h.e.l

# Process Safety and Scale-up

Hazard screening, reaction calorimetry and adiabatic calorimetry solutions for process safety and scale-up

# Solutions in Process Safety

In industries ranging from pharmaceuticals to fine chemicals, there is a need to take small, laboratory scale chemical reactions to mass manufacture of a product.

Central to the risks involved with scale-up are the changes in heat loss behaviour with scale:

- Many reactions are exothermic and require cooling to ensure safe operation when performed on a large scale;
- Components in the reaction may become unstable under certain operating conditions, leading to additional thermal hazards.

It is necessary to identify and mitigate sources of risk during the process scale-up. H.E.L provides a suite of safety scale-up tools to help you do this.

## Your Problem

## Our Solution

**Are these materials safe to proceed with?**

Discovery

**Raw Material Hazard Screening**
TSu
Phi-TEC I

**What operating conditions are required to minimize risk?**

Process Development

**Reaction Calorimetry**
Simular

**Reaction Mix Hazard Screening**
TSu

**What is the extent of the thermal risk?**

**What safety factors are required to mitigate worst-case scenarios?**

Scale-Up

**Adiabatic Testing**
Phi-TEC I

**Hazard and Operability Assessment**
Phi-TEC II

Manufacture

# Raw Material Hazard Screening

## TSu (Thermal Screening Unit)
## Phi-TEC I

Hazard screening of raw materials early in development allows timely decisions to be made on how to develop a reaction or process.

TSu (Thermal Screening Unit)

### Identifying thermal and pressure hazards

The **TSu (Thermal Screening Unit)** enables rapid screening of both the temperature and pressure characteristics of a sample on the same platform. Parameters such as the onset temperature of decomposition ($T_d$) and rate of pressure increase can be determined, enabling an initial hazard assessment on the material.

Some of the most hazardous reactions to scale up are ones that involve the production of non-condensable gases, with the rapid increase in pressure representing a potential explosion risk. Therefore, the ability to study pressure events in addition to thermal events is vital in effectively screening a sample.

Phi-TEC I

### Rapid reactions

If there is a need to characterize especially rapid decompositions, the **Phi-TEC I** offers a high data-rate acquisition option, which provides higher resolution data on the rate of pressure and temperature changes.

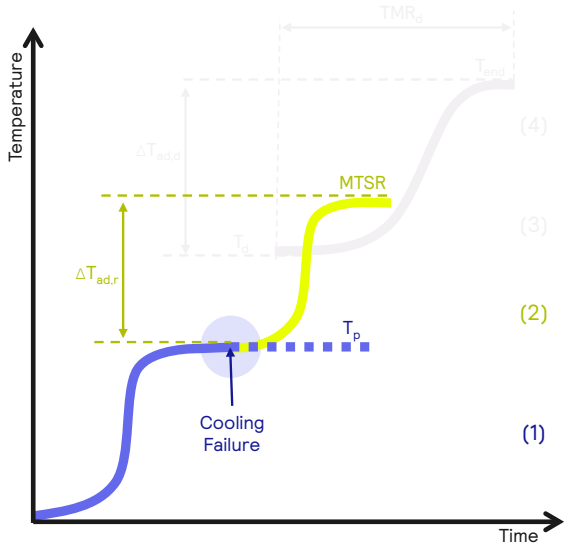
# Reaction Calorimetry

## Simular

Running a chemical process safely requires a thorough understanding of the main reactions and any possible, unintended, side reactions or decompositions.

Reaction calorimetry evaluates the main reactions. From this, operating conditions can be optimized to mitigate the hazards identified.

**Phases of a Thermal Runaway**




(1) Thermal properties of the desired reaction
(2) Thermal runaway of the reaction

**Simular**

### Thermal properties of the desired reaction (1)

The **Simular** measures the energy evolved in the reaction. Subsequently, this enables you to calculate the plant cooling capacity required to keep the reaction isothermal ($T_p$).

### Thermal runaway of the reaction (2)

In the event of plant failure, it is critical to understand the maximum temperature the main reaction will reach during any subsequent thermal runaway.

The **Simular** enables the Maximum Temperature of Synthesis Reaction (MTSR) to be calculated from the data of the reaction. Multiple reaction conditions can also be screened to help understand the kinetics of the reaction. From this, it can be assessed whether there will be sufficient time and emergency cooling capacity to deal with the temperature increase.

### Minimizing the risk

Hazard assessments may highlight insufficient plant emergency capacity to avert the risk of thermal runaway. The **Simular** can be used to explore and design safer reaction conditions, thereby facilitating the optimization of safe operations and minimizing process risk.

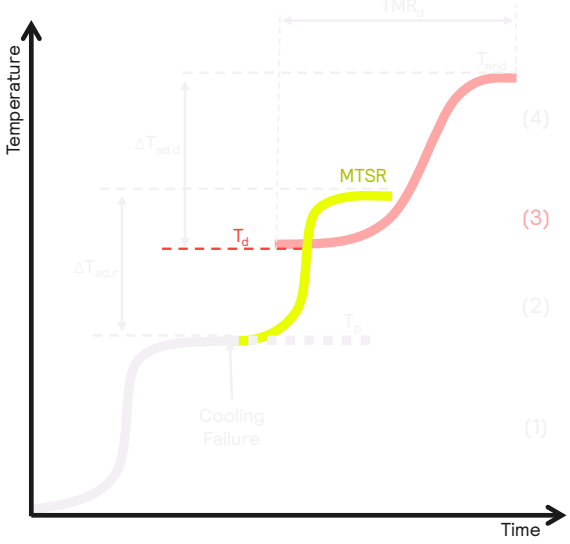
# Reaction Mix Hazard Screening

## TSu (Thermal Screening Unit)

Understanding if there are additional sources of thermal runaway risk within the reaction mixture is a further consideration of process development.

Reaction mix hazard screening, combined with the data generated from reaction calorimetry, enables the criticality of the reaction to be classified, and identifies if further characterization of exothermic events is required in order to define safe operating conditions.

**Phases of a Thermal Runaway**




(3) Secondary thermal runaway risk

**TSu (Thermal Screening Unit)**

### Secondary thermal runaway risk (3)

If the MTSR is greater than the onset temperature ($T_d$) of a component within the reaction mix, an undesired side reaction or decomposition may be triggered, leading to a secondary thermal runaway.

The **TSu (Thermal Screening Unit)** supports large-volume measurements, enabling representative samples of the reaction mix to be screened and reliable onset temperatures to be determined for the reactants, intermediates and products in the reaction mix. It also enables the vital assessment of pressure events in the reaction mix and can find use in the study of the waste streams from reactions.

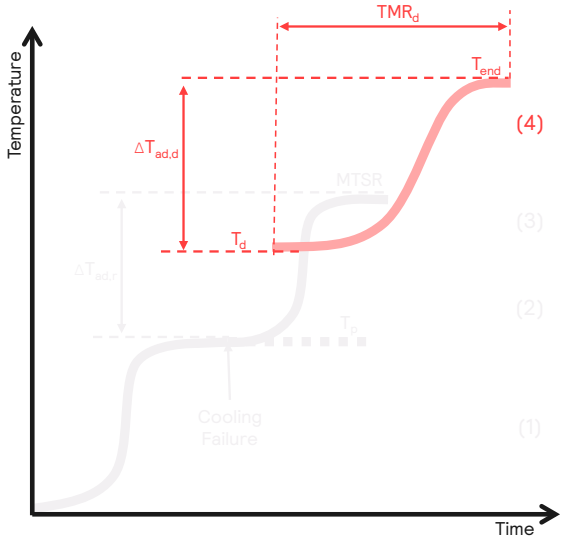
If this highlights a secondary thermal runaway is likely, it is necessary to screen this hazard more thoroughly using adiabatic calorimetry, for example, with the **Phi-TEC I.**

# Adiabatic Testing

## Phi-TEC I

When scaling up a process, accurate knowledge of an exothermic event is vital to ensure the magnitude of the thermal runaway risk is fully understood.

**Phases of a Thermal Runaway**




(4) Characterizing the thermal runaway

**Phi-TEC I**

### Adiabatic calorimetry

Large scale reactors lose very little of the heat generated in a reaction to the surroundings. This poses a potential hazard when operating at large scale, as that heat will be retained within the reactor. At best this will require plant cooling and at worst may trigger a thermal runaway.

The **Phi-TEC I** mimics the processes at large scale, while operating at laboratory volumes.

### Characterizing the thermal runaway (4)

Providing a direct measurement of the sample temperature, coupled with a rapid response to thermal changes, the **Phi-TEC I** accurately tracks exothermic events and maintains adiabatic conditions.

Adiabatic screening of a process enables accurate characterization of the onset temperature ($T_d$) and facilitates calculation of the time to maximum rate ($TMR_d$), the adiabatic temperature rise ($\Delta T_{ad,d}$) and the rate of pressure change. These key parameters can help describe the magnitude of the thermal runaway hazard.

# Hazard and Operability Assessment

## Phi-TEC II

The ability to thoroughly simulate thermal runaway risks under manufacturing plant conditions, at the laboratory scale, is a valuable way of de-risking the process. Appropriate safety measures can be designed and implemented before the final scale-up.

Phi-TEC II

### Plant-scale parameters from the laboratory

The **Phi-TEC II** is a more advanced type of adiabatic calorimeter, which supports the use of low Phi factor test cells. This capability means that very little of the heat produced during a reaction or thermal runaway is consumed in warming the test cell. As a result, the runaway rate is not tempered.

The measured rate of pressure increase and final temperature ($T_{end}$), along with the calculated Time to Maximum Rate (TMR) and adiabatic temperature rise ($\Delta T_{ad}$), are representative of what would be expected to occur during a manufacturing scale incident. Thus, the **Phi-TEC II** enables the hazards to be fully evaluated and explored, facilitating their mitigation prior to scale-up.

### Safety by design

The data generated by the **Phi-TEC II** can be used to directly compare the impact of different operating scenarios. From this, the necessary safety controls for the manufacturing plant can be selected. Examples of these are:

- Emergency and evaporation cooling
- Quenching
- Controlled depressurization
- Vent sizing (in accordance with DIERS methodology)

# Unleash Your Full Potential

**Looking for more information, why not take a look at our other product and knowledge areas:**

- **Knowledge –** Application Notes, Training, Podcasts and Blog
- **Thermal Hazards & Calorimetry –** Adiabatic and Heat Flow Calorimetry, Screening and Hazard Assessments
- **Bioreactors –** Flexible and Adaptable Bioreactors for Microbial or Cell Culture Applications
- **Automated Lab Reactors –** Chemical Reactors from Research to Pilot Scale
- **Parallel Synthesis –** Parallel Reactors for Reaction Screening and Optimization
- **Catalytic Processes –** Continuous Flow and Catalyst Screening, Including High Pressure options
- **Crystallization & Particle Studies –** Multi-Sample Solubility from 1ml Upwards

# Upgrades, Support and Training

We understand that your needs can change over time and you may require:

- **A system upgrade**
- **Training for new team members**
- **Support on your processes**
- **To book some time with our service team**

Our dedicated service team and highly knowledgeable technical staff will work with you to find the right solution.

## Customer Service Enquiries & Technical Support Requests

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# About H.E.L Group

H.E.L Group's mission is to work together with chemistry, safety and biotechnology experts to engineer and unleash the full potential of the scientific community. To this end, H.E.L develops and manufactures innovative scientific instruments and software designed to optimize the efficiency, safety and productivity of key processes in chemistry and biology applications.

The H.E.L team of 70 includes highly skilled process and software engineers, based at their extensive research and manufacturing facilities in the UK, as well as sales and support offices around the world.

H.E.L has a long history of solving complex challenges for customers. For more than 30 years the Company has worked with businesses and laboratories globally, providing proprietary automated solutions for the pharma, biotechnology, chemical, battery and petrochemical sectors.
H.E.L is accredited with ISO 9001 : 2015

- With a strong focus on the customer, our **service and support** enables our customers to keep working efficiently
- Our **wide range of customizable products** put the customer at the heart of what we do, with solutions designed around their needs


**H.E.L Group**

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