PSCI PHARMACEUTICAL SUPPLY CHAIN INITIATIVE
Building responsible supply chains

Chemical Process Safety: Which parameters are important to perform a chemical reaction in a safe way?

Dr. Daniel Rehm
HSE Advisor Elanco External Manufacturing EMEA & API
由Daniel Rehm博士来演讲
HSE顾问，礼来动物保健外部制造，欧洲 & 原料药

Bio

- Daniel is HSE Advisor in the Elanco External Manufacturing EMEA & API Hub Basel, Switzerland
- PhD in Chemistry from Humboldt University in Berlin, Germany with 19 years of experience in Chemical Industry, Insurance and Pharmaceutical Industry. Functional experience in Process Development, HSE, Engineering and Manufacturing
- Working in Elanco for 3.5 year.
- Additional qualification as Fire Protection Manager CFPA-E

Dr. Daniel Rehm
HSE Advisor
Elanco External Manufacturing EMEA & API Hub Basel
rehm_daniel@elanco.com

AGENDA 大纲

Session 1

Session 2

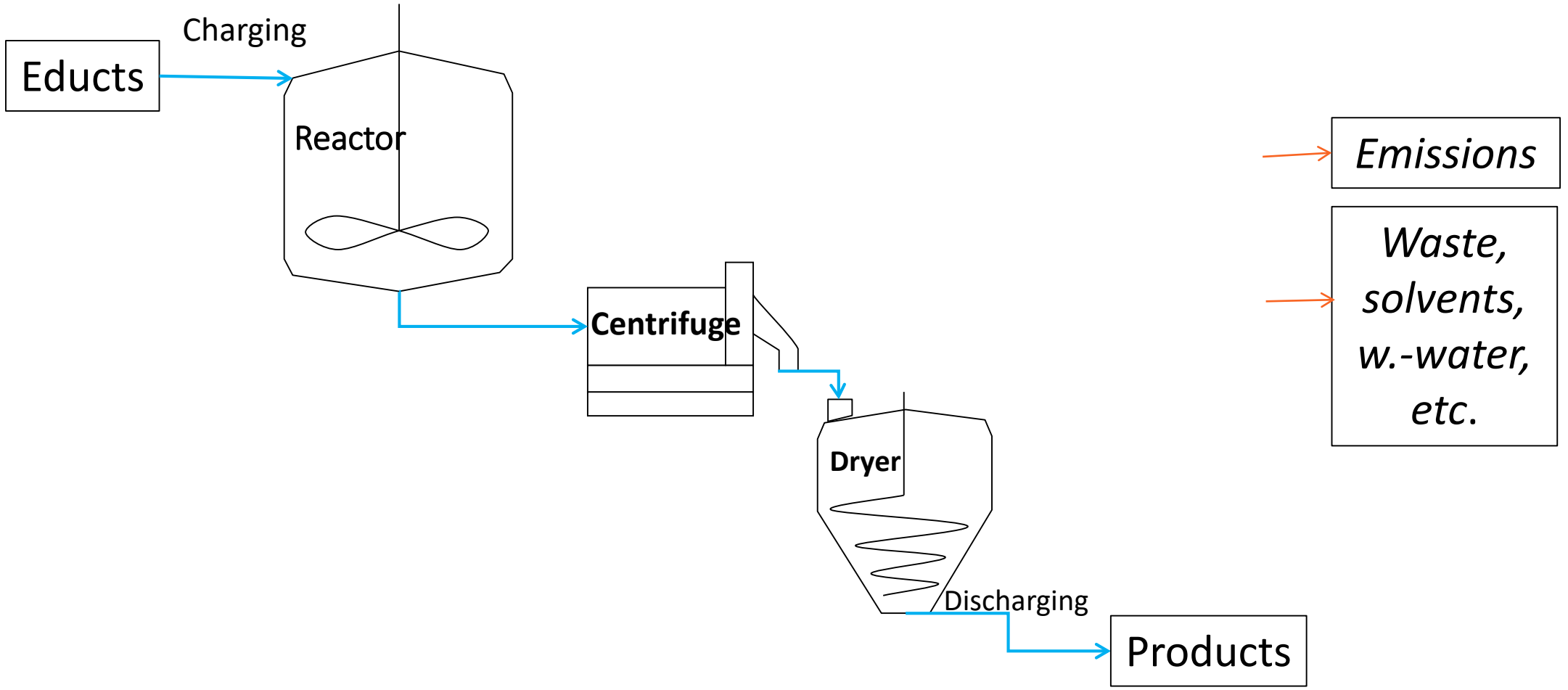
TRAINING STRUCTURE

1. Session 1
   - Process safety parameters
   - Essential information to chemical processes
   - Critical interactions of material
   - Exothermic and run-away reaction
   - Scale up

2. Session 2
   - Runaway reaction
   - PSCI Questionnaire & Typical Observations

3. Audience questions & discussions

Chemical reaction in a production plant



Which information is necessary for a safe process?

- Knowledge about the used chemicals regarding thermal stability, physical safety parameters and toxicology
  - Educts
  - Products (incl. side products)
  - Reagents
  - Solvents & Auxiliaries

- Knowledge about the chemistry
  - Main reaction and side reactions
  - Waste streams (gas release, liquids and solids)
  - Consecutive reaction, decomposition?

- Reaction type
  - Batch reaction
  - Semi-batch reaction
  - Continuous flow reaction

What is necessary for a safe process?

- Calorimetric data of the chemical reaction
  - Adiabatic temperature rise
  - Gas evolution rate (→ reactor venting sufficiant?)
  - precipitation of solids (→ reduction of heat transfer, stirrer blocking?)
  - Accumulation of reactants, thermal output/time
  - Stability of reaction mixtures, distillation residues, etc.
  - Potential for runaway reaction, abnormal operating conditions
  - If necessary: investigation of the runaway reaction

- Knowledge about critical interaction between the used chemicals and other material
  - Material resistance of reactor & other equipment
  - Possible material contact (e.g. media supply)

What is necessary for a safe process?

- Plant equipment “state of the art”
  - Materials of the equipment = > material tests, corrosive data, etc.
  - Inertisation of equipment
  - Earthing of the equipment, explosion-proof equipment
  - Blow-down system, pressure relief valve, rupture disc,
  - Heating and cooling medium & capacity
  - Safety concept e. g. for electrical shut down

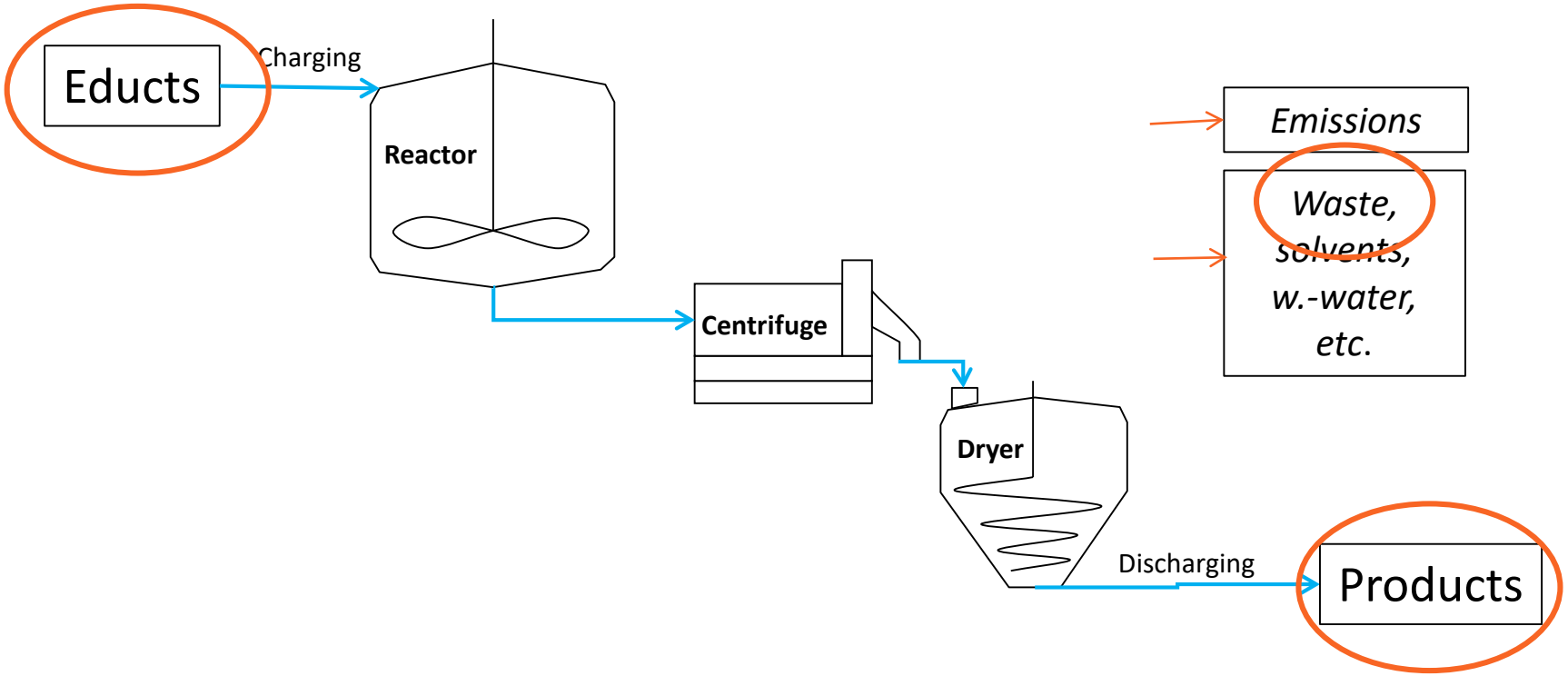
→ Process Hazard Analysis

Examination of the chemical properties and chemical process safety data together with the technical installation of the plant.

A safe chemical process is always an adequate combination of safe substance handling, known chemical process and adapted equipment.

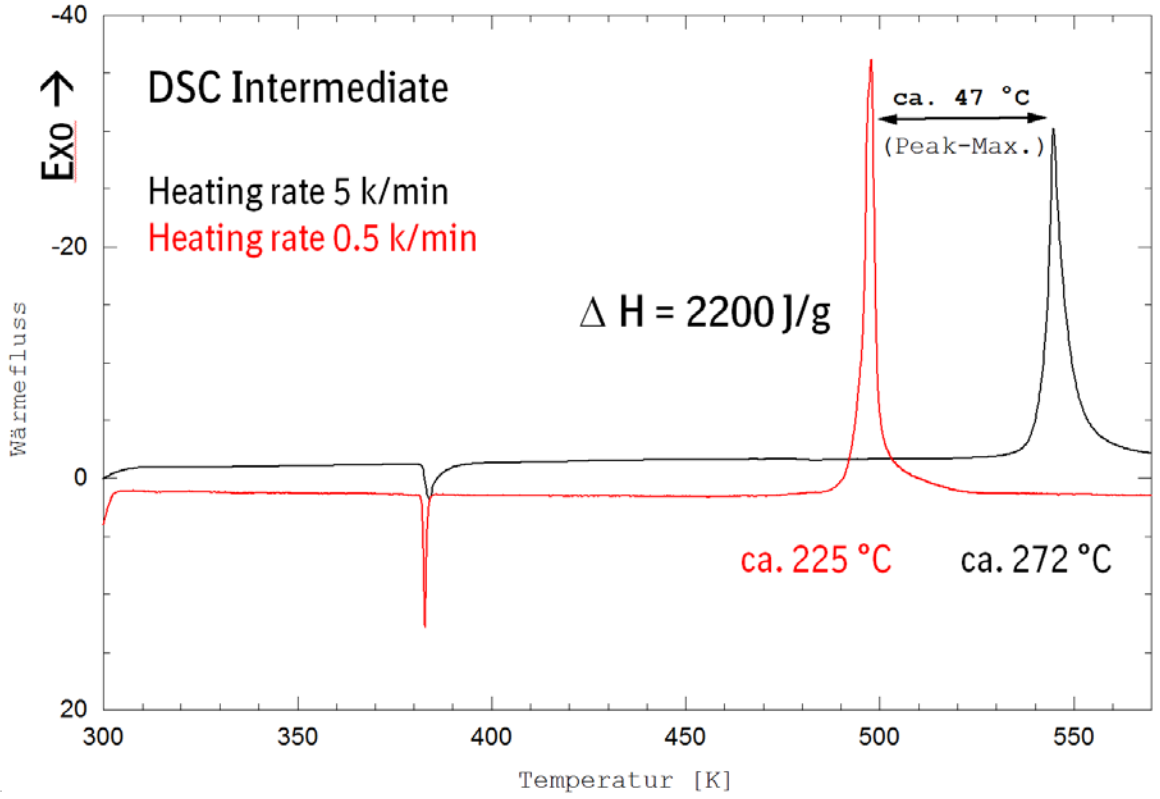
What is necessary for a safe process?

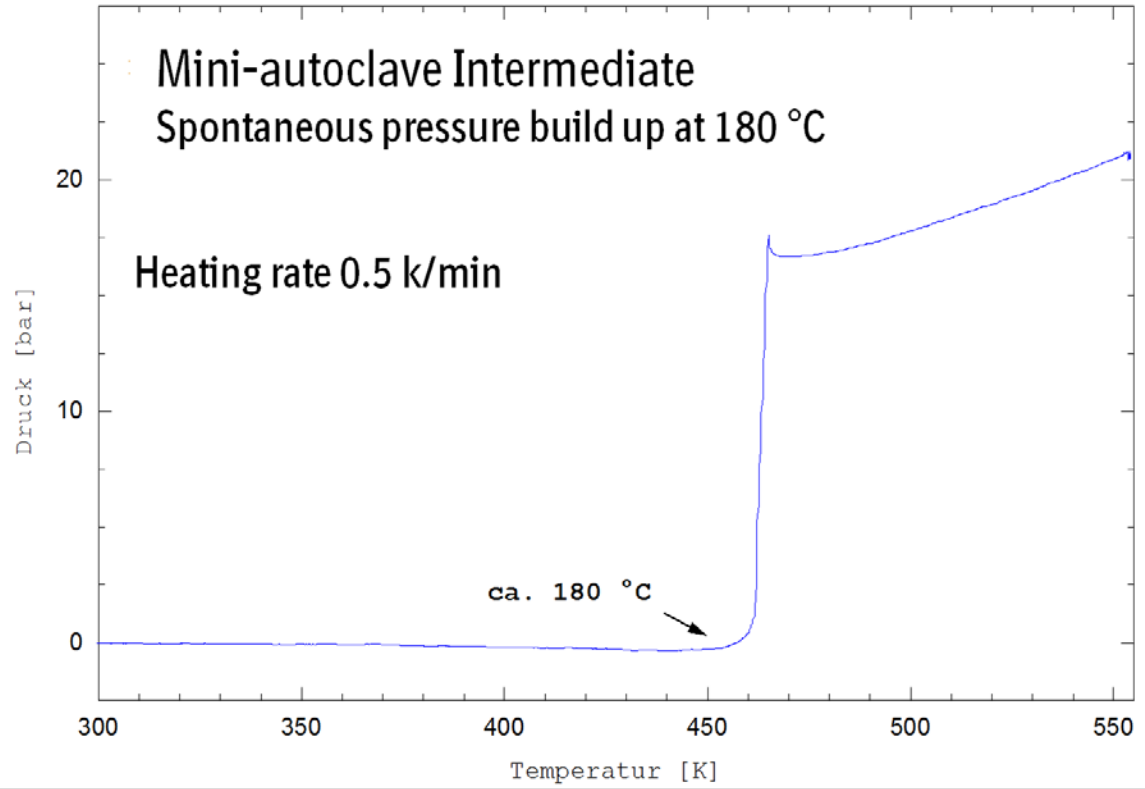
Thermal stability of chemical substances and reaction mixtures



Thermal stability of chemical substances and reaction mixtures

- Thermal stability:
  - Differential Scanning Calorimetry (DSC) or Differential Thermo Analyses (DTA)
- **Decomposition** test closed vessel (pressure build-up):
  - e.g. in a mini-autoclave





Known hazardous substances

- Typical chemical functions in thermodynamically unstable compounds:

-C≡C-	acetylene and acetylide
$-N_3$	azide and hydrogen azide
$-N{\equiv}N^+$	diazonium salts, triazene, tetrazene
-N=N-	azo compounds
-HN-NH-	hydrazide
>C=N=O	fulminates, oximates
>N-X	halogene nitrogene compounds
$-NO_x$	nitrites, nitrates, nitro- and nitroso compounds
-O-O-	peroxides, peroxy acids, ozonids
$-O-ClO_x$	(per-)chlorate, (hypo-)chlorite

Known highly reactive substances

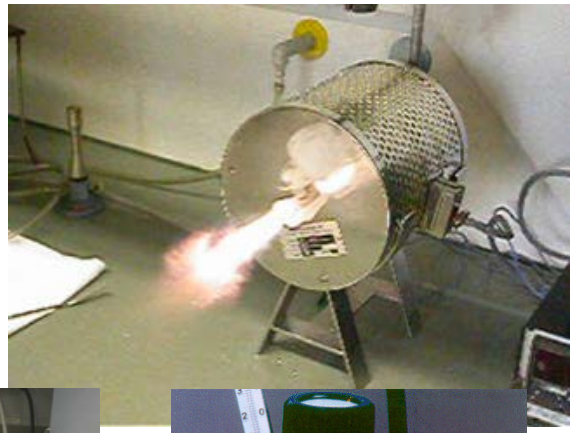
- Typical compounds or chemical functions:

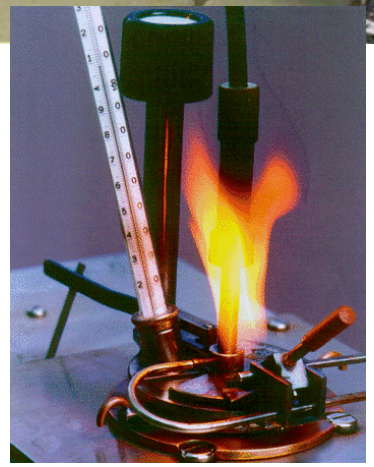
R-Mg-X	Grignard reagents
R-Li	organic lithium compounds
-COCl	acid cloride
-CO-O-OC-	acid anhydride
Na-, K-OR	Sodium-, Potassium alkoholate
$POCl_3$, $SOCL_2$	inorganic anhydride
„H_2SO_4“	conc. acids, lyes
NaH, $LiAlH_4$	hydride
Na, K, Mg, Li …	metals
O_2, H_2	gases
F_2, Cl_2, Br_2	halogen

General handling characteristic of substances

- Additional test for thermal stability
  - Thermogravimetry (TG) or combination TG/DSC; TG/DTA
  - Quasi-adiabatic heat aging in a Dewar flask (or an adiabatic calorimeter)
  - Time Pressure Test

- Flammability of solids or liquids
  - Combustion test
  - Flammability of solids
  - Smoldering temperature; minimum ignition temperature of a dust layer
  - (minimum) dust cloud ignition temperature
  - Ignition temperature of liquids
  - Flash point (of liquids)





General handling characteristic of substances

- Dust explosibility:
  - Dust explosion test
  - Dust explosion characteristics (pmax; (dp/dt)max; KSt; explosion limits
  - Minimum ignition energy (MIE)

- Mechanical sensitivity, further safety characteristics
  - Sensitivity to impact
  - Sensitivity to friction
  - Self-ignition test
  - Conductivity

Details to: Dust stability/explosibility

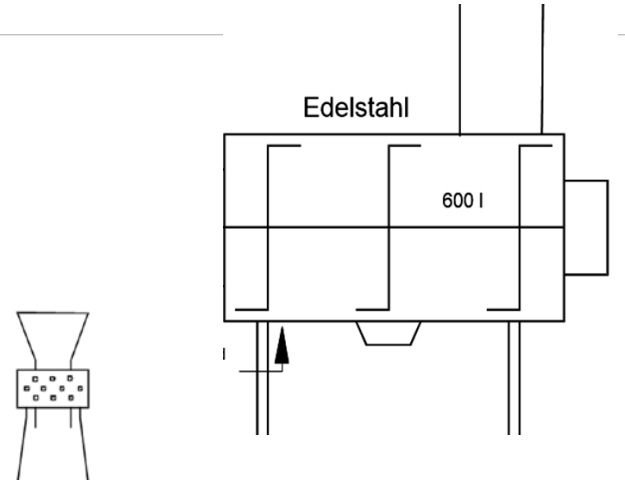
- Mechanical sensitivity: Sensitivity to impact / friction

➢ Important for mechanical actions
(e.g. transport systems, in dryer with agitator, in a pin mill,)
→ maximum temperature & agitation time

- Maximum explosions pressure p_{max}

For most of the organic gases and vapors in mixture with air p_{max} is between 8 bar to 10 bar under initial atmospheric conditions.

➢ Important for e.g. venting pipes/filter units, for mills, dryers („dust containing air“)
→ explosion-resistant design



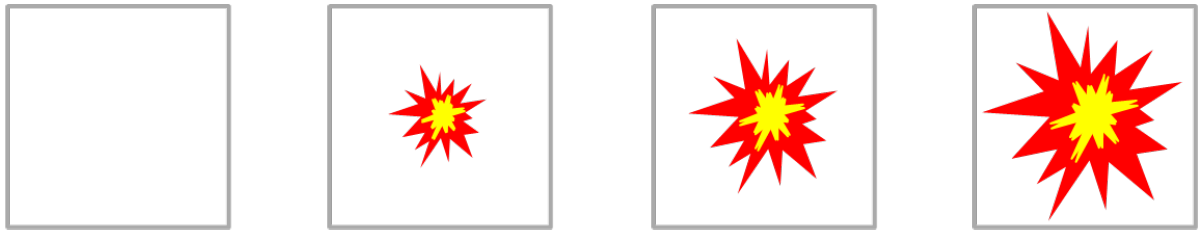
Details to: Flammability of solids or liquids

- Ignition temperature

Auto-ignition temperature (according to EN 14 522)	Temperature class	Maximum surface temperature
> 450 °C	T 1	450 °C
> 300 °C to 450 °C	T 2	300 °C
> 200 °C to 300 °C	T 3	200 °C
> 135 °C to 200 °C	T 4	135 °C
> 100 °C to 135 °C	T 5	100 °C
> 85 °C to 100 °C	T 6	85 °C

Details to: Dust explosibility

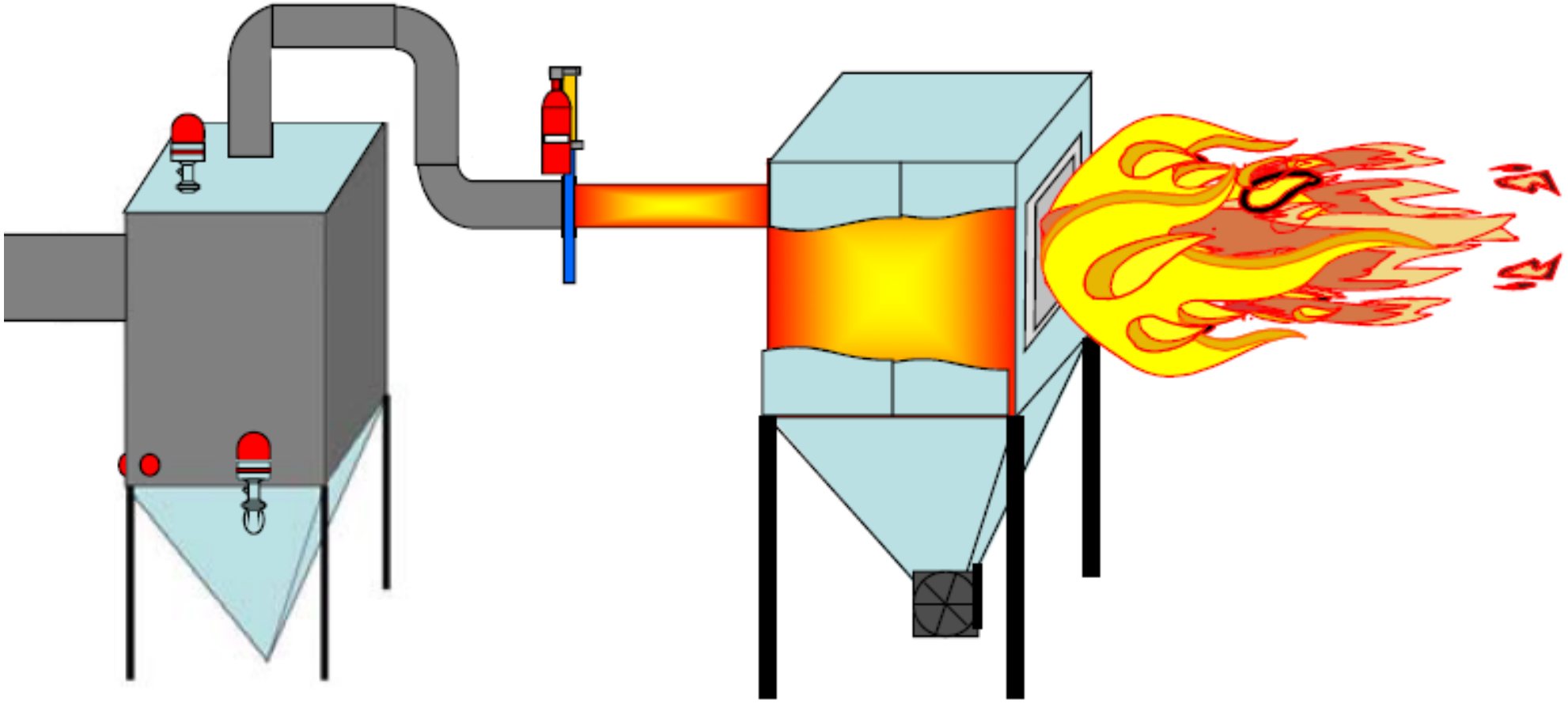
- Maximum explosion pressure rise $(dp/dt)_{max}$ and K_{St}



Dust explosion group	St 0	St 1	St 2	St 3
Kst bar.m.s^{-1}	0	> 0 ≤ 200	> 200 ≤ 300	> 300
Explosion characteristics	no explosion	weak/ moderate	strong	very strong

➢ Important for design of “explosion relief“, “explosion suppression” system

Examples of Process Equipment

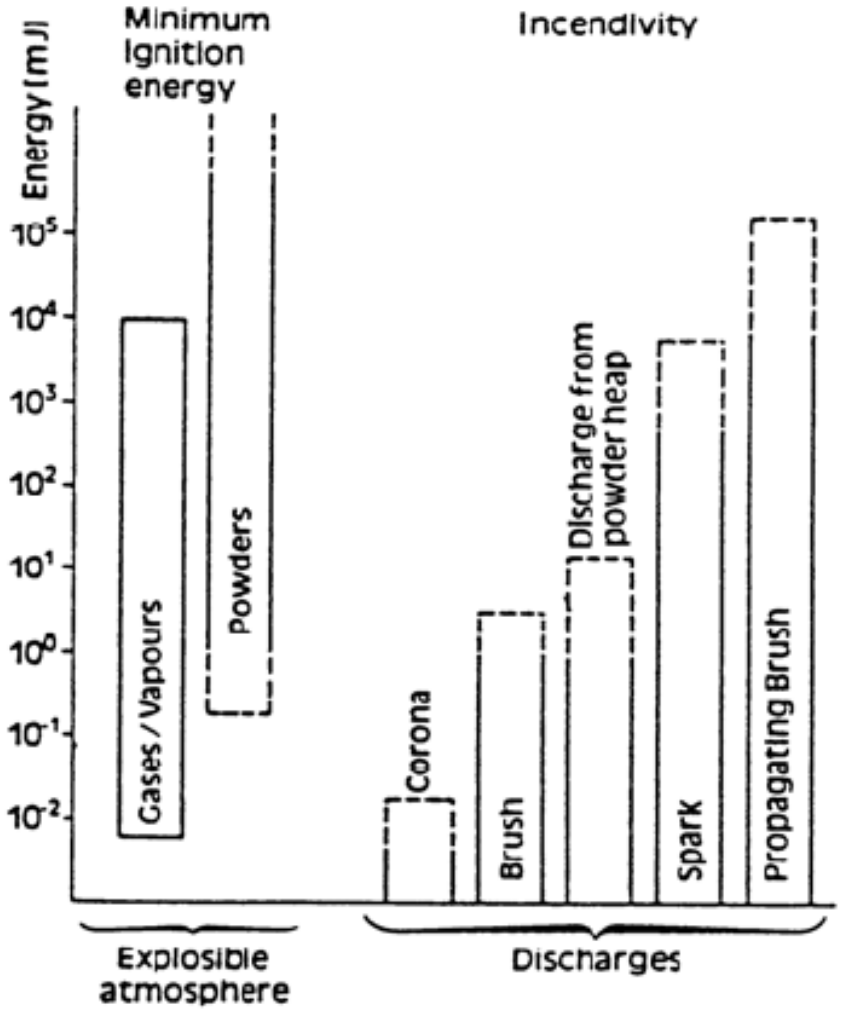


- If the K_{st} is above 300 bar m/s, the valve would not work

Details to: Dust explosibility

- Minimum ignition energy (MIE)

Risk	Substance Name	MIE in air
High risk < 25 mJ	Hydrogen	0.01mJ
	Methanol	0.14 mJ
	n-HeptanE	0.24 mJ
	Acetone	1.15 mJ
	“Normal organic" dust	>10 mJ
	Paracetamol	<10 mJ
Medium risk 25 – 100 mJ	Wheat flour	~50 mJ
	Sugar powder	30-100 mJ
	Coal	30-100 mJ
Low risk >100 mJ	PVC	1500 mJ



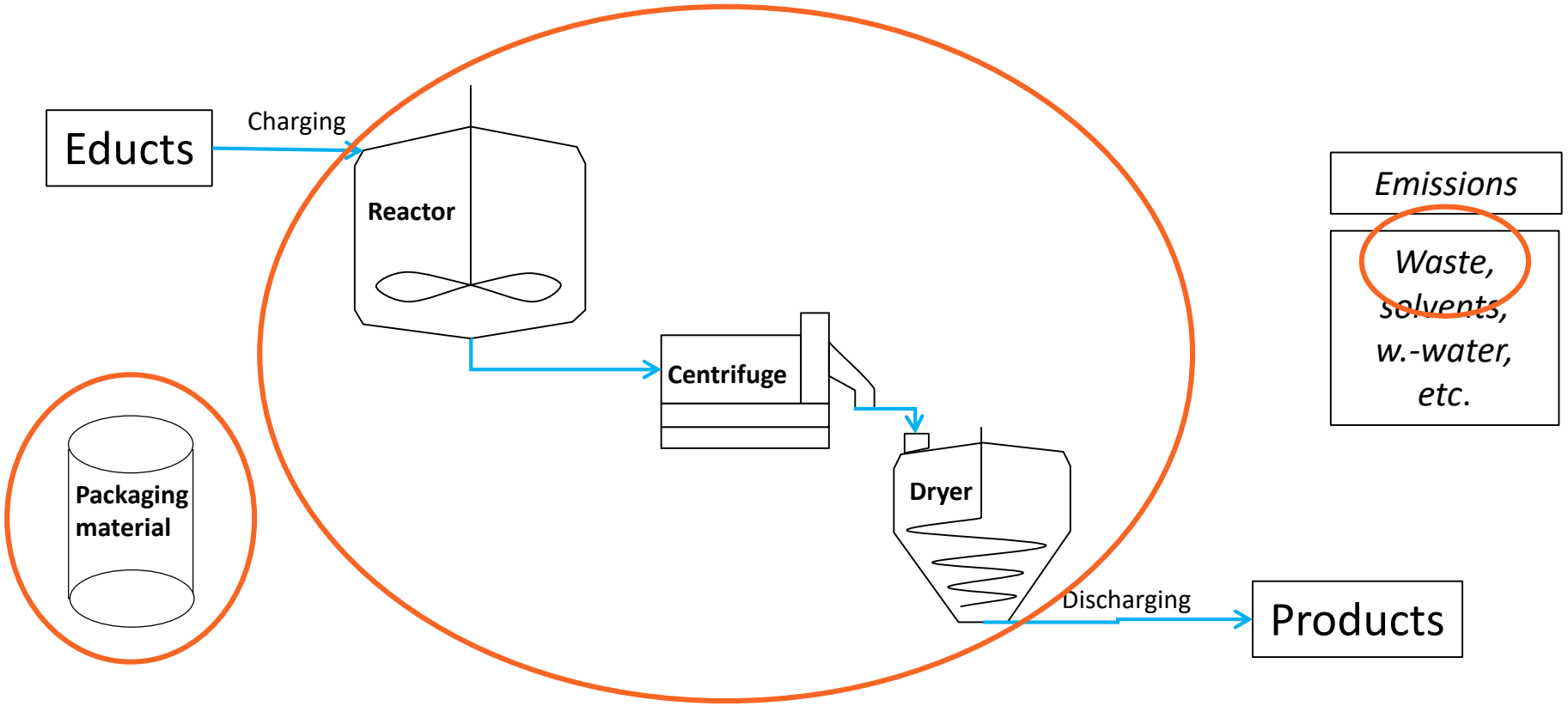
Resulting technical requirements of equipment

Temperatur Class						
Explosion Group	T1 (> 450°C)	T2 (> 300°C)	T3 (> 200°C)	T4 (> 145°C)	T5 (> 100°C)	T6 (> 85°C)
IIA	Acetone Acetic acid Methane Propane Ammonia Benzene Toluene	Fuel Methanol Butan	Hexane Diesel Fuel oil	Acetal-dehyde		
IIB	Hydrogen cyanide	Ethanol Ethane	Hydrogen sulfide			
IIC	Hydrogen					Carbon disulfide

MIE

What is necessary for a safe process?

Critical interaction between the used chemicals and between chemicals and materials



Critical interaction between chemicals and materials

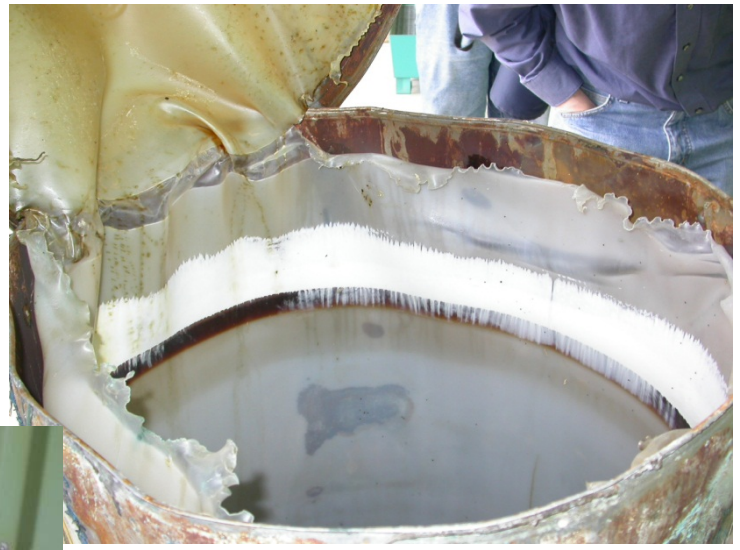
- Incident in a chemical production plant
  - Due to an operational error a mixture of thionyl chloride, ethyl acetate and acetyl chloride have to be disposed of. For disposal the worker used the empty thionyl chloride drum. Short time later the drum exploded

- Result of safety examination in laboratory
  - No critical reaction between thionyl chloride, ethyl acetate and acetyl chloride.

  - But, the used drum was zinc-coated
    ➔ critical reaction under pressure build-up between ethyl acetate, thionyl chloride and zinc !

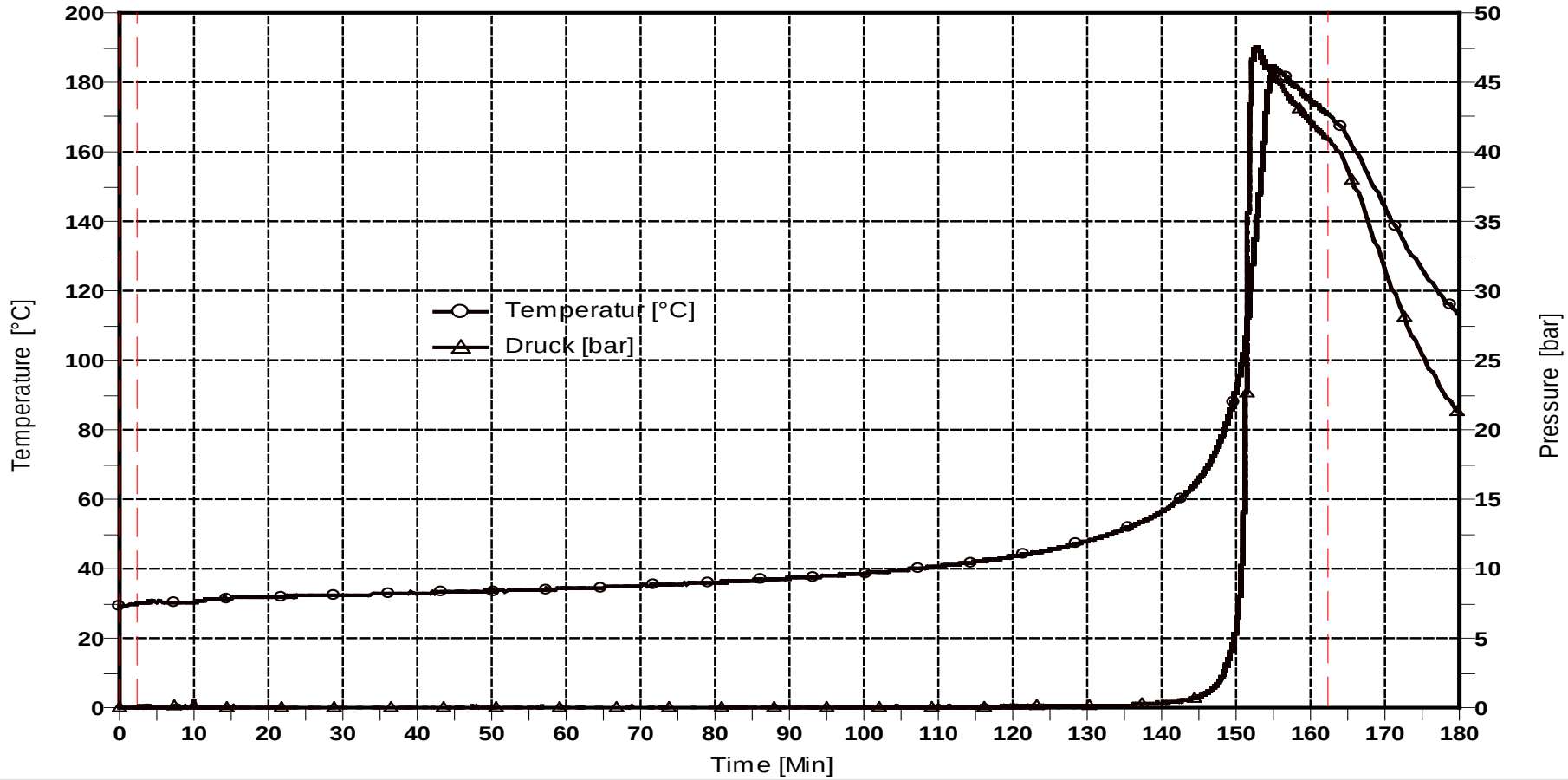
Critical interaction between chemicals and materials

- Incident in a chemical production plant B:
  - In a process the excess of POCl3 is distilled off and purged into a 200 l steel drum with a PE-inliner. Approx. 10 h later the drum burst.
  - Between the batches the pipes were washed with acetone. Residual quantities of acetone remained in the pipes.
  - Result of safety examination in laboratory:
  - Retarded critical reaction between acetone and POCl3.



Critical interaction between chemicals and materials

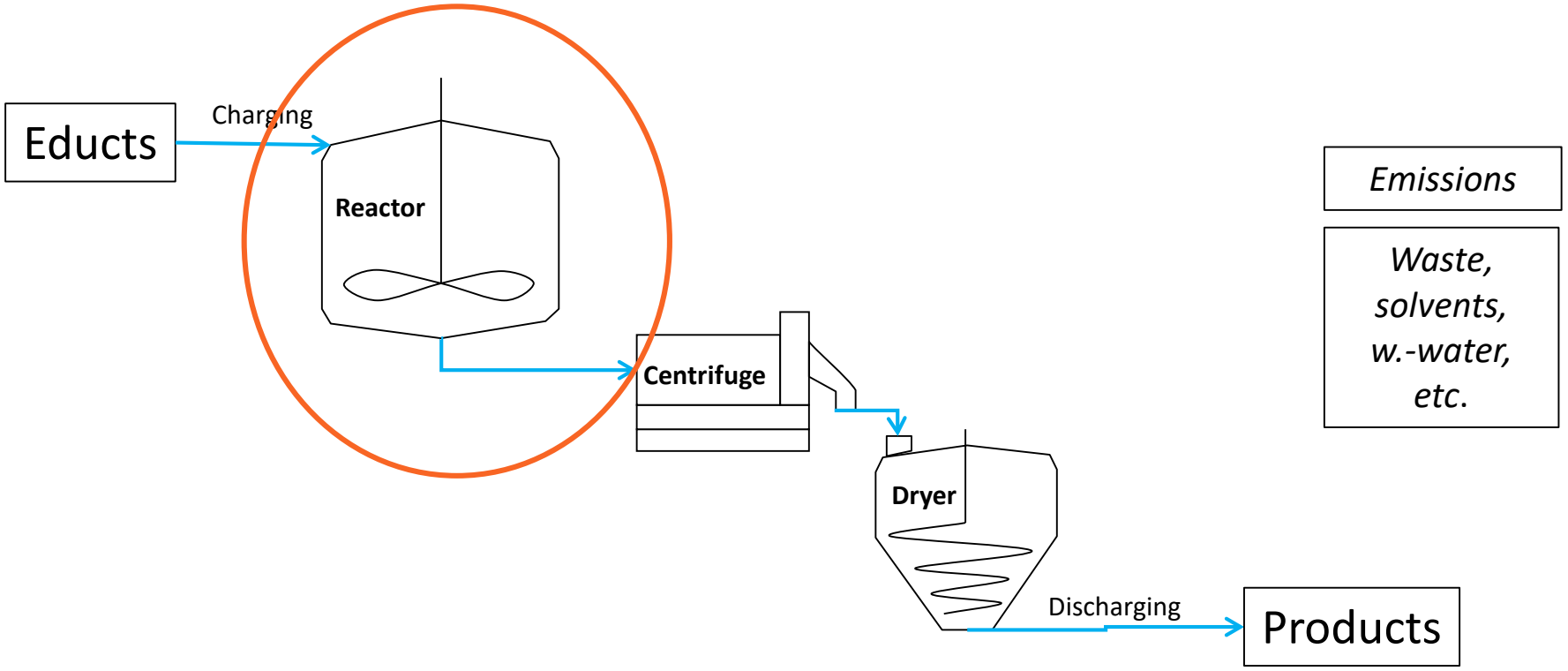
- Reaction experiment
  - closed cell test, POCl3 overlay with ca. 5.8 weight-% acetone



What is necessary for a safe process?

Chemistry – chemical reaction

Calorimetric measurements for chemical reactions



Chemistry – chemical reaction

- The chemical reaction should be known, including side reactions and consecutive reaction. The chemical reaction can depend on the reaction temperature or the working procedure.
- Mass balance of the whole reaction is very useful
- Side products can have a big influence on process safety
- Are decomposition reactions known?
- Waste streams can contain highly reactive compounds or unstable substances (e. g. slow gas generation leading to a pressure build up in waste containers)

Working procedure for chemical reaction

- Batch reaction:
  - All reagents are charged to the reactor.
    Then the content is heated to the reaction temperature.

The accumulation of reaction partners is at the beginning 100 %.

For an exothermic reaction, if the cooling capacity is not sufficient, an uncontrolled temperature rise occurs and a run away reaction is possible.

Batch reactions should only be applied with endothermic or very slow reaction with smooth exothermic behavior.

- What is in general the best temperature for running a exothermic batch reaction?
- The lowest possible reaction temperature is in general the safest temperature!

Working procedure for chemical reaction

- Semi-batch reaction

One reaction compound (including solvent) is charged to the reactor.
The other compound is added over a defined time at the reaction temperature.

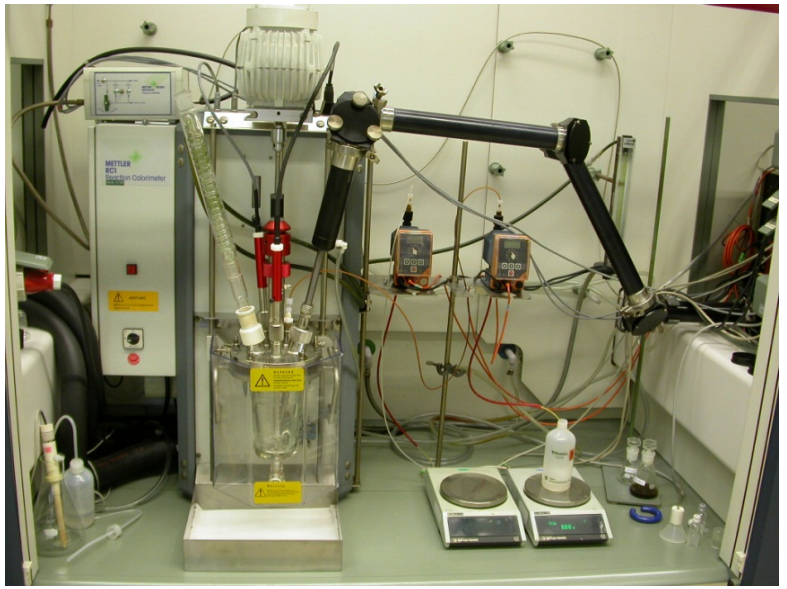
- The accumulation of reaction partners is at the beginning 0 %.
  Across the whole addition time the accumulation should be small.
- Always add the reactive compound.
  (Adding a catalyst or a compound in a huge excess is not a semi-batch process!)
- A stop of the addition stops further heat generation (if low accumulation).

What is in general the best temperature for running a exothermic semi-batch reaction?

The highest possible temperature is the best! -> fast reaction -> less accumulation

Chemical reaction parameters, calorimetric measurements

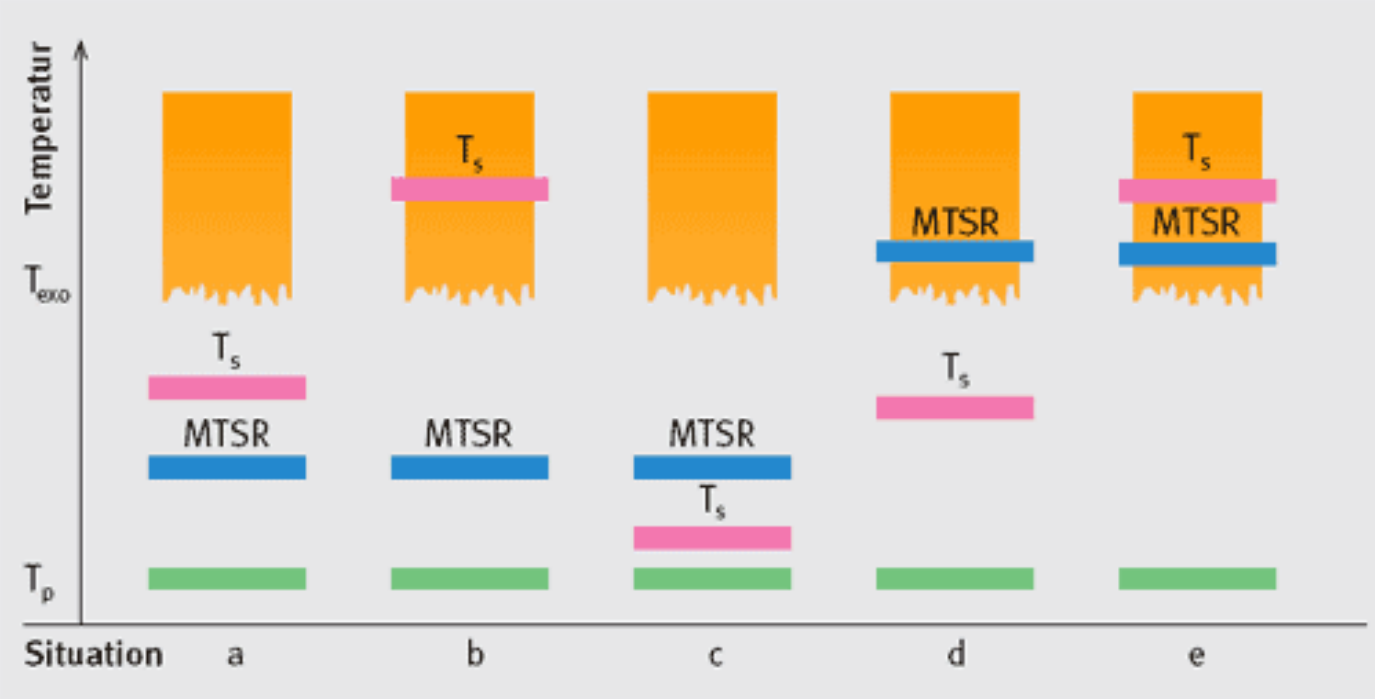
- Safety investigation of reaction under process like conditions:
- Reaction calorimeter (e.g. Mettler RC1) with dosing, gas measurement etc.



- Determination of:
  - Heat of reaction ΔHR [J/g] or [J/mol]
  - Heat capacity cp [J/g K]
  - Adiabatic temperature rise ΔTad [K] or [°C]
  - Degree of accumulation [%]
  - Gas release [l/min]

- Adiabatic investigation of abnormal operating conditions:
- Determination of thermal stability under adiabatic conditions (no heat exchange, like DTA)

Thermal hazard potential of chemical reactions



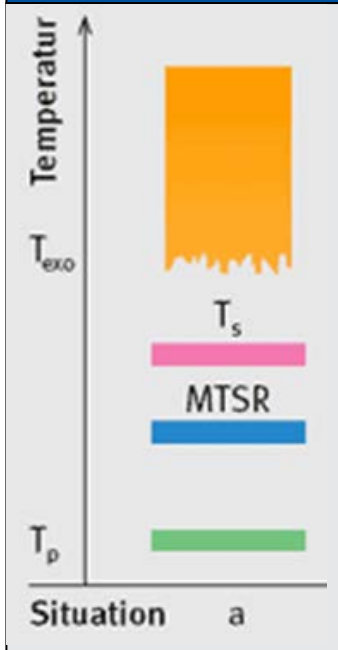
T_p : process temperature at the start of the deviation

MTSR: maximum temperature of the synthesis reaction; $MTSR = T_p + \Delta T_{ad} \cdot \alpha_{accu}$

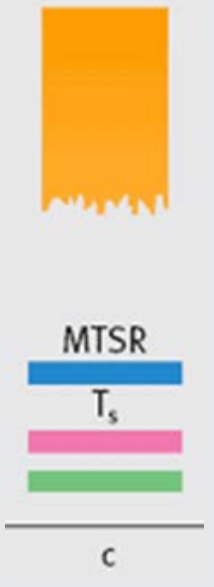
T_{exo}: the maximum temperature at which a substance or reaction mixture can just be handled safely

T_s: (=T_b) the boiling point in an open system

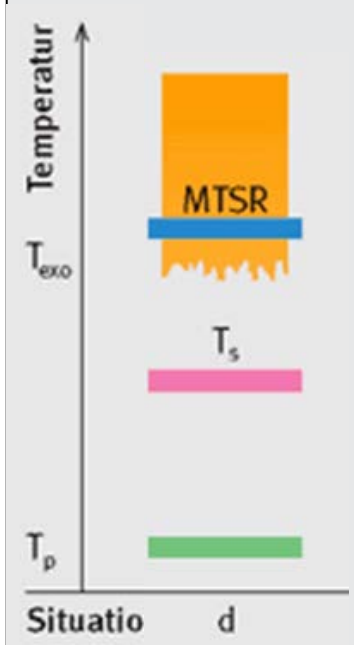
Thermal hazard potential of chemical reactions

Case	Description - criticality
	The boiling point of the mixture and the maximum reaction temperature stay below T_{exo}. Such processes may be regarded as inherently safe with respect to the process deviation evaluated.

Case	Description - criticality
	Absence of the boiling point barrier, but maximum reaction temperature below T_{exo}. The process may be regarded as safe.

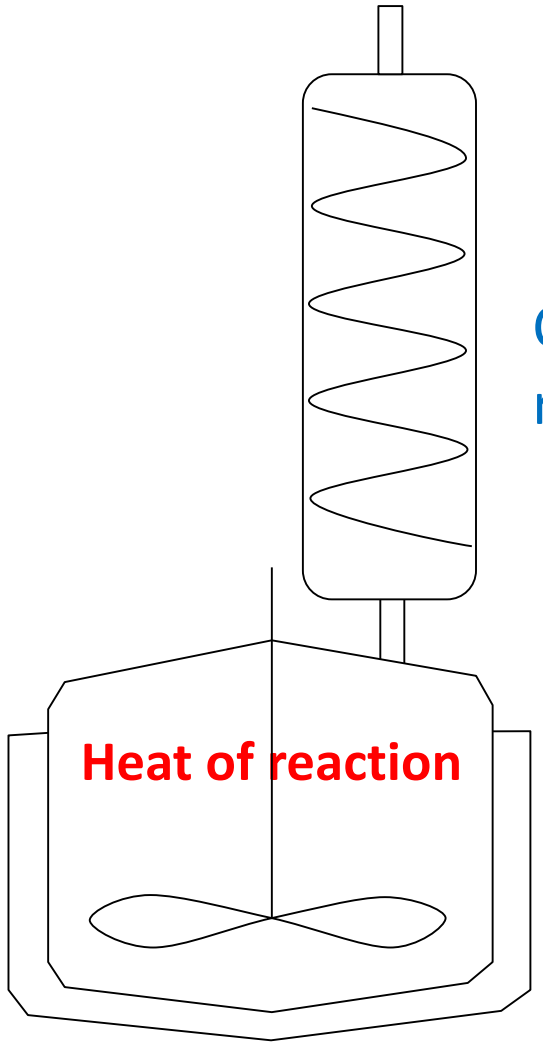
Case	Description - criticality
	The boiling point with its latent heat of evaporation may be considered as a safety barrier (adquate condenser!) In a closed system, the reactor must be designed for the maximum expected overpressure or be equipped with a pressure relief device. It would be better to reduce the accumulation so that the boiling point could not be reached.

Thermal hazard potential of chemical reactions

Case	Description - criticality
	It must be evaluated if the evaporation capacity provides sufficient safety. If not, additional organizational or technical measures have to be implemented. If the operation is performed in a closed system, the temperature corresponding to the relief valve's set pressure may not be too high.

Case	Description - criticality
	This case must be rated as problematic. In case of a (simple) cooling failure, the reaction can pass over the safe temperature range. Plant and/or process modifications should be evaluated in such situations.

Temperature control of chemical reaction



Cooling by
reflux condension

Cooling jacket

Heat balance of exothermic reactions

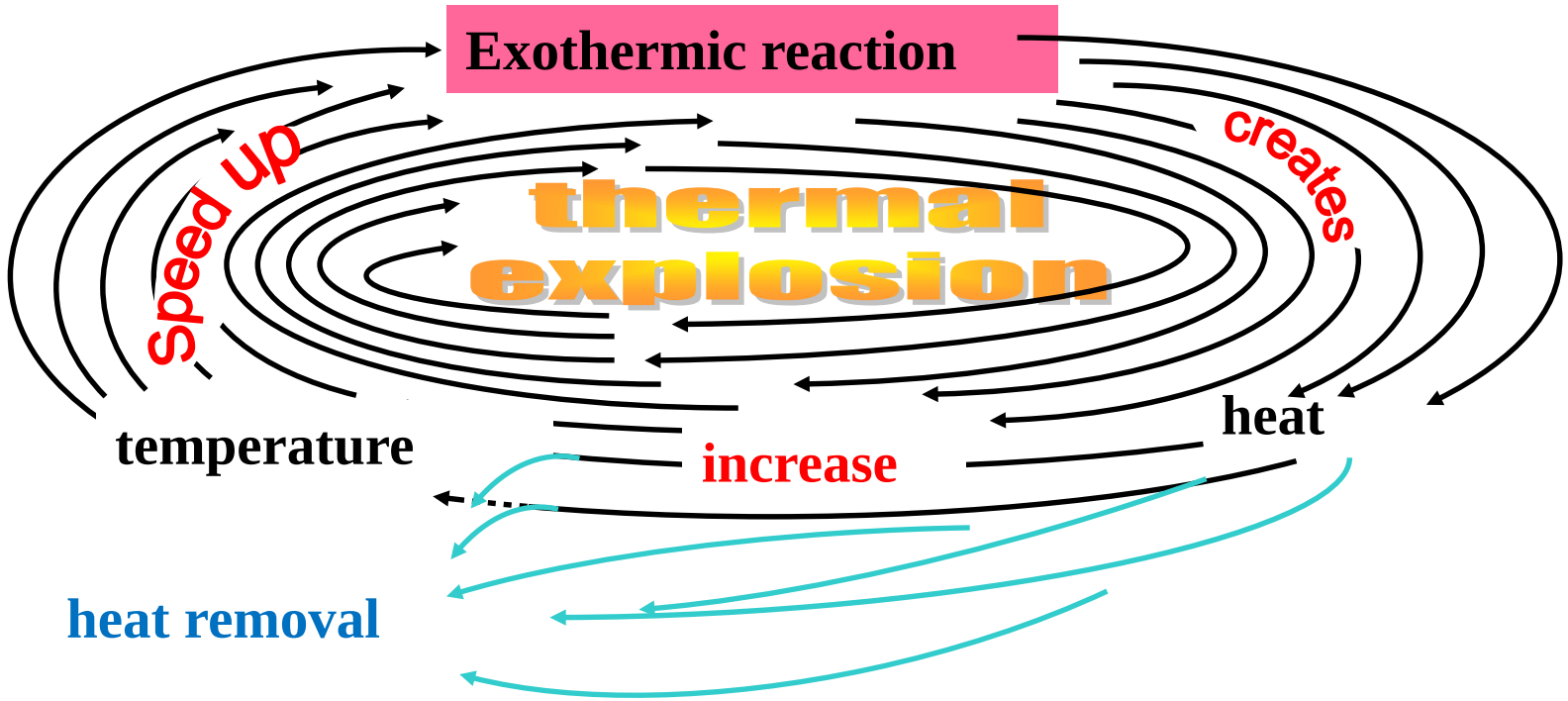
heat production

heat removal

Increased heat production	Decreased heat removal
• Additional energy supply (e.g. heating, stirring, pumping) • Higher concentration of reactants (e. g. missing solvent) • Presence of a catalyst (e.g. rust, nonferrous metals) • Initiation of other exothermic processes (e.g. side reaction, decomposition)	• Loss of cooling (e.g. pump failure, solvent evaporated) • Degrade heat transfer (e.g. fouling, adhesion) • Increase of viscosity (e.g. higher degree of polymerization) • Inadequate mixing (e.g. pump failure, solvent evaporated, stirrer failure)

Exothermic and run-away reaction

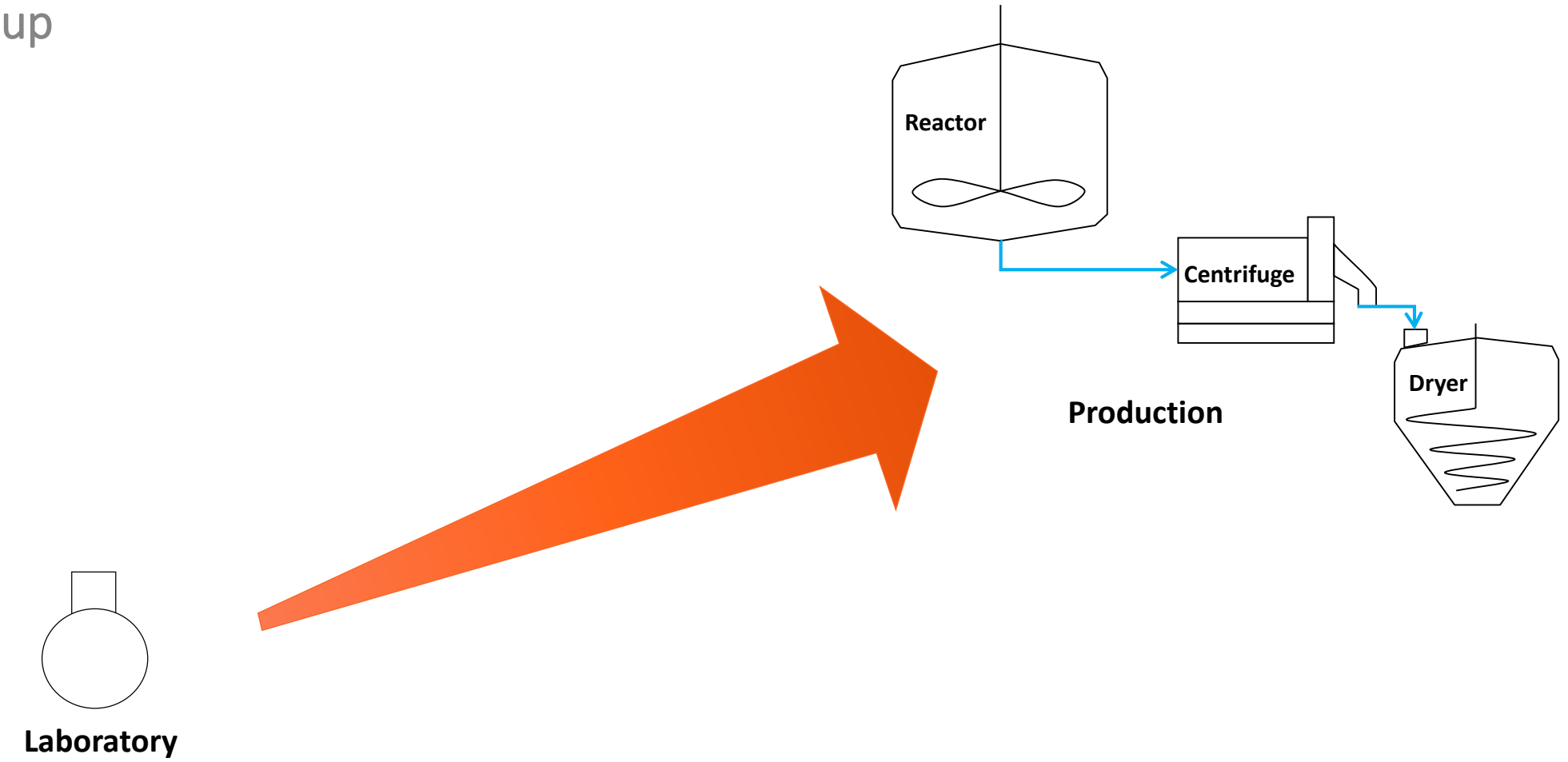
- An exothermic reaction produces heat which leads to an increase of the reaction temperature if the cooling capacity is not sufficient.
- A runaway reaction is an exothermic chemical process, which leads to uncontrollable reaction conditions due to an uncontrolled rise of the reaction speed.



Exothermic reaction and run-away reaction

What is necessary for a safe process?

Scale up



Scale up laboratory → (pilot) plant

- Example of a heat balance change during the scale up
  - From laboratory (1 l) to pilot plant (1 m^3).
  - Dosing controlled reaction
  - Exothermic reaction
  - Reaction heat of 360 kJ kg–1 (= 0,1 kWh kg-1)
  - Density of reaction mass is 1 g cm–3
  - Reaction temperature 80 °C
  - Filling degree is 100 %
  - Heat transmission of both apparatus are 500 W m–2 K–1
  - Effective temperature difference for cooling is 30 K

Scale up – laboratory – (pilot) plant

	Laboratory	Pilot or production plant	
Reactor size	1 l	1 m^3	Factor 1000
Cooling surface	0,046 m^2	4,4 m^2	Factor ~100
Specific cooling power	15 kW m^{-2} (= 500 W m^{-2} K^{-1} * 30 K)		
Cooling power	**0,69 kW** (= 15 kW m^{-2} * 0,046 m^2)	**66 kW** (= 15 kW m^{-2} * 4,4 m^2)	Factor ~100
Reaction power with 3 h dosing time	0,03 kW (= 0,1 kWh kg^{-1} * 1 kg /3h) *heating required*	33 kW (= 0,1 kWh kg^{-1} * 1000 kg /3h) cooling sufficient	
Reaction power with 2 h dosing time	0,05 kW (= 0,1 kWh kg^{-1} * 1 kg /2h) *no cooling required*	50 kW (= 0,1 kWh kg^{-1} * 1000 kg /2h) cooling sufficient	
Reaction power with 1 h dosing time	0,1 kW (= 0,1 kWh kg^{-1} * 1 kg /2h) cooling sufficient	**100 kW** (= 0,1 kWh kg^{-1} * 1000 kg /1h) **cooling insufficient**	

Expectation of an EHS auditor

R&D → scale up → production

Amounts of substances	Location	Working documents	Guidance documents
miligrams to grams	Research & Development Laboratory	- Lab documentation - First observations to process safety	- Policy „Safe Research & Development“ - Lab safety SOPs
grams to kilograms	Transfer from tab to kilolab / pilot plant	- Basic safety report - Transfer report	- Regulation to „Basic safety examinations“ - Transfer protokoll
kilograms	kilolab / pilot plant	- Batch records - Safety assessments - Process safety examinations	- Guidelines for safety examinations - SOPs to substance handling etc.

Expectation of an EHS auditor

R&D → scale up → production

Amounts of substances	Location	Working documents	Guidance documents
kilograms to tons	Transfer from pilot plant to production	- Transfer report - Risk assessment - Technical measures	- Transfer protokoll - SOP „Risk assessement/ HAZOP“
kilograms to tons	Production plant	- Batch records - Change Control documents - Maintenance of technical installation	- SOP „ CC“ - SOPs „Maintanance“
kilograms to tons	Transfer to other plants	- Transfer report - Risk assessment - Technical measures	- Transfer protokoll

Usefull Links/ Infos

- https://www.bgrci.de/fachwissen-portal/topic-list/hazardous-substances/
- https://downloadcenter.bgrci.de/resource/downloadcenter/downloads/R003e_Gesamtdokument.pdf

Accident Prevention & Insurance Association - data sheets
[BG-Merkblätter R 001-007]

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2. **Session 2**
   - **Runaway reaction**
   - **PSCI Questionnaire & Typical Observations**

3. **Audience questions & discussions**

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Investigation Video

Runaway Reaction Explosion

- **T-2 Labs , Jacksonville, Florida (USA)**
- **Video 1**
- **Video 2**

Investigation Report - Explosion in T-2 Labs

- Location: Jacksonville, Florida (USA)
- Incident: Explosion in Reactor due to runaway reaction
- 4 employees killed, 32 injured (including 28 from surrounding community
- Explosion force: Equivalent to 1,400 lbs of TNT (≈ 635 kg TNT)

Causes:

- Company did not recognize the worst credible scenario
- No redundancy in cooling system
- Inadequate pressure relief device

Reaction Hazards - Historical Data of Incidents

(Ref. Book: Chemical Reaction hazards by John Barton)

Following data was collected for 189 industrial incidents in UK involving thermal runaway reactions:

- 134 incidents were classified by processes, key ones are:
  - Polymerization (condensation): 64 (48%)
  - Nitration: 15 (11 %)
  - Sulphonation: 13 (10%)
  - Hydrolysis: 10 (7%)
  - Raw Materials Quality: 15 (11%)
  - Others: 13%
- 34 incidents were caused because **there was no study done for reaction hazards**

Reaction Hazards – Incidents by Causes

(Ref: Book: Chemical Reaction hazards by John Barton)

- 35 incidents were caused by mischarging of reactants or catalysts (29%)
- 32 incidents were caused by temperature control (27%)
- 25 incidents were caused by maintenance (21%)
- 17 incidents were caused by agitation (14%)
- 11 incidents were caused by human error (9%)

PSCI Questionnaire and Typical observations

Audit Questions Summary – Process Safety

Topic	Question summary
Process Safety	76: Top 3 most hazardous process activities conducted at this facility 77: Process hazard assessment 78: Evaluated the impact of its operation on the community Evaluated the impact from the activities of neighboring businesses 79: Risk assessment for explosion of flammable liquids, vapors, powders, and gases 80: Preventive maintenance of safety relevant equipment. 81: Handling compressed gases safely 82: Bulk chemical handling procedures 83: Safety measures around direct fire equipment (e. g. boiler, incinerators, ovens etc.)

Process Safety - Typical Observations

77	Does the facility perform Process Hazard Assessment (PHA)? *Aim is to identify processes or operations that could present significant risks in case of deviation (exothermic reactions, use of flammable, combustible or toxic materials, processes involving extreme temperatures or pressures).*	… • Collection of process information (process safety data, design information, operating parameters, and equipment specifications) • Hazard evaluations capturing significant risks during process development, preliminary engineering, and upon completion of process design? • Sizing of pressure vessels and relief devices according to appropriate codes and standards? • Flammable storage areas separate from production and well managed?

No safety data for any chemical reaction are available (example: heat of reaction, adiabatic temperature rise, decomposition temperature,…)
The auditee has made some improvement to collect process safety data and to conduct PHA for high sophisticated chemical reaction (nitration, oxidization, hydrogenation etc.) running at site. Nevertheless the interpretation of this data and the transfer into safety measures for the production is not always reliable.
Basic safety data for chemical processes are available from the Development report. However data are archived and in case of changes these data are not any more reconsidered, since there is no systematic approach in place to cover chemical safety data in a change control system.

Process Safety - Typical Observations

Most of the vent pipes coming from safety valves or rupture disks have at least 3 ninety degree angles. Therefore there is no evidence about the pressure profile inside the venting pipe. This leads to back pressure build up in case of activation with a certain risk for pipe bursting.
The reactor where the bromination takes place misses a safety valve or rupture disc respectively. Furthermore the adiabatic reaction heat is not known.
The explosion vent of the fluid bed dryer in the Bromhexine clean rooms is venting into the cleanroom.
In the chemical production building, the venting pipes of the safety valves end close to the floor in the production room. Taking into consideration the highly hazardous nature of the ingredients (e.g. Oleum, CO, SO_3) this may lead to fatal accidents in case of a pressure relief.

Process Safety - Typical Observations

79	Does the facility perform risk assessment related to the explosion of flammable liquids, vapors, powders, and gases in processing operations (including storage, transfer and charging)? Does it include the following steps?	• Assessment of the hazards (Minimum Ignition Energy, Kst classification rating, Impact sensitivity etc.) of the handled combustible dusts and powders • Hazardous area classification (zones according EU-ATEX and Classes according to US-NFPA) … • Installation of special electrical equipment for flammable vapors, gases, combustible dusts, … • Periodic testing of grounding and bonding circuits, lightning arresters, and electrical distribution equipment? • Maintenance/calibration done for critical safety equipment (e.g. sensors, instruments, valves, interlocks, reactors, condenser etc.) at suitable intervals. • Assessment of the hazards due to mechanical ignition sources? • Installation of special electrical equipment for flammable vapors, gases, combustible dusts, and wet areas? • Periodic testing of grounding and bonding circuits, lightning arresters, and electrical distribution equipment? • Maintenance/calibration done for critical safety equipment (e.g. sensors, instruments, valves, interlocks, reactors, condenser etc.) at suitable intervals. • Assessment of the hazards due to mechanical ignition sources?

Process Safety - Typical Observations

Safety data like MIE, St Class etc. are available for most of the finished products (API). No data is available for isolated intermediates. Hence it could not be proven if the Fluid Bed Drying of intermediates can be done safely.
The company has not assessed the hazards (Minimum Ignition Energy, K_{st} classification rating, Impact sensitivity etc.) associated with combustible dusts and powders being handled in various operations at site.
At the installations in the production area stainless steel clamps were installed instead of using copper wires for grounding and bounding. No evidence was provided showing that this type of bounding grounding is as safe and effective as copper wires.

Process Safety - Typical Observations

The Customer product is received in packaging, treated in anti-static agents and the specifications for the finished product require it to be packaged in liners that are treated with anti-static agents. However, the material handled in the intermediate steps is not treated with anti-static agents. Site personnel assume that the minimum ignition energy is low enough to warrant this type of packaging if the incoming and finished product are packaged in anti-static treated liners.
There is no gas detector near the ethanol recovery device at VB1 workshop, no O2 detector at centrifuges which used N2.
In the production plant, grounding points and grounded piping are installed. A detailed SOP for working in Ex-zones is available and trained. But an instruction, how to ground mobile equipment (e.g. solvent drums) is not included in this SOP.
An Ex light in the hydrogenation room was labeled as “Ex ed IIB T4”, which was not the proper type for hydrogen environment.

Process Safety - Typical Observations

80	Describe how the facility ensures preventive maintenance of safety relevant equipment.	• Pressure safety relief valves/rupture disks • Bonding/earthing systems • Mass transfer systems (e.g. piping systems) • Pressurized vessels • Explosion prevention system (e.g., prevention of static electrical discharge) • Is there emergency power supply for relevant equipment?

Anti-static bridge connection of pipes for transporting flammable chemicals is very rusty in Building A-6.
Most of the P+IDs presented during the audit where not up to date. Furthermore the guidelines of ISO14617 regarding the symbols are not followed. P+IDs should always be up to date, showing the "as build" situation to avoid any risk due to mistaken identity of any component of an equipment.

Process Safety - Typical Observations

81	Does the facility provide a means for handling compressed gases safely that includes:	Inspection and approval before acceptance of delivery? Storage in a segregated area designed for compressed gases? Separation or barriers to manage compatibility issues? Gas classification labeling? Regulator, hose and flexible connection inspections?

Video – Gas bottles transporter

(optional: Video gas transporter)

PSCI Questionnaire

82	Has the facility developed and implemented bulk chemical handling procedures that include:	Not applicable Specific unloading and loading procedures? Identification sampling before unloading? Hose inspection? Fire protection? Spill control measures (dike or bund area)?

Storage of Oxalyl Chloride is done under “normal” conditions (Hyderabad room temperature in the warehouse). As of the “Tech Pack” information, the storage temperature should not exceed -10°C. Even if there are some newer SDS available that storage at middle European room temperature range (max. 25°C) might be sufficient, the company could not show evidence that the change of storage conditions was assessed.
The bulk unloading process needs improvement. The unloading area is asphalt but no defined retaining volume in case of any spillage is provided.

Process Safety - Typical Observations

83	What are the safety measures around direct fire equipment (e. g. boiler, incinerators, ovens etc.)? *Consider gas accumulation, steam overpressure...*	

In the Building B, Water For Injection (WFI) system, the clean steam generator operates at 65 psig with a safety relief valve venting directly to the room. In the case of activation, 155°C steam would be released and fill the room.

CONTACT

pscinitiative.org

info@pscinitiative.org

Annabel Buchan:
+55 (11) 94486 6315

PSCI

@PSCInitiative

For more information about the PSCI please contact:

PSCI Secretariat
Carnstone Partners Ltd
Durham House
Durham House Street
London
WC2N 6HG

info@pscinitiative.org

+55 (11) 94486 6315

About the Secretariat
Carnstone Partners Ltd is an independent management consultancy, specialising in corporate responsibility and sustainability, with a long track record in running industry groups.

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PSCI PHARMACEUTICAL SUPPLY CHAIN INITIATIVE
Building responsible supply chains

1) Emergency Preparedness and Response
2) Hazard Information

Dr. Daniel Rehm
HSE Advisor Elanco External Manufacturing EMEA & API
由Daniel Rehm博士来演讲
HSE顾问，礼来动物保健外部制造，欧洲 & 原料药

Bio

- Daniel is HSE Advisor in the Elanco External Manufacturing EMEA & API Hub Basel, Switzerland
- PhD in Chemistry from Humboldt University in Berlin, Germany with 19 years of experience in Chemical Industry, Insurance and Pharmaceutical Industry. Functional experience in Process Development, HSE, Engineering and Manufacturing
- Working in Elanco for 3.5 year.
- Additional qualification as Fire Protection Manager CFPA-E

Dr. Daniel Rehm
HSE Advisor
Elanco External Manufacturing EMEA & API Hub Basel
rehm_daniel@elanco.com

AGENDA 大纲

Emergency Preparedness and Response

Hazard Information

1 – AUDIT OVERVIEW

Audit Questions Summary – Emergency Prepardness and Response / Hazard Information

Topic	Question summary
Emergency Preparedness and Response	• Fire detection/protection systems • Emergency response equipment inspection • Fire alarm system monitoring and notification to emergency services • Fire water for fire protection • Emergency exits and evacuation routes clearly marked, kept free of obstructions • Emergency exit signs illuminated with emergency backup power • Regular emergency evacuation drills • Emergency response plans • On-site emergency response team that is trained for fire or other emergencies

Topic	Question summary
Hazard Informatic	
Worker protection	• Does the facility have a safe work permit system **(Hot Work Permit)**

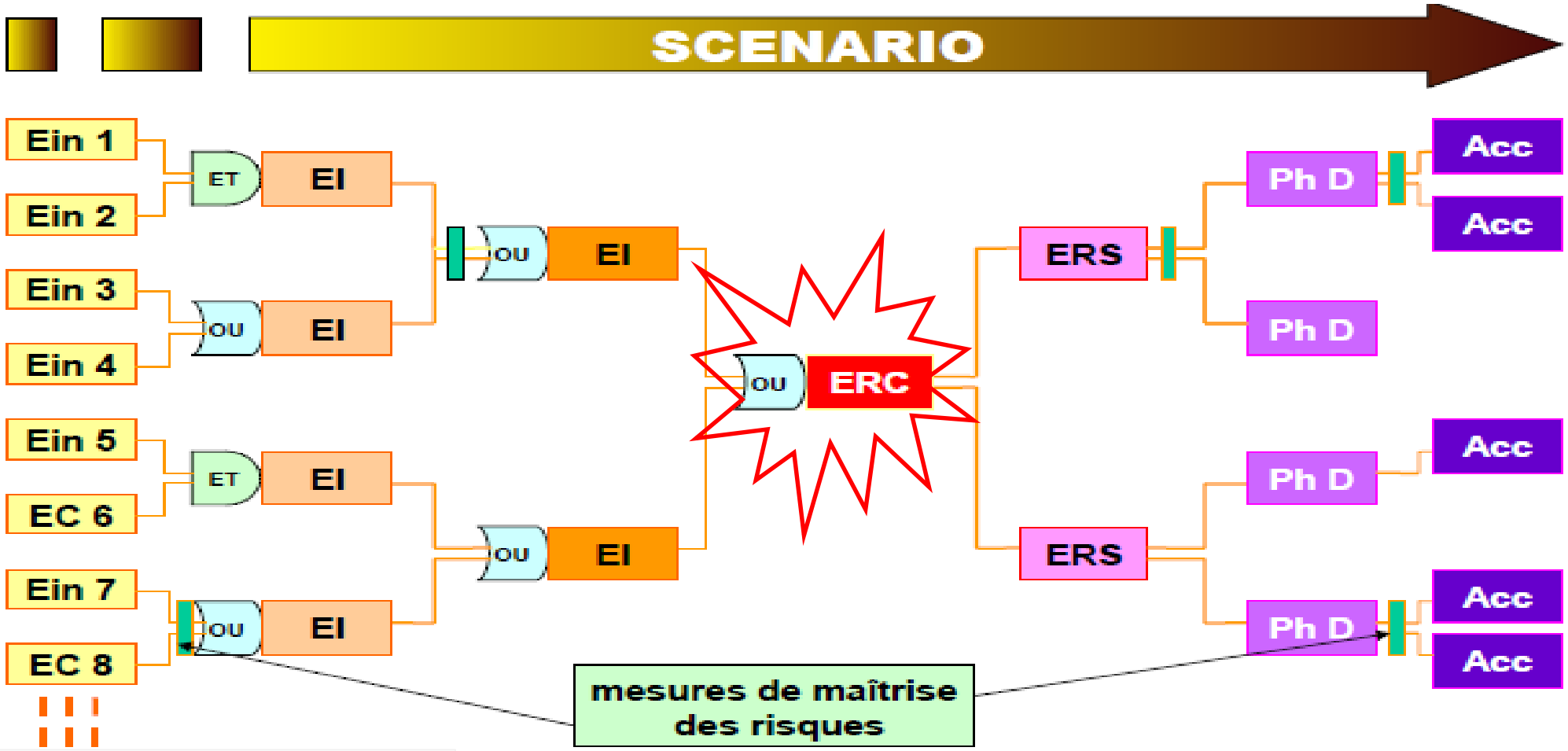
Topic	Question summary
Process Safety	• Impact of its operation on the community • Safety measures around direct fire equipment (e. G. Boiler, incinerators, ovens etc.)

1 – AUDIT OVERVIEW

Topic	Question summary
Process Safety	• Impact of its operation on the community • Safety measures around direct fire equipment (e. G. Boiler, incinerators, ovens etc.)

78	Has the facility evaluated the impact of its operation on the community? Has the facility evaluated the impact from the activities of neighboring businesses?	Yes No NA Yes No NA	Yes No NA Comments
83	What are the safety measures around direct fire equipment (e. g. boiler, incinerators, ovens etc.)? *Consider gas accumulation, steam overpressure...*	Please describe:	Yes No NA Comments

1 – AUDIT OVERVIEW



Emergency scenario: 3 types of effects

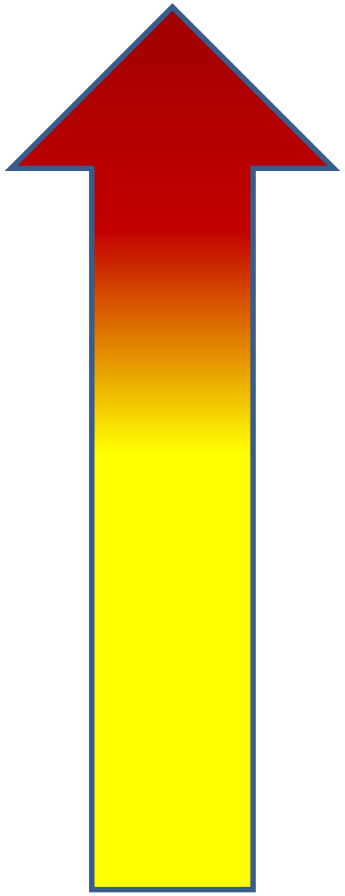
1 – Thermal effects : burns, suffocation

2 – Toxic effects: inhalation, intoxication

3 – Overpressure direct effets : Explosion of lungs or eardrums, Projection against an obstacle, …
Or indirect (missile effect): breaking of windows, moving objects…

1 – AUDIT OVERVIEW

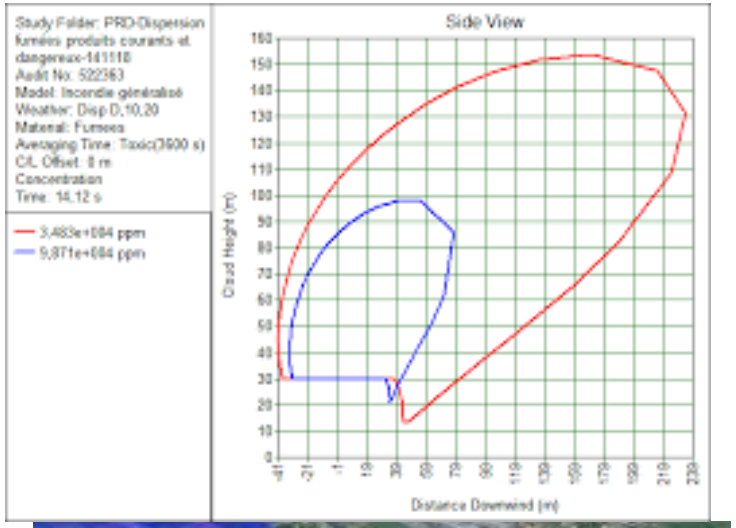
4 thresholds of effects on the people

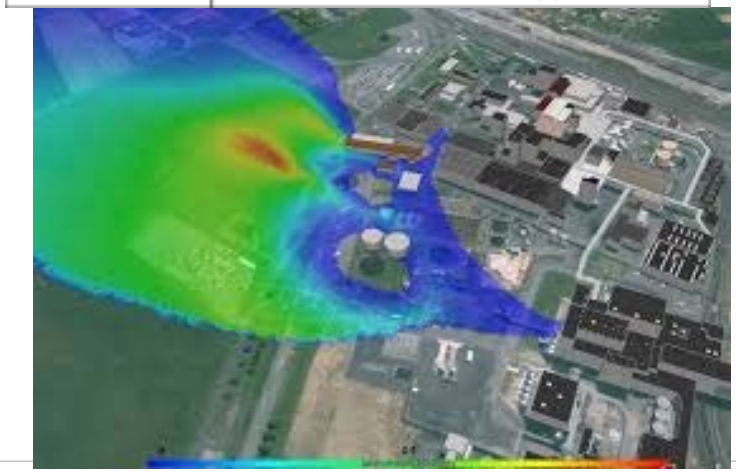


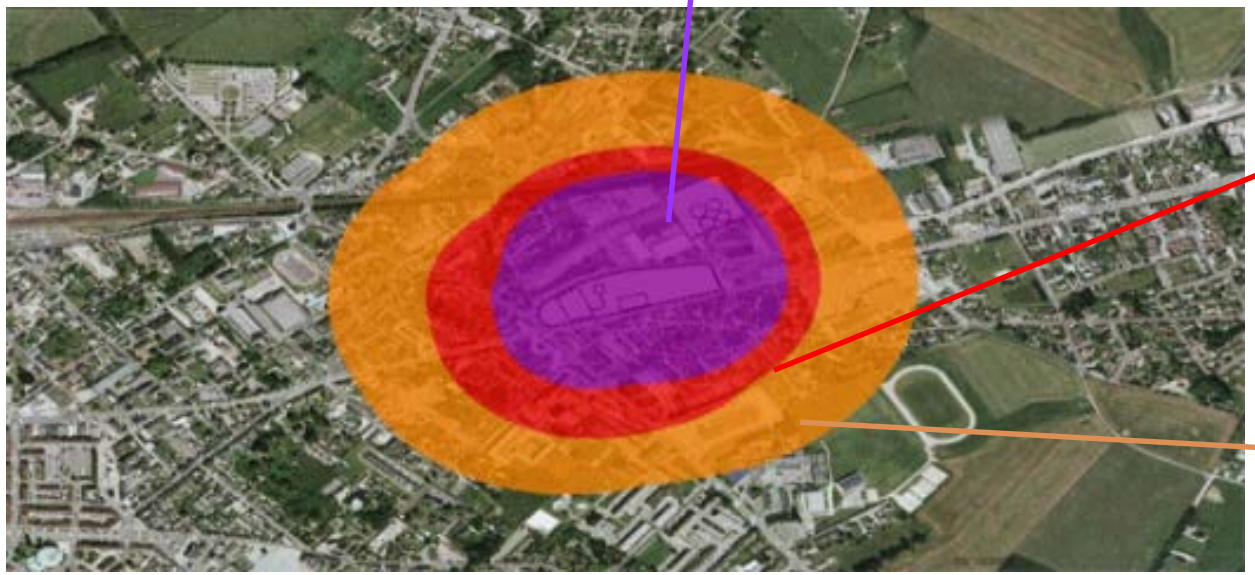
Treshold of effects on human	TYPES OF EFFECTS		
	Thermal	Toxic	Overpressure
LETHAL SIGNIFICANT (SELS)	8kW/m²	CL 8%	200 mbar
LETHAL (SEL)	5kW/m²	CL 1%	140 mbar
IRREVERSIBLE (SEI)	3kW/m²	SEI	50 mbar
INDIRECT (Breaking of windows)			20 mbar

1 – AUDIT OVERVIEW

Specific softwar calculation and graphic representation







1 – AUDIT OVERVIEW

Topic	Question summary
Worker protection	• Does the facility have a safe work permit system **(Hot Work Permit)**

55	Does the facility have a safe work permit system for the following?	**Hot Work: Yes No NA** Confined Space Work: Yes No NA Energy Isolation or Lock Out/Tag Out: Yes No NA Line Breaking: Yes No NA Work at Height: Yes No NA General Permit Yes No NA Other: Yes No Please describe:	Yes No Comments **AUDITOR GUIDANCE:** Provide the procedure title or # as reference and comment on the applicability at the site.

1 – AUDIT OVERVIEW

Topic	Question summary
Emergency Preparedness and Response	• Fire detection/protection systems • Emergency response equipment inspection • Fire alarm system monitoring and notification to emergency services • Fire water for fire protection • Emergency exits and evacuation routes clearly marked, kept free of obstructions • Emergency exit signs illuminated with emergency backup power • Regular emergency evacuation drills • Emergency response plans • On-site emergency response team that is trained for fire or other emergencies
Hazard Information	• Safety Data Sheets (SDSs) for all hazardous substances

1 – AUDIT OVERVIEW

84	Are the following areas of the facility equipped **with fire detection/protection** systems?	Site areas	Fire/smoke detectors	*Sprinkler or suppression* systems	Comments AUDITOR GUIDANCE Briefly describe the site's fire protection program and to what extent it has been implemented. Describe any observations that could impair a normally acceptable fire protection plan in terms of building construction, fire load, general state sprinkler system, smoke detectors, alarm system, inclusion of key equipment in preventive maintenance program etc. Check for stored materials that could create a fire hazard, such as idle pallets.
		Raw material storage areas	Yes No	Yes No	Yes No Comments
		Flammable liquid storage tanks	Yes No	Yes No	Yes No Comments
		Process areas	Yes No	Yes No	Yes No Comments
		Finished product warehouse	Yes No	Yes No	Yes No Comments
		Hazardous waste storage area	Yes No	Yes No	Yes No Comments

1 – AUDIT OVERVIEW

85	Is the facility emergency response equipment **(fire extinguisher, fire pumps, sprinkler systems) visually inspected monthly,** comprehensively inspected annually, and documentation maintained for all inspections?	Yes No Please explain:	Yes No Comments
86	Is the **fire alarm system monitored 24 hours** a day (including weekends and holidays) with prompt notification to emergency services (within 5 minutes)?	Yes No Please explain:	Yes No Comments
87	Does the facility ensure that an adequate amount of fire **water is maintained for fire protection**?	How many cubic meters of fire water is maintained for fire protection? How was it determined to be sufficient? Can the capacity of the pumps meet the requirements of NFPA (sufficient water flow?) Yes No Please explain if No:	Yes No Comments

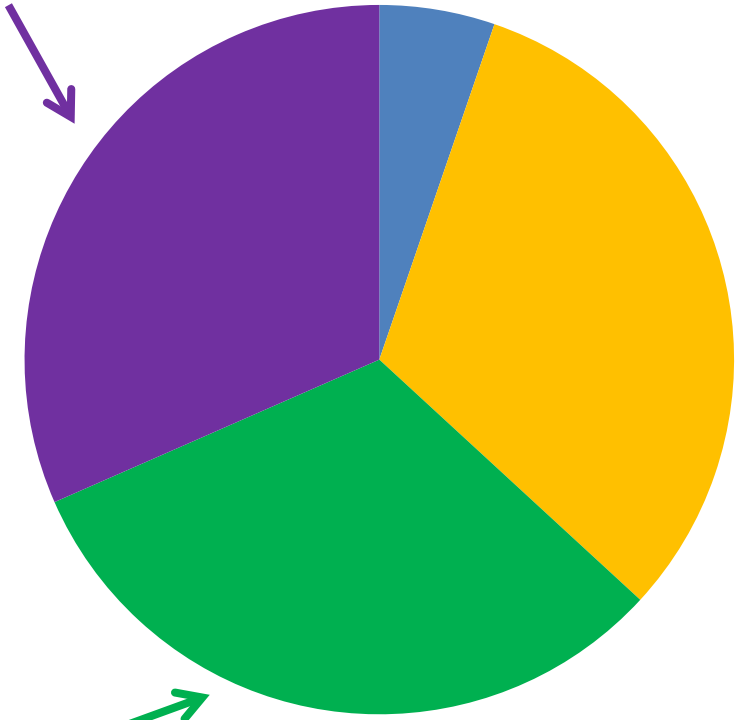
2 – SUBJECT OVERVIEW : FIRE SOURCES

SMOKING

>> Smoking policy

ELECTRICITY

>> Electrical inspection
>> Electrical rooms
>> Infra red – Thermography
>> Lightning protection



HOT WORK

>> Hot work Permit

PROCESS

>> Chemical : process safety
>> Other activities : ??

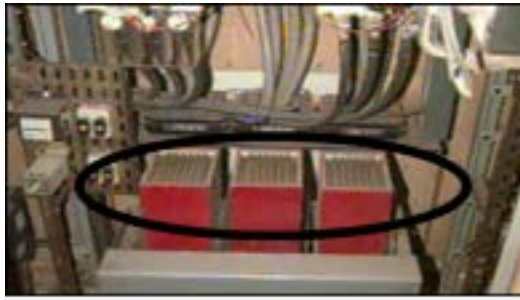
2 – SUBJECT OVERVIEW : FIRE PREVENTION

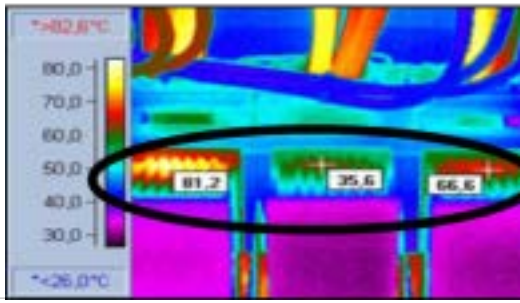
SMOKING

- Smoking policy specifies at the site entrance / visitor training ?
- Clear signs/ limits ?? To see during the site tour
- Do you find cigarette end during your site tour ?

ELECTRICITY

- Electrical inspection >> Maintenance / regular check
- Electrical rooms >> Visit electrical room, transformers PSCI 56
- Infra red – Thermography
  PSCI 56
- Lightning arresters
  PSCI 79
- Location of electrical equipments near combustible material ???





2 – SUBJECT OVERVIEW : FIRE PREVENTION

PROCESS

- **Chemical/Pharmaceutical : process safety chapter PSCI 76-82**
- **Warehouse:**
  - **Where are located the battery chargers ?**
  - **Lights above the storage /aisle ?**
  - **Stability chamber in Polyurethane / cooling system ?**
- **Pharmaceutical processes**
  - **Milling ,** Sieving**, Micronization** (see process safety / powder data)
  - **Granulation** (Use of solvant: see process safety)
  - **Electrical dryer**
  - **Equipment running 24/7**
- **Laboratories:**
  - **Oven (24/7) CPLG: H2 ?**
  - **Mixing of waste …**
- **Technical area**
  - **Filters, Heater, Electricity**

2 – SUBJECT OVERVIEW : FIRE PREVENTION

HOT WORK

during the documentation review :

- Check the Hot work Permit
- Procedures / SOP (link with HW Permit)
- Who signs hot work permit ?
- What if : Fire detection above the hot work permit ????
- Hot work permit in ATEX Areas >> LEL

- NO Fire detection >> Visit 1 to 3 hour after the end of the work
- Permanently present for 1 hour.
- Patrols every hour for 3 hours

Hot Works

Check the fire systems

Visit the location and neighbouring vicinity

Combustible load

Extinguishers

Protect and cover up

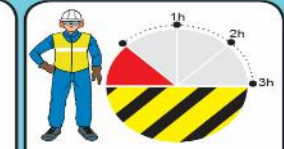
≥10m (33ft)

Equipment Conformity

Qualified & protected operators


Specific 1 day permit


Alarm/Emergency



Safety visit after work


Explosimeter control

Before starting the work...

➔ Study the possibility of doing the work in the maintenance shed or in another zone specially designed to avoid fire or explosions.

➔ Visit the location and neighbouring vicinity:
Look for links with neighbouring installations (pipes, casings, gutters, false-ceilings, openings…).

Specific permit

➔ Draft a specific 1 day permit .

Yellow Tag

Combustible material

➔ Displace combustible material beyond 10 m (33ft).

Protection

➔ Protect exposed areas and block openings though which incandescent particles could pass.

➔ Cordon off the area

➔ Wet floor

Explosion control

➔ Take specific measures for zones with a risk of explosion

As a minimum scan explosimetre monitoring (before and during).

➔ ATEX areas, flammable liq tank / waste water network …..

Fire fighting

➔ Be prepared for fire fighting.

As a minimum have extinguishers at hand.

Fire systems

➔ Depending on work in progress and the difficulties encountered (false alarms) decide whether to impair

Equipment Conformity

Check the equipment (pipes, gas cylinders secured ..)

Qualified and protected operators

Post work fire watch

➔ Permanently present for 1 hour.

➔ Patrols every hour for 3 hours

Alert / Help

➔Define the means of alerting help
➔Check the work
➔In the case of a problem or unexpected event:
Stop the work, alert and call a supervisor

Hot works

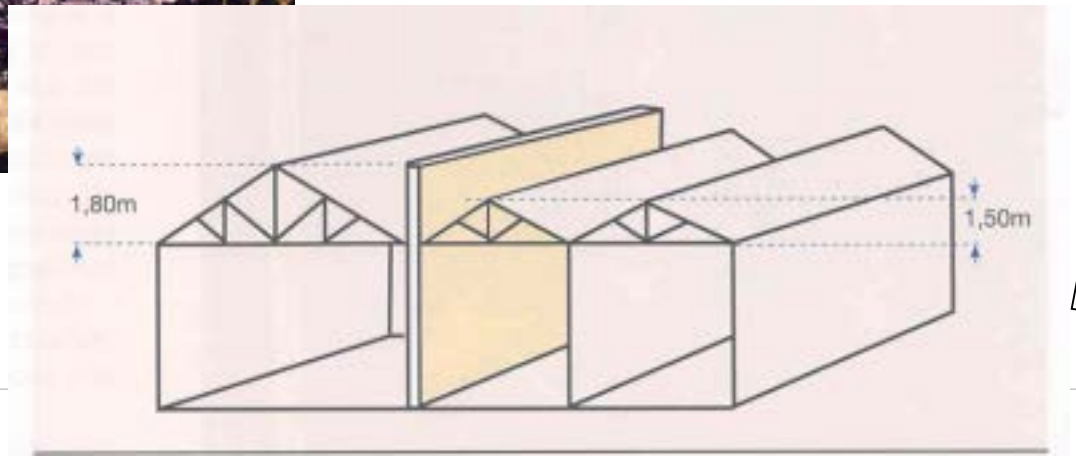
HSE SANOFI

2 – SUBJECT OVERVIEW : FIRE PROTECTION

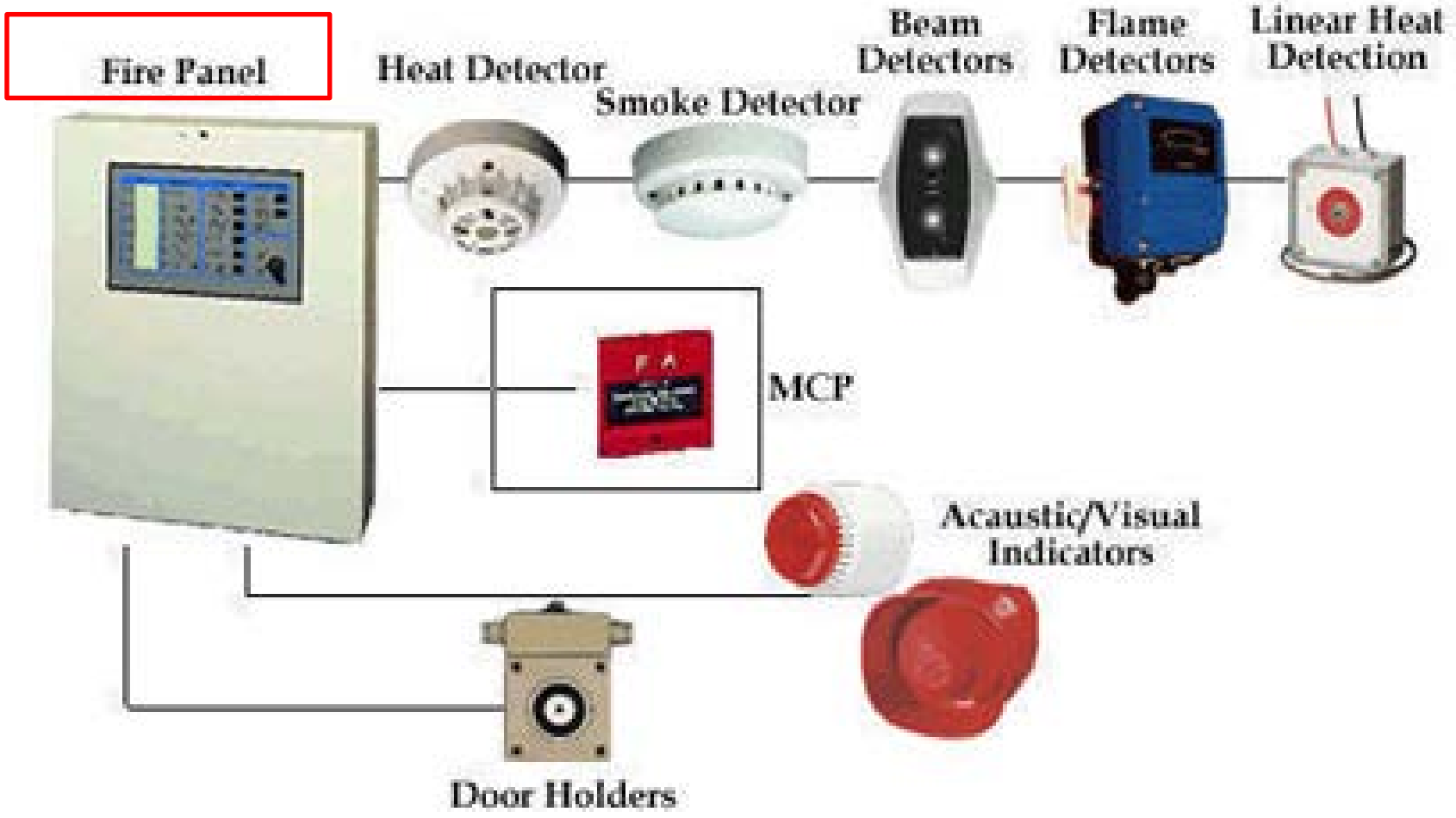
FIRE PARTIONING ASSESSMENT

- One block ?
- Many buildings/workshop ?
- Fire wall + door ?

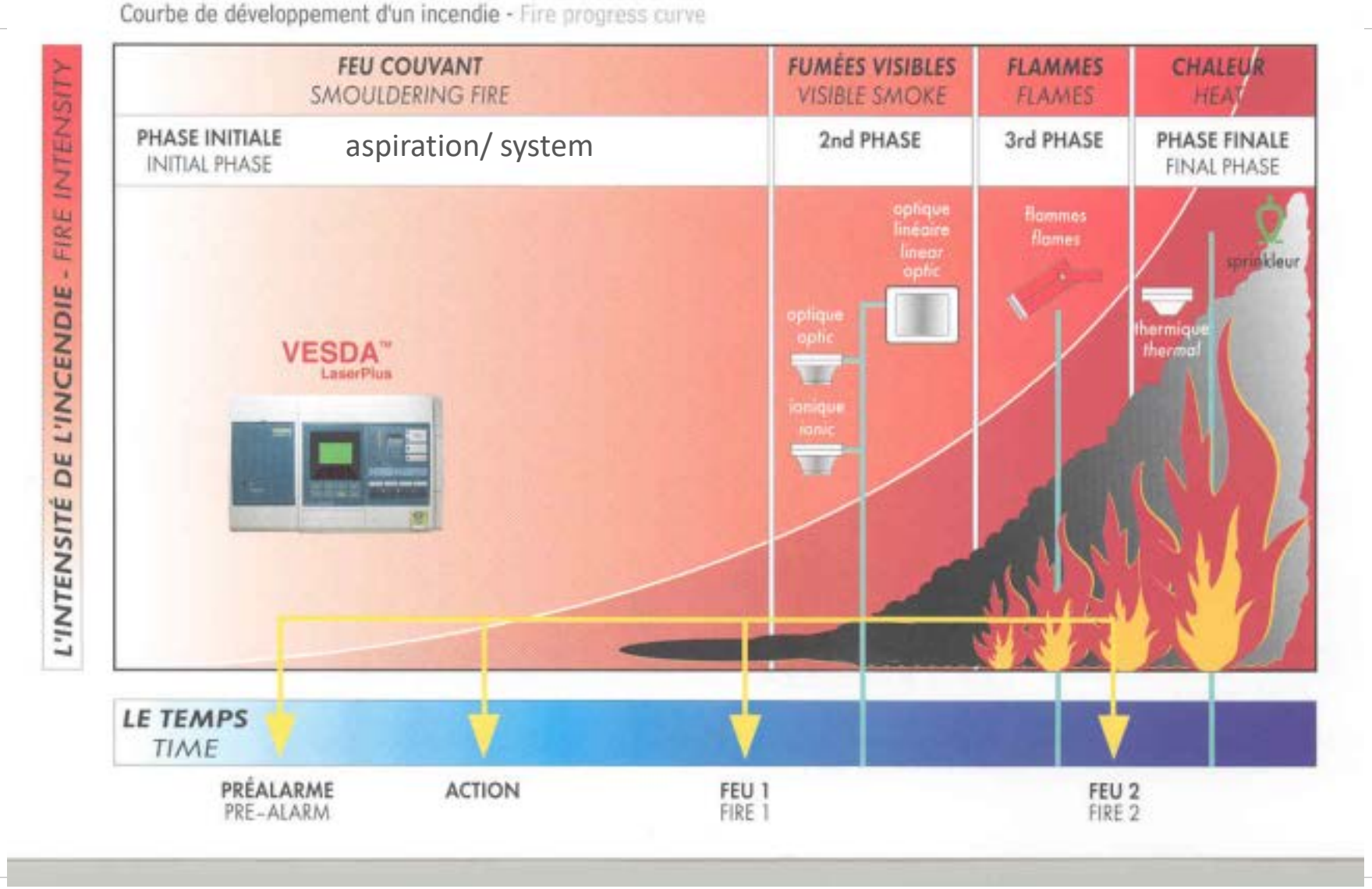
2 x 2 hours fire doors



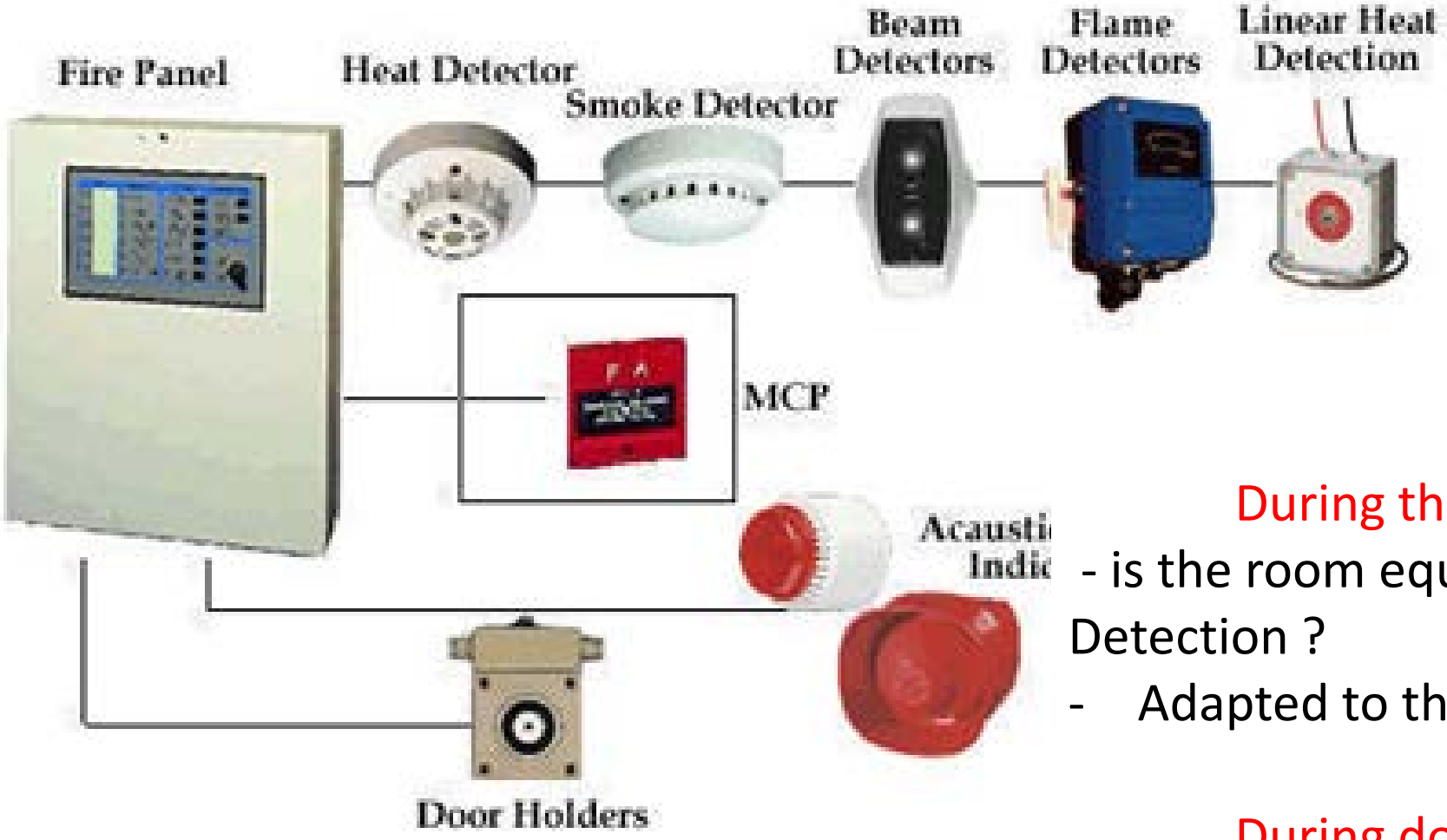
2 – SUBJECT OVERVIEW : FIRE DETECTION



2 – SUBJECT OVERVIEW : FIRE SOURCES



2 – SUBJECT OVERVIEW : FIRE DETECTION



Smoke removal

During the visit:

- is the room equiped with Fire Detection ?
- Adapted to the risk ?

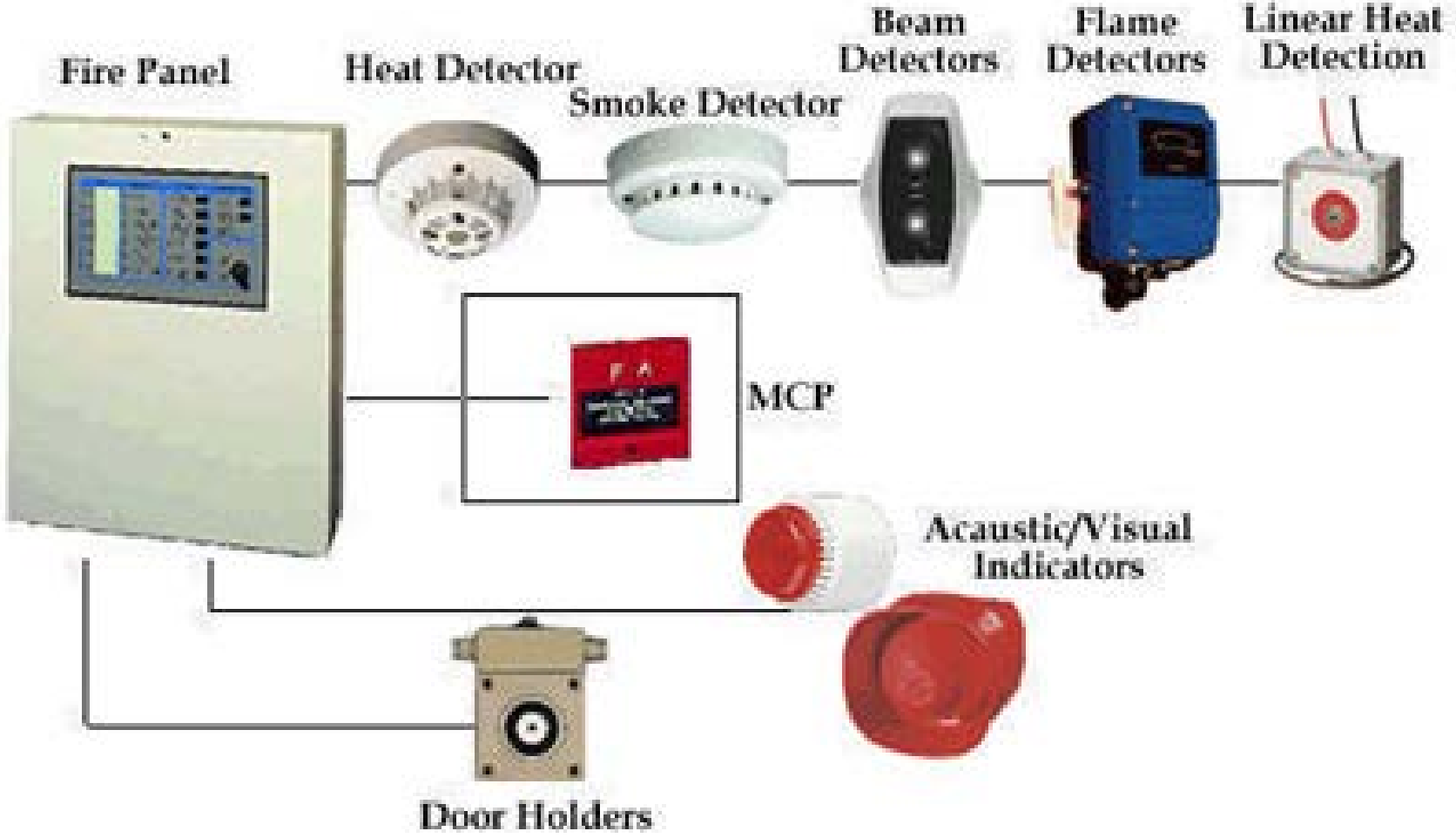
During documention review:

- Maintenance / inspection ?

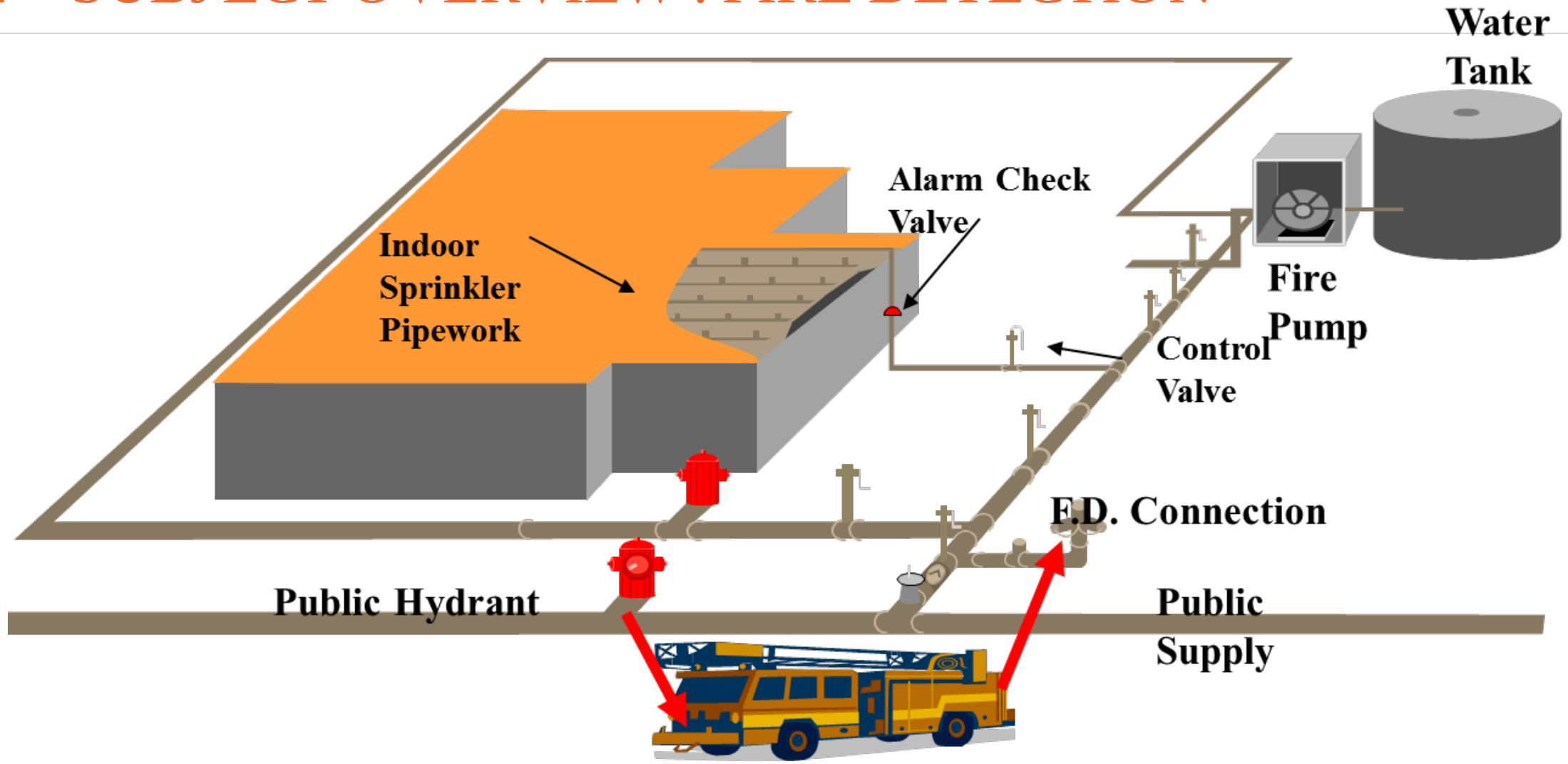
2 – SUBJECT OVERVIEW : FIRE DETECTION

24h/7 ?

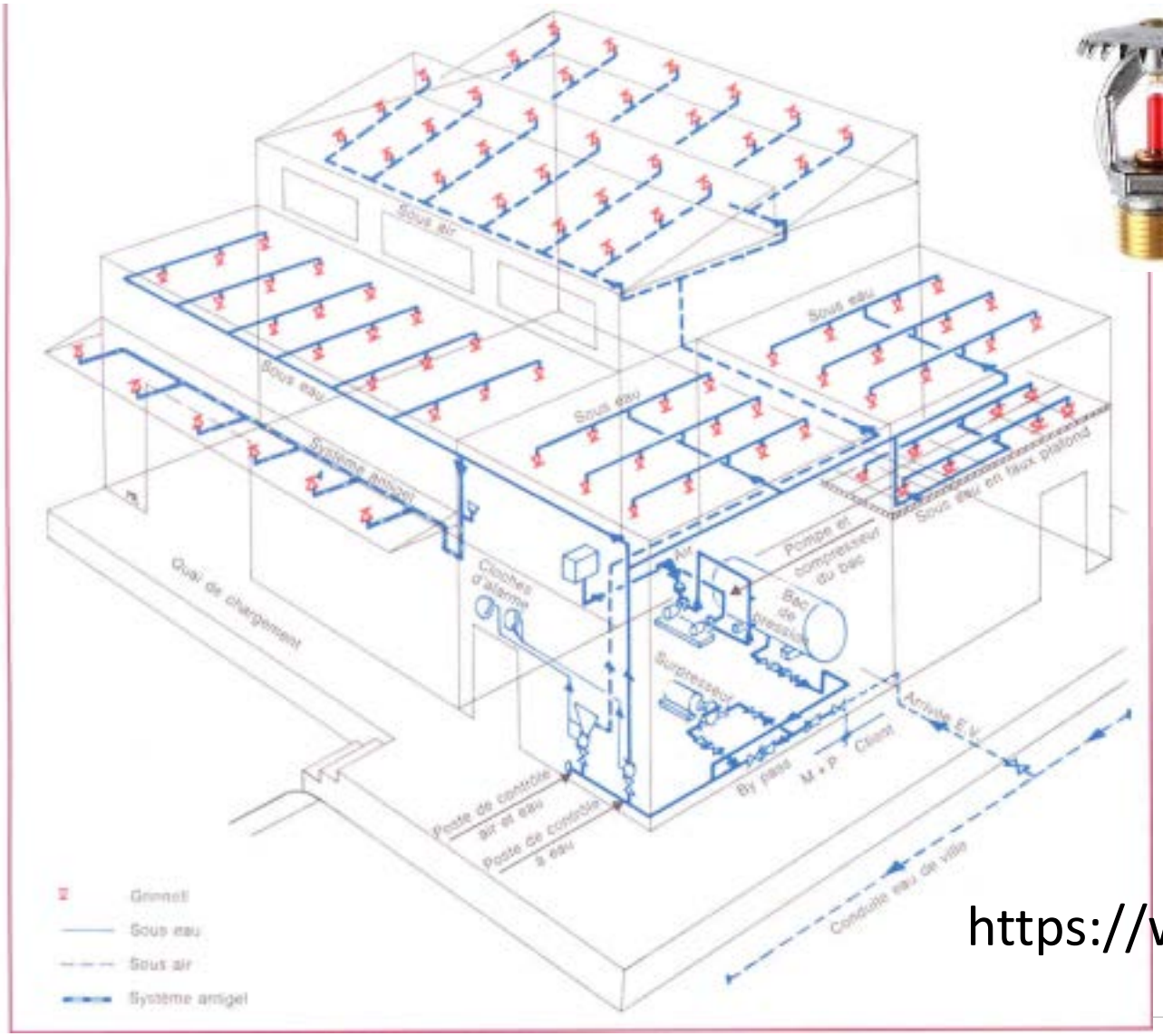
Distance to the fire brigade ?



2 – SUBJECT OVERVIEW : FIRE DETECTION



2 – SUBJECT OVERVIEW : SPINKLER Network



Extinguishing activation:

- By sprinkler network
- By dry sprinkler network
- By fire detection
- Manually (?)

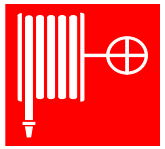
During the visit:

- Is the workshop covered by Sprinkler?
- Adapted to the risk ?

https://www.youtube.com/watch?v=o-ylvugYc0w

2 – SUBJECT OVERVIEW : SPINKLER

(Sprinkler System Demand + Hose Stream Demand) x Required Duration = Water Supply Demand

( + ) x 3 hours =

- Total capacity ?
- Anti-freezing system ?
- Low level alarm ?

- Sprinklers: 12.2 l/min/m². over 278 m²
- Hose stream demand: 2840 l/min
- Required duration: 3 hours

EXAMPLE :

(12.2 l/min/m²) (278.8 m²) (110%) = 3741 l/min

Hose demand = 2840 l/min

3741 l/min + 2840 l/min = 6581 l/min

(6581 l/min) (60 min/hr.) (3 hrs.) = 1185 m³

2 – SUBJECT OVERVIEW : SPINKLER PUMP

During the visit: at sprinkler pump station

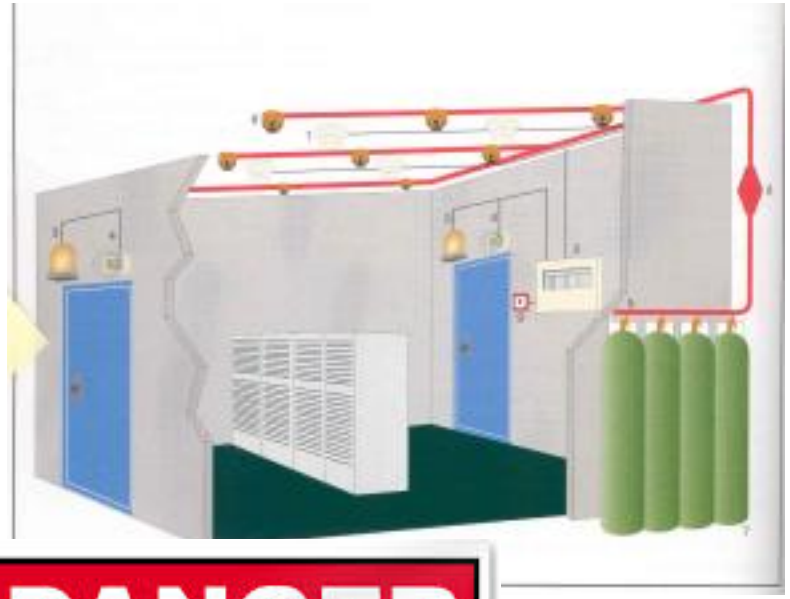
- 1,2,3 pumps ?
- Diesel ? Electrical pumps ? (generator)
- Flow m3/h
- Fuel storage /Battery / Oil
- Lamps / Key of the control panel
- Safe conditions: fire proof, locked, order
- Maintenance

During documention review:

- Sprinkler certificat
- Maintenance / inspection

2 – SUBJECT OVERVIEW : FIRE Protection

Other extinguishing systems



2 – SUBJECT OVERVIEW : Fire extinguishers

Industrial Activity

1 extinguisher 9 l of water or 9 kg of powder by 200 m2 or
1 extinguisher 6 l of water or 6 kg of powder by 150 m2 or
3 extinguisher 5 kg CO2 by 200 m2

Additional subsidy

Localized hazard (electric cupboard, transformer, compress
generator, electric engine, special machine):
An adapted fire extinguisher has to be unless 5 m of the danger

Storage (height > 3 m)

1 extinguisher on wheel of 50 kg (water or powder) by 100 m2, from 400 m2 of storage

This *subsidy is useless on the storage witch is provided with RIA*

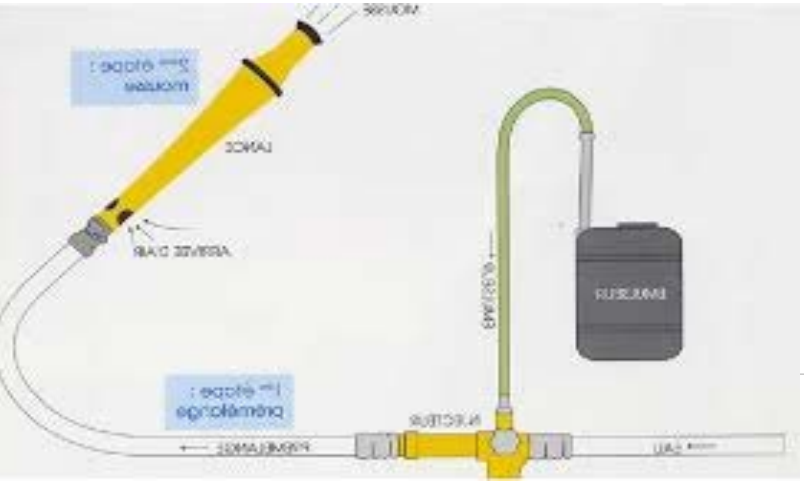
During the visit

Clear access + Labelling + check inspection label

During documentation review

Training + inspection

2 – SUBJECT OVERVIEW : Fire reels and hose



- A specific fire hose network should supply fire fighting points with a fire reels and hose (FPHS).
- The location of the FPHS's should make it possible to sprinkle one point of the building with 2 FPHSs.

- + FOAM << Quantity / time limit use

<u>During the visit</u>

Clear access + Labelling + check inspection label

<u>During documentation review</u>

Training + inspection

2 – SUBJECT OVERVIEW : FIRE STRATEGY???

What is the site fire prevention and protection strategy ??? Human/Organizational or Technical

EXAMPLES	Solution 1 (-)	Solution 2 (+)
Chemical site	Fire or gas detection and on site fire brigade	Automatic sprinkler system with foam
Chemical workshop with sodium handling	Clear sign: No water! / No connections of water pipe in the process	Gas extinguishing system / special powder
Warehouse	Fire detection and on site fire brigade Fire hoses /	Automatic sprinkler
Sterile Pharmaceutical class A	Fire detection and on site fire brigade Gas extinguihers Contamination by smoke ????	*Sprinkler with preaction ????* *Sometimes water and smoke can cause more damages ?????*
Packaging	Fire detection and on site fire brigade Fire hoses /	Automatic sprinkler
OEB5 workshop	Fire detection and on site fire brigade Gas extinguiher / Water polution	(sometimes sprinkler can create more dammages ?????)
Biological agent workshop	Fire detection and on site fire brigade Gas extinguiher / Water polution	(sometimes sprinkler can create more dammages ?????)
Technical areas (Electrical / Dust collector/Filters ….)	Fire detection and on site fire brigade Gas extinguiher	Automatic sprinkler

1 – AUDIT OVERVIEW

88	Are **emergency exits and evacuation** routes clearly marked, kept free of obstructions (unlocked)? Are emergency exit signs illuminated with emergency backup power?	Yes No Please explain: Yes No Please explain:	Yes No Comments
89	Are regular **emergency evacuation drills** conducted, and what is the frequency?	Yes No Frequency:	Yes No Comment
90	Are **emergency response** plans in place?	Yes No Please explain the key points of the emergency response plan: Indicate when the plan was last revised:	**AUDITOR GUIDANCE:** Describe if the relevant emergency scenarios been addressed in the emergency response plan - Natural: Earthquake, flood, tornado, hurricane, drought, etc. - Chemical: Spill, fire, wastewater treatment plant upset, - Human: Evacuation, first aid, medical emergency, civil unrest, active shooter/security threat, Does the facility have a communication system to alert the local community of impacts in the event of major emergency?
91	Does the site have an o**n-site emergency response team that is trained for fire or other emergencies?**	Yes No NA If yes, please explain:	Yes No NA Comments

2 – SUBJECT OVERVIEW : EVACUATION

<u>During site visit: In each workshops/room:</u>

- are the evacuation ways clear and easy access?
- with emergency light?
- evacuation plan ?
- siren ?

<u>During the documentation review</u>

- Date of evacuation drill + report
- Emergency Siren/light suply power ?
- Who gives alarm?
- Training ?
- Including in emergency plan or in a SOP ?

2 – SUBJECT OVERVIEW : FIRE SOURCES

During the visit

- Equipment for Fire / Environment / Chemical Risk ….
- PPE

During documentation review :

- Number of emergency team?
- Shift 24/7/365 ?
- Distance of fire-brigade ?
- Check emergency plan : Roles and responsabilties / Alert to the authorities




3 – PROBLEM TOPICS: FLOOD

Historical data

On live data and alert network

3 – PROBLEM TOPICS: FLOOD

Prevention /Protection measures

<u>Before the flood</u>

- **Evacuate the raw material/ finished product**
- **Protect equipment**
- **Anti-flooding system**

<u>During the flood</u>

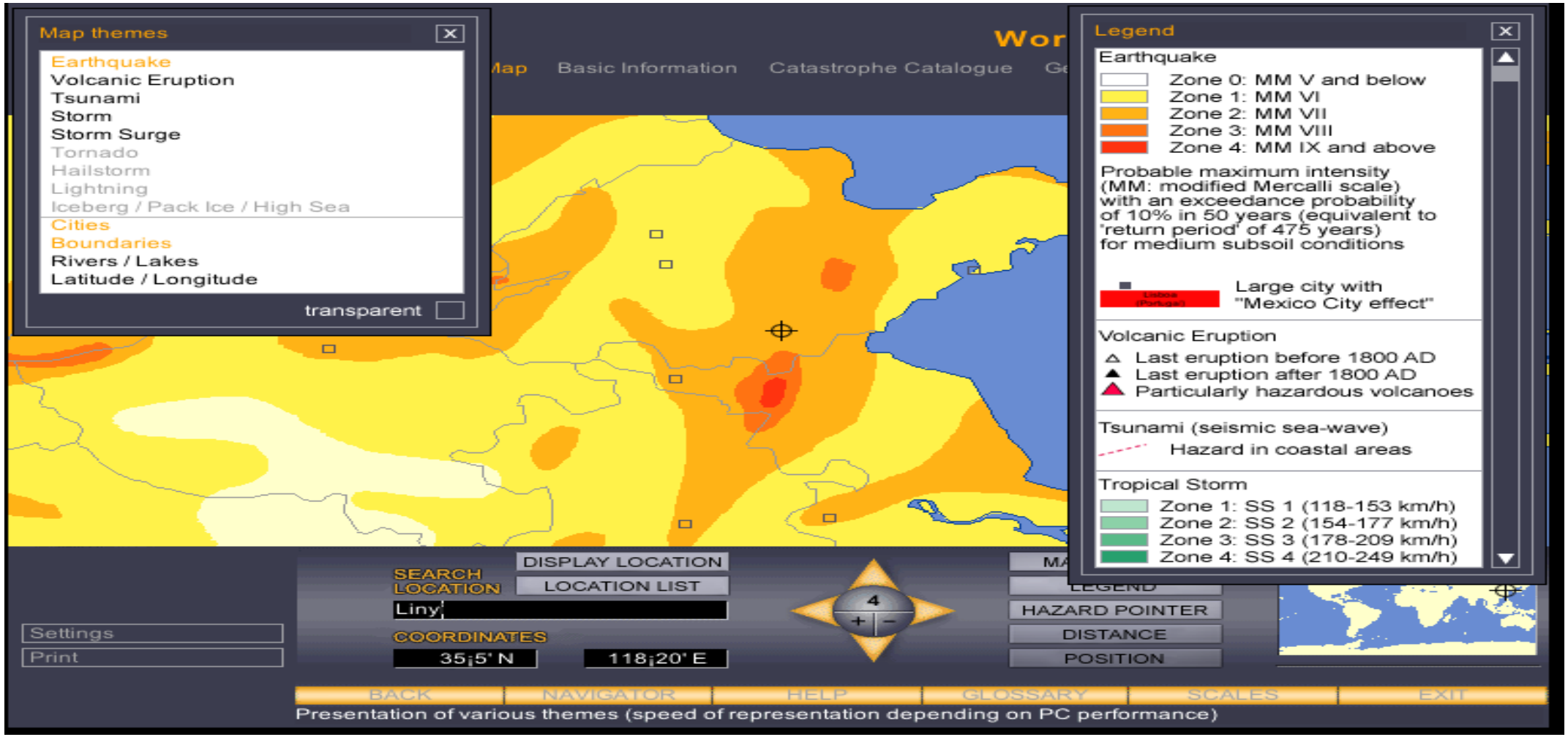
- Inspection

<u>After the flood</u>

- **Pumping / Cleaning**
- **Ventilation/ Drying**

Natural Hazards

Munich Re Nathan Natural Hazard Database: Earthquake



3 – PROBLEM TOPICS

- Eartquake resistant building
- Specific Storage
- Automatic seismic gas shutoff valv
- Specific sprinkler design
- Training

AGENDA 大纲

Emergency Preparedness and Response

Hazard Information

1 – AUDIT OVERVIEW

Topic	Question summary
Hazard Information	• Safety Data Sheets (SDSs) for all hazardous substances

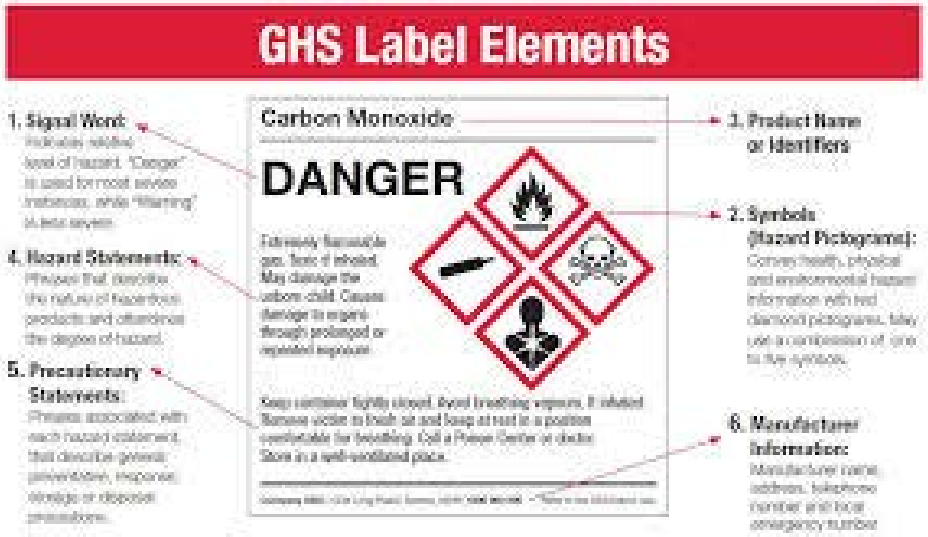
92	Does the facility maintain Safety Data Sheets (SDSs) for all hazardous substances?	Yes No Please explain:	AUDITOR GUIDANCE **WHO** edit/valid MSDS of your products ? **HOW** do you collect MSDS from your suppliers? Local **LANGUAGES** ? **ACCESS** for your operators/occu physician …? **ACCESS** for your clients ? TRAINING program covering the properties and health effects of the hazardous substances, use of and access to SDSs, container labeling and safe handling procedures?

1 – AUDIT OVERVIEW

During the site visit:

- Ask for a SDS to an operator
- Check labelling of raw, material, INTERMEDIARE, finish product

- During the documentation review:
  - WHO edit/valid SDS or labels of your products (16 chapters)?
  - HOW do you collect SDS from your suppliers?
  - Local LANGUAGES ?
  - ACCESS for your operators/occu physician …?
  - ACCESS for your clients ?
  - TRAINING program?



4 – EXAMPLE AUDIT FINDINGS

- No exit doors in the raw material warehouse W2 and finished goods warehouse W6
- Emergency light in the workshop B56 are not available.
- There are no smoke detectors, nor sprinkler, nor permanent presence on the site. Fire water storage is not available
- All emergencies doors are not identified
- The liquid substance Trimethylchlorosilane (CAS-# 75-77-4), which is violently reacting with water under formation of massive amounts of gaseous HCl, is stored in 200 L steel drums (in total about 4-5 to) together with all other flammable liquid drums in the area W34. There is no warning signs “no extinguishing with water” .
- Emergency evacuation drill are not conducted regularly , the latest drill was conducted in September 2014 . (we were in 2018 !!)
- Emergency response team responsibilities are not defined in the emergency plan
- Occupational physician has no access to the SDS database

EXAMPLE What is wrong?

84	Are the following areas of the facility equipped with fire detection/protection systems?	Site areas	Fire/smoke detectors	*Sprinkler or suppression* systems	Comments The site is partialy covered by sprinkler and fire detection.
		Raw material storage areas	Yes	No	Yes
		Flammable liquid storage tanks	Yes	Yes	Yes
		Process areas	Yes	Yes No	Yes
		Finished product warehouse	Yes	Yes No	Yes No
		Hazardous waste storage area	No		No

EXAMPLE

84	Are the following areas of the facility equipped with fire detection/protection systems?	Site areas	Fire/smoke detectors	Sprinkler or suppression systems	Comments Sprinkler is designed according NFPA rules. 2 diesel pumps (350m3/h) and a sprinkler tank 500m3 The site is partialy covered by sprinkler and fire detection.
		Raw material storage areas	Yes	No	Fire detection / fire hoses at all gates of the buildings
		Flammable liquid storage tanks	Yes	Yes	Manual foam canons in place
		Process areas	Yes	Yes No	Process areas are all equiped with fire detection Worshop A B are sprinkled Whorshop C is not covered by Sprinkler
		Finished product warehouse	Yes	Yes No	There is no sprinkler in FP warehouse
		Hazardous waste storage area	No	No	No

4 – EXAMPLE AUDIT FINDINGS

What is wrong ?

118	Does the site have an on-site emergency response team that is trained for fire or other emergencies?	Yes If yes, please explain: Team in place for spills.	No Comments Site leadership team provided documentation about spillage training

4 – EXAMPLE AUDIT FINDINGS

118	Does the site have an on-site emergency response team that is trained for fire or other emergencies?	Yes If yes, please explain: Team in place for spills.	No Comments Site leadership team provided documentation about spillage training

4 – EXAMPLE AUDIT FINDINGS

What is wrong ?

120	Does the facility maintain Safety Data Sheets (SDSs) for all hazardous substances?	Yes Please explain: Training session	No Comments Site leadership team provided details and documentation for Haz Comm training to site personnel.

4 – EXAMPLE AUDIT FINDINGS

What is wrong ?

120	Does the facility maintain Safety Data Sheets (SDSs) for all hazardous substances?	Yes Please explain: Training session	No Comments SDS access trough Online system. XYZ SDS are not in local langage.

CONTACT

pscinitiative.org

info@pscinitiative.org

Annabel Buchan:
+55 (11) 94486 6315

PSCI

@PSCInitiative

For more information about the PSCI please contact:

PSCI Secretariat
Carnstone Partners Ltd
Durham House
Durham House Street
London
WC2N 6HG

info@pscinitiative.org

+55 (11) 94486 6315

About the Secretariat
Carnstone Partners Ltd is an independent management consultancy, specialising in corporate responsibility and sustainability, with a long track record in running industry groups.

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PSCI PHARMACEUTICAL SUPPLY CHAIN INITIATIVE
Building responsible supply chains

Sprinkler Protection 喷淋防护
From basics to special applications
从基础到特殊应用

Presented by
Dr. Daniel Rehm
HSE Advisor Elanco External Manufacturing EMEA & API
由Daniel Rehm博士来演讲
HSE顾问，礼来动物保健外部制造，欧洲 & 原料药

Agenda 议题

Sprinkler Systems Basics 喷淋系统基础

Sprinkler Systems in Production 生产车间的喷淋系统

Sprinkler Systems in Warehouses 仓库的喷淋系统

Sprinkler Systems: History 喷淋系统：历史

- **Leonardo da Vinci** designed a sprinkler system in the **15th century**. Leonardo automated his patron's kitchen with a super-oven and a system of conveyor belts. In a comedy of errors, everything went wrong during a huge banquet, and a fire broke out. "The sprinkler system worked all too well, causing a flood that washed away all the food and a good part of the kitchen."
- 莱昂纳多·达·芬奇在15世纪设计了一套喷淋系统。莱昂纳多用一个特大号的烤箱和传送带在他顾客的厨房设计了一套自动化（喷淋系统）。在一次盛大的宴会上，大家都犯了戏剧性的错误，这些错误导致了火灾的发生。“喷淋系统运行的非常好，大量的水清洗了食物和厨房”。
- Ambrose Godfrey created the first successful automated sprinkler system in **1723**. He used gunpowder to release a tank of extinguishing fluid.
- 1723年，安布罗斯·戈弗雷成功的建立了第一套自动化喷淋系统。他使用黑火药将一储罐的灭火剂释放出来。
- The world's first modern recognizable sprinkler system was installed in the Theatre Royal, Drury Lane in the United Kingdom in **1812** by its architect, William Congreve, and was covered by patent No. 3606 dated the same year
- 1812年，在英国德鲁里巷的皇家剧院，建筑师威廉·康格里夫安装了世界认可的第一套现代化喷淋系统，同年包括在他的专利号3606里面。
- Sprinklers have been in use in the United States since **1874**, and were used in factory applications where fires at the turn of the century were often catastrophic in terms of both human and property losses.
- 自1874年，美国使用喷淋系统来保护工厂设施。在世纪之交，喷淋系统被用于保护灾难性的火灾导致的人员（受伤）和财产损失。

Sprinkler Systems: Design of sprinklers
喷淋系统：喷淋头设计

- Determination of fire hazard by building use and contents
- 通过建筑物用途和存放物料来确定火灾危害
- Hazard groups: 危害分组
  - Light hazard: offices, dwellings, church seating areas
  - 轻微危害：办公室，民居，教堂休息区域
  - Ordinary hazard group 1: parking garages, kitchens
  - 普通危害组1：汽车停车场，厨房
  - Ordinary hazard group 2: retail stores, warehouses
  - 普通危害组2：零售商店，仓库
  - Extra hazard group 1: saw mills, plywood manufacturing
  - 严重危害组1：锯木厂，胶合板制造
  - Extra hazard group 2: chemical manufacturing
  - 严重危害组2：化学品制造

HAZARD CLASSIFICATION	QUANTITY OF COMBUSTIBLES	COMBUSTIBILITY	RATE OF HEAT RELEASE
LIGHT	Low	Low	Low
ORD., GROUP 1	Moderate	Low	Moderate
ORD., GROUP 2	Moderate/High	Moderate/High	Moderate/High
EXTRA, GROUP 1	Very High	Very High	High
EXTRA, GROUP 2	Very High	Very High	High

Sprinkler Systems: Design of sprinklers
喷淋系统：喷淋头设计

- Density of sprinklers is defined per hazard group
- 基于危害组别来决定喷淋头的密度。
- Design area: worst case area of a fire in a building
- 设计区域：建筑里面，火灾发生的最糟糕情况的区域。
- Example: office (light hazard) 举例：办公室 （轻微危害）
  - Design area: 1500 ft^2 = 140 m^2 设计区域：1500平方英尺=140平方米
  - Design density: 0. 1 gal/min per ft^2 = 0.38L/min per 0.093 m^2
    设计密度：0.1加仑/分钟每平方英尺=0.38升/分钟每0.093平方米
  - Sprinkler system design: 570 L/min over 140 m^2
  - 喷淋系统设计：570升/分钟，覆盖140平方米
- Example: manufacturing facility (ordinary hazard group 2)举例：制造类工厂（普通危害组2）
  - Design area: 140 m^2 设计区域：140平方米
  - Design density: 0. 2 gal/min per ft^2 = 0.76L/min per 0.093 m^2
  - 设计密度：0.2加仑/分钟每平方英尺=0.76升/分钟每0.093平方米
  - Sprinkler system design: 1100 L/min over 140 m^2
  - 喷淋系统设计：1100升/分钟，覆盖140平方米

Sprinkler Systems: Design of sprinklers
喷淋系统：喷淋头设计

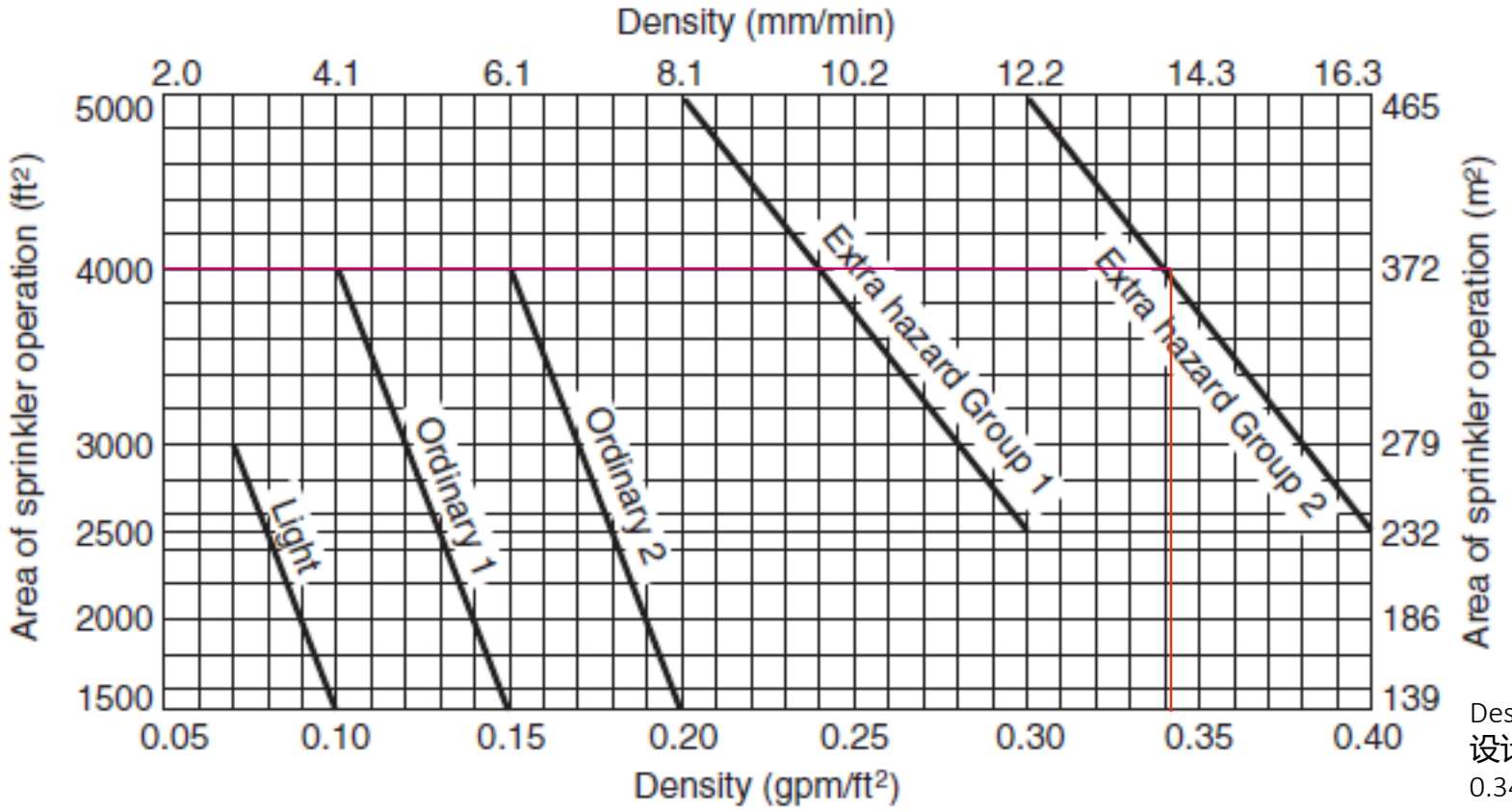


FIGURE 11.2.3.1.1 Density/Area Curves.

Occupancy	Inside Hose		Total Combined Inside and Outside Hose		Duration (minutes)
	gpm	L/min	gpm	L/min	
Light hazard	0, 50, or 100	0, 189, or 379	100	379	30
Ordinary hazard	0, 50, or 100	0, 189, or 379	250	946	60–90
Extra hazard	0, 50, or 100	0, 189, or 379	500	1893	90–120

Design area 4000 ft2 at extra hazard group 2:
设计区域 4000平方英尺，严重危害组2
0.34 gal/min/ft2 over 4000 ft2 for 90 – 120 min
0.34加仑/分钟每平方英尺，覆盖4000平方英尺，90-120分钟
→ 5168 L/min over 372 m2
→ 5168升/分钟，覆盖372平方米

Sprinkler Systems: meaning of the colors?
喷淋系统：颜色的含义

- The bulb color specifies the temperature the bulb breaks
- 玻璃管颜色代表玻璃管破裂的温度
- The bulb breaks as a result of the thermal expansion of the liquid inside the bulb
- 玻璃管内部液体的温度膨胀导致了玻璃管的破裂
- Under standard testing procedures, a 68 °C sprinkler bulb (RED) will break within 7 to 33 seconds
- 按照标准测试程序，达到68度时，喷淋头玻璃管（红色）应该在7-33秒内破裂。

Temperature		Color of liquid alcohol inside bulb
°C	°F	
57	135	Orange
68	155	Red
79	174	Yellow
93	200	Green
141	286	Blue
182	360	Purple
227 260	440 500	Black

Agenda 议题

Sprinkler Systems Basics 喷淋系统基础

Sprinkler Systems in Production 生产车间的喷淋系统

Sprinkler Systems in Warehouses 仓库的喷淋系统

Sprinkler systems in production
生产车间的喷淋系统

- Design of sprinkler systems in production units depends on use
- 生产单元喷淋系统的设计依赖于用途
- Sprinkler design needs to be re-visited after every change of installation and use
- 在每次变更安装和用途之后，喷淋系统设计需要再次评估。
- Placement of sprinkler heads needs to be done very carefully
- 喷淋头的布置需要非常认真仔细
  - Sprinkler heads should be below reaction vessels at outlet valve
  - 喷淋头应该位于排水阀反应器的下方
  - Sprinkler heads should not be obstructed by piping and other equipment
  - **喷淋头不能被管道和其它设备阻挡**

Sprinkler systems in production
生产车间的喷淋系统

- For production units with solvent handling the installation of foam systems is recommended
- 在生产单元内有溶剂处理的操作，推荐安装泡沫系统
- Available foam qualities: 可选的泡沫种类：
  - Alcohol Resistant Film-Forming FluoroProtein (AR-FFFP) 抗酒精型成膜氟蛋白泡沫
  - Film-Forming FluoroProtein (FFFP) 成膜氟蛋白泡沫
- Foam needs to be tested annually for degradation and is replaced every 5 years
- 每年测试泡沫的降解情况，每5年更换

Agenda 议题

Sprinkler Systems Basics 喷淋系统基础

Sprinkler Systems in Production 生产车间的喷淋系统

Sprinkler Systems in Warehouses 仓库的喷淋系统

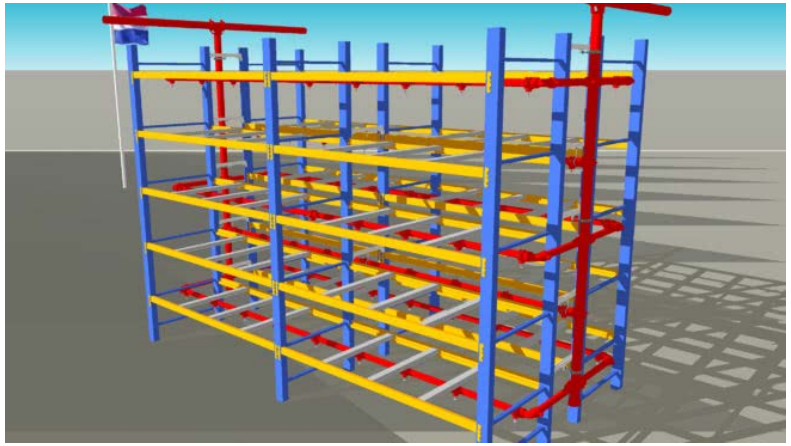
Sprinkler systems in warehouses
仓库的喷淋系统

- Sprinkler protection in warehouses:仓库内的喷淋保护：
  - Sprinkler systems protect buildings not stored goods
  - 喷淋保护建筑，不保护储存的货物
  - Water and smoke damage render goods unusable
  - 水和烟气损害致使货物不稳定
  - Loss for electronics and pharmaceuticals: 100%
  - 电子（设备）和药物损失率：100%
- Maintaining small fire areas is crucial to limit loss of product
  为了减少产品损失，维持小范围过火区域至关重要

	Structural damage **结构毁坏**	Damage to stored goods **储存的货物毁坏**
No sprinkler protection **无喷淋保护**	100%	100%
Sprinkler protection **喷淋保护**	<10%	50 to 100%

Sprinkler systems in warehouses
仓库的喷淋系统

- To protect stored goods it is important that the fire is extinguished at a very early stage
  为了保护储存的货物，在火灾初期扑灭是非常重要的
- Two systems are suitable: 两种可行的系统
  - Ceiling mounted sprinklers plus in-rack sprinkler heads (every 2.5 m)
  - 安装在顶部的喷头加上货架内喷头（每2.5米）
  - ESFR (Early Suppression Fast Response Fire Sprinkler Systems)
  - ESFR （早期抑制快速响应消防喷淋系统）



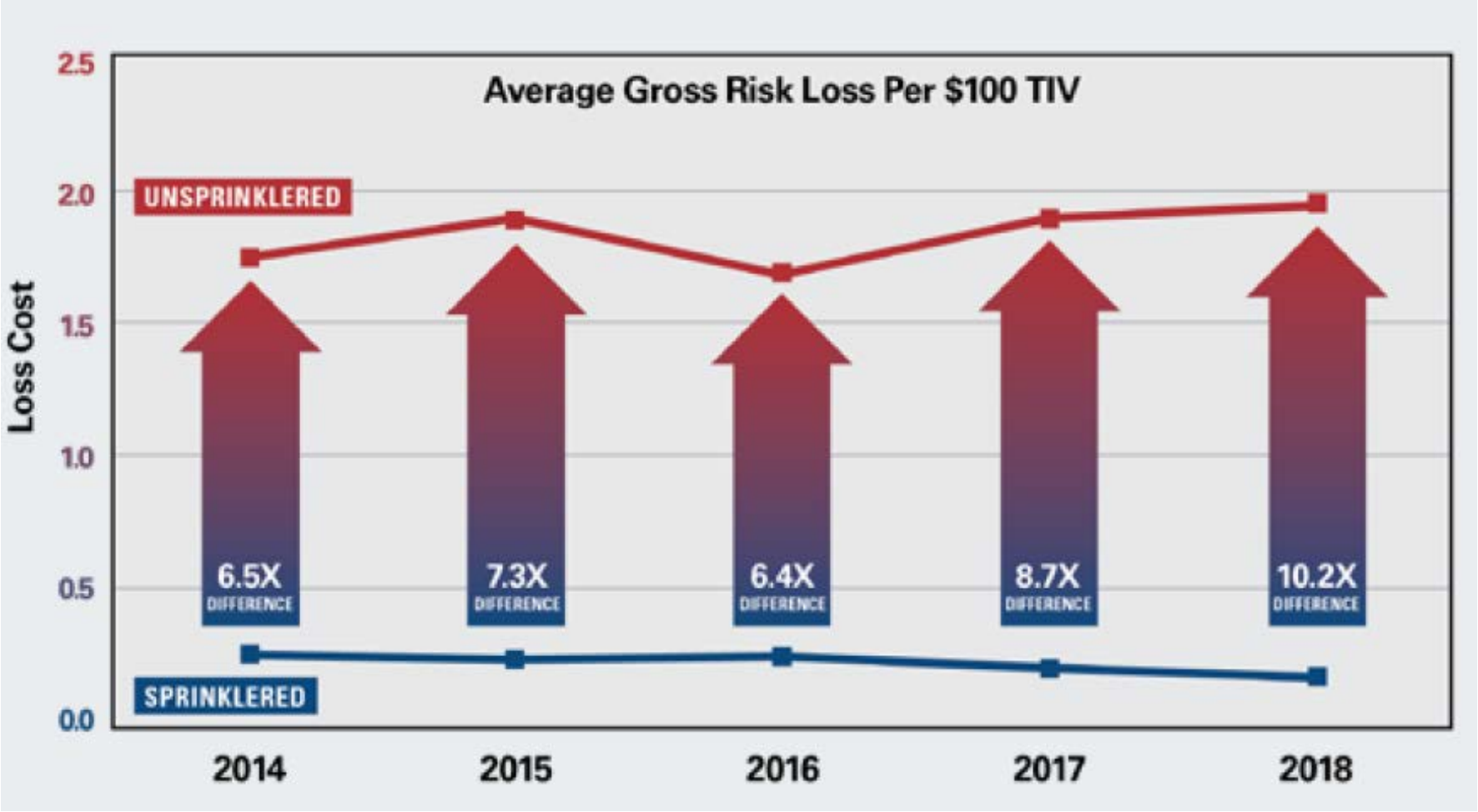
Sprinkler systems in warehouses
仓库的喷淋系统

- Stacked IBCs with flammable/combustible liquids: max height 2 when foam is available
- 叠放的IBCs内装有易燃/可燃液体：最大高度是2层IBCs（叠放）的情况下，泡沫系统才能正常工作。

Sprinkler Systems: Costs vs benefits
喷淋系统：成本 vs 收益

- Costs 成本
  - Average costs of sprinkler installation: US$ 3.3 – 38.7 per m^2
  - 喷淋安装的平均成本： 3.3-38.7美金 每平方米
  - Sprinkler protection installation as retrofit is generally more expensive
  - 改造时安装喷淋防护常常要更贵一些
- Benefits 收益
  - Fires in hotels with sprinklers averaged 78% less damage than fires in hotels without them (1983–1987).
  - 安装有喷淋系统的酒店，比没有安装喷淋系统的酒店，发生火灾时伤害损失平均减少78% （1983-1987）。
  - Average loss per fire in buildings with sprinklers was $2,300, compared to an average loss of $10,300 in unsprinklered buildings
  - 安装有喷淋系统的建筑，每次火灾的平均损失是2,300美金。作为对比，没有安装喷淋系统的建筑，每次火灾的平均损失是10,300美金。

Sprinkler Systems: Costs vs benefits
喷淋系统：成本 vs 收益



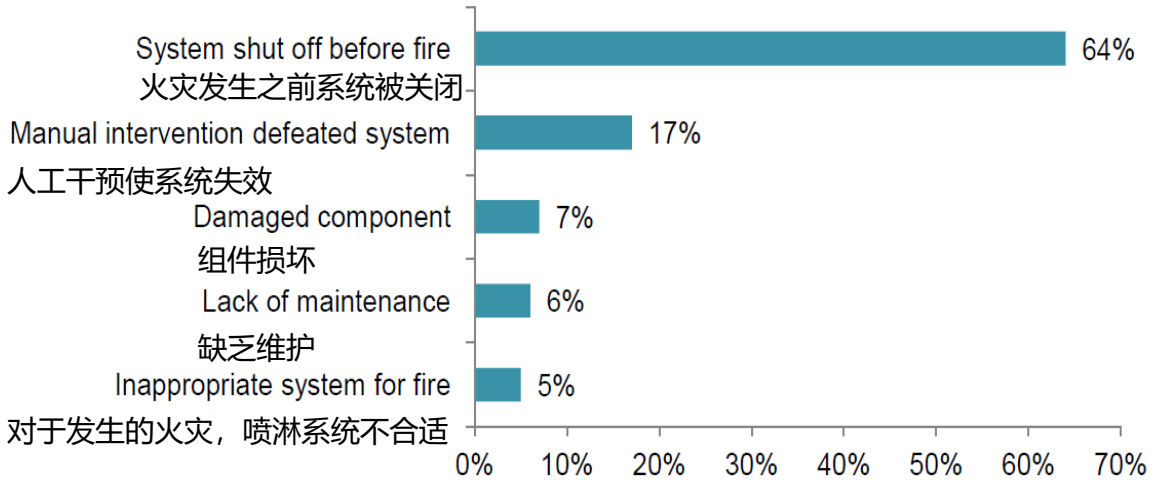
Why sprinklers fail to operate
喷淋系统无法正常启动的原因

In 2007-2011 fires large enough to activate them, sprinklers operated in 91% of fires in sprinklered properties. The graph below is based on the other 9% in which sprinklers should have operated but did not.

2007-2011年，发生火灾启动喷淋系统，正常启动的概率是91%。下图统计了另外9%的情况下，喷淋系统应该启动却没有启动的原因。

Reasons When Sprinklers Fail to Operate, 2007-2011

喷淋系统没有正常启动的原因，2007-2011



What to look for
需要注意什么

- Correct system? 系统是否正确
  - Foam system for flammable liquids? / Alcohol resistant foam needed? 针对易燃液体的泡沫系统/是否需要抗酒精型泡沫?
  - Automatic or manual? (sprinkler or deluge system?) 自动还是手动 （喷淋还是雨淋系统）？
  - In-rack sprinkler (every 2.5 m in high rack storage) 货架内喷淋（每2.5米，高层货架储存）
- Regular testing and Maintenance by qualified 3rd party 有资质的第三方进行常规的测试和维护
  - Flow test: 1/a, valve check 1/month/ visual check 1/week
  - 流量测试：1年1次，阀体检查：1月1次，目视检查：1周1次
- Protection against freezing? 防冻保护
  - Anti-freeze can lead to leakage during summer 未做好防冻保护，在夏季时会导致泄漏。
- Closed valves at foam tanks and headers! 泡沫罐和顶部的阀门被关闭
- Design documentation 设计文件
  - Correct occupancy 是否正确应用
- Fire load below sprinklers 喷头下方的火灾负荷
  - <1.8 m wooden pallets 木质托盘，小于1.8米
  - < 2.5 m empty plastic container 空的塑料容器，小于2.5米
  - <2 IBCs with flammable liquids 装有易燃液体的IBCs，不超过2层
- MOC! 变更控制
  - Change of sprinkler design in case of change in occupancy
  - 一旦用途变更，喷淋设计也要变更

Sprinkler systems: Standards
喷淋系统：标准

- NPFA 13: Standard for the Installation of Sprinkler Systems 喷淋系统安装标准
- CEA 4001
- NFPA 2001: Standard on Clean Agent Fire Extinguishing Systems (CO_2, Foam, FM200 etc.) 清洁剂灭火系统标准（二氧化碳，泡沫，FM200等）

CONTACT

pscinitiative.org

info@pscinitiative.org

Annabel Buchan:
+55 (11) 94486 6315

PSCI

@PSCInitiative

For more information about the PSCI please contact:

PSCI Secretariat
Carnstone Partners Ltd
Durham House
Durham House Street
London
WC2N 6HG

info@pscinitiative.org

+55 (11) 94486 6315

About the Secretariat
Carnstone Partners Ltd is an independent management consultancy, specialising in corporate responsibility and sustainability, with a long track record in running industry groups.

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