Battery Safety & Calorimetry

Reduce Battery Explosion Risk

Adiabatic Battery Testing Calorimeter (BTC)

- Adiabatic 'ARC-Type' system for thermal runaways and other 'abuse' tests on batteries and their components

isothermal-Battery Testing Calorimeter (iso-BTC)

- Heat-release profile during battery charge/discharge, at constant temperature
- Data for battery development, thermal management and performance modelling, at different temperatures

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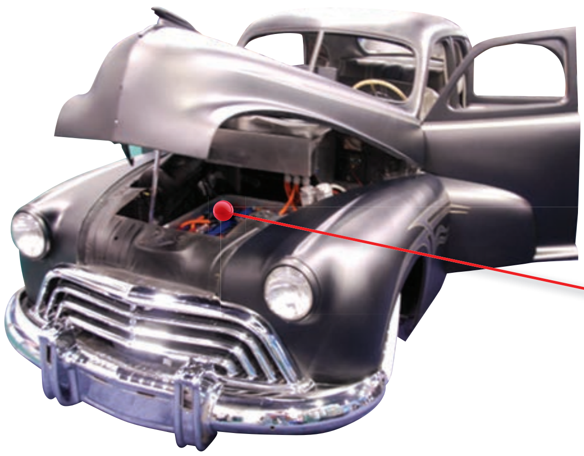
Battery Fire/Explosion... Why Calorimetry?



- Hundreds of cells, tightly packed
- No natural cooling

Batteries generate heat during use, this can lead to explosive overheating

Adiabatic Calorimetry

Predict thermal explosion hazard

- High temperature
- Unsafe (high) discharge current
- Effect of internal short
- Consequences of nail penetration

Data under 'worst case' conditions to predict real life safety limits.

Effects of various thermal explosions

Isothermal Calorimetry

Prevent thermal explosion

- Data for better thermal management design
- Real-life data for battery modelling
- Improved battery performance by better understanding of internal mechanistic effects

Determining heat generation rate for a range of temperatures and range of discharge rates, easily and accurately.

Wide range of battery types can be tested

Adiabatic Battery Testing Calorimeter (BTC)

Adiabatic 'ARC-Type' system for thermal runaway and other 'abuse' tests on batteries and their components

The BTC determines safe working limits to avoid thermal runaway explosion under 'worst case' (adiabatic) conditions it provides data that can be relied upon in real-life applications. The limits can only be measured with an adiabatic device, any other system will not provide safe operating values.

The specific measurements are:

- Maximum safe temperature
- Maximum discharge rate (current)
- Maximum charge (voltage)
- Specific heat, gas sampling and photographic evidence
- Nail penetration and short-simulation

The last two tests do not strictly need to be run in an adiabatic device but the BTC provides a convenient and safe environment. The discharge current and charge voltage tests require integration with a cycler, which is optional.

Compact: BTC-130

Large Scale: BTC-500

	BTC-130	BTC-500
Footprint	70 x 60 x 80cm (W x D x H)	120 x 90 x 198cm (W x D x H)
Internal Diameter	13cm (~5 inches)	50cm (~20 inches)
Internal Height	20cm (~8 inches)	30cm (12 inches) or 50cm
Battery Types	For any battery type as well as electrolytes, anodes, cathodes, SEI etc. Cylindrical 18650 and larger sizes, pouch, prismatic, button plus all manner of samples can be tested.	All the samples listed for the BTC-130 can be tested here as well as for larger EV, HEV, military and commercial aircraft types. The system works equally well for small batteries and components.
Operator Safety	Steel enclosure built into compact 'Phi-TEC' frame, is suitable for standard fume hoods. Enclosure is vented to prevent any pressure build-up, plus automated shut down in case of excessive high temperature.	Steel plate (20mm thick) is used for the end plates and steel plate is also used for the cylindrical sides. Mechanical relief as well as software and operator triggered shut down provides layers of protection for any eventuality.

Main Thermal Runaway Tests

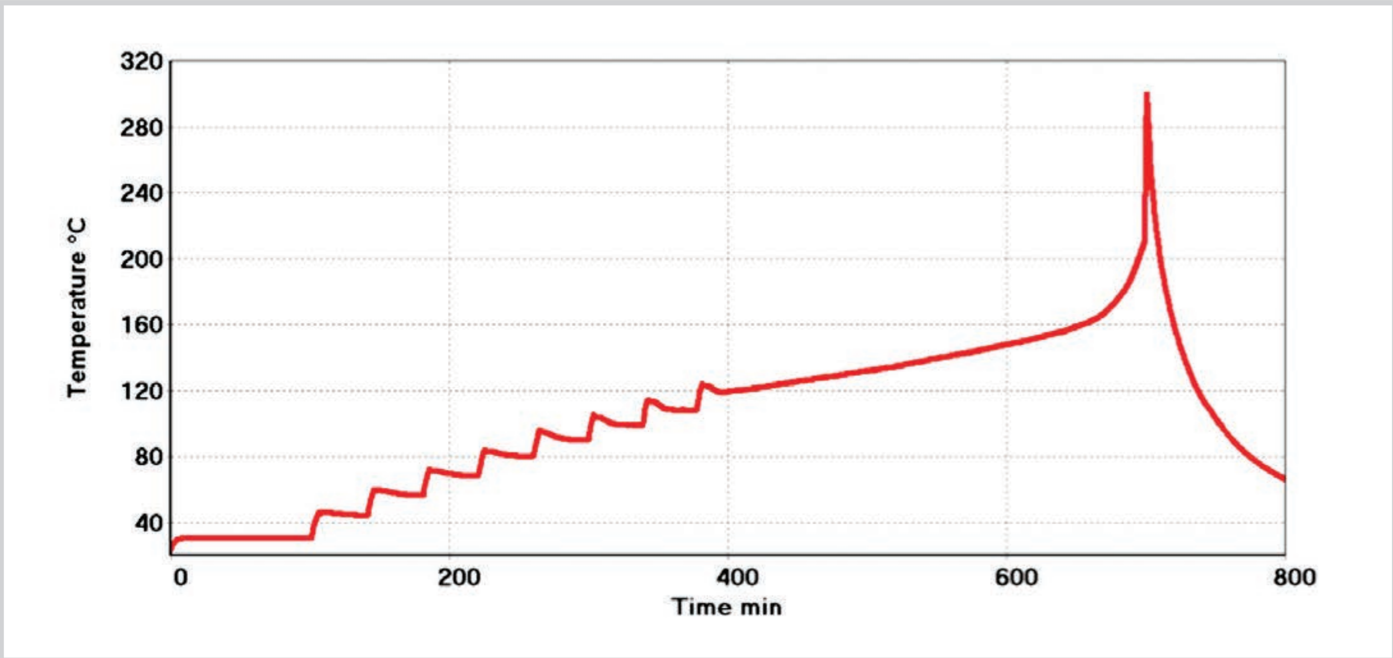
For maximum safe temperature, maximum discharge onset and maximum over voltage.

The main function of the BTC is to create the 'worst case' environment (i.e. adiabatic conditions) under which limits for thermal runaway explosion can be measured.

Safe maximum working temperature

The maximum temperature of the environment which results in a battery thermal explosion that can be predicted by placing the sample in the BTC and performing well established adiabatic tests.

This involves stepwise heating, followed by a wait-and-search period can be used with cells and large battery packs alike to determine the maximum safe operating temperature.



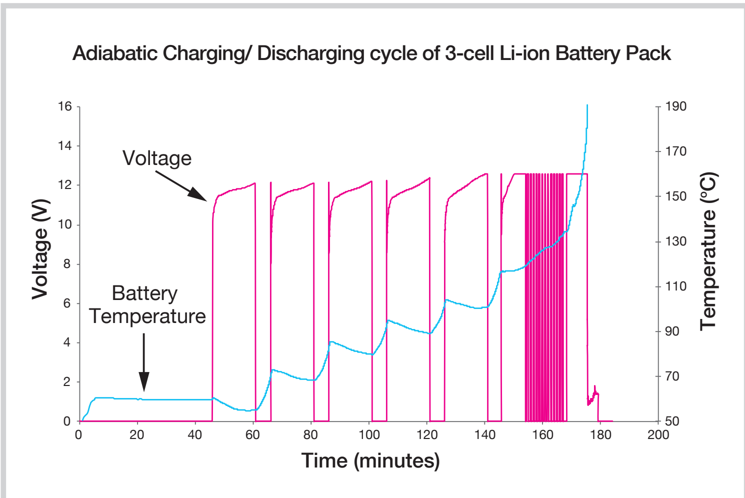
Heat-Wait-Search test to determine the thermal stability of a pouch type Li-ion battery. In this example the battery ruptures at an elevated temperature and this often gives the impression that the runaway has stopped – see the sudden fall in temperature after exceeding 300°C

Over charging and Discharging limits leading to battery explosion

It is also important to determine how a thermal runaway can be triggered when a battery is discharged at too fast a rate or if it is overcharged (voltage too high).

The results of a 3-cell Li-ion polymer battery connected to a cycler and discharged at 15A, while placed inside the BTC are shown.

BTC calorimeter connected to Cycler. Placing the battery inside the BTC (while connected to a cycler) is the only way to predict the true safe limits of discharge and overcharging

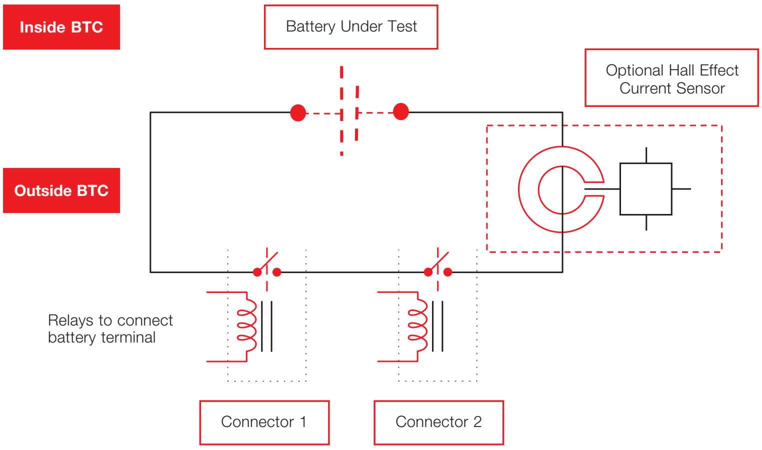


Thermal runaway resulting from fast charging/discharging rate. At an elevated temperature, the battery develops an internal short and therefore can no longer be charged. As a result the cycler switches back and forth frantically (see the pink lines in the figure from approximately 150 minutes onwards)

Additional Features

Battery Short Simulation

Battery shorts are a huge concern as they can often lead to thermal explosions at any time. The consequences of this can be simulated by artificially creating shorts between the terminals, while the battery sample is inside the BTC. A range of resistances can be tested to allow for ‘soft’ and ‘hard’ shorts.



When the relays are energised the battery terminals are connected, creating a short

Remote Video - Viewing Via Probe

Integrated video camera with HEL software for real-time visualisation and also recording of selected sequences.

Live video and thermal imaging, under runway conditions

Nail Penetration Apparatus

Mechanical rig to simulate ‘mechanical’ abuse via nail penetration. Nail speed and penetration distance can be specified through the software. Also a range of ‘nail’ sizes can be used.

Gas Sampling

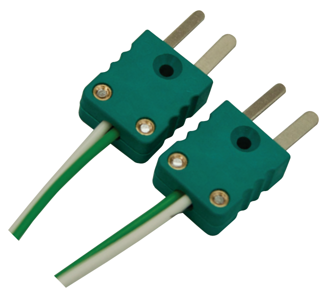
Gas generated in a thermal runaway can be automatically sampled by opening a valve using the HEL WinISO software. This feature can also be used to divert the gas to a GC.

Analogue Inputs

Additional Analogue inputs from any client supplied device can be recorded and displayed, together with all other calorimeter data.

Temperature Sensors

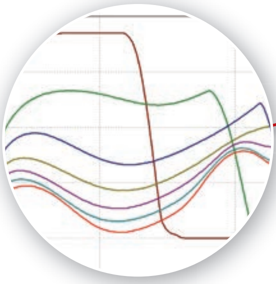
Extra sensors (type-K thermocouples) can be supplied for measuring battery temperatures at different locations during self-heating. Working range -100°C to +1000°C, fully logged in software.



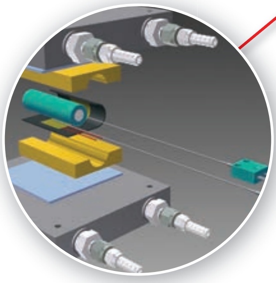
isothermal-Battery Testing Calorimeter (iso-BTC)

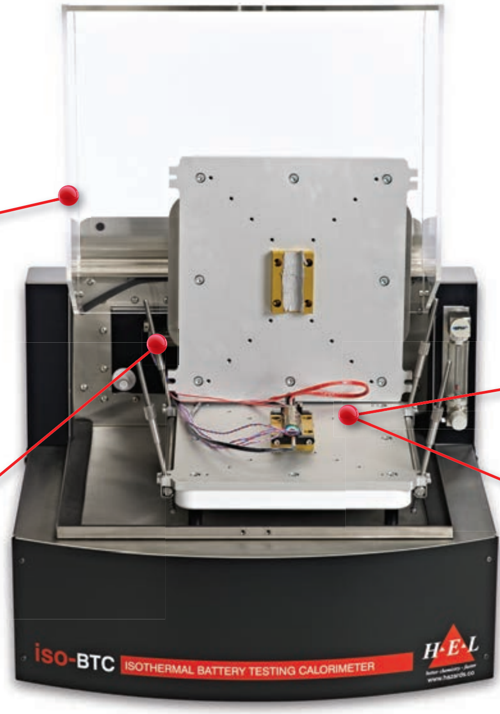
Heat-release profile during battery charge/discharge, at constant temperature. Data for battery development, thermal management and performance modelling, at different temperatures

Fast & Accurate Results

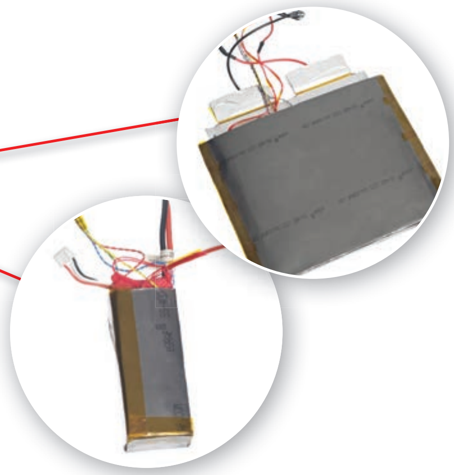


Wide Temperature Ranges





Variety Of Battery Sizes & Shapes



Compact Design

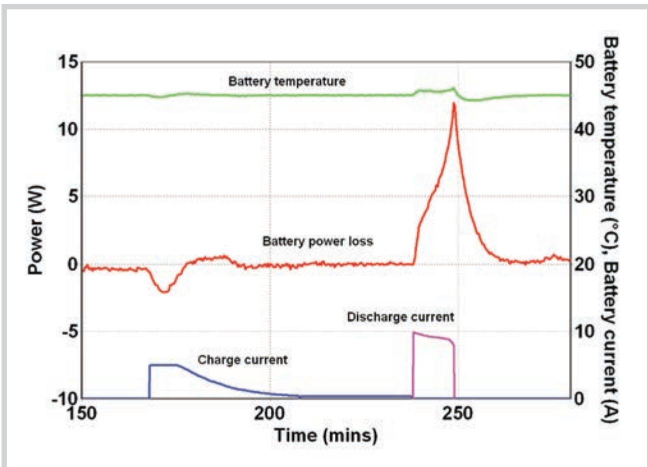
21cm x 72cm x 75cm (W x D x H)

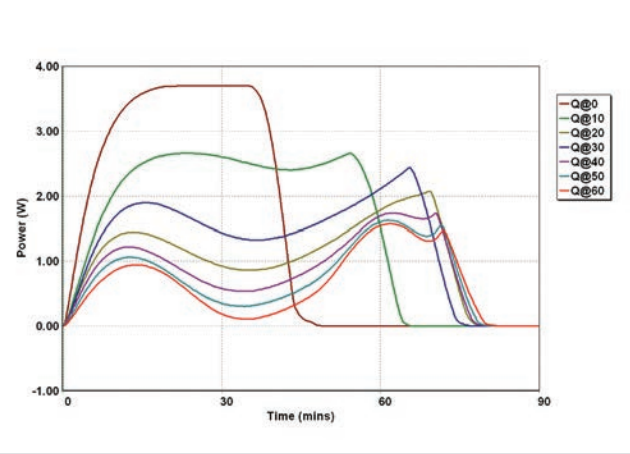
Operating Principles

Heat produced during normal battery use can be measured, while keeping the temperature constant, using the iso-BTC. The heat release profile at different temperatures and charge/discharge rates provides information about the performance of the battery as well as being essential for cooling (thermal management system design). The iso-BTC consists of a thermal chamber where different sizes and shapes of batteries can be placed and their temperature held constant, while attached to a cycler for charging/discharging. In keeping the battery temperature constant, the iso-BTC heats/cools the battery – and this heat is measured and recorded which directly reflects the heat changes within the battery.

Heat Release At Fixed Battery Temperature

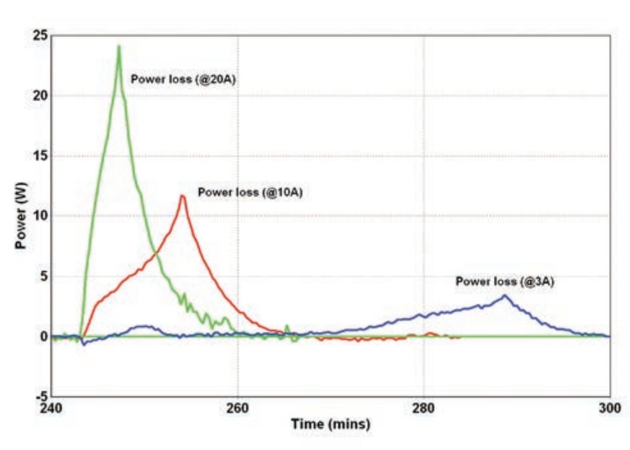
Typical data from iso-BTC for a charging followed by a discharge step, while holding battery at ~45°C. During charging the battery loses heat (cools) while during discharge, heat is produced (the heat information is labelled 'battery power loss'). During discharge (at 10A) a maximum ~11W of power is generated i.e. lost as heat.





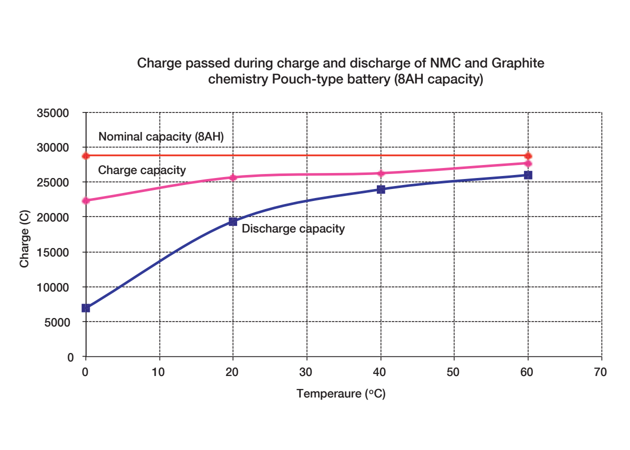
Effect Of Temperatures

The amount of heat produced, for a fixed discharge current, varies with the temperature of the battery and this relationship can be quantified in the iso-BTC.
The resulting profile for a 8.8Ah NMC-graphite battery, over a temperature range of 0 to 60°C shows a three fold increase in heat generation.



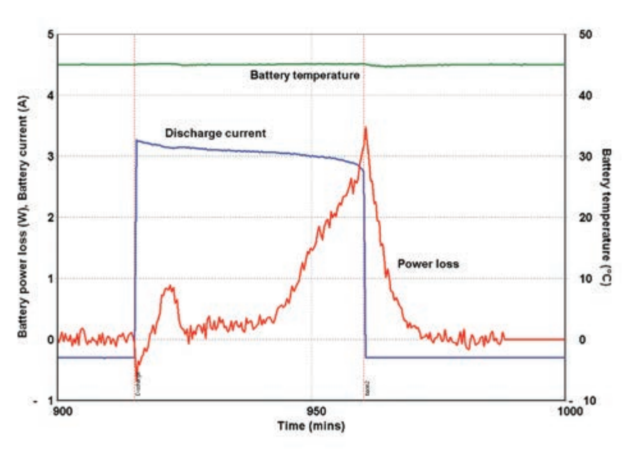
Effect Of Different Discharge Currents

This shows the effect of changes in the discharge current (while holding the temperature constant) for the same battery (Li-polymer, rated to 2.2Ah). From this information, it is possible to specify the demand on a thermal management system.



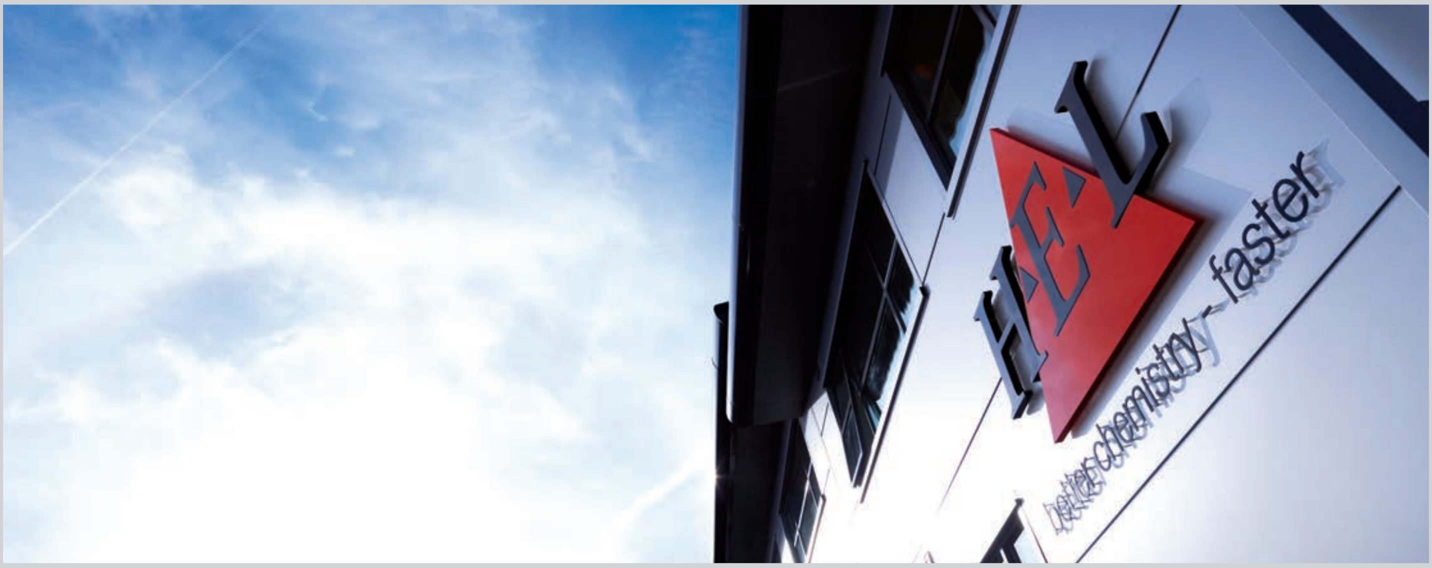
Capacity Change With Temperature

Changes in charge and discharge capacity with temperature can be also be deduced from the same experiment. As an example, the change in charge and discharge capacity for the same NMC-graphite type battery is shown. The discharge capacity is seen to drop by 70%.



Tracking Of Fine Mechanistic Details

Finally, a detailed look at the heat generation profiles reveals that battery discharging involves a number of consecutive steps, both exothermic and endothermic, some fast and some very slow - shown here for the Li-ion polymer battery. These steps correspond to the different events going on within the battery and their understanding can be invaluable to battery developers not only in terms of safe design but also for improving performance.



About HEL

HEL is an international company that specialises in research and pilot scale chemical reactors and related data logging/automation tools for process R&D in the pharmaceutical, fine chemical and petrochemical industries. Established in 1987 and with clients worldwide our key strengths are:

Knowledgeable staff - highly qualified and experienced chemical engineers and chemists
Quality - underpinned by ISO9001 certification for over 16 years
Service - choice of service contracts backed by established culture of unmatched client support
Range of products - both off-the-shelf and custom designs, manual and fully automated controls, low and high pressure/temperature applications, single and parallel/multi-vessel products

Consultancy & Testing Services

Over the past 20 years we have developed expertise and become industry leaders in:

- Reaction hazards, calorimetry, vent sizing
- Process development and optimisation
- Dust and powder flammability
- Other hazard consultancy services, including expert opinion, HAZOPS, DIERS, incident and accident investigation and professional training

What our Users Say:

“We at TUV Rheinland consider ourselves to be quite fortunate in finding a vendor like HEL as the supplier of our Adiabatic Battery Testing Calorimeter. Not only does HEL provide a dynamic, but also a flexible team to work with. HEL’s expertise and experience in calorimetry has proven to be one of their strongest assets. The joint partnership with HEL has enabled us to develop services from which our company and our customers have benefited. We feel this “BTC” system has been a key factor to the success of our laboratory.” **TUV Rheinland Battery Laboratory**

HEL Ltd // UK	e: marketing@helgroup.com	t: +44 20 8736 0640
HEL Inc // US	e: marketing@hel-inc.com	t: +1 609 912 1551
HEL China // Beijing	e: info@helchina.com	t: +86 10 8210 1033
HEL Germany // Hamburg	e: dach@helgroup.com	t: +44 20 8736 0640
HEL India // Thane	e: info@helindia.com	t: +91 22 4153 3317
HEL Italia // Milan	e: helitalia@helgroup.com	t: +44 20 8736 0640
HEL Russia // Moscow	e: marketing@helgroup.com	t: +44 20 8736 0640

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