Sharing Experience in Process Safety and SEVESO Directive
Case Studies on Process Plants

1st International Process Safety Symposium
Proses Güvenliği Sempozyum

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Introduction

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D’Appolonia SpA is an Italian Company with 700+ technical staff and offices in Italy and worldwide (including Turkey) belonging to the RINA Group, providing services to Clients in the O&G, Transportation and Infrastructures markets from concept to decommissioning, through consultancy, design, management and operation & maintenance engineering. For the O&G sector, in addition to PMC, Basic and Detail design, Gesoscience, Asset Integrity Management, O&M services, D’Appolonia has a long term experience in Safety and Environmental consultancy to major O&G Operators and EPC Contractors Worldwide.
Agenda

1. Background for Safety Report
2. Safety Report and Process Safety
3. A practical approach to Safety Reports: Case studies
Background: “Seveso” Directive

In 1976 in Seveso (Italy) an accidental release of Dioxin from a Process Safety Valve caused extensive contamination and chronic damage to population and environment, requiring a vast inhabited area (15 ha, 600 inhabitants) to be permanently evacuated and houses demolished.
Background: “Seveso” Directive

After this and other accidental events, to avoid these incidents to happen again, in 1982 Council Directive 82/501/EEC on the major-accident hazards of certain industrial activities, so-called “Seveso Directive”, was adopted.


Purpose of the “Seveso” Directive is to set up a procedure to ensure that major hazards are prevented and that their consequences are mitigated.
Operators should have a general obligation to take all necessary measures to prevent major accidents, to mitigate their consequences and to take recovery measures.
“Seveso” Directive

Why a Safety Report?

The Operator should provide the competent Authority a Safety Report.

The Safety Report should contain details of possible major accident scenarios and risk analysis, prevention and intervention measures and the management systems available in order to prevent and reduce the risk ......
“Seveso” Directive
Safety Report Contents?

Article 10
Safety report

1. Member States shall require the operator of an upper-tier establishment to produce a safety report for the purposes of:

2. The safety report shall contain at least the data and information listed in Annex II.
"Seveso" Directive
General Philosophy

INSPECTIONS

Safe Technology
Safe Management
Demonstrate Safety within the Safety Report

Emergency Planning

Land-Use Planning

Accident Reporting and Lessons Learnt

Information to the Public
The Safety Report shall provide (Annex II of “Seveso III”):

- Information on the management system and the organisation;
- Information on the Plant and the Site;
- Information on the technological and process aspects;
- Identification and accidental risk analysis and prevention methods;
- Information on measures for protection and mitigation.
The Safety Report has the purposes of (art. 10 of “Seveso III”):

- a) demonstrating that a MAPP and a safety management system for implementing it have been put into effect in accordance with the information set out in Annex III;
- b) demonstrating that major-accident hazards and possible major-accident scenarios have been identified and that the necessary measures have been taken to prevent such accidents and to limit their consequences for human health and the environment;
- c) demonstrating that adequate safety and reliability have been taken into account in the design, construction, operation and maintenance of any installation, storage facility, equipment and infrastructure connected with its operation which are linked to major-accident hazards inside the establishment;
- d) demonstrating that internal emergency plans have been drawn up and supplying information to enable the external emergency plan to be drawn up;
- e) providing sufficient information to the competent authority to enable decisions to be made regarding the siting of new activities or developments around existing establishments.
In summary, the Safety Report shall document that:

a) A **Safety Management System** is adopted;

b) The **Major Hazards** are known and prevention and mitigation measures are adopted to limit consequences to man and environment;

c) The **design, construction, operation and maintenance** of the plants are safe and reliable

d) **Internal Emergency Plans** are in place and the competent authority has all the **elements** to prepare an **External Emergency Plan**.

with the final purpose to demonstrate that **hazards are recognized and controlled** and that the plant is **compatible with the surrounding territory**.
The same Risk Analysis flow can be followed at different levels of detail and by use of different techniques and tools. There is not a single tool or a single method that can satisfy all cases and needs.

As an example:

- **Hazard identification**: can be based on historical data, checklists, generic scenarios or on systematic methods like HAZOP, HAZID, FMEA, Event Trees...
- **Scenarios probability**: can be assessed by expert judgment, historical data, fault/event trees, Bow-Tie, Montecarlo ..
- **Scenarios consequence assessment**: can be based on simplified nomograms, analytical calculations based on process data, 3D modeling....
- **Risk assessment** can be based on isorisk contours, risk matrixes...
The issue is: which set of tools and procedures can be suggested, based on the operating experience in other EU countries where Safety reports are applied since 1982?

- A Safety Report is not just “paperwork”. A Safety Report provides the Operator a framework for a better management and operation of the plant and the Authority a framework for a more effective Inspection and Emergency planning.

- A Safety Report shall be consistent with the intrinsic hazards of the establishment and its characteristics. A chemical process plant is not as a storage......

- A Safety Report shall give the Operator information useful for the managing of plant.

- A Safety Report is a “living document” that will follow the establishment life. The analysis can be deepened as necessary with time.
The first and most important step of a Safety Report is the Identification of Hazards.

A poor identification can lead to:
- crude overestimation of the hazards creating public acceptance problems and waste of money/resources against non realistic hazards (e.g. “worst case” approach; adopting generic data without proper tailoring to the situation);
- serious underestimation of the hazards, making the process safety activity non efficient (e.g. reference only to past individual plant experience; adopting “small leakages” hazards as being the only credible; adopting generic data without proper tailoring to the situation)
The technique for identification of Hazards shall be tailored to the specific situation considering:

- plant complexity
- presence and type of chemical reactions
- hazard characteristics of substances
- criticalities related to the surrounding
- level of information available (operating plant; conceptual phase; basic design, detail design...)

The technique to be adopted shall satisfy the need to balance the identification of hazards related to controls and reactions, with those related to “simple” loss of containment.
Safety Report- Case Studies
Hazard Identification

Depending on the cases, the tools to be adopted can vary from:

- Reference to Historical data and “generic” hazards;
- Systematic Loss of containment analysis;
- HAZID analysis / What-If analysis;
- HAZOP Analysis.

Whichever the technique adopted, a personalization to the specific situation to avoid over- or underestimation of hazards shall be done in strict cooperation between the Hazard Analyst and the Plant operator.

The Hazard identification shall also consider the credibility of events, selecting for further analysis only those whose likelihood of occurring is not so low to make them “not credible”.
Safety Report - Case Studies
HAZOP

For complex process plants, where the effect of controls and safety systems is essential for the safety of the process, and where the Operator wants to obtain the most information from the Safety Report activity, an HAZOP analysis is to be recommended.

HAZOP requires the analysis of all plant P&IDs lines, it can be a very resource-demanding activity. However it allows to identify both safety and operational issues and to make use of the safety report activity also for the optimization of plant performances. From the HAZOP, the list of all elements that are critical to prevent accidents is obtained. This is the input to any future Process Safety and Asset Integrity activity.
Safety Report - Case Studies
“Typical” deviations

Where an HAZOP analysis is not strictly required, or where it can not be adopted due to resource constraints, identification of typical process deviations for the process can be done, based on past experience and on the analyst experience.

In this case, the list of process hazards shall be validated by the Operator, and each plant equipment where a given “typical” deviation can occur shall be analyzed to identify prevention measures (controls and safety measures) for further assessment.
In all cases, identification of the Loss of Containment Cases that can occur shall be a part of the Safety Report.

Identification of Loss of Containments cases is independent from the assessment of the causes (and therefore its use to identify prevention measures is limited) and focuses on the effects and the mitigation measures.

Given that a Loss of containment can occur in principle in any section of the plant, and its effects are strongly related to the specific section involved, the first step is to identify all Shut down valves and other devices that can isolate sections, and list each section (“Isolatable Sections”) with its process and geometrical characteristics.
Isolatable sections are identified on PFDs and P&IDs by the location of any isolation element that can represent an effective barrier to the flow and can isolate the section within a short time from the release.

They are characterized by:
- the mass of the isolated material (inventory);
- the phase of the isolated material (gas, liquid, or mixed), and the operating conditions (pressure and temperature).

For each section, the most representative stream(s) is(are) selected for further quantitative analysis, based on the operating conditions and on the location of the items included in the section. This reduces the quantity of simulations to be handled in the consequence assessment while maintaining the correctness and precision of the analysis.
After having identified the plant sections, a further essential step shall be taken: How much “loss” is a Loss of Containment? Can in theory range anywhere from a Full Bore catastrophic failure to a small drip from a gasket.

The analysis requires a number (a diameter) to be associated to the loss of containment cases, this is done by the following procedure:

- consider the set of possible rupture values given by recognized historical failure data bases (e.g. OGP, API, OREDA.....);
- neglect cases too small to be considered a “major hazard”;
- catastrophic rupture, unless specific local conditions (e.g. impact) can make it credible, is not considered;
- merge the considered cases into two or three classes;
- sum the frequency value of the catastrophic case to the immediately lower one, to maintain the overall historical frequency of occurrence.

As an example (considering the OGP classification data):

<table>
<thead>
<tr>
<th>1-3 mm</th>
<th>3-10 mm</th>
<th>10-50 mm</th>
<th>50 – 150 mm</th>
<th>&gt;150 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 mm</td>
<td>100 mm</td>
<td></td>
<td></td>
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</tbody>
</table>
The methods adopted for the Hazard identification also drives the tools to be used for the calculation of the probability of accidents.

- Process upsets (Hazop or Typical deviations) -> Fault Tree Analysis

The Fault Tree Analysis is a well known technique that allows to consider in a proper way the actual prevention measures of the plant, and to rank the importance of the elements (input to testing and inspection optimisation).
The methods adopted for the Hazard identification also drives the tools to be used for the calculation of the probability of accidents.

- Identification of “Loss of containment” cases for the Plant isolatable sections -> Parts Count analysis based on same statistical database used for the identification.
A final step of the analysis is the calculation of Accidental scenarios probability with Event Tree Analysis. The Event Tree contains the physical phenomena and the mitigation measures (barriers) between the release and the outcome scenario.

Example of simplified Event tree
Analysis of Consequences: calculation of the distances to given value of damage due to the identified accidental scenarios.

In this step also, an assessment that does not consider the actual plant conditions and any factor that can limit (or worsen) the consequences will result in over- or under-estimation of the damages.

• The analysis should consider the events having a “credible” probability of occurrence, neglecting those that are shown by the calculation to be not realistic;
• The analysis requires a number of (explicit or implicit) assumptions that can have a significant impact on the results;
• The consequences are assessed with reference to population and operator safety, and where necessary with reference to environmental damage.
Safety Report - Case Studies
Consequence analysis - Data

- Released material
- Quantity of released material
- Release temperature and pressure
Safety Report - Case Studies
Consequence analysis - Hypotheses

Hole Size

Vessel/Pipe: IS 8 Gas

Scenario Type:
- Catastrophic Rupture
- Line Rupture
- Disc Rupture

Location:
- Leak
- Fixed Duration
- Relief Valve

Geometry:
- Vent from Vapor Space
- Long Pipeline
- Tank Roof Failure

Outdoor / In-Building Release:
- Outdoor Release
- In-Building Release

Building Wake Effect:
- Roof / Lee Effect
- Chimney Effect

Phase to be Released:
- Vapor
- Liquid
- Two-Phase

Tank Roof Effect:
- Roof Collapsed
- Roof Removed

Model Effect:
- Instantaneous effects

Basic scenario data:
- Hole Diameter: 25.4 mm
- Gas Volume Flow

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Safety Report - Case Studies
Consequence analysis - Assumptions

- Height of release
- Release direction
<table>
<thead>
<tr>
<th>Event</th>
<th>Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>LNO release due to unaligned decoupling of the unloading arm</td>
</tr>
<tr>
<td>1b</td>
<td>LNO release due to capture of an unloading arm (90°)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2.24E-03</th>
<th>2.36E-03</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20.48E-05</td>
<td>1.35E-05</td>
</tr>
<tr>
<td></td>
<td>1.13E-05</td>
<td>4.16E-05</td>
</tr>
<tr>
<td></td>
<td>1.66E-05</td>
<td>6.4E-05</td>
</tr>
<tr>
<td></td>
<td>2.22E-05</td>
<td>4.8E-05</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Event</th>
<th>Frequency (n/yr)</th>
<th>Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Size m³</td>
<td>LFL</td>
</tr>
<tr>
<td>2F</td>
<td>Flash Fire</td>
<td>20.48E-05</td>
</tr>
<tr>
<td>2D</td>
<td>Flash Fire</td>
<td>1.35E-05</td>
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The process of developing a Safety Report as in the procedure described allows to:

- Identify the Safety Critical Elements (barriers), both prevention and mitigation measures;
- Document that the reliability of barriers is adequate to ensure a low probability of occurrence of hazards;
- Assess realistic damage distances allowing to address any layout issue and to optimise the Internal (Operator) and External (Authority) Emergency Plan;
- Assess the overall plant safety towards the external population and the environment.
**Individual risk**
annual frequency of occurrence of the reference damage (e.g., the death), in any point of the geographical area, for a person present in the area, taking into account the probability of the presence of the person.

**Societal Risk**
An *F-N* curve describes the cumulative frequency (F) of accidents from all risk sources leading to the reference damage (e.g. death) for a number of people equal to or greater than N. This figure characterises the societal dimension of possible accidents.

Criteria used in particular in UK, Ireland, The Netherlands
Criteria adopted in Italy, based on both probability of a scenario and level of damage occurring on predefined land use classes.

<table>
<thead>
<tr>
<th>Accident frequency</th>
<th>Land Use classes allowed for Damage Effect Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fatalities</td>
</tr>
<tr>
<td>&lt; 10(^{-6})</td>
<td>DEF</td>
</tr>
<tr>
<td>10(^{-4}) – 10(^{-6})</td>
<td>EF</td>
</tr>
<tr>
<td>10(^{-3}) – 10(^{-4})</td>
<td>F</td>
</tr>
<tr>
<td>&gt; 10(^{-3})</td>
<td>F</td>
</tr>
</tbody>
</table>

Classes A to F correspond to different Land Uses (A: highly populated areas, F: Industrial Areas)
Safety Report - Case Studies
Assessment of Results

In absence of specific risk criteria, each individual scenario can be assessed based on its capability to impact on populated areas or critical/vulnerable areas, with the criterion to reduce damage distances so as to avoid interference or, when this is not practical, to keep the frequency of damaging scenarios below the one to which population is exposed due to other causes.

- Minor injuries
- Serious Injuries
- Lethality threshold
- Fatality
The information contained in the Safety Report, both in the Risk Analysis part and in the description part, makes the Safety Report a significant document to be developed and assessed. Can vary from a major document composed by many volumes, as in this example for a Refinery (21 process Units).....

To a single volume (plus the annexed technical documentation) as in this example for an LNG regasification Terminal...
Conclusions

The Safety Report is due following the “Seveso” Directive, recently enforced in Turkey. The need for Plant Operators to comply with this new regulation can be seen as a further “paperwork” required to continue the business.

The experience in the EU Countries where this regulation is enforced since 30 years has shown that the Operator can gain many advantages from the process of preparing and updating a Safety Report. These advantages are related to:
- A more documented knowledge of the actual safety issues of the plant;
- Optimization of the operations by systematic identification and ranking of Safety Critical Elements and optimization on testing and inspections;
- Identification of any “hidden” critical point and of the solutions before an accident occurs;
- Improvement of the personnel safety culture through their participation to the process of analysis.

To achieve these advantages, the experience has shown that the analysis shall not be driven by shortcuts and shall be as realistic and linked to the actual plant characteristics as possible.
Thank you for your attention