OSU Heat Release Rate NBS Smoke Density General Overview

2012 Collaborative Meeting Singapore

Michael Burns, FAA Tech Center

February, 2012

AGENDA

- Scope
- Definitions
- Principle of the Method
- Apparatus
- Test Specimen
- Calibration Procedure of Equipment
- Preparation/Performance of Test
- Presentation of Results/Requirements/Report
- NBS Smoke Density

SCOPE

TEST METHOD

http://www.fire.tc.faa.gov/handbook.stm

•Compliance with requirements of FAR 25.853.

•Heat release rates by materials and products when exposed to one level of radiant heat.

•Measures and describes properties of materials in response to heat and flame under controlled laboratory conditions

•Measures heat release from injection, period of ignition and progressive flame involvement of the surface.

DEFINITIONS

Heat Release (2-Minute Total)

Amount of heat energy evolved ($kW \cdot min/m^2$)

Heat Release Rate (Peak)

Rate of heat energy evolved (kW/m^2)

Maximum heat release rate occurs when the material is burning most intensely

Heat Flux Density

The intensity of the thermal environment the specimen is exposed to when burned ($3.5\ W/cm^2$)

DEFINITIONS

Thermopile

Generates thermoelectric current

Temperature difference - entering / exiting

Increase gas temperature - proportional to heat release

Integrating data over time = total heat release

Calibration Factor (Kh)

Burning known flow rates of Methane (mv)

Heat released (specimen) = Heat content of Methane.

Methane Gas (CH4)

Burners / Calibration gas (99% Purity)

PRINCIPLE OF THE METHOD

- Constant air flow
- Radiant heat source - desired heat flux
- Vertical orientation
- Point ignition / ignition of evolved gases
- Heat release rate = Changes in exhaust temperature

HEAT RELEASE RATE APPARATUS

Ohio State University (OSU) heat release rate apparatus - modified (ASTM E906)

3 Main Sections:

Holding Chamber

- Holding area prior to testing
- Injection mechanism slides through outer door
- Door = sealed, hinged

HEAT RELEASE RATE APPARATUS

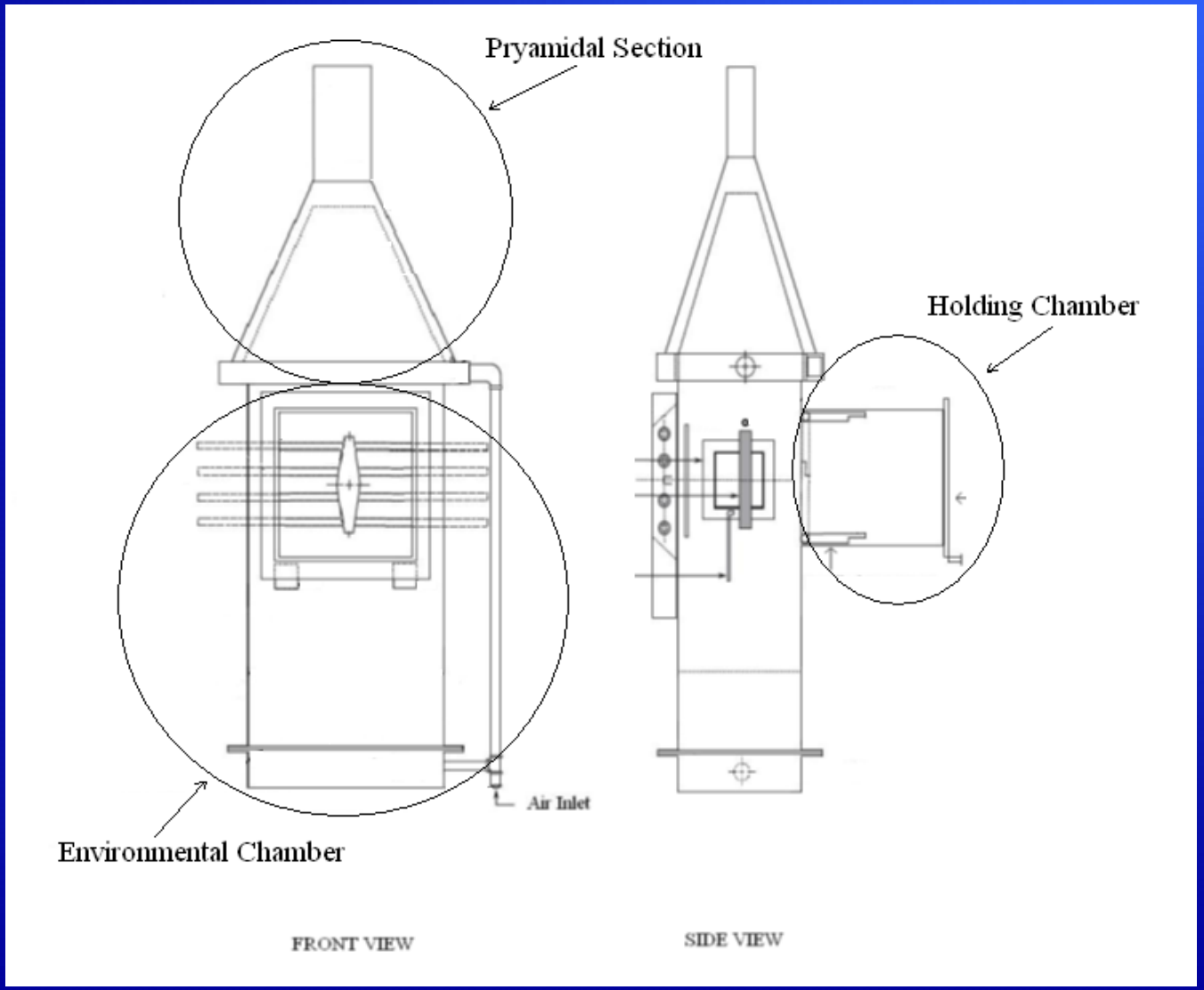
Environmental Chamber

- Radiant heating elements (Globars)
- Reflector plate and diamond shaped mask
- Upper and Lower pilot burners
- Air distributor plates (2)
- Cold Zone Thermocouples (Thermopile)
- Two-part hinged insulated radiation door assembly
- Heat resistant viewing window

Pyramidal Section

- Chimney or exhaust stack
- Cooling manifold - releases constant temperature air between two inner and outer cone sections
- Baffle plate - facilitates mixing of air as it exits the chimney (Hot Zone Thermocouples)

FAA OSU Rate of Heat Release Main Sections



COMPONENTS

Radiation Source

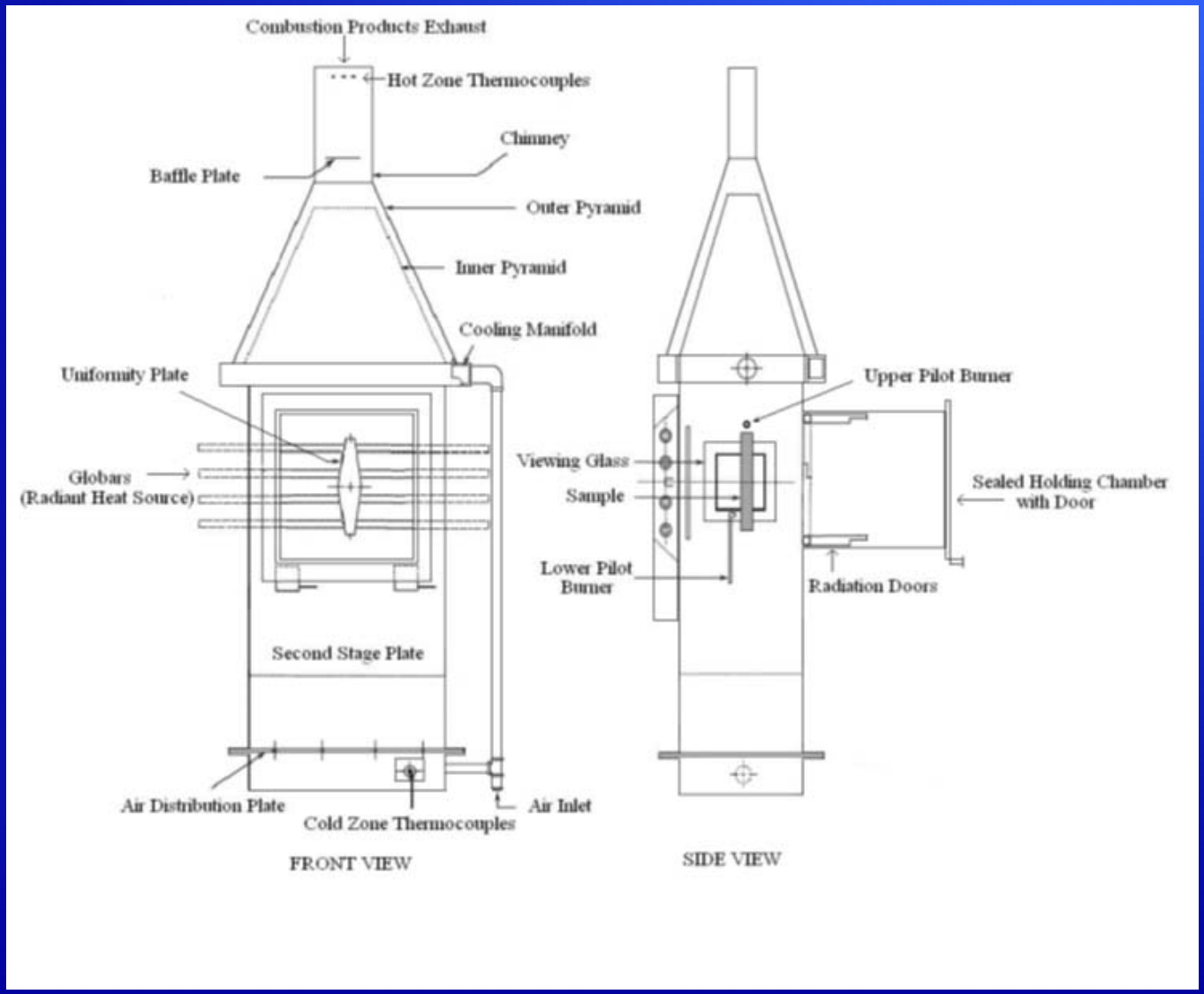
- Adjustable power supply
- Four Silicon Carbide (SiC) elements
- Diamond-shaped mask / reflector plate

Thermopile

- Type K, 24 gauge wire
- 5 hot zone thermocouples, 4 cold zone thermocouples, reference junction
- Thermocouple bead - 0.050 ± 0.010 inch (1.3 ± 0.3 mm) in diameter
- Free of insulation for a minimum of 0.75 inch (19 mm).

Lower / Upper Pilot Burner /Igniter System (Optional)

FAA OSU Rate of Heat Release Components



RADIANT HEAT COMPONENTS

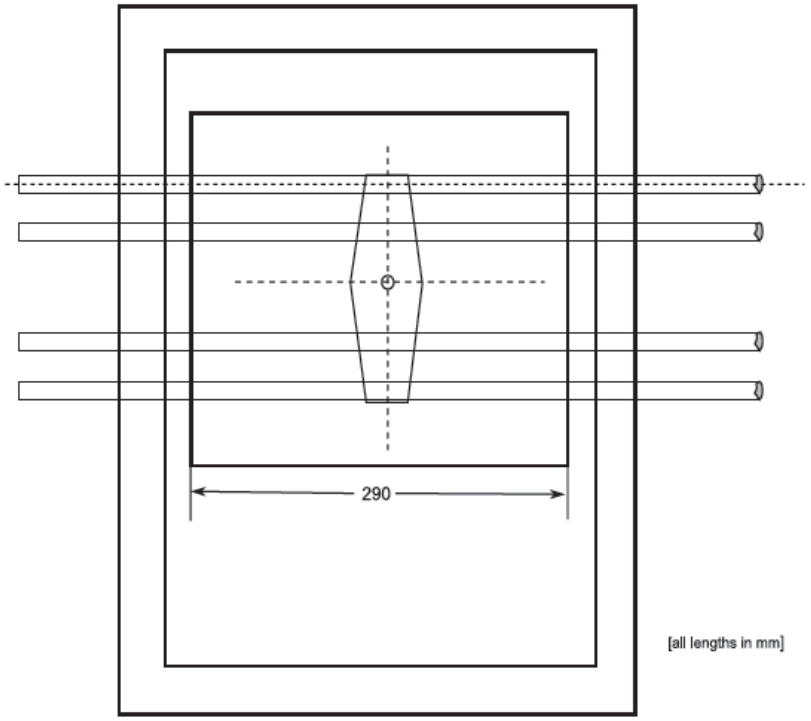


Figure A.4 – Radiant heat panel (front view)

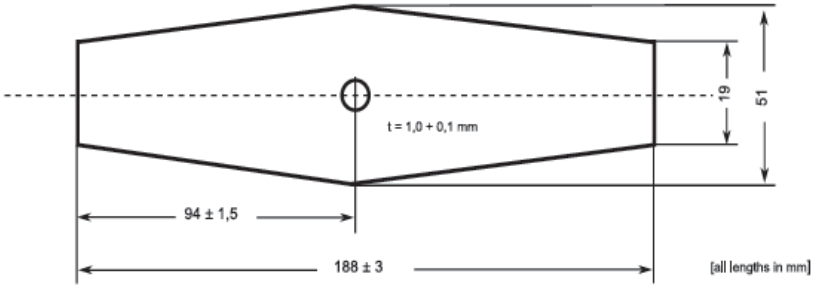
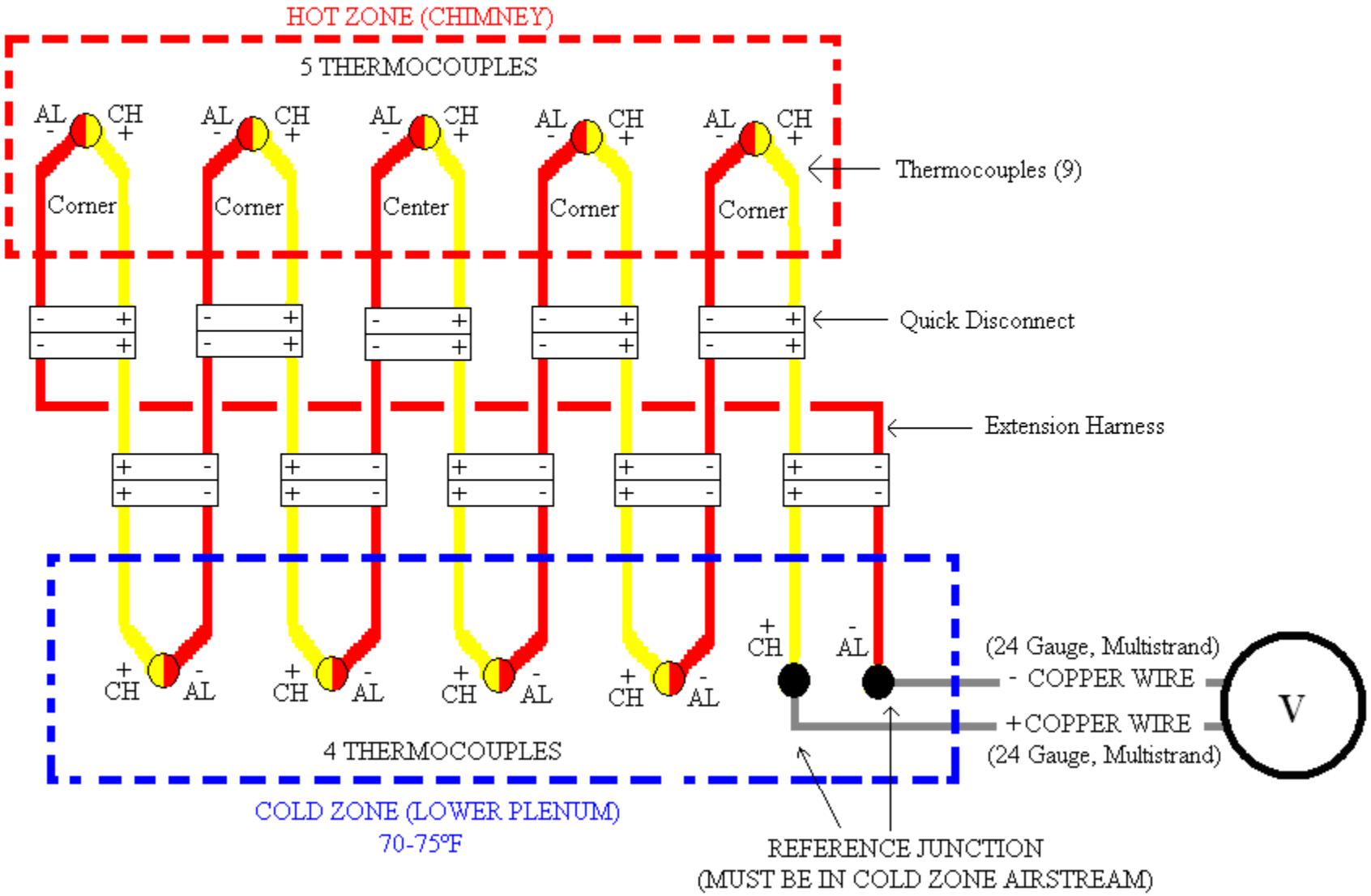
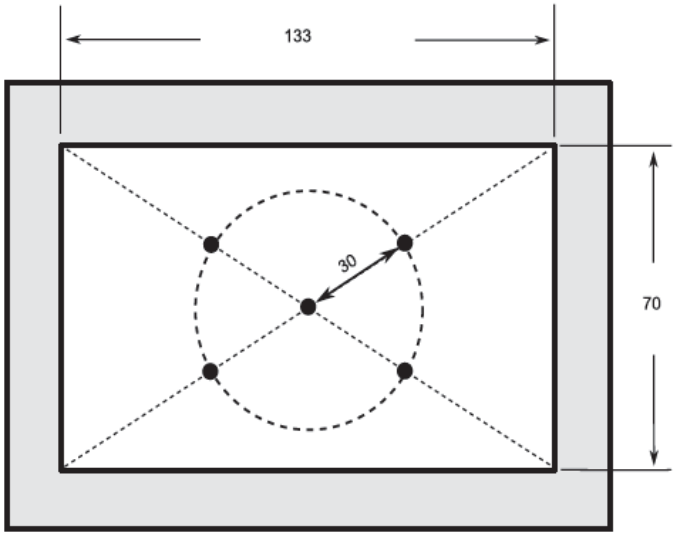


Figure A.5 – Diamond shaped mask

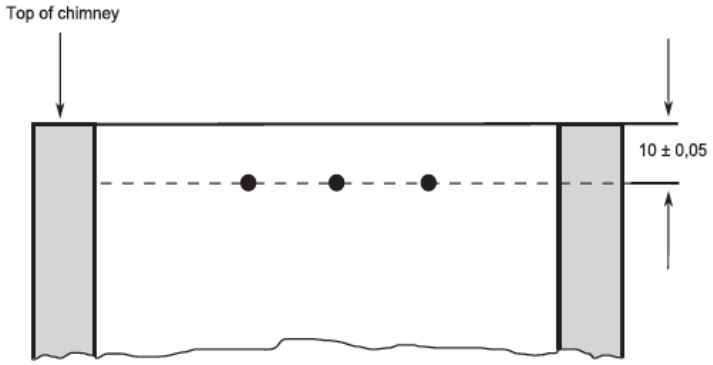
Thermopile


HOT ZONE (CHIMNEY)
5 THERMOCOUPLES
AL
CH
Corner
Corner
Center
Corner
Corner
Thermocouples (9)
Quick Disconnect
Extension Harness
4 THERMOCOUPLES
COLD ZONE (LOWER PLENUM)
70-75°F
(24 Gauge, Multistrand)
- COPPER WIRE
+COPPER WIRE
(24 Gauge, Multistrand)
V
REFERENCE JUNCTION
(MUST BE IN COLD ZONE AIRSTREAM)

THERMOPILE



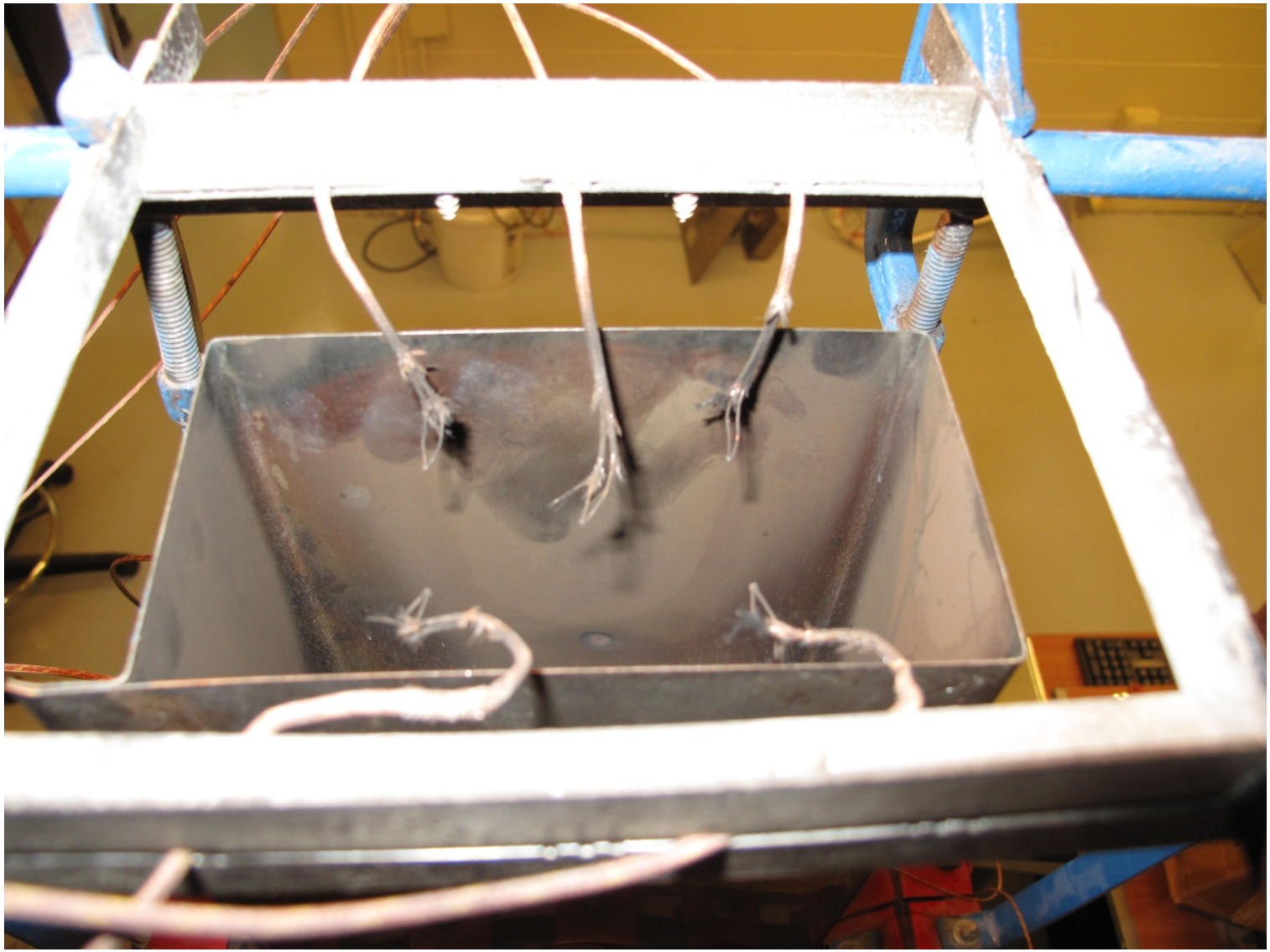
Cross section of chimney



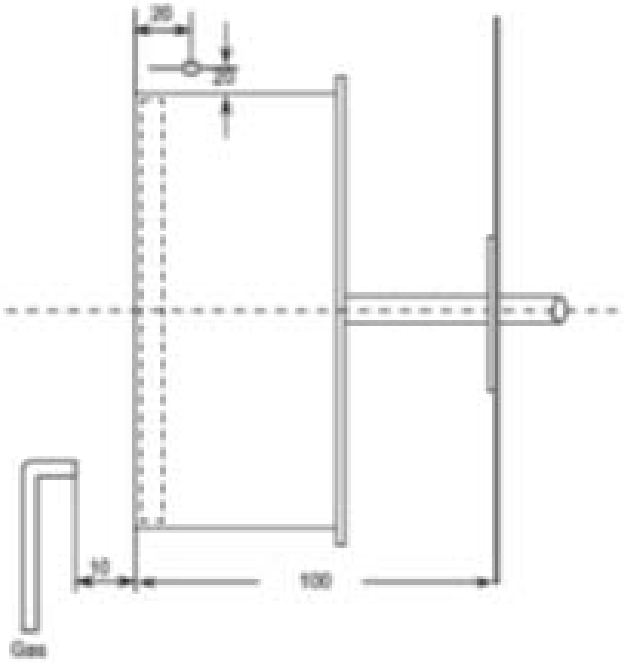
[all lengths in mm]

Figure A.8 – Position of thermocouples in chimney

UPPER THERMOPILE IN CHIMNEY



UPPER AND LOWER PILOT BURNER POSITION



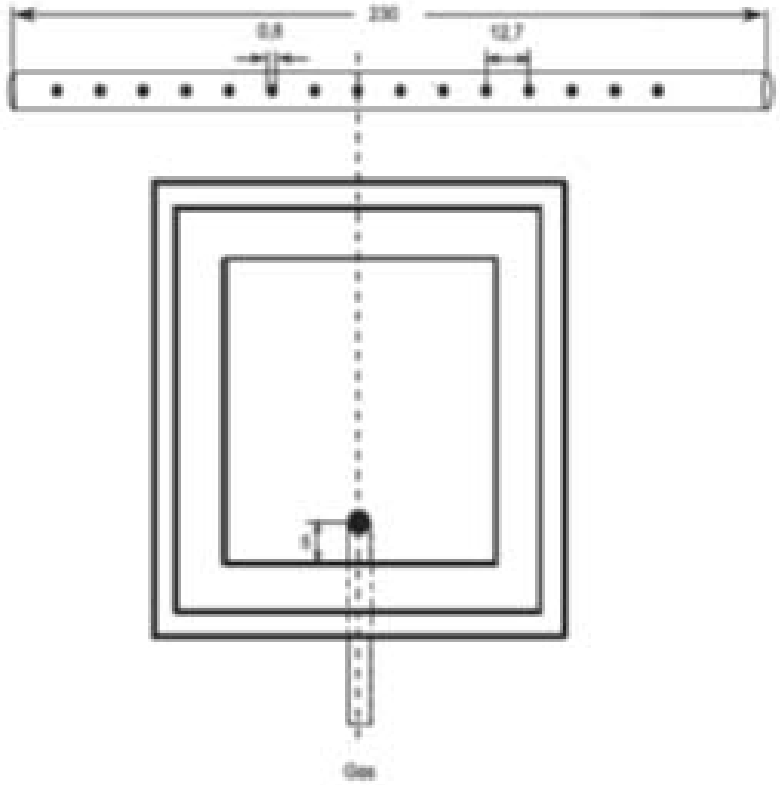
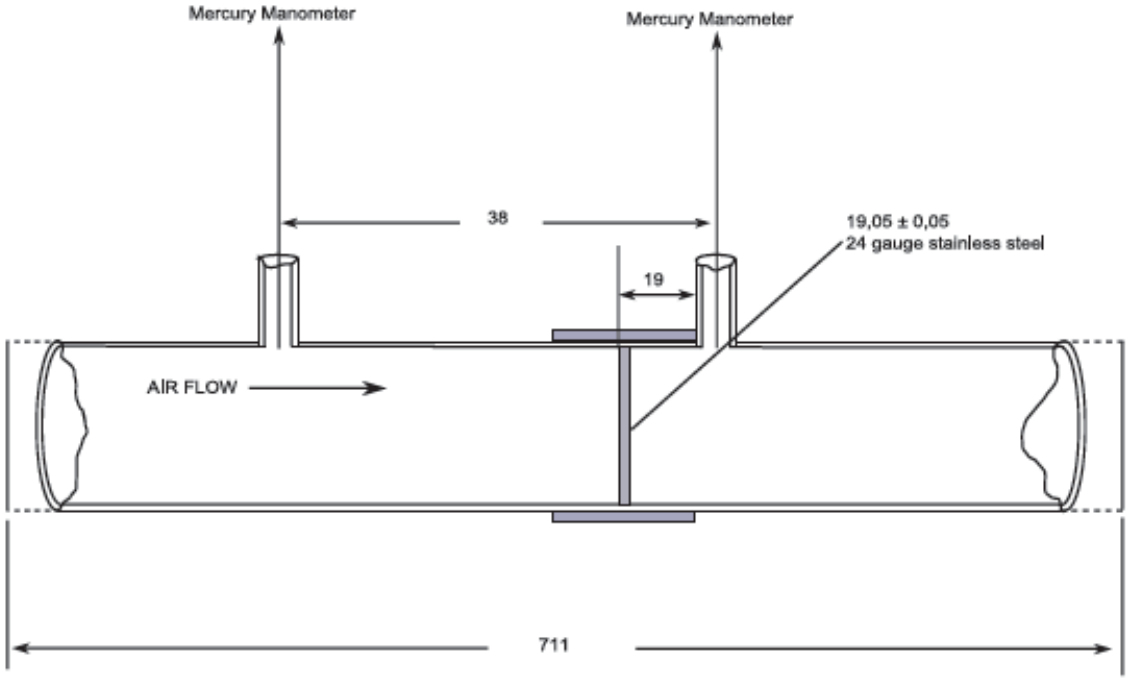


Figure A.9 – Position of upper and lower pilot burner

AIRFLOW METERING

- **Orifice Meter**
  - 70 to 75°F (21 to 24°C) @ 85 ft^3/min (0.04 m^3/s)
  - Squared-edged circular orifice plate in pipe 1.5 inches (38 mm) diameter
  - Two pressure ports 1.5 inches (38 mm) upstream and 0.75 inch (19 mm) downstream (mercury manometer)
  - Pressure differential 7.87 inches (200 mm) of mercury.
- **Air Distribution Plate** – 8 Hole Plate mounted at base of the environmental chamber.
- **Second Stage plate -** 120 Hole Plate 6 inches (152 mm) above the aluminum plate
- **Cooling Manifold -** 48 Hole (Box Tubing)

AIRFLOW METERING ORIFIC PLATE



NOTES

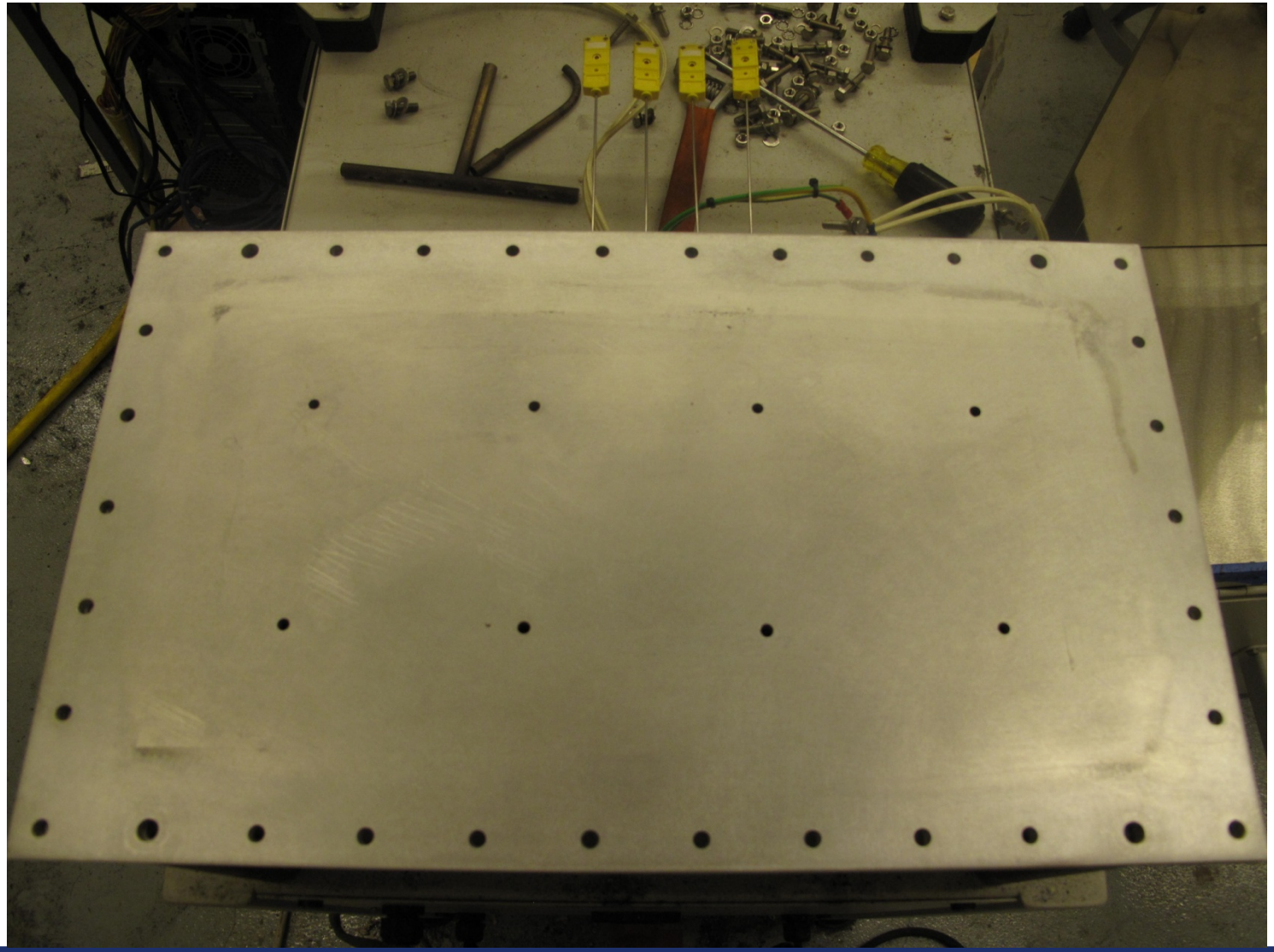
1) The manifold duct lengths are minimum necessary before and after the orifice meter (e.g. 711 and 279,5 mm) to achieve a steady state flow through the meter

2) To achieve the specified air flow, a pressure drop of 200 mm of manometric fluid should be observed.

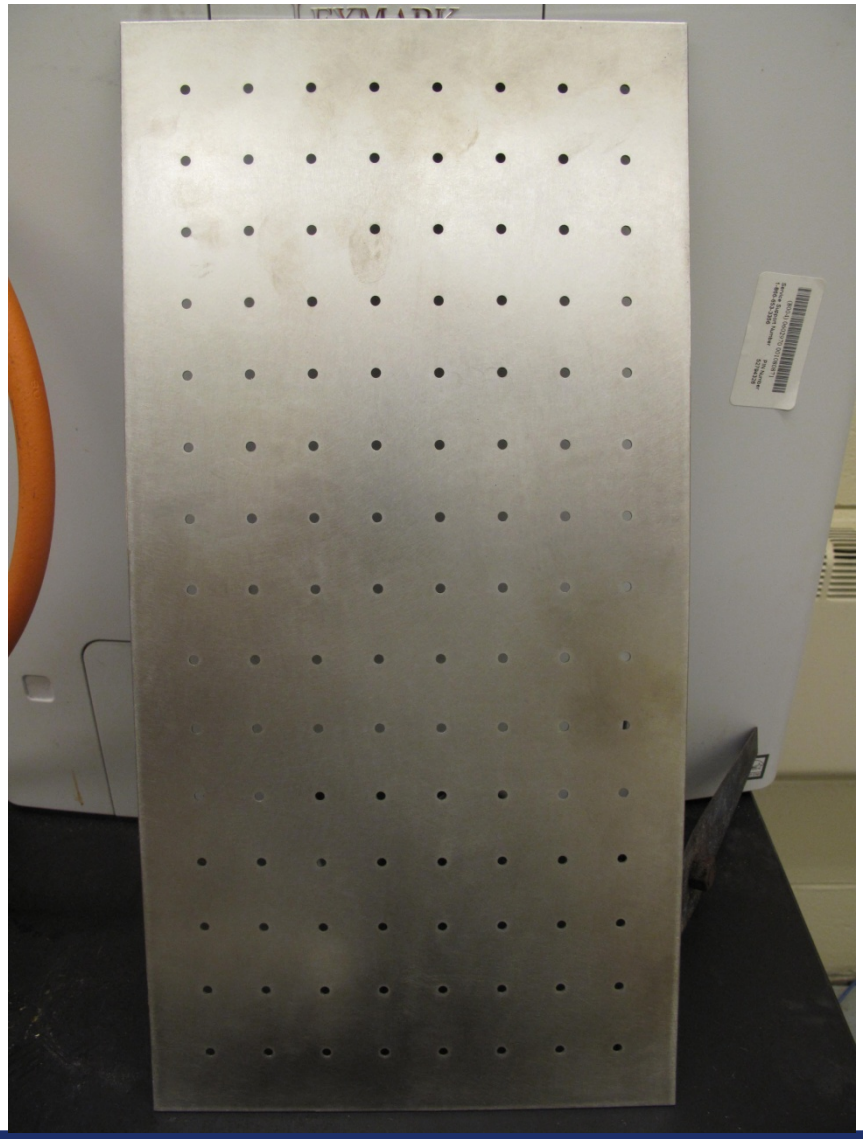
[all lengths in mm]

Figure A.10 – Orifice meter

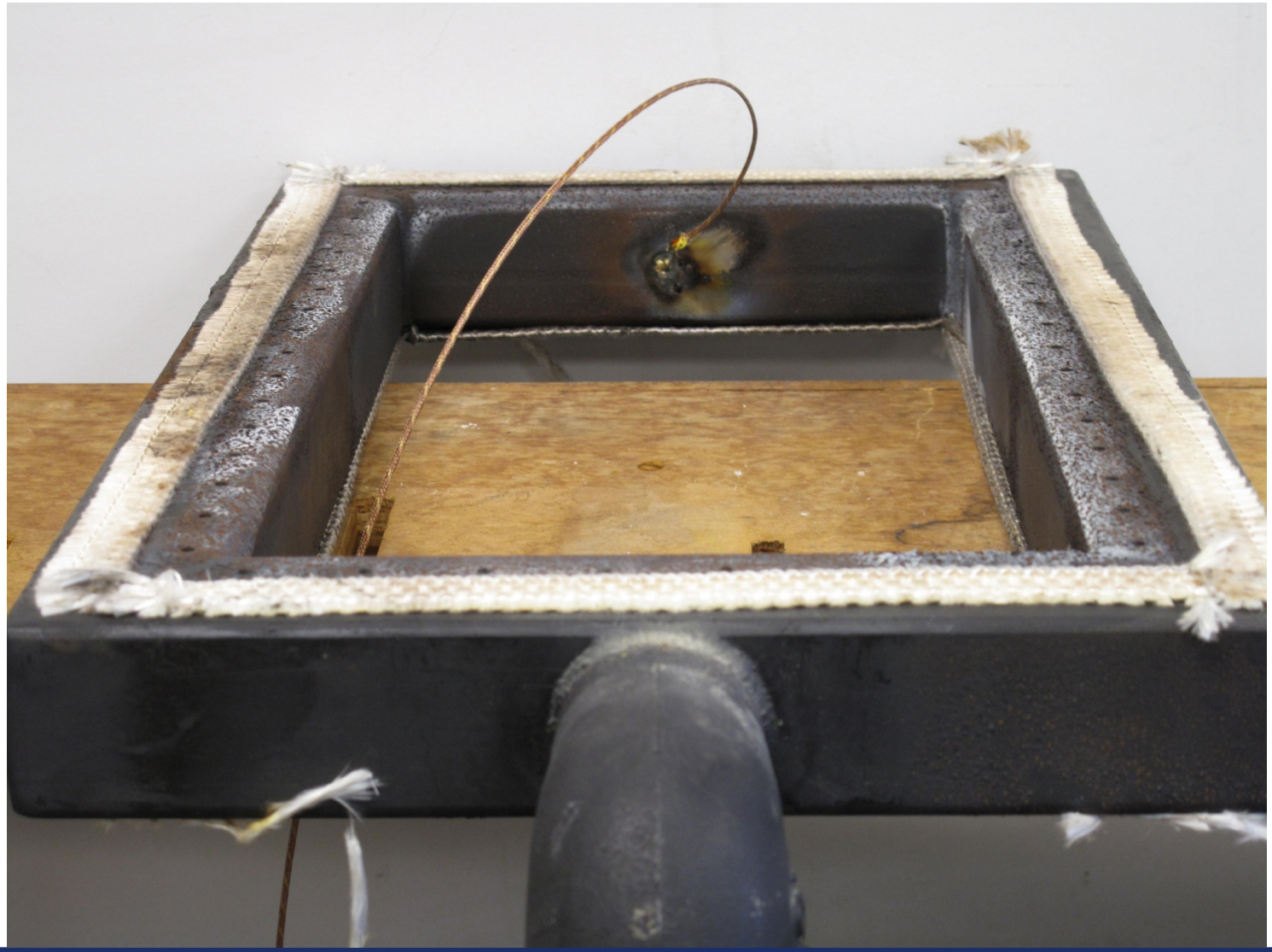
AIR DISTRIBUTION PLATE



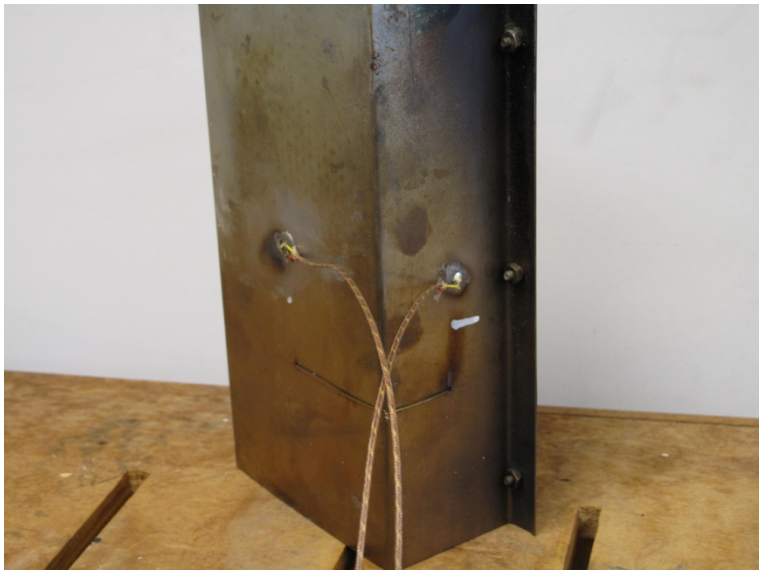
SECOND STAGE PLATE

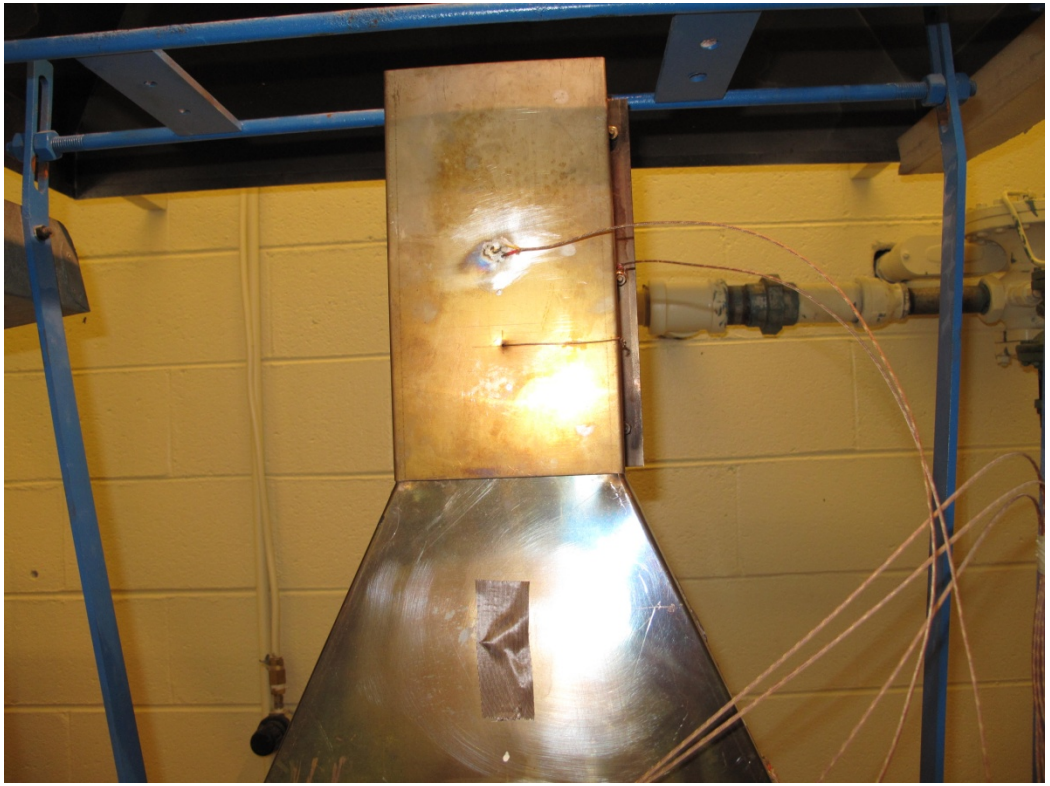


COOLING MANIFOLD



EXHAUST CHIMNEY





HOLDER / INJECTION MECHANISM

Specimen Holder

Drip Pan

Holding Chamber/Injection Mechanism

SPECIMEN HOLDER COMPONENTS

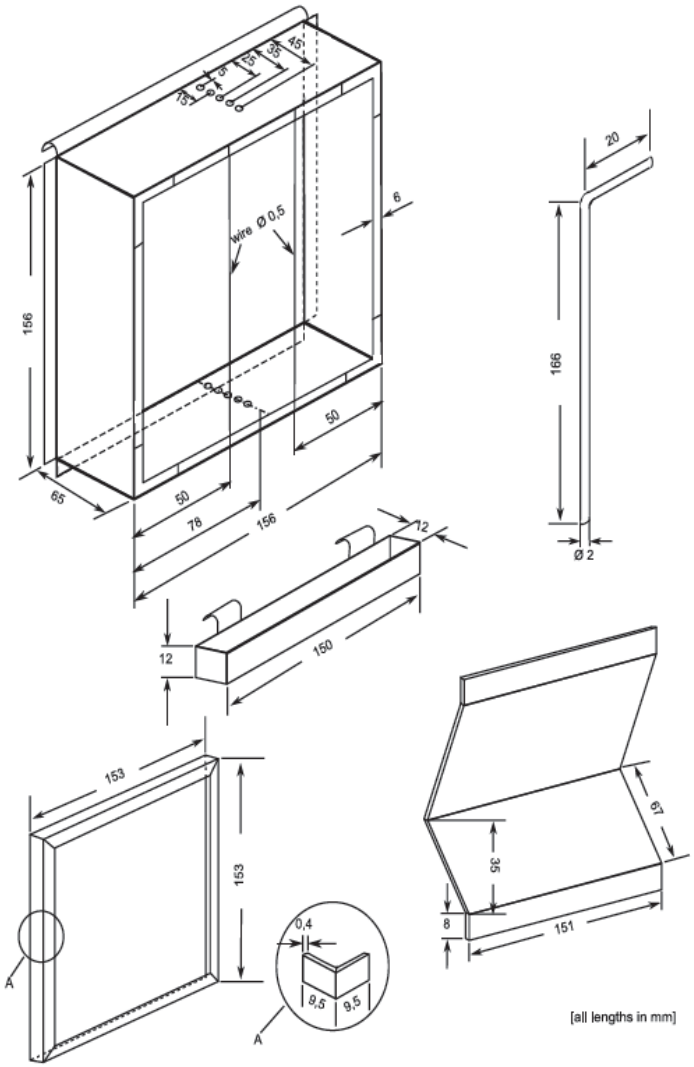


Figure A.14 – Specimen holder and parts

INJECTION MECHANISM

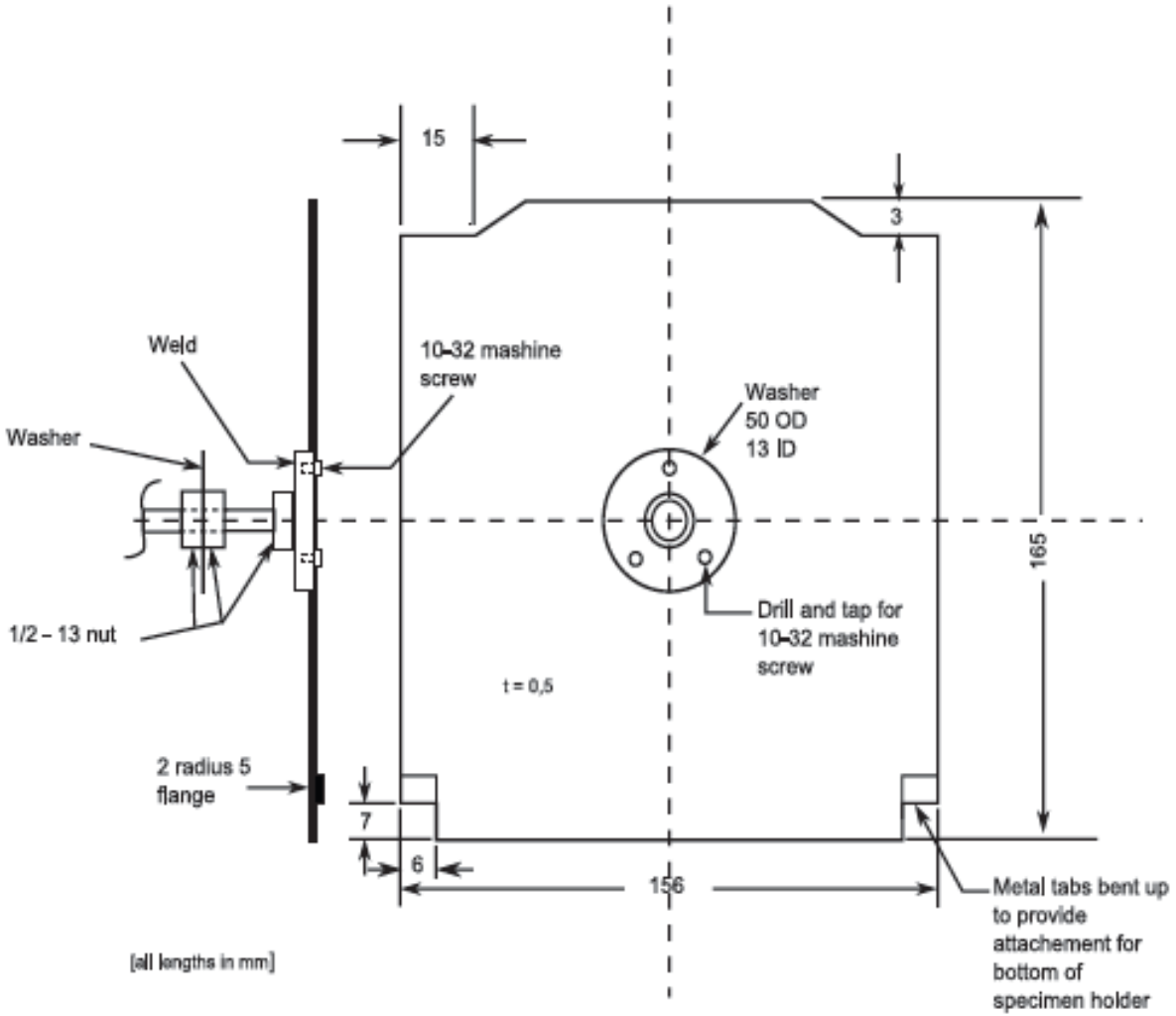


Figure A.16 – Example of mounting bracket

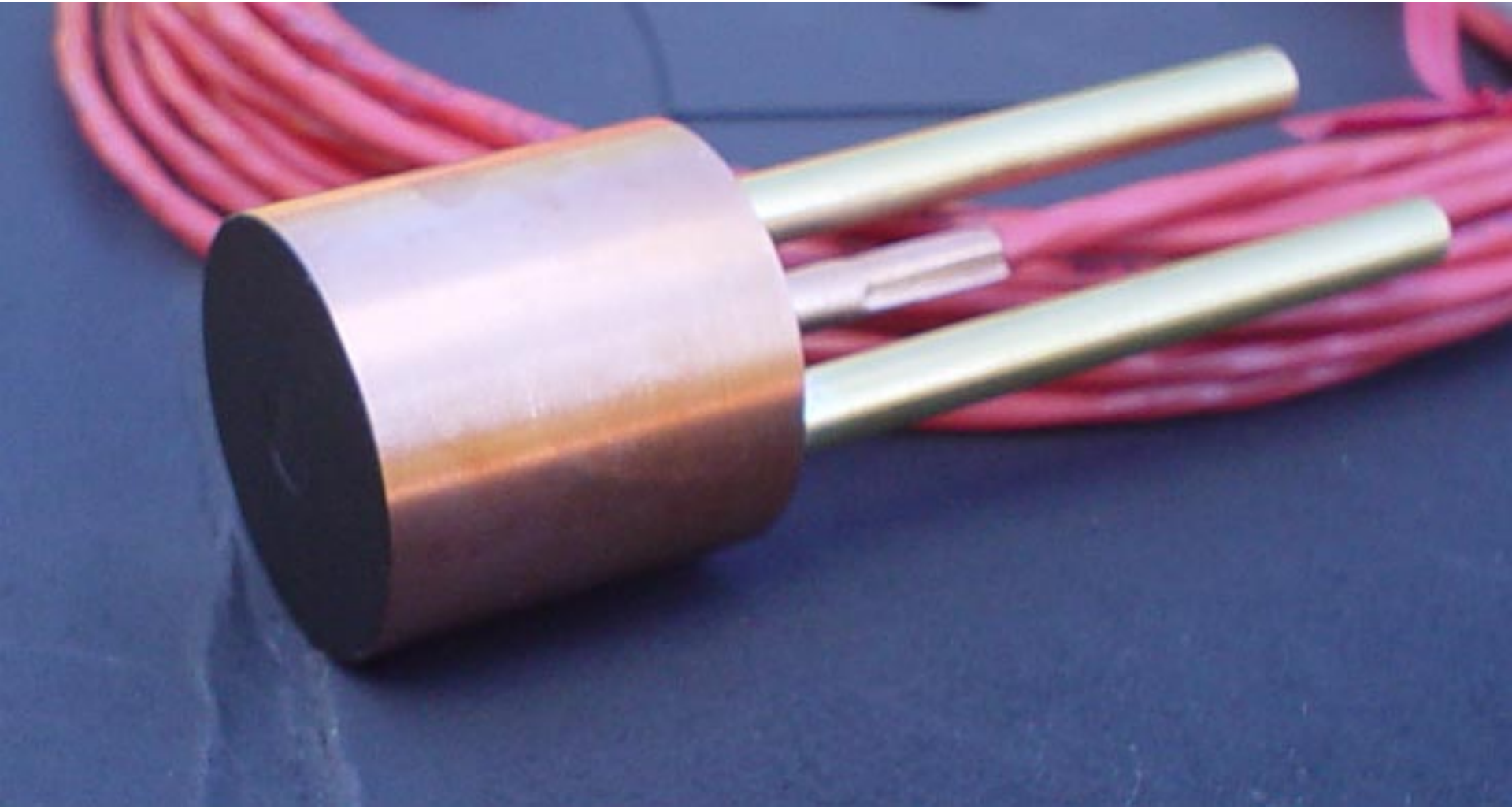
CALIBRATION EQUIPMENT

Heat Flux Sensor

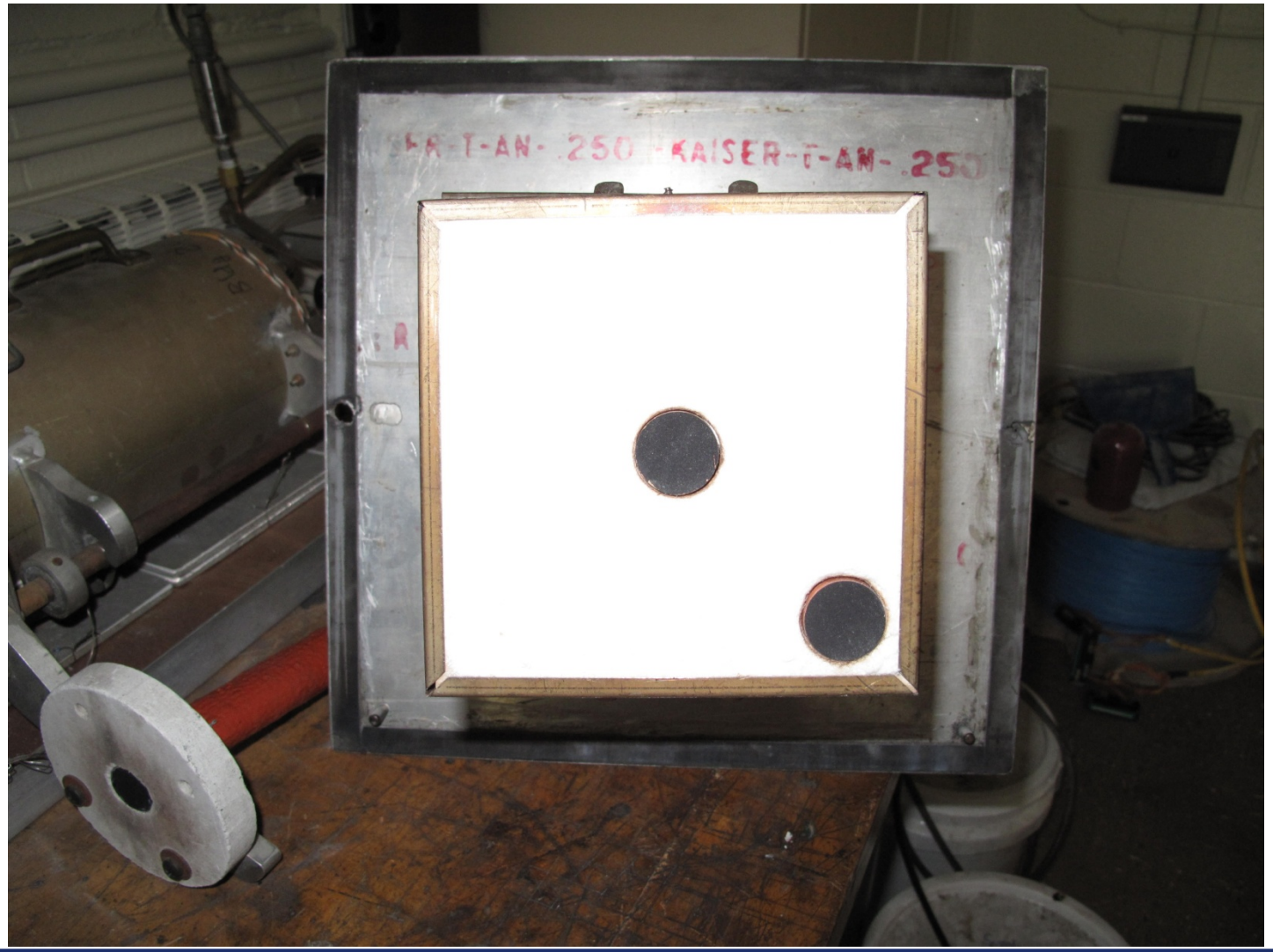
Calibration Burner

Calibration Gas Wet Test Meter / Control Panel

HEAT FLUX SENSOR



HEAT FLUX SENSORS



CALIBRATION BURNER

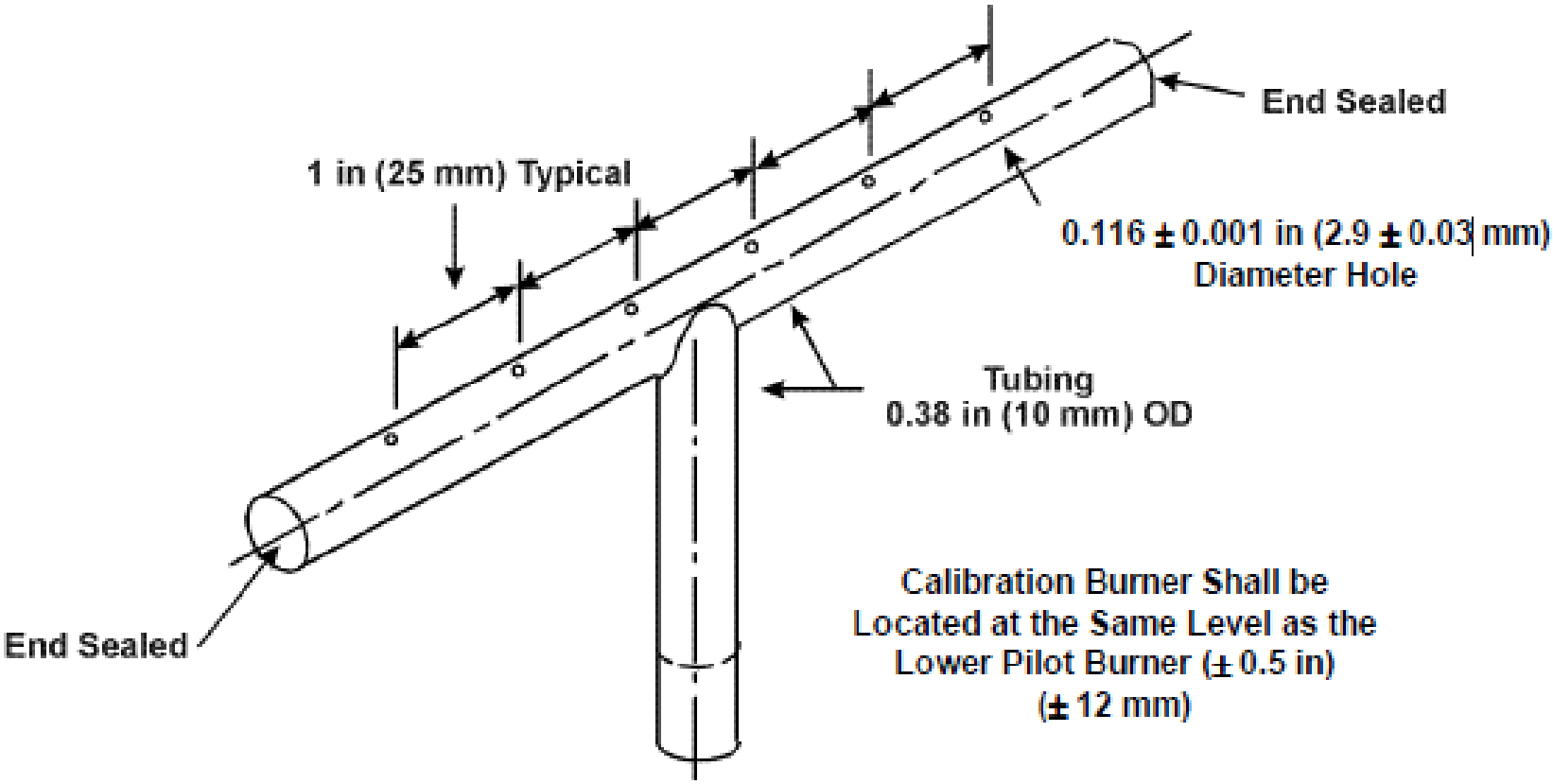


Figure 5-7. Typical Calibration Burner

WET TEST METER

CALIBRATION PROCEDURE OF EQUIPMENT

Heat Flux Calibration (Center)

Heat Flux Uniformity Calibration (Corners)

Determination of the Calibration Factor (K_h)

DETERMINATION OF CALIBRATION FACTOR

- Record
    - Barometric Pressure (Torr)
    - Wet Test Meter Internal Temperature (Degrees C)
    - Calculate Water Vapor Pressure (Torr)
- Precondition chamber
- 2 minutes / 10s = record average, decrease flow rate to baseline flow (1 L/min)
- 1 - 4 - 1 - 6 - 1 - 8 - 1 - 6 - 1 - 4 L/min
- Compute calibration factor (i.e., 1 - 4, 1 - 6, 1 - 8, 1 - 6, 1 - 4 L/min) according to the following formula:

DETERMINATION OF CALIBRATION FACTOR

$$k_h = 25.31 \times \frac{273}{T_a} \times \frac{(P_a - P_v)}{760} \times \frac{(F_1 - F_0)}{(V_1 - V_0)} kW / m^2 - mv$$

F_1 = Actual upper flow rate of calibration gas, in L/min (either 4, 6, or 8)

F_0 = Actual baseline flow rate of methane (approximately 1 L/min)

P_a = Ambient atmospheric pressure (Torr)

P_v = Water vapor pressure of wet test meter water temperature (Torr)

T_a = Ambient temperature (°K)

V_1 = Thermopile voltage at upper flow rate (mv)

V_0 = Thermopile voltage at baseline flow rate (mv)

TEST SPECIMEN

Specimen Number

- 3 specimens

Specimen Size

- 5.94 + 0, - 0.06 by 5.94 + 0, - 0.06 inches (150 + 0, - 2 by 150 + 0, - 2 mm)
- Thickness 1.75 inches (45 mm) Max.

Specimen Preparation

- One surface tested
- Foil wrapped - dull side facing the specimen (Trim excess)

Specimen Orientation

- Highest results

Conditioning Specimens

- 70 ± 5 °F (21 ± 3°C) and 50% ± 5% relative humidity, 24 hours

PREPARATION / PERFORMANCE OF TEST

Preparation

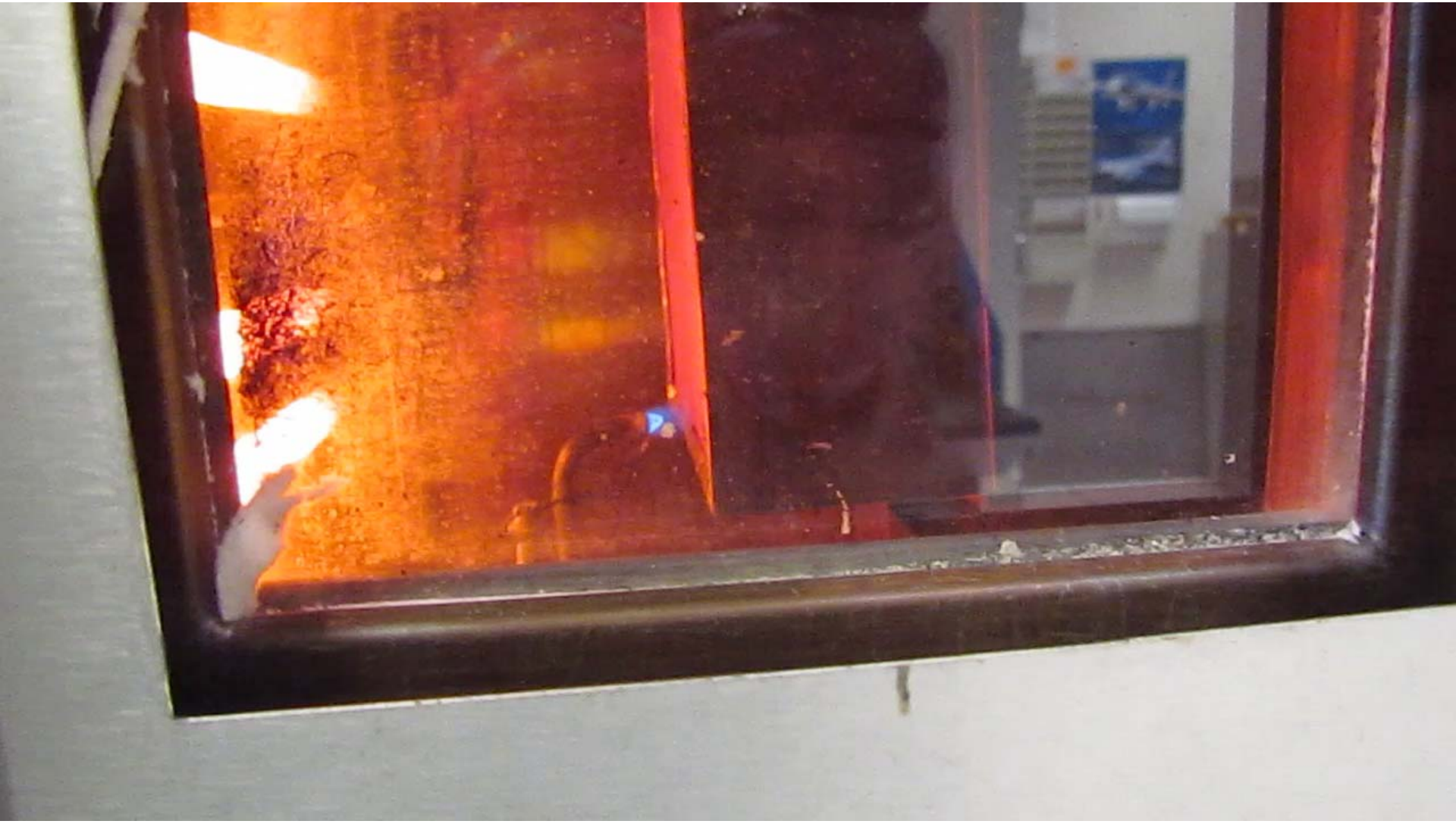
- Clean upper thermocouples / check position
- Air flow
- 3.5 ± 0.05 W/cm^2
- Burners
- Prepare specimen / drip pan

Performance of Test

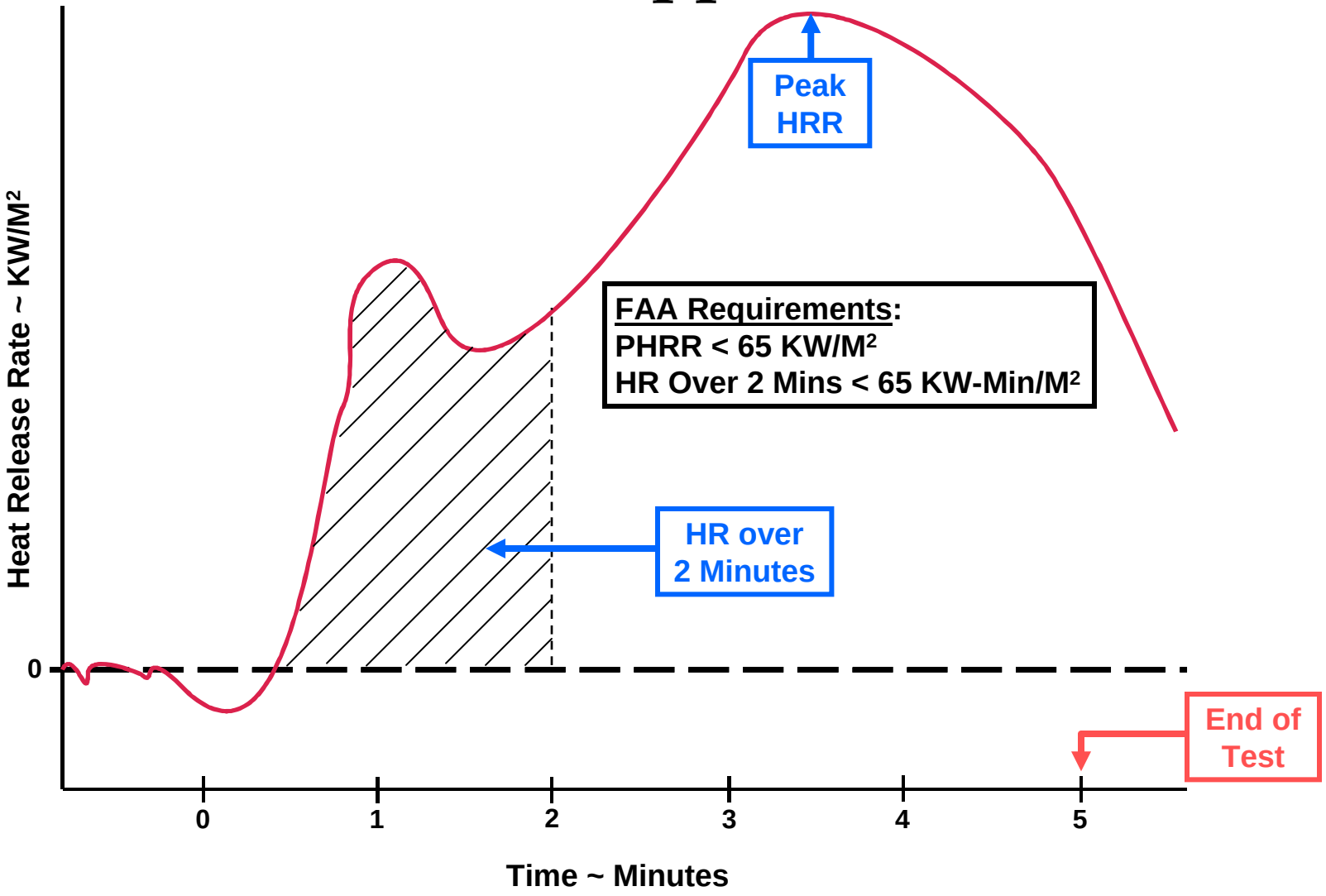
- Doors closed
- 3 to 5 seconds, open door, specimen on mounting bracket, close door, start test
- Holding chamber 60 ± 10 seconds. Record thermopile during final 20 seconds

PERFORMANCE OF TEST CONT.

- Baseline, open doors, inject, close doors, record
- Watch burning process
  - Record melting, sagging, delaminating or other behavior (time)
- Watch pilot flames
  - Lower pilot – No period longer than 3 seconds
  - Upper Pilot – Not 3 no longer than 3 seconds
- 5- minutes – End test, remove sample



Hypothetical Heat Release Rate Measurement in OSU Apparatus



HEAT RELEASE RATE TEST - CONCLUSION

Presentation of Results

- HRR = $K_h \times (V_1 - V_0)$ kW/m^2
- Average:
  - HRR (Max)
  - Total HR - 2 minutes (worst-case direction)

Requirements

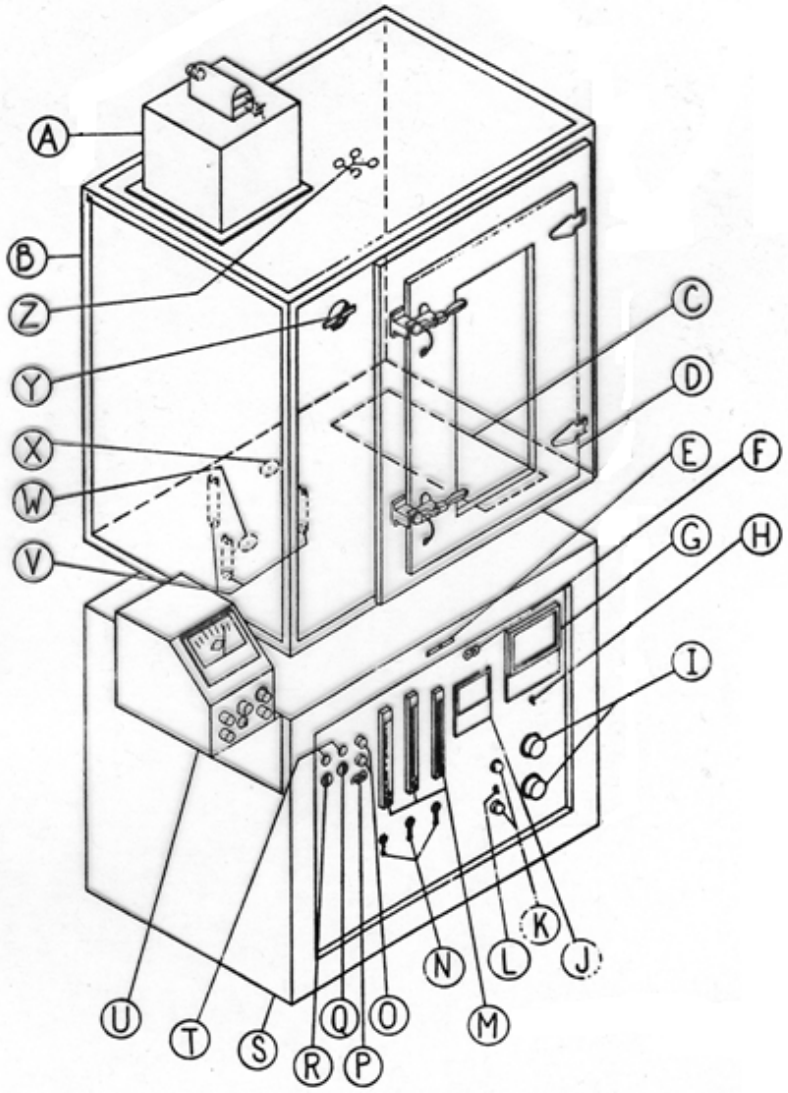
- Average Max HRR (5 minute) $\leq$ 65 kW/m^2.
- Average Total HR (2 minutes) $\leq$ 65 kW min/m^2.

Test Report

- Fully identify the material
- Report melting, sagging, delaminating (Time)

NBS Smoke Density Photometric System

NBS Smoke Chamber Components

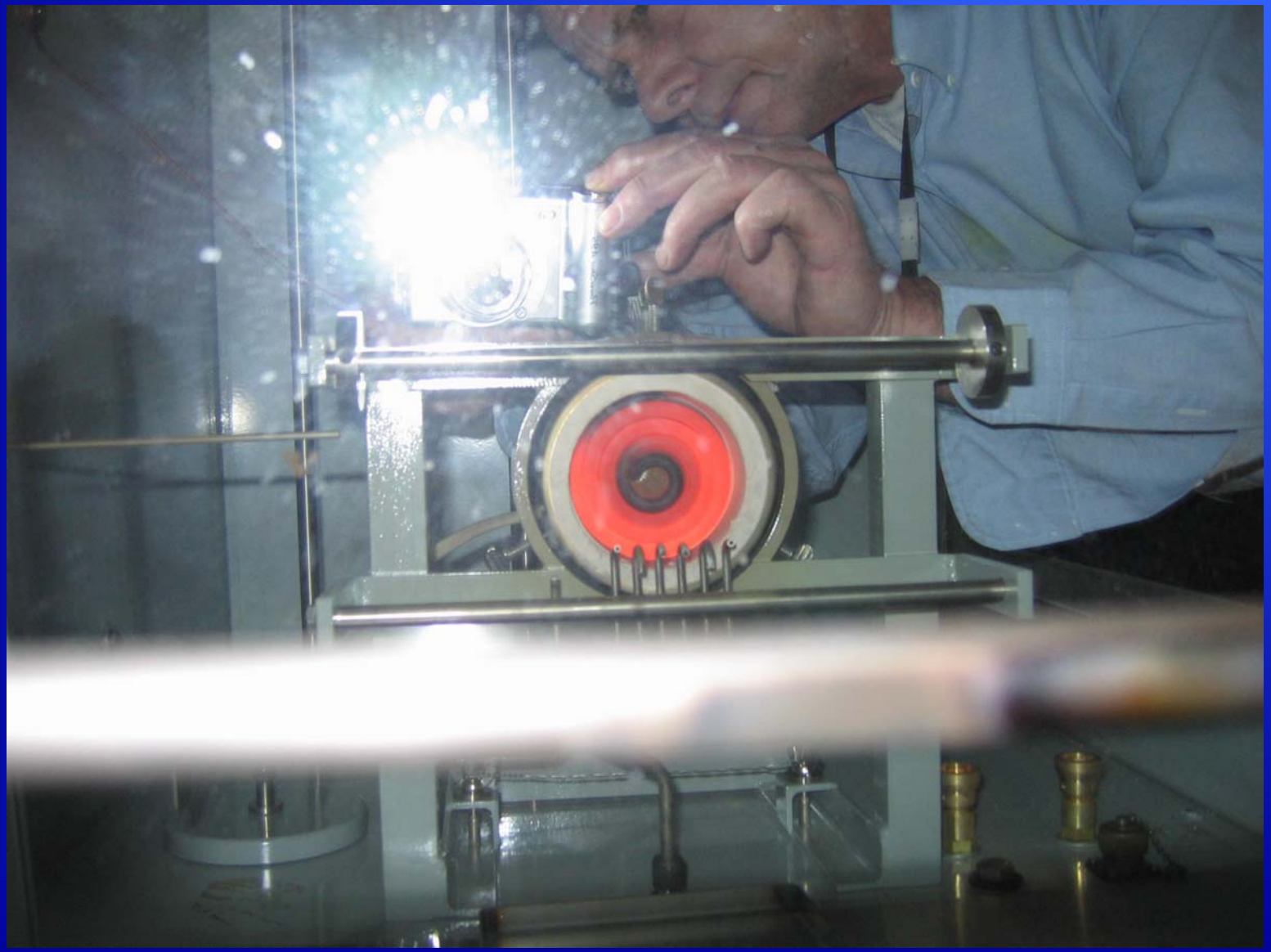


A - Phototube Enclosure
B - Chamber
C - Blowout Panel
D - Hinged Door with Window
E - Exhaust Vent Control
F - Radiometer Output Jack
G - Temperature (Wall) Indicator
H - Temperature Indicator Switch
I - Autotransformers

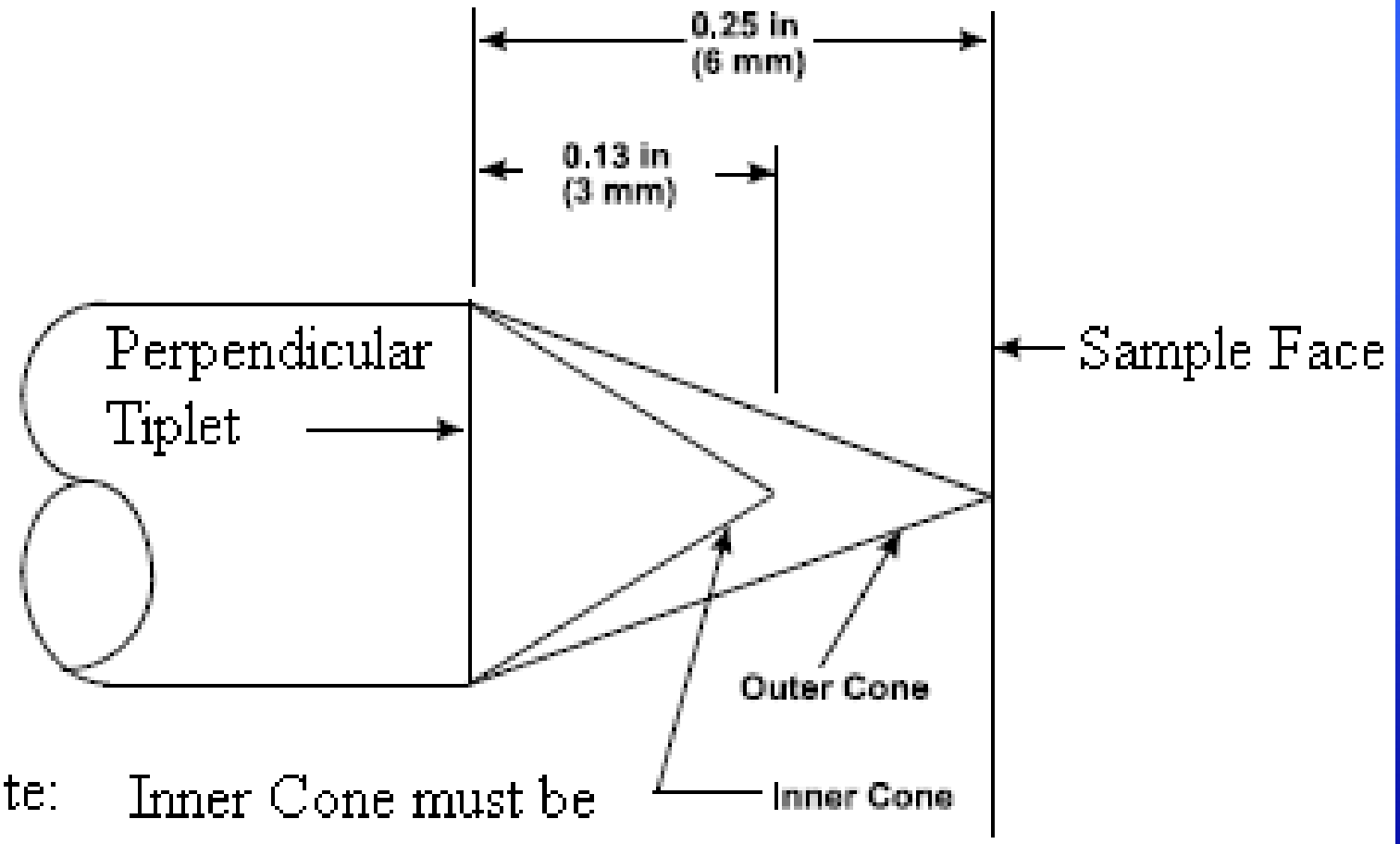
J - Voltmeter (furnace)
K - Fuse Holders
L - Furnace Heater Switch
M - Gas & Air Flowmeters
N - Gas & Air Shutoff Valves
O - Light Intensity Controls
P - Light Voltage Measuring Jack
Q - Light Source Switch
R - Line Switch

S - Support Frame
T - Indicating Lamps
U - Photometer Readout
V - Rods
W - Glass Window
X - Exhaust Vent
Y - Inlet Vent
Z - Access Ports

NBS Smoke Chamber Furnace / Pilot Burner and Sample Mounting Fixture



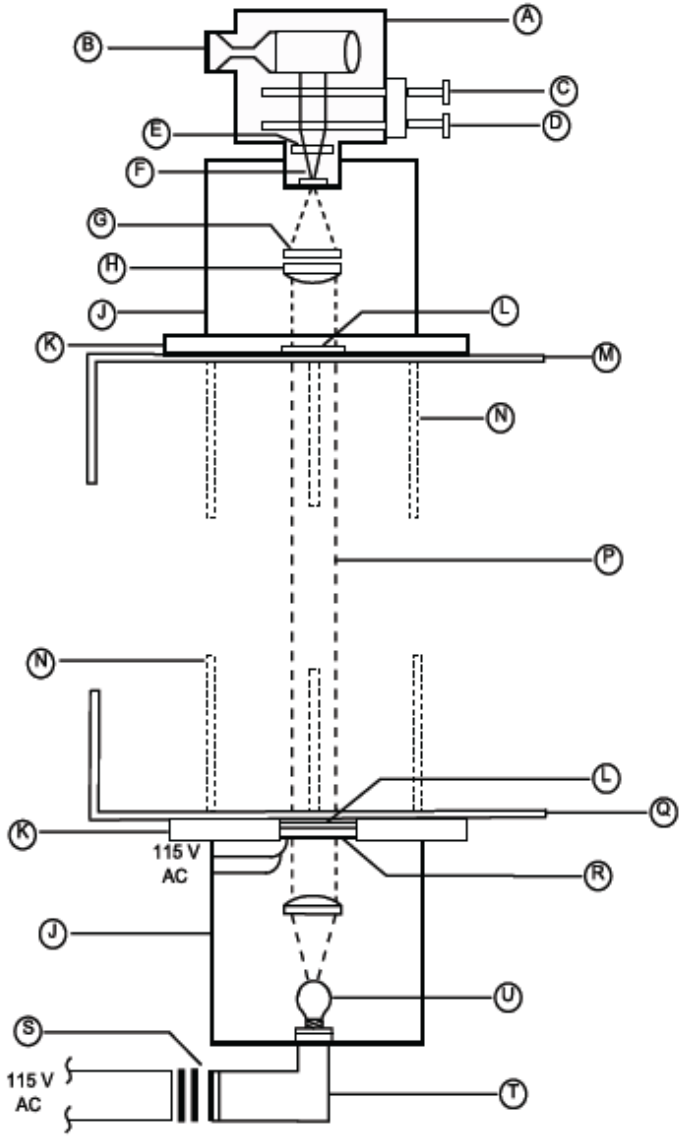
NBS Smoke Density Chamber



Note: Inner Cone must be 1/2 the distance to the sample face

NBS Smoke Density Chamber

NBS Smoke Density Photometric System

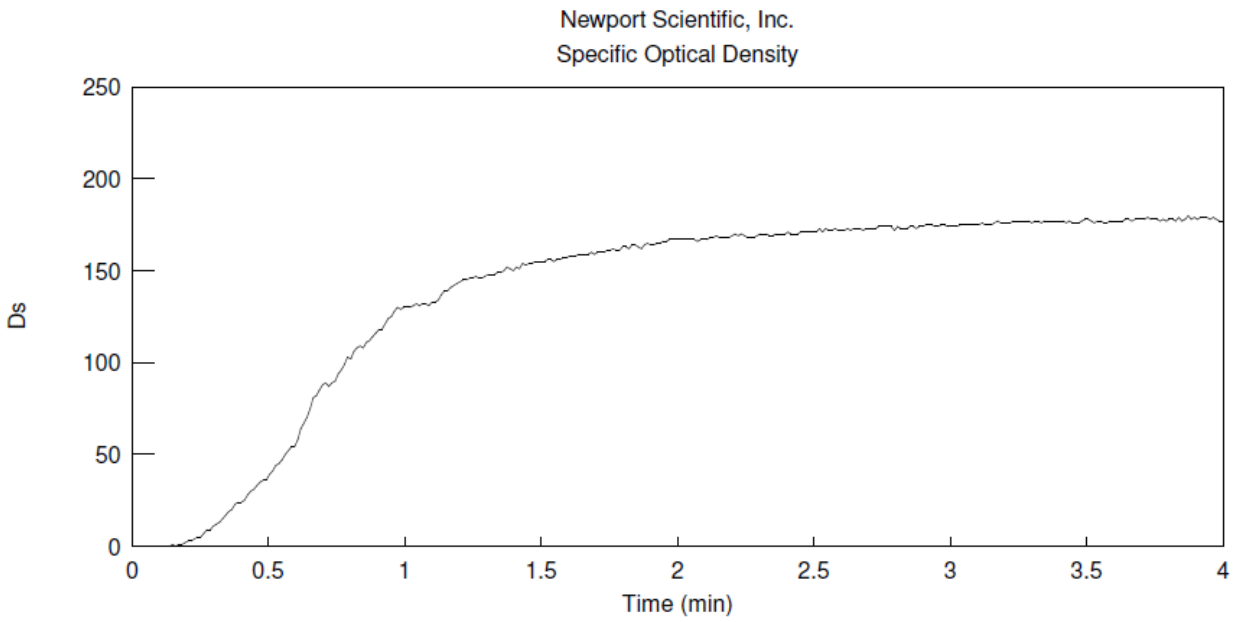


A Photomultiplier housing
B Photomultiplier tube and socket
C Upper shutter blade with H2O filter over one aperature
D Lower shutter blade with single aperature
E Opal diffuser filter
F Aperature disk
G Neutral density compensating from set of 8
H Lens 7 diopter (2)
J Optical system housing (2)
K Optical system platforms (2)
L Optical windiws (2)
N Alignment rods (3)
M Chamber roof
P Parallel light beam (38 mm in diameter)
Q Chamber floor
R Optical window heater, silicon-fiberglass 50W/115V
S Regulated light source transformer 115/125 V - 6 V
T Adjustible resistor. Light source adjusted for 4 V
U Light source

NBS Smoke Density Photometric System

Sample: FLAMING B1
Sample #: FLAMING B1
Sample Size:
Sample Weight:
Thickness:
Lot #:
Run #:
Company:
Operator: SOON SK

Time:3:36:30 PM
Filename:2012 FL B1.SCP



Ds at 1.5 min: 155.0
Ds at 4 min: 177.0
Max. Ds (first 4 min): 180.0
Max. Ds Time (first 4 min): 3:52.4
Max. Ds: 180.0
Max. Ds Time: 3:52.4
Clear Beam Ds: 0.0
Corrected Max. Ds: 180.0

Average Backwall Temp: 111.4 ºFahrenheit
Minimum Backwall Temp: 102.0 ºFahrenheit
Maximum Backwall Temp: 114.8 ºFahrenheit

Questions?