Incident investigation by DNV

DNV has a long history of providing incident investigation services and developing root cause methodologies

- **Support of client investigation team** – by provision of a team lead, discipline experts, a root cause method expert (DNV Loss Causation Model, SCAT and BSCAT), or a coach
- **Independent Investigation** – by a team of DNV experts
- **Investigation training**
- **Standards and procedures** - review, audit on or development of corporate incident investigation standards and learning from events procedures
- **Lab analyses** – metallurgical failures, fuels and lube oil testing
- **Supporting technical analysis** – accident HAZOPs, dispersion, fire and blast, CFD
- **Consequence simulations** – large scale fire, explosion & blast research and testing
- **Litigation support**

Macondo BOP Forensic Examination

Tarragona - explosion in an chemical plant

Chemical explosion in Tarragona, Spain 2020 - key aspects of the DNV investigation

DSB – Norwegian Seveso Conference 2021

Hendrik Ebel, Clara Huéscar Medina, Mark Hopwood

21 September 2021

Objectives

- To describe the Tarragona incident – type of incident, effects on surroundings
- To provide an overview of the incident investigation process adopted by DNV, and explain how a rigorous process can help understand and manage major accident hazard risks
- To explain the lessons that can be learnt from the incident and that can be applied to Seveso sites

Agenda

1. Description of the incident
2. Need for incident investigation
3. Investigation process
4. Investigation assessment – selected results
5. Findings of investigation - recommendations and expectations
6. Comments from GenCat
7. Concluding remarks

1. Incident description

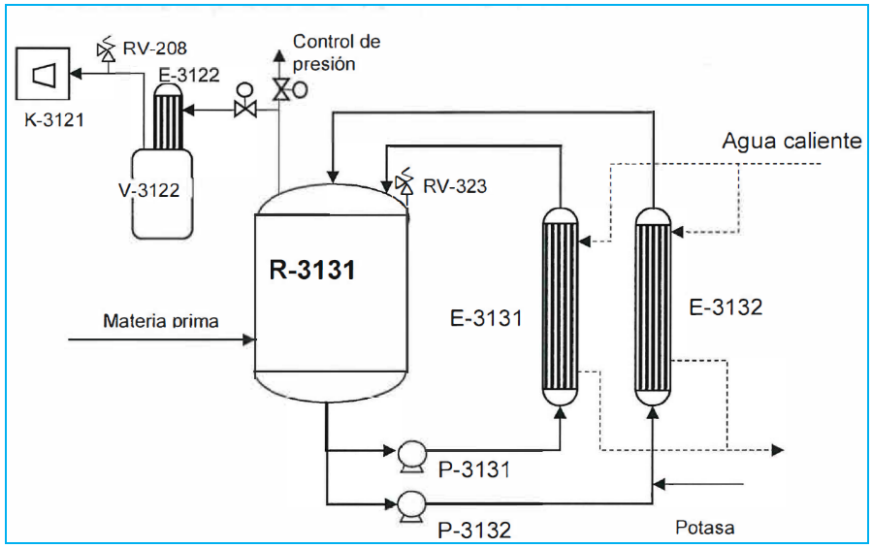
The incident – as in the local media the day after

The incident

The IQOXE plant in Tarragona, suffered a large explosion on 14th of January 2020 causing multiple fatalities, injuries and major damage:

- Three fatalities: one person killed by missile fragment from explosion in his flat in a nearby village (Torreforta). One operator employee got killed working in the control room and another operator employee died as a result of his injuries
- Missile fragments also damaged neighbouring plants in the industrial area of Tarragona

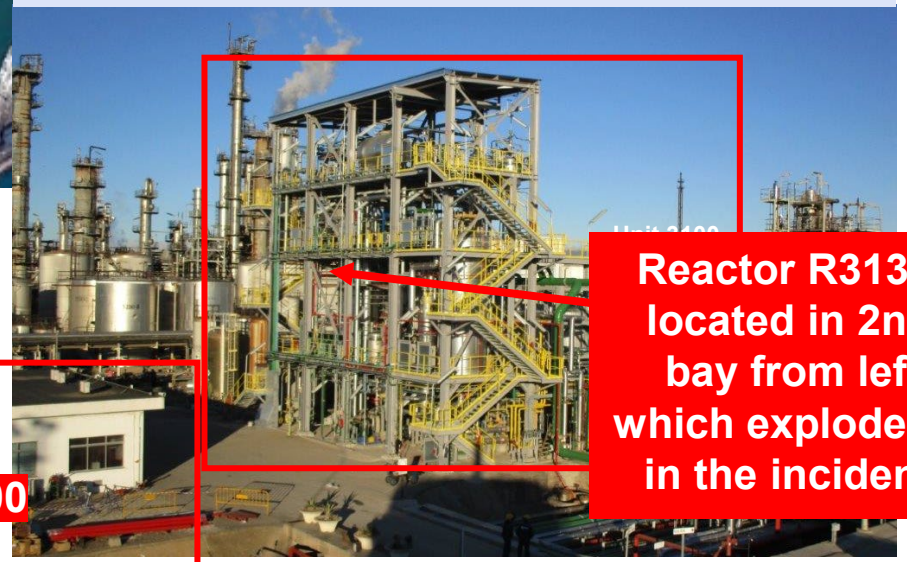
The explosion happened at the end of the production of a batch of MPEG 500, an ethoxylation derivative used e.g. as an additive for cement. The reactor vessel R3131 of the derivates plant U3100 exploded.



Incident location

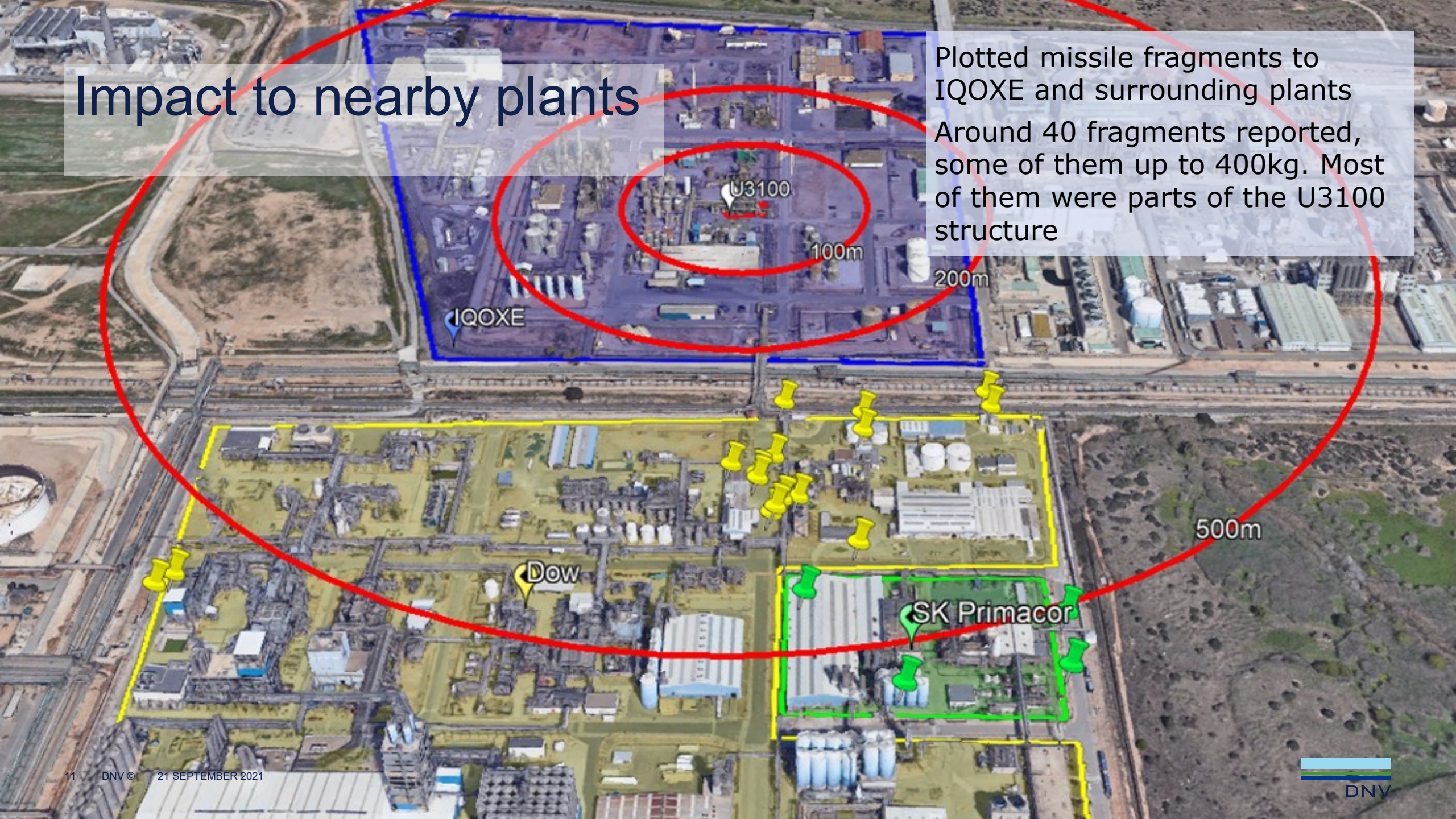
Tarragona area with IQOXE plant location (blue frame) and U3100 (red frame)

Unit 3100 prior to incident



Plant damage – U3100 directly after explosion

Impact to nearby plants

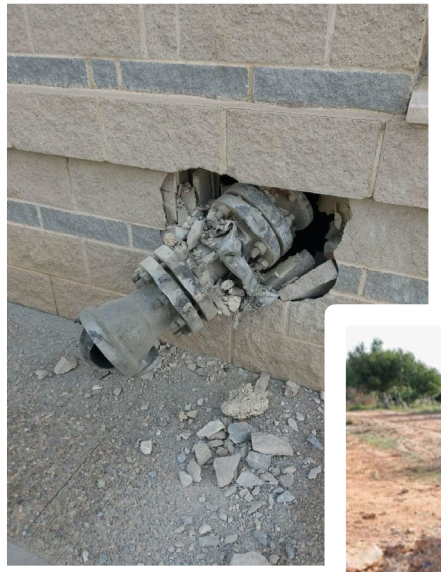


Plotted missile fragments to IQOXE and surrounding plants

Around 40 fragments reported, some of them up to 400kg. Most of them were parts of the U3100 structure

Assessing Explosion Characteristics

- Observed damage to structures and fragments found were crucial to quantify likely overpressures and energy available in the event.
- In turn, knowing the likely overpressure and energy can help determine the most likely cause of the explosion.
- Research experience has shown the consequences of different levels of overpressure in structures



Overpressure (mbar)	Expected Damage
30	Minor structural damage.
30-70	Windows shattered, window frame damage.
70-550	Slight to serious laceration injuries from flying glass and other missiles.
70	Partial demolition of houses, made uninhabitable.
165-840	Range for 1-90% eardrum rupture among exposed population
200	Steel frame buildings distorted and pulled away from foundation
700	Probable building destruction
1000-2000	Range for 1%-99% fatalities among exposed populations due to direct blast effects

*Lees, Frank P. 1980. *Loss Prevention in the Process Industries*, Vol. 1. London and Boston: Butterworths.

2. Need for investigation

Need for investigation

- Responsible department for Industrial Safety and Mining Safety of the Catalonian Government (GenCat) commissioned DNV to investigate the explosion

- Purpose of DNV' s investigation was to find out:
  - What has happened?
  - Why could it happen?
  - What changes are required, to avoid such an incident from happening again?

- Verification of regulatory compliance was not the purpose of this investigation

Challenges and limitations to DNV investigation

- DNV was commissioned by GenCat in April 2020

- DNV was asked to prepare the report withing two months – due to the below limitations, we ended up with four months

- Limitations GenCat decided to adapt to focus on the information available which was limited by several factors including:
  - Secrecy of the judicial police investigation
  - Absence of process record data due to destruction by the explosion
  - Prevention by the court of access to the site of the damaged unit (until the end of May 2020)
  - Restrictions on travel and physical meetings due to COVID-19

3. Investigation process

The DNV team

Hendrik Ebel
Project Manager/
Deputy Lead Investigator
Hamburg, Germany

Mark Hopwood
Lead Investigator
Manchester, UK

Eduardo Pallarés
General Support
Madrid, Spain

Jeff Jones
Forensic Expert
Loughborough, UK

Benjamin Barbette
Process Safety Specialist
Antwerp, Belgium

Clara Huéscar Medina
Explosions Expert
Spadeadam, UK

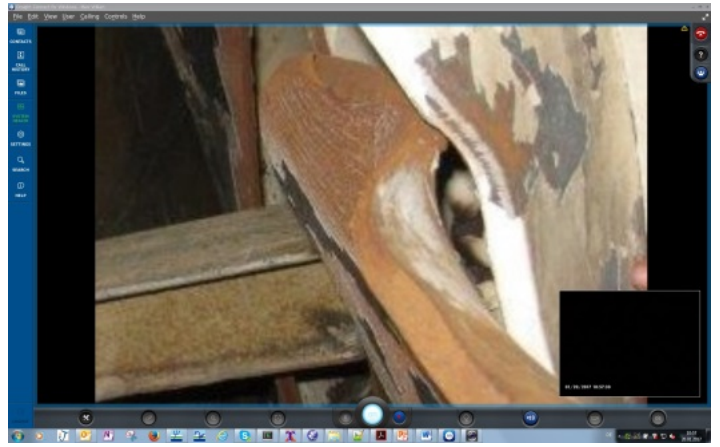
Juan Ignacio Sánchez
General Support
Madrid, Spain

Michael Johnson
Explosion Expert
Spadeadam, UK

Gathering information - Remote investigation

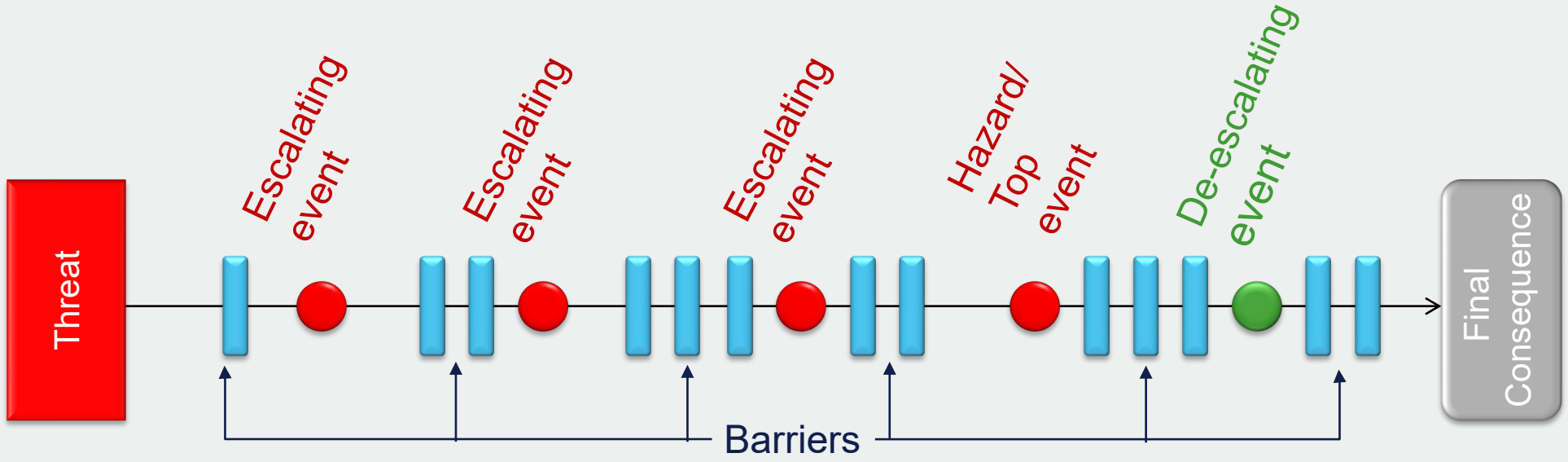
- Regular virtual meetings in the team and with GenCat
- Information request and exchange with the operator based on a Q&A list
- Once the site was declared to be accessible – a remote site visit was carried out

Sample picture not related to the actual incident



Sample picture not related to the actual incident

Analysing information - Essence of BSCAT
Understanding incidents as a series of barrier failures



What is a barrier?

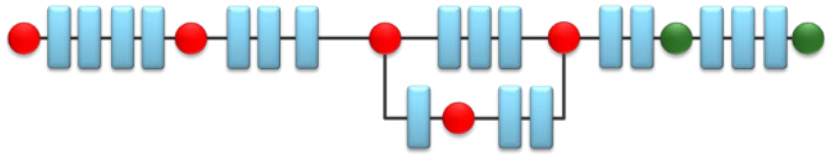
Equipment, system or set of procedures (either hardware, software, or organizational), PPE….

- that lowers the probability of hazard occurrence (prevention) ….
- or the severity level of the consequence (mitigation, reduction of vulnerability of object)

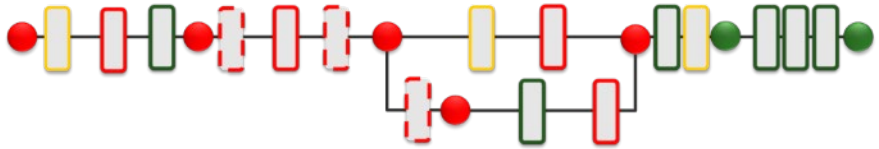
BSCAT – Using barrier diagrams for incident investigation

- Develop and analyse barrier diagram to analyse the incident

Identify key events and hypotheses



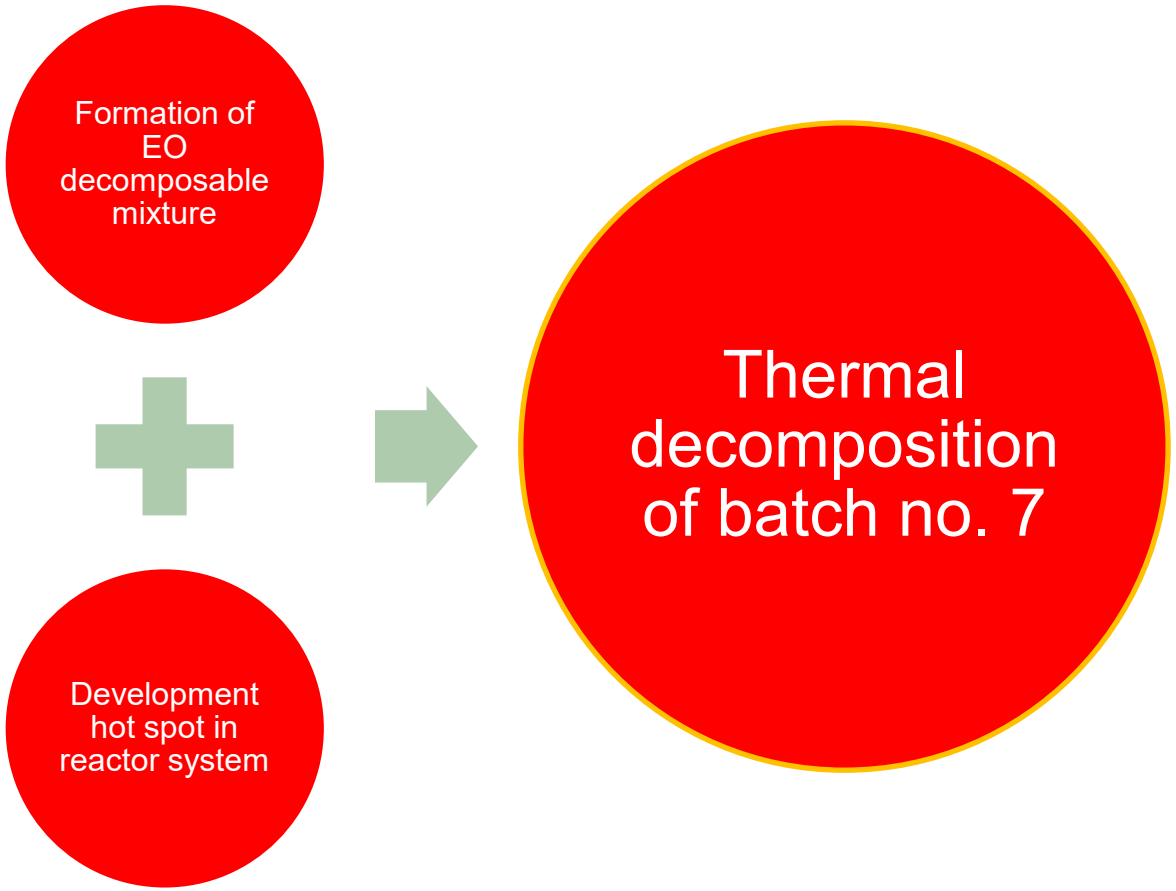
Analyse barriers

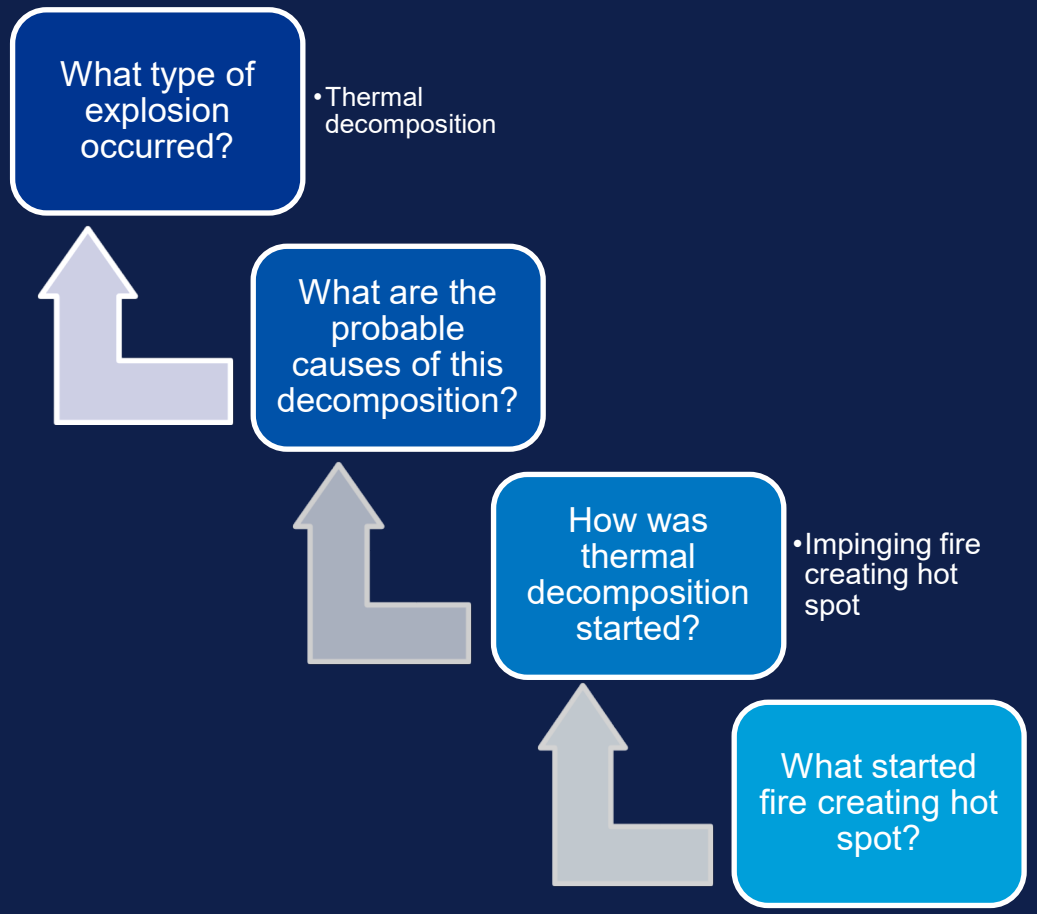


- Use loss causation model for each of the failed or ineffective barriers to find
  - Immediate causes
  - Basic (root) causes, and
  - Associated management system deficiencies

4. Investigation assessment

Analysis of type of event



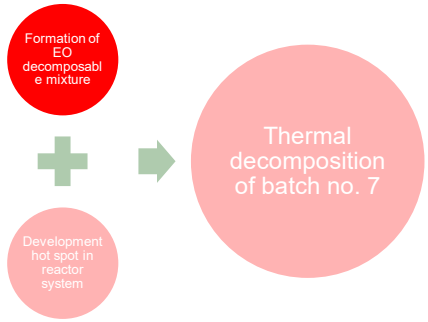


Understanding the type of event

Potential cause	Evaluation
Thermal decomposition inside the reactor leading to overpressure	High likelihood
Loss of control of exothermic reaction leading to overpressure of the reactor	Medium likelihood
Loss of temperature control leading to overheating of the batch, increase in vapour pressure and causing overpressure of the reactor	Low likelihood
High pressure caused by connected feeds or service	Low likelihood
Overpressure due to fire engulfment, leading to a BLEVE	Low likelihood

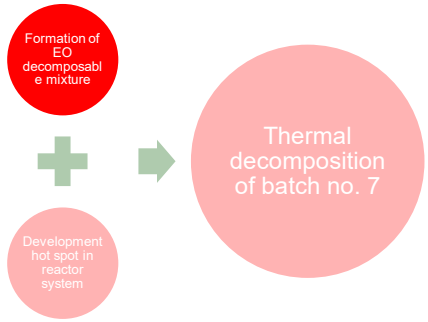
- The event was very rapid, very energetic and gave no warning.
- Although U3100 was a new design with many safety features, ethylene oxide reactors have a history of explosion accidents due to decomposition.
- Ethylene oxide vapour decomposes explosively with energy 3 MJ/kg. The energy of detonation of TNT, for comparison, is 4.184 MJ/kg.
- A decomposition event can cause a pressure rise of 25 bar/sec. Gases are produced which are extremely flammable (fireball)

Potential causes for thermal decomposition



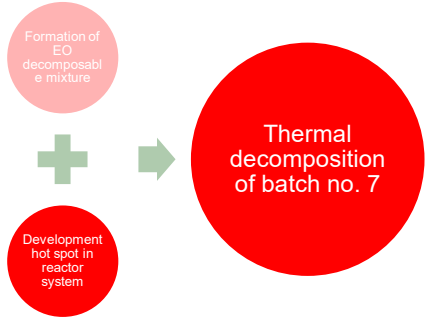
Potential cause	Evaluation
A fault in the nitrogen pressure control	High likelihood
An external leak would release a mixture of nitrogen and EO but be replaced by pure EO if addition continued	High likelihood
EO accumulation in the reused nitrogen between batches	High likelihood
Opening, or passing, of the reactor vent valve (31XV332) to the vent header	Medium likelihood
Venting through the pressure relief system would release a mixture of nitrogen and EO but be replaced by pure EO if the feed were continued	Low likelihood
Presence of liquid EO in the reactor	Low likelihood

Possible initiation causes of thermal decomposition



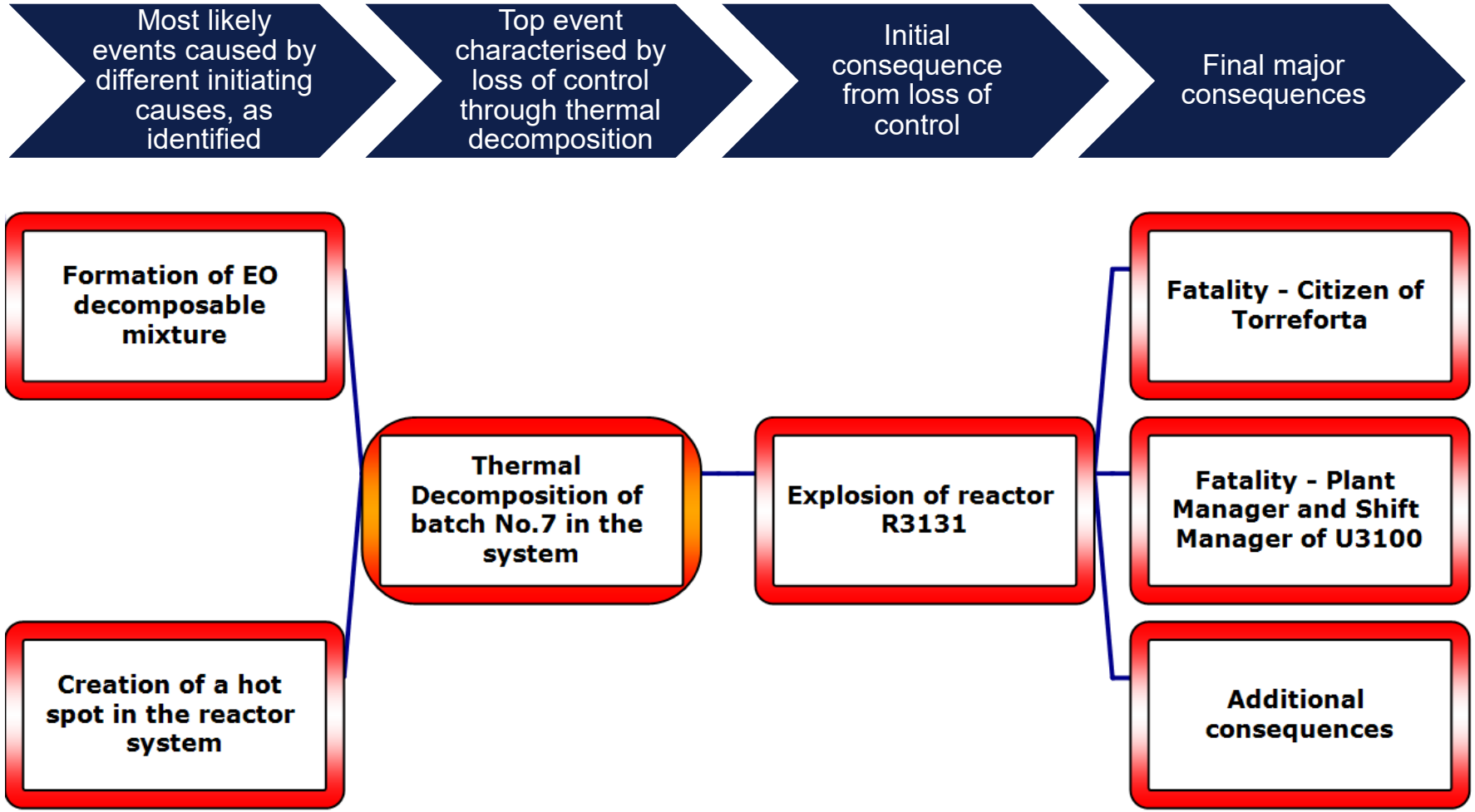
Potential cause	Evaluation
A fire impinging on part of the attached process	High likelihood
Runaway reaction reaching the decomposition temperature	Medium likelihood
A fire impinging on the vent system connected to the reactor	Medium likelihood
Heat from unintended reaction catalyzed by contaminant	Medium likelihood
A fire impinging on the reactor vessel	Low likelihood
A mechanical fault in a pump connected to the reactor	Low likelihood
Maloperation of a pump connected to the reactor	Low likelihood
A fault in the electric heat tracing positioned adjacent to some of the pipework connected to the reactor	Low likelihood
Hot work such as welding or cutting on a connected system	Low likelihood

Fire

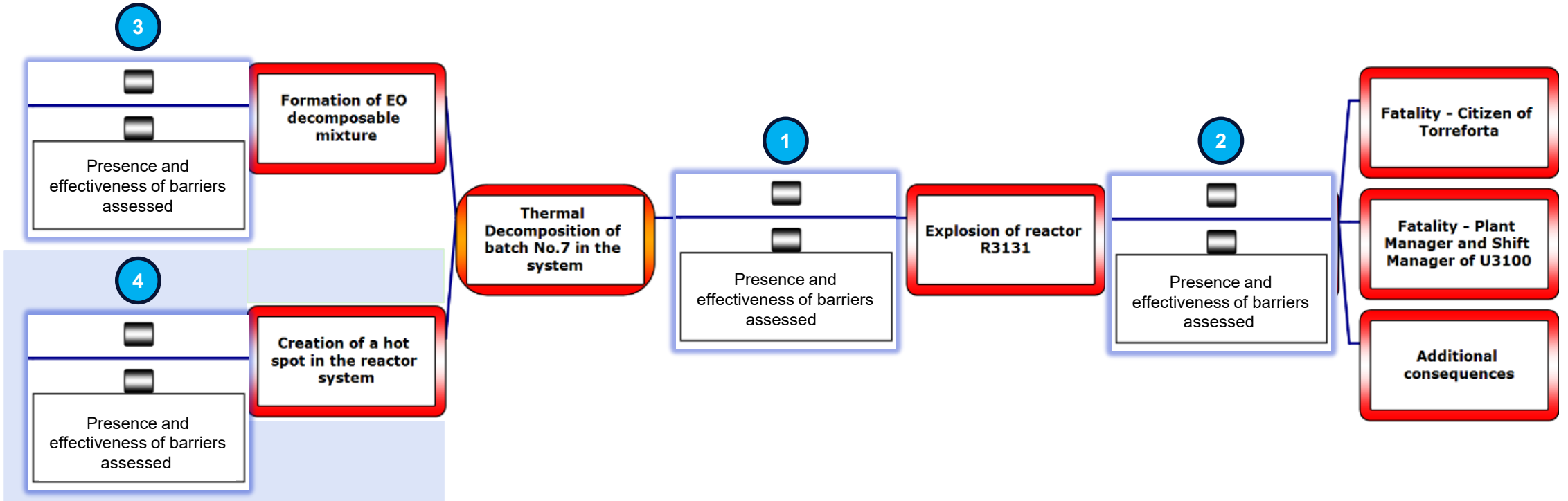


- Examination of photographs of missile fragments as well as photographs from the incident scene suggests that fire damage had been caused prior to the explosion
- Recommendation for forensic testing

Key events leading to the incident

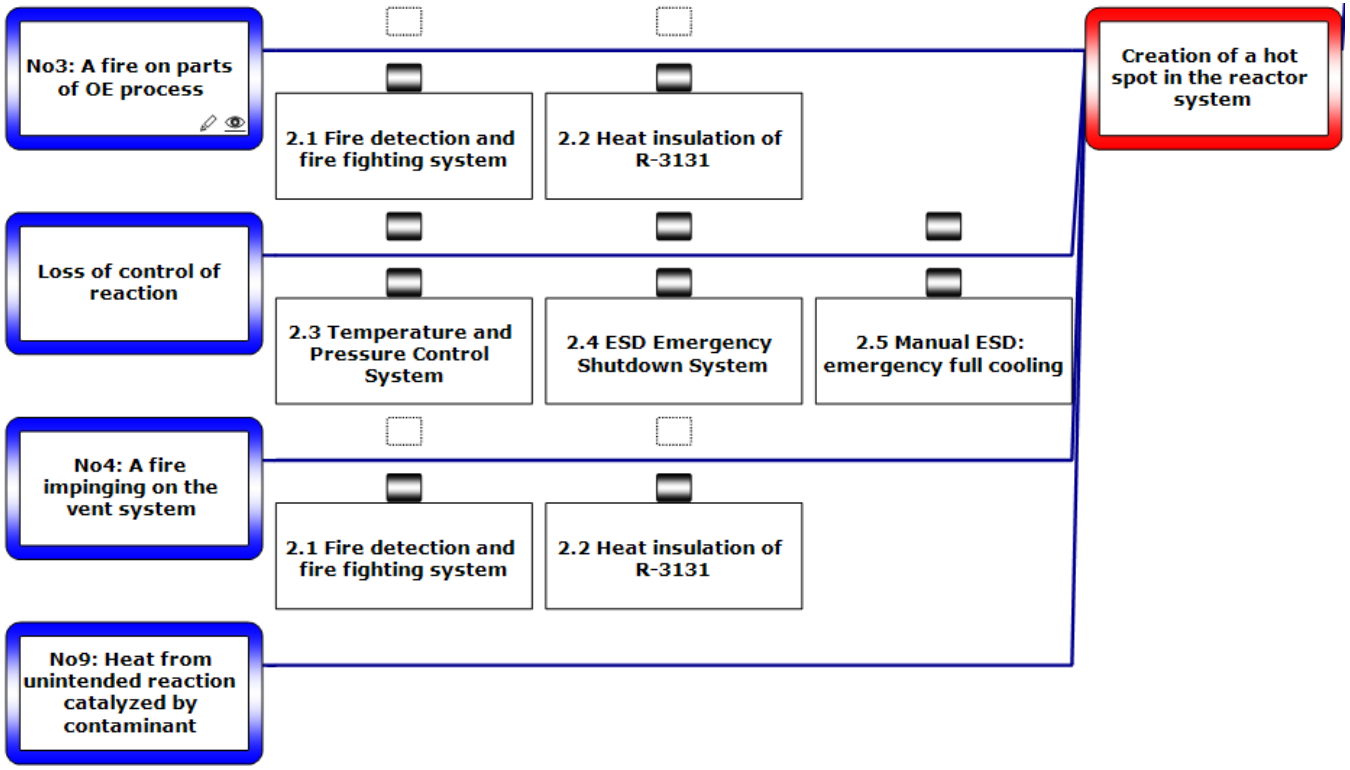


Identification and assessment of barriers and root cause analysis



Example barrier analysis, 'creation of a hot spot in the reactor system' (next slide)

Barrier diagram for ‘creation of a hot spot in the reactor system’



E.g. root cause analysis for fire detection and fire fighting system (2.1) (next slide)

Direct cause(s)

Basic cause(s)

Improvement area in management system

Root cause analysis for fire detection and fire fighting system

Direct cause(s)	• Insufficient fire detection system • Inadequate firefighting systems
Basic cause(s)	• The installed sprinkler system only protected the reactor vessel, but not the entire EO connected system in U3100 • No evidence was seen of safety studies to identify possible fire sources in U3100, that might affect the EO-connected system, nor was evidence seen of identification of required active or passive fire protection other than a design document based on industrial building regulatory requirements • **The EO User Guide** suggests applying NFPA 58 and API 2510 and 2510A to the design of fire protection systems for EO storage and processing areas. Moreover, it suggests using process hazards analysis methods that examine the severity of the consequences of a fire scenario for identification areas appropriate for deluge protection • Furthermore, the basic design documents specify that **gas and fire detection in the neighbourhood of sources of possible leakage** shall be installed. Dilution of leakage and control of fire will result if automatic operation of a water spray system
Improvement area in management system	Determination of risks and needs and location for fire detection and types of firefighting systems

5. Findings of investigation

Findings of incident investigation

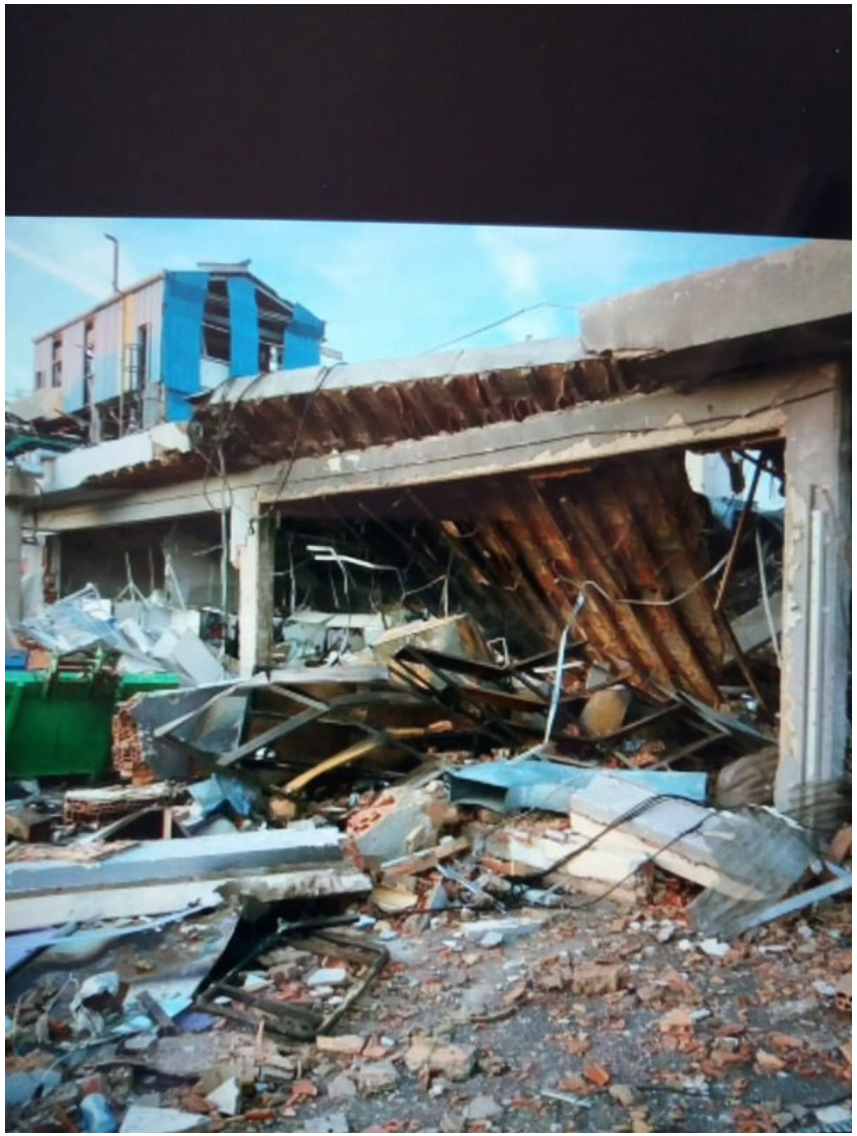
- **Recommendations**: ensure that failed or inadequate barriers are improved on a management system level and thus the likelihood for further incidents is reduced
- **Expectations**: allowing the operator and other stakeholders to verify the management systems and barriers against good industry practices
- **Actions**: further actions specific to the incident to resolve outstanding questions currently unanswered

Recommendations

1. Ensure appropriate risk identification and management
2. Review and improve the management of change process
3. Ensure safe control room or occupied buildings
4. Assess level of prevention barriers/safeguards to take account for limited containment
5. Apply good industry practice for the fire detection and firefighting system
6. Install appropriate gas detection in the unit
7. Assess possibility for reactor gas analysis
8. Review approach for risk reduction from ethylene oxide installations

3. Ensure safe control room or occupied buildings

- Predicted over pressure,
- Likelihood,
- How many people?
- Distance,
- Reinforcement



<u>Recommendation details:</u>
Existing and new control rooms and occupied buildings should be assessed to ensure safety of people within them

Assessment should include consideration of building survivability, control systems, safety shutdown systems or use of the control system for managing emergency

Recommendations

1. Ensure appropriate risk identification and management
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5. Apply good industry practice for the fire detection and firefighting system

- Where can leaks occur?
- Where should gas detectors be placed?
- Where can fires start?
- Where should fire detectors be located?
- What fire fighting system is needed to stop the identified fires?

Fire sprinklers (red piping system) around reactor before accident

<u>Recommendation details:</u>

- Apply NFPA 58 and API 2510 and 2510A to the design
- Using process hazards analysis for identification of areas appropriate for deluge protection
- Gas and fire detection in the neighbourhood of sources of possible leakage should be installed.

Recommendations

1. Ensure appropriate risk identification and management
2. Review and improve the management of change process
3. Ensure safe control room or occupied buildings
4. Assess level of prevention barriers/safeguards to take account for limited containment
5. Apply good industry practice for the fire detection and firefighting system
6. Install appropriate gas detection in the unit
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Expectations

1. Reliability of the control system
2. Competence assurance for critical tasks
3. Adequate fire resistant insulation of the R-3131 system
4. Prevention of EO accumulation in the head space
5. Leak prevention
6. Prevention of leaks to the vent header
7. Fire prevention by inspection and maintenance
8. Prevention of contaminants

6. Comments from GenCat

GenCat (Government of Catalonia)

One of several institutions within GenCat affected by the SEVESO directive is **Industrial Safety.** The role of this institution is to verify that installations, products and sites comply with the requirements of the technical regulations.

As soon as the accident occurred, the "**ACCIDENT EVALUATION AND MONITORING GROUP**" was set up, consisting of the Administration and parties involved such as representatives of the chemical companies, the majority unions, Port of Tarragona, the tourism sector close to chemical companies, and environmental groups.

In addition to the loss of three lives and several injuries, the accident has highlighted the following aspects:

- The accident caused confusion and concern among citizens and highlighted the need to adapt the response of emergencies to the uniqueness of the chemical risk of Tarragona and it must be demanded to bring decision-making closer to the territory.

GenCat (Government of Catalonia)

- It is necessary to recover the mutual trust that during the last decades have prevailed in the relations between the chemical sector, the institutions and city councils, the rest of productive sectors, the entities, associations, neighborhood movements and the citizenship in general.
- It highlighted the importance of the chemical industry for territorial development, but at the same time, it is necessary to strengthen safety measures for good coexistence.
- Aspects to be reviewed and opportunities for improvement in the management of chemical emergencies have been identified. It has become clear that existing protocols need to be reviewed and updated.
- The need for more drills has been identified. Everyone needs to know what to do, especially in the immediate aftermath of an emergency.

Following this process of reflection, a whole set of concrete proposals for improvement emerged.

GenCat (Government of Catalonia)

Proposals for improvement:

- To condition the return to business of the company to reliably justify compliance with the security conditions imposed, which included the implementation of some of the measures proposed in the study commissioned.

- To update the regulatory framework. It is necessary to reconsider the land use planning model, the methodology of evaluation of the analyzes of risks, the possibility to bunkerize the control rooms in determinate sites, or how to be able to guarantee of reliable form the conservation of the records of the reactions in the case of 'a fatal accident like this.

- Increase the staff dedicated to control and inspection tasks. We want to visit Seveso sites at least twice a year, and always do it with the same person. Analyzing documentation can extract a lot of information, but visits allow us to check the business climate, which is sometimes perhaps as much or more important than validating formal compliance with regulatory requirements.

- Finally, we have decided to increase the frequency of the meetings of the Major Accidents Working Group, which is attended by representatives of the various agents involved in the safety value chain.

7. Concluding remarks

Concluding remarks

- Structured and detailed incident investigation reveals many improvement opportunities in managing major hazards
- BSCAT provides a structured for the investigation. It helps manage complexity by assessing all barriers
- Incident investigation has added value even if time is limited and not all evidence can be immediately accessed
- Investigation can be done remotely
- The need for appropriate risk identification and management is an important recommendation often found in incident investigations. It is the basis of the Seveso-III Directive
- Many important recommendations have been made regarding ethoxylation operation that should contribute to preventing such a catastrophic accident in the future.

Thank you

Question and answers

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Link to full DNV incident investigation report: dfe03039-741d-4c8c-8241-68b64916bcc6.pdf (govern.cat)

www.dnv.com