

A PROGRESSIVE RISK ASSESSMENT PROCESS FOR A TYPICAL CHEMICAL COMPANY: HOW TO AVOID THE RUSH TO QRA

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Safety Management Systems are a requirement for compliance with the Seveso 2 Directive. A very important part of any Safety Management System for a chemical company is the Process Safety Management System. Most companies have constructed their own approach to the task and in some cases these pre-dated any regulatory requirements. A fundamental part of the process Safety Management System is the risk management process and this in turn requires a risk assessment to determine the scale and likelihood of the operational risks of an establishment. Once this has been accomplished, decisions need to be made about acceptance, reduction or cessation on the basis of some risk tolerance criteria set by the operator or by the regulator. Figure 1 illustrates the risk management 'process'.

The assessment part of the process can range from the simple to the complex. As time goes by and technology advances, we seem to be moving in the direction of the complex. For small and medium enterprises and even for larger companies, this increasing complexity may not always bring a benefit in managing risk. Drawbacks include:

- A lack of full understanding of methods
- Reliance on experts who may be remote from the operation
- Undue reliance on third parties to evaluate risk
- Key operations staff being vaguely aware of the true risks of the production process and potential deviations
- A lack of appreciation of the impact of changes to the manufacturing process on the level of risk
- Illusory 'precision' in methods which use elegant models and mathematical expressions.

There is no doubt that the complex models are needed and have brought real benefits, but their application needs to be selective and consistent. In the past three years, several risk management systems have been observed where:

- Risk Assessments (including QRAs) have been done and no one was quite sure why they were done, what the results really meant and what was done with them. In extreme cases it appeared that little had been done to address risks which could have been reduced easily and economically. Furthermore, obvious risks had been overlooked.
- Several studies at European and National levels have shown that the consistency issue remains unresolved.

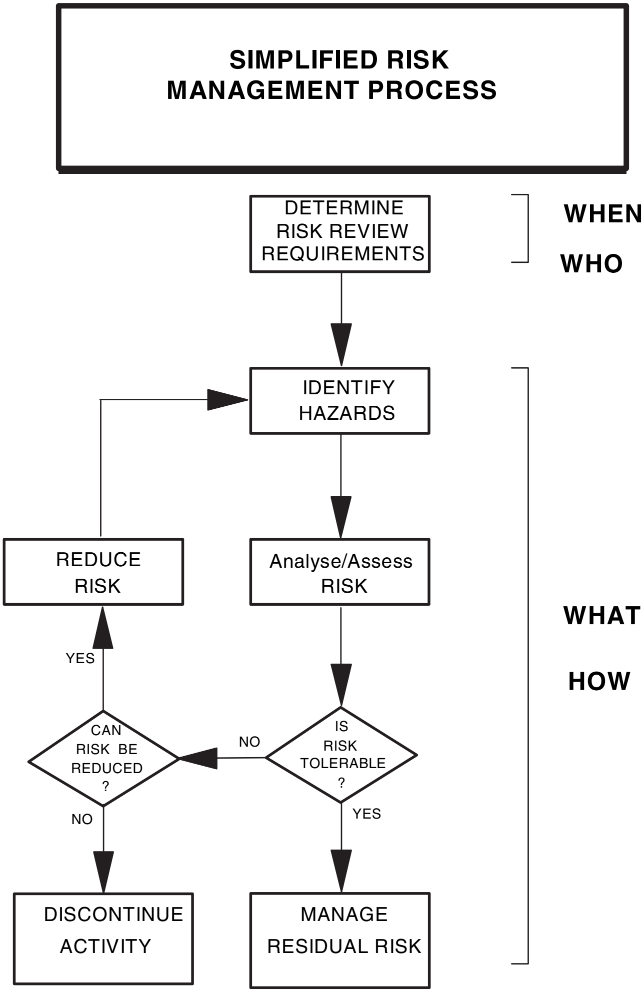

Figure 1.

We do not need to be reminded that it would be bad practice reject a method simply because we did not understand it. It would also be irresponsible to seek an assessment system which gives us the least provocative answer, or to manipulate the inputs or assumptions used in a given method to achieve the same thing. Whilst examples of this are rare, they do exist and are not always inspired by the establishment operator.

The following demonstrates a progressive approach which allows the use of simple tools to approximate the risk so that comparison with 'tolerance criteria' or 'risk review elevation criteria' can be made. Those cases which exceed these criteria are then taken to a deeper, more complex level of study. The example approach gives 4 levels of study, starting simple and progressing to complex. Each of these levels requires the use of tools, many of which are well known industry generic best practice and therefore allow some comparison establishment to establishment. Furthermore, some specific tools have appeared as examples in regulatory guidance from some member states in the European Union and other countries such as Thailand and Australia.

How it can be done:

Starting from the design phase of a plant it is normal to be able to identify the process materials and their physical and hazard properties

- process steps
- process conditions (temperature, phase, pressure etc.)
- basic reactive chemical issues (Thermal runaway potential etc.)

In the case of existing facilities, all these are well known and documented.

With such basic information it should be possible to make an estimate, at least in relative terms and in some cases in quantitative terms the consequences of major process deviations. In the case of Fire and Toxic releases, there are well established methods such as the Dow Fire and Explosion Index and the Dow Chemical Exposure Index.

For the case of vapour cloud explosion, there are simplified methods which can apply the TNO Multi Energy approach in a conservative way. These can all be used to quickly estimate the hazard consequences of deviations. A further resource is provided for worst case toxic release scenarios by the Environmental Protection Agency in the United States which supports the RMP plan.

It may help to have a standardised group of scenarios for the estimates being made. The ARAMIS project of the European Commission devotes some time to this topic. The referenced Dow methods include suggested scenarios and the explosion case is well covered in papers from Martin Goose of the United Kingdom Health and Safety Executive.

The whole risk management 'process' can be described graphically in the following diagram.

At each stage the work is done and the outcome compared with the elevation criteria to decide if the next level risk review needs to be done. The effect is that only the risks which have a high severity or about which there is most doubt reach the stage of Quantitative Risk Assessment. Furthermore, the scope of work for QRA will probably be narrowed because of all the knowledge gained from the lower level reviews.

The tools used range from the simple to the complex:

Stage 1 (simple)

- Formal Review to demonstrate operator knowledge of the production process
- Questionnaires designed to extract all process deviations and hazardous scenarios

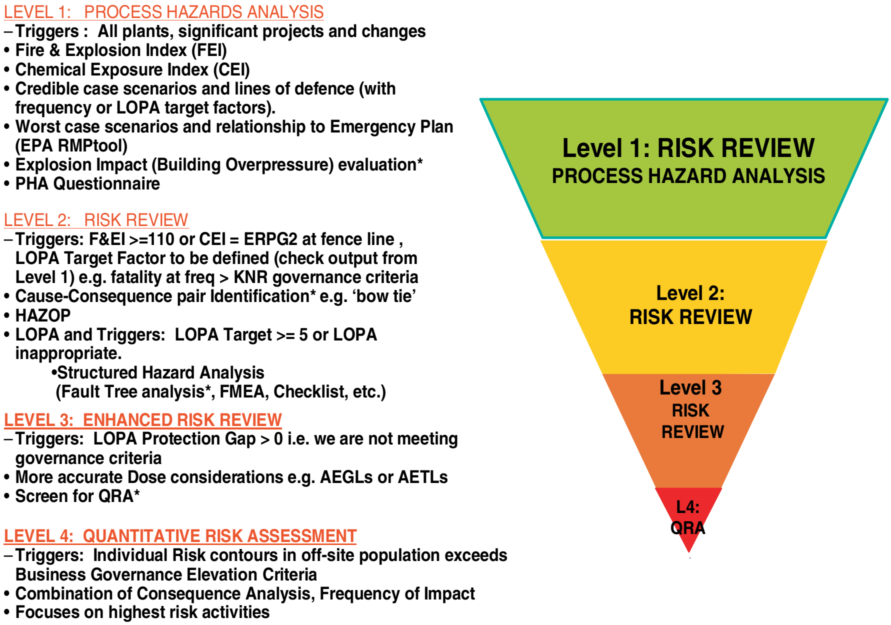

Figure 2. Summary diagram of a progressive system

- Semi Quantified Screening tools for Consequences of Fire, Explosion and Toxic substance releases. Examples are shown in Appendix 1, 2 and 3.
- Comparison of results with screening criteria set by the company

All these activities are carried out by **plant based production technical personnel** who have been trained by Process Safety expertise. The results are communicated to Process Safety Expertise for validation.

Stage 2 (intermediate)

- Detailed Hazard Identification (HAZOP)
- Layer of Protection Analysis
- Comparison of results with screening criteria set by the company

These activities are carried out by plant based production personnel under the facilitation of Process Safety expertise for the technology being used.

Stage 3 (Technology based Process Safety expertise)

Confirmation of severity and frequency of potential consequence by use of more complex modelling including

- Dispersion models e.g. DNV PHAST
- Potential exposure e.g. AEGLs, AETLs, for each predicted event
- Screening and scoping for QRA

These activities are carried out by Process Safety expertise for the technology being used with assistance of Technology Leaders and plant based production personnel.

Stage 4 (Corporate Process Safety Expertise/3rd party provider)

- Quantitative Risk Assessment

THE SIMPLE TOOLS EXPLAINED:

1) Toxic release from standardised credible case scenarios

First taking the case for toxic release, the Chemical Exposure Index can quickly provide the distance which is travelled by a specified toxic release. Criteria are based on Emergency Response Planning Guidelines. The estimate of 'hazard distances' from each case are made available. It seems logical that if the toxic release travels a distance which is less than the distance to the company's fence line it should be possible to protect site based persons from adverse effects. Various methods play a role from detection and response to Personal Protective Equipment and 'shelter in place' etc. These measures are not practical for application outside the site. In the scheme presented, it is suggested that any scenario which develops a toxic concentration of ERPG2 or greater outside the fence line should be subjected to deeper study.

The same approach can be made using the EPA dispersion model for catastrophic worst case scenarios. If these demonstrate a potential for ERPG3 concentrations at the fence line, it could be assumed that extra studies would be needed. These would be used to refine the on and off site emergency plans and any possible scale reduction or mitigation measures. The principle of Inherently Safer Design might be intensified or in extreme cases, the process changed. An example is shown in APPENDIX 1. The software is demonstrated in the presentation of the paper.

2) The worst case toxic release scenarios are studied via the EPA RMP approach

This assumes the catastrophic failure scenario with all inventory discharged in 10 minutes. This is available from the EPA website http://yosemite.epa.gov

3) For Fire Cases, the Dow Fire and Explosion Index can be used to assess fire effects

In this case the criteria for deeper study would be based on the criteria used by some companies and some legal authorities. For example – Fire and Explosion Index exceeds 110. An example is shown in APPENDIX 2: where the results are reproduced from a simple Excel spreadsheet with simple user inputs.

4) Occupied Buildings close to plants where flammable materials present an explosion risk

This is studied with the use of TNO Multi Energy Methodology. An example is illustrated in APPENDIX 3 where the results are reproduced from a simple Excel spreadsheet with simple user inputs.

APPLICATION

The Dow Chemical Company has based its approach on using these kind of criteria, its trigger criteria are developed, but the system may be used with user defined numbers.

CONCLUSION

The work of process risk assessment is aided by many tools. It seems reasonable that the greatest hazards should receive the deepest studies, possibly involving greater complexity and expense. The combining of simple publicly available indexing tools with screening or trigger criteria offers a way of adding efficiency to the activity. Most importantly, it ensures that the people closest to the risk and whose responsibility in managing it daily, understand their process and its hazards and the role they must carry out in preventing or responding to unsafe deviations.

APPENDIX 1 EXAMPLES:

Chemical Exposure Index Calculation	Make Entries in yellow cells only
Plant:	Chlorination
Unit of Process Plant:	store V101
Calculation by:	Gowland
Material in case studied	Chlorine in pressurised store
Date: January 4 2006	

Piping release or vessel nozzle release

Level 2 Risk Analysis is triggered	*(Liquid Release)*
Level 2 Risk Analysis is triggered	*(Gas Release)*

Distance travel by ERPG2 concentration Metres (Liquid Release)	16932
Distance travel by ERPG2 concentration Metres (Gas Release)	3571

The software also allows the cases of hoses, overflows and relief systems to be studied.

APPENDIX 2: FIRE AND EXPLOSION INDEX

	Solids pesticides warehouse	
	Fire and Explosion Index	41.78
	Material Factor (see Material Data)	14.00
	NFPA Health rating (Nh)	1
	NFPA Flammability rating (Nf)	2
	NFPA Instability rating (Ni)	1
	General Process Hazards	
	Base	1
1A	Exothermic Reaction (range of input 0.3–1.25)	0.00
1B	Endothermic Reaction (input range 0.2–0.4)	0.00
1C	Material Handling and Transfer (input range 0.25–0.8)	0.00
1D	Enclosed or Indoor Process or storage Units handling Flammable materials	0.00
1E	Ease of Access for Emergency Responders	0.35
1F	Drainage and Spill Control	0.50
	General Process Hazards Factor	1.85
	Base	1
2A	Toxicity of the material handled.	0.20
2B	Process or Storage operates at vacuum (<500 mmHg) – penalty 0.5	0.00
2C	Operation in or near the flammable range (input range 0.0–0.8)	0.00
2D	Dust Explosion (input range 0.0–2.0)	0.00
2E	Pressure Penalty	0.00
2F	Low Temperature Operation	0.00
2G1	Combustible and Flammable materials in Process	0.00
2G2	Liquids or gases in Storage	0.00
2G3	Solids in Storage or Process	0.41
2H	Corrosion and Erosion (input range 0.0–0.75)	0.00
2I	Leakage, Joints, packing, flexible joints	0.00
2J	Use of Fired Equipment (Fig 6)	0.00
2K	Hot Oil Heat Exchange Equipment (Table 5)	0.00
2L	Rotating Equipment	0.00
	Special Process Hazards Factor	1.61
	Fire and Explosion Index	41.78
	Level 2 Risk Analysis is not triggered	

Software calculation demonstration is included in the oral presentation.

APPENDIX 3: OCCUPIED BUILDING VULNERABILITY

Vapour Cloud Explosion Screening for: *Distillation Unit*

Date: 2/20/07

By Angel

Dimensions of the confined or semi-confined Zone which can be filled by a leak of flammable vapour above its flash point.

	Width (M)	Depth (M)	Height (M)	Volume	Standoff distance between source and potentially affected building (M)	Calculated Fuel mass (Kg)		
INPUTS in this row	15	15	5	1125	20	91.575		
TNO M.E.	Curve 1	Curve 2	Curve 3	Curve 4	Curve 5 Y	Curve 6 Y	Curve 7	Curve 8
Approximate Predicted Side on Overpressure at building (mBar)	10.00	20.00	52.10	109.25	201.70	612.93	1000.00	1641.29
Standard Brick or block construction without independent roof support	O.K.	O.K.	O.K.	Not Suitable	Not Suitable	Not Suitable	Not Suitable	Not Suitable
Conventional Windows allowed?	YES	NO	NO	NO	NO	NO	NO	NO

In this case, the screening criteria suggested is a peak side on overpressure of 70 mBar. If this pressure is exceeded, the building is vulnerable to major damage and consequent serious injury to occupants. When these criteria are met, the procedure outlined by HSE (Martin Goose) is very helpful. It proposes a system of estimating cumulative frequency of these events and assessing the result against ALARP (As Low As Reasonably Practicable) criteria frequency (e.g. frequency of serious injury meets tolerability criteria)

Software calculation demonstration is included in the oral presentation.

REFERENCES

The Dow Chemical Company Fire and Explosion Index Hazard Classification Guide Ed 7 1994

The Dow Chemical Company Chemical Exposure Index Guide Ed 2 1993

Location and Design of Occupied Buildings at Chemical Plants – Assessment Step by Step. Martin Goose – U.K. Health and Safety Executive