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User's Guide for the Cone Calorimeter

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User's Guide
for the
Cone Calorimeter

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National Institute of Standards and Technology

Contents

Page

Tables

Page

1

Introduction

In 1982 the National Institute of Standards and Technology[1] (NIST) developed a new type of apparatus for making bench-scale rate of heat release measurements. Rate of heat release was then beginning to be seen as a key factor in describing the flammability of materials, products, and assemblies. Laboratory instruments for measuring the rate of heat release had already been available at that time for over a decade. These earlier devices, however, were either of a very simple design and subject to serious measurement errors; or, they were capable of good measurement accuracy, but were of extremely complex and costly construction.

During the late 1970's an entirely new principle was discovered for making rate of heat release measurements. This was termed the “oxygen consumption principle.” The method required very precise means of measuring oxygen concentrations; given such capability, however, it was shown that highly accurate rate of heat release measurements could be made without the greatly complex hardware required for earlier designs. A program was then started at NIST to develop a bench-scale rate of heat release test method which could serve as a standard laboratory test. The apparatus became known as the Cone Calorimeter (due to the conical shape of the heating element). It has been provisionally published by ASTM as P 190.

This Guide is intended to provide supplemental information on installation, set-up, daily operational procedures, and also on maintenance and troubleshooting.

! Babrauskas, V., Development of the Cone Calorimeter — A Bench-Scale Heat Release Rate Apparatus Based on Oxygen Consumption, **Fire and Materials. 8**, 81-95 (1984). Also issued as NBS Report NBSIR 82-2611 (1982).

! Proposed Test Method for Heat and Visible Smoke Release Rates for Materials and Products using an Oxygen Consumption Calorimeter (E-5 Proposal P 190), **Annual Book of ASTM Standards**, Vol. 04.07, pp. 1221-1237, American Society for Testing and Materials, Philadelphia (1986).

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[1] Formerly National Bureau of Standards (NBS).

The first two background documents give the theory behind the Cone Calorimeter, explain the design features of the apparatus, and provide the basic equations of rate of heat release calorimetry. The user **must** have these documents on hand, since the information given in them is not duplicated in the this User's Guide.

Since it is expected that future revisions of these operating instructions will not necessarily coincide with any revisions of the hardware details, the Figures illustrating the features of the apparatus are not incorporated into the Guide — whenever this document refers to drawings or Figures, the user should refer to the **Construction Drawings for the Cone Calorimeter**.

The user is assumed to be at least passably knowledgeable in the operation of ordinary analytical chemistry laboratory equipment, and to be well-versed in ideal gas law computations.

There is a large number of actual apparatus details which depend on the laboratory installation. These include the exhaust system switches, instrument control switches, zero and spanning valves, supplemental gas analysers, etc. The Construction Drawings do not, and cannot, prescribe a mandatory location or configuration for such features. Since the present document was originally developed for training new personnel on the use of the original Cone Calorimeter at the NIST laboratories, such details are described in this Guide as they have been implemented at NIST. Since it became evident that the Guide could form useful guidance for users in other laboratories, it is being made generally available. The installation—specific details given in this Guide will, however, apply directly only to the NIST instrument.

This Guide is a somewhat lengthy document, since the NIST installation contains a very large number of optional features (soot measurement, additional gas analysers, etc.); in many installations, lacking such supplemental equipment, the operating procedures will be substantially simpler.

1.1 Sequence of events

The sequence of events listed below, in most cases, is not of specific importance. In those instances where the sequence is important, this fact will be pointed out.

1.2 User comments

Users finding difficulties with these procedures, or encountering anomalous conditions not described in the documentation are urged to contact Fire Testing Technology Limited. User comments are specifically invited, and will be incorporated into future editions of this Guide. Telephone: +44 (0)10342 323600 or Fax: +44 (0)1342 323608. Future editions of this Guide will incorporate additional information and suggestions received from users.

1.3 Safety precautions and procedure

SAFETY PRECAUTIONS

This test method may involve hazardous materials, operations and equipment. Therefore, we specifically exclude any liability whatsoever for claims arising from use or misuse of the equipment.

It is the responsibility of whoever uses this equipment to consult and establish appropriate health and safety practices and determine the applicability of regulatory limitations prior to use.

A) All service inputs must be made secure.

B) The mains power must be connected using the leads supplied by Fire Testing Technology. Fuses must conform to Fire Testing Technology specifications.

C) As high voltage is available to ignite the sample, the ignition switch should not be energised when loading or unloading the sample.

The equipment must be supervised at all times when in use.

Adequate means for extinguishing a fully developed fire should be available.

PERSONAL SAFETY REQUIREMENTS

OPERATING PERSONNEL

This equipment must only be operated by authorized personnel who are fully conversant with the safety requirements. Where this equipment is used in any apparatus in which materials are burnt, the operator must have a thorough knowledge of the chemical properties of the materials under test and what combustion products can be expected from them.

Suitable safety glasses should be worn at all times.

Protective gloves should be worn when handling sample holder.

The installation, siting and provision of services to the equipment must have the approval of the Safety Officer.

Power to the unit should be off when handling the electrode assembly as the supply voltage to it is 10 kV. Care should be taken when handling the unit and removing the push-on electrode leads.

The cover to the Spark Generator unit which is mounted on the underside of the test chamber should only be removed by authorized personnel. Covers to the Control Unit also should only be removed by authorized personnel.

WARNING

When calibrating the system with methane gas, ignition can be delayed due to insufficient oxygen in the gas for combustion. Ensure the extraction system is in operation and either ignite the gas with a separate flame or if using the spark ignition turn the gas valve on/off/on to assist ignition. If burner does not ignite immediately, turn off gas supply and try again after a 1 minute's delay to remove gas from hood and duct.

2

Installation and initial set-up

2.1 Laboratory environment

The apparatus has been designed to operate satisfactorily only in a draft-free environment. While adequate ventilation must be ensured, as described below, it is essential that there be no serious cross-drafts blowing through the test area. Such drafts will create combustion complications and non-uniformities.

2.2 Services required

1. Ventilation. A hood system is required which can (a) remove the maximum of 50 ℓ/s from the exhaust stack, while being decoupled from it [that is, the Calorimeter exhaust stack should empty into a collection hood, rather than being directly plumbed into the building exhaust]; (b) remove any smoke drifting up due to specimen insertion or removal; and © allow burned specimens to be temporarily placed in a safe location. The requirement for a decoupled configuration is to avoid introducing pressure fluctuations from the building ventilation system or from the outside weather. In practice, thus, the actual rated capacity will have to be, possibly, ten times the maximum 50 ℓ/s coming from the exhaust itself.

2. Electrical power. Electrical power providing 230 VAC at the instrument must be available. If only a lower voltage, *e.g.*, 208 VAC, is available, a boost transformer will be required. If nominal 230 VAC mains are available, but actual delivered voltage is less, the user should expect to find that the rated 100 kW/m^2 irradiance capability may not be achieved. Thus, a boost transformer will be necessary in such cases also. The minimum current capacity required is at least 25 A for the heater, plus the total rating for the remaining devices and instruments. This, in general, will depend on the installation.

3. Water supply. Water supply is necessary to cool the heat flux meter and cooling collar. This is a very minimal flow; a pressure regulator set at 250 kPa (35 psi) should be provided if house pressure may undergo surges greater than this value.

4. Drain. A drain line is required to handle the water being provided.

5. For the calibration burner, methane gas of at least 99% purity with a maximum flow of 25 l/min at a maximum pressure of 2 bar (30 psi)

6. Calibration gas of CO/CO_2 which should be in the range of 80/90% of the analyser's full scale and at a maximum pressure of 0.8 bar (10 psi). Typical ranges are 8% CO_2 and 2500 ppm CO.

7. Oxygen free Nitrogen is required to zero the oxygen analyser with a maximum flow of 250 ml/min at a maximum pressure of 0.8 bar (10 psi).

2.3 Calibration and auxiliary equipment required

1. Dry test meter. A dry test meter is an essential calibration tool, used for maintaining the accuracy of the electronic mass-flow controller. The mass-flow controller is the device used to control the flow rate of methane being delivered when the daily heat release rate calibration is done. Since it lacks intrinsic calibration, it must be regularly calibrated against a reference dry test meter.

2. The dry test meter must be calibrated for methane and sized so as to be capable of, at least, 25 ℓ/min flows. It must also be equipped with pressure and temperature monitoring sensors having a precision of 1 part in 1000, or better.

3. Digital voltmeter. A high-quality digital multimeter, with at least 5½ digit resolution is required for calibration and troubleshooting purposes. This is in addition to the voltage measuring device(s) associated with the data acquisition system.

4. A precision voltage/millivolt source is optional, but can make troubleshooting much easier.

5. Reference heat flux meter. In addition to the heat flux meter used for regular calibration, it is required that the user possess a second, identical flux meter, also accurately calibrated. The second flux meter is to be used only for a monthly comparison against the operating flux meter. Otherwise, it is to be kept in a safe storage location. The additional flux meter is necessary because, otherwise, there is no means of detecting a change in the calibration of the operating heat flux meter. Such a change may occur, over time, by itself, or may be provoked by a shortage of cooling water, excessive fluxes, or similar inadvertent incidents. Users expecting to have full-time testing operations should possess **three** heat flux meters. This will allow one heat flux meter to be sent back to the manufacturer for service.

6. Micro-balance. A balance for weighing samples is needed which has a resolution of .01 mg.

7. Laboratory weights. A set of laboratory weights is required for checking the calibration of the load cell.

8. Specimen holder equipment. In addition to two each (minimum) of the horizontal and vertical orientation specimen holders, the user may need the following items:

    a. An edge frame, used for testing in the horizontal orientation, of wood products and other specimens whose edges need special protection against edge burning.

b. A wire grid, used either inside the vertical specimen holder, or else in conjunction with the horizontal edge frame, which functions to restrain intumescing materials.

c. A fabric specimen tensioning insert, used for testing fabric specimens over a dead air space; used in conjunction with the edge frame above.

Descriptions of all these items are given in the Construction Drawings.

9. Special tools for aligning and calibrating laser smoke photometer. For alignment, two main tools are desirable. The first is a metal rod, somewhat smaller than the I.D. of the beam tubes that are welded onto the sides of the exhaust duct. The second is a translucent plastic plug with a thin area in the centre, used for inserting in place of a photodetector assembly (or at the end of the main photometer tube, farthest away from the laser). This plug is used as a target for aligning the laser beam. Two glass neutral density filters are required, typically at values of approximately 0.3 and 0.8 optical density ("OD") units, calibrated at the laser wavelength of 623.8 nm. Filter positioning provisions are already incorporated into the photometer, thus, the user needs only to have a calibration filter already mounted in a filter holder which mates with the special filter slots.

10. Vacuum cleaner. A shop vacuum cleaner is normally required to clean up the debris of specimen burning.

2.4 Calibration samples

The user should procure and regularly use the normal calibration sample for the Cone Calorimeter. This sample is PMMA (polymethylmethacrylate) cast sheet stock. It can be obtained as Polycast[2], black, 25 mm thick[3]. [The prior manufacturer for these specimens had been Rohm & Haas. They are no longer producing this plastic in the required thickness, and, therefore, Polycast is now specified as the supplier. The new data obtained from Polycast will *not* be identical to any old measurements obtained from Rohm & Haas stock.] Note that PMMA from different sources can yield different results from those suggested in Section 10.2, for example extruded PMMA from ICI gives an average SEA of 150 ± 10 m^2/kg. These samples are not prepared in the standard way, as described in ASTM P 190, but rather are to be prepared in the following special way:

> Cut the specimens to be 100 mm by 100 mm in area. Obtain cardboard stock, approximately 0.5 mm thick. Prepare from the cardboard strips 25 mm wide by 100 mm long. Use a thin layer of adhesive to attach the strips to each edge of the specimens. Cure for at least 24 hours. The adhesive used must hold the cardboard strips firmly during the burning process. Note that no aluminum

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[2] Certain commercial products and materials are identified in this document in order to adequately specify the experimental procedure. In no case does such identification imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the product or material identified is the best available for the purpose.

[3] Type Cellcast BK2025, from Polycast Co., 69 Southfield Avenue, Stamford, CT 06902. Telephone: (800) 243-9002.

foil is used with these specimens, and that the protective paper sheets on the top and bottom faces of the plastic must be removed prior to testing. The purpose of the cardboard strips is to create a slow-burning condition at the edges. This allows the specimen regression rate at the edges to approximate that at the centre.

The user should retain test data from previous PMMA calibration runs, and compare against those, when necessary in the process of troubleshooting. The flux values are normally chosen to be 25, 50, 75 kW/m^2. Note that since these calibration runs are for the purpose of diagnostic testing within one laboratory only, ASTM P 190 does not standardize this procedure.

2.5 Initial set-up steps

1. Test all services described above to make sure they are operational. Double check the values of all calibration gases.

2. Make sure that all the calibration equipment, described above, is available and functional.

3. Prior to placing the Calorimeter under the intended room-exhaust hood, turn on the hood and burn a small item in the place where the Calorimeter will stand. Make sure that all combustion products are adequately cleared, and that the air flow into the sample area is as symmetric from all sides as possible.

4. Roll in the Calorimeter and connect all the services. Turn on all the power switches. Turn on the temperature controller for the cone heater to 100 EC. Leave everything on for a while to make sure electric faults do not develop.

   The Test Assembly (Fig. 1.1) comprises:-

   - Load Cell Assembly with optional water cooling plate.
   - Spark ignition assembly with hand operated lever.
   - Heat Shutter assembly with hand operated lever.
   - Water cooling collar for cone.
   - 3-Thermocouple sockets for cone control.
   - Spark ignition interlocks.

   As a safety feature a spark will occur only when:-

   I) Ignition switch on control unit is on

   ii) Spark lever is in rear position

   iii) Shutter level is in left position (i.e. shutter open)

AS HIGH VOLTAGE IS AVAILABLE TO THE SPARK IGNITION THE IGNITION SWITCH SHOULD NOT BE ENERGISED WHEN LOADING OR UNLOADING THE SAMPLE.

THE CONTROL UNIT (Fig. 1.2)

THE FRONT PANEL:

On the Front Panel, the following are mounted:-

! Temperature Controller, Eurotherm 847

! Load Cell Controller, Newport Infinity 1010-DC1

! Tare Button

! Control Switches, comprising:-

4 red. on/off push button switches which operate by firm pressure and light up when activated.

Power - switches on mains electricity to the unit.

Cone - switches on the Eurotherm controller. This, in turn, energises a Solid State Relay which switches the power to the cone heater (5kW). (See separate supplier's instruction manual).

Ignition - switches on the spark generator circuit housed in base on Test Chamber.

Load Cell - switches on the Newport controller. (See separate supplier's instruction manual.

5. Turn off heater; leave on all the remaining power overnight. This will allow gas analysers and other electronics to stabilize.

6. Check out the load cell, the smoke photometer and each gas analyser provided with the system. It is important to verify at this stage that there is no electrical interference, ground loop problems, or other conditions which would result in interference being present on the instrument output. Turn the heater, the cold trap circuit, and the electric spark ignition on and off in doing this. The outputs should all be correct, constant, and showing only an acceptable amount of thermal noise.

7. Temperature Controller - this has been Factory set to give suitable PID settings and these should not need changing. The unit as supplied, has a 60EC/min heating rate. The push button arrows are for setting the set point. Approximate settings for:-

   25kW = 625EC
   50kW = 770EC
   75kW = 880EC
   100kW = 975EC

   It is recommended that if the unit has not been used for a few days to heat to only 400EC for 15 minutes to allow it to settle down.

Water Cooling Collar - the water cooled collar is to reduce distortion of the top plate assembly at elevated temperatures and minimize the distance (25 mm) between the cone and the surface of the sample. Adjustment of the height of the sample is by slackening the knurled screw and sliding the platform to the required height and re-tightening.

Load Cell Controller - this unit has been Factory set to give suitable performances for the application, and has been calibrated at 100 gm. The unit takes approximately 20 minutes to settle down before adjustment should be made.

The Tare button can be used to zero the unit to compensate for changes in the sample holder weight.

The Switch Panel (Fig. 1.3) - 4 red on/off push button switches which operate by firm pressure and light up when activated:-

Pump - switches on the sample pump of the gas train

Cold Trap - switches on the refrigerant cooling unit

Laser - switches on the laser assembly

Analyser - switches on the CO/CO_2 Analyser

The Gas Flow Panel (Fig. 1.4):-

Air/Nitrogen Valve - during normal use this 2-way valve should be in the "Air" position. When zero-ing the O_2 Analyser it is rotated to the "Nitrogen" position.

CO/CO_2 - adjusts the flow to the CO/CO_2 Analyser. For normal operation this should be set to 3 on the Analyser.

Methane On/Off - supply valve for the methane gas calibration burner. This valve should always be in the off position during normal use of the instrument and only in the on position when carrying out calibration routines.

Flow - this adjusts the methane gas flow for the calibration burner. When this valve is set for a typical methane calibration test (5 kW) this valve can then be left at this position and use the "Methane On/Off" valve mentioned above to turn off the gas flow.

The Remote Switch Panel (Fig. 1.5):-

Mounted on this panel is a 5 pin DIN socket, this is for connecting the Remote Switch Assembly for introducing various parameters during the test.

Button 1	indicates	start test
Button 2	indicates	ignition time
Button 3	indicates	event
Button 4	indicates	flame-out

This assembly has magnetic tape for attachment of the item to the frame of the instrument.

The Extraction Panel (Fig. 1.6):-

The dial on this rotates to adjust the speed of the fan and is set to the required flow as indicated on the computer.

The Drying Panel (Fig. 1.7):-

The outer two columns contain Drierite for removing moisture and the centre one Soda Lime for removing CO_2. The flowmeter indicates the flow to the Oxygen Analyser and is adjusted by the knob positioned above the flowmeter and should be set at 150 ml/min. (Flow of greater than 250 ml/min can damage the Oxygen Analyser)

8. Setup and test out the computer programs to be used for data collection and reduction. With the program running, check that cold-junction compensation is being properly done for all thermocouple channels. The operator must make certain, however, once the hookup has been made and the data collection and reduction programs to be used have been installed on the computer, that the proper operation is checked out. To do this, prepare the computer software to output the necessary temperature channels. Make sure the instrument has not been heated and all temperatures are at ambient. Measure the laboratory air temperature with a thermometer. Then scan the temperature channels on the data system and record their readings in EC. A reading close to that obtained from the room thermometer should be found. If not, adjust the computer program routines. It may also be desirable to make a similar check at an elevated temperature, for which a boiling water bath can be used.

9. Put in all soot filters and turn on the sampling pumps to all analysers, even if their outputs are not to be used, so room air will not be drawn backwards through one of the other analysers and pumps and appear as a leak in the sampling line.

10. Roughly check the zero and span on each gas analyser. Check that the load cell responds to weights. If any instruments are seen to be faulty, repair them before proceeding.

11. Perform all the steps indicated in the LESS-FREQUENT CALIBRATION PROCEDURES Chapter, below. Steps which had been performed by the instrument manufacturer may not need to be repeated at this time.

12. Perform all the steps indicated in the WEEKLY CALIBRATION PROCEDURES Chapter, below.

13. Perform all the steps indicated in the START-UP AND DAILY CALIBRATION PROCEDURES Chapter, below. An orifice flow constant in the range 0.040 to 0.046 will be obtained for a unit which is constructed exactly according to the NIST drawings. For units with different duct dimensions, different blowers, etc., a different orifice flow constant will be expected. Once it has been verified that all systems are fully correctly operational and that no leaks are present anywhere in the gas sampling system, the operator should record the constant obtained. Future calibrations which do not produce this constant, to within about ±0.003, will indicate a need for troubleshooting and repair.

14. Once all is in good operation, it is desirable to procure some calibration PMMA material, burn it, and compare results to expected values (details are given in the WEEKLY CALIBRATION PROCEDURES Chapter). Once this is successful, it can be assumed that the installation is satisfactory.

2.6 Calibration levels

The standard calibration procedures, described in the START-UP AND DAILY CALIBRATION PROCEDURES Chapter, call for calibration at a 5 kW level. This level has been chosen because it represents a high heat output, but is not the maximum output detectable. Values up to approximately 20 kW can be recorded.

The 10 kW calibration level is chosen to avoid overheating the equipment. At this level, indefinite operation can take place, therefore, calibrations may be made in a deliberate and methodical manner. Extensive operation at the 20 kW level may result in some ductwork warpage. Heat release rate peaks in excess of 10 kW are rare; it is expected that they are accurately measured, however, since linearity studies have shown excellent linearity in the 0 to 12 kW region.

3

Spares and supplies

The user will need to maintain certain supplies and spare parts for the Calorimeter. The needed items are listed here in three categories: (1) regular operating supplies. The quantities to be maintained will depend on the testing schedule being maintained. (2) Essential spare parts. (3) Spare parts which are less essential to a laboratory doing occasional testing, but which may be essential to a laboratory doing full-time testing.

Operating supplies

- Calibration specimens of PMMA, as described in the previous Chapter
- Fuses for all instruments; thermal cut-out for O_2 analyser; 30 A I^2t ("sub-cycle") fuses for the cone heater power controller
- Soda Lime (unless not used since instead of scrubbing CO_2, correction to the heat release rate formula is made using CO_2 analyser readings)
- Drying medium (Drierite or silica gel)
- Filter cartridge for soot filter
- Filters for analyser
- Floppy disks and tape cartridges for computer
- Ceramic fibre blanket, 13 mm thick, 65 kg/m^3 nominal density
- Aluminum foil (available as 0.025 mm thickness in USA and 0.040 mm in Europe)
- Stainless steel foil, 0.050 mm thick
- Wire grids, if replaceable type grids are used

- Glass wool, bulk, for backup filtering
- Silicone sealant of the RTV (room temperature vulcanizing) type
- Span and zero gases for each gas analyser (where nitrogen is used as the zero gas, it should generally be 99.99% minimum purity)
- Methane, 99.9% purity or better, for calibration
- Gas for leak-checking (use pure CO_2 if a CO_2 analyser is available, else use pure O_2)
- Combustion air and fuel gases for hydrocarbon analyser

Essential spare parts

- Overhaul kit for main sampling pump
- Laser, for smoke photometer
- Pressure transducer for exhaust duct (these usually fail due to internal corrosion from combustion gases and, thus, are not repairable)
- Thermocouples for cone heater, stack, and smoke photometer
- Thermocouple connectors and wire, Type K
- Heater element for cone heater
- Ceramic fibre refractory gasketing material, 2.5 mm nominal thickness

Additional spare parts

- Inside cone, stainless steel, for heater
- Orifice plate, for exhaust stack flow rate measuring
- Power supply for laser
- Hydrocarbon analyser spares: burner parts, capillaries, sample filter(s)
- Temperature controller for cone heater
- Infrared sources for all infrared gas analysers

4

Software for Cone Calorimeter User's Manual

See separate manual.

5

Daily start-up and calibration procedures

The steps below are predicated on the assumption that the Calorimeter has been shut down in the prescribed manner the previous day and no problems were noted in any of the equipment. Maintenance and troubleshooting are described in later Chapters. In each case, the expected result for each action taken is described. If the unexpected does occur, some troubleshooting and corrective action will be necessary.

The order of the steps indicated in this Chapter should be followed unless there are specific reasons to the contrary.

Note that there are mandatory calibration procedures to be followed on a weekly basis. If a week, or more, has elapsed since the last time these calibrations were performed, these weekly calibrations must also be performed before testing is done. In such a case, the user should complete the daily start-up procedures, but before any testing is actually started also complete the necessary weekly calibrations (see the WEEKLY CALIBRATION PROCEDURES Chapter). There are also additional calibration procedures which are done on a less frequent or as-needed basis. Those are described in the LESS-FREQUENT CALIBRATION PROCEDURES Chapter.

5.1 General

! Turn on the power switch.

The power switch controls the power to the pumps and blowers on the apparatus. It does not turn off any of the analysers. It can be used to shut down the main electrical power quickly in an emergency.

! Turn on the WATER supply.

5.2 Checking the cold trap temperature setting

The cold trap temperature is regulated by a controller and a thermocouple. The normal operating temperature of the cold trap is 2E-6EC. A minimum temperature will have to be established which does not lead to trap freezing. Each day, before the first test is run, a check should be made on the cold trap temperature to make sure it is within the right range. This temperature may need adjusting depending on the sample burned. Samples which liberate a lot of water vapour throughout a long test may cause the cold trap to freeze up and block off the flow of gas to the analysers. If this should occur, raising the controller's temperature setpoint up a few degrees will solve this problem.

5.3 Changing the drying and CO_2 removal media

The drying agent is always necessary and is either Drierite or silica gel. Drierite and Ascarite or Soda Lime, respectively, are used for these functions. They are located in glass tubes next to the oxygen analyser. The Drierite is in the outer columns and the Ascarite is in the centre column.

1. The Drierite cartridge uses $CaSO_4$ to remove any residual moisture which may be left after passing through the cold trap. At least some fresh (indicating) Drierite is mixed in any regenerated (white, non-indicating) Drierite to give a visual indication of when the Drierite is saturated and needs replacing. The indicating Drierite is blue when it is fresh and becomes pink as it gets saturated. One should always check the colour in the tube before starting a test to be sure there is enough active Drierite to complete the test.

2. The Ascarite is used to scrub out the CO_2 in the gas stream going only to the oxygen analyser. Ascarite is NaOH on a clay filler. The colour of fresh Ascarite is a light brown. As it absorbs CO_2, the colour changes to white. Excess water in the gas stream will cause the individual grains to fuse together and may even cause a solid plug to develop and block the gas flow. Always check the analyser rotameters before starting a test to be certain that the Ascarite is not blocking the gas flow. It is important to correctly replace the Ascarite in the centre column and the Drierite in the outer columns. If they do get reversed, the CO_2 reading will be wrong.

   Supplied with the unit is Soda Lime which changes colour from white to violet. (size 1.0 to 1.7 mm)

PRECAUTION

Because Ascarite is a strong base, care must be exercised in handling it. It is recommended rubber gloves be used for handling Ascarite to avoid skin irritation. Also, Ascarite spilled on the apparatus can damage it. Avoid spilling any of it on the equipment-clean it up promptly with water if you do.

Soda Lime: Irritant to eyes, respiratory system and skin etc.

5.4 Draining the condensed water from the cold trap

The cold trap condenses water from the gas sample line. When the Calorimeter is shut down at the end of the day's testing, the power is turned off to the cold trap. This causes the water which was previously frozen to the condensing tube to melt and drip down into a collection tube. At the bottom of this tube is a large ball valve. This valve is opened and a cup placed below it to collect the water. Once all the water is drained out, simply turn the valve 90 degrees to close it. Discard the collected condensate.

5.5 Changing the soot filters

The O_2, CO_2, and CO sampling line has a non-heated disposable soot filter in it. This filter prevents soot from getting into the pump and the analysers. This filter is located on the rear of the unit. This filter must be changed as often as necessary. Some samples burn clean enough to allow the same filter to be used for several tests. Other samples burn so dirty that the filter will only last through one test. Of course, never change any of the filters while running a test. When a new filter is inserted, make sure that it is firmly seated and that there are no leaks around the edge. If there is any evidence that soot has blown by the filter, the backup filter must be taken out of the line and renewed. Hepa Vent 0.3 F m Pt.No. 6723-5000. For very smokey specimens it is suggested to fit a pre-filter between the sampling ring and the primary soot filter. A suitable pre-filter consists of glass wool in a glass column.

5.6 Gas analyser calibration (Zero/Span)

In doing the calibrations below, it must be emphasized that, if the flows to any gas analyser are not identical in the zero, span, and sample conditions, a correct calibration will not be achieved! It is assumed that all the analyser flow rates were previously set up correctly, as described in the Chapter on LESS-FREQUENT CALIBRATIONS. During daily calibration, however, the operator should check that the flow rates, as indicated by the appropriate rotameter, are identical during zeroing, spanning, and sample running. If necessary, correct the flow rates by adjusting the pressure regulator on the zero or span gas cylinder.

! Setting the correct ranges on the analysers.

The CO_2 range is fixed at 10% maximum.

The O_2 analyser has a range switch, but this should never be changed. The correct setting is for the 0-25% range.

The CO range is fixed at 0-3000 ppm

! Zeroing the O_2, CO_2, and CO analysers. (See instructions in specific analyser's manual).

! Spanning the CO_2 and CO analysers. (See instructions in specific analyser's manual).

! Spanning the O_2 analyser. (See instructions in specific analyser's manual).

5.7 Setting the flow rates for the exhaust and for the soot sampler

1. Check that the exhaust system has been turned on and is exhausting air properly.

2. For normal testing, where room air is to be used as the combustion air, the Cone Calorimeter exhaust control blower is on CONSTANT VOLUME. In this mode the motor speed is held constant and the mass flow through the duct is allowed to change as the gas temperature changes.

3. Check the Calorimeter exhaust flow rate. This should read 30.0 grams per second; adjust the manual flow rate setting knob, if need be.

4. The optional soot sampler flow rate is adjusted next. This is the most convenient time to do that, since the exhaust system is cold and the main exhaust duct mass flow rate is not varying. Set the soot sampler to the PROPORTIONAL MODE switch position. Set the proportional-mode flow setting control knob to an appropriate setting depending on the sootiness of the sample — 1/500 of the main duct flow is the typical setting. [This ratio has to be determined by determining what 1/500 of the exhaust duct flow would be, which is 30/500 = 0.060 g/s for normal operation, and then setting to that desired value.] The soot sampler has a range from approximately 1/200 to 1/1000 of the main duct flow. For sootier samples, a lower sampling fraction should be chosen.

5.8 Checking the orifice flow constant

[The instructions below presume that the weekly calibration of the electronic mass-flow controller has been made successfully, as described under LESS-FREQUENT CALIBRATION PROCEDURES, *below.]*

1. Make sure that the exhaust system flows have been correctly set up, as described above, and that no ventilation difficulties are observed.

2. Insert the calibration burner in place, and set the mass flow controller valve setting (located below the burner) on the front of the machine for its correct 5 kW value. Ignite the burner with the spark ignition. **(See Warning in Safety Chapter)**

3. Set up the computer for the calibrations as described in the DATA COLLECTION AND ANALYSIS Chapter.

4. During the baseline value check, recheck the oxygen analyser reading to be sure it is 2.0950 volts. If it has drifted slightly, it should be readjusted. Experience has shown that if such a slight drift occurs, it is most typically associated with the zero, rather than the span, end of the scale. Thus, to readjust, turn the *zero* knob on the analyser. If the oxygen analyser reading has shifted significantly, find the reason for this sudden shift and correct it before proceeding.

5. Turn on the methane gas calibration cylinder (make sure that the gas is of $ 99.9% purity).

6. With the calibration burner in place, turn on spark ignition. Turn on the gas-flow valve. This will allow the methane gas to flow. Ignite the gas; make sure a steady flame is established.

7. Let the test flame burn for 3 to 4 minutes, then depress the appropriate button on the computer.

8. Obtain the orifice flow constant. If the actual value is substantially different from the reference value established for the instrument during its initial set-up (0.040 to 0.046), consult the TROUBLESHOOTING AND REPAIR Chapter.

9. Turn off the methane gas at the gas cylinder. Allow all gas in the line to burn off, then turn off the valve. (Failure to bleed the line may cause the burner to leak methane during a test.) This procedure is now finished.

6

Preparative procedures

The following procedures are done as needed to assure adequate preparation for actual testing.

6.1 Sample preparation

1. Conditioning. The manner in which samples are prepared can have a very significant effect on achieving reproducible and valid output from the Cone Calorimeter. Hygroscopic samples should be conditioned in an environment of 50% relative humidity (±5%) and 23EC (±3E) until a stable specimen weight is reached. If nonstandard environmental conditions are used in preparing the sample (such as oven drying), these conditions must be documented and included in the comment section of the test data file. Conditioning of some samples and, especially, oven-drying can shrink the specimen size; thus, it is preferable to condition first, and cut to size afterwards.

2. Determining the exposed surface area. The exposed surface area of the sample is an important parameter in data analysis, and must be well known. For consistency in conducting tests, it is, therefore, desirable to have all the samples conform to this 0.01 m^2 (100×100 mm) surface area dimension after all sample conditioning has been completed. With those sample holders which have an edge lip, the area exposed to heating at the start of the test is 0.008836 m^2 (94×94 mm). A correction for this is not normally made, since it is assumed that shortly after burning starts, the surface recedes somewhat, exposing the whole 0.01 m^2 specimen. The use of the wire grid, when used to restrain intumescing samples, is also assumed not to reduce the nominal exposed surface area.

   For certain cases, it may not be possible to test 100×100 mm samples, and a different geometry may be necessary, for instance, a circular specimen. Within reason, it is possible to take care of this deviation by entering the actual specimen's surface area, when asked that question by the computer program. Excessive liberties, however, should not be taken with the specimen size, since it has been shown that both the ignition time and the rate of heat release could become somewhat changed. These effects are not expected to be detectable for area changes of <50%.

3. Preparing the specimen to the correct thickness. In all cases, sample thickness must be determined during the sample preparation. Where the sample being tested is supplied in a standard thickness of less than 50 mm thick, it is a simple matter to determine and record the sample thickness. (See the caveat about very thin samples in § 6.3.3 of ASTM P-190). In instances where the product is made up of several different layers totalling greater than 50 mm in thickness, the test protocol will usually specify some means of how the thickness should be proportioned. The procedure that was actually used should then be reported in the test Report.

   For some applications, the test protocol being used will specify that thin layers, ones less than a certain number of mm thick (which would be difficult to section), should be used in full-thickness, whereas the remaining, thicker layers should be depth-sectioned so that the ratio of their depths in the test specimen resembles the ratio in the product.

   When composite specimens are encountered, very likely special means of edge protection will have to be used. This is especially true if some layers serve a protective function. In the case of upholstered furniture samples, for example, the procedures which have normally been used at NIST involve initially cutting the fabric, plus any protective interliner layers, to a size of 200×200 mm. From this piece, a square of 50×50 mm is removed from each corner. The resulting cruciform-shape covering is then laid over the padding material, and the four sides folded down. Finally, after the specimen has been weighed (see below), the covering material is stapled at a 45E angle at the bottom edge.

   Composite specimens may also present special problems if the layers need to be bonded together. A careful note should be made in the test report of any necessary bonding procedures.

4. Weighing and final preparation. Once the actual arrangement of the sample has been completed, the sample is weighed. This should be done before any pins or staples are used to assemble the various layers or pieces together. Weigh only the sample, record this weight, and enter it when the computer program asks for the sample mass. The completed sample is then wrapped in one layer of heavy-duty aluminum foil, leaving the appropriate surface exposed. Stainless steel foil may need to be substituted for the aluminum foil where high temperatures or specimen reaction chemistry destroy the shape or integrity of the aluminum foil or allow the sample to spill out or off the load cell. Be sure to note in the test comments the use of the stainless steel foil instead of the aluminum foil. The sample is now ready to be placed in the appropriate sample holder. *Note:* The wrapping with aluminum foil is not done for the case of the standard PMMA calibration specimens.

5. Non-uniform products. The case of specimens which are non-homogeneous in the thickness dimension has been considered under the thickness measuring procedure above. Some products, further, exhibit non-uniformities in the direction(s) parallel to the thickness. In such cases, the testing protocol established for the particular test series will usually include a specification describing how many different specimens are needed and where they should be taken from. An example of a product with such non-uniformities would be an upholstered chair where the seat and back constructions are different.

6.2 Preparing the specimen holder

For the horizontal specimen holder, the specimen is placed on top of a layer of ceramic fibre blanket, which is placed into the holder. The total thickness of the blanket should be 13 to 20 mm. The actual thickness will depend on the weight of the specimen and on the age and condition of the blanket. The blanket should be replaced if it is contaminated with specimen melt or residue.

For the vertical specimen holder, the specimen is directly backed by at 13 to 20 mm thickness of ceramic fibre blanket. At least one layer of rigid ceramic fibre board is then placed in back of the ceramic fibre blanket layer. The thickness of rigid board to be used will depend on the thickness of the specimen. The complete assembly, when mounted in the holder, must fit snugly, but without forcing.

6.3 Use of special sample holder equipment

In addition to the normal horizontal or vertical sample holders, three other accessory devices may be needed for special testing. These are (a) the horizontal holder edge frame, (b) the wire grid, and © the fabric tensioning insert.

The **horizontal holder edge frame** is used for testing in the horizontal orientation: those composite specimens where edge burning is anticipated, all wood specimens, and any other specimens where experience shows that its use is necessary to prevent unrepresentative edge burning. The edge frame must also be used if it is desired to test in the horizontal orientation using either the wire grid or the fabric tensioning insert. The edge frame is equipped with two thumbscrews, located near the bottom edge. To use, place the specimen on top of the refractory fibre pad on the specimen holder. Place the edge frame on top of the specimen. Check that it fits snugly against the top of the specimen, but do not force down. Tighten the two thumbscrews against the edge of the horizontal specimen holder to achieve a rigid connection.

The **wire grid** is used primarily for intumescing or delaminating materials. It is normally used in the horizontal orientation in conjunction with the edge frame; however, it can also be used in conjunction with the standard vertical specimen holder. The ASTM and ISO standards and the Construction Drawings show an example of a wire grid. Different specimens can have different behaviours when they intumesce; thus, a single design for a grid may not cover all possibilities. The test operator should select the restraint method which is appropriate to the specimen being tested. In some cases, this may be as simple as two thin wires wrapped around the specimen. In any event, the test report must specify what restraint method — if any — was used. If a restraint method is used which is not the standard design, the test report must contain a description of the design that was actually used.

In the horizontal orientation, place the specimen on the specimen holder, place the wire grid on top, then place the edge frame on the assembly. Check that the frame fits snugly against the top of the wire grid, and that the wire grid is snug against the top of the specimen. Tighten the two thumbscrews against the edge of the horizontal specimen holder to achieve a rigid connection. In the vertical orientation a separate edge frame is not needed, and the wire grid is simply placed first into the holder, before loading the specimen.

The **fabric tensioning insert** is used in conjunction with the horizontal edge frame for testing fabrics and films that need to be tested over a dead air space (it is not intended to be used in the vertical orientation). The fabric specimen is cut with about a 25 mm extra border around its four edges. It is then placed over the tensioning insert. The horizontal edge frame is then forced on top, until it is fully seated. The assembly is then placed on top of the horizontal specimen holder, creating a dead air space underneath the sample. Finally, the thumbscrews are used to secure the assembly.

6.4 Recording pre-test data

Information to be recorded in the laboratory notebook should include the mass of the specimen (excluding any aluminum foil, pins, staples or other fasteners not normally associated with the sample), its thickness, and its area (if non-standard). It is also desirable to record the thickness and the mass of the separate layers of composite samples. The identity of material, if known, and any other distinguishing or unusual characteristics of the material should be recorded. The mass information on the soot filters to be used should be recorded, along with the serial numbers which have been assigned to them.

7

Running tests

7.1 General

At this point, it is assumed that the operator has a fully-operational apparatus, and has followed all the steps of the DAILY START-UP AND CALIBRATION PROCEDURES and of the PREPARATIVE PROCEDURES.

The running of routine tests is covered by ASTM E1354/ISO 5660. The user should consult this for instructions, which are not repeated here. A few additional points on equipment operation are given below, however.

7.2 Checking gas analysers, sampling lines, filters

The actual running of the test can only be carried out after the analysers have been properly set up, including the zeroing and spanning of all the gas analysers. The gas analysers should all be set in the "run" mode and drawing air from the main exhaust duct of the Calorimeter. Before each new test, check if the flows through the analysers are at the same level as was used in the calibration of these analysers; this should also be occasionally checked during the course of each test to ensure that they are not dropping due to clogged filters or icing of the cold trap. If during a test the analyser flows do fall, replace the filters (after the end of the test) and check the waste regulator to be certain it is set correctly. The waste regulator may also be adjusted during a test run to restore the proper flow setting on the gas analysers. Always start the day's first run with clean filters and look at them after each run, replacing as necessary. Visual inspection of the filters is generally a good indication of clogging (some materials, however, seem to produce sticky deposits on the filters which restrict the flow, even though the filter does not look particularly dirty). Cold trap freeze-up can also be a cause of low flows to the analysers. If ice plugging occurs, turn off the power to the cold trap and allow ice to thaw, then drain the water from the collection tube.

Check that all the sampling pumps are running, even if a particular analyser is not being used (this ensures that no room air is drawn back through these idle pumps and appear as a leak in the sampling system). Check the Soda Lime, Ascarite and Silica Gel/Drierite to be certain that there is enough to complete the test.

[Note that it is not permissible to change filters, Ascarite, or Drierite during a test. Thus, if it is discovered during the course of test that any of these are clogged or used up, the test must be re-run.]

7.3 Checking the cold trap

Check the cold trap temperature to be sure it is at the desired setpoint.

7.4 Checking the exhaust duct flow

The exhaust duct flow is usually set at 30 g/s (cold). Remember that the duct flow will drop after the heater is turned on. Do not readjust the warm flow back up to a 30 g/s rate.

For non-routine testing, it is possible to use a different main duct flow setting without adversely affecting any of the results. It may be desirable to use a lower setting if detailed gas analysis measurements are to be made on a specimen where a very small heat release rate is expected. Remember to increase the flow back to the 30 g/s range for subsequent tests. The instrument can safely measure heat release rate values up to 2000 kW/m^2 only if there is sufficient duct flow to provide adequate cooling and prevent metal warpage and possible ductwork damage.

7.5 Setting the cone heater orientation and height

> *(This should, if at all possible, be done with the heater* ***cold****, otherwise gloves have to be worn, and the operation becomes more difficult.)*

Set the required orientation, horizontal or vertical.

In the vertical sample orientation, the sample to heater distance is fixed by the holder; the operator should, however, verify that the cone heater height is correct. The height is correct when the centre of the opening of the cone corresponds to the centre of the specimen's face.

In the horizontal orientation, the operator has to check before each test that the correct cone-to-specimen spacing is maintained, and will have to re-adjust the heater height when specimens of different thickness are tested. If the heater is cold, to set the proper height of the cone heater above the specimen's exposed face, place the sample on the horizontal sample holder pan, which is resting on the load cell, and move the sample support up or down until a 25 mm spacing between the top of the sample and the lower surface of the cone's base plate is obtained. If necessary, it is possible to set this spacing when the cone is hot. To do this, place the empty holder on the load cell and measure the spacing above the top of an imaginary specimen with a ruler. This should be done first on the bench by measuring the distance from the top of the specimen holder's lip to the top of the specimen, as it actually sits on the (now compressed) refractory blanket. This measurement must be added to 25 mm, and the total distance then measured from the holder's lip when it is placed under the cone. When running the test, some final adjustment may be necessary in this cone/sample spacing. This correction should be made as soon as possible after the start of the test to help minimize the time the sample is exposed to the wrong flux. This positioning correction should be very small or ideally not required at all. Significant errors in this spacing (greater than 4 mm) should be cause for aborting the test and correctly readjusting the spacing and rerunning the test.

When testing in the horizontal orientation, remember to have available a second, empty (no specimen, but with a refractory blanket) specimen holder, which will be kept on top of the load cell whenever possible that the heater is on and keep the shutter closed except during running a test or while using the heat flux meter.

7.6 Checking the load cell

The load cell must be checked before each test.

Insert the sample holder which is going to be used for the test and wait for the digital meter to stabilize and then press the Tare button so that 0.0g is displayed. With a weight similar in range to the specimen being tested, place this on the sample holder and confirm that the digital meter and the computer are recording the value. If readings are incorrect see "Software for Cone Calorimeter User's Manual".

In order for the software, or a chart recorder, to record the mass of the specimen correctly, the load cell controller maximum mass, m_{max} must be set to greater than the mass of the specimen. For example, if your specimens weigh around 75 g then set the maximum to 100 g, if your specimens weigh around 25 g then set the maximum to 50 g. At this maximum the signal sent to the computer, or chart recorder, must be 10 Volts and at zero mass 0 Volts must be sent to the computer, or chart recorder (note that the chart recorder must be on the 10V calibrated scale). The following sequence show how to set the maximum output.

PUSH	**DISPLAY**	**COMMENTS**
MENU×17	OT.SC.OF	
MIN	READ 1	
MAX/MIN	00000.0	READ 1 must be 00000.0
MENU	OUTPT1	
MAX/MIN	00.0000	OUTPT1 must be 00.0000
MENU	READ 2	
MAX/MIN	m_{max}	Enter maximum mass here (for example 00100.0)
MENU	OUTPT2	
MAX/MIN	10.0000	OUTPT2 must be 10.0000
MENU	STORED 6 RESET2	

If a PC is connected, in the software chose **[Calibrate|Mass]** and in the Mass FSD field enter the maximum mass you entered into the controller, m_{max}. Ensure that the Volts FSD field is 10. Press **<Apply>** and then place a weight on the load cell and ensure that the screen agrees with the instrument. Then press **<Accept>**.

7.7 Setting up the desired flux of the cone heater

This procedure will only be necessary if changing to a different heat flux or orientation from the previous test.

A calibration table should be available for this purpose, as described under the LESS-FREQUENT CALIBRATION PROCEDURES. The table will contain both the heater temperatures corresponding to various common irradiance fluxes and the corresponding millivolt outputs for the heat flux meter. To set up the heater, turn on the switch labelled CONE and adjust the controller to the desired temperature by holding in the button on the controller marked • or – as appropriate, to raise or lower the displayed setpoint. Once the controller's setpoint is adjusted to correspond to the value referenced in the look-up table, the final adjustment should be made with the heat flux meter in place under the cone. The heat flux meter holder is designed so that inserting it into the mating holder on the cone it will automatically position the heat flux meter 25 mm from the bottom of the cone and directly at the centre of it. Periodically this position should be checked to be certain the hardware has not been bent or misaligned. The output from the heat flux meter is fed through to the D/A board. Periodically, with a digital voltmeter, the millivolt output of the heat flux meter can be determined. The final tuning of the cone heater can be accomplished by adjusting the controller setpoint temperature to produce the expected millivolt output from the heat flux meter. Be sure to give the controller time to stabilize and overcome the thermal lag associated with the heating elements.

Note: The heat flux meter will be typically rated at less than 110 kW/m^2 maximum output; leaving it exposed under the heater for long periods of time at higher than rated fluxes can damage it or cause the calibration to change or degrade.

Special warning: The heat flux meter will lose its correct calibration if the flat black coating of its sensing face is damaged. This coating is rather easily damaged if the face is struck against any other metallic object. The operator should establish a safe-keeping position for the heat flux meter where it can be placed and rested without the danger of contact with its sensing face.

7.8 Computer program setup and starting the test

See Software for Cone Calorimeter User's Manual, Chapter 7.

7.9 Ignition

The presence of ignition is observed next. This may require some experience on the part of the operator, since the ignition event to be recorded is a sustained ignition, rather that a brief, non-sustained flash. When ignition is observed, press the **IGNITION** key. Turn off the sparker power and remove the sparker arm.

> *Note:* Some materials have a propensity for intumescence, bubbling up, or bowing up. In each case, this can interfere with the operation of the sparker. If such problems are experienced, it will usually be necessary to re-run the test, using a wire grid to hold the specimen in place. In extreme cases, even the use of the wire grid may not be sufficient to prevent interference with the sparker. The test operator should observe the specimen closely as it is intumescing. If the standard wire grid is not successful, it may be appropriate to consider a restraint of a different kind.
> It has been found that the effect of the wire grid on the ignition time data is proportional to the total grid mass. Thus, for specimens which intumesce only mildly, it can adequate to wrap them around at several places with a thin wire. If such non-standard restraint techniques are used, the test report must contain a description of the actual method used.
>
> In some cases, successful ignition may still be achieved if the sparker is used in a location closer to the edge, rather than in the normal location at the centreline. In more severe cases, it is sometimes possible not to use the sparker and, rather, to ignite

with a propane torch. Such procedures, however, definitely fall into the category of non-standard testing, and should be documented as such in the test report.

7.10 Observing the test

Soon after starting the test, the operator should take a look at the reading on the load cell indicator, to make sure that a value fairly close to the actual specimen mass is seen. If an implausible reading is seen, the test should be stopped and the load cell re-adjusted or repaired.

The burning specimen should be observed during the entire course of the test. The operator should look for:

- pieces falling off
- dripping
- excessive swelling (the specimen should not swell so much as to foul any metal portions of the apparatus)
- explosive spalling
- any other anomalous behaviour.

If any of those are observed, an appropriate note must be recorded.

The operator should also observe that pyrolysed matter is not accumulating on the heater coils. This is very rarely a problem, but has been noticed with certain types of silicone specimens tested in the vertical orientation. If such residue is building up upon the coils STOP THE TEST. The test is to be stopped by turning off the 230 VAC power to the heater. If testing is continued with such buildup occurring, the heater coils will, very likely, overheat and burn out at the place where the buildup has occurred.

The operator should periodically observe the rotameters on the gas analysers to see that flow rates are not dropping. The oxygen analyser should also be periodically observed to see that plausible values are being shown. Occasionally, it is worthwhile to see that the cone heater temperature controller is in good control. The controller will register a positive deviation of a few degrees when ignition occurs. This deviation should rapidly diminish, however, and values close to the setpoint should be seen during most of the test. If a systematic offset is seen, the controller settings should be checked and re-adjusted, as explained in the instruction manual supplied with the controller.

Caution: Make sure not to blow upon the specimen during testing. Such an action will put anomalies into the heat release rate curve.

7.11 End of test

The test is normally ended when all signs of combustion have ceased, with the possible exception of a very small, continued mass loss. The end has not yet been reached if there is any flaming or any visible pyrolysis or smoking. Some types of specimens may show an extended period where there is no flaming or active smoke being emitted, but there is still a char matrix which is glowing and losing mass at a very slow rate. Normally, it is considered acceptable to stop a test when that state has been reached. In specific cases, however, the preferences of the sponsor of the test should be considered. The operator should use good judgement to make sure that a test is not stopped short where the combustion has entered a non-flaming stage, but, where there is an amount of combustible material still unconsumed which will flare up at a later time. If in doubt, the test should be continued longer than necessary rather than risk stopping it too quickly. *Make sure now that 2 additional minutes of test data are collected after the end of combustion has been declared.*

At the completion of the test, stop disk logging and close the disk file OFF. This stops data being logged to the hard disk.

Close the shutter mechanism.

Remove the specimen holder (using gloves or pliers!), and place in a chemical exhaust hood to cool down. The hood is necessary so that any remaining degradation products do not enter into the habitable laboratory space. Take the specimen out of the holder, so that the holder would cool off faster for re-use. Note that each test *must* be run with a cold holder, so that at least two holders will always be necessary. Check the holder and the ceramic fibre blanket for any residues. If necessary, clean the holder and replace the blanket.

If testing in the horizontal orientation, place a blank specimen holder under the cone heater, in order to avoid excessive heating of the load cell.

Type into the computer program the post-test comments, which will normally consist of any observations of specimen behaviour made during the test.

8

Daily shutdown procedures

The prescribed shutdown does not turn everything off. The O_2, CO_2, CO, and H_2O analysers are left on constantly. Other devices are also left on: the pressure transducer/transducer power supply, smoke meter electronics, and the data acquisition system. This is done to keep the electronics stable and avoid an excessive warm-up period the following day. The detector cells in the various analysers are also kept at a slightly elevated temperature to prevent the condensation of water in them. It should be noted that, even though the analysers are left on, no gas is flowing through them except during zero/spanning and testing. Some of the analyser manufacturers do recommend a dry N_2 purge be run through the analyser when the analyser is not being used. All the manufacturers recommend purging their analysers before turning their power off for long-term storage. We do not employ an overnight purge in any of our analysers and have yet to see any deleterious effects. We do, however, purge the entire gas sampling system with room air for about 10 minutes after the last test of the day so the analysers and lines will not sit overnight with residual combustion gasses in them.

1. Continue running the analysers and the sampling system for about 10 minutes after the end of the last test.

2. After room air has been run through the analysers, turn off all the pumps: Turn off the switch marked PUMP.

3. Turn off all gas cylinders — do this by turning off the cylinder valve at the top of the cylinder; **do not turn off the regulator outlet valve nor the regulator control handle**. Normally all the gas cylinders except for the hydrogen/helium and the air cylinders feeding the hydrocarbon analyser would have been turned off once their spanning and zeroing was finished. Double-check, especially, that all combustible gas cylinders have been properly turned off. The special precautions in shutdown and purging of the hydrogen chloride cylinder have been covered under DAILY START-UP AND CALIBRATION PROCEDURES, above, which should be consulted.

4. Turn off the Calorimeter exhaust. Do **not** do this before all smoke has been fully cleared out from the apparatus. Shutting off the exhaust with a smoky atmosphere still present may lead to smoke particulates being deposited on the optics of the smoke photometer.

5. Turn off the Cone heater. The toggle switch marked CONE does this.

6. Turn off the water supply when the cone heater has cooled down.
7. Be sure all samples which have been tested are extinguished.

This completes the shutdown procedure.

9

Test report

The basic requirements for the test report are given in the ASTM/ISO document. Most of the numerical data are obtained directly from the data reduction using the computer software. Other items are normally entered in the comment lines on the test data file. Only a limited amount of information, however, can be incorporated into those comment lines. Thus, it is the responsibility of the operator to maintain a supplementary laboratory notebook, where deviations from standard procedure, additional test conditions established for a particular test series, problems of equipment malfunction, and similar data are recorded. The operator is responsible for verifying that the data entered into the computer test file and the information recorded in the laboratory notebook for each test include each item mandated by ASTM/ISO, in addition to the operator's noted observations during test and the necessary supplemental data.

For most applications, especially for research and development, significantly more numerical test data will need to be tabulated than is the minimum specified in ASTM/ISO. For this purpose, the Construction Drawings include an example computer-generated test report. Before designing their own report format, users should consult this example report. While additional information is always easy to add, it is strongly advised not to omit any data tabulations shown in this example for which the user possesses the necessary instrumentation. It is much easier to cope with a superfluity of data than it is to have to re-generate tests because now-needed data are missing.

9.1 Computer-generated standard reports

A large enough number of data items are associated with Cone Calorimeter testing, that data management has to be addressed systematically. For the last few years, NIST has been working on developing a standard report format. The FDMS software contains a menu choice which allows a ‘standard’ Cone Calorimeter to be generated. Users will presumably eventually desire to define additional report formats which present special data of interest to them. Such ‘user formats’ should generally aim to supplement, rather than exclude information. Both the variables printed out and the form of these variables (*e.g.*, averaging routines, significant decimal places, etc.) have been carefully studied and have been found to be important for normal fire safety design purposes.

10

Weekly calibration procedures

There are some essential procedures which must be accomplished on a weekly basis. They are sufficiently time-consuming so that their use daily would unnecessarily slow down testing. If when they are accomplished it is discovered that an error was present, it will usually be necessary to discard the test data generated after the time of the last good calibration. Thus, extending the calibration interval to more than 1 week would be imprudent.

10.1 Checking the calibration of the electronic mass flow meter

For daily calibrations, the settings of the electronic mass-flow controller are very stable; nonetheless, since the electronic mass-flow controller is not intrinsically calibrated, its readings must be checked against a reference method weekly, according to the procedure below.

- Turn on the exhaust system; set the flow rate for 30 g/s.

- Insert the calibration burner in place and strike a match. Flip the methane-flow toggle switch to the horizontal position. This will allow the methane gas to flow. Ignite the gas.

- Check the methane flow rate by clocking the required (indicated) litres of methane in a one minute time period. This is done with a dry test meter calibrated for methane. For typical laboratory conditions where the absolute pressure of the methane, monitored inside the dry test meter, is 108.1 kPa and the corresponding temperature is 293 K, a flow rate of 16.86 litres of methane (indicated) per one minute is required. The above flow rate then represents a 10 kW rate of delivering methane. If laboratory temperatures or line pressures are different from above, then the required volumetric flow rate will have to be recomputed, using the basis of 50.0×10^3 kJ/kg as the net heat of combustion of methane. This gives the following required actual gas flow rate, $\dot{V}$ to obtain the 10 kW rate of methane:

$$\dot{V} = 16.76\left(\frac{101.3}{P}\right)\left(\frac{T}{273}\right) \ \text{l/min} \tag{1}$$

  where P is the gas pressure in the test meter (kPa), and T is the gas temperature (Kelvins) in the test meter.

- Adjust the potentiometer setting the level for the electronic mass-flow controller to a new setting if the desired flow rate is not obtained.

- *Note:* With current versions of the data acquisition software, it is not necessary to deliver exactly 10 kW for calibration purposes. A different kW-value may be delivered, if that value is accurately known and is entered into the program when the relevant question appears on the screen. If a value different than 10 kW is used, a note must be saved which records what potentiometer setting corresponds to what flow level. The kW rate for an arbitrary (indicated) volume flow rate of methane is computed from:

$$\dot{q} = 0.597\left(\frac{P}{101.3}\right)\left(\frac{273}{T}\right)\dot{V} \ \ \text{kW} \tag{2}$$

10.2 Checking system calibration with PMMA

The basic check of the stability of the various measurement systems is the test burn made with PMMA. To do this, use a PMMA calibration specimen, prepared as described in the INSTALLATION AND INITIAL SET-UP Chapter. Set up the Calorimeter for normal operation in the horizontal orientation, with an irradiance of 50 kW/m^2. Burn the specimen and record the data as for a normal test. Once reduced, the test data are then examined for:

- Heat of combustion (test avg.)

  This should be in the range of 24.0 to 24.9 MJ/kg.

- Ignition time

  This should be 24.0 ± 2 s.

- Average heat release rate

  Over the time period from ignition to 900 s past ignition, the average rate of heat release should be 620 ± 20 kW/m^2.

- Specific extinction area (test avg.)

  This value should be 110 ± 8 m^2/kg for Polycast PMMA and 150 ± 10 m^2/kg for extruded PMMA

- Soot yield

  This should be 0.0104 ±0.0014 (kg/kg).

- CO_2 yield (test avg.)

  This value should be 2.20 ±0.15 (kg/kg).

- CO yield (test avg.)

  This value should be 0.0060 ±0.0010 (kg/kg).

- H_2O yield (test avg.)

  This value should be 0.72 ±0.03 (kg/kg).

- Total hydrocarbons yield (test avg.)

  This value should be 0.0010 ±0.0005 (kg/kg).

If any of these values do not conform to the expected ones, further troubleshooting and repair must be done; see the Chapter devoted to these procedures.

10.3 Calibrations with ethanol

Some laboratories prefer to do additional calibrations using ethanol, as a separate check on the correct value of C. The procedure is as follows:

- The Cone Calorimeter system should be in a condition of being ready for testing, but the heater power is to be turned off.
- Weigh out carefully about 20 to 30 g of ethanol, held in a quartz cup. The weighing should be done on a laboratory balance, not on the normal load cell.
- Place the cup on the sample horizontal sample holder, making sure that the appropriate layer of ceramic fibre blanket is present in the holder.
- Start the data collection system.
- Ignite the ethanol with a match.
- Collect data for two minutes after all fuel is gone.
- Compute the expected total heat release as 26.78 (kJ/g) x mass of ethanol (g). This should compare very closely to the value computed from the software, if the flow constant C is correct.

11

Less-frequent calibration procedures

11.1 Calibrating the heater thermocouples to actual heat flux values

(This procedure is normally done once monthly.)

In the normal operation of the calorimeter, the correct setting of the heat flux can be quickly attained if one knows the temperature of the thermocouples which give the desired heat flux. To do this, it is necessary to first generate calibration tables of heater temperatures *vs.* heat flux to the sample. Separate tables are to be made for the horizontal and for the vertical specimen orientations. To make these calibration tables, insert the heat flux meter in its holder, being certain the centre of the heat flux meter is at the centre of the cone and exactly 25 mm from the bottom of the cone heater plate. (By this reference is meant the bottom of the over-all heater retaining plate.)

Note that for this calibration step, NO specimen holder or specimen blank is to be used.

Select the desired — horizontal or vertical — orientation. With the heat flux meter set up, turn on the fan to the typical 30 g/s and increase the temperature setpoint on the controller for the cone heater until the millivolt output of the heat flux meter (converted to kW/m^2 by using the heat flux meter calibration) shows the appropriate reading. Be sure to give the controller enough time to stabilize before recording the temperature. When complete, the procedure should generate the heater temperatures which correspond to flux readings starting from 10 kW/m^2 to 100 kW/m^2 in 10 kW/m^2 increments plus three intermediate values of 25, 35, and 75 kW/m^2. Now perform the same calibration steps for the other orientation.

With these tables, it becomes a easy matter to get a particular flux simply by setting the controller temperature to the temperature corresponding to the desired flux from the lookup table. It is important to realize that the temperature of the thermocouples in the cone heater will **not** give the exact flux but only a close approximation. It is always necessary to use the heat flux meter to set the final flux. This may require setting the controller's setpoint temperature a few degrees higher or lower than what was originally calibrated for the lookup table. This slight variation in temperature *vs.* heat flux is to be expected as the thermocouples age and shift their position due to expansion and contraction of the heating element. If any major variations develop in these ratios, this is a sign of possible trouble and should be investigated. See the TROUBLESHOOTING AND REPAIR Chapter for further details.

As a final check that the table has been done on a properly working heater, compute the effective emissivity × view factor quantity. This is done by computing *eF* as:

$$\varepsilon F = \frac{\dot{q}''}{\sigma \left(T_c^4 - T_o^4\right)} \tag{3}$$

where $\dot{q}''$ is the measured heat flux measured by the heat flux meter (kW/m^2), s = 5.67 × 10^{-11} kW/m^{2}K^4, T_c^4 is the temperature of the cone heater (in degrees K!), and T_o^4 is ambient temperature (298 K). This check should be made, as a minimum, at least at one mid-range flux value, typically 50 kW/m^2. The result for eF should be between 0.65 and 0.85 if the thermocouples are operating properly. Values of 0.9 or greater indicate a fault with one or more of the thermocouples. If this occurs, the thermocouples should be fixed, then the above calibration procedure re-done.

11.2 Gas burner checks, 5 and 10 kW level

(This procedure is normally done once monthly.)

See Warning in Safety Chapter

The heat release calibration is normally highly linear and no linearity corrections need to be applied. In some cases, however, it is possible to have a problem, such as a line leak that shows up at certain temperatures and not at others. Such a malfunction would introduce a non-linearity into the calibration. Thus, periodically it is desirable to check the performance at another level, specified as the 5 kW level in the Standard. The check involves using the normal methane gas calibration burner. Since a steady-state reading alone may not indicate certain potential anomalies, it is desirable to record a complete square-wave test at each chosen level. Often, it is desirable to go in 1 kW steps from 1 to 10 kW. To perform this calibration, first do the normal daily calibration at the 10 kW level, then progressively introduce other, known burner flow rates. *(Do not rely on assumed linearity for the potentiometer setting the mass flow controller. This linearity can be poor, especially at the lower end of the scale. Instead, use the dry test meter to first calibrate the potentiometer for each different methane flow level.)* To obtain square-wave shapes, first light the burner *outside* the Calorimeter hood, and keep it there temporarily. Start the data acquisition system as if running a test, but do not introduce the burner; instead, wait for about 4 minutes. During this time, baseline, 0 kW data will be recorded. Now, quickly introduce the burner from the outside to underneath the hood. The burner does *not* have to be pushed into its normal calibration slot. Record at least 4 minutes of data. Quickly pull out the burner to outside of the hood. Record at least 4 minutes of baseline data. If additional levels will next be run, reset the flow controller to a different level, and repeat the procedure. The reduced test data should show clean square waves and good agreement (±5%) for all plateau levels.

11.3 Checking the operating heat flux meter against the reference meter

(This procedure is normally done once monthly.)

The calibration of the operating heat flux meter is to be checked against the reference heat flux meter at several fluxes. Typically, fluxes of 25, 50, 75, and 100 kW/m^2 are used in checking. It is not important that these exact values be chosen, but it is essential that the cone heater be operating properly, and that a true equilibrium be reached at each calibration level. The temperature controller must have reached a constant temperature, and must also show nearly zero deviation on the deviation scale. The two heat flux meters should be inserted one after the other, making sure that the reading is again fully equilibrated. Readings should agree to within 2% over the entire range. If the operating heat flux meter is found to disagree with the reference heat flux meter by a constant factor (to within a 2% spread) over the whole flux range, then a new calibration factor (units of [kW/m^2]/mV) is established for the operating heat flux meter, and the heat flux meter used with the new factor. If the operating heat flux meter cannot be brought to within a 2% agreement over the entire range by the use of a single, new factor, then the heat flux meter must be rebuilt or replaced.

> **Repeated warning: Do not under any circumstances use the reference heat flux meter as the daily-use heat flux meter — this will destroy the capability of having a reliable standard.**

11.4 Checking the laser smoke photometer

(This procedure is normally done once monthly.)

To perform a routine laser smoke meter check, first remove the end from the photometer tube. Insert the translucent plastic plug specified under CALIBRATION AND AUXILIARY EQUIPMENT NEEDED section above. A clean, well-centred laser beam image should be seen. No glow should be seen in the area surrounding the laser image. There should also be no “streamers” of light visible. If any of these are present, cleaning or re-alignment are necessary; see the TROUBLESHOOTING AND REPAIR Chapter. If the optics are visibly satisfactory, then the filter readings with a neutral density filter can be verified. This will be a very abbreviated version of the calibration procedure described below as CALIBRATING THE SMOKE PHOTOMETER. Zero the front panel control, then using one or two of the neutral density filters, verify that the expected reading is obtained. If the expected reading is not obtained, then the full calibration procedure will have to be done.

11.5 Setting the gas analyser flow rates

(This procedure is normally done only when changes or additions are made to the gas analysis system.)

! Oxygen analyser.

See analyser manual

11.6 Determining the gas analyser time offsets

(This procedure is normally done only when changes or additions are made to the gas analysis system.)

The response of the thermocouple, stack pressure transducer, and the load cell are fast enough that they are assumed to occur without a time offset. The gas analysers, however, show a significant time offset, and this has to be corrected by time-shifting the data appropriately. These values will be different for each analyser and each installation, and depend on the analyser itself, the pumps, and the flow paths. There is not any one "standard" offset time; times less than 45 s are reasonable.

To determine the appropriate offset time, the instrument must be fully operational. Since the flow rates established through the gas sampling train, including adjustments to the waste regulator will affect the time offset, it is essential that the analyser flow rate adjustments must be successfully completed *before* the time offsets are determined.

Start the data system. Then light the calibration burner while holding it *outside* of the hood, so that the flame is vented into the room hood, not into the Cone Calorimeter collection hood. Quickly thrust the burner under the Calorimeter hood. Allow about 10 minutes to reach a steady state. Remove the burner by quickly pulling out manually. Extinguish the burner once it is outside of the Calorimeter hood. Collect another few minutes of data points. Shut off the data system.

The offset for each analyser is now determined by trial-and-error, adjusting the offset in steps equal to the scan interval. The data analysis software should be programmed to specify some fixed, arbitrary, mass loss rate (the burner, unlike a solid specimen, obviously does not show a load cell indication). Now reduce the data and examine the heat release rate, the "kg CO/kg fuel," and similarly the values from the other gas analysers. The correct value for each analyser will be that time offset which indicates the closest to a square-wave shape, both on the rise and on the fall, for each particular gas. (The reason that, with an incorrect offset, non-square-wave shapes will be indicated on the reduced data columns is that there will then be a relative time error between the gas channel reading and the stack readings for the thermocouple and ? P.)

This procedure can always be double-checked using a stopwatch and a strip chart recorder. The correct offset time will be somewhat greater than the time required to the first signs of pen deflection, but less than the 50% rise point.

11.7 Load cell set-up

(This procedure is normally done only after completing any needed repairs to the load cell.)

This unit has been factory set to give suitable performances for the application, and has been calibrated at 100 g. The unit takes approximately 20 minutes to settle down before adjustment should be made.

The Tare button can be used to zero the unit to compensate for changes in the sample holder mass.

Notes on operation of controller menu system:

a. The MENU button advances through the configuration menus. When in the configuration mode, the MENU button will store changes made to the configuration and advance to the next menu item.

b. When in configuration mode and in a sub-menu, the MIN button allows you to scroll through the available choice. When setting a value of a menu item, the MIN button advances the flashing digit to the right.

c. When in configuration mode the MAX button is used to change the numerical value of the flashing digit displayed. For sub-menu items such as "L1C.1=0", pressing MAX toggles the choice from 0 (off) to 1 (on). The meter allows rapid changes of a displayed numerical value by making 0 the first value to occur when the MAX button is pressed. After that the numbers increase to 9 and then roll over to 0 again. A negative sign may be displayed in the most significant digit.

d. In configuration mode pressing the RESET button once displays the previous menu item. Press the RESET button twice to return to the run mode.

Note that in the following procedure ? means a previously stored value.

11.7.1 Initial set-up

NOTE: This full calibration should not need to be changed, with normal operation, by the user, but the mass calibration and load cell controller output may need to be changed from time to time.

A) Lockout Configurations

PUSH	**DISPLAY**	**COMMENTS**
MENU	L1.CNF	
MIN	L1C.1=?	This will be equal to 0 or 1
MAX	L1C.1=1	Set L1C.1 equal to 1, if necessary, else continue
MIN	L1C.2=?	This will be equal to 0 or 1
MAX	L1C.2=1	Set L1C.2 equal to 1, if necessary, else continue
MIN	L1C.3=?	This will be equal to 0 or 1
MAX	L1C.3=1	Set L1C.3 equal to 1, if necessary, else continue
MIN	L1C.4=?	This will be equal to 0 or 1
MAX	L1C.4=1	Set L1C.4 equal to 1, if necessary, else continue
MIN	L1C.5=?	This will be equal to 0 or 1
MAX	L1C.5=1	Set L1C.5 equal to 1, if necessary, else continue
MIN	L1C.6=?	This will be equal to 0 or 1
MAX	L1C.6=1	Set L1C.6 equal to 1, if necessary, else continue
MIN	L1C.7=?	This will be equal to 0 or 1
MAX	L1C.7=0	Set L1C.7 equal to 0, if necessary, else continue
MIN	L1C.8=?	This will be equal to 0 or 1
MAX	L1C.8=0	Set L1C.8 equal to 0, if necessary, else continue
MENU	STORED 6 L2.CNF	Note that STORED will not be displayed if no changes have been made
MIN	L2C.1=?	This will be equal to 0 or 1
MAX	L2C.1=0	Set L2C.1 equal to 0, if necessary, else continue
MIN	L2C.2=?	This will be equal to 0 or 1
MAX	L2C.2=0	Set L2C.2 equal to 0, if necessary, else continue
MIN	L2C.3=?	This will be equal to 0 or 1
MAX	L2C.3=0	Set L2C.3 equal to 0, if necessary, else continue
MIN	L2C.4=?	This will be equal to 0 or 1
MAX	L2C.4=0	Set L2C.4 equal to 0, if necessary, else continue

MIN	L2C.5=?	This will be equal to 0 or 1
MAX	L2C.5=0	Set L2C.5 equal to 0, if necessary, else continue
MIN	L2C.6=?	This will be equal to 0 or 1
MAX	L2C.6=0	Set L2C.6 equal to 0, if necessary, else continue
MIN	L2C.7=?	This will be equal to 0 or 1
MAX	L2C.7=0	Set L2C.7 equal to 0, if necessary, else continue
MIN	L2C.8=?	This will be equal to 0 or 1
MAX	L2C.8=0	Set L2C.8 equal to 0, if necessary, else continue
MENU	STORED 6 L3.CNF	Note that STORED will not be displayed if no changes have been made
MIN	L3C.1=?	This will be equal to 0 or 1
MAX	L3C.1=0	Set L3C.1 equal to 0, if necessary, else continue
MIN	L3C.2=?	This will be equal to 0 or 1
MAX	L3C.2=1	Set L3C.2 equal to 1, if necessary, else continue
MIN	L3C.3=?	This will be equal to 0 or 1
MAX	L3C.3=1	Set L3C.3 equal to 1, if necessary, else continue
MIN	L3C.4=?	This will be equal to 0 or 1
MAX	L3C.4=1	Set L3C.4 equal to 1, if necessary, else continue
MIN	L3C.5=?	This will be equal to 0 or 1
MAX	L3C.5=1	Set L3C.5 equal to 1, if necessary, else continue
MIN	L3C.6=?	This will be equal to 0 or 1
MAX	L3C.6=1	Set L3C.6 equal to 1, if necessary, else continue
MIN	L3C.7=?	This will be equal to 0 or 1
MAX	L3C.7=0	Set L3C.7 equal to 0, if necessary, else continue
MIN	L3C.8=?	This will be equal to 0 or 1
MAX	L3C.8=0	Set L3C.8 equal to 0, if necessary, else continue
MENU	STORED 6 L4.CNF	Note that STORED will not be displayed if no changes have been made
MIN	L4C.1=?	This will be equal to 0 or 1
MAX	L4C.1=1	Set L4C.1 equal to 1, if necessary, else continue
MIN	L4C.2=?	This will be equal to 0 or 1
MAX	L4C.2=1	Set L4C.2 equal to 1, if necessary, else continue
MIN	L4C.3=?	This will be equal to 0 or 1
MAX	L4C.3=1	Set L4C.3 equal to 1, if necessary, else continue
MIN	L4C.4=?	This will be equal to 0 or 1
MAX	L4C.4=1	Set L4C.4 equal to 1, if necessary, else continue
MIN	L4C.5=?	This will be equal to 0 or 1
MAX	L4C.5=1	Set L4C.5 equal to 1, if necessary, else continue
MIN	L4C.6=?	This will be equal to 0 or 1
MAX	L4C.6=1	Set L4C.6 equal to 1, if necessary, else continue
MENU	STORED 6 INPUT	Note that STORED will not be displayed if no changes have been made

B) Input Class (INPUT)

MIN	?	Display should read BRIDGE
MAX	BRIDGE	Press MAX at least once until BRIDGE is displayed
MENU	STORED 6 RDG.CNF	

C) Reading Configuration (RDG.CNF)

MIN	RDG.1=?	This will be equal to 0 or 1
MAX	RDG.1=0	Set RDG.1 equal to 0, if necessary, else continue
MIN	RDG.2=?	This will be equal to 0 or 1
MAX	RDG.2=0	Set RDG.2 equal to 0, if necessary, else continue
MIN	RDG.3=?	This will be equal to 0 or 1
MAX	RDG.3=0	Set RDG.3 equal to 0, if necessary, else continue
MIN	RDG.4=?	This will be equal to 0 or 1
MAX	RDG.4=1	Set RDG.4 equal to 1, if necessary, else continue
MIN	RDG.5=?	This will be equal to 0 or 1
MAX	RDG.5=0	Set RDG.5 equal to 0, if necessary, else continue
MIN	RDG.6=?	This will be equal to 0 or 1
MAX	RDG.6=0	Set RDG.6 equal to 0, if necessary, else continue
MIN	RDG.7=?	This will be equal to 0 or 1
MAX	RDG.7=0	Set RDG.7 equal to 0, if necessary, else continue
MENU	STORED 6 RDG SC	Note that STORED will not be displayed if no changes have been made

D) Reading Scale (RDG SC) and Reading Offset (RDG OF)

MIN	?	Previously set value displayed
MAX/MIN	1.00000	Use MAX and MIN to change the displayed value
MENU	STORED 6 RDG OF	Note that STORED will not be displayed if no changes have been made
MIN	?	Previously set value displayed
MAX/MIN	000000 or 00000.0	Use MAX and MIN to change the displayed value (display depends on the decimal point setting)
MENU	STORED 6 IN CNF	Note that STORED will not be displayed if no changes have been made

E) Input Configuration (IN CNF)

MIN	INP.1=?	This will be equal to 0 or 1
MAX	INP.1=0 or 1	Set INP.1 to 0 for 60 Hz, 1 for 50 Hz line frequency
MIN	INP.2=?	This will be equal to 0 or 1
MAX	INP.2=0	Set INP.2 equal to 0, if necessary, else continue
MIN	INP.3=?	This will be equal to 0 or 1
MAX	INP.3=0	Set INP.3 equal to 0, if necessary, else continue
MIN	INP.4=?	This will be equal to 0 or 1
MAX	INP.4=0	Set INP.4 equal to 0, if necessary, else continue
MIN	INP.5=?	This will be equal to 0 or 1
MAX	INP.5=0	Set INP.5 equal to 0, if necessary, else continue
MIN	INP.6=?	This will be equal to 0 or 1
MAX	INP.6=0	Set INP.6 equal to 0, if necessary, else continue
MIN	INP.7=?	This will be equal to 0 or 1
MAX	INP.7=0	Set INP.7 equal to 0, if necessary, else continue
MENU	STORED 6 IN.SC.OF	Ignore this menu item for now
MENU	DEC PT	

F) Decimal Point (DEC PT)

MIN	?	Display window is 6 F’s with a decimal in position to indicate the number of decimal points displayed
MAX	FFFFFF.	Push MAX until the decimal point is moved to the end of the row of F’s (i.e. no decimal places)
MENU	STORED 6 CNT BY	

G) Count By (CNT BY)

MIN	?	Previously set value displayed
MAX	001	Push MAX until 001 is displayed
MENU	STORED 6 FIL.CNF	Note that STORED will not be displayed if no changes have been made

H) Filter Configuration (FIL.CNF)

MIN	FIL.1=?	This will be equal to 0 or 1
MAX	FIL.1=0	Set FIL.1 equal to 0, if necessary, else continue
MIN	FIL.2=?	This will be equal to 0 or 1
MAX	FIL.2=1	Set FIL.2 equal to 1, if necessary, else continue
MIN	FIL.3=?	This will be equal to 0 or 1
MAX	FIL.3=1	Set FIL.3 equal to 1, if necessary, else continue
MENU	STORED 6 FIL TI	Note that STORED will not be displayed if no changes have been made

I) Filter Time Constant (FIL TI)

MIN	?	Previously set value displayed
MAX	008	Push MAX until 008 is displayed (note that damping can be increased by setting this to 016 or 032, although the time response will be increased - 008 is the recommended time constant)
MENU	STORED 6 OUT.CNF	Note that STORED will not be displayed if no changes have been made

J) Output Configuration (OUT.CNF)

MIN	OUT.1=?	This will be equal to 0 or 1
MAX	OUT.1=1	Set OUT.1 equal to 1, if necessary, else continue
MIN	OUT.2=?	This will be equal to 0 or 1
MAX	OUT.2=0	Set OUT.2 equal to 0, if necessary, else continue
MIN	OUT.3=?	This will be equal to 0 or 1
MAX	OUT.3=0	Set OUT.3 equal to 0, if necessary, else continue
MIN	OUT.4=?	This will be equal to 0 or 1
MAX	OUT.4=0	Set OUT.4 equal to 0, if necessary, else continue
MIN	OUT.5=?	This will be equal to 0 or 1
MAX	OUT.5=1	Set OUT.5 equal to 1, if necessary, else continue
MIN	OUT.6=?	This will be equal to 0 or 1
MAX	OUT.6=0	Set OUT.6 equal to 0, if necessary, else continue
MENU	STORED 6 OT.SC.OF	Ignore this menu item for now

MENU	RESET2 6 Run Mode	

K) Input Scale and Offset (IN.SC.OF)

Place a sample holder on load cell and note the output from the display, V_0 (e.g. 009641). Then place a calibration weight (e.g. 100 g) in the sample holder, on the load cell, and note the output from the display, V_1 (e.g. 010647).

MENU×10	IN CNF	
MIN×6	INP.6=0	
MAX	INP.6=1	INP.6 must now be set to 1
MENU	STORED 6 IN.SC.OF	
MIN	INPUT1	
MAX/MIN	V_0	Enter the value V_0 recorded when the sample holder is placed on the load cell
MENU	READ 1	
MAX/MIN	000000	Use MAX and MIN to adjust the display for 000000.
MENU	INPUT2	
MAX/MIN	V_1	Enter the value V_1 recorded when the sample holder and the calibration weight are placed on the load cell
MENU	READ 2	
MAX/MIN	000100.	Use MAX and MIN to adjust the display for the mass of the calibration weight (in this case 000100. for a 100 g weight)
MENU	STORED 6 DEC PT	
MIN	FFFFFF.	No decimal places should already be set
MAX×5	FFFFF.F	Set the display to show one decimal place
MENU	STORED 6 CNT BY	
RESET×2	RESET2 6 Run Mode	The display is now the mass in grams

L) Controller Output Scale and Offset (OT.SC.OF)

In order for the software, or a chart recorder, to record the mass of the specimen correctly, the load cell controller maximum mass, m_{max} must be set to greater than the mass of the specimen. For example, if your specimens weigh around 75 g then set the maximum to 100 g, if your specimens weigh around 25 g then set the maximum to 50 g. At this maximum the signal sent to the computer, or chart recorder, must be 10 Volts and at zero mass 0 Volts must be sent to the computer, or chart recorder (note that the chart recorder must be on the 10V calibrated scale).

MENU×17	OT.SC.OF	
MIN	READ 1	
MAX/MIN	00000.0	READ 1 must be 00000.0
MENU	OUTPT1	
MAX/MIN	00.0000	OUTPT1 must be 00.0000
MENU	READ 2	
MAX/MIN	m_{max}	Enter maximum mass here (for example 00100.0)
MENU	OUTPT2	
MAX/MIN	10.0000	OUTPT2 must be 10.0000
MENU	STORED 6 RESET2	

If a PC is connected, in the software chose **[Calibrate|Mass]** and in the Mass FSD field enter the maximum mass you entered into the controller, m_{max}. Ensure that the Volts FSD field is 10. Press **`<Apply>`** and then place a weight on the load cell and ensure that the screen agrees with the instrument. Then press **`<Accept>`**.

This completes the full set up and the controller, load cell and software (if applicable) are set up to record the mass of a sample up to a maximum of 100 g (assuming m_{max}=100) to one decimal place.

11.7.2 Mass calibration

This routine sets the mass calibration of the controller to ensure that the displayed mass is accurate.

PUSH	**DISPLAY**	**COMMENTS**
MENU×10	IN CNF	
MIN×6	INP.6=1	
MAX	INP.6=0	INP.6 must now be set to 0 (active mV signal display)
MENU	STORED 6 IN.SC.OF	
MENU	DEC PT	
MIN	FFFFF.F	
MAX	FFFFFF.	Set the display to show no decimal places
MENU	STORED 6 CNT BY	
RESET×2	RESET2 6 Run Mode	The display is now the active mV signal from the load cell

Place a sample holder on load cell and note the output from the display, V_0 (e.g. 009641). Then place a calibration weight (e.g. 100 g) in the sample holder, on the load cell, and note the output from the display, V_1 (e.g. 010647).

MENU×10	IN CNF	
MIN×6	INP.6=0	
MAX	INP.6=1	INP.6 must now be set to 1
MENU	STORED 6 IN.SC.OF	
MIN	INPUT1	
MAX/MIN	V_0	Enter the value V_0 recorded when the sample holder is placed on the load cell
MENU	READ 1	
MAX/MIN	000000	Use MAX and MIN to adjust the display for 000000.
MENU	INPUT2	
MAX/MIN	V_1	Enter the value V_1 recorded when the sample holder and the calibration weight are placed on the load cell
MENU	READ 2	
MAX/MIN	000100.	Use MAX and MIN to adjust the display for the mass of the calibration weight (in this case 000100. For a 100 g weight)
MENU	STORED 6 DEC PT	
MIN	FFFFFF.	No decimal places should already be set
MAX×5	FFFFF.F	Set the display to show one decimal place
MENU	STORED 6 CNT BY	
RESET×2	RESET2 6 Run Mode	The display is now the mass in grams

The displayed mass on the controller should now be calibrated. This can be checked by placing calibrated weights of different masses on the load cell and observing the displayed mass. Remember that the controller will take a little time to settle to the final steady reading.

11.7.3 Load cell controller output

In order for the software, or a chart recorder, to record the mass of the specimen correctly, the load cell controller maximum mass, m_{max} must be set to greater than the mass of the specimen. For example, if your specimens weigh around 75 g then set the maximum to 100 g, if your specimens weigh around 25 g then set the maximum to 50 g. At this maximum the signal sent to the computer, or chart recorder, must be 10 Volts and at zero mass 0 Volts must be sent to the computer, or chart recorder (note that the chart recorder must be on the 10V calibrated scale).

PUSH	**DISPLAY**	**COMMENTS**
MENU×17	OT.SC.OF	
MIN	READ 1	
MAX/MIN	00000.0	READ 1 must be 00000.0
MENU	OUTPT1	
MAX/MIN	00.0000	OUTPT1 must be 00.0000
MENU	READ 2	
MAX/MIN	m_{max}	Enter maximum mass here (for example 00100.0)
MENU	OUTPT2	
MAX/MIN	10.0000	OUTPT2 must be 10.0000
MENU	STORED 6 RESET2	

If a PC is connected, in the software chose **[Calibrate|Mass]** and in the Mass FSD field enter the maximum mass you entered into the controller, m_{max}. Ensure that the Volts FSD field is 10. Press **`<Apply>`** and then place a weight on the load cell and ensure that the screen agrees with the instrument. Then press **`<Accept>`**.

11.7.4 Damping and filters

The controller has a range of filter settings. As supplied, a moving average filter with a "time constant" of 8 is used. The filtering can be increased by following the steps in Section 17.7.1 I) (to access the FIL TI menu item press MENU 15 times).

To adjust the damping, hook up a strip chart recorder to the output of the load cell. Run the recorder at a high chart speed to be able to observe the timing. Check the cell to ensure that it is in its dynamic range (see the DAILY START-UP AND CALIBRATION Chapter above). A mass in the range of a typical sample is gently placed on the load cell (at NIST, a weight of 200 g is typically used) and thirty seconds or so later it is gently removed. The output of the strip chart is observed. The ideal shape of the trace would be a square wave with sharp corners. The rise and fall times should be such that 90% of the rise (or fall) is typically achieved in 3 s or less. If the cell does not have enough damping the strip chart will show an overshoot of the final value.

Increase the damping on the cell until the overshoot just disappears and a square corner is obtained. Then, turn on the exhaust blower and verify that the damping as initially set is still effective in controlling the inevitable vibration associated with the exhaust system. If the load cell output is noisier than when the test was first conducted, then more damping may be required.

For further information on the load cell, see the manufacturer's instructions and Chapter 6 in the software manual.

12

Regular maintenance

12.1 General cleaning of the instrument

1. Cleaning interval

The apparatus, because of its intended use, will always collect a certain amount of dirt, soot, and ash. Some of this material will inevitably be deposited on the inside of the ductwork and sample lines. This material should regularly be removed by brushing and vacuuming. All safety precautions regarding potentially toxic or carcinogenic dusts should be carefully observed when cleaning the ductwork. The interval between cleaning will largely depend on the nature and amount of material burned; typically, every two to three months. Production type testing with very sooty samples may necessitate a much more frequent clean out interval. Normally a modest amount of soot in the duct will not affect the performance of the apparatus unless it reduces the inside diameter of the orifice plate or blocks the beam on the laser. The daily calibration check will give an indication of the condition of the orifice plate. A gradual drift in the orifice constant will be noted as soot accumulates on the orifice plate.

2. Laser smoke photometer cleaning

Soot deposited on the optics of the photometer can cause measurement errors. Unfortunately, this error is often undetectable by using neutral density filters alone; thus, it is essential that a regular cleaning program be followed. Before cleaning the photometer itself, it is a good idea to inspect and clean the main exhaust duct, especially in the area near where the photometer tubes are attached. Within the smoke photometer itself, if only a modest soot accumulation has occurred, it is sometimes possible to blow it out without disassembly. The necessary frequency of cleaning will depend entirely on how much testing is being done and on how sooty are the specimens. If this cleaning is not done regularly, then soot buildups can occur. This may require a complete disassembly of the photometer. If disassembled, after re-assembly an optical re-alignment will generally be needed. Instructions are given in the TROUBLESHOOTING AND REPAIR Chapter.

In normal operation, the exhaust blower causes a small flow of room air to be drawn down the photometer tubes, keeping the soot from entering them. If the blower has been inadvertently left off, or is turned off too soon after the test, or if the fire produces so much smoke as to overwhelm the collection hood and fan, then soot may be forced into the tubes leading to the laser and the detectors. By careful setting of the exhaust control, however, the operator can minimize the need for such major cleaning tasks.

3. Specimen area

Frequent cleaning is necessary for the area around the sample holder and the load cell platform. Material falling off the sample during testing tends to accumulate in this area and may interfere with the load cell readings. Vacuuming will normally eliminate any problem. At the same time, check that the aluminum foil protecting the Marinite heat shield has not been moved so as to bind on the load cell.

4. Gas sampling system

The sampling ring and associated lines which connect it to the various analysers require periodic cleaning. The usual indication of clogging is the need to re-adjust the waste regulator repeatedly to maintain the proper flow to the analysers. Cleaning of these lines consists of disassembling the various sections of tubing and blowing them out with 100 psi air, working from the analyser end of the line toward the sampling ring. *Do not direct high pressure air into the any of the analysers and remember to vent the dirt and soot to a safe place.* The sampling lines between the Drierite and the analysers generally remain quite clean, due to the filtering action of the glass fibre plugs used to retain the Drierite in the tube. The lines most susceptible to clogging are those from the sampling ring to the main soot filter. The flow controllers, being downstream of the Drierite, will only very rarely require any cleaning, as will the analysers. Consult the specific analyser manufacturer's instruction manual for details on cleaning the measuring cell and possible recalibration.

The soot filters in the gas sampling lines are expected to be changed after every few tests or as often as necessary to ensure an adequate flow to the analyser throughout a run. Also, it is necessary to check the screens supporting the filter elements periodically — if these show some soot accumulation, they should be carefully cleaned with a solvent.

The back-up fibreglass packing filter should be replaced whenever leakage from the main sampling filter is noted. A thorough solvent cleaning of the affected area should then also be done.

The diaphragm and seat in the dump regulator also collect soot and tars, so periodic disassembly and cleaning are required; the frequency will depend entirely on the tarriness of the materials being tested.

5. Various pumps

There are several sampling pumps in a typical Cone Calorimeter system, which will include the main sampling pump for the oxygen analysers, but may also include several additional pumps for different gas analysers, and a pump for the soot sampler (if central vacuum is not used). Pump cleaning or maintenance is usually necessary when a flow rate drop is noted or, in case of the soot sampler vacuum, the normal maximum flow through the filter cannot be achieved. The usual problem with these small pumps is flapper valves tending to get coated with soot and tars, preventing them from sealing properly. Follow the manufacturer's recommendations on how to disassemble and clean these parts.

6. Miscellaneous effects

Cleanliness of the duct has little or no effect on the heat release rate value because the soot has only the smallest affinity for the oxygen in the duct. Certain other gasses which may be of interest, such as HCR, HBr, HCN, can be more reactive with soot. In studies where these gasses will be under investigation, the level of soot deposition in the ductwork should at least be recorded and recognized as a possible source of error.

12.2 Maintenance of the heat flux meter

With reasonable care in handling and positioning, the heat flux meter should need to recoated only very occasionally. Recoating is needed when the flat black coating over the centre sensing area of the heat flux meter becomes chipped, abraded, or discoloured (*i.e.*}, grey instead of black). Any such visible defects will cause the coating to lose its intended value of the radiant absorptivity, and, thus, to shift in calibration. The heat flux meter need not be recoated if only the coating along the outside edge of the gauge becomes damaged, since that does not correspond to the active sensing area.

To recoat the heat flux meter, first strip off the old coating by gently rubbing the surface of the heat flux meter with a soft cloth with a little acetone on it. The Medtherm Model GTW-732-485A heat flux meter is a Schmidt-Boelter type heat flux meter, which is relatively hardy and can withstand a modest amount of rubbing, nonetheless no abrasive type cleaners should be used. If you are using a Gardon type flux meter, which uses a thin-foil sensor, be especially careful during the stripping of the coating not to press on the foil. If the coating does not come off by using acetone, then other solvents can be used. Methyl-ethyl-ketone or a mixture of xylene and toluene are stronger solvents but present a greater health concern for the user. With the old coating removed, the new coating must be applied in a smooth and uniform layer. The easiest way to recoat the heat flux meter is to hold it by the water cooling tubes in one hand and spray a light coat from about 20 to 25 cm away. Let this first coat dry to the point of losing all its gloss and then turn the heat flux meter 90 degrees and apply a second coat. This technique will reduce the chance of spraying n excessively heavy coating on the heat flux meter. If you have not masked the water and electric lines, wipe the overspray off them before the paint fully dries. The recommended coating can be purchased from Medtherm Corp. in spray cans. The coating must be fully dried before using the heat flux meter or recalibrating it. The coating can be dried by leaving it overnight at room temperature, or by drying in an oven at about 65 to 120EC for 15 minutes. The final step in recoating is to recalibrate the heat flux meter against the reference heat flux meter. This completes the recoating procedure.

13

Troubleshooting and repair

The purpose of this Chapter is to help the user diagnose and solve any problems arising out of the Calorimeter operation. Also included are certain instructions for assembly and disassembly, where the steps to be taken are not obvious. Since this document is not a textbook on scientific instrument repair, it is assumed that the user already has basic experience in the repair of gas analysers, load cells, and other laboratory instruments.

It is assumed here that all the commercially supplied analysers (O_2, CO_2, CO, etc.) have been set up and are working according the manufacturer's specifications. If any of these analysers are malfunctioning, see the troubleshooting section of the manual supplied with the particular analyser. Analyser malfunctions will usually be spotted in the process of spanning and zeroing the individual analyser, or, possibly, when problems are encountered while trying to obtain the orifice calibration constant.

13.1 General

! Erratic specimen burning during the last few minutes of a test.

Such behaviour can often be due to drafts blowing non-uniformly across the specimen. Observe the surface of the specimen as it is nearing the completion of its combustion (this is easier to observe during horizontal orientation tests). When the specimen is burning out, the material should be disappearing uniformly over the entire face. If one portion of the specimen's face is consumed before the remaining ones, the cause may be a draft blowing across the specimen.

Make sure that any glass [by which we mean Pyrex, or other suitable glazing] enclosure panels around the Cone are symmetrical, that is, there may be a complete enclosure on all four sides, panels on two opposing sides, or no panels at all. Any other arrangements will lead to unsymmetrical air patterns. Make sure that there are no other unsymmetrical objects nearby blocking out large areas of air flow. Finally, check out and remedy any draft problems associated with the laboratory ventilation system.

! Incorrect, very high values indicated for effective heat of combustion.

If a non-ambient combustion atmosphere test was used for the test, incorrect values of the heat of combustion can be attributed to malfunctions or incorrect setting of the exhaust constant-mass flow mode. An error will be seen if either (a) constant-volume (instead of constant-mass) mode was erroneously selected, or (b) a malfunction of the motor speed controller or its associated millivolt controller has occurred.

! Noisy data, especially heat of combustion or specific extinction area.

One general cause of noisy data can be vibrations introduced into the load cell. Load cell readings are used in many of the reduced-data channels, especially heat of combustion and smoke. Any vibration of the load cell will show up as noise here. The vibration usually comes from inadequate de-coupling from blower vibrations.

13.2 Computer program

13.2.1 Errors in the operating software

It is always wise to hand check several points of the computer-generated data to be doubly sure when using a new or different data acquisition system or any time changes are made in either the acquisition or data reduction programs. There is almost a limitless number of ways in which software errors can masquerade as hardware errors. Thus, if a malfunction shows up for the first time after a new version of one of the computer programs has been installed, troubleshooting the computer code should be the first step.

Some extremely vexing problems can arise if thermocouple cold-junction compensation is not properly done. This can include very obscure difficulties which arise if temperature correction voltages are mistakenly applied to non-thermocouple channels! The proper setup of data scanner channels should be verified carefully each time any data scanner equipment is replaced or repaired. (The correct setup procedures are different for each manufacturer and even each model.)

13.2.2 Errors in the generated data printouts

! Printout errors in the cumulated results

Sometimes a condition is observed that data on the printouts appear plausible on a time-step by time-step basis, but give all zeroes for cumulated values. This is most often due to failure to have the specimen properly seated on the load cell before pressing the start key. As a result, the first mass value recorded is negative, and this invalidates all further calculations which require the use of the initial specimen mass. The simplest solution is to re-run the test correctly.

! Values for one or more data channels are very low

For most data channels, the reduced data value which is reported is obtained by subtracting the baseline (time 0^-) value. If the values for the baseline were not correctly stored, the reduced data will be defective. Check the software and the hardware to make certain that a correct baseline interval is being stored. Such errors might also arise from improper test starting procedures. Repeat the test once the problems have been corrected.

- Square-wave burner tests do not give square-wave results

- Using the calibration burner for a square-wave test is one of the simpler and more general diagnostic techniques for the Cone Calorimeter. The expected heat release rate output is, of course, of square-wave shape. A serious spike at either end of the plateau will, most likely, indicate that the oxygen analyser offset time has not been properly determined. See the pertinent section in the LESS-FREQUENT CALIBRATION PROCEDURES Chapter. The yield data from the remaining gas analysers should, again, show a square-wave response. If not, similar corrections must be made. A more shallow hump or depression to the response curve can, most likely, suggest an improperly functioning stack thermocouple. Thermocouple troubleshooting is described below.

13.3 Data system and system voltmeter

- General voltmeter problems

  When setting up the Calorimeter, the user should have available a good quality and reliable digital voltmeter to ensure that the acquisition system is really recording the correct voltages from the instruments. Incorrect operation of the scanner input can be an extremely frustrating problem if not identified as such early. Very general-looking errors, such as all zeroes for all output, or the first or last scan always a garbage value, etc., are often attributable to miscommunicated settings sent to the system voltmeter, or an improper hookup of the hardware. If such general faults are found which affect more than one data channel, then this is the place to start troubleshooting.

- Stair-stepping on the data channels

  Results are sometimes observed which show a “stairstep” effect. Since most burning specimens will not show this type of degradation behaviour, an artifact is presumed. This artifact is usually either due to the use of an A-to-D converter of an insufficient number of bits, or because a data channel was improperly configured with the wrong gain or range. The solution is to fix the gain scaling, or to use a better A-to-D converter.

13.4 Electronic components

The most common source of failures with electronic circuits is the failure of active devices, i.e., op-amps and analog signal modules. Problems which are determined not to be interconnect or data system problems, and which manifest themselves as

- greatly drifting output, or

- output equal to the value of the plus or minus power supplies,

are very likely due a failure of an active device. This can be circuit-traced by examining the inputs to each stage, and then determining if the output is correct for the given input.

In general, there should not be any analog instrument outputs, nor any outputs from intermediate stages, which are nearly equal to the supply rails, *i.e.*, either +15 VDC or -15 VDC. Such a measurement should be an immediate suggestion that some component failure has occurred. When circuit-tracing, as usual, proceed from the input end, apply within-range inputs, and then keep checking intermediate outputs until you have worked your way to the final device output stage.

13.5 System check with the orifice flow constant

As mentioned earlier, the simplest and quickest check of the Calorimeter is the orifice flow constant check. This check does not verify all of the analysers, only the O_2 analyser, but it does check the integrity of the gas sampling system, thermocouple, orifice plate, and pressure transducer circuits. This test, even though somewhat limited, should always be performed at least daily. Then, as necessary, other, more complex, tests can be performed using certain well-characterized, reference test materials, which can be used to give an indication of the proper functioning of other analysers, soot and smoke measuring devices, and other systems which might be hooked up to the Calorimeter.

Again, it must be remembered that the orifice flow constant is computed in the data acquisition program, and any error in programming will, of course, yield an error which has nothing to do with a physical malfunction of the equipment. This is an unlikely source of error if the program has been working properly previously and has not been changed. It is always desirable to check the constant by hand if a specific malfunctioning device cannot be pinpointed. When the burner is being supplied with methane at a flow rate equivalent to 10 kW, the relevant equation is obtained from the basic equation on the top of p. 18 of NBSIR 82-2611. The value of $\ddot{q}$ here is 10 kW, and the specific constant for methane, 12.54×10^3 is used instead of the general 13.1×10^3 constant, giving:

$$C = \frac{7.25\times10^{-2}\sqrt{\dfrac{T}{\Delta P}}-\left(1.105-1.5X_{0_2}\right)}{0.2095-X_{0_2}} \tag{4}$$

where X_{O_2} is the oxygen concentration, T is the stack temperature (K), and ΔP is the stack orifice differential pressure (Pa).

The easiest way to perform this check is to start with a cold instrument. Set up all the steps for a daily start-up. Make some provision to collect oxygen, thermocouple and pressure data every 1 minute, either on strip chart recorders, or using the data collection computer. Insert a burner, and turn it on to a 10 kW level. Record the data for 10 minutes. Determine the value of the orifice coefficient at each 1 minute interval. For an instrument constructed according to the current NIST documents, the value of C will be between 0.040 and 0.046. The value pertinent to the user's machine should have been established and recorded during the initial set-up of the instrument. If the constant does not fall within the expected range (except for the first few readings, which might be somewhat further out), then it should be noted that one of three devices may be defective: the oxygen measurement system, the thermocouple associated with the orifice plate flowmeter, or the pressure transducer. Compare the table of values generated with the values in Table 1.

Table 1. Typical oxygen and flow values

Time (min.)	Oxygen (vol. fract.)	Pressure (Pascals)	Temperature (EC)
0	0.2095	152	22.4
1	0.1724	73	212.0
2	0.1701	67	238.0
3	0.1684	66	261.0
4	0.1671	64	276.0
5	0.1665	63	283.0
6	0.1656	63	300.0
7	0.1652	63	302.0
8	0.1648	61	309.0
9	0.1643	61	316.0
10	0.1640	61	318.0

Keep in mind that the values recorded of all of these instrument channels can change dramatically if a different cold flow is chosen or the Calorimeter ductwork and fan have had a chance to heat up. However, the values under such conditions should correspond approximately to one of the later sets of readings. If only one of the channels is showing significant deviation from expected readings, the device has been pinpointed. Conduct further troubleshooting by following the instructions pertinent to that device below. If all three readings are substantially off, then there are two possibilities: (1) the rate of methane being introduced is not 10 kW; or (2) the duct flow rate is not 30 g/s.

Note that mis-setting the flow rate to a value other than 30 g/s will not by itself cause an error in the orifice coefficient. However, if the value is mis-set, with an otherwise well-functioning instrument, all three channels of data will deviate from their reference values (even though the C is finally determined correctly). If there is, in addition, some other system fault, trouble tracing may get very difficult.

13.6 Methane calibration system

See Warning in Safety Chapter

Errors in metering 10 kW of methane are very difficult to trace, since a redundant measuring system is not provided. If, for instance, a 95% purity cylinder is substituted for the required 99.9% one, this may be extremely difficult to detect. The errors here can be due to:

- wrong calibrating gas
- defective or miscalibrated dry test meter
- defective temperature indicator on dry test meter
- defective pressure indicator on dry test meter
- errors in timing flow or in making required computations.

If the electronic mass flow controller setpoint changes suddenly, this should not simply be re-adjusted, but a cause should be sought. These controllers normally show very good long term stability; thus, a shift may well indicate some other component's failure, rather than an actual shift within the controller.

If required, error tracing consists of progressively substituting new gases, test meters, etc., in the list above.

13.7 Exhaust system blower and indicator

13.7.1 Mechanical speed check-out

If a stroboscopic tachometer is available, Table 2 provides some reference values to be used in determining if the flow calibration is approximately correct. This procedure should normally be done first, since trying to make electrical adjustments would not be useful if there is a motor or sheave problem.

Table 2. Typical flow rates at specified fan shaft speeds

Fan Shaft Speed	Differential	Stack Temp.	Flow Through Duct	
(RPM)	Pressure	EC	Calc.	Meas.
1000	0.42-0.43 V	21.8	18.8	18.6
1500	0.93-0.94 V	21.8	27.9	27.6

The flow rates in the table above are given in g/s, not in m^3/s, as discussed in ASTM P 190, since the exhaust flow rate panel meter is calibrated in g/s. Note that the speed readings are taken on the fan shaft rather than on the motor shaft; thus they are not affected by the sheave ratio. An incorrect sheave ratio, however, may prevent the top limit of 50 g/s from being reached.

13.7.2 Checking the zero flow condition

Calibrations of the flow rate cannot be done successfully unless it is verified that the zero-flow condition corresponds to a 0.0 g/s flow indication. To do this, shutting down the fan is not sufficient to create the no-air-flow condition needed. This must be checked by having the calorimeter cold, and then placing a cap on the exhaust duct opening, to make sure that there is no air flow induced by room currents. Under those conditions, the panel indicator should read exactly 0.0 g/s. If this reading is slightly off, adjust the zero-trim potentiometer on the body of the pressure transducer, until the panel meter reads 0.0. This procedure will be successful only if there are no defective components; if a zero-flow error occurs due to equipment failures, see the troubleshooting discussion below.

13.7.3 Flow rate checking with CO_2

The Chapter on LESS-FREQUENT CALIBRATION PROCEDURES gives instructions on routine calibrations of the exhaust flow rate indicator, if it can be assumed that the orifice calibration constant is correct. If this constant is also in question, an independent flow check is possible by using CO_2 gas as a tracer. This requires having a CO_2 analyser, a cylinder of CO_2 gas, and an accurate flowmeter for metering in the CO_2. A baseline reading, $X^{o}_{CO_2}$, (typically around 0.04%) is obtained. The gas is introduced into the specimen hood at a known mass flow rate, $\dot{m}_{CO_2}$. The same amount of CO_2 should be recovered through the duct. Thus,

$$\dot{m}_{CO_2} = \dot{m}_{ex}\left(\frac{44.0}{28.97}\right)\frac{\left(X_{CO_2} - X^{o}_{CO_2}\right)\left(1 - k_{rh}\right)}{\left(1 - X^{o}_{CO_2}\right)} \tag{5}$$

To solve for the needed duct flow, $\dot{m}_{ex}$, it is also necessary to know the correction term, k_{rh}, which is the mole fraction of water in air at the given temperature and at the ambient relative humidity. This can be obtained from standard tables, and adjusts for the fact that CO_2 is measured on a dry, rather than total, basis. It can also be obtained directly by reading the baseline value on the H_2O analyser, if that analyser is in good calibration.

To adjust the flow indicator, use the front panel setscrew adjustment. Before doing this, however, make sure that the zero setting has been adjusted correctly; see above.

13.7.4 Troubleshooting the exhaust system

Possible problem areas here include:

- Blower wheel out of balance.

  Excessive noise and vibration will be noticed if the wheel is out of balance. Such a condition can result from heat warpage, or due to corrosion. It can also happen if foreign objects are lodged on the wheel. To check, remove the duct section holding the laser photometer (which is welded onto one side panel of the blower). Inspect for foreign objects and clean the wheel. Check to see that the wheel is centred within the housing. If not, the bearing supports are to be shimmed with some flat metal plates, until proper elevation is established. If these measures are not sufficient to return the unit to balance, it will be necessary to re-balance. To do this, remove the shaft and the wheel. Have both rebalanced dynamically by a machine shop specializing in shaft balancing. It should normally not be necessary to pull off the bearings from the shaft in order to rebalance. When re-installing, make sure that the heat slinger is not missing and that it is properly adjusted on the shaft. It should be nearly, but not quite touching the blower housing.

- Defective blower motor.

  This will be manifested in a number of ways. If the brushes fail completely, then the motor will not spin. Check the electrical terminals first to see that the controller has not failed. The motor may show erratic behaviour or propagate noise — both conditions also indicate the brushes should be checked. In rare cases, bearings or windings may burn up.

! Miscalibrated indicator.

The possibilities are an offset zero, or an erroneous on-scale reading. For checking the zero adjustment, see the pertinent section above.

13.8 General gas analyser problems

A Cone Calorimeter installation may typically be fitted with a number of additional gas analysers. These will, to some extent be checked out as they are individually zeroed and spanned. Most of the problems described below in connection with the oxygen measurement system can also occur with the other gas analysers, except for barometric effects, which are small for these supplementary analysers and are ignored.

Sometimes, after a test, the flow rates for a particular gas analyser will be seen to have dropped below the normal reference value for that analyser. This will, most typically, be due to clogging of a soot filter, or due to clogging of the Drierite or Ascarite cartridges. In all cases, in addition to the main (heated or unheated) soot filter, there is at least one stage of backup filtering (and possibly a pre-filter). For both the filters, there is a packing of loose-fill fibreglass to serve this function. In addition, the total hydrocarbons and the oxygen analysers have additional filters associated with the analyser. The hydrocarbon analyser has two filter assemblies: a sintered-metal in-line filter located at the sample gas inlet port, and a replaceable cartridge filter located inside the analyser case. The oxygen analyser has an external in-line filter located in the sample line directly ahead of the analyser inlet. In case of dropping flows, if replacing the primary filter does not restore the correct flow rate, it is necessary to remove and replace the fibreglass packing. Note that there is also a fibreglass packing associated with both the Drierite and the Ascarite cartridges.

13.9 Oxygen measurement system

Oxygen measurement errors can arise from the following sources:

! Incorrect calibration cylinders

A paramagnetic analyser is intrinsically a very linear device. Cylinders of nitrogen (zero gas), an intermediate oxygen/nitrogen mixture, and room air at 20.95% will form a 3-point calibration. If one of these points is out, the cylinders should be compared against new cylinders, to see if they are in error. It is also possible to introduce an error by calibrating at a non-standard oxygen level in the room. Obvious safety concerns dictate that no operations should be done in a laboratory which is not adequately ventilated.

! Clogging of Ascarite or Drierite

If either of the cartridges is clogged, usually a slow response will be seen and a “tailing” will be noticed on the heat release rate data. Clean out and repack the cartridges.

! Leaks in sampling system

The instructions here assume that the daily calibration procedure was followed, and that the oxygen analyser could be successfully spanned and zeroed to its expected values. If not, see the sections above. For a correctly set up analyser, the typical orifice plate calibration error encountered is that the oxygen analyser does not show enough drop in the oxygen concentration. Thus, if an orifice constant significantly greater than the normally expected reference value for the instrument is obtained, a leak in the sampling system may be suspected. A leak may also be suspected if the instrument is first calibrated at the 10 kW level, and a subsequent check at the 5 kW level does not show 5 kW ±5%.

Small leaks in the sampling system will affect the results only if they are on the negative pressure (inlet) side of the sampling pump. This is because some room air is mixed in with the sample gas readings, and their concentrations are no longer correct. Out-leaks, on the positive pressure side, will not affect the results unless they are so large as to actually change the flow rate conditions. Good operating practice still suggests, however, that out-leaks be avoided.

Searching for in-leaks in the cold trap and sample lines is most easily done by using a tracer gas being played around the suspect fittings and watching the appropriate analyser to see if there is a sudden increase in the concentration of this gas. Generally it is easiest to use CO_2 as a tracer, since a CO_2 analyser is located in the same line as the oxygen analyser and since CO_2 is a safe and heavy gas. Oxygen could also be used, but it has two disadvantages. One is that the oxygen analyser is set on a larger scale, typically 0-25% while the CO_2 analyser has a scale of only 0-5%, so the oxygen indications are less sensitive. The second is that the CO_2 is heavier than air and is less likely than the oxygen to get sucked up in the hood and give a false reading when checking the fittings. If the oxygen analyser is all that is available, then using pure oxygen will have to do. Watch the output of the oxygen analyser carefully as you play the oxygen discharge around the various fitting and the cold trap looking for leaks. Once the leak is found, it should be fixed and the orifice coefficient re-checked. Wait several minutes for the leak-tracing gases to clear from the system before doing the new calibration.

The two items most typically found to leak are the soot filter holder and the cold trap. The soot filter holder is the first place to check, because it is the only part of the sampling system regularly opened and closed. Check the holder to see if the top is properly seated on the O-ring and that there is no dirt or pieces of old filter paper keeping the top from seating properly. Wipe the seating area and the O-ring with a clean tissue to assure good contact. Recheck the orifice coefficient. If this is still not at the expected value, then check the cold trap and sampling lines for leaks. The line fittings are less likely to develop leaks than the cold trap.

Line leaks often occur after the lines have been taken apart to be cleaned and have not been reassembled correctly. If the lines have just been taken apart for cleaning, then their fittings will certainly be suspect, but if the system has been working well and no maintenance has been performed on the lines recently, then the most likely place for a leak after the soot filter is in the cold trap.

! Defective analyser

This will typically be noted in the daily calibration procedure as an inability to zero or span the analyser. Make sure that there is no failure in the plumbing to it. Then follow the manufacturer's instructions. Make sure that no particles of thread burr, Teflon tape, etc., have become lodged in the detector. An oxygen detector will seize up if solid particles enter into it. Make sure the final filter in front of the analyser is in good condition.

! Poor analyser inlet pressure control

Most of the analysers used in fire testing are sensitive to the pressure which shows up at sample inlet. The most common failing here, other than clogging or a gross mis-setting, is if this pressure is not the same when specimen testing is being done as it was during both the span and the zero steps. If pressures are not kept identical for these three conditions, anomalous results will occur. Since the plumbing arrangement is normally not changed in operation, inlet flows are customarily metered instead of inlet pressures. A constant inflow rate becomes tantamount to a constant pressure at the inlet. Physical malfunctions may include a clogging or mis-setting of a mechanical regulator, or an electric failure if an electronic mass flow controller is used. These can be checked by removing them and bench-testing.

! Poor compensation for barometric pressure in the analyser

Unlike most other analysers, the oxygen analyser is sensitive enough that care must be taken to isolate it from the effects of varying barometric pressure at its outlet. The effective pressure which the detector registers includes the barometric pressure component. Thus, the analyser has an electrical pressure transducer is incorporated which corrects the signal output.

Problems with barometric effects will manifest themselves as an unsteady baseline on stormy days. The system can be checked out by running a cylinder's span gas through the analyser and alternatingly hooking up and disconnecting a throttling valve to the analyser outlet. The signal should show only a small blip at the time of the changeover, but return to exactly the same baseline. If this does not happen, the pressure measuring system should be investigated.

! Unstable analyser output *(Servomex analyser)*

The detector element has a natural resonant frequency in the range of 120 to 200 hz. Unstable output will result if a vibration is present in this range. Such a vibration can result from either (a) vibrations coming through the case, or (b) pulsations through the gas stream flow. If this problem arises, both sources have to be explored. To pinpoint cabinet vibrations, it will normally be necessary to disconnect other vibrating equipment progressively. Gas stream pulsations can result due to pump characteristics or due to a flow controller which has a pulsating characteristic.

13.10 Thermocouples

Thermocouples are used for the cone heater itself, for the orifice plate exhaust flow measurement, for the laser smoke photometer, and for monitoring the cold trap. Additionally, thermocouples are incorporated into several of the gas analysers. Finally, the heated sample lines contain both thermocouples and thermistors for monitor and control purposes.

The essential thermocouples are the ones in the heater circuit, in the exhaust duct, and at the photometer. Spares of all of these should be maintained.

The 3 thermocouples fitted to the cone heater should be fitted so that they are positioned on the outside of the heater element. This is to reduce the effect of the sample burning and influencing the thermocouple temperature and hence reducing the flux of the cone.

While it is possible to buy thermocouple testing devices or to rig up boiling point and freezing point arrangements (using highly pure water!), it is normally uneconomical to do so. It is easiest to maintain replacement thermocouples on hand, and replace as needed.

In case of faulty thermocouple indications, realize that the error can be in the thermocouple itself, in the indicating circuit (including wiring and computer hardware), or in the computer software.

Testing the thermocouples themselves is standard laboratory procedure. Note, however, that shielded thermocouples are prone to develop a short from the shield to one of the signal wires if the end connection has not been prepared properly. Always use the tool available from the manufacturer for making up the end connections.

To check the indicating circuit, use a high quality digital voltmeter and repeat the tests with the voltmeter hooked up to the thermocouple output. Compare the results of the voltmeter-read temperature (using a millivolt-to-EC table for Type K thermocouples) to what the program thought the actual temperature was. Remember to add the cold junction temperature to voltmeter readings taken directly from the thermocouple. If these two temperatures do not agree, then the source of the error must be located. There are several possible places where the error could originate. The data scanning multiplexer may be defective; the cold junction compensation may be broken; wires may be shorting out; the data system may be reading the wrong channel; or, some error may have been introduced into the computer program itself. Trace and identify these in turn. For doing this, a precision millivolt source is very convenient.

Any time that input scanners are repaired or replaced, it is very easily possible to end up with an improper treatment of cold-junction compensation, so that it is no longer done by either software or hardware, or else is done twice over. This can be checked by comparison of computer program reduced data to temperatures which are checked with thermometers.

To make a thorough check of the computer program, it is convenient to use a precision millivolt source as input to the program. Set the millivolt source to some reasonable output and see if the temperature channel reading from the program corresponds to what it should be, as found in a Type K thermocouple reference table. If this checks out correctly, then set the millivolt source to some lower level and check again, to see if the linearizing portion of the program is working. If these checks do not work, then the problem is in the program code and must be corrected.

For the stack thermocouple, a possible source of error is the connection of the stack thermocouple with the motor speed controller circuit. Stray current may be getting into the thermocouple by this path. If this is a possibility, then use a precision millivolt source, or at least separate the thermocouple from the motor speed control circuit when checking the output of the data acquisition system. If there is a measurable current leakage into the thermocouple circuit, be sure to locate and correct it before proceeding. Often, the simplest way to solve such problems is to install an additional separate stack thermocouple, located a short distance away from the first one. With such a two-thermocouple arrangement, one can be dedicated to the motor speed controller, while the second one is used for the data acquisition system.

13.11 Pressure transducer

The pressure transducer should normally be suspected if errors in obtaining the orifice calibration constant are found, and the stack thermocouple and the oxygen system were checked out successfully. If the pressure readings look low, check the voltage output from the pressure transducer to be sure the data acquisition system is recording the same voltage as the pressure transducer is generating. If the amplifier/smoother is correct but the pressures indicated are still not close to those expected, then the lines and hoses connecting the ports above and below the orifice plate to the pressure transducer should be checked for leaks. Leakage in the upper line will cause a reduction in the differential pressure. It is difficult to determine if the lines are actually sealed. If after tightening all the fittings on the lines, no improvement is noted in the differential pressure reading, try squirting a little water on the various fittings, while watching the output of the pressure transducer. If the leak is not too large, the water will temporally seal the leak and give an increase in the differential pressure. This is a risky procedure as water may get sucked into the lines or the transducer. A safer method is to remove the transducer from the lines and, plug the ends by the orifice plate, slightly pressurize the line with air and use a soap solution on the various joints. This will check all the fittings, except those which connect the lines to the transducer. Before re-attaching the transducer to its lines, zero the pressure transducer. See the LESS-FREQUENT CALIBRATION PROCEDURES Chapter for details on this zeroing. Re-attach the lines to the pressure transducer and re-try the orifice flow constant. If the pressure transducer still does not give the appropriate response, then the span on the pressure transducer may be in error. If all other possibilities have been eliminated then the up-scale reading must be checked. See the calibration procedure for this check.

13.12 System checking with additional gas analysers

It will be assumed here that CO_2 and H_2O analysers are available and have been fitted as in Fig. A14 of the construction drawings. In such laboratories, additional system check-out procedures are possible. These involve using methane and PMMA (polymethylmethacrylate) as test materials. These compounds have a simple, known composition, thus the yields of CO_2 and water vapour, and the expected heats of combustion can be established. The methane used is the same high-purity methane as is used in normal calibrations. The block of PMMA used must be thick enough to show good steady-state readings, and the edge burning must be controlled. The normal size of PMMA blocks used is 100 mm × 100 mm × 25.4 mm. These burn long enough even at the highest fluxes to give a steady-state burning rate. For these special calibration purposes, the specimens are prepared not by wrapping in aluminum foil, but by providing slow-burning side protection, so that the edges regress no faster or slower than the bulk of the block. For instructions on preparing calibration specimens for this purpose, consult the section on CALIBRATION SAMPLES, above.

! Check involving mass yields.

The test basically involves comparing the indicated values of CO_2 (kg/kg) and H_2O (kg/kg) against expected values for PMMA and methane. For PMMA, load cell data are used to indicate the specimen mass loss rate. For methane, load cell data are, of course, not relevant. The mass flow rate for methane is, instead, directly computed and inserted into the computer program in the appropriate place. For these two reference materials, the expected values are given in Table 3, below.

Table 3. Mass yields for reference materials

Ref. Material	CO_2 (kg/kg)	H_2O (kg/kg)
methane (CH_4)	2.75	2.25

Readings which are too low compared to these reference values are indicative of possible leaks. If the values obtained are correct (as checked at several different heat release rate values), then the CO_2 and H_2O analysers have been operationally checked out. Values which are too high are only rarely encountered, and would indicate some specific malfunction of the analyser, rather than a problem with leaks. Separate checks are made on the CO_2 and the H_2O systems, because the analysers are connected to two different sampling systems (one heated and one not heated). Within each sampling system, in-leaks can only occur on the inlet side of the pump. The split for O_2/CO/CO_2 analysers is on the outlet side of the pump, therefore, separate checking of leaks for each of these analysers is not necessary.

! Check using mole ratios.

Additional checking can be done on a mole basis. For each combustible, the stoichiometrically correct mole ratios of CO_2/O_2 and H_{2O}/O_2, as given in Table 4 below, should be attainable.

Table 4. Molar relationships for reference materials

Ref. Material	CO_2/? O_2	? H_2O/? O_2
methane (CH_4)	0.5	1.0
PMMA ($C_5H_8O_2$)	0.833	0.667

The mole-concentrations needed here are not simply the meter readings, since it has been assumed that the CO_2 sampling line has had H_2O removed from it, while the O_2 sampling line has had both CO_2 and H_2O removed. For such an analyser implementation, the proper evaluation, assuming that the 0.04% CO_2 baseline has been directly subtracted from the CO_2 readings, is:

$$\frac{CO_2}{?\,O_2} \; ' \; \frac{X_{CO_2}\left(1 \,\&\, X^{o}_{O_2}\right)}{X^{o}_{O_2} \,\&\, X_{O_2}\left(1 \,\&\, X_{CO_2}\right)} \tag{6}$$

and

$$\frac{?\,H_2O}{?\,O_2} \; ' \; \frac{X_{H_2O}\left(1 \,\&\, X^{o}_{O_2}\right)}{\left(X^{o}_{O_2} \,\&\, X_{O_2}\right)\left(X_{CO_2}\right)\left(1 \,\&\, X_{H_2O}\right)} \;\&\; \frac{X^{o}_{H_2O}\left(1 \,\&\, X^{o}_{O_2}\right)}{\left(X^{o}_{O_2} \,\&\, X_{O_2}\right)\left(1 \,\&\, X^{o}_{CO_2}\right)\left(1 \,\&\, X^{o}_{H_2O}\right)} \tag{7}$$

The CO_2/? O_2 ratio will drop if there is a leak into the sampling line going to both the O_2 and CO_2 analysers.

! Check using the heat of combustion.

Finally, the heat of combustion of PMMA can be verified. This should be slightly less than the reference value of 24.88 MJ/kg. If the measured value is less than about 24.0, further troubleshooting should be done. Errors here can be also due to improper load cell calibration or errors in the computer data reduction program.

13.13 Heat flux meter

The easiest way to maintain an accurate reference is to have available two, identical heat flux meters. Compare and record their relative readings initially. Do not use the second heat flux meter in normal operations; set it aside for use solely as a reference. Periodically compare the two heat flux meters. If they show any drift, send back the working heat flux meter to the manufacturer for recalibration, repair, or replacement. Laboratories which expect to be in continual operation will need **three** heat flux meters — one reference heat flux meter, one working flux meter, and one more meter which may be in repair or in transit.

Flux meters which show a non-negligible change in calibration from the last time they were calibrated should be checked at *multiple* flux levels. If the flux meter is beginning to show non-linearities in its flux *vs.* voltage relationship, it should be replaced.

Special precaution. When shipping a heat flux meter via common carrier, etc., make sure that the water-cooling circuit has been thoroughly drained of water and dried out with compressed air. If this is not done, and the flux meter is shipped during winter, it is possible that the held-in water will freeze; a burst flux meter will result.

! Additional checks on proper irradiance.

The reference samples of PMMA serve an additional purpose. The ignition times will correspond directly to the irradiance given to the specimen. If a new PMMA test is made and the ignition times do not correspond, within normal test scatter, to the ignition times obtained when the Calorimeter was first set up and calibrated, it can be suspected that some error has been introduced into the measurement of irradiance. For instance, it may happen that the reference heat flux meter was damaged, and then the working flux meter was recalibrated to this erroneously reading flux meter.

13.14 Cone heater

13.14.1 Heater troubleshooting

If the heater has failed by welding itself, it may also be necessary to replace the inner cone at the same time.

If the fuse trips reset after investigating fault.

- Drift

  The initial temperature/heat flux tables should not be attempted until the unit has been run in by about a day's worth of operation, including burning some solid specimens. Once these tables are made up, drift should be very slow. A significant discrepancy from earlier values suggests problems in the heater circuit, or a failure of the heat flux meter. Check the flux meter, as described above.

- Inability to reach high fluxes

  Inability to reach the maximum 110 kW/m^2 flux level usually indicates that a full 230 VAC is not available to the heater element, or that the connection is corroded at the heater. Take apart and clean this connection. Measure the voltage being delivered with the temperature controller being set to the maximum feasible value. If less than 230 VAC is indicated, check the house mains and the boost transformer. If necessary, disconnect the signal line from the temperature controller and use a precision voltage source to apply the maximum 10 VDC to the power controller. If a full 230 volts is obtained then, but not when using the temperature controller, test the temperature controller and double-check the wiring going to the power controller.

  For a heater being used for the first time, this problem could also arise because an incorrect heater was installed, was improperly wound (there should be 8-1/2 turns of windings, evenly spaced), or was improperly installed (there should be no gaps in between the layers, and the connector ends should be of about equal length).

- Erratic operation

  Erratic operation usually indicates that one of the three cone thermocouples is failing. This can be determined by progressively removing their plugs one by one and noting when the problem disappears. This approach is feasible since the thermocouples are joined in parallel. Removing one of them still permits a reasonable measurement to be made, although with less good representativeness.

- Non-uniform heating

  When viewing an operational heater from the specimen's position, a uniform glow should be seen. It should be noted that there should be no gaps, and no turns of the coil must have jumped out of their normal position. If irregularities are noted, it may be possible to remove the coil and gently straighten these portions. If this does not alleviate the problem, a new coil must be fitted.

- The heater is dead

  This may be due to a failure of any number of components: the temperature controller, the power controller, the heater element itself, the wiring, or the power circuit which supplies the 230 V to the power controller. Controllers can be checked out one-by-one by determining that their input and output voltages are reasonable. Heater element failure can be subtle or dramatic. A subtle failure may result from a corrosion of the contacts, or a broken contact slightly inside the element itself. A dramatic failure occurs when the heater fails by arc-welding itself. This is very similar to a corresponding failure on an electric oven heating element.

The heater is generally very long-lived and tends to die only from obvious damage. One source of damage to guard against is the deposition of substances evolved from the burning specimen. If any specimen is being burned which is ejecting material that gets deposited on the coils in a substantially thick layer, heater failure is likely to occur. (Some silicone products have been seen to do this). This is because the place where the buildup has occurred creates a zone of over-heating on the coils. Specimens which show this type of behaviour cannot be tested in the orientation (horizontal or vertical) that exhibits this problem.

13.14.2 Heater replacement

A heater element may need to be replaced either because its windings have gotten too badly shifted out of place and cannot be re-aligned, or because it has burned out. To replace, disassemble the cone assembly and remove the heater. Check the thermocouples at the same time. This is a good time to replace any dubious thermocouples. Check that the refractory packing in between the outer and the inner cones is in good shape and has not all drooped to the bottom. Replace if necessary. When inserting a new heater, check that the heater has been wound so that the two connector ends are of approximately equal length. Fix the winding lengths if this has not been done properly. When inserting the heater element into the slots in the outer cone, it may be necessary to slightly bend the ends into a curve in order to be able to insert it. Do this carefully with a pair of gripper pliers. When the heater is installed, bend back the ends carefully to be straight. *Do not* grip the heater element by the electrical connectors in doing this; rather, grip the heater surface itself. Check that all the heater turns are smooth, without visible gaps. Check that the top winding is centred as well as possible in the top cone hole. Re-connect and re-insulate the electrical connection.

13.15 Load cell testing

Most problems with the load cell are spotted during routine calibrations. Occasional problems which have been encountered include:

- ! The load cell reading is steady until the fan is turned on, at which point a lot of jitter is noted. This usually indicates that the specimen holder is not sitting true in its intended position, but is rocking, instead. To fix, file rough edges or otherwise correct physical irregularities.

- ! With no heating or burning taking place, the load cell signal, when examined on a strip chart recorder, shows periodic excursions which are large and are unexpected. This will typically be identified to be grounding or shielding problem. Step-by-step tracing of grounds, shields, and signal connections will usually enable the problem to be identified. If external, nearby equipment is causing interference, it may be necessary to fit electrical filtering devices to such sources.

- ! Noisy output due to blower vibrations being transmitted into the load cell. The solution for this problem has already been described in the GENERAL section at the start of this Chapter.

13.16 Laser smoke photometer

PRECAUTION

The laser fitted to the smoke photometer emits light energy at the red wavelength of 632.8 nm. Even though the laser fitted is the smallest output commercially available He-Ne type (0.5 mW nominal power), the user is still cautioned not to stare into the beam during any installation, maintenance, or repair operations.

Important: After any maintenance or repair procedures on the laser smoke photometer circuit, the user must make sure that all components associated with the photodetectors have been cleaned thoroughly with a solvent suitable for cleaning printed circuit boards. This includes contacts on the detectors themselves, contacts on all plugs in the circuit, and the associated circuit board. Fingerprints, soot, etc., deposited in these places are likely to result in noisy, unpredictable operation.

13.16.1 Alignment of the laser smoke photometer

During initial assembly, and any time the photometer assembly has been removed or the clamp which holds the two halves of the photometer has been removed, the alignment will have to be checked. Re-alignment may also have to be done if improper values for PMMA are being registered, and the electronics have been found not to be mis-calibrated.

For a unit already installed, there are several troubleshooting steps that can be taken to determine if mis-alignment exists.

! Remove the detector assemblies (do not disassemble the individual components there) and the end cap (if any). Successively, insert into each of these places the plastic target cap. Carefully examine the image: there should be two bright pinpoints of laser light. If more than two images are seen, or if there is a "halo" around these images, mis-alignment exists.

! In line with the laser image coming straight out the end of the main tube, put up a white paper target, about 1 m away from the tube. Mark a spot to indicate the two images. Now, gently push on the laser head itself. Push the laser up, down, left, and right. It should be possible to shift the image on the target by about 3 cm in each direction. If the image disappears, breaks up into multiple images, acquires a halo, or becomes suddenly broad and diffuse when moved in any of these directions, an indication of mis-alignment has been found.

! If the above procedures do not indicate mis-alignment, but such difficulties are still suspected, there is one other test available; it is, however, more time-consuming. Remove the section of the main exhaust duct that is upstream of the photometer. Remove the ring sampler. Now, carefully inspect the purge-air tube openings from the inside of the duct. The laser light should be essentially invisible. If red spots are seen in the vicinity of the tubes, this indicates that some portion of the beam is improperly making contact with the tube walls.

- Re-install the detector assemblies and the end cap. If the duct section and ring sampler have been removed, re-install them. Take care the ceramic fibre gasket at the exhaust hood end is installed straight and is undamaged.

To perform a re-alignment, it will normally be necessary to remove the photometer and then to re-install, following the steps below. These same steps are also followed in performing the initial photometer installation.

- Remove photometer assembly from the framework.

  - On the bench, remove the laser assembly, the detector assemblies, the main photometer tube end cap, and the two beamsplitters. Do not remove the laser head itself from its mounting flange hardware; only unscrewing the three screws holding the laser flange is necessary. Also, do not disassemble the detector assemblies themselves, unless there is something specifically wrong to repair. The beamsplitters and the detector assemblies are each held in by hex setscrews onto the outside barrel. When these are loosened, the detector assembly should pull right out. The beamsplitters are set into inner tubes which slide within the main barrel. These assemblies may be more difficult to remove. It may be necessary to insert prying devices from the barrel end, from the detector opening, or both, in order to free out a beamsplitter tube. Do this carefully!

  - Visually examine the tubes on the exhaust duct. They should be straight, one collinear with the other, truly horizontal, and not deflected right-to-left. Next pass the metal alignment rod through both tubes at the same time. There should be adequate clearances; no burrs or weld slag should be encountered. Next, examine the weld attaching the tubes to the exhaust duct. The weld should be small and clean, and should not form a fillet larger than about 2.5 mm. (Large, sloppy welds will prevent the adequate seating of the yoke.) Correct any metalwork problems observed.

  - Start the re-assembly.

  - Bring up the two photometer halves onto the exhaust duct. Pass the alignment rod through the air purge tube. Place an end cylinder onto each end of alignment rod, to allow clearances to be judged more accurately. Adjust the four clamping screws progressively until the end cylinders are well centred within each respective tube end. Then tighten up the assembly until it is snug. Remove the alignment rod and the end cylinders.

  - Put in a translucent plastic target cap onto the end of the main barrel. Attach the laser assembly and turn on the laser. Check to see that the light image (since there are no beamsplitters, there will be only one) are centred within the central portion of the target and that there are no spurious images, diffuse images, or haloes. Adjust the three screws which retain the laser to the photometer, as necessary, until the proper light image is seen. If there is not enough adjustment in these screws, slightly changing the torque on the four main yoke screws can improve alignment. Then, tighten the counter-nuts on the yoke screws. Verify that the image has not been disturbed. Remove the plastic target cap.

- Using the white paper target described above, perform the same test of pushing the laser in each direction. Correct light image characteristics should be seen, as described above. Adjust the laser mount screws or re-torque the yoke to achieve this. Once this is achieved, spin up the counter-nuts on the laser mount to mark the correct insertion length of each screw, then remove the laser assembly.

- Carefully examine the beamsplitter tube(s) and the main barrel inside surface for any burrs or damage. Fix burrs. Re-insert the beamsplitter tube(s), making sure the glass is facing at the correct direction. Get the beamsplitter(s) into the approximately correct position by pushing them from the ends of the barrel and also moving them from the detector assembly openings.

- Re-install the laser assembly. Again, examine the characteristics of the light images on the white paper target. If necessary, slightly re-adjust the laser assembly screws. Tighten the laser assembly counter-nuts.

- Next, set up the final alignment of the beamsplitter(s). A small hand-held mirror may be necessary for this. Insert the plastic target cap at the place of the reference beam detector assembly. Check that the two light images are reasonably centred and have the proper light characteristics. If the spots are too close to the edge, make a note in what direction the spots should move, remove the target cap, insert a small, stiff, bent metal rod into the barrel opening and gently push the beamsplitter tube in the correct direction. (If you did not carefully remove all burrs and other obstacles to the free movement of the beamsplitter tube, this will prove to be impossible!). Re-insert the target cap and check that the images are now adequately centred. When successful, lock in the beamsplitter setscrew.

- Repeat the same operation with the second beamsplitter. The alignment of the main detector beamsplitter will be somewhat easier, since access for manipulating the beamsplitter tube is also available from the end of the main barrel.

- Install the end cap or the main beam detector onto the end of the main barrel.

- Check that the detector wiring is nowhere touching any hot surfaces. This completes the mechanical alignment of the photometer. At this point, the calibration of the smoke photometer electronics, described in the LESS-FREQUENT CALIBRATION PROCEDURES Chapter, would normally be performed.

13.16.2 Troubleshooting of the photometer

- Total lack of output.

  This is most likely due to a failure of the laser. To check, remove the end cap (new version) or main beam detector assembly (original version), and check for laser light output. Replace laser head, if necessary.

- Zero offset large enough so it cannot be corrected by the front panel control.

This is generally due to a soot deposit on the optics. Such a deposit can happen if the hood system has not been cleaned in a long time, and then the exhaust blower is repeatedly cycled on and off. The pressure surges can then deposit soot on the optics. To correct, check the beamsplitter at the laser, and either main beam detector (if the instrument has not been fitted with a second beamsplitter) or the beamsplitter located above the main beam detector (if the instrument has two beamsplitters). Clean as necessary. Also, clean out the air purge tubes at the same time.

! Excessively rapid sooting up of the optics.

Sooting up sufficient to require disassembly and cleaning should be occurring only every six months, or so. If rapid soot accumulation inside the photometer tubes or on the optics is noted, it may be suspected that the air purge holes in the outside tube barrel are not functioning properly. The repair is simple. Clean out the holes; remove any obstructions. If problem persists, it may be useful to increase hole diameter to the next drill size.

! Calibration with PMMA indicates excessively high smoke readings.

The simplest possibility is that the slope control in the signal electronics was not properly calibrated using neutral density filters. The instructions for checking this are given in the LESS-FREQUENT CALIBRATION PROCEDURES Chapter.

If a re-calibration of the electronics does not correct the problem, the next most likely possibility is optical alignment problems with the laser beam. See the preceding section for instructions.

! Calibration with PMMA indicates smoke readings too low by about 10%

The function of the photometer thermocouple is to allow corrections to be made to the volume flow rate determined in the stack. The corrected value is supposed to indicate the actual volume flow rate at the photometer location.

This will typically be higher (very roughly by 10%) than at the stack measuring location, due to the higher local temperature. An error of this magnitude will be made if (a) the photometer thermocouple is defective, or (b) the data reduction software does not perform the needed adjustment. To remedy, check voltage readings from the two thermocouples, then check the software algorithm.

! Noisy, erratic, or incorrect smoke values recorded

The smoke values reported by the computer software include outputs from: the photometer circuit itself, the photometer thermocouple, the load cell, and the exhaust volume flow rate measurements (pressure and temperature). An error in any of these will result in improper smoke data being reported. When this condition is seen, the first diagnostic step is to determine which subsystem is at fault.

The source can usually be discovered by making a dump of the raw data channels and determining which channel is giving noisy or faulty data. If the problem is due to the exhaust duct pressure or temperature measurements or specimen mass loss rate values, these should be solved as explained in the preceding sections. Likewise, the procedures for checking and correcting problems with the photometer thermocouple are similar to those pertinent to the orifice plate flowmeter thermocouple (see above).

If the problem is now identified to be with the photometer circuit itself, first check if noise and erratic value problems disappear when exhaust fan is shut down. If they do, this indicates a mechanical problem. Check the various pieces (detectors, beamsplitters, laser) to make sure they are rigidly affixed. Then check that the whole photometer yoke is properly clamped onto the duct. This should clear up mechanical vibration problems.

If problems do not go away when the fan is turned off, this may be due to a wide variety of causes. The ones to consider first are:

- Misalignment of the beam. Instructions for mechanical alignment are in the preceding section.

- Dirty electrical contacts or circuit components. The detector circuitry is high impedance, and is very sensitive to the effects of grease, etc., on the connections, on the circuit board, and other places. Treat contacts with the spray recommended in the REGULAR MAINTENANCE Chapter above. Spray circuit traces, high-value resistors, and other critical components with a regular Freon-type electrical cleaning spray.

- Defective photodetector diode(s). This is best checked by substitution. Check also that the diode is of the type currently recommended in the Construction Drawings, and is not of the older, less stable type.

- Incorrect photodetector polarity. Unpredictable results may be experienced if a detector diode polarity is wrong. Check both detectors to see that polarity is correct. The tab on each diode should be located at the same place as the tab on the socket. This alone does not guarantee necessarily correct polarity, since someone may have wired the cable up wrong. Check all connections further, if necessary.

- Incorrect components. Verify that the signal cable going to the detector diodes is of the Teflon type, and that a PVC, etc., type has not been substituted. Such a substitution may cause unacceptable drift in the output. Also, for the NIST version of the electronics, check that the bias resistors are of a proper low temperature coefficient type.

- Defective laser output. A defective laser head, laser power supply, interconnect cable, or high voltage connector/receptacle can all show up as a wandering, unstable output of the photometer. First check the electric connections. If problem still persists, remove the beam detector or end cap from the end of the photometer tube and check laser output visually. If problem is isolated to either the power supply or the laser head, further troubleshooting by successively substituting these items will usually be necessary.

  It must be emphasized that unstable photometer operation can result from a bad laser **even though the laser gives output which seems visually adequate**. A number of users have noted a laser failure mode whereby the laser output seems of adequate strength, yet very noisy operation is seen. The best way to check for this is to substitute a new laser head. If the noisy operation stops when this is done, the laser head should be sent back to the manufacturer for repair.

- Calibration controls are pegged out at the extremes of their range.

  This will usually be due either to defective or significantly mismatched detector diodes, or due to some failure of connectors, wires, or plugs. Check the integrity of all wires and connections. Replace diodes with new diodes.

- Laser beam spot is not correct.

  When the end cap is removed, the laser beam can be shined on the translucent alignment plug, or on an opposing wall. In either case, there should be one bright, well-formed laser spot. Two improper patterns are: (1) a diffuse glow surrounding the central laser spot, or (2) many small bright spots or "streamers." The first problem is normally caused by mechanical mis-alignment of the photometer. With such mis-alignment, a portion of the beam strikes the side wall and undergoes multiple reflections. To correct, it is necessary to completely disassemble the unit and to re-assemble after mechanical straightening and re-adjustment (see the preceding section). In the case of multiple bright spots or streamers, soot deposited on the inside tube walls or on the beamsplitters is the cause. A simple cleaning by using the high-pressure air gun against the purge air holes may be all that is needed. If this does not suffice, it will be necessary to perform some disassembly for cleaning. Again, the instructions in the preceding section must be followed for re-assembly.

13.17 Cold trap

- No cooling.

  This is an electrical problem which may be due either to a malfunctioning power supply or failure of the compressor unit module.

- Clogging with soot.

  Normally the soot filter and the backup to it will take care of all soot problems. In exceptional cases, it both of these have failed, it may be necessary to clean the insides of the cold trap. It is easy to disassemble and clean out the insides. It is much more difficult, however, to re-assemble the unit in a leak-free manner. Thus, it may be desirable to first try pumping a mild solvent through the trap, before disassembly is judged necessary. Remove the top and bottom compression fittings and clean the inside of the stainless steel tube by pushing through cloth soaked in cleaning agent. Re-assemble ensuring the olives are in good condition. After a uniform tightness, without distortion, has been achieved, re-connect the unit and leak test. If leaks are found, slightly changing the tightening torque may help. If this turns out to be very difficult to do, it can be helpful to disassemble again and to coat appropriate places with RTV silicone sealant.

- Leaks.

  If leaks are detected, it will typically be necessary to disassemble the unit, find the cause and fix it. Follow the instructions in the item above.

NOTES

Should any errors or omissions be found in this user's manual or should you require any further information, please contact Fire Testing Technology Limited. Telephone: +44 (0)1342 323600 or Fax: +44 (0)1342 323608

Appendix 1: Cone Calorimeter Schematic

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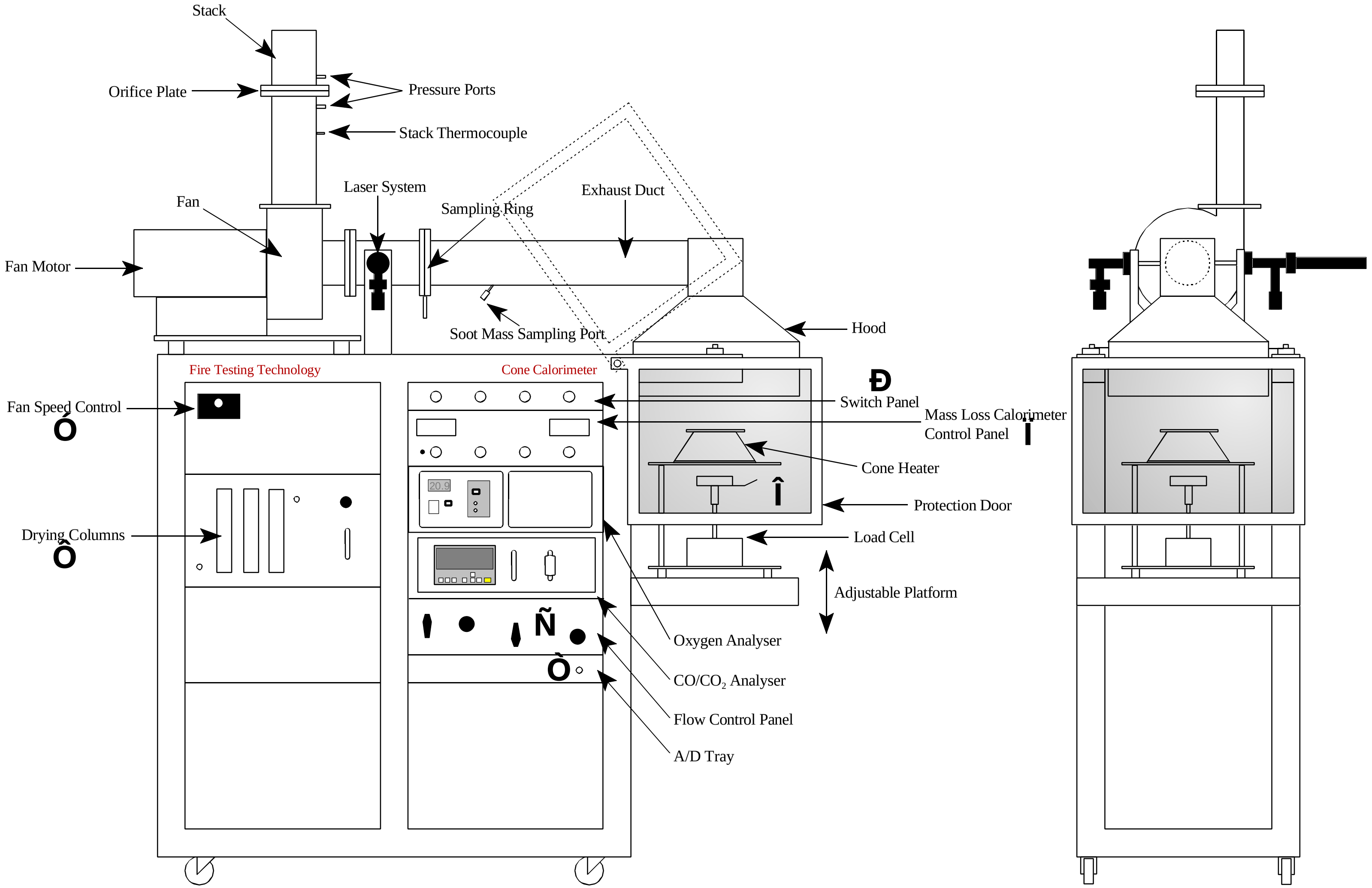

Figure 1: Schematic Diagram Of The FTT Standard Cone Calorimeter

Appendix 2: Dual Analysis Rack

The dual analysis rack has been designed for use with both the Cone Calorimeter and large scale calorimeters and contains all of the common instrumentation - oxygen analyser, CO/CO_2 analyser, sample line drying columns, cold trap, A/D tray and analyser flow controls. With a Dual Analysis Cone Calorimeter this analysis rack plugs into the left hand side of the instrument and the system can then be used as a standard Cone Calorimeter - the only difference being that the specific controls are in different positions.

The figures on the following pages shows schematics of the Dual Analysis Cone Calorimeter and its connection with the analysis rack.

To connect the analysis rack to the Dual Analysis Cone Calorimeter, wheel the analysis rack under the fan on the left hand side on the Cone. Ensure that the mains power to both the Analysis Rack and the Dual Cone are off. Connect the 3 thermocouples (Stack, Smoke and Cold Trap) being careful to observe that the correct thermocouple plug, from the analysis rack, connects with the correct thermocouple plug on the Dual Analysis Cone Calorimeter. All the other connections, from the Calorimeter input signal cables bundle, are either 3,4 or 5 way DIN pairs.

Next connect the 3 way Bulgin plug-socket extension cable between the Laser Power socket on the Dual Cone service panel and the Laser Power Output on the Analysis Rack (the laser power is taken from the rack rather than from the Cone so that when the rack is connected to a large scale calorimeter it can power the laser on that system).

Finally connect the analysis rack to the mains. This can either be performed by using the mains extension cable connected between the Mains Outlet on the Dual Cone service panel and the Mains In on the Analysis Rack, or the mains can be taken directly from a wall socket. The former is preferred when connected to the Dual Cone.

Connect the sampling line (from the sampling ring and filters) to the Analysis Rack using the quick release pipe union (labelled Sampling Line Inlet). Similarly connect the nitrogen and CO/CO_2 span gas to the analysis rack.

Connect the PC signal cables to the computer, observing the correct positioning of the two 20-way connectors (the cable labelled CN1 must be connected to the plug labelled CN1 - the right hand plug when the computer is viewed from the rear).

Finally push the Analysis Rack into position under the fan and put the exhaust lines from the gas analysers into the extraction system above the Cone.

Turn the Analysis Rack and Dual Cone on and continue operation as for a standard Cone.

To disconnect the Analysis Rack from the Dual Cone, ensure that all of the power is off to both units and reverse the connection process. The rack can then be connected to a large scale calorimeter. Care again must be taken to connect the correct signal cables to the transducers on the large rig apparatus.

With the large rig apparatus FTT will supply an extension cable bundle to allow for the longer distance between the analysis duct section and the Analysis Rack. The signal cables are extended except the “Cone T/C” thermocouple, “Fluxmeter” and “Weight Output” which have no connection in the large scale calorimeter.

The table below summarises the connections and labels for the Analysis Rack and Dual Cone and the large rig apparatus.

Cable No.	Label	Dual Cone Connection	Large Rig Connection
1	Stack T/C	Stack T/C socket on service panel	Stack T/C in-line socket from analysis duct section
2	Smoke T/C	Smoke T/C socket on service panel	Smoke T/C in-line socket from analysis duct section
3	Cone T/C	Cone T/C socket on service panel	No Connection
4	Fluxmeter	Fluxmeter 3 way DIN socket on service panel	No Connection
5	Weight Output	Weight Output 3 way screw lock socket on service panel	No Connection
6	Laser Signal	Laser Signal 4 way DIN socket on service panel	Laser Signal 4 way DIN in-line socket from laser cradle
7	DPT	DPT 5 way 240° DIN socket on service panel	DPT 5 pin 240° DIN in-line socket from differential pressure transducer
8	Mass Flow Meter	Mass Flow Meter 5 way 180° DIN socket on service panel	Mass Flow Meter 5 pin 180° DIN in-line socket from the gas burner system
9	Laser Power	Laser Power 3 way Bulgin socket on service panel	Laser Power 3 way Bulgin in-line socket from laser power supply unit.
10	Mains	Mains Outlet 3 way mains socket on service panel	Connection from wall socket

In addition, the large rig system has a separate load cell which has its own signal and PC (RS232) cables. If supplied, the control unit is mounted in the Analysis Rack belwo the Flow Control Panel.

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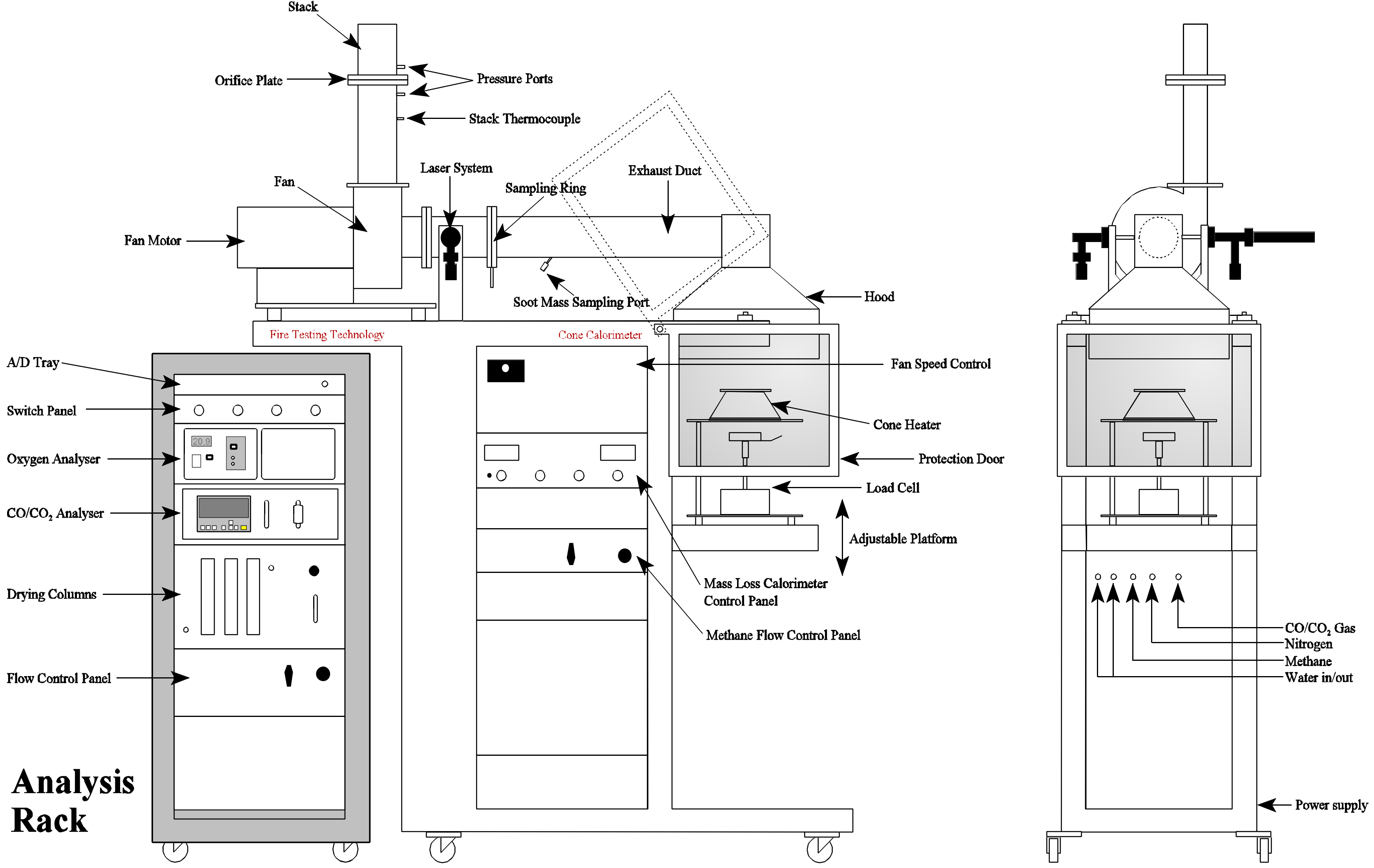
Schematic Diagram Of The FTT Dual Analysis Cone Calorimeter



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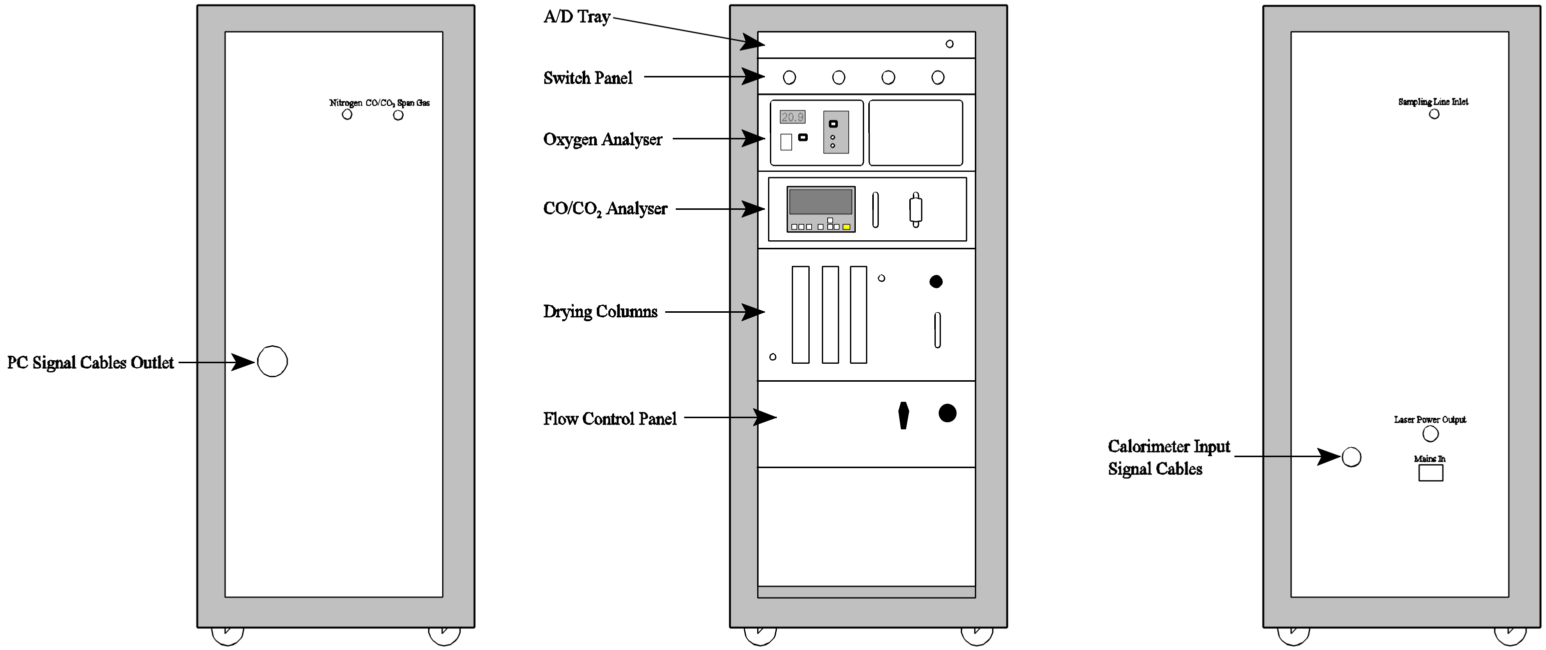
Schematic Diagram Of The FTT Dual Analysis Rack



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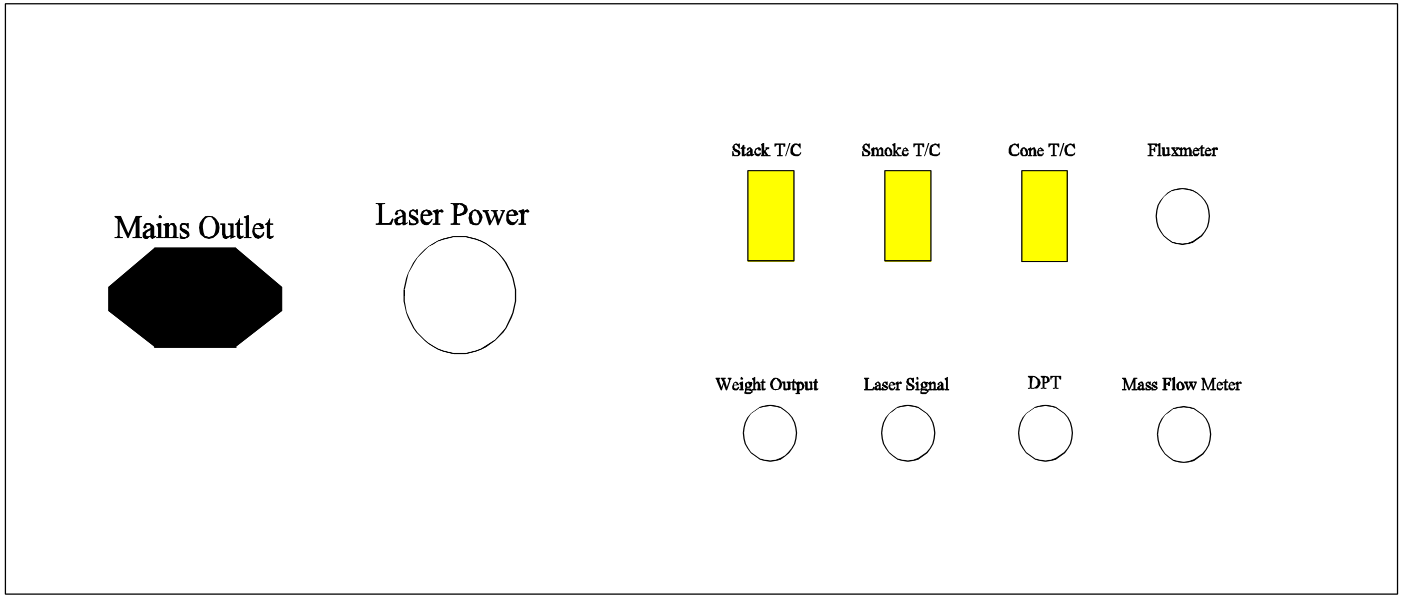
Schematic Diagram Of The Dual Analysis Cone Calorimeter Service Panel



Appendix 3: Spare Parts List

The spare parts list for the Cone Calorimeter is given in the following pages. Please contact FTT or their agents if there are any spares items not included on the list that you require or for prices.

FTT Cone Calorimeter Spare Parts List

Part Number	Part type	Part Name	Unit Price	Notes	Instrument
4211	AV Mount	Fan plate anti-vibration mount	POA	4 required per instrument (green spot)	FTT Cone
4212	AV Mount	Hood and fire model plate anti-vibration mount	POA	2 required per hood, 4 required per fire model plate (purple spot)	FTT Cone
442-505	AV Mount	Sample pump anti-vibration mount	POA	4 required per instrument	FTT Cone
442-549	AV Mount	Cold trap anti-vibration mount	POA	4 required per instrument	FTT Cone
U217	Burner	Methane calibration burner	POA		FTT Cone
DPT Recal	Calibration	DPT calibration	POA	Original to be returned to FTT	FTT Cone
HFM Recal	Calibration	Calibration of heat fluxmeter	POA	Original to be returned to FTT	FTT Cone
MFM Recal	Calibration	Calibration of mass flow meter	POA	Original to be returned to FTT	FTT Cone
C209-4	Ceramic	Load cell cover	POA	Rectangular cover with slot	FTT Cone
U199-4	Ceramic	Shutter Pad - Set of 2 (L/H & R/H)	POA		FTT Cone
U203	Cold Trap	S/A Cold Trap Drain	POA	Includes parts G136-3, 4816, 4607, 4635	FTT Cone
FTT0156	Controller	Temperature controller for Cone Calorimeter	POA		FTT Cone
4528	Data Acquisition	16 Channel MUX board for data logger	POA		FTT Cone
4541	Data Acquisition	PCL-816 16-bit, 16 channel data acquisition board	POA		FTT Cone
4542	Data Acquisition	PCLD-789 16 channel MUX board	POA	Replacement for PCLD-779 8 channel MUX card (the PCLD-779 is now obselete)	FTT Cone
4222	DPT	Differential pressure transducer	POA		FTT Cone
U207	Drying column	S/A Drying column	POA		FTT Cone
U007-4	Exhaust	Orifice Plate	POA		FTT Cone
4367	Ferrule	Back Ferrule (8 mm) (stainless steel)	POA		FTT Cone
4424	Ferrule	Front Ferrule (8 mm) (stainless steel)	POA		FTT Cone
4659	Ferrule	Front Ferrule (6 mm) (stainless steel)	POA		FTT Cone
4660	Ferrule	Back Ferrule (6 mm) (stainless steel)	POA		FTT Cone
4530	Filter	Membrane filter for soot analyser (PTFE) (each)	POA	per filter	FTT Cone

POA: Price On Application - please contact FTT for availability and price

Part Number	*Part type*	*Part Name*	*Unit Price*	*Notes*	*Instrument*
4641	Filter	In-line filter	POA	Filter after oxygen and carbon dioxide flowmeter (one for each flowmeter)	FTT Cone
U208	Filter	S/A Glass pre-filter & fittings	POA		FTT Cone
4290	Filter (Primary)	58P filter element housing	POA	Includes 2 male adapters (part # 4661)	FTT Cone
U180-4	Filter (Primary)	BA100 primary filter element	POA	0.1 micron, 10% discount on orders of 100+	FTT Cone
U184-4	Filter (Secondar	6723 HEPA vent secondary filter	POA		FTT Cone
4046	Flow control	Flashback arrestor	POA	Body only - no fittings	FTT Cone
4523	Flow control	Flostat flow stabilsation controller	POA	For Cone Calorimeters supplied before November 2000 (fitted with Servomex 1440 oxygen analyser) - instrument serial numbers up to 0101584	FTT Cone
4714	Flow control	Sample gas flow regulator	POA		FTT Cone
4450	Flowmeter	Oxygen analyser flow meter	POA		FTT Cone
4493	Flowmeter	Methane mass flow meter	POA		FTT Cone
U003-4	Gasket	Gasket for extraction hood ducting	POA		FTT Cone
U006-4	Gasket	Gasket for sampling ring & orifice plate ducting	POA	4 required for complete system (2 for sampling ring and 2 for orifice plate)	FTT Cone
U186-4	Gauge	23 mm spacing gauge (cone to sample)	POA	Use for sample holder with edge frame	FTT Cone
U187-4	Gauge	25 mm spacing gauge (cone to heat flux meter or sample)	POA	Use to position heat flux meter at correct height or sample with no edge frame	FTT Cone
FTT0012	Heat Flux Meter	S/A Heat flux meter assembly	POA		FTT Cone
M002-2	Heater	Cone inner shell	POA		FTT Cone
U135	Heater	Heater element winding	POA		FTT Cone
U149	Heater	Cone heater assembly and thermocouples	POA		FTT Cone
U216	Heater	Cone winding termination kit (ring terminal, sleeve and Autostic)	POA	set of 2 (ring + pyrex sleeve + Autostic)	FTT Cone
4449	Interface	PCI GPIB Card	POA	Interface card for data logger	FTT Cone
4484	Laser	Laser head OEM05P	POA		FTT Cone
4485	Laser	Laser power supply LSS05	POA		FTT Cone
G123-4	Laser	Nylon beam alignment plug for laser smoke system	POA		FTT Cone
G200	Laser	S/A Beam splitter laser	POA	"compensating" detector	FTT Cone
G201	Laser	S/A Beam splitter detector	POA	"main" detector	FTT Cone
U142-4	Laser	Photodiode pre-amp unit	POA		FTT Cone
4473	Load cell	Load cell controller	POA		FTT Cone

POA: Price On Application - please contact FTT for availability and price

Part Number	*Part type*	*Part Name*	*Unit Price*	*Notes*	*Instrument*
U999	Manual	User's guide for FTT Cone Calorimeter	POA		FTT Cone
4536	Nut	Pipe nut (8 mm) (stainless steel)	POA		FTT Cone
4260	Optical filter	ND 0.3 filter without holder	POA	25 mm diameter	FTT Cone
4262	Optical filter	ND 0.8 filter without holder	POA	25 mm diameter	FTT Cone
G120-3	Optical filter	Optical filter holder	POA		FTT Cone
G145-4	Optical filter	Blank filter holder	POA		FTT Cone
FTT0135	Photodiode	Main photodiode assembly	POA	Photodiode in clamp assembly with red phono plug	FTT Cone
FTT0136	Photodiode	Compensating photodiode assembly	POA	Photodiode in clamp assembly with black phono plug	FTT Cone
591-124	PSU	+-15V PSU	POA	Order with 592-947	FTT Cone
592-947	PSU	Screw terminal panel (for 15 V PSU 591-124)	POA		FTT Cone
4613	Pump	Service kit for pump	POA	2 required for double-ended pump	FTT Cone
4720	Pump	Complete single-ended sample pump (230 V)	POA	Not for FTT Dual Cone	FTT Cone
4725	Pump	Complete double-ended sample pump (230 V)	POA	For Dual Cone and all FTT Cones from November 2000	FTT Cone
U209	Refrigeration	S/A Cold Trap (Vapour Cooler)	POA		FTT Cone
346-918	Relay	Surface mount relay (solid state)	POA	For cone heater assembly control	FTT Cone
FTT0013	Sample	S/A Sample holder assembly (tray and edge frame)	POA		FTT Cone
U139-4	Sample	U139-4 retaining grid	POA		FTT Cone
U164	Sample	Backing board	POA		FTT Cone
U197	Sample	Ceramic fibre backing pads (4 pieces)	POA	100 x 100 x 25 mm (4 per pack)	FTT Cone
U206	Sample	S/A Vertical sample holder	POA		FTT Cone
U008-3	Sampling Ring	Sampling ring for Cone Caloirmeter	POA		FTT Cone
4084	Spark	New spark generator	POA	Continuous spark	FTT Cone
4397	Spark	10 kV spark generator unit	POA	Intermittent spark, no detection	FTT Cone
M015-4	Spark	2.5 mm electrode assembly with Tufnol block	POA		FTT Cone
U148-4	SRM	PMMA test sample	POA	18 mm thick	FTT Cone
U215-4	Support	Dual height fluxmeter/burner holder	POA	Bracket for side of cone heater to allow heat flux meter to be positioned at 25 or 60 mm from the bottom of the heater	FTT Cone
319-433	Switch	Red DPST latching pushbutton switch	POA		FTT Cone
4151	Thermocouple	Cone heater thermocouple	POA	Requires olive (part number 4615). Heater requires three.	FTT Cone

Part Number	Part type	Part Name	Unit Price	Notes	Instrument
4615	Thermocouple	1.5 mm thermocouple olive and nut	POA	Not for stack thermocouple	FTT Cone
4735	Thermocouple	1/16" front ferrule for stack thermocouple	POA	For stack thermocouple only. Order part 4736 for full ferrule set.	FTT Cone
4736	Thermocouple	1/16" rear ferrule for stack thermocouple	POA	For stack thermocouple only. Order part 4735 for full ferrule set.	FTT Cone
4822	Thermocouple	Thermocouple for stack, smoke or cold trap	POA	Requires olive (part number 4615)	FTT Cone
4298	Tubing	Black nylon tubing, 6 mm external diameter (per metre)	POA	per metre (Black)	FTT Cone
4299	Tubing	Clear nylon tubing, 6 mm external diameter (per metre)	POA	per metre (Clear)	FTT Cone
4614	Tubing	1/4 Nylon (clear) - price/metre	POA	per metre (Clear)	FTT Cone
4699	Tubing	Silicone tubing 5 mm ID 8 mm OD	POA	per metre	FTT Cone
4592	Valve	Solenoid valve in methane line	POA		FTT Cone

POA: Price On Application - please contact FTT for availability and price