

IS HAZOP ALWAYS THE METHOD OF CHOICE FOR IDENTIFICATION OF MAJOR PROCESS PLANT HAZARDS?

Alfredo Verna[1] and Geoff Stevens[2]
Arthur D. Little Limited, Science Park, Milton Road, Cambridge, CB4 0XL, UK
[1]E-mail: verna.alfredo@adlittle.com
[2]E-mail: stevens.geoff@adlittle.com

Hazard and Operability Analysis (HAZOP) has long been established as one technique for risk identification in Process Plants and many firms incorporate HAZOP procedure into their safety management approach. HAZOP studies appear at various phases of project development including FEED (Front End Engineering and Design), as part of Detailed Design and for engineering modifications to existing plants.

An alternative approach to HAZOP is described suitable where potential hazards are well understood and where time is limited but independent assurance is desirable. The method was applied as a review of a design that had already been fully studied by HAZOP but still revealed a number of important new hazard issues. Apart from describing the new technique, the paper examines reasons for shortcomings of HAZOP conducted too early in the engineering development and conditions under which it can be cost effective.

INTRODUCTION

Hazard identification is one of the key steps in systematic Safety Risk Management which can be illustrated in diagrams such as Figure 1.

The process illustrated is iterative and can be applied at a number of stages in the project cycle. Because it is recognized as a primary methodology for conducting hazard analysis, some suppliers offer HAZOP at any stage of the design[1]. The approach in practice needs to be varied according to the documentation (especially the diagrammatic representation) available at each stage. Even in the operating phase, HAZOP can be used, for example, when modifications are planned or when a major turnaround is anticipated including safety related upgrading.[2]

HAZOP STUDIES CONDUCTED WITH LIMITED TECHNICAL DEFINITION

The contract stage at which design information emerges will vary with the contractor's approach and the degree of integration they have achieved[3]. At the early stages of the project (development of the design basis manual and to some extent the Front End Engineering) the technical definition includes limited (sometimes no) information on the proposed control instrumentation and Safety Interlocks either for machine protection or plant emergency shut-down. It is not uncommon for details of machinery protection functions to be delayed until vendor selection has been completed and this can be quite

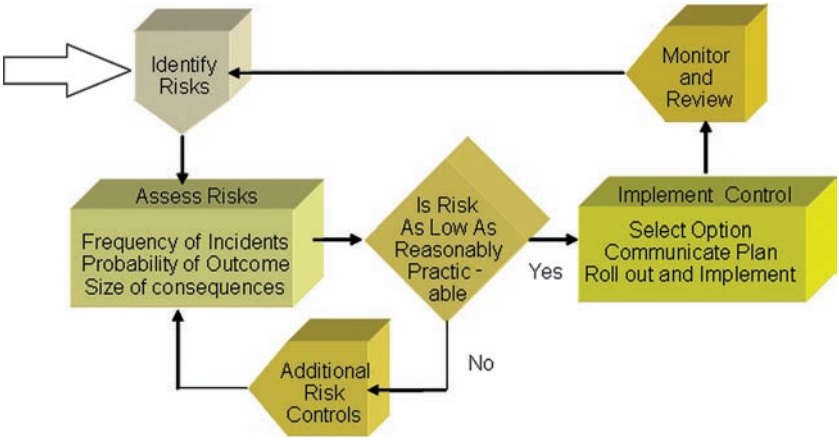


Figure 1. Block flow diagram of the process of Safety Risk Management. Source: Arthur D Little

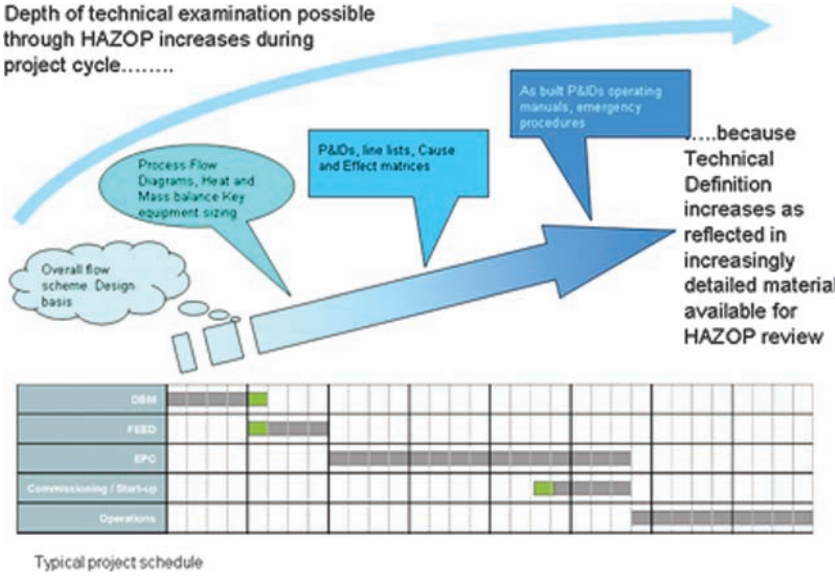


Figure 2. Project schedule and application of the HAZOP approach. Source: Confidential

advanced in the EPC (Engineer Procure and Construct) phase of the project. If a full recording HAZOP technique is employed at each of the key stages in the project the following outcomes can be expected:

- In the early stages there is sufficient information to identify the main hazardous inventories and the generic hazards associated with the type of equipment available. If a coarse HAZOP is undertaken, each deviation with hazard potential is likely either to recommend the issue is revisited when better definition is available or (in the case of major hazards posing intolerable risk) to suggest a review of the design.
- When Process Flow Diagrams are available, the HAZOP can deal with potential hazards associated with each deviation but there may not be sufficient definition of control systems or materials selection to determine if adequate levels of protection are provided.
- Once P&IDs are available, including control arrangements, main trip functions, equipment design conditions and piping material, a full recording HAZOP can be conducted. Typically this review works well for the engineering contractor's scope but there may be a number of "black boxes" where information is missing from equipment vendors. The HAZOP record is likely to note issues to be referred to the "vendor package" HAZOP.
- After vendor selection the P&IDs and the control system can be matched to the vendor's arrangements including machinery protection trips. This may be the earliest point at which Cause and Effect diagrams for vendor trips can be compared to proposed ESD and plant or plant section protections. It needs to be recognized that the reliability of the plant and its ability to meet the owner's service factor expectations can be materially affected by choices at this stage and these come late in the project schedule when changes imply a high cost and schedule penalty.
- Once in operation a full documentation including the as built arrangements is available. In practice operators may already have made some changes, for example removing or overriding some interlocks and trips which inhibited start-up. Some additional maintenance or start-up lines may also have been added either for convenience or to make good oversight in the earlier stages of the project. Two issues arise in the HAZOP at this stage, firstly diagrams which are not actually "as built" and need to be modified and secondly the operator's typical belief that a potential hazard which they themselves have not experienced is not likely to happen on their plant.

The main practical point from this discussion is that HAZOP study at any stage faces some difficulties. In the EPC/Vendor/Operations Phase these issues can be managed by effective project control, particularly scheduling. In the case of Conceptual Design and FEED the difficulties may be inherent if HAZOP is attempted with limited technical definition. In these circumstances other techniques may be more effective and this paper describes one such alternative approach.

INDEPENDENT HAZARD REVIEW

The independent review is based on the use of a workshop firstly to review the major hazards and then to assess if the proposed risk controls are appropriate.

Rather than piping and instrumentation diagrams (P&IDs), the review works using Block Flow Diagrams and Diagrams of Pressure, Temperature and Composition to highlight the main process hazards which must be managed. The PTC diagram identifies each of the major items of equipment and shows the temperature, pressure and material characteristics as shown in Figure 3.

For each item of equipment such as pumps, heat exchangers, furnaces, reactors, compressors and so forth typical failure modes can be readily identified based on previous HAZOP studies and on accident accounts. The block flow diagram can be annotated with these main potential hazards and their significance judged by reference to the P-T-C chart.

For any particular item of equipment for example Heat Exchangers, generic arrangements and options for level of protection can be drawn up using analyses from previous HAZOP studies.

During the review workshop we check whether the level of protection proposed for all main potential hazards in each section of the Block Flow Diagram is appropriate. Where the protections are found to be lacking or inadequate, changes will be recommended. These are recorded in the same systematic manner as used for HAZOP studies.

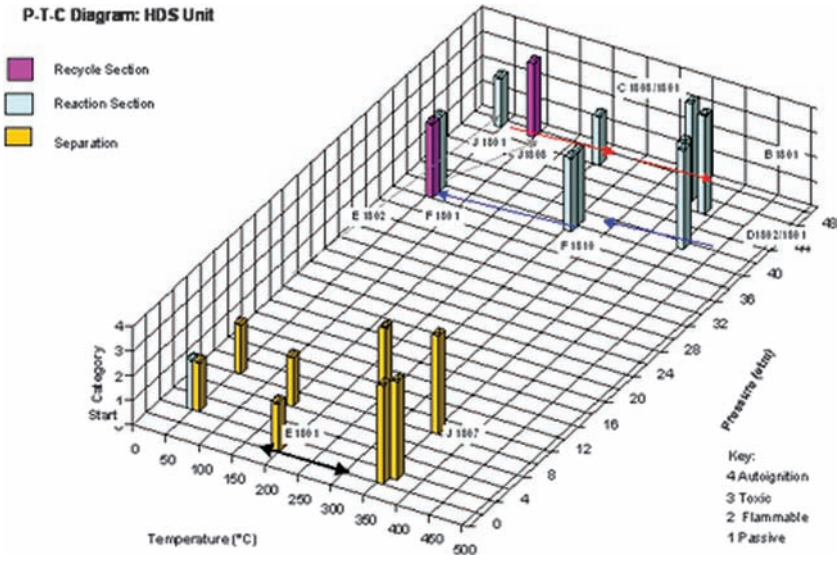


Figure 3. Typical P-T-C diagram for a hydrosulphurization unit. Source: Confidential

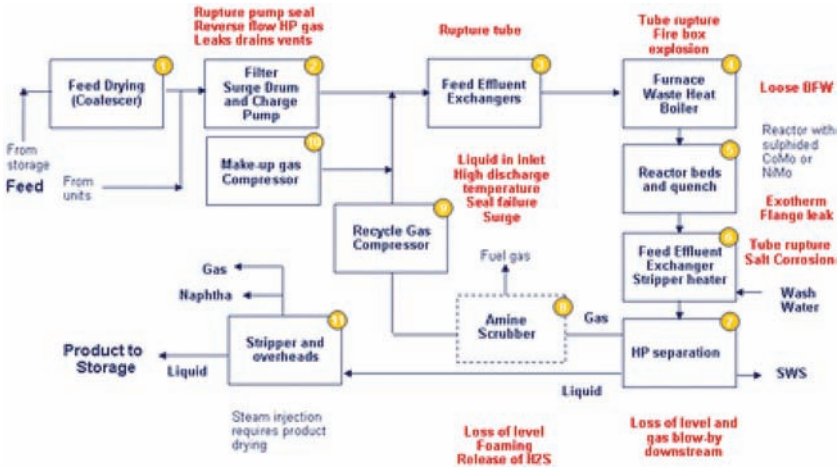


Figure 4. Main hazards in the plant. Source: Confidential

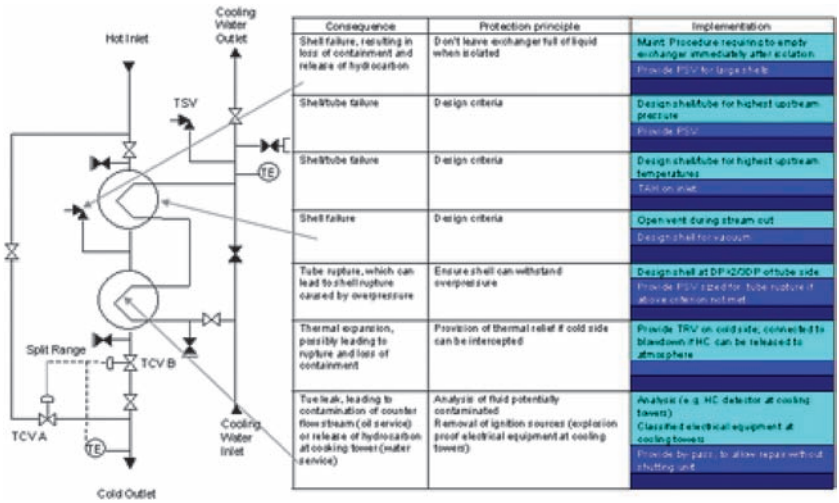
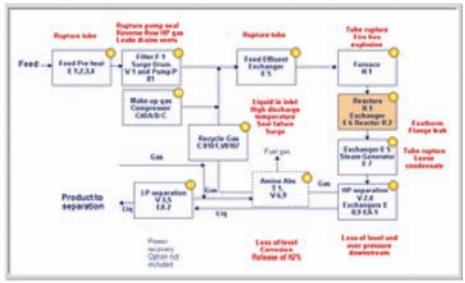


Figure 5. Protection for heat exchanger. Source: Confidential

A main hazards tabulation is developed for each plant Section.....



Topic	Specific Issue	Hazard Description	Existing control	Issues/Questions
Hydrogen rich gas leak and ignition	Failure of hydrogen quench line	Line rupture or leak followed by ignition may result in intense flame capable of severe damage	1. Shut C1 to reduce pressure and inventory in the hydrogen line. 2. Keep P1 running to maintain a cooling hydrocarbon flow through the reactors. 3. Cut H1 furnace to reduce the temperature of the hydrocarbon reactor inlet stream. 4. Depresssure	No specific shutdown sequence will proposed to deal with this situation, all leaks in HP section will be managed by initial depressurisation. Basic design requirements should be implemented (small bore pipework removal, minimisation of flanges, re

Figure 6. Main hazards in the plant. Source: Confidential

Depending on the stage of the project at which the independent hazard review occurs, documentation like PFDs or P&IDs as well as any available hazard identification reports – including HAZOP – will be used as a basis for the review. However, the study will only be focused on protections and controls against the main potential hazards associated with the process being examined.

The hazards are based not only on findings from HAZOP studies conducted on similar plants but also on accident accounts. As for the selection of the most effective prevention and protection measures for specific hazards a useful input can be provided by what other operators have implemented in similar units (see Figure 7).

This review approach allows a Risk Register to be developed in which the Loss Aversion offered by additional actions over and above those proposed by the project team can be assessed [4]. If a demonstration of completeness is required, a Loss Profile simulation can be carried out to demonstrate that the assessment is credible in terms of losses which have occurred elsewhere in the industry[5].

Regarding the resources required, the independent review workshop requires much less time than a full HAZOP study. For example, for a refinery unit typically it takes between one and two days to carry out a review workshop compared to 10 days or so for a HAZOP study. These are indicative times and of course vary with the number of P&IDs requiring review (for HAZOP) and the complexity and intrinsic hazards in the process (for the Review Workshop). The hazards and recommendations arising from a review, embodied in a risk register, require a similar period of one or two days for risk assessment and ranking, if a Risk Assessment Matrix is used.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	[illegible]			[illegible]
B	[illegible]	[illegible]	[illegible]	[illegible]
C	[illegible]	[illegible]	[illegible]	[illegible]
D				[illegible]
D				[illegible]
E				[illegible]

	REF 1			REF 2		REF 3	REF 4	REF 5
	66 bar	74 bar	108 bar	54 Bar	50 Bar	67 Bar	36 Bar	40 Bar
PSV sized full-open valve + 50% DP (PSV placed on LP separator to protect downstream equipment, safety valve correctly sized)	?	?	yes	PSV exists but size unknown	PSV exists but size unknown	PSV exists but size unknown	PSV exists but size unknown	PSV exists but size unknown
BPCS LC (only control valve)	yes	yes	yes	yes	yes	yes	yes +PC/FAH	yes
Independent LAL								
LSLL on LCV (independent cut-off valve driven by primary element)				Yes, controlled By FAHH on LP separator				yes
LSLL on XV (independent cut-off valve driven by independent instrument)	yes	yes				yes		
2 out of 3 LSLL on XV (as above with 2 out of 3 voting logic)			yes		Yes LCV and XCV both close.			

Figure 7. Accident records and operators survey tabulations. Source: Confidential

One benefit of the Review Workshop approach is that it delivers a balanced allocation of resources between hazard identification, assessment and the evaluation of improved controls. With HAZOP the potential is to spend a disproportionate time on the identification procedure (with the temptation to cut short the assessment of risk and the implementation of actions).

Before adopting a Review Workshop approach there are some important provisos.

1) EXPERTISE

The ability to conduct the Workshop depends on the data available to the facilitator, especially knowledge of the hazards identified in several previous HAZOP studies of similar plant as well as understanding of the root cause of accidents which may have occurred elsewhere on plants of the type being studied. HAZOP study also requires expertise but provided the HAZOP facilitator is experienced with the method, he can rely more on the knowledge of team members regarding process hazards.

2) LIMITATION TO MAJOR HAZARDS

It must be clearly understood that a Review Workshop only addresses major hazards and will not pick up detailed issues which require line by line analysis. Generic matters such as leaks from vents or drains and manual operation such as sampling can be addressed through typical arrangement drawings but there will not be time to check that these have been consistently applied across all plant P&IDs. Similarly, materials selection can be examined as a general topic but there is not the time to check line by line that materials of construction have been correctly selected. For this level of detail, a full recording HAZOP study is recommended for example when P&IDs are to be "Approved for Construction" in situations where no other independent design review is to be conducted.

REFERENCES

1. For example http://www.upop.com/services/2090.html
2. G C Stevens and M Marchi: (June 2001) *A Benefit/Cost approach for prioritising expenditure during plant turnaround* 10th International Symposium on Loss Prevention and Safety in the Process Industries
3. E Tipton, S Mullick and A McBrien (2007) *Focus on integrated FEED* Hydrocarbon Engineering
4. P Beall and G Stevens (2007) *Making HAZOP the method of choice for identification and assessment of process hazards* 9th Process Plant Safety Symposium. AIChE Houston
5. G C Stevens, A Verna and M Marchi, (October 2001) *Getting full value from HAZOP. A practical approach to the assessment of risks identified during studies on process plants.* IChemE Hazards XVI Manchester England