*i*Cone *mini* and *i*Cone *classic*

(ISO 5660; ASTM E1354)

firetesting technology

The *i*-series of Cone Calorimeters

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A Judges Scientific plc company

Following a successful launch of the *i*Cone Calorimeter in 2013, the release of two new models called the *i*Cone *mini* and *i*Cone *classic*, marks the beginning of a second generation of the *i*Cone series, offering semi-automated control and a further enhanced fire model.

The *i*Cone series is now completed by two semi-automatic models – the *i*Cone *mini* which features a separate gas analysis rack and the *i*Cone *classic* which has a fixed gas analysis console mounted on the instrument main frame. These have replaced the **FTT** Dual Cone and Standard Cone respectively. The *i*Cone has undergone further modification on its fire model and glass protective screen and is now called *i*Cone *plus*.

The *i*Cone series brings calorimetry to a new level of automation and make it available at different budget levels.

Cone Calorimeter

The name "Cone Calorimeter" was derived from the shape of the truncated conical heater that Dr. Vytenis Babrauskas used to irradiate the test specimen (100mm × 100mm) at fluxes up to 75-100kW/m^2 in the bench-scale oxygen consumption calorimeter that he and his co-workers developed at NIST. The Cone Calorimeter is now the most significant bench-scale instrument used in the field of fire testing because it measures important real properties of the material being tested under a variety of preset fire conditions. These measurements can either be used directly by researchers, or they can be used as input data for correlation or mathematical models for predicting fire development.

Directly measured properties include:

- Heat release rate
- Time to ignition
- Mass loss rate
- Smoke release rate
- Effective heat of combustion
- Rates of release of combustion gas (e.g. carbon oxides)

Oxygen Consumption Principle and Heat Release Rate

The heat release rate is the single most important parameter that can be used to characterise fire. It provides a measurement of the size of the fire, and the rate of fire growth, and allows calculation of the time available for escape or suppression. Most fire parameters are directly proportional to the size of the fire so by knowing the heat release we also have a good indicator of the level of smoke and other combustion products being generated.

Huggett and Parker examined in detail Thornton's assumption that constant quantity of heat was released per unit of oxygen consumed using a variety of fuels,

*i*Cone *classic*

- Semi-automatic
- Fixed gas analysis console

and assessed its effect on the accuracy of heat release measurement based on it. He concluded:

1. The heat release rate in a fire can be estimated with good accuracy from two simple measurements, the flow of air through an exhaust and the concentration of oxygen in the exhaust.
2. The heat release from a fire involving conventional organic fuels is 13.1kJ per gram of oxygen consumed, with an accuracy of ± 5% or better.
3. Incomplete combustion and variation in fuel have only a minor effect on this result. Appropriate corrections can be made if necessary.
4. The oxygen consumption technique for heat release measurement is adaptable to a wide range of applications ranging from small-scale laboratory experiments to very large-scale fire system tests. A number of heat release apparatuses have been developed since and based on these findings. The most important of these is the 'Cone Calorimeter'.

Oxygen Consumption Calorimetry

$$\dot{q} = (13.1 \times 10^3)\ 1.10C \sqrt{\frac{\Delta P}{T_e}}\ \frac{(X^{\circ}_{O_2} - X_{O_2})}{(1.105 - 1.5\, X_{O_2})}$$

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)
X_{O_2} = Measure mole fraction of O_2 in the exhaust air (no units)
$X^{\circ}_{O_2}$ = Initial mole fraction of O_2 in the exhaust air (no units)

*i*Cone *mini*

- Semi-automatic
- Mobile gas analysis rack

*i*Cone *plus*

- Fully automatic
- Computer controlled
- Mobile gas analysis rack

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 test (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, and FIPEC (Fire Performance of Electric Cables) for electric cables.

FTT's Contribution to the Development of Calorimetry

In the mid 1980s **FTT** directors worked with Babrauskas and other colleagues to help develop international test standards based upon oxygen consumption calorimetry.

They also designed European prototypes and Stanton Redcroft's commercial Cone Calorimeter. **FTT** has been the world's leading manufacturer of all calorimeters, including full scale calorimeters (e.g. Furniture Calorimeter, the ISO 9705 Room Corner test and the SBI) since 1989. Throughout this period **FTT** scientists and engineers have worked on several calorimetry research projects and contributed extensively to International, European, ASTM and British Standardisation groups.

International standards have been published describing the equipment and several national standardisation bodies have also published product standards for use of the Cone Calorimeter in assessing performances of finished products as listed below:

- Furniture (ASTM E1474)
- Wall lining materials (ASTM E1740)
- Prison mattresses (ASTM F1550)
- Electric cables (ASTM D6113)
- Railway rolling stock applications (EN 45545-2)
- Maritime applications (IMO)

FTT has supplied more than 400 Cone Calorimeters to customers in more than 40 countries for both research studies and testing in accordance with fire safety standards. **FTT**'s specialist calorimetry design engineers ensure their products integrate new developments **FTT**'s production engineers are the world's most experienced Cone Calorimeter builders and its team of specialist service engineers ensure that **FTT** calorimeters are promptly maintained on all 5 continents.

*i*Cone Calorimeter Series

FTT provides customers with automated instruments that utilise state-of-the-art technology to improve the efficiency and accuracy of the fire test process. The **FTT** *i*Cone Calorimeters have been developed as an industry-leading third generation of Cone Calorimeter.

They feature an interactive and intuitive interface, sophisticated and flexible control options, and builtin data acquisition technology for robust data collection, analysis and reporting. They incorporate many new features not previously seen by fire testing laboratories while being compact, accurate, reliable and easily maintained.

FTT's *i*Cone *plus* is the only fully automatic Cone Calorimeter in the world and the most advanced model in our new range of Cone Calorimeters designed using decades of **FTT**'s experience in calorimetry. The other two models in the *i*Cone range are the *i*Cone *mini* and *i*Cone *classic* which have replaced the **FTT** Dual Cone and **FTT** Standard Cone respectively. These three *i*Cone models differ in the level of automation, requirements to meet the various needs for fire science research and testing laboratories.

For applications and tests where users would like to be more involved in the operation and running of the tests, and/or for smaller budget, *i*Cone *mini* and *i*Cone *classic* are the best solutions.

A full system of the *i*Cone *mini* and *i*Cone *classic* consist of:

Conical Heater

- 5kW electrical heating element wound in the form of a truncated cone, rated 5000W at 230V with a heat output up to 75-100kW/m^2
- Motorised specimen height adjustment during test to accommodate materials that intumesce or shrink
- Facility for testing horizontally or vertically orientated specimens

Temperature Controller

- Temperature of the conical heater is controlled using 3 type-K thermocouples and a 3-term (PID) temperature controller
- Testing at varying heat fluxes to a present heat flux profile (of up to 10 steps or changes between 10kW/m^2 up to 75-100kW/m^2), can be set using the ConeCalc software

Motorised Heat Shield

- Automatic/Manual controlled split shutter mechanism to protect specimen from heat exposure before test
- Ensures the initial mass measurement is stable and the operator has ample of time for system checks before starting the test. This facility is essential for easily-ignitable samples, which often ignite prematurely if a shutter mechanism is not used

Specimen Holders

- Made of stainless steel
- For specimens 100mm × 100mm up to 50mm thick

Base view of the conical heater

- Different specimen holders supplied for horizontal and vertical orientation testing

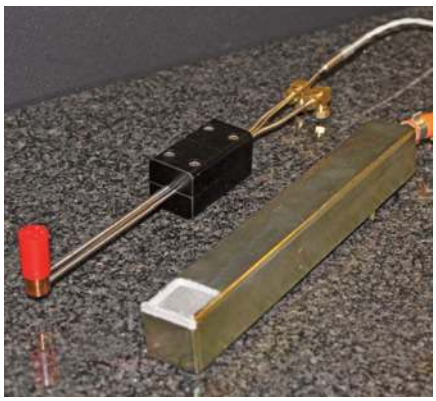
Specimen Spacers

- A set of 6 different specimen spacers are provided for easy and precise adjustment

Load Cell

- Mass measurements are taken using a strain gauge load cell with a sensitivity better than 0.01g
- Mounted on an independent table to avoid any vibration from exhaust fan

Specimen spacers



Heat flux meter and calibration burner

Spark Ignition

- 10kV spark generator fitted with a safety cutout device
- Positioning and control of spark igniter to ignite the combustion gases from the specimen

Glass Protective Screen

- Made of heat resistant glass
- Provides a draft-free environment around the fire model
- Three sides of the screen are hinged for easy access to the fire model

Exhaust System

- Manufactured from stainless steel for long life
- Comprising stainless steel hood and ducts, gas sampling ring probe, exhaust fan (with adjustable flow controls) and an orifice plate flow measurement thermocouple and differential pressure transducer)
- Normal operation is at a nominal 24L ℓ/s (range 0-50 ℓ/s)

Gas Sampling

- Comprising of soot filters, pump, moisture removal traps (CO_2 removal traps if not measured)

Combustion Gas Analysis

- Paramagnetic oxygen analyser with a range of 0-25% O_2 and a performance compliant with the standards
- Non-dispersive infrared detectors with a range of 0-10% CO_2 and 0-1% CO (option)
- Developed specifically for **FTT** calorimeters. This analyser features low drift, low noise and fast response

Smoke Obscuration

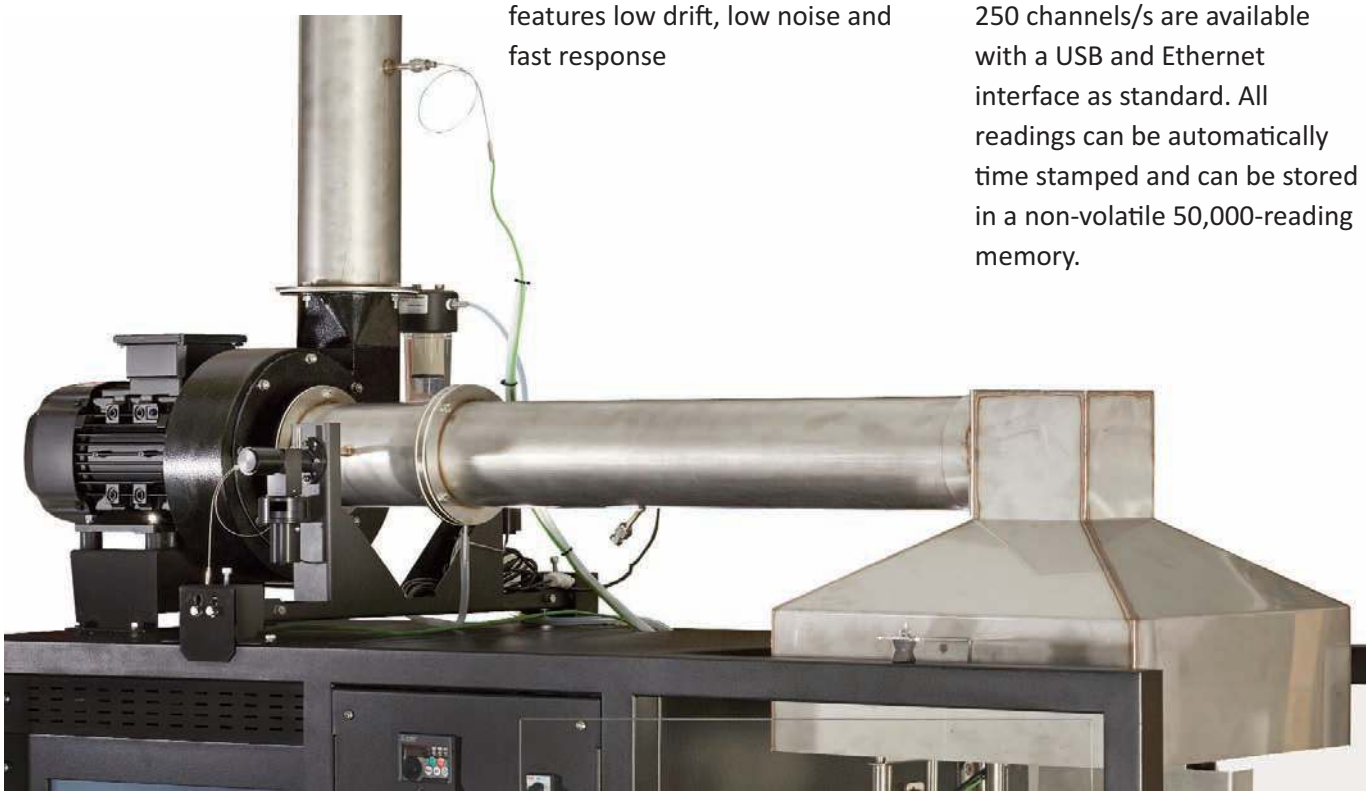
- Measured with a laser system, using Silicon photodiodes, and a 0.5mW Helium-Neon laser, with main and reference (compensating) photo detectors
- Supplied with alignment cradle and 0.3, 0.8 neutral density filters for calibration Heat Flux Meter
- For setting the irradiance level at the surface of the specimens
- The heat flux is automatically set using the ConeCalc software, heat flux meter and temperature controller

Calibration Burner

- For calibrating the heat release rate measured by the apparatus using methane of 99.5% purity.

Data Acquisition

- Data Acquisition/Switch Unit featuring a 3-slot cardcage with up to 6½ 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 USB and Ethernet interface as standard. All readings can be automatically time stamped and can be stored in a non-volatile 50,000-reading memory.



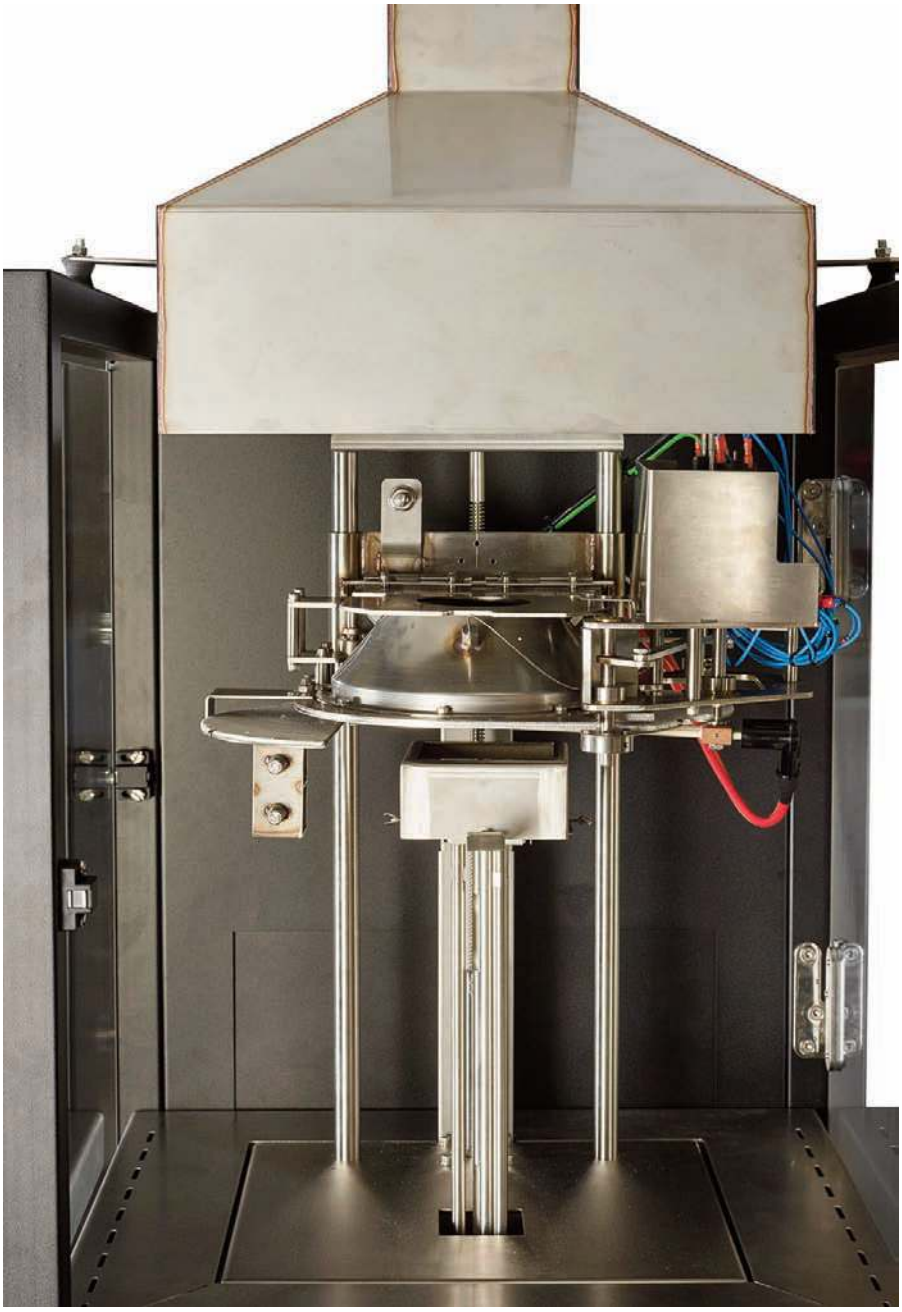
Exhaust, sampling and smoke measurement system

ConeCalc Software

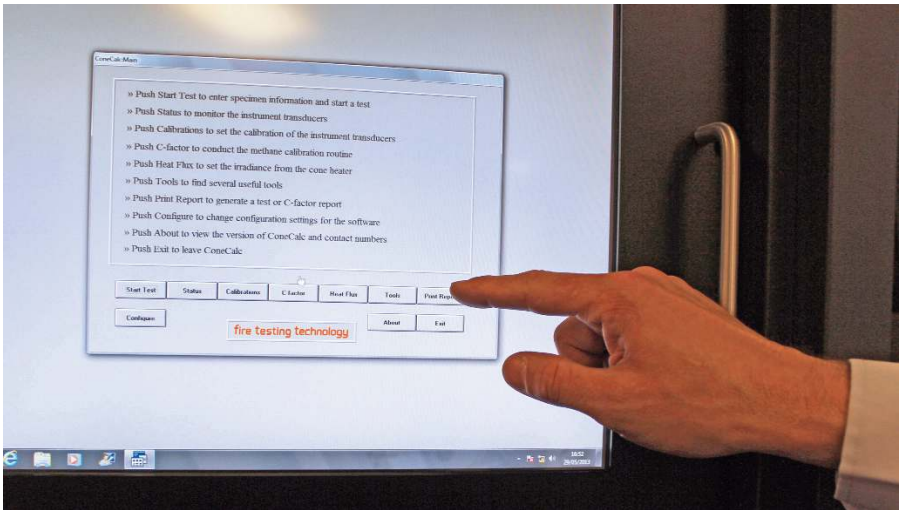
- User-friendly Windows based ConeCalc user interface with push-button actions and data entry fields and capable of:
  - Instrument control and showing status of the instrument
  - Calibration of gas analysis instrumentation and storage of calibration results
  - C-factor calibration with the use of mass flow controller
  - C-factor calibration via pool fire (ethanol) routine
  - Collecting data generated during a test
  - Calculating the required parameters
  - Averaging of multiple tests
  - Presenting the results in a manner in accordance with ISO 5660-1 and ASTM E1354
  - Exporting calculated data to CSV (comma separated variable) files for quick transfer to spreadsheets

Test Parameters

- Heat flux (kW/m^2)
- Flow rate in exhaust duct (l/s)
- C-factor ($m^{1/2} \cdot kg^{1/2} \cdot K^{1/2}$)
- Ignition time and extinction time (s)
- Heat release rate (kW/m^2)
- Smoke production rate (m^2/s)
- Mass loss, Mass loss rate (g, g/s)
- Effective heat of combustion (MJ/kg)
- Specific extinction area (m^2/kg)
- CO_2 yield (kg/kg)
- CO yield (kg/kg)
- Total heat release (MJ/m^2)
- MARHE (kW/m^2) [Maximum average rate of heat evolved]
- Total oxygen consumption (g)



Fire model and specimen inside glass protective screen



17" touchscreen PC and ConeCalc software

Unique Features of FTT's *i*Cone *mini* and *i*Cone *classic* Calorimeters

- Remote cone assembly positioning control, so that heater-specimen surface separation can be adjusted pre- and mid-test, to facilitate testing of intumescing or thermally distorting specimens
- Programmable heat flux exposure. Up to 10 consecutive heat flux ramping or holding can be programmed
- Motorised heat shield to protect specimen from heat exposure before test
- Motorised positioning and control of spark igniter to ignite the combustion gases from the specimen
- Hinged heat resistant glass protective screen which provides a draft-free environment around the fire model with clear viewing and easy access
- Semi-automatic/manual calibration by ConeCalc Software
- Load cell resolution of 0.01g and load capacity up to 8.2kg (Sartorius cell)
- Load cell mounted on an independent table to avoid any vibration from exhaust fan
- Fire model protection alarm system
- Online support and remote control of instruments from **FTT** for internet connected system
- Optional larger Cone fire model for testing specimens with very low heat release rates. 150mm × 150mm specimens are exposed to uniform heat flux over entire surface
- Optional fully integrated FTIR gas analysis system supplied with heated sampling module, heated lines/probes and PLC controller

Flexibility with FTT Calorimeters

All modern heat release measurements use oxygen consumption calorimetry. The analysis and instrumentation used for quantitative oxygen, carbon monoxide and carbon dioxide measurements in both large and small calorimetry have similar specifications. Thus a single set of instrumentation can be used for many test apparatus.

The *i*Cone *mini* Gas Analysis Rack can be used both for *i*Cone and Large Scale Calorimeters which require higher capacity pumps and gas handling filtration [e.g. ISO 9705 Room Corner test, Furniture Calorimeters, Cable Fire Testing Rigs (EN 50399), SBI Apparatus (EN 13823)].

When used with the Cone Calorimeter, the gas analysis rack is completely housed within the *i*Cone *mini* unit.

When required for the Large Scale Calorimeter this analysis rack is quickly decoupled from the *i*Cone main frame and transferred, on the factory-fitted castors, to the new location for equally quick connection to power, signal and sampling lines of the larger calorimeter.

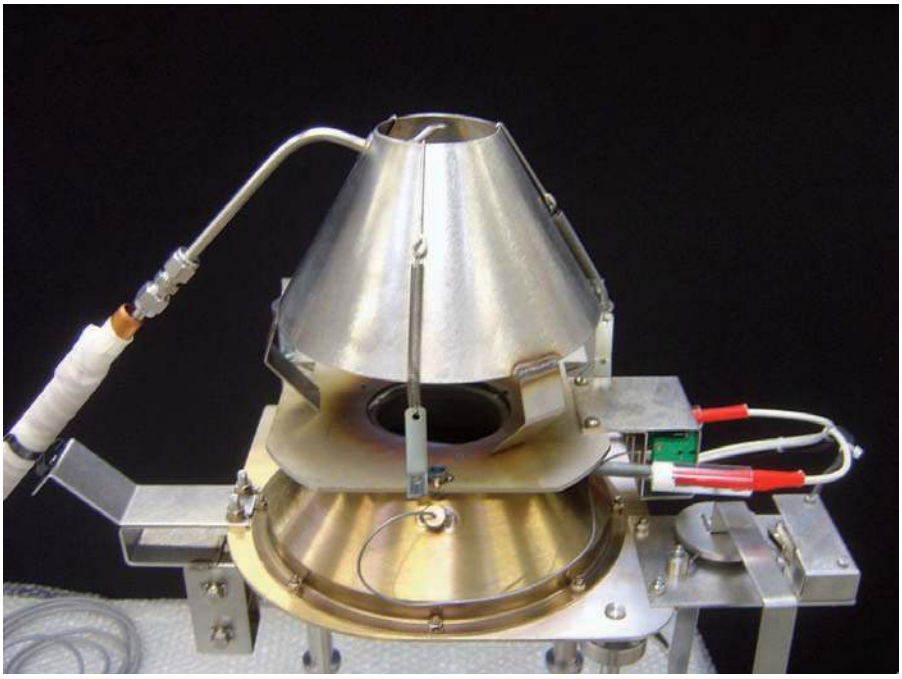
FTT calorimeters are designed to have interchangeable modules that give the user maximum operational or upgrade flexibility. Almost all ducted rigs like the IEC 60332-3 can be readily converted to large calorimeters by use of the analysis rack from the *i*Cone and an instrumented duct insert which FTT provides. The latter houses all necessary gas sampling, temperature and duct flow rate probes.

*i*Cone *mini* **Gas Analysis Rack**

Options

The flexibility and versatility of the *i*Cone Calorimeters are further enhanced by the availability of a range of components and test modules from FTT.

- Integrated 17" Touchscreen and 1u keyboard with touchpad and drawer
- Integrated Computer system
- Integrated Carbon Dioxide and Carbon Monoxide – NDIR gas analysers
- Sartorius Load Cell (increased range)
- Soot Mass Sampling
- Large Cone Fire Model (ISO/TS 5660-4, ASTM E2965) – for testing samples 150mm × 150mm and gives uniform heat flux over entire sample surface



Cone Corrosimeter

- 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 through the cone only. The cabinet replaces the conventional cone assembly but uses the same controllers as the normal cone. There is a door on the front of the assembly with a viewing window
- Changing between the standard fire model and this unit is simple. 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 in a mobile control unit
- FTIR – the **FTT** FTIR is an advanced gas analyser used for continuous measurement of combustion gases in conjunction with **FTT**'s Cone Calorimeter, Smoke Density Chamber or SBI. 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 EN 455452. It is capable for individual analysis of airborne concentrations of CO, CO_2, NO, NO_2, SO , HCl, HF, Phenol, Acrolein, water vapour, etc. The **FTT** FTIR is a modular construction comprising of FTIR gas analyser, heated sampling unit and a touchscreen PC which are mounted in a 19" rack
- Cone Corrosimeter – built in accordance with ASTM D5485 and used for assessing the corrosive potential of combustion products

Controlled Atmosphere Attachment

Large Cone Fire Model and Control Unit

FTIR Combustion Gas Analysis System

TECHNICAL SPECIFICATIONS	
Truncated Conical Heater and Fire Model	
	*i*Cone *mini* and *i*Cone *classic*
Element	5kW electrical heating element
Heater	Heat flux up to 75-100kW/m^2 Heat flux can be gradually increased during test in 10 predetermined steps, e.g. ten 10kW/m^2 increases up to 75-100kW/m^2 Motorised height adjustment and control on front panel during test for materials that intumesce
Heat shield	Motor driven via push button on front panel to protect specimen from heat exposure before test
Spark igniter	Spark gap of 3.0mm located 13mm above the centre of the specimen Motor driven via push button on front panel to ignite the combustion gases from the specimen
Heat resistant glass protective screen	Provides a draft-free environment around the fire model Manual operation, hinged on 3 sides
Work area	Stainless steel top, 560mm × 530mm
Event buttons (Start Test, Ignition, Event, Flame Out)	On front panel and keyboard
Large cone fire model (Optional)	For testing samples 150mm × 150mm Uniform heat flux over entire surface

Specimen Holder, Weighing Device & Specimen Handling	
	*i*Cone *mini* and *i*Cone *classic*
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	a pump, soot filter, moisture and CO_2 removal traps, mass flow controller (for low drift) controlled via software
Extraction hood	400mm × 400mm Standard hood size Polished stainless steel option available
Soot mass sampling (optional)	Operated by mass flow controller

Heat flux meter	
	*i*Cone *mini* and *i*Cone *classic*
Water cooled	Yes

Calibration Burner	
	*i*Cone *mini* and *i*Cone *classic*
Construction	A tube with a 500mm^2 square orifice covered with wire gauze
Methane flow	Adjust with valve on front panel or set via software (option) Measured with mass flow meter or controlled by mass flow controller (option) Displayed in software

Instrumentation for Oxygen and Gas Analysis		
	i*Cone *mini	***i*Cone *classic***
19" Gas analysis rack	Detachable to be used with other large scale calorimeters, e.g. SBI, Room Corner test, etc.	Integrated into instrument
Dimensions	600mm W × 600mm D × 1640mm H	n/a
Oxygen analyser	Paramagnetic type with a range of 0-25% Oxygen. t_{10}-t_{90} response time less than 12s. Drift typically less than 20ppm in 30 minutes. Specially designed by Servomex solely for **FTT**	
Carbon dioxide (optional)	Non-dispersive infrared type with a range of 0-10%. Fast response. Specially designed by Servomex solely for **FTT**	
Carbon monoxide (optional)	Non-dispersive infrared type with a range of 0-1%. Fast response. Specially designed by Servomex soley for **FTT**	
Control of flow rate into analyser	Pressure relief valve adjusted on front panel	
Measurement of flow into analyser	Flow meter on front panel	
Selection of gas into analyser	Valve on front panel	
Gas analyser calibration	Manual	
Sample pump on/off	Switch on front panel	
Sample drying column	1 column (drierite) for 2 cell analyser and 3 cell analyser 3 columns (drierite, ascarite) for 1 cell analyser	

Data Logger	
	i*Cone *mini* and *i*Cone *classic
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

Smoke Density Measurement	
	i*Cone *mini* and *i*Cone *classic
Light source	0.5mW Helium-Neon laser beam
Detector	Silicone photodiode

Dimensions and Mass		
	i*Cone *mini	***i*Cone *classic***
Overall dimensions	1600mm W × 600mm D × 1700mm H	1520mm W × 600mm D × 1700mm H
Net weight	480kg	480kg

TECHNICAL SPECIFICATIONS

17" PC (integrated in Gas Analysis Rack)

User-friendly Windows based ConeCalc 6 software user interface with push-button actions and data entry fields and capable of:

- Instrument control and showing status of the instrument.
- Software and hardware supports all major types of Cone Calorimeters.
- Configuration settings and transducer calibration details can be fully modified in the software.
- Easy to use calibration routines for gas analysers, mass flow meters, smoke system and load cell.
- Full access to all calibration details.
- C-factor calibration with the use of mass flow controller (option).
- C-factor calibration via pool fire (ethanol) routine.
- C-factors are recorded and can be viewed in the software.
- Ambient pressure compensation either through software or built into oxygen analyser.
- The signals from each transducer connected to the data logger system can be viewed in both engineering units and raw voltages.
- The cone heater temperature for each combination of heat flux, separation and orientation is stored.
- A temperature profile during the test, consisting of up to 10 steps, can be set.
- Optional pre-test calibrations automatically set oxygen reading to 20.95%, mass flow meters to zero and balances photodiodes on laser system.
- Full edit of data after test.
- All test information is stored in one file and all data is stored as recorded no corrections are made to the raw data.
- Report can be printed and previewed from within the ConeCalc application.
- Reports can include data from multiple tests. Several average scalar values are calculated and the data from each test run can be printed on each graph.
- Reports can be printed in colour.
- All reduction parameters can be edited and the data rereduced without affecting the original data.
- Full support for maximising the functionality of the CO/CO_2 analyser (so that the heat release rate can be calculated including the carbon oxide data).
- Data can be reduced using a number of different criteria.
- Includes drift and noise calculation routine for both the oxygen analyser and smoke system as described in the ISO 5660 standards.
- Presenting the results in a manner in accordance by ASTM E1354, ISO 5660-1 & 2 and EN 45545-2.

Test Parameters

- Heat flux (kW/m^2)
- Flow rate in exhaust duct (ℓ/s)
- C-factor ($m^{1/2} \cdot kg^{1/2} \cdot K^{1/2}$)
- Ignition time and extinction time (s)
- Heat release rate (kW/m^2)
- Smoke production rate (m^2/s)
- Mass loss, Mass loss rate (g, g/s)
- Effective heat of combustion (MJ/kg)
- Specific extinction area (m^2/kg)
- CO_2 yield (kg/kg)
- CO yield (kg/kg)
- Total heat release (MJ/m^2)
- MARHE (kW/m^2) [Maximum average rate of heat evolved]
- Total oxygen consumption (g)

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

SERVICE REQUIREMENTS

Electric	230VAC, 28A, 50/60 Hz. Single phase for the *i*Cone 230VAC, 8A, 50/60 Hz. Single phase for the gas analysis rack
Water	250kPa (35 psi)
Exhaust Extraction	250-500 ℓ/s
Standard Gases	Oxygen-free nitrogen, methane (UHP 99.5%)
Optional	CO 0.85%, CO_2 8.5%, balance nitrogen

Unrivalled Experience in Design and Manufacturing

FTT's site in East Grinstead, is home to the largest group of fire scientists and instrumentation design engineers working on fire testing instrumentation, and is at the heart of our design and manufacturing. For almost 30 years **FTT** has provided the highest quality instruments and service for fire testing and research professionals worldwide, directly and through its extensive global sales and support network.

Quality

- World-class manufacturing in accordance with multiple international and national standards, including: EN, ISO & ASTM
- ISO 14001, ISO 9001 certified

Integrity

- A dedicated team passionate about fire testing instrumentation and continuous product improvement
- Delivering reliable, robust and easy-to-use instruments for the past 30 years

Excellence

- A world-class team made up of qualified fire scientists, mechanical, electrical and electronic fire instrument design engineers and production, installation and maintenance engineers

Global

- World-wide distribution network for global sales, installations, training, maintenance and technical support
- Leading global supplier of the Cone Calorimeter, Large Scale Calorimeter, NBS Smoke Chamber and Oxygen Index