

Basic Understanding of “Process Safety”

Part-I



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BDMA India

Conference Hall, Jeedimetla

By
Hari Bukya

Hari Bukya

EHS professional; Experienced in Process Safety Management | Safety Management | Reactive Chemical Safety Testing's (RC1mx, ARC, RSD, ARSST, TSU, DSC & Powder Safety) Data Interpretation | Safe Scale Ups | Design Safety - Plant Automation (Logic's and Recipes) | Played Corporate EHS Role with strong chemical engineering back ground.

Experience : 15 + years

Qualification: Chemical Engineer

Current Company: Hetero Group



Certifications

Name/ Certificate of Training	Issuing Organization	Issue Date	Credential ID Certification Number
Certificate in Industrial Safety, (State Government Departments Boards of Technical Education, Telangana).		July'2012	No Expiration ID (IS614061305)
Certified PHA Leader (By Acutech Consulting Group)		Sep'2021; Mar'2023	No Expiration ID
ISO 45001:2018 (Lead – Auditor Course)		June'2019	3524812405
OHSAS 18001:2007 (Lead – Auditor Course)		Aug'2013	OHSAS-IA/2013/C
Reaction Calorimetry (RC1e) Operation, Data interpretation		Nov'2020	MTIN/AC/Sai/14.
Thermal Screening Unit (TSu) Operation & Data Interpretation		July'2020	No Expiration ID
Rapid Screening Unit (RSD) Operation & Data Interpretation		March'2020	No Expiration ID

Work Experience

	Aragen Life Sciences (Formerly GVK BIO) Corp. Dy. General Manager – Process Safety,
	Pfizer Healthcare India Pvt. Ltd. Process Safety Lead (Pfizer Global Supply)
	Alembic Pharmaceutical Ltd. Corporate Process Safety Lead
	Dr. Reddy's Laboratories Ltd. Sr. Team Member – SHE (PSM)
	Mylan Laboratories Ltd. Sr. Engineer – EHS (Process Safety)



Today's Major challenges –for Industries



- To Decreasing Production costs.
- To Meet Regulatory compliances.
- Shortage of skilled/ unskilled laborers which affects the productivity of the industry.

Today Outline – Part 1

1) Part-I

Basic Understanding of Process Safety in Pharma & Chemical Industries.

- What is Process Safety ?
- What is Process Safety Management ?
- A Comparative analysis of Process safety management (PSM)
- Why Process Safety ?
- What is Process Safety Triangle ?
- What is necessary for a safe Process?
- General Flow in Manufacturing in Intermediates / APIs
- Type of Processes, Reaction and Thermal Stabilities & Criticalities ?
- Video & Discussions

2) Part –II

++ Powder Safety.....



What is Process Safety ?

Definition : Process Safety is an interdisciplinary engineering domain focusing on **“Prevention of unintentional release of chemicals, energy , or other potentially dangerous materials** during the course of chemical manufacturing processes that can have a serious effect on the **People , Property & Environment.**

Interdisciplinary engineering:

like Combination of Mechanical, Chemical, Environmental, Electrical & Industrial Engineering ...etc.

Process Safety helps to understand & Prevention of hazards

Hazards Examples:

- Prevention of leaks , spills, over pressure , over temperature, equipment malfunction, corrosion , metal fatigue and other similar conditions.
- Focus on design and engineering of facilitates . Maintenance of equipment effective alarm , effective control point , procedure & training.

What is meant by Process Safety Management ?

Process Safety Management, or PSM, is a standard (OSHA/ CCPS/ CIMAHA...) that requires employers to identify, evaluate, and control the hazards associated with the highly hazardous chemicals used in their processes.

Is a Blend of

→ Engineering

management
skills



A Comparative analysis of Process Safety Management (PSM) systems in the process industry

Process Safety Management (PSM) System Elements

These all models organized similarly to the OSHA, CCPS, PDCA & CIMAHA framework only.

OSHA, CCPS, DuPont, ILO PSM Models are More Robustness & More Flexible in Pharma & Chemical Manufacturing Industries.

Process Safety Management (PSM) System Elements	Energy Institute High-Level PSM Framework - Energy industry	DuPont ORM/PSM Model (Various industrial)	OSHA PSM (Manufacturing Chemicals)	AICHe/CCPS RBPS- (Chemical Process Industries)	Responsible Care Process Safety - Petro	CSCHE PSM - Chemical (CCPS Frame)	API RP 75/SEMS Oil and Gas	API RP 750 Oil and Gas	COMAH Regulations All hazardous Indu	CIMAHA Regulations - All industrial	Safety Case - offshore	BP OMS Oil and Gas	ExxonMobil OIMS Petro	IOGP/IEPCA OMS Oil and Gas	PSI4MS - Chemical	CMS (Ref; OSHA Mng)	EPR model Hhazardous Indu OSHA	ILO PSM Frame Hhazardous Indu C	EPA RMP Chemical petroleum	IPSMS Model - Oil and Gas
1. Management commitment, responsibility and accountability to process safety	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2. Compliance with legal and industry standards	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3. Worker consultation	✓		✓	✓					✓	✓	✓			✓				✓		✓
4. Objectives, targets and safety programs				✓	✓	✓	✓	✓						✓		✓	✓			✓
5. Employee, contractor and supplier selection and management	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓
6. Stakeholder involvement	✓			✓			✓	✓				✓	✓	✓			✓		✓	✓
7. Process hazard analysis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
8. Health evaluation and fitness for duty				✓			✓	✓				✓	✓	✓					✓	✓
9. Document and record control, and process knowledge management	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓
10. Operating manuals and procedures	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
11. Process safety information	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓			✓	✓	✓
12. Standards and safe work practices	✓	✓		✓		✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
13. Management of change	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓
14. Operational readiness and pre-startup reviews	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
15. Emergency planning and response	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓
16. Inspection and maintenance	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓
17. Performance and quality assurance		✓		✓					✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
18. Asset integrity and management of safety critical devices	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
19. Operational control, permit to work and risk management	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
20. Communication amongst workers				✓	✓		✓	✓						✓						✓
21. Training, competency and performance		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
22. Incident reporting	✓			✓			✓	✓	✓	✓	✓			✓		✓			✓	✓
23. Benchmarking				✓			✓	✓				✓	✓	✓		✓				✓
24. Audits	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			✓				✓	✓	✓
25. Incident investigation	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓		✓	✓	✓
26. Management review and intervention for continuous improvement	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓

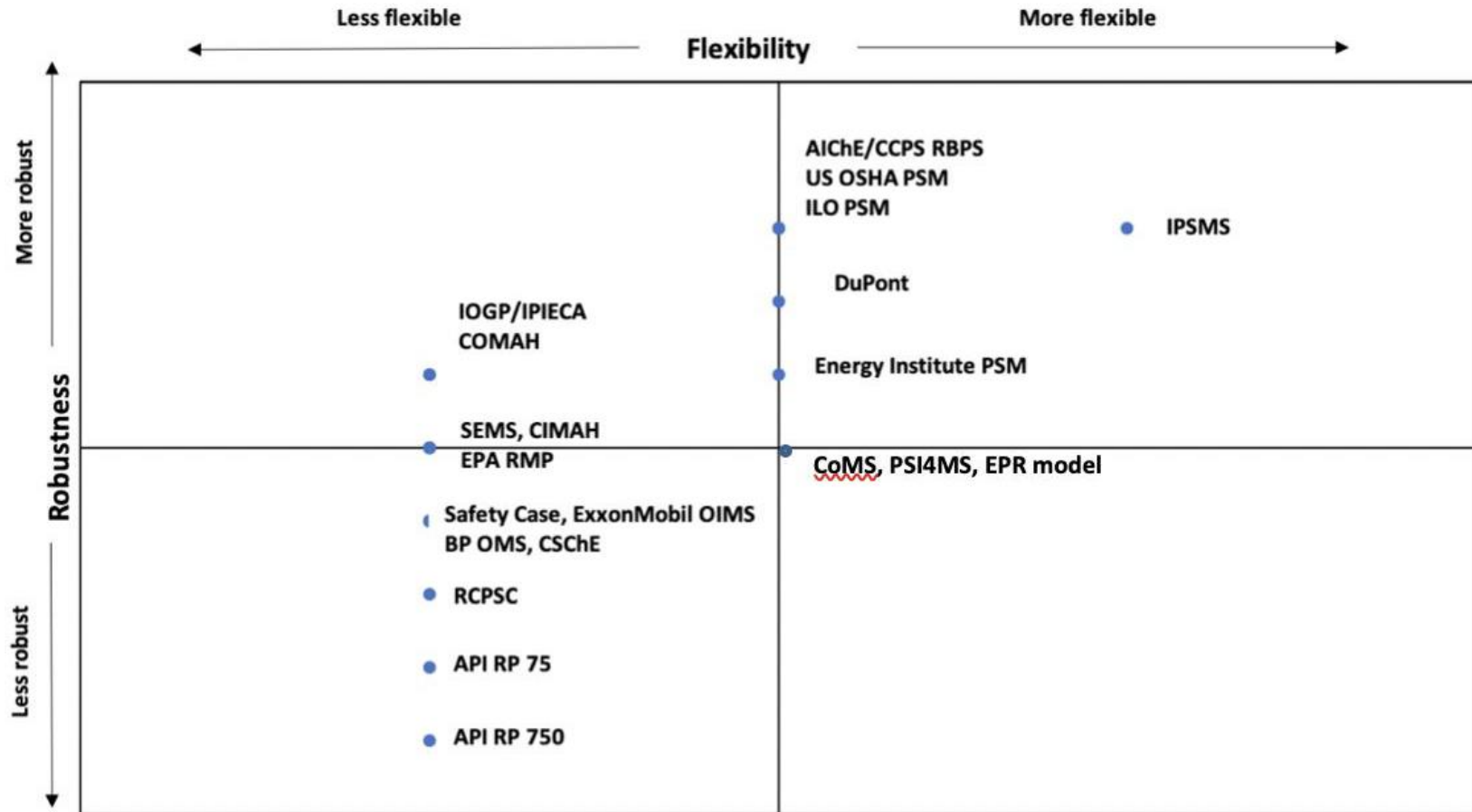


Figure. Quadrant matrix showing the flexibility and robustness of PSM systems in the process industry

Why Process Safety ?..



Incidents in chemical industries take lives, cost businesses, damage company reputation and may even result in the industry close down.

- Due to Lack of knowledge and understanding/ Assessment of hazards associated with the process.



Process Safety Triangle ??

FIRE TRIANGLE

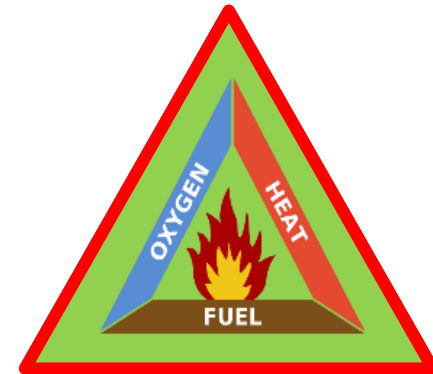


DUST EXPLOSION



PROCESS SAFETY TRIANGLE

Chemicals
(Potential Energy)



Reaction Rates

(Energy Release and gas production)

Plant System

(Capability to deal with the heat & gas production).

- Inadequate knowledge & improper implementation of any of these elements – Leads to process safety incident (**FIRE/ EXPLOSION/ SPILL/ EXPOSURE.....**)

Exothermic reaction:

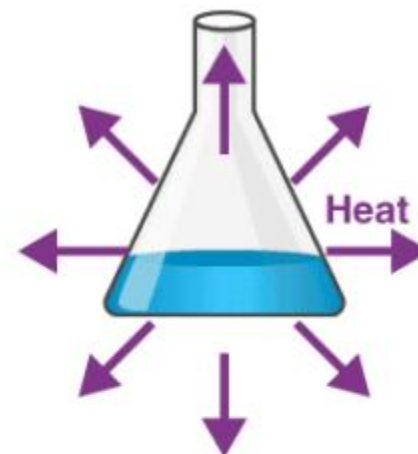
An exothermic reaction that releases energy from the system in the form of heat.

And can be controlled

Runaway Reaction:

reaction that releases energy from the system in the form of heat. And which cannot be controlled

. This is often result in an explosion.

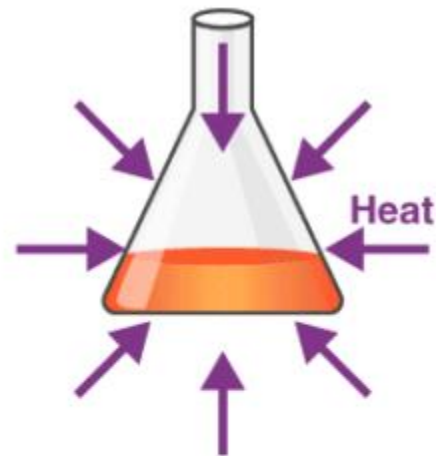


Exothermic Reactions

A reaction that releases energy from the system in the form of heat.

Endothermic reaction:

An endothermic process absorbs heat, from its surroundings in the form of heat



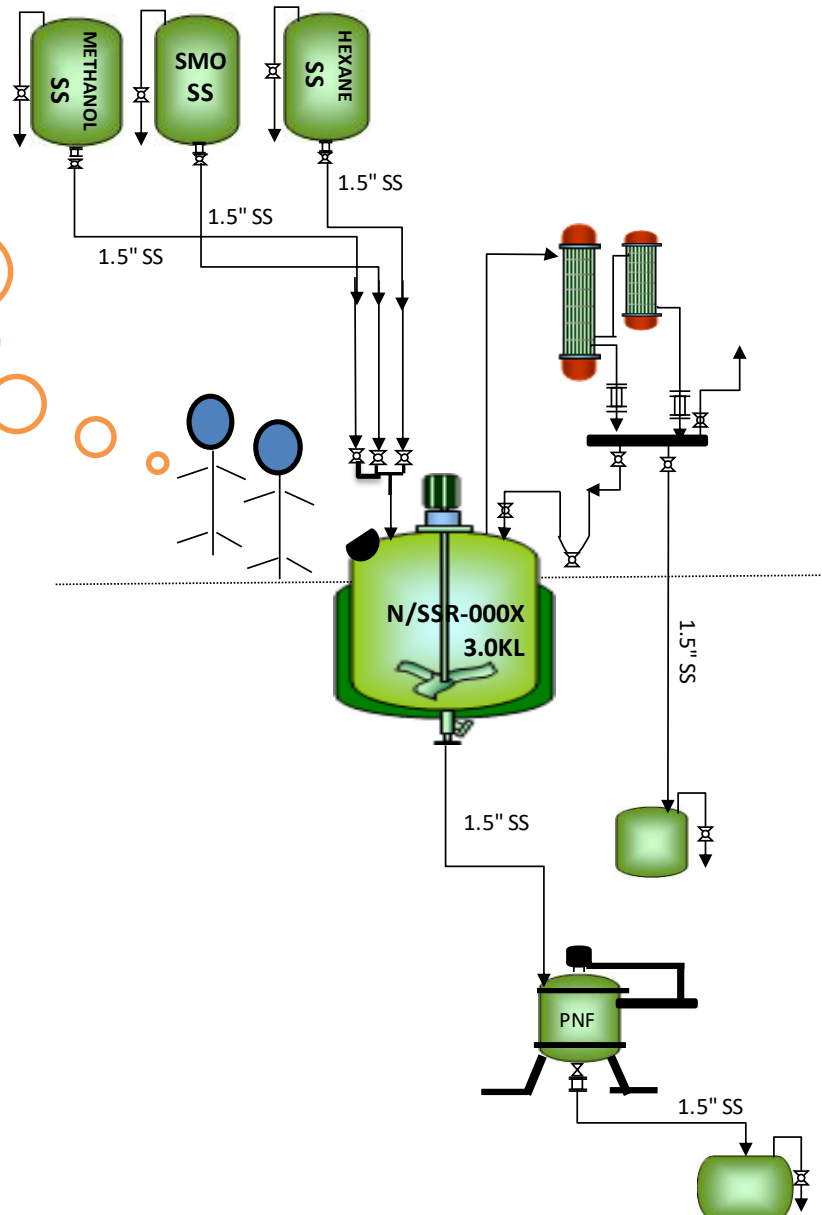
Endothermic Reaction

A reaction that the system absorbs energy from its surrounding in the form of heat.



What is necessary for a safe Process?

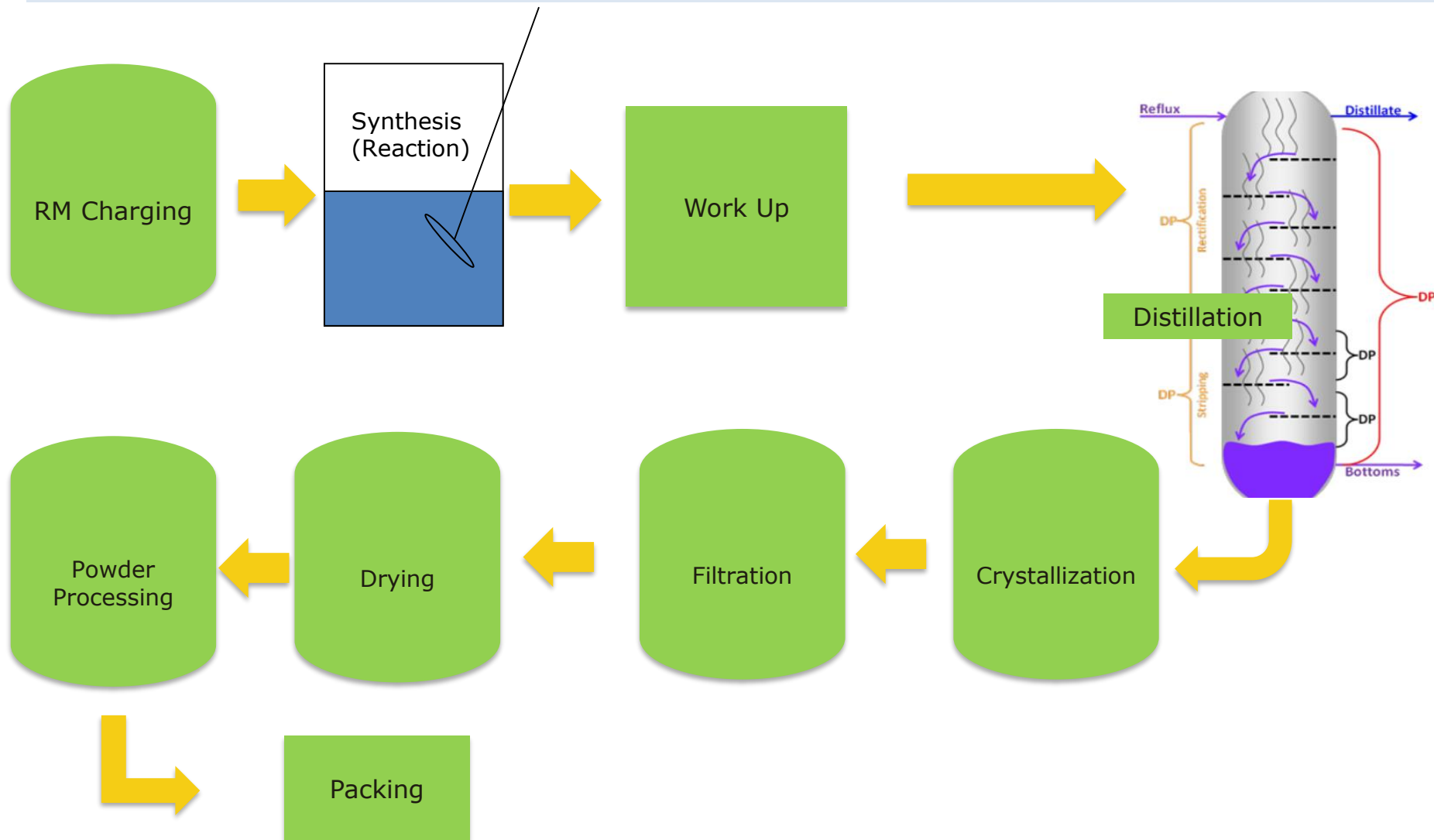
What is
necessary for a
safe Process?



VTD



Unit Process & Unit Operation flow in Manufacturing in Intermediates / APIs



Type of Processes

Batch Processes

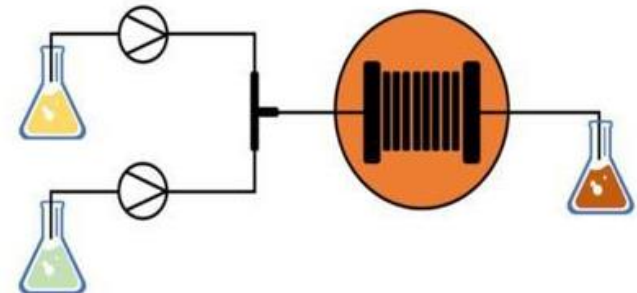
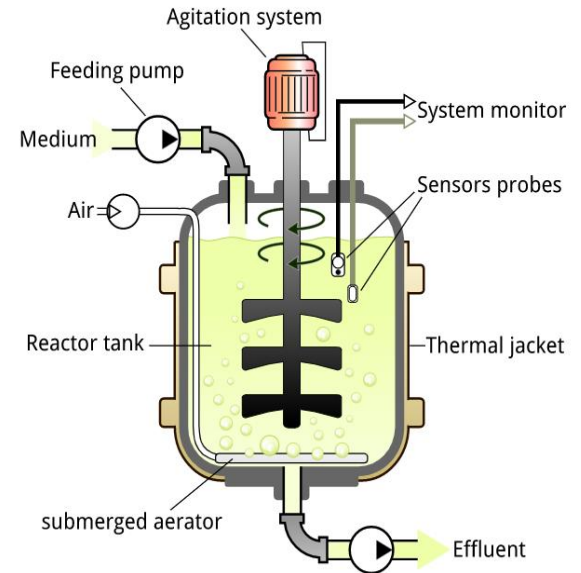
All reactants fed to the reactor at the beginning of the process and the products are removed when the reaction is complete. No reactants are fed to the reactor and no product is removed during the process.

Semi Batch Processes

A semi-batch process is when reactants are **periodically** added or products are periodically removed. The textbook defines semi-batch processes as “neither batch nor continuous.”

Continuous flow processes

Continuous flow processes are where the inputs and outputs of the reactor flow at a constant

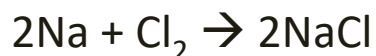
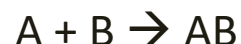


Types of chemical reactions from chemistry point of view :

There are 4 types of chemical reactions:

1. Synthesis Reaction

2 or more simple substances combine to form a new, more complex substance.



2. Decomposition Reaction

A complex substance breaks down into 2 or more simpler substances. These are the reverse of synthesis reactions!



3. Single-Replacement Reaction

An element replaces another element that is part of a compound.



4. Double-Replacement Reaction

Atoms from two different compounds replace each other. Two compounds react to form two new compounds.



Examples of Few reactions and their severity

Reaction Type	Severity	ΔH (KJ/Kg)
Amination	Moderately exothermic	80 to 420
Esterification	Moderately exothermic	80 to 420
Methylation	Mildly exothermic	< 80
Alkylation	Mildly exothermic	< 80
Hydrolysis	Mildly exothermic	< 80
Salt formation	Mildly exothermic	< 80
Reduction	Slightly exothermic	< 80
Electrolysis	Slightly exothermic	< 80
Isomerization	Slightly exothermic	< 80
Cyclization	Slightly exothermic	< 80

Reaction Type	Severity	ΔH (KJ/Kg)
Oxidation	Highly exothermic	> 1250
Nitration	Highly exothermic	> 1250
Halogenation	Highly exothermic	> 1250
Organometallics	Highly exothermic	> 1250
Diazotization	Highly exothermic	> 1250
Hydrogenation	Highly exothermic	> 1250
Thermal decomposition	Highly exothermic/ Exothermic	420 to > 1250
Polymerization	Highly exothermic/ Exothermic	420 to > 1250
Sulfonation	Exothermic/ Moderately exothermic	80 to 420
Condensation	Exothermic/ Moderately exothermic	80 to 420

Based on rate of Reaction

Semi Batch Processes



Type of Reactions

1. Instantaneous Reaction / Fast Reaction / Dose Controlled.
2. Accumulation Reactions
 - Starts from reagent addition to reaction completion during maintenance
 - Accumulated energy release - During Heating
3. Delayed Initiation of Reaction
 - After 20-30% of addition of reagent
 - Accumulated energy release - During Heating

Batch Processes



Type of Reactions

1. Energy release during heating & maintenance.

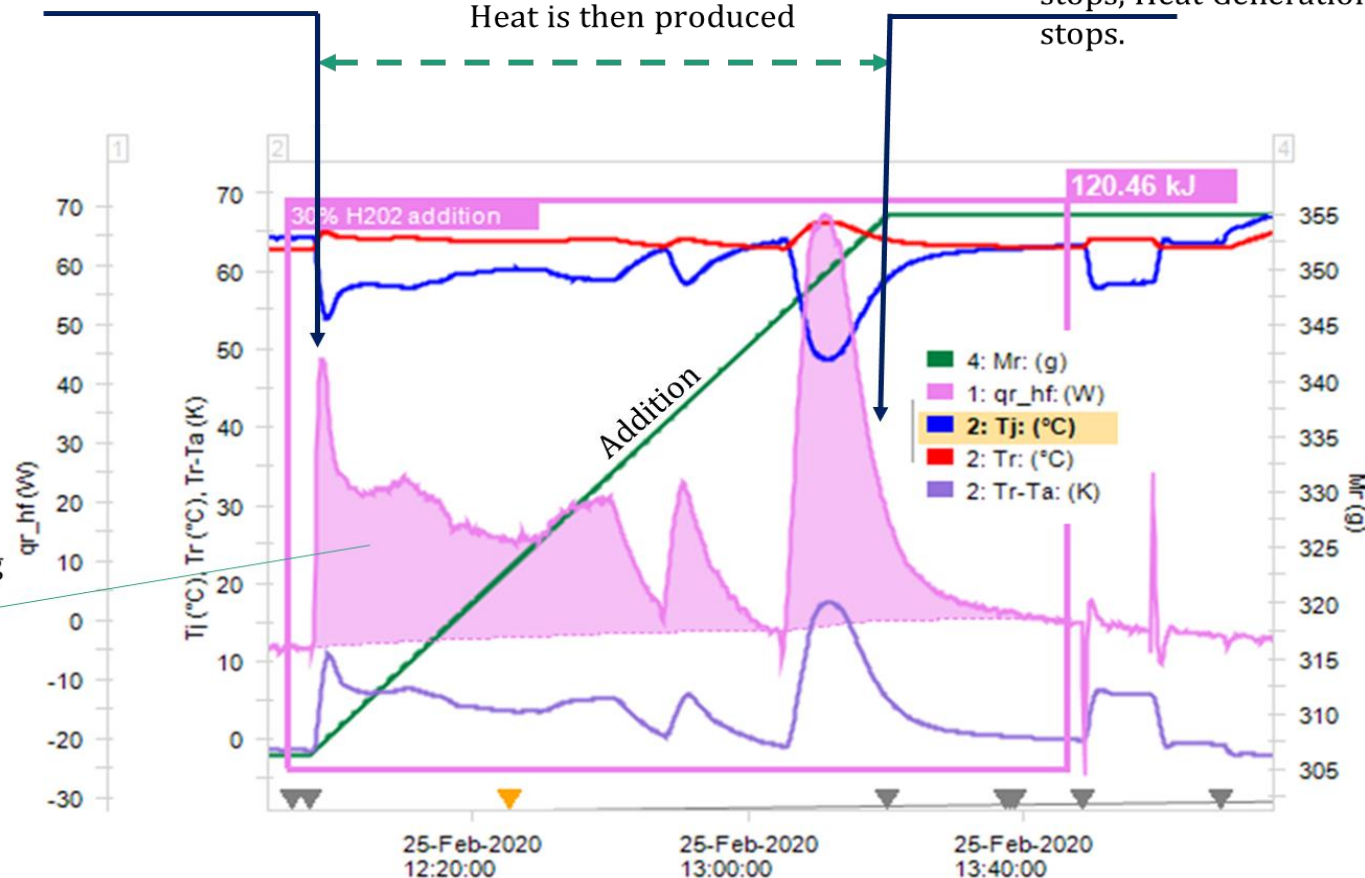
Instantaneous Reaction / Fast Reaction (Dose Controlled Reaction)

As Soon as the addition starts, Heat Generation can be seen in the Isothermal Calorimetry data

As Soon as the addition stops, Heat Generation stops.

Heat is then produced

Heat output during addition

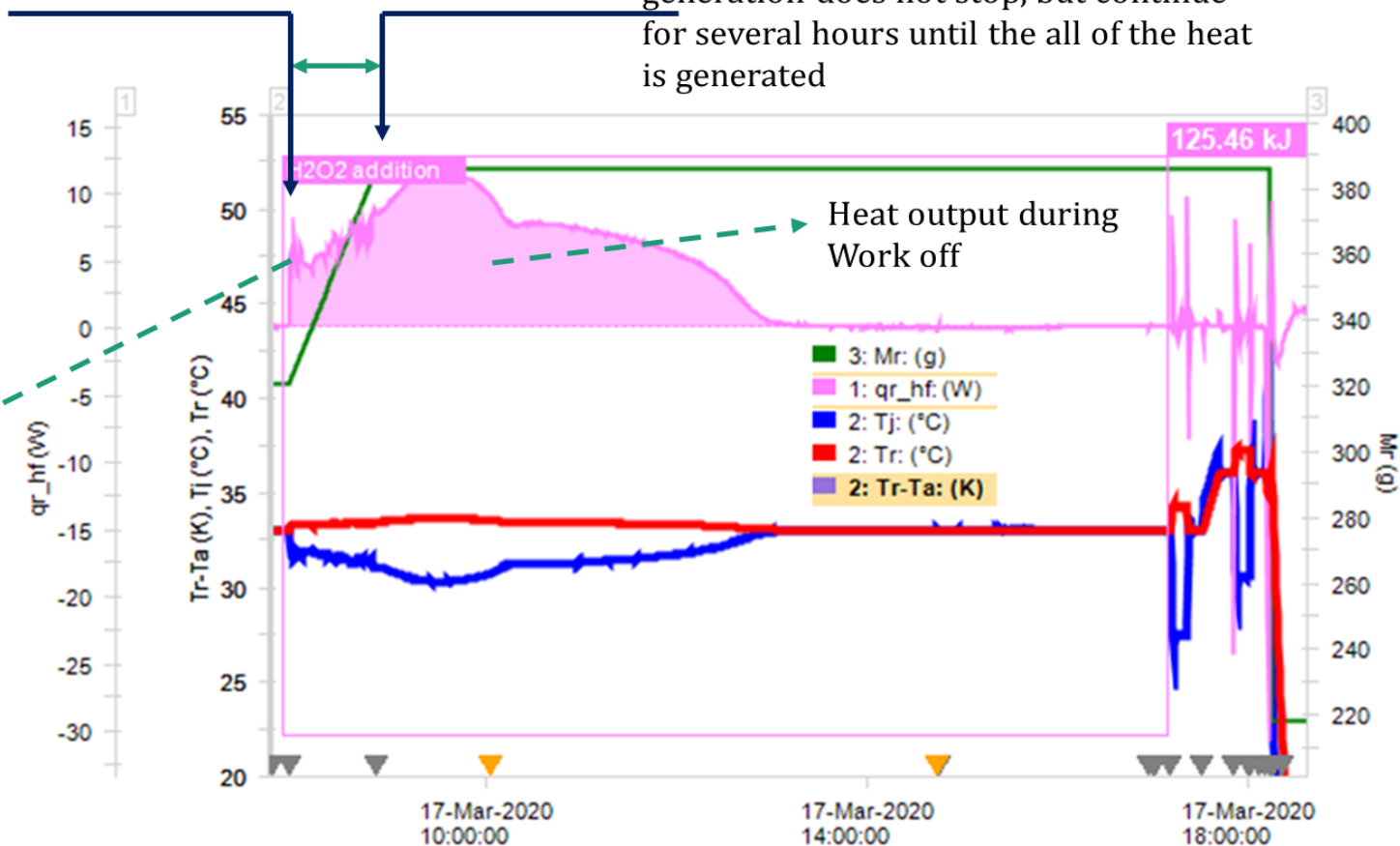


Accumulation Reaction

When the addition starts, the reaction slowly starts to generate Heat

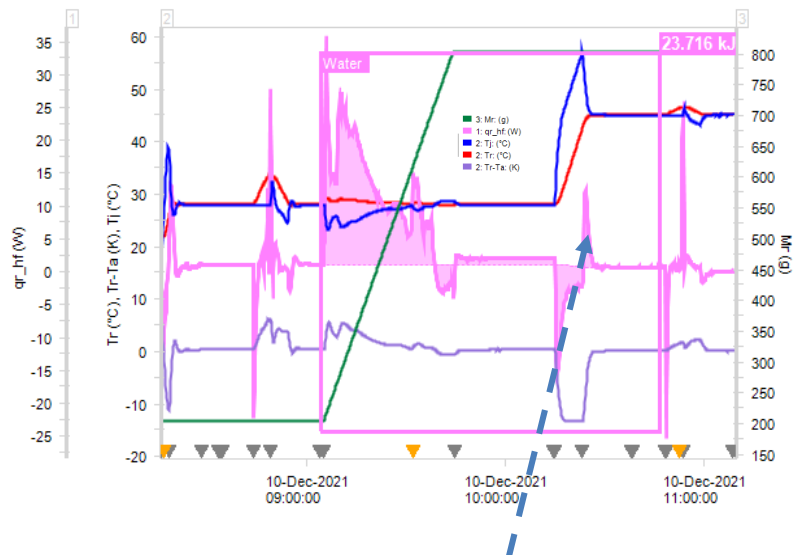
When the addition stops, the heat generation does not stop, but continue for several hours until the all of the heat is generated

Heat output during addition

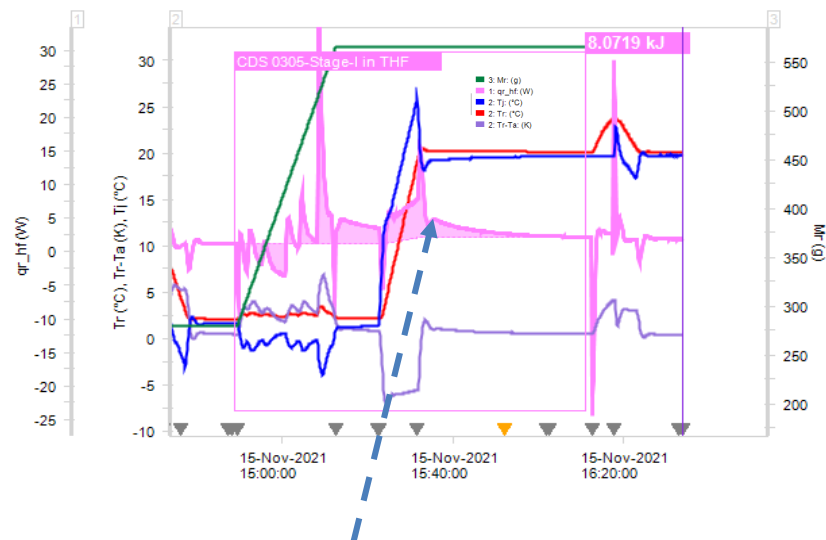


Example – Graphical Representation :

Accumulation Reaction-Energy release during heating



Heat liberation
during heating



Heat liberation
during heating

Example – Graphical Representation :

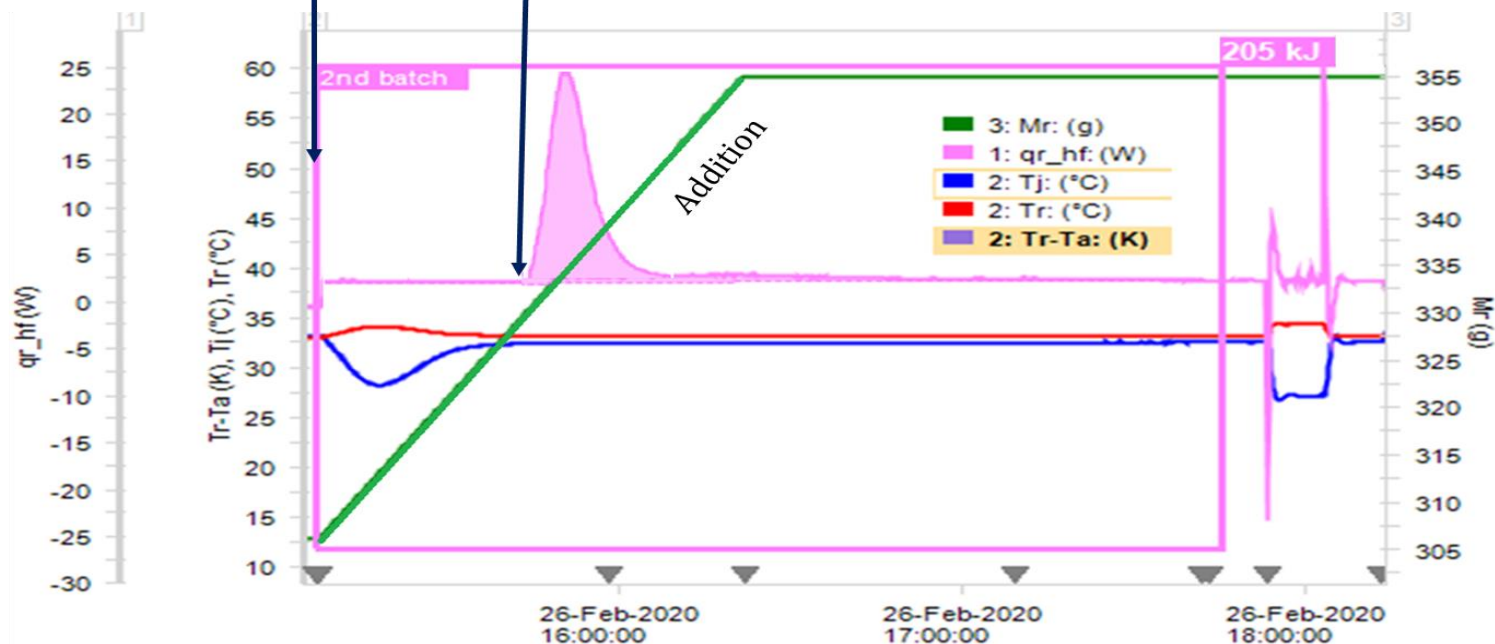


Delayed Initiation of Reaction

When the addition starts, the reaction does not have any significant heat generation.

No Significant heat is generated for the first 15 mins of the addition

After Approximately 15 Mins the reaction initiates and suddenly release a large amount of heat



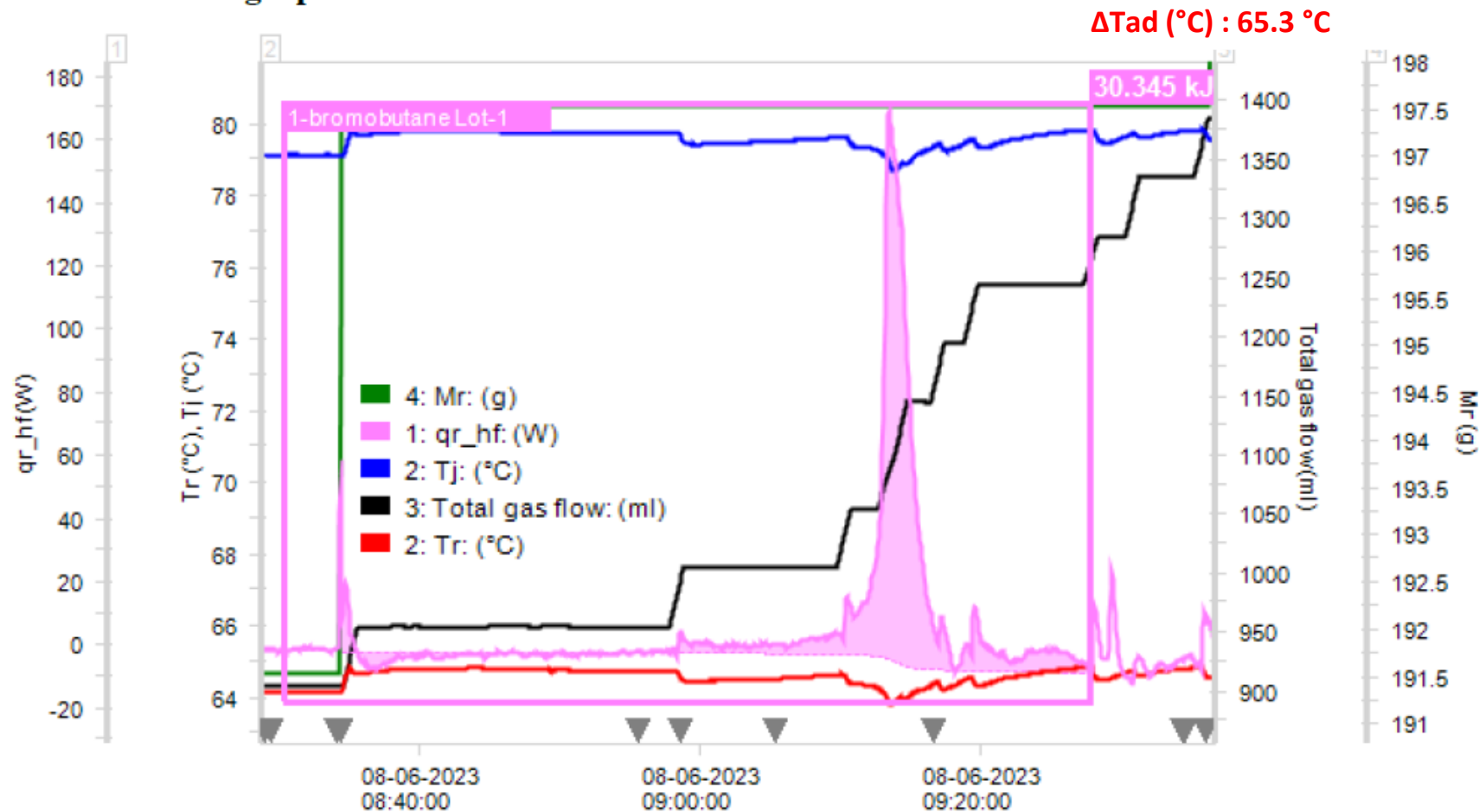
This could be hazardous on plant as the large heat generation may exceed the cooling capacity of the plant. This may cause a significant rise in the temperature of the batch

Example – Graphical Representation :

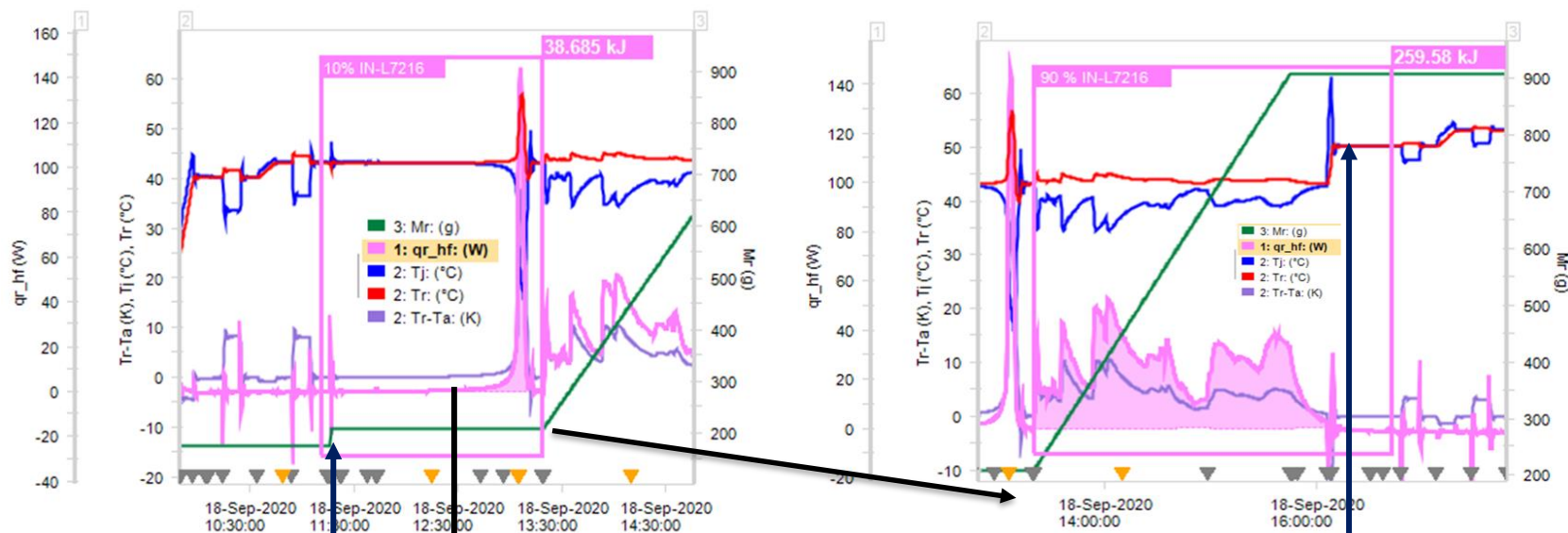
Delayed Initiation of Reaction – Grignard Preparation



RC1mx trends graph: 1-Bromobutane Lot-1 addition



Delayed Initiation of Reaction – Grignard



After 10% addition of reagent the addition starts, the reaction does not have any significant heat generation.

After Approximately 60mins the reaction initiates and suddenly release a large amount of heat

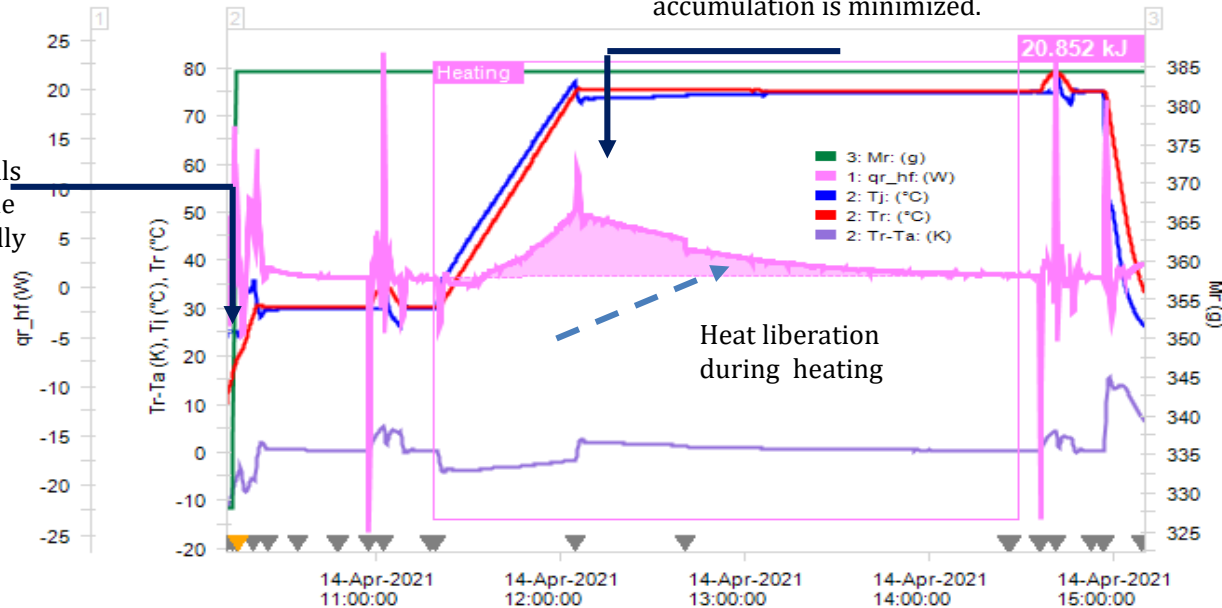
Heat liberation during remaining 90% addition of the reagent and during heating

- This could be hazardous on plant as the large heat generation may exceed the cooling capacity of the plant. This may cause a significant rise in the temperature of the batch

4. Batch Process - Energy release during heating & maintenance.

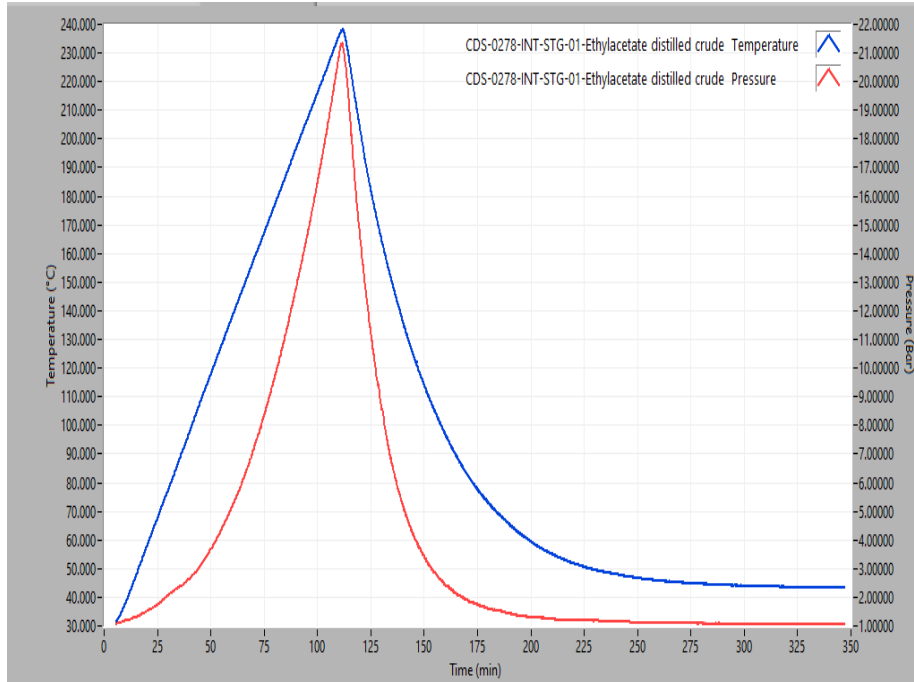
The heat generation continue for several hours until all the thermal accumulation is minimized.

All the raw-materials are charged in to the reactor and gradually heated to desired temp.

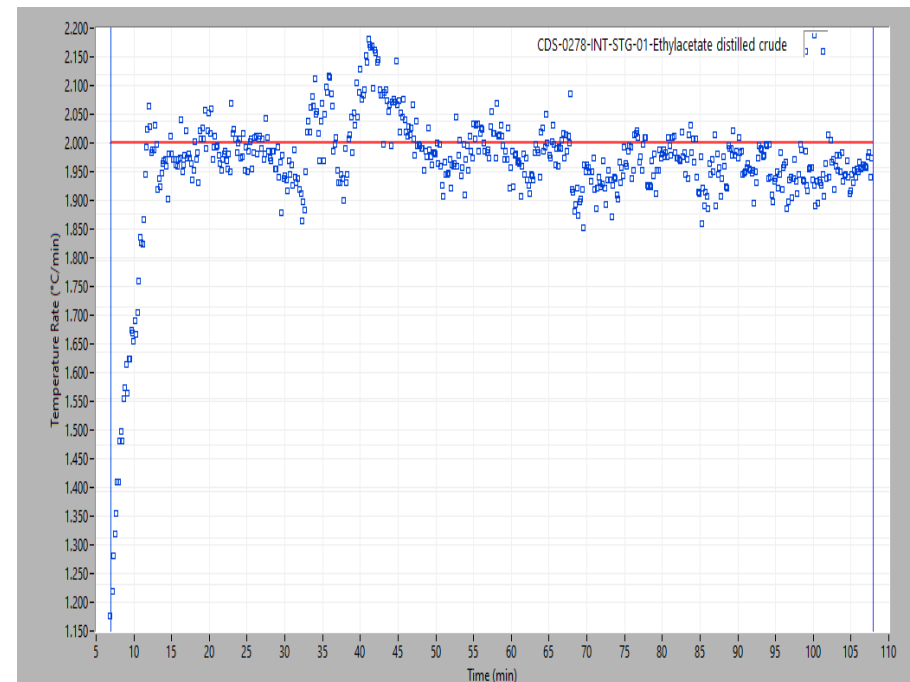


This could be hazardous on plant scale as the large heat generation may exceed the cooling capacity of the plant due to high thermal accumulation. This may cause a significant rise in the temperature of the batch in such scenarios it is recommended to convert the batch process to semi-batch mode to reduce the severity of the risk.

Typical - Thermal Stability Report (Graphical Representation)

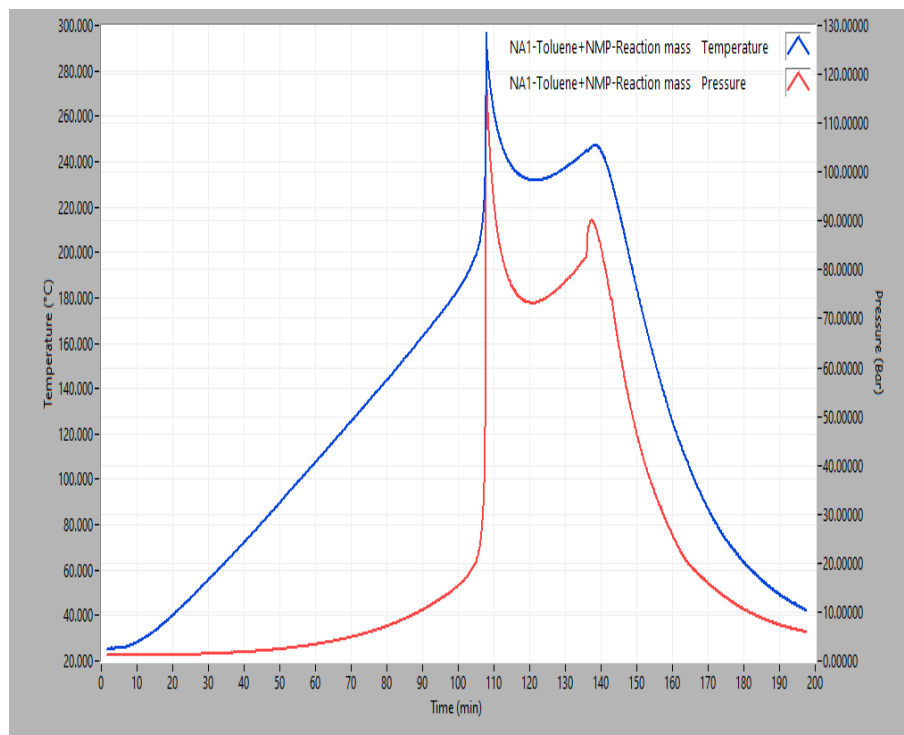


Temperature and pressure graph

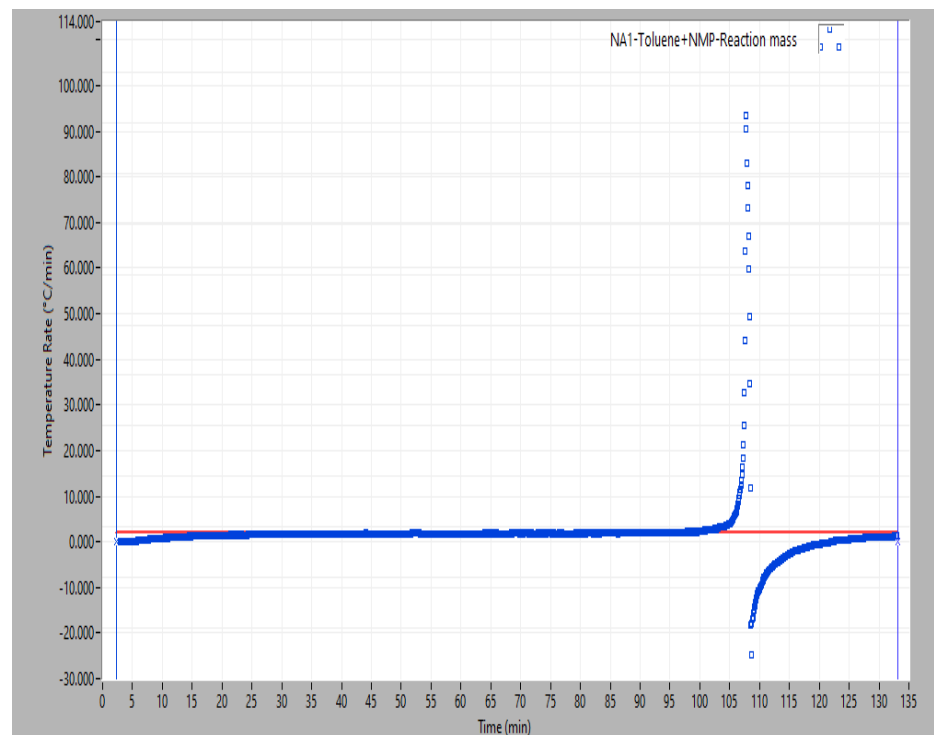


Temperature rate graph

Typical - Thermal Stability Report (Graphical Representation)



Temperature and pressure graph



Temperature rate graph

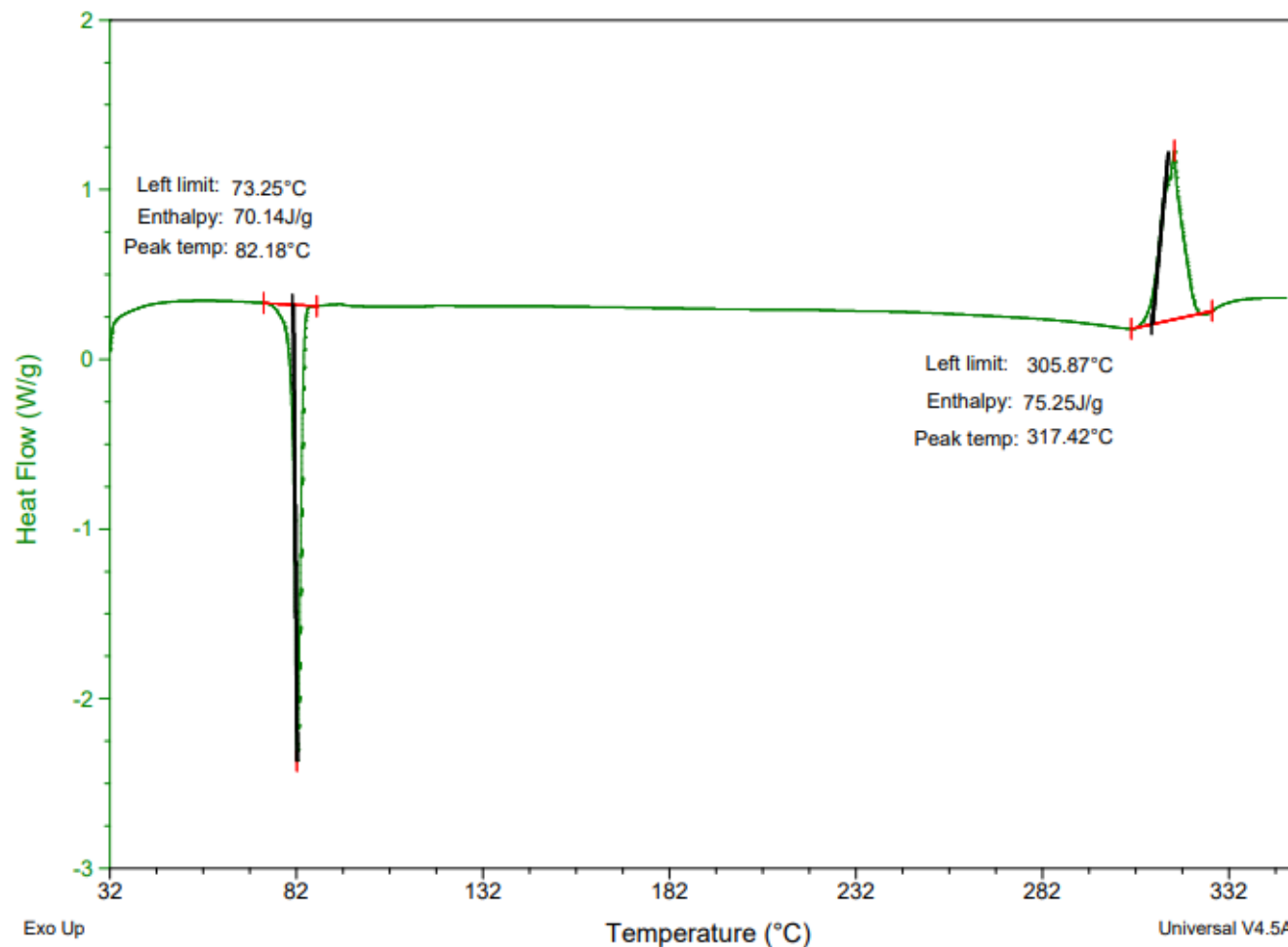
Typical - Thermal Stability Report (Graphical Representation)

Sample: CPP (Starting material)
Size: 4.8200 mg
Method: Ramp:5.00 °C/min to 350°C

DSC

File: C:\... \ENC-1\CPP (Starting material).001

Run Date: 19-Apr-2023 15:05
Instrument: DSC Q20 V24.11 Build 124



Reference

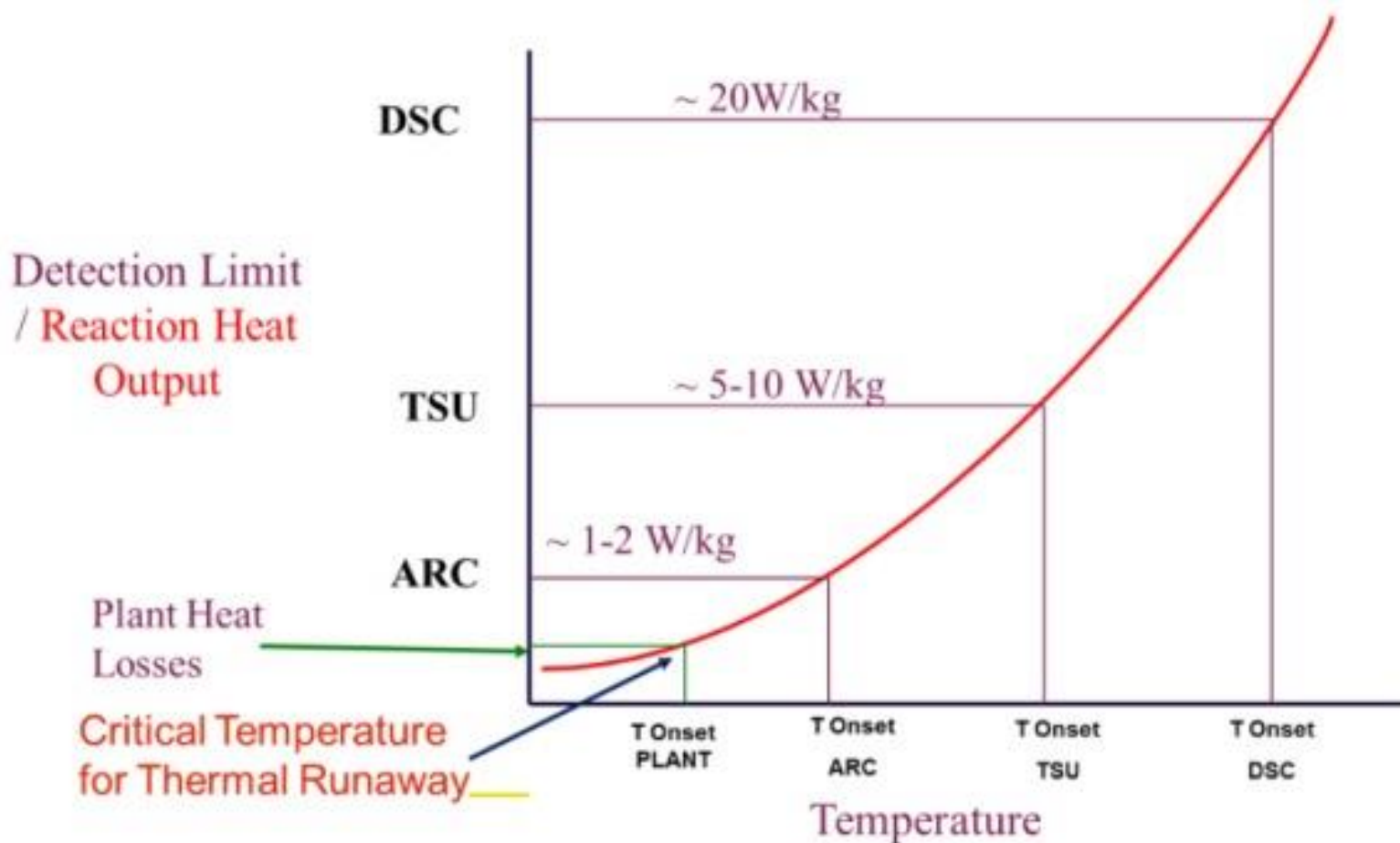


Table below gives a summary of onset of decompositions by DSC, TSU and ARC

Source: A comparison of reaction hazard screening techniques, OPRD 2002,6, 933-937, D.J.Dale, Pfizer global research and development, Pfizer Ltd

Compound name	DSC (°C)	TSU (°C)	ARC (°C)
2-amino-4-chloro-5-nitrophenol	205	198	166
Di-tert- butylperoxide	164	160	116
4-methoxy phenylhydrazine hydrochloride	135	130	121
Methyl carbazate	189	180	141
Azo-iso-butyronitrile	99	79	56
Hydroxylamine sulphate	190	161	131
2,4-dinitroaniline	285	280	266
Dibenzoyl peroxide	99	94	86
3-methyl-4-nitrophenol	247	193	181

Some Reference Graphical Representation



Definitions

Heat of reaction, also called enthalpy of reaction, the amount of heat that must be added or removed during a chemical reaction in order to keep all of the substances present at the same temperature.

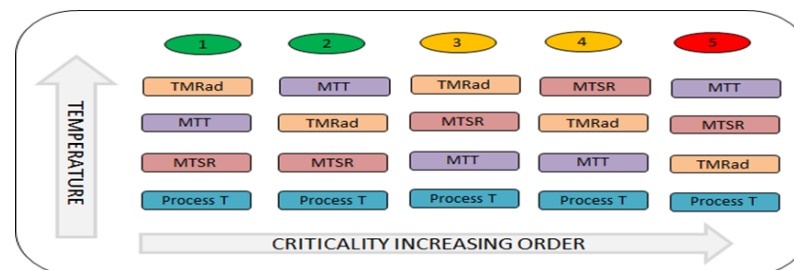
Adiabatic Temperature Rise ($\Delta T_{adiabatic}$): The maximum temperature rise that can be achieved from an exothermic reaction. It assumes that all of the heat from the reaction went to raise the temperature of the reaction mixture and is calculated from the heat of reaction assuming adiabatic conditions.

($\Delta T_{adiabatic} = \Delta H_r / m \cdot C_p$ where C_p is the average molar **heat capacity** of the sample).

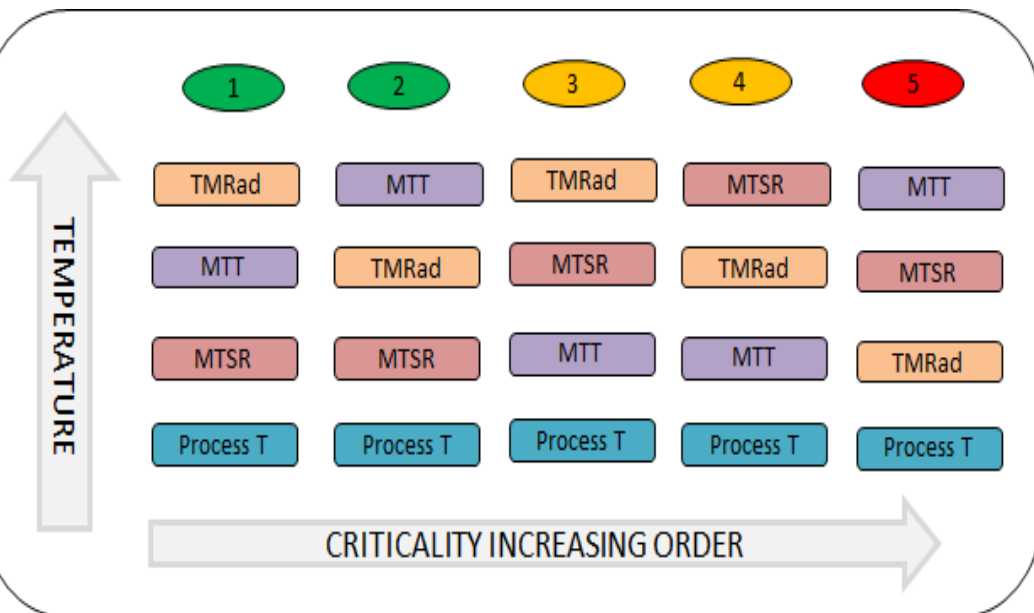
Specific Heat of Water: (C_p) is approximately 4.2 J/g°C

Time to Maximum rate (TMR): The time taken for a material to self-heat to the maximum rate of decomposition from the specific temperature.

Stossels Criticality Index (SCI) uses the heat of reaction data and thermal stability data to define a reaction class.



Chemical Reaction Risk Assessment: Stoessel Criticality Class

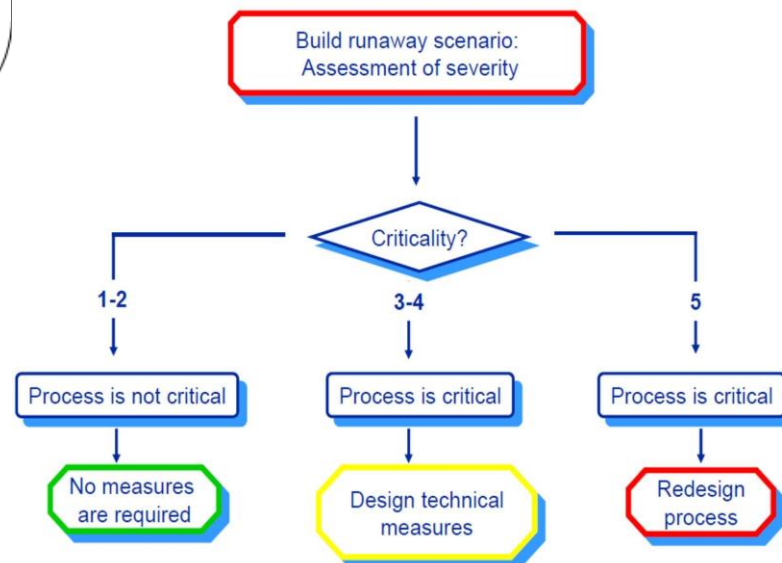


Tp: Process Temperature;

MTT or B.P.: Maximum Technical Temperature or Boiling Point

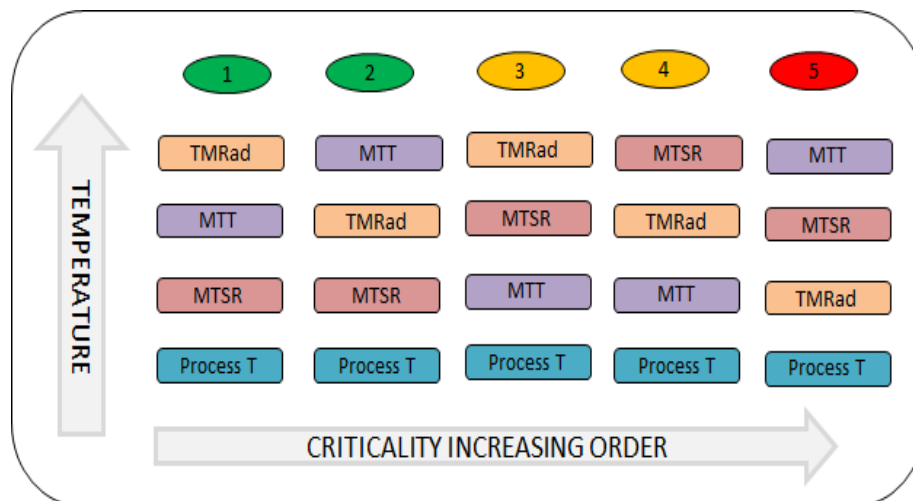
MTSR: Maximum Temperature of Synthesis Reaction

ADT24/ TD24: Temperature at which TMRad is 24 Hrs



Chemical Reaction Risk Assessment: Stoessel Criticality Class

S.No	Type of Reaction	Reagent Name	Process Temp(°C)	MTSR (°C)	Process Solvent	MTT (B.P)	Thermal Onset (°C)	Criticality class
1	Chlorination reaction	DMF addition	0	3.2	DCM	39.6	ND upto 200	I
2	Mesylation reaction	Methane sulfonic acid addition	15	19.4	DMSO	189	170	II
3	Esterification reaction	Thionyl chloride	10	216.5	Methanol	64.7	ND upto 200	III
4	Vilsmeier-Hack reagent preparation	POCl ₃ addition	0	112.7	Chloroform	61.2	90	IV
5	Reduction	Sodium Borohydride (8-Lots)	70	228.5	N,N dimethylacetamide	165	125	V



Severity Classification

Risk = Severity x Probability

Severity gauged by Interpretation of adiabatic temperature rises

Probability gauged by Interpretation of adiabatic induction time or time to maximum rate

Adiabatic Temperature Rise range	Severity Interpretation	Time to maximum rate range	Probability interpretation
$\Delta T_{ad} > 200^{\circ}\text{C}$	High	$\text{TMR}_{ad} < 8\text{hr}$	High
$50^{\circ}\text{C} < \Delta T_{ad} < 200^{\circ}\text{C}$	Medium	$8\text{h} < \text{TMR}_{ad} < 24\text{hr}$	Medium
$\Delta T_{ad} < 50^{\circ}\text{C}$ and no gas evolution	Low	$\text{TMR}_{ad} > 24\text{hr}$	Low

Hazard Class	Severity Range	Heat of Reaction (Q) in kJ/Kg
High	Catastrophic	>800
	Critical	400-800
Medium	Medium	100-400
Low	Negligible	<100



**WHEN,
WHERE,
WHAT data to be generated ?**

Activity/ Process	Thermal Stability Studies (DSC/RSD/TSu/ ARSST/ ARC)	Reaction Calorimetry Studies RC1mx/ Simular	Powder Safety
Raw Material's, Key Starting Material's			
Reactions $A + B + C + D \rightarrow E + F + G$ Media – Any Solvent			
Quenching/ Reverse Addition			
Distillation / ML's			
Drying (TD/ VTD/ ANFD/ RCVD/ Fluid Bed)			
Powder Processing (Mixing/ Milling/ sieving/ Blending/ Packing)			
What Data we get ?			

Activity	Thermal Stability Studies (DSC/RSD/TSu/ ARSST/ ARC)	Reaction Calorimetry Studies RC1mx/ Simular	Powder Safety
Raw Material's, Key Starting Material's	YES - Solids (or) Liquids Sample	NA	*YES (Example: For Solids – charging
Reactions $A + B + C + D \rightarrow E + F + G$ Media – Any Solvent	*YES (Rxn. Mass) <u>Before Maintenance:</u> For Rxn. kinetic Study & Decomposition. <u>After Maintenance:</u> For decomposition Temperature	Yes - Perform RC Studies - (For Desired Reactions : Semi Batch / *Batch Rxn.'s)	NA
Quenching/ Reverse Addition	*YES (Suggested for neat Rxn's. Not for Aqueous Solution Media)	Yes (Perform RC Studies)	
Distillation / ML's	*YES (After Distillation - Crude)		
Drying (TD/ VTD/ ANFD/ RCVD/ Fluid Bed)	YES (Melting Points & Tonset - Decomposition Temperature)		YES
Powder Processing (Mixing/ Milling/ sieving/ Blending/ Packing)	YES (Melting & Tonset - Decomposition Temperature)		YES
What Data we get ?	T _{onset} , (Primary & Secondary) P _{onset} , dT/dt. dP/dt, TMRad/TD24, Melting Range, Heat of Reaction.	Heat of Rxn, Adiabatic Temp, MTSR, Cp, Criticality Class, Add. Temp. & heat Load Capacity	Dust Explosion Screening, MIE, MIT, Impact Sensitivity, Friction Sensitivity

Few instruments with Data ?

S. No	Equipment / Activity	What data we get?
Reaction Calorimetry studies		
1	RC	Heat of reaction(ΔH), Adiabatic temperature rise (ΔT_{ad}), MTSR values, G as liberation, Cp values, Thermal accumulation (%)
Thermal screening		
2	Accelerating Rate Calorimeter	TD24, dT/dt & dP/dt etc.
3	Rapid Screening Device	Non condensable gaseous, dT/dt & dP/dt
4	Differential scanning calorimetry	Tg,Melting,decomposition,heat of reaction
5	Advanced reactive system screening tool	ΔT_{ad} , ERS, SADT,Heat of reaction
Powder safety		
	Ignition sensitivity	
6	Minimum Ignition energy (MIE) with Dust Explosivity Screening unit	MIE values (mJ) , Dust Explosion Class (Stb)
7	Minimum Ignition Temperature Test (MIT)	Minimum Ignition Temperature values
8	5mm Layer Ignition Temperature Test (LIT)	MIT of 5mm thickness of powder
	Impact sensitivity	
9	BAM Fallhammer Test	Impact Sensitivity
10	BAM Friction Test	Friction sensitivity
	Electrostatic properties	
11	Powder Resistivity Test	Conductive,disippative,resistivity values
12	Charge decay (CD) Analyser	Charge relaxation time
13	Liquid Conductivity Test	Liquid Conductivity data
	Fire analysis	
14	Burning Behaviour Test	Burning classification

<https://www.youtube.com/watch?v=C561PCq5E1g>

Managing reactive chemistry Hazard

Example : Explosion in T-2 Labs Investigation.

Location: Jacksonville, Florida (USA)

Date: 19th Dec 2007

Company: T2 Laboratories, Chemical producer

Process: MCMT process (Lab Scale to Commercial Scale)

Incident: Explosion in Reactor due to runaway reaction

4 employees killed, 32 injured (including 28 from surrounding community)

Process: Batch process

Reaction: metalation (hydrogen–metal exchange)

Amount of Energy & Exothermicity : ???

Gas : Hydrogen

TMRad/ TD 24 : ?

Tp: 148Deg C

Explosion force: Equivalent to 1,400 lbs of TNT ($\approx$ 635 kg TNT)

Causes:

1. Company did not recognize the worst credible scenario
2. No redundancy in cooling system (No Back for Cooling System)
3. Inadequate pressure relief device

What are the Questions to be asked before standing Reactor ?



Which type of Process it is ?

Which type of Reaction ?

How much Exothermicity in Rxn/
Quenching & any Gas Liberation ?
(Adiabatic Temperature Raise) ?

What is the decomposition Temperature of
Rxn Mass & Distillation Crude ?

What is Safety criticality Class ?

What are the Questions to be asked before standing Reactor ?



Which type of Process it is ?	1. Batch Processes 2. Semi Batch / Semi Continuous Processes 3. Continuous flow processes								
Which type of Reaction ?	1. Dose Controlled Reaction (Instantaneous/ Fast) 2. Accumulation Reactions 3. Delayed Initiation of Reaction (Safer than accumulation & delayed Rxn.)								
How much Exothermicity in Rxn/ Quenching & any Gas Liberation ? (Adiabatic Temperature Raise) ?	<table border="1"> <thead> <tr> <th>Adiabatic Temperature Rise range</th><th>Severity Interpretation</th></tr> </thead> <tbody> <tr> <td>$\Delta T_{ad} > 200^{\circ}\text{C}$</td><td>High</td></tr> <tr> <td>$50^{\circ}\text{C} < \Delta T_{ad} < 200^{\circ}\text{C}$</td><td>Medium</td></tr> <tr> <td>$\Delta T_{ad} < 50^{\circ}\text{C}$ and no gas evolution</td><td>Low</td></tr> </tbody> </table> Hydrogen/ Ammonia/ HCl/ SO₂/ Butane/ CO₂.... NaOH	Adiabatic Temperature Rise range	Severity Interpretation	$\Delta T_{ad} > 200^{\circ}\text{C}$	High	$50^{\circ}\text{C} < \Delta T_{ad} < 200^{\circ}\text{C}$	Medium	$\Delta T_{ad} < 50^{\circ}\text{C}$ and no gas evolution	Low
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What is the decomposition Temperature of Rxn Mass & Distillation ?	➤ TMRad/ TD24 ?								
What is Safety criticality Class ?									

