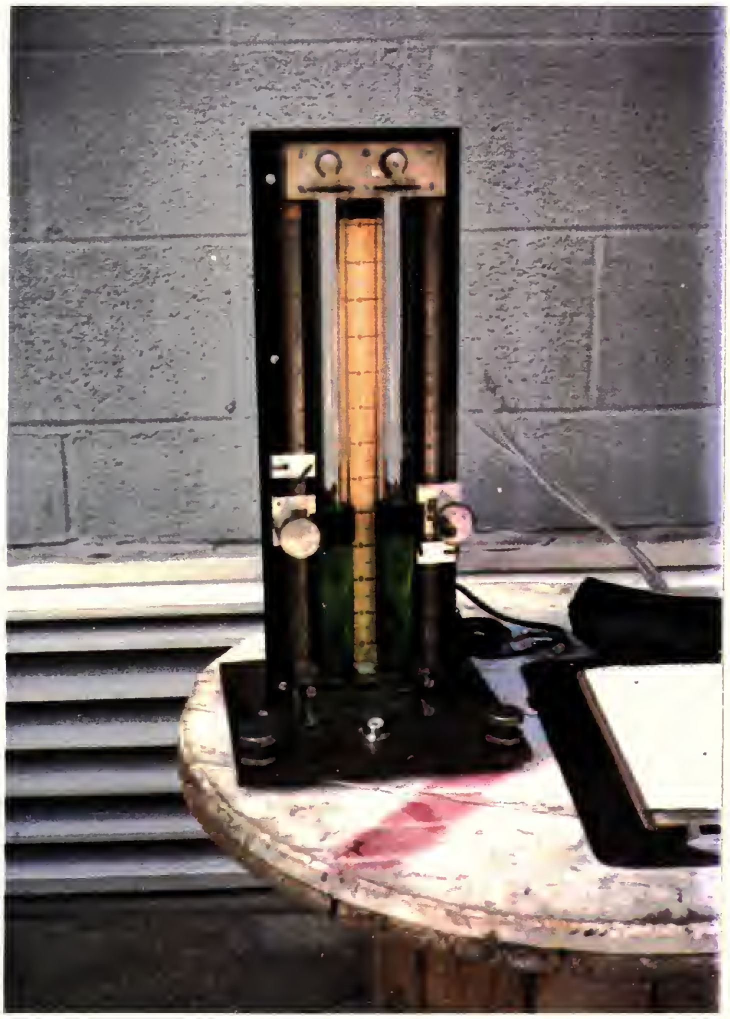

Figure 11. Precision Manometer

Figure 12. 19F1A - Duct Flow Measurement Sites

Figure 13A - vent Ducts on 19F3-B1

Figure 13B - Holes for Flow Measurement 19F3-B1

Figure 14A - 19F3-B4 Ventilation Ducts

Figure 14B. Measurement Locations, 19F3-B4

Figure 15A. Typical Hole for Pitot Tube

Figure 15B. Tube Guided Through Hole by Magnetic Flange

Appendix

Typical Instruments

Location	Thermocouple Tree	Data Chan	Scan Local	Data Card
Test room	1	0-9	A0-A9	#1
" "	2	10-19	B0-B9	#1
" "	3	20-29	A0-A9	#2
" "	wall	30-33	B0-B3	#2
" "	ceiling	34-37	B4-B7	#2
" "	duct	38-39	B8-B9	#2
Duct gas	O_2	40	A0	#3
" "	CO_2	41	A1	#3
" "	CO	42	A2	#3
Test room	O_2	43	A3	#3
" "	CO_2	44	A4	#3
" "	CO	45	A5	#3
Heat flux	rad 1	46	A6	#3
" "	rad 2	47	A7	#3
Expansion		48-59	A8-B9	#3

NOTE: Channel order may change in final test extra thermocouples will be placed after present TC's

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

Equipment and procedures are described for taking data during hot fire tests of prototype Navy Fire Fighter Trainers at the Mayport Naval Station, Jacksonville, Florida. Gas and wall temperatures, radiant fluxes, ventilation flow velocities, and gas composition will be measured. The data will be used to validate or improve a mathematical model which can be used as a design tool for future facilities.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Compartment modeling; fire trainers; Mayport; Navy trainers; test plan

13. AVAILABILITY

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