

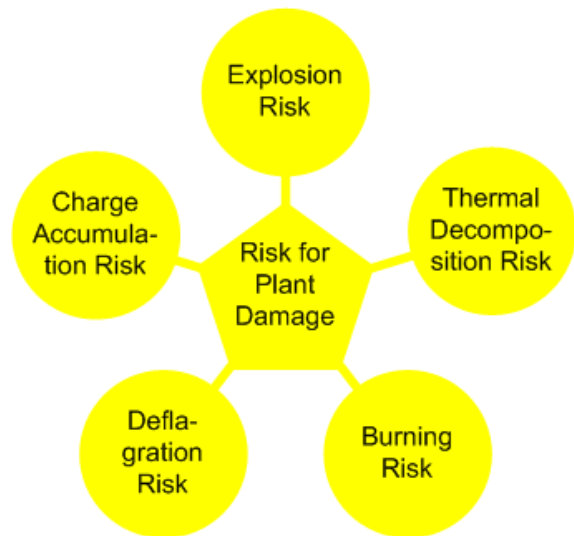
## Visualising of inherent hazards in process steps

In processing steps, chemicals—as liquids or as powders—are treated thermally and mechanically, sometimes in the presence of air. This can lead to dangerous operating conditions. That is why this process steps must be examined for their inherent dangers. For defining the risk, standardized tests must be carried out for the subjects dust fire, exothermic decomposition, dust explosion, mechanical sensitivity and electrostatic behaviour regarding their tendency and severity.

### Powder handling

Knowledge of the inherent hazard of a powder includes the understanding of its tendency to react dangerously, as well as the violence of this reaction. The processing of a chemical involves the risk to trigger off a hazardous reaction. However, a chemical is not risky for itself. Its risk depends on how it is processed. As an example, let us look at cellulose—the raw material of paper. Cellulose is flammable and explosible. The process of reading a newspaper, we consider as non-hazardous—we do it every day, quite relaxed. However, the processing of the same weight of fine cellulose powder can be very dangerous. If it is swirled up—and ignited—it will explode and the pressure will increase within a very short time. Processing powders can be very dangerous. If this is not done correctly, it can lead to plant damage or disaster.

It is impossible to estimate the hazard of a powder by examining case histories or by carrying out computations. As well, it is no easy task to judge whether the operation will be safe when the powder is processed in a given facility. Experimental work is necessary to visualise the hazard that is associated with the handling of a powder in a process step. The most reliable method of estimating the hazard potential of a powder regarding to **ignition, fire, explosion** and **thermal decomposition** is to carry out a combination of standardized tests.



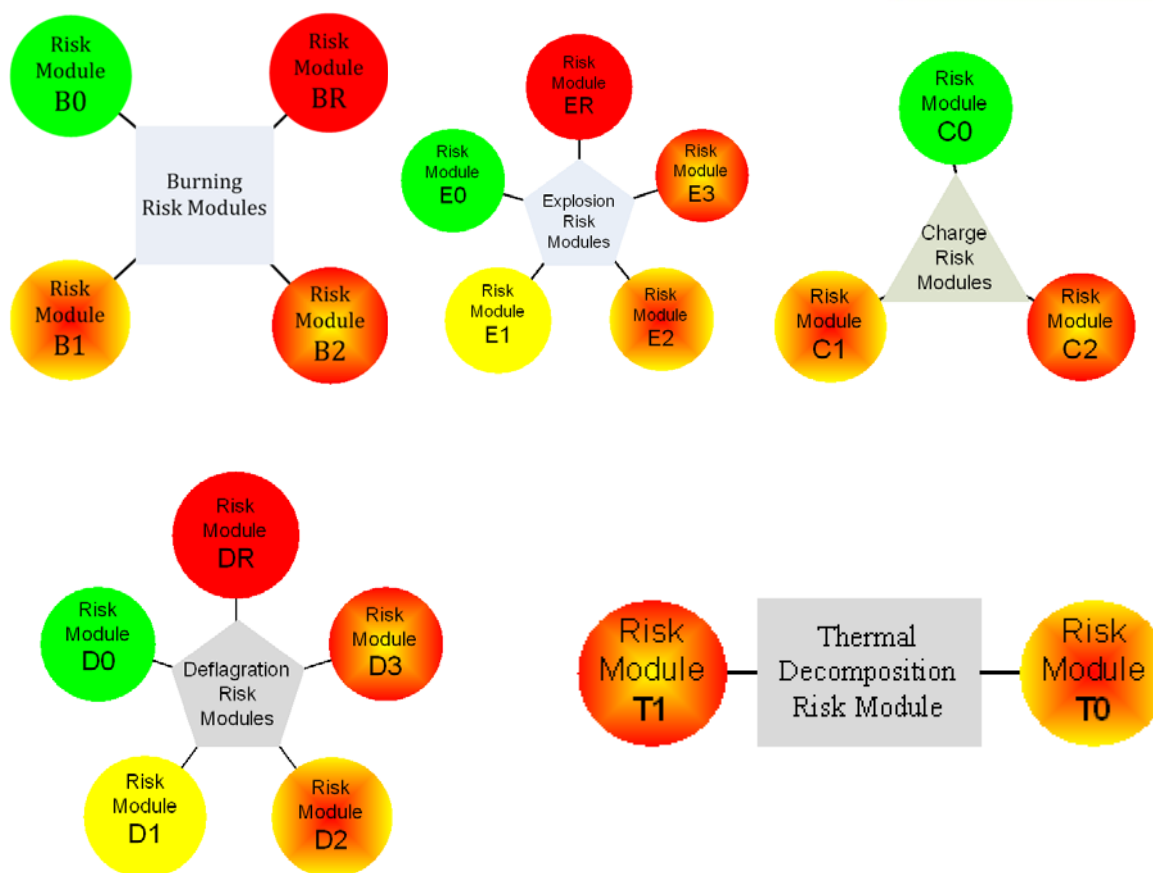
To understand the risk associated with processing a powder, one has to visualize its tendency, through which it leads to a dangerous reaction of great consequence. The tendency to react dangerously depends on the external stimulation by the process module. Therefore it is necessary to understand how the powder is worked on by the process module. The potential damage to a facility indicates the severity of decomposition. Features of the severity of decomposition reactions are the decomposition or explosion rate, the temperature and pressure that is reached, the amount of gas generated and the heat of reaction.

### Our way to look at powder processes

With our «Powder Pack» and «Special Tests» services, we visualize the inherent dangers of dust layers and dispersed dust. The **Powder Pack** is divided in two parts:

- The «Basic Tests»
- The extent of «Additional Tests» depends on the results of the Basic Tests.

On the base of the testing results the inherent hazards of a powder can be visualised by Risk Modules. In order to show the specific hazards of the powder, the risk modules are subdivided into risk module-sections. Every risk module-section allows on the one hand analysing the powder Process Module and on the other hand, to decide whether the Safety Modules are designed properly.



Read more about this subject in our publication, Powder as a Risk factor in Multi-product facilities.

### Thermally decomposable material

Condensed masses such as reaction masses, distillation masses, distillation residues, solutions, melts, but also solids can be dangerous if they are thermally stressed in process steps. Exothermic decomposition of condensed masses, accompanied by the generation of much heat and gas, is a common cause of accidents in the chemical industry.

#### Description of the phenomenon

Adding thermal energy to a chemical system increases the mean energy in the system. This increases the number of collisions in which energy is transferred to the molecules. Molecules are activated. Collisions also take place between the same molecules A.



During the collision, the molecules  $A^{\text{act}}$  took on so much vibration and rotational energy that chemical bonds in the molecules weaken and the conversion into «more stable» products and thermal energy can take place. The result is a thermal decomposition. Thermal decomposition reactions are not simple chemical reactions. As a rule, they take place in partial steps according to complicated mechanisms.

Decomposition reactions can follow three different physicochemical mechanisms. The literature distinguishes between deflagration, detonation and thermal explosion.

**Deflagration** is a decomposition reaction that can be initiated locally and is propagated through the entire material in a self-sustaining exothermic reaction. The initiation of deflagration depends on the material properties; it can be triggered by friction, impact or a sufficiently powerful heat source (e.g. by contact with hot apparatus).

**Detonation** is also a decomposition reaction that can be initiated locally and is propagated through the material in the form of a reaction front not by heat transfer, but by means of a shock wave sustained by the energy liberated by the decomposition reaction.

**A thermal explosion** is not initiated locally and spreads throughout the entire volume of material more or less homogeneously and not as a moving front. If a mixture capable of thermal decomposition finds itself in a situation where more heat is produced than can be dissipated to the surroundings, spontaneous overheating occurs resulting in a thermal explosion. This explosion is typified by a progressive increase in heat output and a massive rise in temperature and pressure.

Phenomenologically, due to the isothermal decomposition behaviour, two large classes of thermal decomposition mechanisms can be distinguished:

**First:** The class of reactions in which—under isothermal conditions—the heat released is greatest at the beginning and slowly decreases over time. This type of reaction can be described by a kinetic law of the  $n$ th order. In fact, reactions with the  $n$ th order mechanism are typical of gas reactions.

Nevertheless, the macro-kinetics of many decomposition reactions that take place in the liquid phase can be described with kinetic laws of almost the first order. This includes decomposition reactions in which simple molecules are eliminated—such as diazo decomposition in which nitrogen is eliminated.

**Second:** The class of reactions in which—under isothermal conditions—the maximum power of heat is a function of time. Many of the decomposition reactions studied so far are of this type. This type of decomposition is found in organic and inorganic molecules with a wide variety of structures, and it almost seems as if it is based on a fundamental reaction mechanism. But that is probably not the case. Thermal decomposition is very complicated and consists of many partial reactions. The partial reactions that take place at the beginning of the thermal decomposition are mostly steps with small energy differences, such as rearrangement reactions. These reactions—which trigger the decomposition—are followed by the energy supply reactions, in which stable molecules—such as polymers and gases—are finally formed. Organic compounds often react to form gaseous and tarry products. The formation of tarry products shows that at the beginning of the thermal decomposition—in precursors—substances are formed that can ultimately polymerize.

### **Our way to look at powder processes**

The thermal hazards of substances and reaction masses are assessed by

- microthermal analysis (DSC, TGA),
- macro thermal analysis (RADEX, SEDEX and SIKAREX thermal analysis systems),
- adiabatic calorimetry,
- and gas development and pressure development experiments.