NETZSCH TAURUS INSTRUMENTS

Cone Calorimeter TCC 918

ISO 5660-1, ASTM E1354
Method and Instrumentation

Analyzing & Testing

Cone Calorimeter TCC 918

For Fire Testing and Fire Safety Engineering

The cone calorimeter is considered the most significant instrument in fire testing. This is because the net heat of combustion is proportional to the amount of oxygen required for combustion. The specimens are irradiated, ignited by sparks and thereby combusted. This apparatus analyzes the combustion gases and measures the smoke produced from a test specimen that is being exposed to a certain heat flux. The principle is known as the "oxygen consumption principle" and is among the methods of calorimetry. From the oxygen concentration, the released heat is calculated. In addition, precision can be improved by analyzing carbon monoxide and carbon dioxide concentrations.

The measurement also involves monitoring the flow rate in the exhaust pipe and the mass loss of the sample. Smoke obscuration is measured as the intensity of the laser light that is transmitted through the smoke in the flue pipe. The extinction coefficient is calculated in accordance with Bourguer's law*. The test results form the basis for determining smoke production and smoke production rate.

The TCC 918 is in accordance with all established standards including ISO 5660-1, ASTM E1354, ASTM E1474; ASTM E1740, ASTM F1550, etc.

* Bourguer's law: Attenuation of a light beam by an optically homogeneous (transparent) medium. Also called Beer's law, Bourguer-Lambert law or Lambert's law of absorption

Flammability Parameters Associated with the Specimen's Burning Properties for Predicting Real-Time Fire Behavior:

- Ignition time
- Mass-loss rate
- Combustion products
- Heat release rate
- Smoke production
- Effective heat of combustion
- Fire modelling
- Prediction of real-scale fire behavior
- Development of new products (pass/fail tests)

TCC tests serve as a data source for material properties and as a source for calculation models to predict the fire behavior.

Principle of Operation

The specimen (100 × 100 × 50 mm³) is positioned onto a sample holder that is placed in the load cell. The load cell monitors the sample mass during the measurement. Depending on the specimen, the sample holder can have open or closed edges.

Igniter and Cone Heater

A spark igniter is located between the specimen's surface and the cone heater. This ignites the flammable gases evolving from the specimen when it is heated. If the entire specimen area is burning, the igniter is turned off.

A conical radiant electrical heater uniformly irradiates the specimen from above. Once sufficient pyrolysis products are produced, an electric spark triggers combustion. The combustion gases produced pass through the heating cone and are collected by an exhaust duct system with a centrifugal fan and hood. In the exhaust duct, the gas flow is measured, as are O_2, CO, and CO_2 concentrations and smoke density. A laser photometric beam determines the amount of smoke produced.

Measurement of Gas Concentration

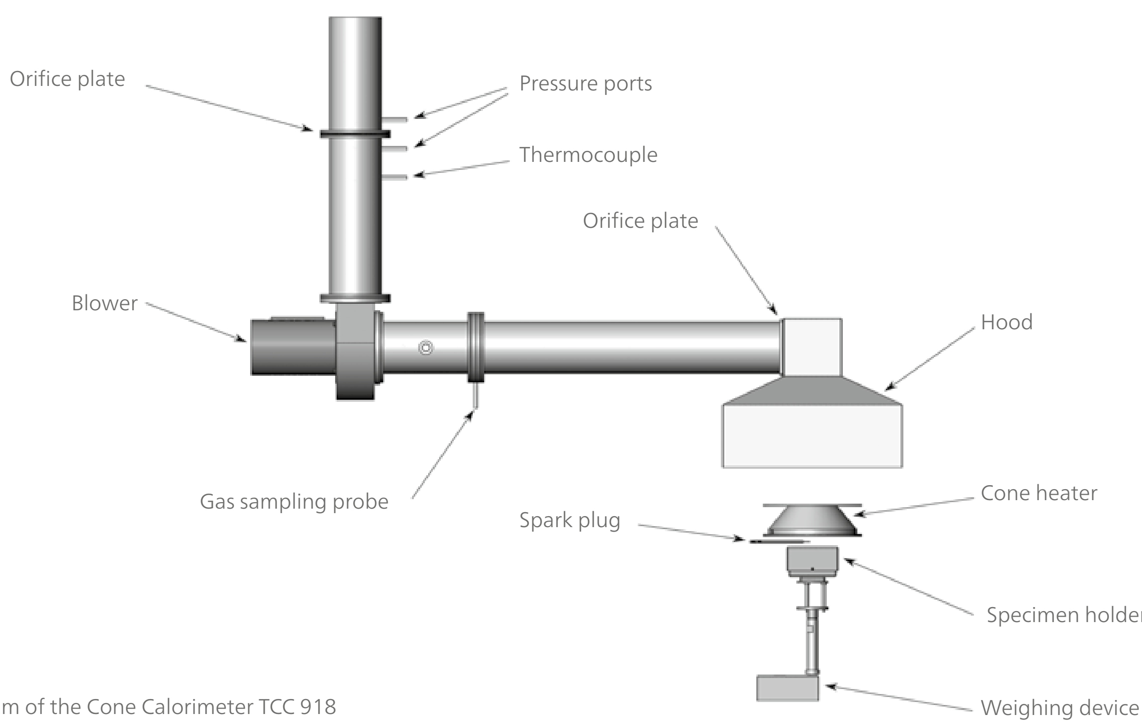
The measurements of gas flow and oxygen concentration are used to calculate the quantity of heat release per unit of time and surface area. The heat release rate (HRR) is expressed in J/s or W. The development of HRR as a function of time is typically used to analyze fire properties.

The analysis of the HRR curve versus time also allows for the characterization of:

- Time of ignition (TOI)
- Time of combustion or extinction (TOF)
- Mass loss during combustion
- CO and CO_2 quantities
- Total smoke release (TSR)

Coupling of a Gas Analyzer

For better understanding of the gases released, an FT-IR spectrometer can be coupled via a heated capillary. Prior to reaching the gas analyzer, the gas sampled in the gas-sampling ring is first passed through two filters to remove particles. The smoke measurement system is located between the gas-sampling ring and the fan.



Schematic diagram of the Cone Calorimeter TCC 918

HERE IS WHY THE DECISION FOR A TCC 918 IS SO EASY ...

Software updates free-of-charge – No license costs!

Efficient Peltier Cooling Device for Gases

The sampling gas is cooled by one controlled Peltier cooler, which can be set down to -10°C. This eliminates any need for the expensive thermostat for gas cooling and/or drying agent which are commonly used.

Ethernet for Control Automation Technology – EtherCAT

The NETZSCH Taurus TCC 918 is designed with the latest in hardware technology, including a new EtherCAT technique for communication between the different devices. It clearly improves reaction times between all electronic components and allows for real time data acquisition as well as excellent synchronization.

Stable and Robust Laser System for Smoke Production Measurement

Between the gas sampling ring and the fan there is a smoke measurement system. This measures the produced amount of smoke by a HeNe laser beam. The optical device has optimized electronics for a stable and safe operation. The stabilization time is reduced to <20 min.

Comprehensive Windows Based Software – No Additional PC Required

The system comes with a single board computer, SBC, including a PC and state-of-the-art touch screen. The software allows for the display of all relevant data and measuring results as graphs and tables and controls all processes.

Automatic Adjustment of Gases

The gas burner is equipped with a mass flow controller (MFC) especially for methane.

Exhaust System Designed for Extended Lifetime

The exhaust fan with collector and measuring tube are made of stainless steel for an extended lifetime.

Moveable Heater and Sample Holder

The conical radiant heater exhibits high performance up to 5 kW. It is a double-walled, stainless steel design with mineral wool insulation. The sample holder is made of stainless steel. It consists of a holding frame and CaSi panels. The specimen is introduced horizontally. Easy handling is supported by the ability to move the sample holder and heater – manually or automatically during an experiment.

Precise Load Cell

During the experiment, the sample mass is recorded by a load cell made by the well-known manufacturer SARTORIUS. It has a load capacity of 8.2 kg and a repeatability of 0.01 g.

Top view of the TCC 918

Continuous Gas Analyzer for the HRR Calculation

The use of optical couplers and optical filters in IR physics leads to an increase in selectivity. This ensures the ability to measure at low concentrations and low detection limits. To this end, the system is equipped with the robust Siemens ULTRAMAT/OXYMAT 6E, featuring corrosion-resistant materials in the gas channel. It serves for the detection of two infrared components, CO and CO_2, as well as O_2 in accordance with the standards.

OXYMAT

The only analyzer needed to perform fundamental cone calorimeter experiments is the oxygen analyzer. Additional analyzers (CO, CO_2, etc.) support a better understanding of the burning process and decrease the uncertainties in the test results.
The OXYMAT physics are based on measuring oxygen using the paramagnetic alternating pressure method for highest detection capabilities. The system is completely integrated in the TCC 918 software, which simplifies and minimizes handling.

Calibration of the Gas Analyzer

For easy handling, the adjustment process is completely automated: calibration gases are managed and adjusted by the software.

Mass Flow Controller Especially for Methane

The methane gas burner comes with a piezoelectric igniter. A mass-flow controller (MFC) especially for methane includes a magnetic valve and shut-off valve, both for methane.
The performance is also adjusted to the requirements of the calibration burner. The burner is protected by a stainless-steel cover.

Sample Holder

The sample holder is made of stainless steel and has a holding frame and CaSi panels. It is horizontally open for easy sample loading. Depending on the specimen, sample holders with open or closed edges are available.
In some cases, a specimen swells during heating and forms a protective char layer. In such cases, a sample holder with wire mesh can be used to hold the sample in place during swelling.

Calibration of the TCC 918

Calibration of the TCC 918 is in accordance with the standards ISO 5660-1 and ASTM E1354. The software simplifies the calibration process. For the evaluation, an EXCEL file is available into which the calibration data can be loaded for further calculations in accordance with the standard.

Hood and Exhaust Fan

The flue gases from the burning sample are collected into the extraction hood situated directly above the conical heater. A flue gas fan is mounted in the flue gas line to set the flow rate of combustion products. The exhaust fan as well as the collector are made of stainless steel.

Heat Release Rate

The rate at which fire releases energy is called the heat release rate (HRR). It is an important parameter in fire modeling. HRR has an impact on the safety aspects of a flammable release or incidents such as thermal runaway reactions. It is calculated from the oxygen concentration in the flue gases (percentage of oxygen consumed during combustion).

Time-to-Ignition

Time-to-ignition (TOI) defines how quickly flaming combustion of a material will occur when exposed to a heat source. Ignition usually occurs when the surface of, for example, a composite is heated to the pyrolysis temperature of the polymer matrix, which is usually in the range of 250°C to 400°C for most organic resins.

TCC 918 – Cone Calorimeter	
Measurement method	Reaction-to-fire tests - Heat release rate (cone calorimeter method) and smoke production rate (dynamic measurement) according to ISO 5660-1 and ASTM E 1354
Heating unit	▪ Double-walled, stainless steel with mineral wool insulation ▪ Electric heating element: 5.0 kW ▪ Total dimensions: Ø = 107 mm, H = 65 mm
Load cell	▪ Load cell with bracket, stainless steel ▪ Weighing range: 0 – 8.2 kg ▪ Weighing resolution and accuracy: 0.01 g/±0.01 g
Exhaust fan	With collector, stainless steel; dimensions: 400 x 400 x 330 mm^3
Burner	▪ Robust methane gas burner for calibration ▪ Mass flow controller for methane* ▪ Software-controlled magnetic valve ▪ Centering adapter for safety adjusment and easy use
Igniter	▪ Robust pneumatic mechanism for fast moving (software-controlled) ▪ Electric spark for precise ignition of burning gases ▪ Variable pulse width and duration adjustable by the software to investigate the ignition behavior of the sample
Measuring tube	▪ Stainless steel, Ø 114 mm, with gas sampling probe ▪ 2 thermocouples and orifice assembly for differential pressure ▪ Adapter for optical measuring section and FT-IR coupling ▪ Special design for easy assembly in case of maintenance
Sample holder	▪ Stainless steel, frame for sample adjustment for defined distance to the cone heater ▪ Inner Dimensions (W x D x H): 100 x 100 x 50 mm^3
Cold trap for test gas	▪ Effective Peltier cooler for gas cooling without mechanical parts ▪ Cooling to -10°C for effective drying without toxic drying agent
Light measuring system	▪ Protection windows with reduced condensation effects by airflow (compressed air) ▪ He-Ne laser light source (0.5 mW) and radiation hardened housing (laser glass 2) ▪ Silicone photo detector with aluminum housing and mounting flange, black anodized ▪ Data acquisition system with two separate and synchronized ADC channels for fast operational readiness and high stability
Gas conditioning	▪ 2 Particle filters, main filter for 2 µm and secondary filter for 0.1 µm particle size ▪ Automatic software-controlled condensate pump
Gas analyzer	▪ SIEMENS ULTRAMAT/OXYMAT 6E ▪ Measuring components: CO_2, O_2, CO ▪ Measuring range: 0 - 100% for O_2 ▪ Automatic calibration of the gas analyzer by software-controlled gas valves ▪ Full integration into the TCC computer system and operation via TCC touch panel
Software	▪ Integrated computer with touch panel for parameter definition and visualization (19“) ▪ Second touch panel for ditigal switches and prameter display (10“) ▪ TCC software for easy operation and full gas analyzer control by digital interfaces ▪ Movable keyboard section, optional operation via network (WiFi or LAN) by additional Windows PC
Instrument dimensions	▪ Industrial cabinet W x D x H: 1550 x 620 x 2700 mm^3 ▪ Weight: approx. 450 kg
Power supply	380/400 V, 50/60 Hz, 32 A

* Burner gas to be provided by the user

Technical Specifications

Influence of Flame Retardants on the Fire Behavior of Electric Components

Flame retardants (FR) in plastic materials ensure their fire safety. The type and quantity depend on the application and the requirements of the flammability standards. Small amounts are desirable to have the least effect on the plastic's properties and processing behavior. Since a small fire can already develop dense smoke to make visual orientation difficult or even obstruct the escape of a trapped person or the smoke can be toxic to the fire victims, special non-halogenated flame retardants and graphite based flame retardants can be used.

To highlight the effect of different flame retardants on the fire behavior of PA 6, samples of the different compounds were injection molded into 100 x 100 x 4 mm^3 plates and tested in the TCC 918.

Figure 1 shows the results of the measurement of neat PA 6 and the visualization in the TCC software.

Figure 2 shows the measurement results regarding mass loss, heat release rate and transmission as a function of time. The sample with graphite-based flame retardant (red curve) shows the lowest mass loss, the lowest heat and smoke release (lowest reduction of transmission) of all samples. In comparison, the sample with non-halogenated flame retardant (green curve) behaves similar to the neat PA 6 material (blue curve). Except that the values for heat release are lower and it ends faster. In the case of transmission, however, the smoke emission is significantly higher than with pure PA 6.

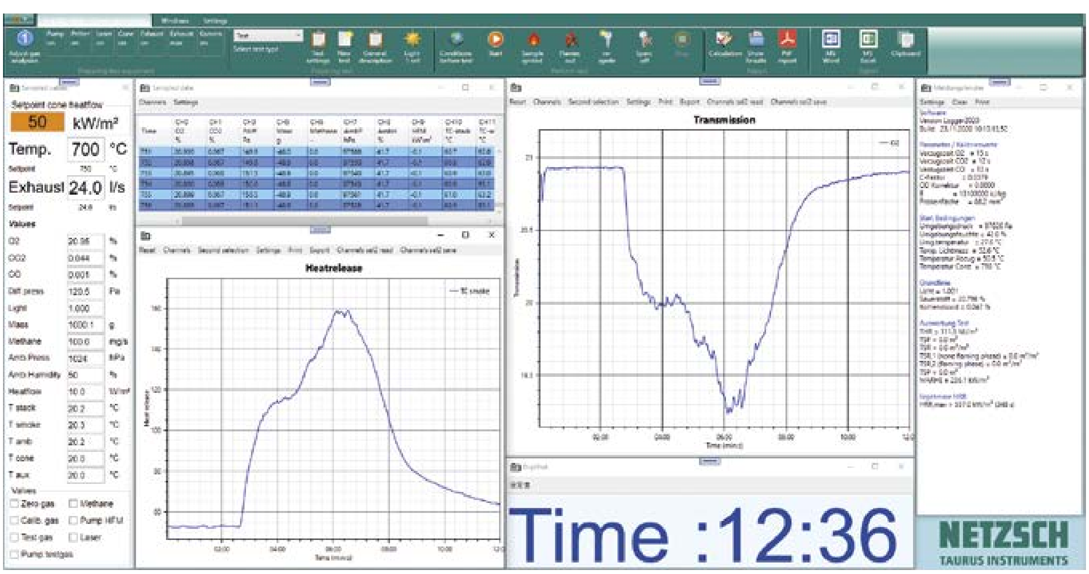


Figure 1:
Overview of TCC measurement on neat PA6 in the TCC software: Measurement input data (left column), measured values from 751 s -756 s and two exemplary measurement curves (middle columns), overview of the selected analysis values (right column).

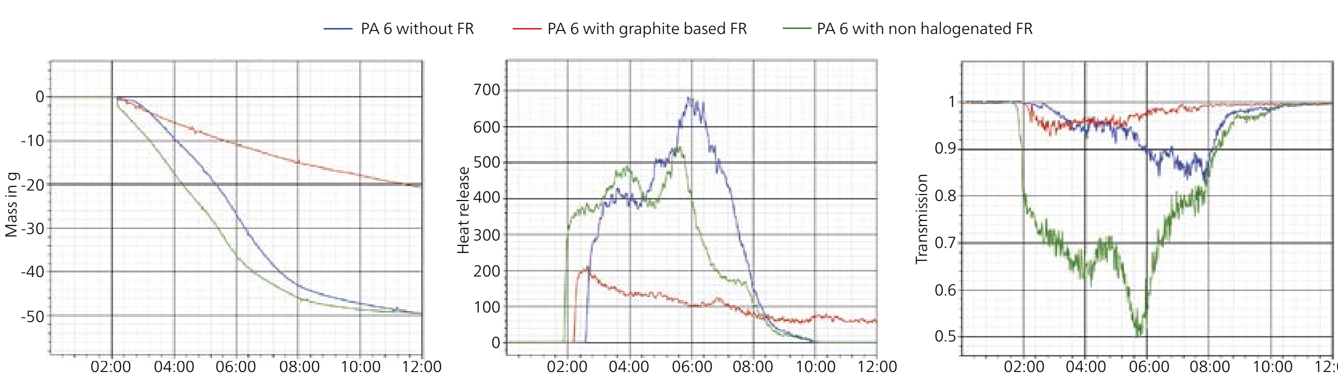


Figure 2:
Neat PA 6 (blue), PA 6 w/graphite-based flame retardant (red) and PA 6 w/non-halogenated flame retardant (green)
a) Mass loss b) Heat release rate and c) Transmission (Source: BPI)

A Windows Software That Leaves No

Display of all Relevant Data and Measuring Results as Graphs And Tables

- Freely configurable display in the form of tables, diagrams, text or graphs
- Ability to freely configure 16 screens per type of display
- Ability to display measured values on separate monitors

Operator-Guided Test Control

- Graphical schedule for test control
- Dialogues with system-specific operator notifications
- Dialogue for the entry of all relevant data/ information in accordance with the standard
- Dialogue for automated execution of the adjustment of the gas analysis
- Recording of pre-test data (300 s)
- Automated control of valves and burner
- Monitoring of the test as pertains to HRR and excessive temperature in the extractor
- Online calculation of all test-relevant data:
  - heating capacity
  - heat flow
  - thermal release
  - effective combustion heat
  - mass loss
  - specific absorbance range
  - smoke emission, and
  - gas level
- Calculation and display of the measurement results in accordance with the standard
- Storage of test in EXCEL file

Measuring Point Configuration

- Assignment of name, measuring range and adjustment factor to each channel
- Assignment and evaluation of limit values for each channel
- Display of all data calculated in accordance with the standard

Calibration Gas Analyzer

- Fully automated adjustment process: calibration gases are managed by software and adjustment is triggered

Wishes Unfulfilled ...

Calibration of the Device According to Standard

- Simplified automated processes for calibration
- EXCEL file available for evaluation for calculations
- Documentation of individual verifications in annex for sensors used

Protocol

- Input screen for all test-relevant data in accordance with standard
- Protocol printout function in accordance with ISO 5660 and ASTM E 1354 with graphical and numerical display
- Display of actual calibration data as part of the protocol
- Protocol conversion into PDF
- Copying of protocol data (texts/graphs) into clipboard for further
- Display of protocol data in text file possible

Additional Features

- Monitoring of the measuring device with display of relevant reports and switch-off in the case of critical excess of individual values
- Storage of all test data as raw data (binary) with interface to EXCEL or WORD via clipboard
- Storage of all data in CSV format

Firmware TCC 2020_SBC

- Hardware control via SBC (Intel Atom)
- 10"-display with PCAP and high resolution for display and operation
- Control of all hardware components, such as valves, gas analyzer, light measuring section and mass flow controller

DISPLAY OF ALL RELEVANT DATA

OPERATOR-GUIDED TEST CONTROL

MEASURING POINT CONFIGURATION

SIMPLIFIED CALIBRATION ROUTINES

HRR MONITORING

ONLINE CALCULATION OF TEST DATA

PROTOCOL

HIGH-RESOLUTION TOUCH PC

IN ACCORDANCE WITH ISO 5660 AND ASTM E1354

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Proven Excellence.

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