Chilworth GLOBAL

Flammability Data Under Process Conditions

Most of the material safety data sheets (MSDS's) supplied with combustible or flammable chemicals contain data on their flammability properties. The most common of which are Flashpoint, Auto-Ignition Temperature (AIT) and, if you are lucky, Flammable Limits (UFL / LFL). These properties have generally been determined in air and under atmospheric pressure and ambient temperature conditions.

How do you extrapolate this data to real processing conditions?

As well as operating at different temperatures and pressures, a process may be operated in a different atmosphere to air. There may be increased concentrations of Oxygen or more of an "inert" gas present (eg. steam, carbon dioxide, nitrogen). The process formulation is also likely to be a more complicated mixture of materials. All of these variations will significantly alter the flammability of the mixture or material and completely invalidate the use of simple literature data.
In such cases, the limited data available in the MSDS's are often of little use and at worst, misleading. Some of the properties that are affected include:

- Flash Point or Lower Temperature Limit of Flammability (LTL)
- Lower and Upper Flammable Limits (LFL/UFL)
- Auto-Ignition Temperature (AIT)
- Limiting Oxygen Concentration (LOC)
- Maximum Explosion Pressure (P_{max}) and Rate of Pressure Rise $(dP/dt)_{max}$ and K_g

For example,

- The upper and lower Flammable Limits broaden with increasing pressure and / or temperature.
- The Auto-Ignition Temperature is generally lower at increased pressures.
- The limiting oxygen concentration is generally lower at elevated pressures.
- P_{max} and $(dP/dt)_{max}$ values increase at elevated pressures.

Apart from MSDS's, flammability data can be sourced from other open literature. Most of these data are for common or pure chemicals and again, are typically determined under ambient / atmospheric conditions. Very limited data on the flammability properties of chemicals or chemical mixtures at low and high conditions of temperature and pressure exist. In such cases, the flammability properties of chemicals must be experimentally determined under conditions which directly simulate the process conditions.

Chilworth Technology have a wide range of equipment for, and expertise in, studying flammability characteristics under a variety of process conditions. The case studies below are provided to demonstrate the value of such testing:

Case Study 1 Effect of Oxygen Concentration on the Lower Temperature Limit (LTL)

A customer wished to assess the effect of different oxygen concentrations on the Lower Temperature Limit of a chemical at increased pressure (20 bara). The experiments were conducted in a 1.8 litre, high pressure reactor. The results obtained are tabulated below:

Test Pressure	Oxygen Concentration	Lower Temp Limit
20 bara	20% (balance Nitrogen)	> 40°C
20 bara	100% (balance Nitrogen)	< 22°C

This case study demonstrates that the Lower Temperature Limit (LTL) of the chemical was significantly reduced when the concentration of oxygen was increased.

Case Study 2 - Effect of Pressure on Auto-ignition Temperature (AIT)

A reaction between high pressure air and compressor lubricants in high temperature inter-stage and discharge regions of a compressor can cause overpressure due to Auto-Ignition of the lubricants.
Two lubricants were tested in air at various pressures up to 170 bar. The AutoIgnition Temperature for both lubricant samples under atmospheric conditions were not reported in their respective MSDS's. However, Flashpoint data was available and reported to be > 220°C, under atmospheric conditions. Based on the Flashpoint data, the AIT for both lubricant samples was expected to be > 220°C. The AIT test was conducted in a 1.1 litre, high pressure reactor. The AIT for both lubricant samples was determined to be < 195°C at 170 bar. The study showed that the AIT was significantly lowered with an increase in pressure.

Case Study 3 - Effect of Pressure and Temperature on the Flammability Diagram

It is known that an increase in pressure and / or temperature widens the flammable limits. Flammability diagrams are important tools to prevent the existence of a flammable atmosphere in a process.

A customer required flammability diagrams for a material at set pressures of 0.0, 6.0, and 9.0 barg, to assess and prevent the existence of flammable atmospheres in their process. Flammability diagram experiments were conducted in a 2.25 litre high pressure vessel. The results showed that the UFL and LFL in the 6.0 barg test were significantly wider than the values obtained for the 0.0 barg pressure test. The flammable limits for the 9.0 barg pressure test were seen to be significantly wider still.

Case Study 4 - Effect of Vacuum Pressure on Flash Point

A customer had experienced two flash fires in a pan filter that contained a combustible liquid with a Flashpoint of 47°C, at atmospheric pressure. The sequence of events leading to the incidents was as follows:

1. The filter cloth was placed on top of the pan and was supported by a metal grid.
2. A vacuum pump had been utilized to draw air from underneath the cloth, generating a negative pressure to enhance the filtration.
3. The filtration took place at ambient temperature, around 25 – 29°C.

Within a period of one week, two flash fires had occurred in the pan filter. One of the questions addressed in the investigation was; Why a flammable vapour / air mixture was formed at a temperature below the Flashpoint of the process liquid?

A Flashpoint test was performed on the liquid at 0.67 bara to reproduce the process conditions and a result of 19.4°C was obtained. The test result indicated that the Flashpoint of the product in the pan filter at 0.67 bara would be significantly lower than the reported Flashpoint found in the MSDS.

Case Study 5 - Effect of Oxygen on Auto-Ignition Temperature (AIT)

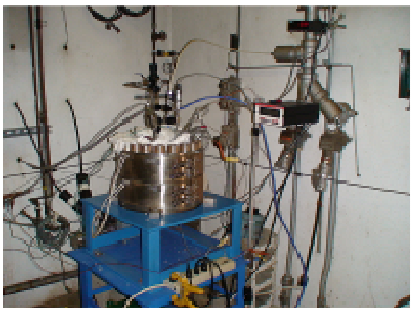
The AIT of a liquid under ambient conditions (in air) was determined at 321°C. In the process, the headspace of the reactor had to be filled with 100% oxygen. To examine the impact on the AIT, the scenario was reproduced in our laboratories in a 5 litre stainless steel high pressure vessel and the AIT result determined to be 210°C. This case study demonstrated that the AIT decreased by 110°C.

How Chilworth Can Help You?

It is essential to define a **Basis of Safety** for any process involving potentially flammable atmospheres. Where a process is operated on a

mixture, away from “standard conditions” or in an oxidant gas mixture markedly different from air, it is essential to develop the necessary data to define safe (and unsafe) process conditions. The vast majority of processes will not be performed at 25°C and atmospheric pressure – making direct measurement under process conditions essential.

Chilworth Technology has highly specialised flammability laboratories and four high pressure barricade (HPB’s) cells to determine / study the flammability characteristics of chemicals under process conditions. Each of the cells can be operated as an individual laboratory to conduct experimentation. The barricade cells have the capability for remotely monitoring the experiments from a control room. Each cell also has blast and missile-resistant windows to allow for direct observation of the experiments.



High Pressure & Temperature Flammability Test Set-up in the Pressure Barricade Cell Area

Based on the type of test (flammability, electrostatic, fire risk etc.), the test conditions (temperature, pressure, oxidant etc.) and the chemicals under test (toxic, corrosive etc.) it is important to select the correct vessel for experimentation. Chilworth Technology has a variety of pressure vessels ranging in volume from 75 ml to 5 litre with materials of construction including Stainless Steel, Hastelloy, glass-lined to Teflon-lined steel.

When dealing with chemicals under conditions of elevated temperatures and pressures, it is important to have technical staff who understand the potential hazards involved.

Chilworth Technology’s Process Engineers and Safety Specialists have extensive expertise in designing and safely conducting complex, bespoke experiments.

Contact us now for further details

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CHILWORTH DIRECTORY OF SERVICES

With the recent expansion of services at Chilworth it is useful to review what is now available.
The list below is an overview of the specialist areas where we are able to provide expert advice.

Consulting Capability

Organisation & compliance

- Safety Management
- Regulatory Compliance Support

Technical Specialist Areas

- Hazard Assessment and Risk Analysis
- Explosion Prevention & Protection
- Modelling
- Chemical Reactions
- Energetic Materials
- Electrostatics
- Fire Prevention & Protection
- Occupational Health & Safety
- Reliability

Protection & Equipment

- Inert Gas Protection
- Instrumentation and Equipment
- Pressure Vessels

Project Engineering

Incidents & Support

- Incident Investigation
- Litigation Support

Insurance Risk

Environment

Testing Capabilities

Process Safety

- Special Testing
  - Laboratory Testing
  - Field Tests (Large Scale)
- Explosion (Deflagration)
  - Dust
  - Gas / Vapour
  - Hybrid
  - Aerosol
- Thermal Stability / Chemistry
  - Chemical Reaction Hazards
  - Powder Thermal Stability
  - Chemical Process Optimisation
- Explosion (Detonation)
  - Propellants / Pyrotechnics
- ExplosivesFire
  - Mattress / Furniture
  - Custom Tests
  - Full Scale Simulation

Electrostatics

- Process Problems
- Applications
- Safety Test

Regulatory

- UN / DoT Transportation
- Classification Packaging Labelling (CPL)
- MSDS
- Notification Registration Evaluation
- REACH

Training Capabilities

Organisation & Compliance

- Process Safety Management
- Process Safety Culture
- COSHH
- OSHA Dust Explosion Prep Training
- ATEX 137 / DSEAR
- Environment / Integrated Management Systems
- Process Hazards Analysis

Technical Specialist

- Dust Explosion Prevention & Protection
- Control of Static Electricity
- Gas & Vapour Explosions
- Chemical Reaction Hazards / Thermal Stability
- Hazardous Area Classification
- HAZOP

Protection & Equipment

- IEC 61508/11 SIL Levels
- ATEX 94/9
- Hazardous / Electrical Area Classification
- Vent Design (Explosion, Pressure, Reactor Protection)

Instrument / Equipment Supplies (Chilworth Systems & JCI)

Process Safety Laboratory Equipment (Chilworth Systems)

- Special Equipment
  - Large Scale Explosion
  - High Pressure / Temperature
  - Custom Design
- Explosions
  - Dust / Gas / Vapour
  - Explosion Testing
- Thermal Stability Chemistry
  - Reaction Hazard Screen Tools
  - Adiabatic Calorimeter
  - Powder Thermal Stability
- Fire
  i-Cal (Fire Calorimeter)

Electrostatic Equipment (JCI)

- Laboratory Equipment
  - Electric Field Meter / Volt Meter
  - Charge Relaxation Time
  - Charge Measurement
- Field Test Equipment
  - Lightening Warning
  - Adverse Conditions Equipment

Regulatory (Systems)

- Physical or Chemical Properties Measurement