Cone Calorimeter

(ISO 5660 ASTM E 1354)

The most comprehensive bench scale fire test

THE BENCHMARK IN FIRE TESTING

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The Cone Calorimeter is the most significant bench scale instrument in the field of fire testing because it measures important real fire properties of the material being tested under a variety of preset conditions. These measurements can be used directly by researchers or they can be used as data for input into correlation or mathematical models used to predict fire development. Directly measured properties include:

- Rate of heat release
- Time to ignition
- Critical ignition flux
- Mass loss rates
- Smoke release rates
- Effective heat of combustion
- Rates of release of toxic gas (e.g. carbon oxides)

FTT Cone Calorimeter

The name "Cone Calorimeter" was derived from the shape of the truncated conical heater that Babrauskas used to irradiate the test specimen (100mm x 100mm) at fluxes up to 100 kW/m^2 in the bench scale oxygen depletion calorimeter that he and his co-workers developed at NIST. The FTT Cone Calorimeter has been produced to be the most compact and easily maintained unit in the marketplace. It fits into the smallest of labs and is easy to operate using the FTT user friendly, menu driven software, which guides users through the calibration, testing and reporting protocols. The apparatus meets all existing Standards (including ISO 5660, ASTM E 1354, ASTM E 1474, ASTM E 1740, ASTM F 1550, ASTM D 5485, ASTM D 6113, NFPA 264, CAN ULC 135 and BS 476 Part 15).

A full system consists of:

- Conical Heater - wound in the form of a truncated cone, rated 5000 W at 230 V with a heat output of 100 kW/m^2.
- Facility for testing horizontally or vertically orientated specimens
- Temperature control by the use of 3 type K thermocouples and a 3-term (PID) temperature controller.
- A Split Shutter Mechanism - protects the sample area before the test. This ensures the initial mass measurement is stable and the operator has additional time for system checks before starting the test. This added time is very important for easily-ignitable samples, which often ignite prematurely if a shutter mechanism is not used.
- Specimen Holders - for specimens 100mm x 100mm up to 50mm thick, in the horizontal and vertical orientation.
- Load Cell - mass measurements are conducted via a strain gauge load cell with an accuracy of 0.01g. Fitted with a quick electronic tare facility and mechanical stops to avoid movement damage, give stable results and long life.
- Spark Ignition - by 10 kV spark generator fitted with a safety cut-out device. The igniter is automatically positioned by a lever linked with the shutter mechanism.
- Exhaust System - manufactured from stainless steel for long life. This comprises: hood, gas sampling ring probe, exhaust fan (with adjustable flow controls from 0-50g/s, at a resolution of at least 0.1g/s) and an orifice plate flow measurement (thermocouple and differential pressure transducer). Normal operation is at a nominal 24 l/s.
- Gas Sampling - comprising particulate filters, refrigerated cold trap, pump, drying columns and flow control.
- Oxygen Analysis - paramagnetic oxygen analyser, which has a range of 0-25% and a performance compliant with the standards.
- Smoke Obscuration - measured with a laser system, using photodiodes, and a 0.5 mW Helium Neon laser, with main and reference (compensating) photo detectors. Supplied with alignment cradle and 0.3, 0.8 neutral density filters for calibration.
- Heat Flux Meter - for setting the irradiance level at the surface of the specimens.
- Calibration Burner - to calibrate the rate of heat release measured by the apparatus using methane of 99.5% purity.
- Data Acquisition – Agilent Data Acquisition / Switch Unit featuring a 3-slot cardcage with $6\frac{1}{2}$ digit (22 bit) internal DMM enabling up to 120 single-ended or 48 double-ended measurements. Scan rates up to 250 channels/s are available with a 115kbaud RS232 and PCI GPIB interface as standard. All readings are automatically time stamped and can be stored in a non-volatile 50,000-reading memory.

- FTT ConeCalc Software – it is available in multi-languages including English, French, German, Spanish and Japanese. The user interface is a Microsoft Windows based system with "user friendly" push button actions and standard Windows data entry fields, drop down selectors, check boxes and switches capable of:-
  - Showing the status of the instrument
  - Calibrating the instrument and storage of calibration results
  - Collecting data generated during a test
  - Calculating the required parameters
  - Presenting the results in a manner approved by the Standards
  - Averaging of multiple tests
  - Exporting data to CSV (comma separated variable) files for quick transfer to spreadsheets.

Options

- Carbon Dioxide and Carbon Monoxide - NDIR gas analysers.
- Protection Screens - to protect the operator from smoke generated by hazardous samples, allow natural test area ventilation and providing a draught free environment for the sample.
- Controlled Atmosphere Attachment - for testing specimens in low oxygen atmospheres (0-21%) that may be found in well developed fires, or for studying the effects of gaseous suppressants or other dynamic controlled atmosphere environments. The cone assembly is located on top of the enclosure with exhaust gas exiting only through the cone. The cabinet replaces the conventional cone assembly but uses the same controllers as the normal cone operation. There is a door on the front of the assembly with a viewing window. Changing between the standard fire model and this unit is very simple and takes approximately 10 minutes. The Cone Calorimeter is fitted with a gas mixing attachment to mix air and nitrogen which can be supplied at flows between 0 - 200 l/min to the chamber. The gas supply lines are fitted with flow meters and flowstat flow controllers and a mixing chamber. These are external to the enclosure chamber and housed on the main Cone Calorimeter chassis.

- FTIR – The FTT FTIR is an advanced gas analyser used for continuous measurement of combustion gases in conjunction with FTT's Cone Calorimeter or Smoke Density Chamber. The analysis of gases in fire effluents is very complex and challenging due to the great number of different organic and inorganic chemicals which these atmospheres can contain. FTT's FTIR is fully configurable to meet the requirements of several international standards including ISO 19702, ISO 9705 and CEN TS 45545-2. It is capable for individual analysis of airborne concentrations of CO, CO_2, NO, NO_2, SO_2, HCl, HF, Phenol, Acrolein, water vapour, etc. The FTT FTIR is a modular construction comprising of FTIR gas analyser, heated sampling unit and an industrial PC which are mounted in a 19" rack.
- Cone Corrosimeter – Built in accordance with ASTM D 5485 and used for assessing the corrosive potential of combustion products.

Mass Loss Calorimeter

For those with a major interest in ignitability, mass loss work or those working to a limited budget FTT offers the Mass Loss Calorimeter which is the complete fire model from the Cone Calorimeter. Use of this instrument under a suitable hood enables the user to carry out thermal exposure studies, under the same precise exposure conditions as those used in the Cone Calorimeter, whilst visibly observing the specimen reaction and measuring the mass change. A flue containing a thermopile can also be added to the unit. Once calibrated using a methane burner the thermopile output can be used to quantify heat release. This is now the subject of a new International Standard ISO 13927 which was developed by the ISO TC 61 (plastics) committee.

The FTT Mass Loss Calorimeter can be enhanced to be a full or partial Cone Calorimeter at any time by addition of Cone Calorimeter components. The chassis, ductwork and fans, the smoke analysis instrumentation, mass flow measurement and oxygen depletion equipment can all be added later.

Dual Cone Calorimeter

All modern heat release measurements use oxygen depletion calorimetry. The analysis and instrumentation used for quantitative oxygen, carbon monoxide and carbon dioxide measurements in both large- and small-scale calorimetry have the same specification. Thus a single set of instrumentation can be used for other tests. FTT's Dual Cone Calorimeter houses the common gas analysis instrumentation, higher capacity pumps and gas handling filtration required for Large Scale Calorimeters (e.g. ISO 9705, Furniture Calorimeters, Cable Propagation Rigs, SBI Apparatus) in a separate rack from the main Cone Calorimeter housing. The instrumentation can then conveniently be used both for Cone and Large Scale Calorimeters.

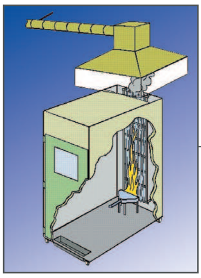
When used with the Cone Calorimeter, the analysis rack is elegantly located with the Cone Calorimeter unit. When instrumentation is required for the Large Scale Calorimeter this section is quickly de-coupled from the Cone frame and transferred, on the factory-fitted castors, to the new location for equally quick connection to power and sampling lines of the larger calorimeter.

The FTT Dual Cone Calorimeter has all the advantages of the conventional single purpose Cone Calorimeter and similarly meets all National and International Standards including:

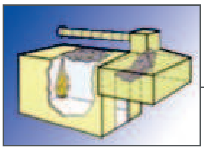
- ISO 5660-1 Rate of heat release from building products (Cone Calorimeter method).
- ISO 5660-2 Smoke production rate (dynamic measurement).
- ASTM E 1354 Heat and visible smoke release for materials and products using oxygen consumption calorimeter.
- ASTM E 1474 Determination of the heat release rate of upholstered furniture and mattress components or composites using a bench scale oxygen consumption calorimeter.

Flexibility with FTT Calorimeters

FTT calorimeters are designed to have interchangeable modules that give our clients maximum operational or upgrade flexibility. A variety of analysers can be housed within our systems and the major components themselves can also have multi-use. The small entry level Mass Loss Calorimeters (ISO 13927 and ISO 17554) can be used as a spare calorimeter furnace model, extended to measure smoke in accordance with ISO 5660-2 or developed further to become a full Cone Calorimeter. The analysis systems of the Dual Cone Calorimeter can be transported to large calorimeters within minutes. Almost all ducted rigs like the IEC 60332-3 can be readily converted to large calorimeters by use of the rack from a Dual Cone Calorimeter and a duct insert which FTT provide. The latter houses all necessary gas sampling, temperature and mass flow probes.



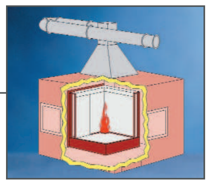
IEC 60332-3 cable testing rig
Readily converted to enable heat release from cable tray tests to be measured.



ISO 9705 Room Corner test
Used extensively to measure the heat release from wall lining materials.

Furniture calorimeter
Used to measure heat release and mass loss from furniture.

Duct Insert
Fitted into exhaust ducts of dynamic test methods. This houses gas temperature and mass flow probes and smoke measuring hardware.



EN 13823
The SBI test method used extensively in Europe to test construction products.

Principle of measurement

This technique is based on the empirical observation that heat released by burning materials is directly proportional to the quantity of oxygen used in the combustion process. Most fuels were found to generate 13.1×10^3 kJ/kg of oxygen consumed. Measurement of the precise concentrations of oxygen in the exhaust duct and the volumetric flow of air gives the rate of oxygen consumption from which the heat release rates can be calculated. In the Cone Calorimeter the rate of heat released is given by:

$$\dot{q} = (13.1 \times 10^3)\ 1.10C \sqrt{\frac{\Delta P}{T_e}}\ \frac{(0.2095 - Xo_2)}{(1.105 - 1.5\ Xo_2)}$$

Where $\dot{q}$ = Rate of heat release (kW)

C = Orifice plate coefficient ($kg^{1/2} \cdot m^{1/2} \cdot K^{1/2}$)

ΔP = Pressure drop across the orifice plate (Pa)

T_e = Gas temperature at the orifice plate (K)

Xo_2 = Measured mole fraction of O_2 in the exhaust air (no units)

Modelling with Calorimeter data

Early work carried out in the USA and Sweden showed how successful the Cone Calorimeter was in generating good input data for models.

After the EUREFIC project demonstrated excellent prediction of Room Corner (ISO 9705) performance for wall lining materials from Cone Calorimeter data the European Commission funded several large multi-lab research projects to develop models for prediction of the performance of finished construction products from small scale calorimeter tests. These include the CBUF (Combustion Behaviour of Upholstered Furniture) project for furniture, the FIPEC (Fire Performance of Electric Cables) project for electric cables and the FIRESTAR project for railway rolling-stock.

FTT now supplies Cone Calorimeters that enable materials and products to be tested both in accordance with product standards and with novel developments for advanced research studies. We also produce a range of larger calorimeters that enable products of all sizes to be tested full scale. FTT researchers continue to cooperate with the worlds leading research teams who are using bench scale calorimetry and flame-spread data to predict fire development rates.

FTT's contribution to the development of calorimetery

In the mid 1980's FTT directors worked with Dr. Vytenis Babrauskas (who invented the Cone Calorimeter) and other colleagues to help develop international test standards based upon it. They also designed European prototypes and Stanton Redcroft's commercial Cone Calorimeter. Since 1989 FTT has been the worlds leading manufacturer of full scale calorimeters (e.g. Furniture Calorimeter and the ISO 9705 Room Corner test). The introduction of the FTT Cone Calorimeter in 1993 offered a new generation commercial instrument to the market at approximately half the price of the then current commercial systems. This brought calorimetry into the budgetary reach of most laboratories and FTT subsequently supplied the major sector of this market. FTT later launched the new Cone 2000 and the Dual Cone 2000. Throughout this period FTT scientists and engineers led several calorimetry research projects and contributed extensively to International, European, ASTM and British Standardisation groups.

The FTT group have supplied more than 300 Cone Calorimeters to customers in more than 40 countries. Our specialist calorimetry design engineers ensure our products integrate new developments, our production engineers are the world's most experienced cone builders and our team of specialist service engineers ensure that FTT calorimeters are promptly maintained on all 5 continents.

Applications

Most leading fire research groups now use cone calorimeters both as a prime source of data on properties of materials and as a source of input data to models used for predicting the fire behaviour of finished products. International standards have been published describing the equipment and several national standardisation bodies have now published product standards for use of the Cone Calorimeter in assessing performances of finished products.

- Furniture (ASTM E 1474)
- Wall lining materials (ASTM E 1740)
- Prison mattresses (ASTM F 1550)
- Electric Cables (ASTM D 6113)
- Railway rolling-stock applications (BS 6853)
- Maritime applications (IMO)

Technical Specification

TRUNCATED CONICAL HEATER	
Element	5kW electrical heating element
Heat flux	Up to 100kW/m^2
Heat Shield	Placed between the cone heater and specimen

SPECIMEN HOLDER AND WEIGHING DEVICE	
Specimen holder	A square pan 106mm x 106mm at the top, and a height of 25mm, constructed from stainless steel
Retainer edge frame	A stainless steel frame with inside dimension 111mm x 111mm, and opening of 94mm x 94mm.
Sample size	100mm x 100mm
Sample thickness	Up to 50mm
Balance sensitivity	0.01g
Load capacity	Up to 5.0kg

EXHAUST GAS SYSTEM WITH FLOW MEASURING INSTRUMENTATION	
Duct diameter	114mm
Nominal exhaust flow rate	24 l/s
Orifice plate	Internal diameter 57mm located in chimney to measure duct flow
Sampling ring	685mm from the hood, contains 12 small holes with a diameter of 2.2mm
Gas sampling apparatus	Incorporates a pump, soot filter, cold trap, moisture and CO_2 removal traps when CO_2 analyser is not fitted
Cold trap	Operate at 0 – 4°C

IGNITION CIRCUIT	
Spark igniter	Spark gap of 3.0mm located 13mm above the centre of the specimen

CALIBRATION BURNER	
Construction	A tube with a 500mm^2 square orifice covered with wire gauze

INSTRUMENTATION FOR OXYGEN AND GAS ANALYSIS	
Oxygen analyser	Paramagnetic type with a range of 0-25% Oxygen
Carbon dioxide (optional)	Non-dispersive infrared type with a range of 0-10%
Carbon monoxide (optional)	Non-dispersive infrared with a range of 0-1%

SMOKE DENSITY MEASUREMENT	
Light source	0.5mW Helium-Neon laser beam
Detector	Silicon photodiode

DATA COLLECTION AND ANALYSIS SYSTEM	
Resolution	Up to 22 bits
Recording time	Up to 250 channels per second
Storage	Raw data recorded for each test is stored and can be retrieved

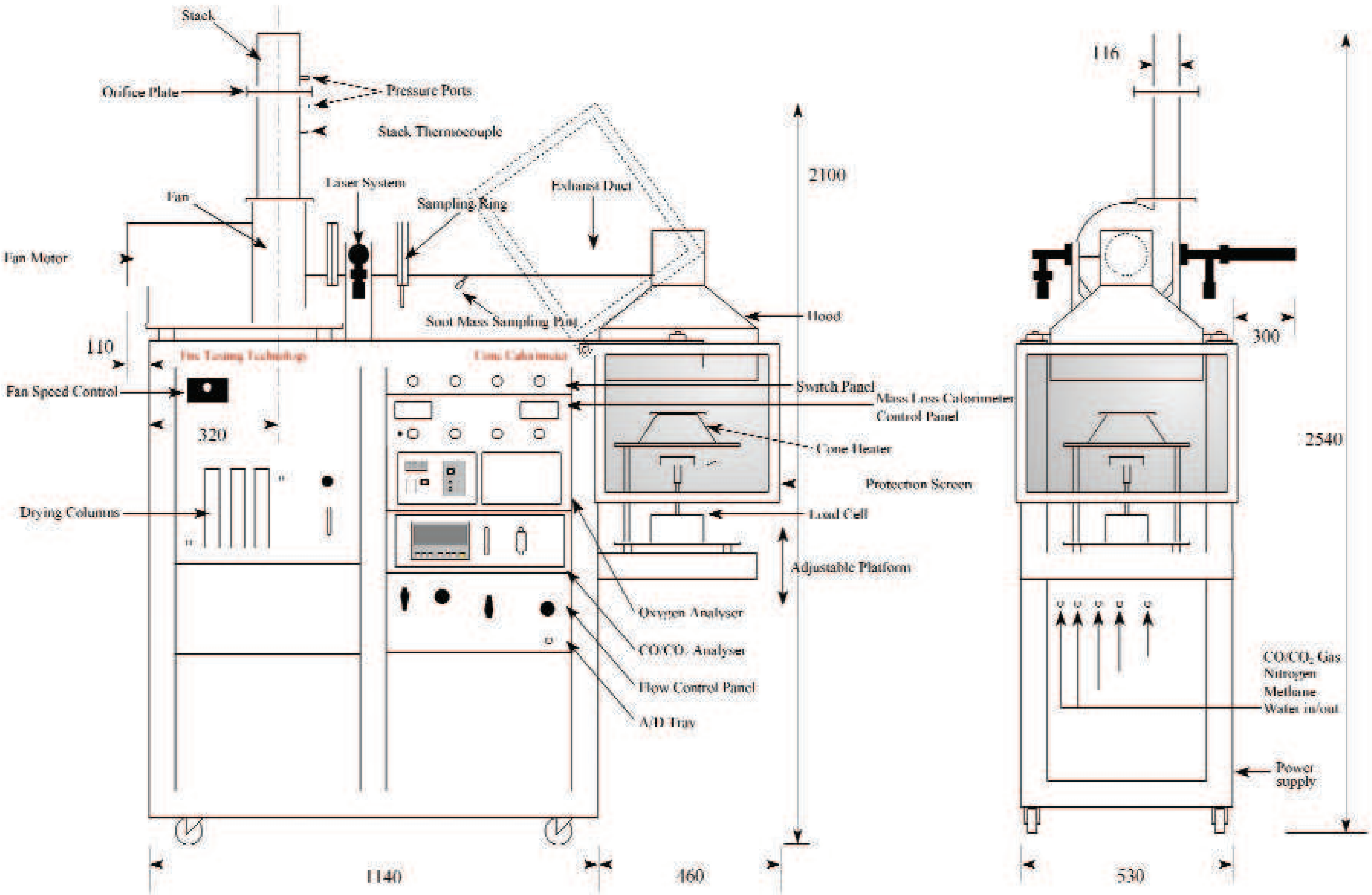
Due to the continuous development policy of FTT technical changes could be made without prior notice.

SERVICE REQUIREMENTS	
Electric	230VAC, 30A, 50/60 Hz. Single Phase
Water	250 kPa (35 psi)
Exhaust Extraction	250-500 l/s
Standard Gases	Oxygen-free Nitrogen, Methane (UHP99.5%)
Optional	CO 0.85%, CO_2 8.5%

Schematic Diagram

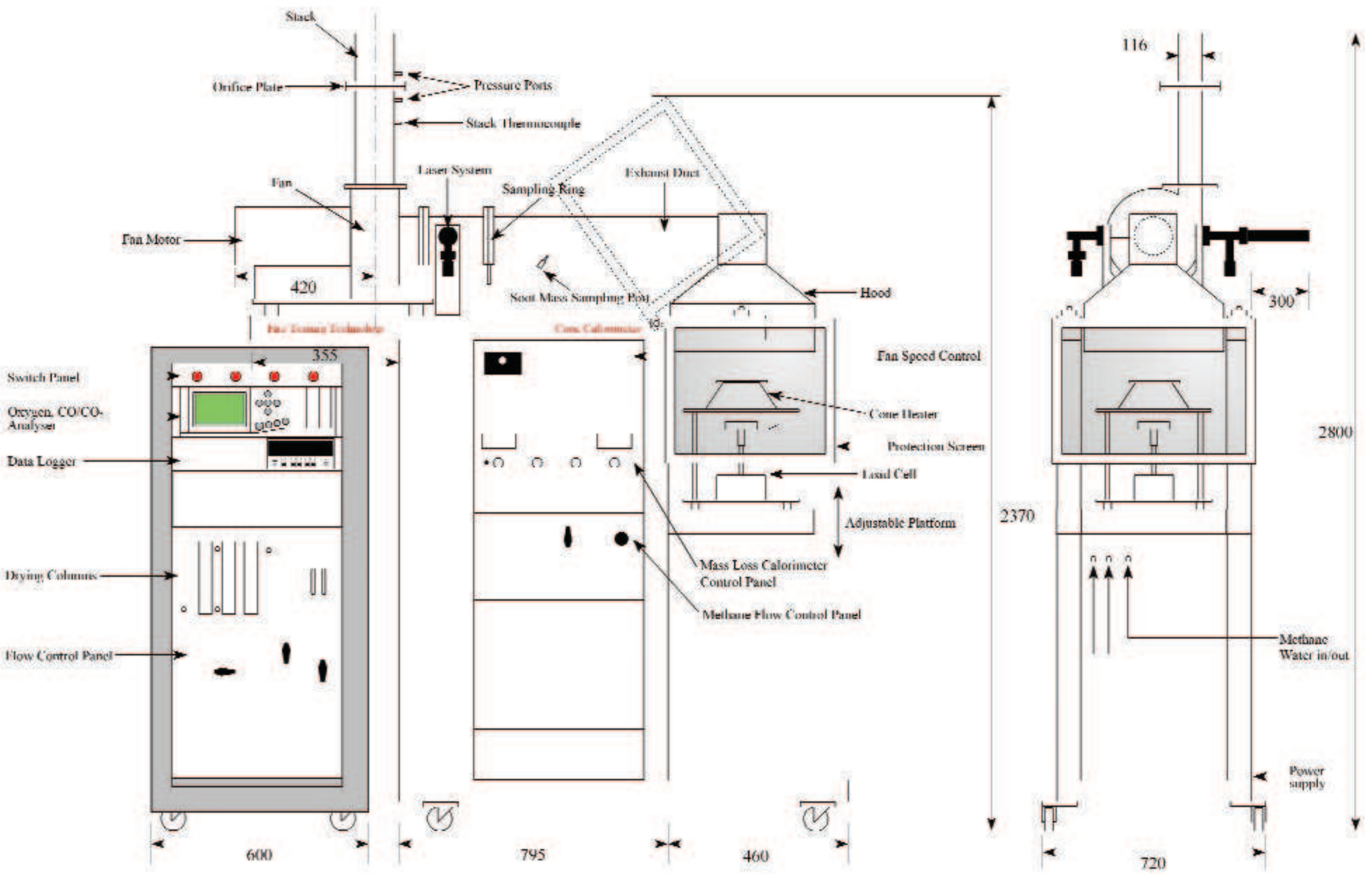
Standard Cone Calorimeter

Not to Scale – Dimensions in mm



Dual Analysis Cone Calorimeter

Not to Scale – Dimensions in mm



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