CHEMICAL ENGINEERING TRANSACTIONS
VOL. 48, 2016
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Eddy de Rademaeker, Peter Schmelzer

ISBN 978-88-95608-39-6; **ISSN** 2283-9216
DOI: 10.3303/CET1648138

Process Risk Analysis within Solvay

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In September 2011 Solvay took control of the Rhodia group of companies and became the 10th largest chemical group in the world. Now the approaches used to carry out risk analysis and ensure safe operation of chemical plants were quite different in Solvay and Rhodia. Following the fusion Solvay has decided to introduce new and harmonized methods to control process risks. The methods adopted draw on elements from both cultures.
In this article the methods used previously within Solvay and Rhodia are outlined. The methods adopted under the new Solvay are described with respect to:

- Process Safety Management System
- Feedback from process incidents within Solvay
- Process Safety Design Guidelines
- Process Risk Analysis
- Process Safety Roadmap.

1. Introduction

1.1 The Solvay group

The Solvay group was founded by a Belgian industrialist, Ernest Solvay, in 1863 [Bertrams, 2014]. He had invented a revolutionary process using ammonia to produce sodium carbonate. He and a few partners started a business to produce sodium carbonate. At first the company faced many difficulties but the new process proved to be economical and soon sodium carbonate from Solvay factories was far cheaper than that produced elsewhere by the traditional Leblanc process. After a few years the Leblanc process was out of business and Ernest Solvay turned his attention to other large scale processes. Just before the fusion with Rhodia the main areas of business were as follows:

- sodium carbonate and sodium bicarbonate,
- hydrogen peroxide,
- chlorine, sodium hydroxide, etc.
- bulk polymers, especially polyvinyl chloride (PVC)
- polymers for special uses such as polyvinylidene difluoride (PVDF)
- organofluorine chemicals.

1.2 The Rhodia group

The Rhodia group was born in 2001 when Rhône-Poulenc was divided into two parts, one making pharmaceuticals and agrochemical products and the other making a large range of bulk and fine chemicals. The first part merged with pharmaceuticals and agrochemical part of Hoescht to create Aventis. The second became Rhodia. The early years of Rhodia were difficult but by 2011 it had become a profitable company whose main interests were in:

- polyamide and its applications in engineering plastics,
- surfactants with applications ranging from beauty care to extraction of oil and gas,
- rare earth elements with applications in electronics and catalysis,
- highly dispersible silica,
- various organic chemicals with niche markets.

Please cite this article as: Egan S., 2016, Process risk analysis within solvay, Chemical Engineering Transactions, 48, 823-828
DOI:10.3303/CET1648138

1.3 The fusion of Solvay and Rhodia

The Solvay group had divested its pharmaceutical interests to Abbot laboratories in 2009 and disposed of a large cash reserve. The acquisition of Rhodia was announced in April 2011 and completed in September of that year. It gave Solvay access to the emerging markets in the Asia-Pacific region, where Rhodia was strongly represented with factories and commercial networks. Moreover Solvay wished to take on board the move Rhodia had already made, away from production of bulk chemicals and towards high value added specialities. Both groups were of similar size, employing around 15,000 people each worldwide. It was a golden opportunity to create something new, which would be better than both.

1.4 The discovery process

It took us roughly one year to survey the ways Process Safety was handled in Solvay and Rhodia and come up with a plan (or “roadmap”) for the new group.

1.5 The Solvay methods

Solvay had a decentralised management system, based on Global Business Units (GBUs). Each GBU had a Research, Development and Technology (RDT) group with a remit to ensure the safety of chemical manufacturing processes used. Solvay used quite classical methods to do this, such as HAZard and OPerability studies (HAZOP) and Layers of Protection Analysis (LOPA). Solvay had the advantage of having many plants using the same or similar processes and the RDT groups were able to use feedback from one plant to improve safety elsewhere. There was no central Process Safety function and few Solvay personnel were dedicated to Process Safety on a full time basis.

1.6 The Rhodia methods

Rhodia was a complete contrast, with a very strong central Process Safety function, including an expert group based in France and teams of engineers in each geographical zone. Rhodia had developed an risk acceptability matrix relating the Severity of a given risk scenario to the target Probability level required for the scenario to be accepted. Rhodia had developed computer software to enable a range of hazard study methods to be used, tailored to the dangers present in the installation. These methods were basically the same worldwide and were adapted to the nature of the Rhodia group: rather fast moving and changing chemistry to meet new demands from customers.

1.7 The new Solvay methods

The new Solvay methods are described below and include:

- a Process Safety Management System
- feedback from process incidents within Solvay
- Process Risk Analysis
- Process Safety Design Guidelines
- Process Safety Roadmap.

1.8 The new Solvay red lines and obligatory corporate procedures

Two “red lines” concerning Process Safety have been defined by the board of Solvay:

- Each production facility must have carry out or fully update a Process Risk Analysis at least once every five years.
- Any situation of unacceptable risk must be flagged up at corporate level and resolved in no more than one year (during this period exceptional measures are applied to control the risk). The methods used to identify and classify unacceptable risks are described below.

Four obligatory corporate procedures concerning Process Safety have been drawn up. They cover Process Safety Management, Risk Analysis, Risk Analysis Leaders and “Risk Sheets” (see § 4.10).

2. Process Safety Management System

2.1 Levels of PSM for chemical manufacturing sites

Solvay has defined three levels of Process Safety Management for its chemical manufacturing sites:

- an upper level corresponding to the requirements of the Occupational Safety and Health Adiministration (OSHA) and Environmental Protection Agency (EPA) in the USA or upper level SEVESO sites in Europe,
- a middle level corresponding to the requirements of lower level SEVESO installations in Europe,
- a lower level corresponding to other sites.

The level of a site is defined on the basis of the installation with the highest classification under OSHA, EPA or SEVESO regulations. That level is then applied to all the installations on the same site.

2.2 Upper level requirements

The requirements of the Solvay PSM system are grouped in 14 chapters as follows:
1 Management review and commitment
2 Process Safety Information
3 Employee Involvement
4 Process Safety Risk Analysis
5 Operating Procedure
6 Training (management of skills and awareness)
7 Contractor Management
8 Pre- Start up Safety Review (Operational Readiness)
9 Mechanical Integrity
10 Work Permit (safe work practices)
11 Risk assessment of change (Management Of Change)
12 Incident Investigation
13 Emergency planning and response
14 Compliance Audits

The 14 chapters have a total of 350 items.

2.3 Middle level requirements

The same 14 chapters are required to be satisfied. However, the number of items in each chapter is reduced, so that the total number of items is 150.

2.4 Lower level requirements

At the lower level, five of the chapters are required:
1 Management review and commitment
4 Process Safety Risk Analysis
5 Operating Procedure
10 Work Permit (safe work practices)
11 Risk assessment of change (Management Of Change).

The total number of items is 30.

2.5 Compliance Audits

Compliance audits will be carried out by designated Solvay personnel, our insurers (FM Global) or qualified outside specialists.

3. Feedback of Process Safety Incidents within Solvay

3.1 Database of Process Safety Incidents

Solvay has a system to flag up incidents of all types, including Process Safety Incidents. The latter are classified on a Severity scale as follows

- Low such as the loss of containment of a chemical requiring no more than first aid,
- Medium such as a loss of containment leading to an irreversible injury,
- High such as an explosion leading to one fatality,
- Catastrophic such as an explosion leading to numerous fatalities.

3.2 Process Safety Letters

Every month there 700 key Solvay employees receive a “Process Safety Letter”. The people receiving this letter are those involved in chemical manufacturing, process development, engineering etc. The letter is distributed in 12 languages including not only English, French and German but also Chinese and Thai.
The letter is based on a real incident or near miss which occurred, nearly always within the Solvay group. The letter describes the incident, its causes and the learning lessons from it. The incidents are carefully chosen to give lessons that are as general as possible. The accent is not on the hazards of a particular substance, which may only be used in one or two of our factories but on more general issues, such as unauthorized deviations from standard operating procedures or inadequate checking of safeguards such as pressure relief valves, flammable gas analyzers and Safety Instrumented Functions.

4. Process Risk Analysis

4.1 Choosing the method

Process Risk Analysis is the heart of Process Safety Management. Solvay has chosen to stay flexible in the choice of method. As described below, there are three options:

- external methods such as HAZOP and LOPA
- GBU methods,
- the Solvay corporate method described below.

Whichever method we choose for a given installation, we will use the corporate Severity-Probability-Risk matrix in order to judge the risk level of a given scenario.

4.2 Solvay corporate methods

As Solvay is a group with a very wide range of different installations, it is clearly essential to define a method adapted to each one. We have defined three levels for a given installation, on the basis of the hazards of the chemicals involved, the novelty of the process, the harshness of operating conditions (temperature and pressure) and so on. The levels are as follows:

- **Z0** applies to low hazard installations typically involving stable and non-flammable materials. Our installations using the Solvay process for sodium carbonate are an example. Z0 means that the installation should comply with the standard design for that process. The site should implement the following elements of Process Safety Management:
  - 1 Management review and commitment
  - 2 Process Safety Information
  - 4 Process Safety Risk Analysis
  - 5 Operating Procedure
  - 6 Training (management of skills and awareness)
  - 9 Mechanical Integrity
  - 10 Work Permit (safe work practices
  - 11 Risk assessment of change (Management Of Change)

  The Process Safety Risk Analysis for Z0 consists of ensuring that the quantities and materials used justify that classification and that the unit and working practices comply with our in-house standards. Any deviations from those standards have to be examined by one of the methods described below.
- **ZA** applies to many installations such distillation columns and storage facilities. The method we use is called Process Hazard Review. We examine the dangers of the chemical industry (physical explosion, gas phase explosion, dust explosion, fire, runaway reaction, loss of containment etc.). We identify precise risk scenarios and we relate them to a Severity-Probability-Risk matrix, as described below.
- **ZB** typically applies to installations carrying out hazardous reactions or handling flammable or toxic materials under pressure. We examine the deviations of process operating parameters according to the principle of the HAZOP method (high level, low level, high flow, no flow reverse flow etc.). Again we relate the scenarios to the Severity-Probability-Risk matrix.

We make the choice of method based on a quite precise internal guide which we have drawn up for the group, aided by professional judgment.

4.3 Training the Process Risk Analysis leaders

We hold regular training sessions for Solvay personnel and outside contractors who wish to become Process Risk Analysis leaders. Candidates are expected to have prior knowledge of the dangers of the chemical industry as this is not covered in the course. The training lasts five days and is followed by a written examination with a pass rate of about 85%. Successful candidates are authorized to use Solvay methods. Today there are around 50 Solvay engineers who have a certificate and around 20 from outside contractors. Indeed, companies such as Adisseo and Bluestar also use Solvay methods and send their engineers on our courses.

4.4 Describing a scenario

Once a scenario has been identified in a Process Risk Analysis, it has to be described precisely in order to relate it to the Solvay corporate Severity-Probability-Risk matrix. This especially applies to the causes, the effects, the consequences and the relevant safeguards.

4.5 Causes

All of the Necessary, Sufficient and Independent causes must be identified, together with a level of frequency on the following scale:

- “Very Frequent” means more than once a year which might typically be the case for operator errors.

- "Frequent" means between once every ten years and once every year, which might typically be the case for operator errors or the failure of control loops or leaks from moving parts such as flexible hoses, pump seals etc.
- "Possible" means between once every thousand years and once every ten years, which would typically be the case for failure of gaskets.
- "Improbable" means less than once every thousand years which would typically be the case for the complete rupture of a process line which is correctly specified, maintained and protected from the impact of vehicles etc.

When a scenario has more than one cause, we calculate the resulting probability in terms of events/year. In this case, our standard assumption is that a given cause will remain undiscovered for a period of five days, during which time a second cause or even a third cause may arise. In principle we study scenarios of up to five primary causes although it is obviously difficult to identify all possible scenarios with multiple causes. In the first instance, we assume that active safeguards, such a pressure relief valves and Safety Instrumented functions do not operate. This leads to the Potential Probability of the scenario.

4.6 Effects

By effects, we mean a physical or chemical phenomenon with an acute effect on human health or the environment. This may be overpressure from an explosion or thermal radiation from a fire or the loss of containment of material which is toxic or harmful to the environment. If a scenario has potential lethal effects, then we estimate the distance to a point where the probability of death for a healthy individual is 1%. This corresponds to 140 mbar for overpressure, 5 kW m^{-2} for fire and different levels of concentration or dose for toxic materials.

4.7 Consequences

By consequences, we mean the potential consequences on people and the environment. In particular, for a scenario with potential lethal effects, we estimate the size of the zone where the probability of death is 1% or more and the number of people who are normally inside that zone. This then used to estimate the Severity of the scenario.

4.8 Severity-Probability-Risk matrix

The Severity and Potential Probability are used to estimate the level of Potential Risk using the Solvay Risk Matrix, which is shown in simplified form in figure 1 (note that the symbol y = year).

Probability		Risk level				
Event/y	Level	**3** = Acceptable		**2** = Intermediate		**1** = Unacceptable
1	**1**	**3**	**2**	**1**	**1**	**1**
10^{-1}	**1 – 2**	**3**	**2**	**1**	**1**	**1**
10^{-2}	**2**	**3**	**3**	**2**	**1**	**1**
10^{-3}	**2 – 3**	**3**	**3**	**2**	**1**	**1**
10^{-4}	**3**	**3**	**3**	**3**	**2**	**1**
10^{-5}	**3 – 4**	**3**	**3**	**3**	**2**	**1**
10^{-6}	**4**	**3**	**3**	**3**	**3**	**3**
Severity		**L** **L**ow	**M** **M**edium	**H** **H**igh	**C** **C**atastrophic	**D** **D**isastrous
Consequences for human health		Minor injury First aid	Serious reversible injury	Serious injury, irreversible, (< 10 in 1 % risk zone)	Numerous fatalities (from ≈ 10 in 1% risk zone)	Numerous fatalities (from ≈ 100 in 1% risk zone)
Consequences for the environment		Minor reversible damage on site	Minor reversible damage on/off site	Serious reversible damage on/off site	Serious damage (lasting<10 y) on/off site	Serious damage (lasting>10 y) on/off site

Figure1: Solvay Severity-Probability-Risk matrix in simplified form

4.9 Safeguards

Preventive safeguards are taken into account, on condition that they meet appropriate international standards, such as IEC 61511 for Safety Instrumented Functions and they are checked regularly. For example a safeguard of SIL 2 reduces the probability by a factor of one hundred or one level in the table above.

Protective safeguards reduce the Severity. From the Residual Probability and the Residual Severity we estimate the level of Residual Risk using the same Risk Matrix as before.

4.10 Risk Sheets

If a Residual Risk of level 1 is found then a Risk Sheet is drawn up, explaining the scenario its causes and how it might be resolved. In the case of a project the Risk Sheet must be resolved before start-up. In the case of an existing installation, the Risk Sheet is validated by the central Process and Transport Safety Department and registered at corporate level. It must then be resolved within a one year period and temporary means must be put in place to reduce the risk in the meantime.

4.11 Regulatory studies

The Solvay corporate method is recognized by regulatory authorities, such as the UK Health and Safety Executive and the French DREAL (Direction Régionale de l'Environnement, de l'Aménagement et du Logement). That is to say, they consider that it is reliable method to identify major risk scenarios arising from causes within the process itself. Of course, in any regulatory study, Solvay will use the criteria of the government concerned to judge the acceptability of the hazards associated with our processes.

5. Process Safety Design Guidelines

We have drawn up three Process Safety Design Guidelines covering transfer loading and unloading stations, atmospheric storage tanks and pressurized storage tanks. More will follow, to cover heat transfer fluids, storage in containers, etc. The idea of these guidelines is to indicate the features that are essential for Process Safety. They are primarily aimed at major capital investment projects. The idea is to identify desirable safety features early on during the design stage, before the Process Risk Analysis has started. It can also be used as a checklist for existing installations, especially when Solvay acquires a facility from another company. The safety features which are listed include some which are very obvious such as retention dykes (bunds) around storage tanks and pressure relief valves for standard scenarios. When such a feature is absent from an existing installation a scenario such as a leak from the tank or overpressure of the tank is studied using the Process Risk Analysis method described above. If the level of Residual Risk is Unacceptable, a Risk Sheet would then be drawn up.

6. Process Safety Roadmap

We have set ourselves a very ambitious target: to have an up to date Process Risk Analysis for all of our plants by the year 2020. Now for some installations we already have such an analysis and we can revalidate the study so long as any modifications have been handled correctly using a Management of Change procedure and relevant incidents on said installation or elsewhere have been taken into account. But for others, we have a great deal of work to do.

7. Reporting

The Solvay board is informed of key leading and lagging indicators for Process Safety at three monthly intervals:

- Progress to achieve the target of an up to date Process Risk Analysis for all of our plants by 2020,
- All situations of unacceptable risk,
- All significant incidents (i.e. those classified C or H plus some classified M but with a high potential).

Incidents of Severity M and L are followed up by the management of geographic zones (Europe and Middle East, North America, Latin America and Asia-Pacific).

8. Conclusion

The fusion of Solvay and Rhodia has given rise to the 10th largest chemical group in the world. The Solvay board has given a clear commitment to safety in general and Process Safety in particular. It has defined its objectives in Process Safety and how it is going to achieve them.

Reference

Bertrams K., Solvay, History of a Multinational Family Firm, Cambridge University Press, England, 2014.