PART B

IDENTIFICATION OF HAZARDS

B 1 Introduction

The identification of hazards is a skill and requires a large “***knowledge base***” as well as a good structure within which to work.

This gives a high level overview of the Identification of Hazards - each company, present or future, will have its own "tools" and these may be corporate confidential. There are, however a number of general techniques for the Identification of Hazards.

1. Codes, Standards

2. Databases

3. Audits/Studies

4. Hazard and Operability Studies (HAZOP)

5. HAZID

6. "Eyeball" the problem - use experience

The “eyeball” approach as unacceptable - it was used for many years and did not work as it was based on the experience of the team and had no structure. Codes and Standards, either corporate or national, are still powerful tools and must not be ignored, there are too many and too varied to even start to outline them but there are various sources such as:-

- American Petroleum Institute (API)
- American Society of Mechanical Engineers (ASME)
- International Standards (I.S.O.)

If nothing else these are the starting point for any design, these will be reintroduced in later chapters. Unfortunately there is no standard design for any one production unit; each has differences due to size, efficiency, feedstock and even the designers own ideas so items 2, 3, 4 and 5 above must not be overlooked. It is almost impossible to achieve a competence in all of the techniques which can be applied so all these notes can do is to give an overview.

B 2 Problems with Identifying Hazards

Do not underestimate the problems associated with "***Identifying Hazards***". Designers are becoming very insular - even within any discipline they are becoming very specialised - so inter-disciplinary problems are common. Projects are becoming more "fast track", these limits the time available to sit down and **think** about the possible problems. The knowledge base is also limited and most of it is shared knowledge over about 20 years, in the meantime the projects are becoming more complex due to a drive for thermal and/or chemical efficiency with all the associated novel problems.

Some of the readers may have already been on some of the studies that will be described during vacation work or placements - please bear with those who have not have been on these studies as they are part of these notes. For those who have experienced these studies please **do** read the notes as they may give you a different perspective into the techniques - and **that** is to be encouraged.

Above all it is now recognised that any team needs a "Facilitator" - (leader in other words – the title Chairperson is not applicable as it does not give the full description of the role of the leader). Even if the reader may never be a Facilitator yourself it is useful to know what he/she is trying to achieve. Some of the "Facilitators" techniques are to be found wrapped up within the notes.

B 3 Hazard Studies/Project Hazard Analysis (PHA)

This is an expansion of the Structure laid out in the Part A. Ideas that can utilise Inherency are to be found under Design Part D 13.

As a project moves on from the "idea" to "completion" **many** SHE problems have to be handled - and **many** potential problems are built into the design. One of the tools used to solve these problems is a Hazard Study (HS), Audit or Process Hazard Analysis (PHA). The classic technique was developed by ICI in about 1970 and had 6 steps. The latest thinking is that there should be two extra studies/phases given the numbers 0 and 7 as discussed in Part A, these are now outlined with the phase of the project during which they are carried out. Some companies use a variation of the technique on the form of an external audit but it must be noted that "ownership" of problems leading to the correct resolution only comes from within the project team.

Study 0 Inherently Safe

Inherently safe and environmentally friendly is a concept that has to be analysed in some detail, it requires "thinking outside the box" and is not easy without some depth of experience. In general, with the pressures on design teams it is not one of the issues that receives a high priority, more particularly should it result in a change in the process or the chemistry. This idea will be expanded upon.

This study is one which should be carried out on the very earliest idea and is at the research/technical boundary.

An inherently safer or "greener" process means a process route which has safety and environmental protection built into the design from the very start. There are many ways in which, theoretically, it is possible to have an inherently safer process but it is not always as easy as it sounds! First of all, and this is typical of all of the identification techniques, it uses a series of "***guidewords***" designed to trigger ideas in the mind of the designer. The guidewords, with their interpretations, are at the start of each technique.

Study 1 C*oncept - well before sanction*

<u>Objective</u> To identify the **major** problems which have to be overcome before the concept can become a viable project.

Basically, are there any "show stoppers" which are so insurmountable that it is not worth carrying on with the Project?

End Point The concept should be capable of development into a project.

SHE Topics HAZID Studies: Toxic Data availability: Reactors Kinetics particularly exothermic properties of reactants and reactions: Effluent Handling: Alternative Processes: Availability of feedstock, the means by which it might reach the site and the "risk" to the public during the transfer: Coarse Hazard Indices: Environmental Impact Studies: Equipment Availability studies: Reliability Studies on "Safety Critical Items" such as shut down systems and gas detection systems: Special materials of construction that might have a safety implication, e.g. corrosion.

SHE Effort A few person months on a large project

Timing Once the project concept has been identified – it could still only be an idea in the minds of the Technical Department

Study 2 Project Development or Front End Engineering Design - before sanction

Objective To analyse and assess all of the major problems and to design in the current safety features to ensure risks are "as low as reasonably practicable".

End Point The project can proceed to detailed design.

SHE Topics Reactor Start-up and an analysis of the stability (risk) and any requirements for safety features: Shut-down dynamics and possible impact on safety through the violation of the pressure-temperature envelope: Initial Layout: Detailed Risk Assessments: This should include the integrity of protective systems (Part D 12 - SIL). Product/feedstock movement and storage studies: Requirements for fire fighting/protection and particular requirements for environmental monitoring, locally or more globally. Resolution of any problems from study 1. Safety Case preparation if required.

Management Systems will be discussed later in Part C and in more detail in Part F

SHE Effort. Up to a person year for a large project. More if there is a safety case.

Study 3 Detailed Design - before the design is "frozen" and as it is sanctioned

Objective To ensure that the detailed design is correct, has addressed all of the problems in steps 1 and 2 and that the plant will operate, start up and shut down safety and efficiency.

End Point The construction can start.

SHE Topics HAZOP Studies, Relief and Blow down Studies: Area Classification: Special protective systems, including shut down/ESD, fire protection, gas detection and other systems: Special operating procedures. Resolution of any problems from study 2.

Design Features will be discussed in more detail later in these notes and Part D

SHE Effort Possibly a number of person years but spread over a few years

Study 4 Construction – after the Project is "frozen"

Objective To ensure the project is built as intended and no "modifications" are missed.

End Point The project can start to move to commissioning.

SHE Topics The SHE topics are really those topics which are of interest to all discipline (punch or reservation lists) plus the outputs from study 3.

SHE Input As much as is required – on a large project the effort should not be underestimated.

Study 5 Commissioning – before start up.

Objective Is everything ready?

End Point Start up.

Topics – Not necessarily unique to SHE. Operating Instructions, training, trip testing, and safety equipment in place.

These will be discussed in more detail in Part C (BEng) and Part F

Study 6 Post-Start up – 1 year of operation.

Objective What went well and what went wrong?

End Point Up date design techniques/data bases

Topics – not necessarily unique to SHE. What was good and what was bad about the design/project? What would you do differently and what might you want to incorporate into your Design Guides?

Study 7 How do you decommission and demolish the plant safely and without any risk to the environment?

Demolition is not the reverse of construction.

Objective How can it be ensured that the equipment is clean and is not weakened by corrosion. What are the disposal routes for metallic materials? Can be identified? Likewise the disposal route for lagging and other residual materials?

End Point Start the demolition

Topics Structural integrity safe size reduction, cleanliness verification (including records from the last shut down), order of removal confirmed (it may not be as constructed!), disposal routes and implications on cleanliness.

In general studies 0 – to – 6 will apply to any task, be it a procedure or a laboratory scale apparatus. It is a good discipline to test the development of any task against these mile stones (kilometres?).

These studies may take days or weeks – no rules can be given and typically there may be a team of 3-5 *persons* of mixed skills.

<u>**The results from all of these studies should become part of the safety register**</u>

It is quite clear that each study is timed to minimise the corrective effort/costs. If the concept is not viable there is no use in designing it – wasting the design effort, delaying the final project and missing a sales opportunity. If the development is wrong there is no use in carrying out detailed design.

NOTE

1. **After a number of years it may be prudent to repeat <u>all or part</u> of study 3 as the design intent and the accumulated effect of a number of changes ("modifications") may have invalidated the original design intent used in the previous studies.**

2. **The earlier design studies should, <u>where possible</u>, reflect the future demolition of the process. Some effort in these stages may be very beneficial in the future. Reflect on the problems of the demolition of the first generation nuclear power stations!**

B 4 Hazard and Operability Studies - HAZOP

What is a 'HAZOP' Study?

See *HAZOP Guide to Best Practice Second Edition* (IChemE 2008)

A HAZOP study is a rigorous, systematic, structured technique for identifying potential failures of equipment or plant systems which may otherwise become HAZARDS or OPERABILITY PROBLEMS. Ideally, the process is carried out during the design phase of a project, before the plant is actually built. The problems are identified and corrected '*on the drawing board*', not only preventing accidents, plant upset and lost production, but also making the start-up quicker and achieving flow sheet rates more quickly. The net result is that the cash flow is high early in the product life **without** unnecessary extra expenditure on modifications.

The whole HAZOP process is exceedingly tiring and requires mental and team discipline with critical and creative thought processes.

Above all a HAZOP <u>**only identifies possible problems**</u>. The analysis and resolution <u>**must**</u> take place outside the study itself. Maybe not all of the data is available during the meeting and much valuable time will be lost if the study becomes a problem solving exercise. Further the analysis is a distraction from the primary objective of "identification". If there is a perceived problem, record the concerns, and move on. Typically only **about** 20% of the points raised need action and some of these end up as notes in the operating instructions.

Do not think that HAZOP only applies to hardware – it can apply to a procedure and a computer system. The parameters and guide words will change but the principals will be the same. See later.

How is a 'HAZOP' Study Carried Out?

It is difficult to teach the HAZOP technique without actually doing a HAZOP Study - it is a practical tool **not** a theoretical tool so the main steps will be outline. Once the reader has been on a HAZOP Study it will be possible to identify with these steps.

A HAZOP is an audit tool it is not a design tool and the Team have no authority to change the design in the study – see the comments on the recording, later.

A HAZOP study requires a team (see under "Who is in a HAZOP Team?") and an object to be studied. The usual item of study is centred on the Piping and Instrument Diagrams (P & ID), sometimes called Engineering Line Diagrams (ELD). Also in the study, there should be access to the following:-

a) Specification sheets

b) Equipment drawings

c) Operating instructions – if available

d) '***HAZOP Matrix'*** used in the study (see later)

A HAZOP is somewhat iterative and uses the same basic words over and over again but it is the role of the Facilitator to make it less of a mechanistic study and to add some colour to the questioning. One way is to ask "**What would happen if the pump were to stop?**" It is clear that this is ***no flow*** but it helps the team to think laterally.

Other duties that the Facilitator is trying to achieve are: -

Involve **all** of the team

Challenge points of confusion/inaccuracy

Avoid conflict and to stop it as soon as it raises its head

Control the progress round the "route map" of the P & ID

Ensure that "due procedure" is followed and all issues are duly recorded

Figure B 4.1 (below) shows the flow diagram for a HAZOP Study taken from the Guide to Best Practice:

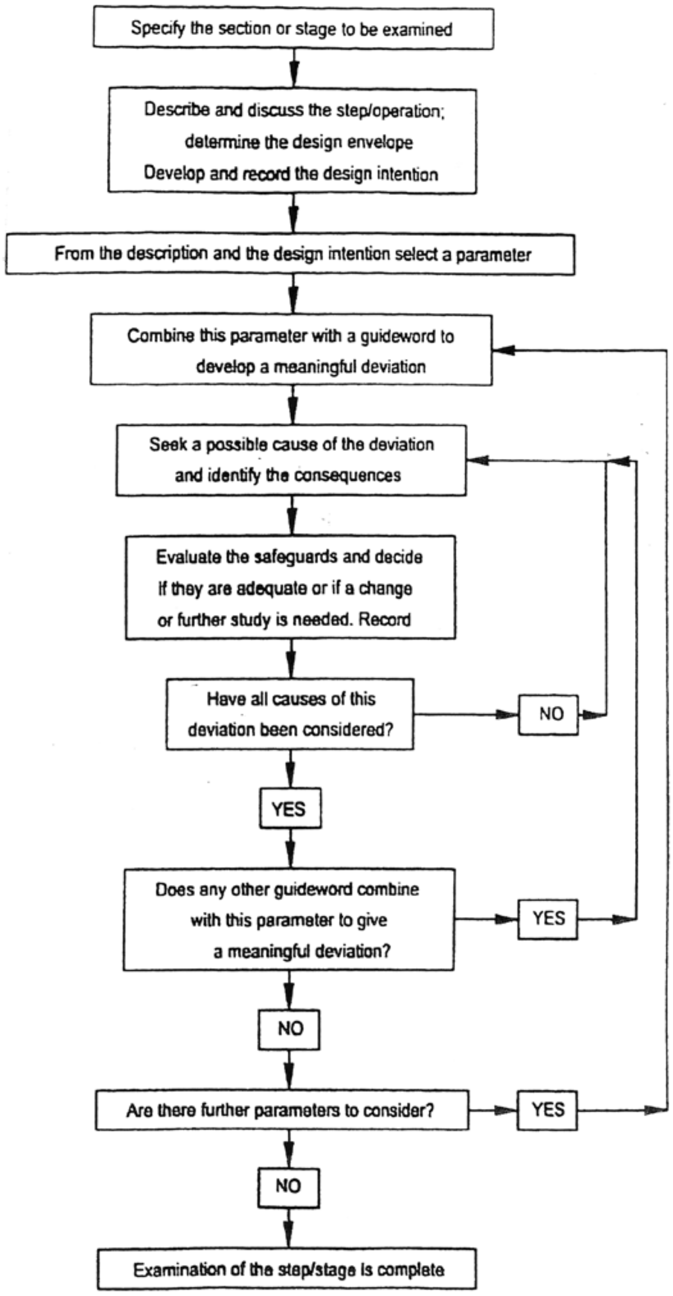


Figure B.4.1 Flow diagram for the HAZOP analysis of a section of an operation – a parameter-first approach (From HAZOP Guide to best practice - IChemE)

Roles of Team Members

The **Facilitator** and **Scribe** should be able to communicate almost telepathically! The **Scribe** should be able to filter the discussion and then to produce accurate and condensed notes within the worksheets. The **Facilitator** will be aware of the Scribe making notes but only occasionally may it be appropriate to ask for a note to be made. Occasionally the discussion becomes a bit confused and the Facilitator has to call the discussion to a conclusion and to ask for a synopsis of the discussion that the Scribe can then record. The Facilitator also has to plan and to follow the route map through the design and to handle problems as they arise. The Facilitator has to steer the discussion, to listen to the discussion, to draw in members into the discussion and when appropriate to curtail discussion if it has entered a "loop". The Facilitator has to be alert to "fatigue" and the drop off in discussion.

The Facilitator has to avoid potential conflicts in the team and head them off in a timely manner. The Facilitator also has to ensure that all of the relevant discussion is carried to completion, the records made, and when a line, or part of the process, has been studied fully that it is marked off as "studied" by a highlighter. The Facilitator has to ensure that all lines and interconnections are studied in full and highlighted.

The Facilitator will also keep a running list of the actions (usually as a note on the P & ID) as part of the Quality Control and will highlight them on an hourly basis so as to reinforce the points and to ensure that the team agrees with the records.

Finally at the end of the day of the study the **Facilitator** and **Scribe** will sit down and analyse the records for construction, language, inaccuracies and completeness.

The other Team Members have to be active contributors to the discussion and deliberations. They MUST BE CONSTRUCTIVE, there is nothing to be gained by being destructive and combative. **It is a team effort**.

How long does a HAZOP study last?

There are no absolute rules, but typically 2 to 3 hours will be spent per major piece of plant equipment such as:

PUMP

VESSEL

HEAT EXCHANGER

These will include all of the connections, instruments and all of the P & I D connections.

A maximum study time of 6 hours per day is advised.

The list of key words is a mixture of "***Parameter***", "***Guidewords***" (deviations) and "***Others***" which have special significance. The derivation of "***Others***" guidewords are often particular to the process itself and may have special meaning for that process, but a skilled Facilitator should be able to flush out the problems with just the use of "***Parameter"***" and "***Deviation"***".

'**Parameter**' words describe how the process might work; they include:-

FLOW (F)
PRESSURE (P)
TEMPERATURE (T)
LEVEL (L)

HEATING (H)
MIXING (M)
REACTION (React)

Table B 4.1 HAZOP Parameters

'**Guidewords**', (sometimes called deviations) describe how the above may depart from the designer's intent; they include:-

MORE (M)
LESS (Less)
NO/NOT (N)
PART OF (Part)
REVERSE (Rev)
OTHER THAN (OT)
LESS THAN (Less than)
MORE THAN (More than)
AS WELL AS (AWA)

Table B.4.2 HAZOP Guidewords

Not all of the Parameters will have a likely associated guideword; however it is important to think of those possible deviations before the HAZOP Study is started. The following matrix gives some of the more likely combinations. However it is not a "global" set and must be reviewed on a case or process basis. Some of the combinations may appear a little odd, before condemning the list think a little deeper! **Reverse** plus **Pressure** could occur during a process upset when the higher pressure system is de-pressured but the lower pressure system is still maintained under pressure. Can an incompatible fluid enter the system? Take for example cooling water entering a system made of Stainless Steel with the resultant stress corrosion cracking (SCC), or the collapse of a tube due to reverse pressure. Note that "other than level" does have a meaning, it could be an emulsion. It is the analysis and the interpretation of the combinations of parameter and deviation which are key to a good HAZOP.

Parameters/Deviations							
	Flow	Pressure	Temp	Level	Heating	Mixing	Reaction
More	X	X	X	X	X	X Emulsions	X
Less	X	X	X	X	X	X	X
No	X		?	X	X	X	X
Part	X					?	X
Reverse	X	X	?				
Other Than	X			? Emulsions			?
Less Than	X		X	?	X	?	? Unreacted Materials
More than	X		X		X	?	?
As Well As	X				???		

Table B.4.3 Typical Combinations of Parameters and Guidewords (Matrix) in a HAZOP Study

X means that there is a likely combination of ***parameter*** and ***guideword***.

The Table B 4.3 above indicates **possible** combinations of "***parameter***" and "***guidewords***" which **may** well have significance during a HAZOP. However, think of the parameter "***Diagnostics***" and the guideword "***No***". It is worth thinking about the requirements to carry out mass balances and the information required in order to analyse an upset process condition. Think also about the meaning of the parameter ***Phase*** and the guideword ***Change*** – this could be sublimation or evaporation or condensation.

'Others' words describe those major differences which may occur during non-steady operation, such as:-

MAINTENANCE
PURGING
ACCESS

Table B.4.4 Some "other Parameters" to consider

Each HAZOP Study Team should spend a little time on identifying special "issues" which can be given particular guide words and attention. The main steps are:-

Describe the Process Intention

This uses the P and ID plus a word description of the design intent or that which is done. It will include a description of the flow temperature, pressure, composition and other properties, each will have a magnitude in appropriate units.

The next part is to select a line (node) and to apply the matrix in table B.4.3. It is important to choose the first line with care as it must represent the START of the analysis. Logically it would be the first line on the first P & I D but maybe it should be the line supplying the feedstock from the upstream Plant. An upset there might cause a bigger upset on the plant being studied!!!

(A ***node*** is a clearly defined section of line where the main parameters are fixed and do not change. With experience it is possible to include within a main node a parameter which has changed – this is very much and advanced technique which has to be handled with skill).

Recording Sheets

These can be as a "spread sheet" or a commercial recording program. The commercial program should follow the recognised convention as shown below.

1 Reference number

A unique number that can be used to track the actions at any time; it could be alpha numeric or by P & ID number but it can only be used once. That reference can then be used to track the actions in electronic format.

2 Parameter

The parameters are a description of the detail of the process as described above. It does not discuss the engineering (see table B 4.1 & B 4.2).

3 Guideword (or Deviation)

This is a description of the violation of the design intent (see tables B 4.1 & B 4.2).

4 Cause

Self explanatory.

5 Consequences

This may need a little more description to explain the effect in a meaningful manner.

6 Hazard

This is a description of the consequences of the effect/event

7 Protective Systems

These are those systems, hardware and software, (defences in depth) which are used to prevent the cause of the event reaching an unacceptable condition. These usually refer to shutdown systems

8 Risk

This is better done outside the meeting.

If the assessment is carried out during the study there is a grave loss of loss of time and momentum and there could be some "arguments".

The effect will be reviewed WITH and WITHOUT the protective system in place. If the protective system is critical the action should specify the performance standard that may be may be required.

9 Action

Again self explanatory but is usually advisory such as "verify", "assess", it is only very rarely that a firm recommendation for a specific remedial action is given. This is out with the competence of the study but does occur occasionally where the team identifies a breach of a code or standard.

10 Action on

The owner of the action or that person who is charged with the resolution of the action.

As the structure of the study is so systematic, it can ideally be described in a flow sheet – Figure B 4.1.

Other Information

Typically the worksheet would also include: -

Date

Intent of that "Node" or section of piping under study

Attendees and their affiliations

P & ID Numbers

How Is A HAZOP Study Recorded?

The records will normally be in column form and contain as a main head the general design intent of the piece of equipment. The columns will then contain:-

Ref N°	**Parameter**	**Deviation**	**Cause**	**Consequences**	**Hazards**	**Protective Systems**	**Risk* M/F**	**Actions**	**Action on**

Table B.4.5 Typical Headings in a HAZOP Worksheet

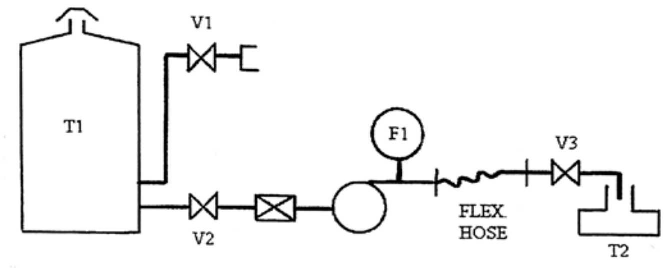
It is best to complete the column Risk* (Magnitude and Frequency) outside the meeting for the reasons given and when the issue has been fully understood.

The structure of the columns may change from process to process or from company to company. A more developed example for the petrol station is shown in Table B 4.6 at the end of the exercise.

The results from these studies should become part of the safety register

HAZOP in Action

The operation of a HAZOP study cannot be described as a strict procedure. It is best described by taking a typical example as a starting point, using the flow sheet shown in Figure B 4.2 shown below. It is the simple flow sheet for a continuous or semi-continuous system to be used to fill a car petrol tank.-



It is recognised that **T1** is the underground bulk storage tank, **F1** is the integrating flow meter on the filling station and **V3** is the manual trigger (and cut-off valve), **T2** is the fuel tank in the car. Only part of the study can be recorded in this illustration and it is self evident only a fraction of the records are given in the worksheet.

Step 1: *Select a vessel:* The storage tank.

Step 2: *Explain the intent:* The storage tank contains 3000 gallons of petrol; it is stored underground near to the forecourt of the petrol station. The pump draws petrol from the tank and discharges it to a flexible hose, at the end of which is a valve which is controlled by the operator. The valve is fitted in a metal filler pipe which fits into the mouth of the car petrol tank.

Step 3: *Select a line:* The hose.

Step 4: *Describe its intent:* To transfer petrol at a **flow** rate of about 5 gallons (25 litres) per minute from the pump to the car tank. (The first parameter is FLOW).

Step 5: Apply a guide word Deviation: NO.

Step 6: Develop a meaningful Deviation: There is no flow into the petrol tank T 2.

Step 7: Possible causes: The valve in the filler is not open.

Step 8: Consequences: The pump overheats and gas locks.

Step 9: Hazard/Operability Problem: The pump loses suction and the filler station cannot be used.

Step 10: Record.

Step 11.1: Other guideword/deviation: MORE.

Step 11.2: *Deviation*: More flow is fed to the tank and the tank over-fills.

Step 11.3: *Causes:* The operator/driver is distracted.

Step 11.4: *Consequences:* Petrol is spilled onto the forecourt.

Step 11.5: *Hazard:* Possible fire.

Step 11.6: Record and note the need for some level cut-off device. etc.

Do not do the design - leave that to a team outside the meeting to review the action.

Step 12: Mark the line: Colour the line with a highlighter pen to record it has been studied, etc.

This shows how the study is exceedingly structured (and potentially boring). The Facilitator has to keep the discussion to the point and also avoid conflict and boredom.

Some of the 'other' words which may be applied to the filling process could include

- Other than – petrol?
- What if there is water?
- What if there is diesel?
- Static electricity, etc.

The HAZOP study tends to be very repetitive but consider this statement. "It is difficult to find a fault if a) you do not know what you are looking for and b) where to look for it."

HAZOP forces the team to concentrate on **one** aspect at a time (where?) and assess the final potential faults (what is it?) in a structured and systematic manner. If the structure is not used it is likely that the team will miss some of the problems.

Illustration

Consider this dialogue as a piece of play-acting to illustrate the HAZOP process.

The team members are:

F = Facilitator

S = Scribe

O = Operations Person (Forecourt attendant)

U = User (the reader)

D = Designer

Only one combination will be considered, that of *Flow* and *High* as applied to the filling line.

F "Can you give the Team a verbal description of the Process?"

D "The intent is to fill a car with 95 Octane lead free petrol. The petrol is stored underground in tank T1, pumped by a pump, through an integrating flow meter F1 into the car fuel tank T2. The tank T1 is fitter with a breather vent. The flow is controlled by valve V3 at a peak flow of 25 l/minute but can be as low as 1 l/m when the car fuel tank is approaching full."

F "Thank you, that was very concise. I would like the team to concentrate on the parameter ***FLOW***. I would like you to think how the flow could exceed the desired rate. However D gave us two flow rates one at the start and one at the end of the cycle. Can we take the start first?"

D "The pump is a swash plate type which is self limiting in rate; it can not exceed 25 l/m".

S "I will note this in the records"

F "Yes please. Can we now look at the ***high flow*** at the middle of the filling cycle?"

D "There is a valve controlled by the car owner and he/she can regulate the flow as required".

O "But what happens if he/she ignores the flow and walks away?"

D "The valve V3 is a "dead-mans handle" and will close automatically on high level in T2".

U "But it will not be the first time that the user has over ridden the V3 and the tank could over fill or V3 could fall out of the filler point in T2".

F "Has anyone any comments?"

O "It is possible but of more concern is the fact that than the 25 l/minute of petrol will be spilled and the drains will possibly become overloaded and then there could be a fire!"

D "Good point, I think that O and I should look at this in more detail"

S "Recorded"

Part of the records sheet for ***FLOW NO*** is shown, it will be noted that the flooding issue has appeared in entry 1.8.

(It is not unusual for the same issue to come up against a number of ***parameters/guide words***. This is a form of "quality assurance".)

Table B 4.6 Operability Study Automobile Filling Worksheet

Ref No	Parameter A	Guideword B	Cause C	Consequence D	Hazards E	Protective Systems F	Actions G	Action on H
1.1	Flow of petrol into car tank i.e. from T1 to T2.	No (flow.)	1. Pump Fails (electrical or mechanical) 2. V2 shut. 3. V3 shut. 4. Strainer blocked. 5. Stock tank empty. 6. Flexible hose fails. 7. Nozzle not in car tank. 8. Vent on stock tank blocked. 9. Line choke.	Tank on car not filled.	1. Sales interrupted. 2. Possible overheating of pump (3,4,9 also). 5. Sludge and/or water pulled out of stock tank. 6. & 7. Spillage of fuel, drainage problems, fire hazards. 8. Possibility of 'pulling-in' stock tank. 2. & 3. If V2 and V3 shut together and pump continues to run, possibility of over pressure due to liquid expansion.	1,2,3,4,5,9. No flow indicated on flow meter. Operator can also observe and hear petrol not flowing. 5. Tank dipping procedure. No indication of pump overheating. No indication of tank vent blockage.	1.1 Check spares availability for pump.	O
1.2							1.2. Morning opening procedure should include opening V2.	O
1.3							1.3 Check whether pump overheating could be a problem.	D
1.4							1.4 Should shutting V3 trip out- pump? 2. & 3.	D
1.5							1.5 Is pump protected against expansion of liquid running 'blocked-in'?	D
1.6							1.6. Ensure that tank is dipped sufficiently frequently.	O
1.7							1.7. Ensure that flexible hose is inspected regularly (e.g. 1.	O
1.8							8. Are drains able to cope with petrol spillage?	O & D
1.9							1.9. Will V3 automatically shut if nozzle falls out of tank?	O & D
1.10							1.10. Ensure that tank vents are checked regularly (is vent big enough?).	O

Variations - Batch Processes

There are variations from this 'steady state' process for batch processes such as batch reactors or any other intermittent process. This is best shown on the following simple filter diagram:

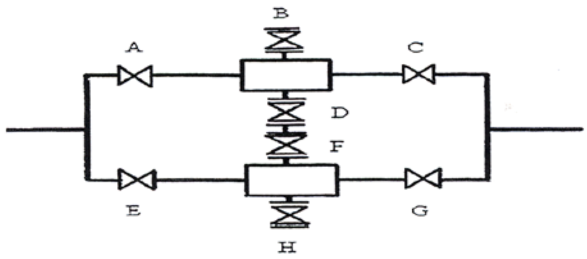


Figure B 4.3 Simplified P & ID of a Parallel Pair of Filters

<u>Note</u> there is **<u>NOT</u>** a physical connection between D and F it is an aberration in the drawing. Maybe there should be a HAZOP action "***Verify that there is no connection between valves D and F***?"

The design intent is to filter solids from the process stream in a duplex on-line filter. The process can be studied as a series or valve positions:

Open A,B,C,D - more flow: discharge to vent or drain. Closed others.
Open A: no flow. Closed B,C,D: no flow to the process.

The ideal method for handling this process is as follows:-

1) Decide how it should be operated - this is fairly obviously B,D,E,F,G,H closed; A, C open - label valve positions with little coloured stickers or coloured pencil 'dots' (Red is Open, Green is Closed).

2) Carry out the HAZOP on all lines in and out of the filter.

3) Change one valve position - cover the original sticker with an overlapping sticker or change the pencil dot colour so that the valve sequence can be followed - Open/Closed/Open/Closed.

4) Carry out the HAZOP on all lines into and out of the filter.

Very quickly it will be seen that B and/or D can not be open when either A or B is open and that A and C MUST be open to allow a flow of process fluids. Following all possible variations of valves A - G you will take ages - it is just too complex and often obviously fruitless. It is better to start with a defined procedure and then to analyse the issues if the procedure is not followed properly. Variations in a batch process could include A added after B, A added to slow/fast, and others.

Other - Batch Processes

The parameters for a truly batch process require a bit of analysis. The following table is a starter.

Batch Parameter
Rate of Addition
Timing of addition
Mixing
Reaction
etc

Table B 4.7 Possible Batch Parameters

Likewise the following is one set of batch guidewords: -

Batch Guidewords
Too slow
Too fast
Too early
Too late
Incomplete
Wrong order
etc

Table B 4.8 Possible Guidewords for a Batch HAZOP

Follow-Up 1

It would be nice to think that the study ended when all of the lines and vessels have been marked off with a highlighter pen as "study complete". Unfortunately this is not true.

The study now needs to assess the consequences of the deviations in more detail - in some cases using simple risk assessment techniques to determine the best change or modification option. This can be done by a small section of the team, usually by the Leader and Secretary. This approach is preferable as if it were to be carried out during the study itself there is the grave risk of a loss of focus and “momentum”.

In an ideal world (and this is where PC records do help), the team should have an overview of the previous day's Minutes before the start of the next meeting. While much of HAZOP is 'consensus engineering', key items must be analysed with skill and in great detail.

Follow-Up 2

It would be nice to think that the study now ended here! Unfortunately, again, this is also not true. Any change proposed by the study must now be "re-HAZOPed" by a small element (say 50%) of the original team.

Study End

The study is complete when **all** actions have been agreed with the client; **all** changes have been re-HAZOPed, the report issued and all marked up P and IDs returned to the client's record system. The Report and marked up P and ID are part of the QA process.

The following g section is a potted summary of a team interaction and one which requires both technical and facilitating skills. Topics such as these can only be learnt from experience are typically:

Where to start the study?

How to link all of the P & I Diagrams?

How to study a modification?

How to handle a cross link such as across a heat exchanger?

How to handle the links of P & ID to a vent or drain system?

When is it justified to treat a spare by “examination” only?

If so, what additional actions might be needed?

See the worked example in the HAZOP Guide to Best Practice - IChemE.

B 5 HAZID

Introduction

The causes of major hazards are not normally immediately obvious and are often the result of a number of simultaneous events or the breaches of the ***defence in depth***. The identification of major hazards was therefore for many years based on experience and allegorical stories from the industry. The HAZOP study is not ideally suited to the identification of these major hazards while HAZID is. Other approaches have been used to address problems such as checklists and peer review but these rely on the knowledge "at the table".

HAZID has been developed over the last few years to identify the interaction between systems and thereby to identify those breaches of the "***defence in depth***" which may lead to major hazards. It has proven particularly effective in analysing the interfaces between systems, layout or juxtaposition of equipment and the roles or interfaces between disciplines and functions. In particular it is consequence driven and pre-supposes a set of scenarios and then tries to identify those defences which have to fail for the event to occur (and of course how the failure may occur). (See the LOPA Onion in part A). The whole process is summarised in the following description.

HAZOP examines the internal process to identify the potential operational hazards and problems which may occur with return periods of, typically, 10 to 100 years, but it does not tend to identify those major hazards which typically have return periods of over 1000 years, that is the role of HAZID.

The HAZID approach has been contrasted with HAZOP and it has been argued that it is more effective as it considers both external as well as very unusual internal events.

HAZOP is still the recommended identification process for P & IDs.

The significant benefits of HAZID over other Hazard Identification techniques such as checklists and peer review lies in its more rigorous and wide ranging approach. Techniques which utilise a checklist and peer review approach rely heavily on the assumption that any type of hazard which might occur has already been thought of, and is incorporated in the checklist. Peer review depends on the direct knowledge that participants bring to the exercise. Whilst HAZID utilised guidewords their only function is as a starting point for further discussion to explore hazards which may or may not have been considered previously and to challenge the accepted practice. Through the guide words and by questioning, the Facilitator can ***elicit*** information. Eliciting ideas and information is the whole basis of the study process. **HAZID** seeks to broaden the hazard understanding of all participants by encouraging lateral thinking. In summary, **HAZID** has been developed to incorporate the best features of **HAZOP**, **checklists** and **peer review** thereby providing an approach that is superior to the other three techniques in isolation.

A further document titled "**Hazard Identification Methods**" has been published by IChemE.

Applications of HAZID

HAZID is a study designed to identify the mechanisms by which safety objectives may be violated, these may be hardware, such as mechanical failure, or software, such as Management System or Procedures. (In this respect it is a form of examination of the LOPA onion Parts A). For example, a safety objective could be the containment of fluids and a violation could be caused by impact, corrosion, fatigue or the like.

While HAZOP is cause driven, HAZID is consequence driven. Further, HAZOP will accept a conclusion that an event can not occur but HAZID assumes that if it is credible it will occur and requires the analyses of the sequence of events required to cause that event.

The following example of car brakes is an attempt to illustrate the differences between ***consequence*** and ***cause*** driven studies. It is very simplified and is a means to illustration only.

The analysis of the P & I Diagram of a car's braking system in a HAZOP could produce the following results:-

System: Hydraulic Piping

Safety Objective: To carry **pressurised** fluid to the brake cylinder

From this a somewhat simplified HAZOP worksheet (and it is recognised that it is simplified) might look as follows:

Parameter	Deviation	Cause	Effect	Recommendation
Pressure	**None**	**Corrosion**	**Loss of braking potential, car crash**	**Install a separate braking system**

Table B 5.1 The "Possible" worksheet from HAZOP on the Car Brakes

This shows that having identified a deficiency via HAZOP the usual response is to recommend installation of further hardware in the form of a redundant braking system.

The analysis of the same system using HAZID which uses a ***guideword*** approach (see later) could produce the following results:-

System: Car Braking System

Safety Objective: To arrest the car in controlled manner.

Guide Word	Event Nature	Cause	Consequence /Escalation	Control of Mitigating Factors	Hazard Index Cons.	Hazard Index Freq.	Action Required/ Comments
Failure of the Brakes	**Leaking master cylinder**	**Seal failure**	**Loss of brakes - car crash & injury**	**Likely to be progressive if corrosion**	**H**	**L**	**Review the reliability of the seal**
Failure (Brakes)	**Leaking hydraulic line**	**Corrosion or impact**	**Loss of brakes - car crash and injury**	**Could use hand brake**	**H**	**M - H**	**Consider fitting a segregated braking system**

Table B 5.2 The "Possible" Worksheet from a HAZID Study on the Car Brakes

The logical end point of this analysis shows that the solution is not always the addition of hardware and in this example it is the desirability of a diagonal braking system as fitted on most, if not all, modern cars.

HAZID Methodology

Reprise

HAZOP study is different from HAZID study, as already noted, in that the former is ***cause*** driven and the latter ***consequence*** driven. The former looks at the internal process and the latter the external process. It follows that the HAZID study requires a considerable degree of preparation.

Definition of Objectives or the *Guidewords*

The first step of the study is to define the ***safety objectives*** and ***safety/hazard issues*** for each section of the installation. This may in part be already prepared as a project document but the older the installation the less likely it is that these will be available. To define the objectives accurately, it is usually necessary to have a pre-meeting between the Facilitator and the client representative, who should have a very good all round understanding of the installation.

For piping the safety objective would be "*no leakage of process lines*", that is no loss of containment. This violation in piping may be due to, amongst others: -

- Corrosion
- Erosion
- Mechanical Impact
- Fatigue
- Overstress/load

This list is only illustrative and typically would run to two pages to define all of the causes of the deviations from the safety objectives for a process plant. The effort put into the definition of ***guidewords*** is considerable but is usually amply rewarded during the study. The length of the initial meeting is initially in the order of 3 to 6 hours total but can be considerably less for a "look alike" installation. The lists of guide words can then be refined and translated under the headings, such as and including:-

- Reactor Design
- Production/loss of containment
- Protective Systems
- Communications

These should only be treated as indicative and would, of course, vary from installation to installation.

During the analysis of the objectives and the derivation of the guidewords it is likely that the tabulation will in the initial stages appear a bit “haphazard” – such is the nature of lateral thought but they can be gathered together under suitable headings. The following is a VERY simple attempt to put this idea into more focus.

Start with the structural failure leading to its collapse. The initial ideas could be:

Causes of structural Collapse
Overload
Degradation
Civil (soil)failure

Table B 5.3 Some of the possible Causes of Structural Collapse

It is now possible to look more closely at each of the causes and to add more definition or "colour".

Take overload for a start. What could be the causes?

Causes of Overload of Structure
New equipment added
Poor Specification in Design
Snow or Ice
Earthquake
Dropped Object
Etc

Table B 5.4 Some of the Contributions to Overload of Structure

The final set of guide words might look as follows:

Overload

New equipment added:

New reflux drum

New piping system

Etc

Poor specification

Does it cater for icing conditions?

What is the basis of the design?

Is there any conflict?

Now?

Future?

<u>Degradation</u>

<u>Corrosion</u>

Acids

Process fluids

Rain water

<u>Snow and Ice</u>

See above – what is the basis for design and can it change with time?

<u>Civils (soil)</u>

Are there any known/unknown under soil workings?

What recent soil surveys have been carried out?

Have there been historical soil surveys?

Is there any record or evidence of mining?

<u>Earthquake</u>

What is the seismic history of the area?

Should a limit of say 0.25g be set?

<u>Dropped Object</u>

Maintenance

Construction

This is only illustrative but should show how much attention **MUST** be paid to the derivation of the ***Guidewords***

Team Selection

Team members should be typically 3 to 6 plus **Facilitator** and **Scribe**. The construction of the team may change but essentially there should be a core of Facilitator, Scribe, Facilities/Operations Engineer and Safety Engineer. In the case of an older installation it would be very beneficial to have at least one senior operator who knows all of the "tricks of the process", how it operates and has to be operated. These would be supported by Structural, Construction, Electrical, Machinery, and Process Design all as appropriate. The team content will change from day to day but too frequent changes must be avoided as there is often a one to two hours learning curve for each member. The balance of the team, its experience and commitment are possibly the second most important feature after the definition of the guide words. If the team is unbalanced the study may not be objective and of course there may be no self catalysis or creative thinking.

Drawings and Documents

The main drawings used in a HAZID study are Plot Plans (including maintenance routes), Escape Route Drawings, Process Flow Diagrams and those drawings depicting the location of emergency systems such as Emergency Shutdown Valves, Relief/Blow down Valves, Deluge Valves and Fire Extinguishers and the like. During the study process the layout diagrams will be used to define the interactions and as a result they must be sufficiently detailed that they show all equipment with significant inventory and be sufficiently “uncluttered” such that process data such as follows can be added to drawing:-

- Pressure
- Temperature
- Flow
- Capacity
- Composition

Once again, the data and drawings should be sufficient to allow all possible interactions to be explored.

Execution of a HAZID Study

The study is potentially more mentally tiring than a HAZOP study due to the need for intense lateral thought. A study period of 3 hours is typical and it is often more difficult than for a HAZOP study to restart a study after a break. Two sessions a day (6 hours) is the suggested limit but external pressures may require greater effort.

The study starts with a brief overview of the installation and then a detailed description of the equipment and its layout. The layout (plant) drawings are used and marked with key equipment data. The object is to show the potential for interaction. This part of the study will take typically one hour and is a "settling in period" when an enhanced understanding of the installation is generated.

The Facilitator uses the **guidewords** to formulate scenarios where the design intent may be violated and therefore centres on the lateral thought processes. The objective is to define **how** an event could happen and what would then be the consequence; the "causes" could be hardware or software failure. The investigation of **how** it can occur will not allow a statement such as "it can **not** occur!" Usually, during this period of time, three thought processes are occurring:-

1. The potential for interaction is being fully appreciated.

2. The lateral thinking process is being developed.

3. The objectives and HAZID study techniques are being fully understood.

The principle step of the HAZID technique is represented in the flowchart shown below as "***step 2***" of the study.

The process flows through the use of ***guidewords*** and the Facilitator constructs scenarios for the team to explore. These naturally lead on to other scenarios and the Facilitator has then only to direct the team away from trivia. As each potential guideword is exhausted the Facilitator moves on to a new guide work. While HAZOP examines a line at a time, HAZID examines a unit operation or part of the process at a time.

The final part of the study is to itemise the mitigations or controls in place. All recording is done on a proforma record sheet, whose headings are typically as shown below.

Ref No	Guide Word	Event Nature	Cause	Consequence/ Escalation	Control of Mitigating Factors	Hazard Index* Consequence & Frequency	Action Required On and any Comments

Table B 5.5 Typical HAZID Worksheet

<u>Note: that the Hazard Index will be filled in after the study is complete.</u>

Follow-up

After the sessions it will be necessary to quantify the various events as to their ***Magnitude*** (consequence) and ***Frequency***. This can take about 10 minutes to half an hour per event (about 20 minutes on average). The final Magnitude and Frequency values must then be ranked against pre-determined criteria and prioritised. Inevitably the assessment does require some simplification and usually falls on the Facilitator and/or Scribe. However, the assessment is usually fairly easy as the AND/OR logic required in Fault and Event outcome trees (see part E) for that event will have already been discussed during the study.

Typically <u>about</u> half an hour will be expended on quantification for every hour of study time.

The final list of events or hazards can then become the core of the safety case and a set of **integrated and objective** safety studies set in motion. The definition of the safety studies may require a further analysis.

The Scribe may be independent or a company employee. Additional specialist staff may be drafted in as the topic under consideration dictates.

<u>Flow Sheet for HAZID</u>

The flow sheet for the whole process is given below.

Step 1 - Prior to Study

(a) Analyse the whole system.

(b) Identify blocks in this system whose function can be clearly defined.

(c) Identify safety objects within the block.

(d) Draw up ***guidewords*** which can be used to describe how the safety objectives may be violated and therefore identify consequence scenarios.

(e) Identify a team of 3 or 4 members (plus Facilitator and Scribe) who can assist in developing the scenarios.

Step 2 - During the Study

(1) Define a block in the system

(2) Identify all of the major elements in the systems.

(3) Note the function, contents and nature of the fluids of the elements in the system.

(4) Note the objective of that piece of equipment if non process

(5) Describe how the elements interact.

1. Use the guideword to construct a series of meaningful violations of the safety objectives. Examples may be structural collapse or impact or corrosion under insulation (CUI).

2. Use the guide word to define what elements may be damaged or which **must** function to achieve the overall safety objective. Examples might be the mechanism which might cause the safety systems to fail to operate.

(6) Discuss the violation and describe a meaningful scenario.

(7) Identify the mechanisms required to create the scenario.

(8) Record the guideword.

(9) Record the cause.

(10) Record the nature of the event.

(11) Record the consequences/escalation.

(12) Record controls or mitigations.

(13) Record any proposals/observation.

(14) Select a new guideword.

(15) Repeat 5.1 to 13.

(16) When all guide words are exhausted chose a new system.

(17) Carry out steps 5 to 13 analyse the interaction across the interface between two adjacent systems.

Assessment - Post Study Meeting

The Facilitator will normally spend about ½ hour assessing the magnitude and frequency of each event identified. This process is much easier than might seem as the logic of the fault tree will be fully understood from the discussion during the study itself the biggest problem will usually be collecting data appropriate to the problem. Once the assessment has been made it is possible to produce recommendations, one of which is to accept the situation of the risk as "trivial".

As HAZID is examining remote events the study cannot accept that it is not possible until it has been fully assessed (and eliminated) by Quantitative Risk Assessment (QRA). See Part E

Variation 1 Operating Procedure

It is possible to examine an operating procedure as a variation of method study by using guidewords such as:-

1. Why then?

2. Why that way?

3. Why that order?

4. What is the end objective?

5. Verification of operation?

6. Only partial operation?

7. Monitoring/supervision

8. Assurance of objective?

9. Accuracy of result?

10. What happens if ....?

A procedure can equally be studied by a HAZOP in line with the “batch process”.

Application of HAZID – An Example

The starting point to the study is to examine all of the possible safety objectives/issues which must be addressed. For example the objectives/issues would start at a high level such as “The Environment” or “The Safety of the Operator” or “The Integrity of the Plant”. Below each “top objective issue/issue” would be another series of more focused objective/issues. “The Integrity of the Plant” could be impaired by “Loss of Containment” (LOC) “or poor protection”. Below the “Loss of Containment” could be a set of causes such as “impact”, “corrosion”, “fatigue” or the like. Below each set of causes there could be another subset. For example “impact” could be due to a dropped object or a swinging load on a crane or a maintenance trolley being pushed without due regard for the work place. The top-level therefore generate a form of “pyramid” with more focused “objective/issues” at a lower level which have to be considered or addressed. The “objective/issues” result in a “set” of guidewords which are specific to that particular problem.

The “pyramid” is illustrated by examining the digging of a hole in a road. The top objective/issues” are **traffic management, access to business or homes, emergency services access, service integrity** and **the safety or security of the operator.** Lesser issues may involve noise and the general disturbance of the public.

Starting with the integrity of the services. It is obvious that there may be some services underground and that the digging may disturb or damage them. Some may be more critical than others for example digging into a power cable could cause the death of the operator but digging into a gas main could cause a fire or an explosion which could kill some “by-stander”. The “pyramid” leading to the Guidewords now can be developed.

Guidewords

Service Damage

Location
` Nature – Electricity, Gas, Water, Sewers, Telephone
Impact following damage on: -
Operator
By-stander
Local industry or housing
Emergency Isolation? Location? Access? Ease of operation?
Should any Service be isolated before work starts? – Public notification? Warning and “back ups”?
Is there an implication for access so far as the emergency services are concerned?

The Operator

Collapse of the Excavation
Does it need shoring up?
Does the excavation require to be pumped out?
Where will the “spoil” be located so as to stop it falling back into the excavation?
Rescue of the operator – How? – Standby? – Emergency Procedures?
Risks from services (see above) – electricity, gas, water, sewers, telephone, others?
Other risks
Fumes – exhaust, other (sewers)
Disease - rats, Wiel’s Disease, other (sewers)
Noise – traffic, digger, drill
Vibration white finger – drill
Eye damage – wind borne, chippings

B 5.6 HAZID Checklist for digging the hole

The check list can be developed further as required but is should be noted that each step becomes more focused until there is a clear point which must be addressed. It will be noted that the check list or “guide works” are generally **“consequence or effect driven”** and are totally different in form to the parameters and deviations of a Hazop which are generally **“cause driven”.**

Illustration: This is a short piece of dialogue to illustrate this example.

F = Facilitator

S = Scribe

D = Designer

E = Installation Engineer

ES = Emergency Services

You will note that the Team is completely different from that of the HAZOP example!

F "Can I have a brief description of what is to be done? I will assume that there is a good reason for this and other options have been investigated".

D "Yes, we have investigated other options and this is the only one available to use".

I "We have to dig a hole in the middle of Lime Street to repair a water pipe".

F "I assume that you have looked at fitting a plastic internal sheath?"

D "Yes, the pipe is in such a state that replacement will be necessary within 2 years whatever is done now".

F to S "I think that this is worth recording".

S "Done"

F "Now, what are the problems with this task and how will you handle them?"

E "We have studied the records in the Council Offices and have identified that there are a number of services underground. Unfortunately the records are old and are not 100% accurate".

ES "You do realise that this is a busy road and is one of the priority routes for the Emergency Services?"

E "Yes, we must develop a strategic plan that addresses this and we will include ALL Services including Police, Fire Brigade and Ambulance".

S "This is recorded".

Etc

Variation 2 Application of HAZID to Existing Plant

The preceding has covered the background to HAZID and the broad methodology for its implementation. It is now necessary to consider particular aspects of its application to existing (as opposed to new) installations.

Background

As has been discussed, the application of HAZID is directed towards identification and preliminary assessment of hazard. This is done by eliciting the knowledge of key personnel in a structured manner. For a new installation this knowledge essentially lies within the design team. For existing plant the base knowledge is held by the operations team. In fact the operations team will hold a large database of knowledge in that they will have first hand knowledge of how the plant performs and fails to perform.

The design team however are likely to be "success oriented" and will logically have concentrated on how the plant is operated to meet its design targets rather than how it might fail to do so.

The operations team will, hopefully, not have had any experience of the major catastrophes that HAZID seeks to identify and even if they do, they cannot possibly have the experience of **all** the major accident scenarios that might conceivably occur, or have occurred elsewhere. What they will have, however, is direct experience of the day to day upset conditions that can occur. They will be aware of the plant's weak points such as a section of the process that is prone to corrosion, a temperamental shut down system or an unreliable pump. These points of reference act as indicators of the existence of potential major accident precursors (*holes in the cheese or layers of the onion*). It is widely appreciated that most major accidents occur as a result of a chain of occurrences, rather than as a result of a single event, thus knowledge of plant weak points may give a strong indication of potential routes to a major catastrophe.

The HAZID of operational plant should not only concentrate on initiating events that have already occurred, the exercise must be wider ranging in order to allow for as yet unseen problems. This, however, requires a degree of discipline in conducting the sessions as operations personnel may tend to dismiss initiating events if there has been no evidence, to date, that they can occur.

Guidewords

These will then be more "process directed" and will include ideas such as:-

- More Flow
- More Pressure
- High/Low Level
- More/Less Reaction
- What equipment causes outage?
- What equipment is hard to access?
- Are there issues of isolation?
- Are there issues of reliability?
- Have you ever had unexpected events that have not been resolved?
- What equipment gives you cause for concern?
- Can you define your concerns?

Example of HAZID:

This is a brief study on the HAZID of a design of a rally car.

1. Safety Objectives

It is not difficult to define the safety objectives as follows:

1) Road Holding

2) Visibility

3) Protection of the Driver

4) Ease of escape.

Note speed is not a safety objective.

Now take each objective in turn and define how it can be violated - this is shown in part in the next table.

Once again it should be noted that the HAZID process is practical and best learnt by "doing it". It is also a very useful tool for stage 1 of the Safety Study/Audit process and exceedingly useful for analysing the potential problems during the construction phase.

Ref No	Guide Word	Event Nature	Cause	Consequence	Control or Mitigating Factors	Consequences F / M	Action Required Comments
1	Visibility Mud	Loss of visibility due to dirt on the windscreen	Mud spray leaves on the windshield	1. Unable to see the road 2. Vehicle slows down (or crashes) 3. Lost time	1. Windscreen wipers 2. Windscreen washers	H H	1. Ensure washer pump has adequate capacity 2. Top up reservoir at end of each stage 3. Fill reservoir with antifreeze (methanol) 4. Ensure wiper motor is over-sized 5. Renew wiper blades at the end of each stage
2	Visibility Mist	Loss of visibility due to mist	Weather changes	1. Unable to see the road 2. Lost time	Weather forecasts	H M	1. Supply radios in the car 2. Locate weather lookouts around the stage with radios
3	Adhesion Mud	Car hits mud and/or water splash	Poor road surface	Car crashes		M H	Supply special profile tyres
4	Adhesion Ice	Car loses adhesion on ice	Ice on the road	Car crashes	Special tyres (see 3 above)	M H	See 3 above
5	Escape	Doors jam shut in a crash. Driver injured	Impact on the side of the car	Driver/navigator trapped in the car	4 point harness	L H	1. Supply crash cage 2. Supply quick release doors 3. Remove doors!
6	Escape Fire	Car crashed and bursts into flames.	Major crash	Driver killed after crash	4 point harness	L H	1. Driver to be clothed in 'Nomex' 2. Supply emergency air 3. Supply emergency automatic fire extinguisher 4. Install fuel cut-out 5. Remove fuel tank

							6. Fill tank with expanded foam matrix to limit fuel spill

Table B 5.6 Possible HAZID Worksheet for a Rally Car

Now that the hazards have been identified it is necessary to eliminate them, manage them, design them out as far as possible or fit protection and finally to demonstrate that the risks are ALARP!

B 6 Relief and Blow down Studies

Relief and Blow down Review has been put into design and operability for safety – Part B as it fits better there so there is no apology for the apparent dislocation. This to be one of the identification tools which you should know about – see Part D 6 later on in this text.

B 7 Fire Protection and Detection

This is covered under Fires – Part E

B 8 Hazards in Operation

How do you identify the Hazards Associated with Routine Maintenance and Operations?

Operations are a topic beyond that of a first degree course. However it is appropriate to note that many of the Management Systems described in Parts C & F apply to Operations.

The Incident Studies Part H show where problems were not handled properly and incidents occurred

The identification of hazards that has been applied will still apply to any changes (see Parts C and F Management of Change) but every form of Maintenance will require a special form of Hazard Identification sometimes given the name "***Task Analysis***" where each step of the maintenance work from isolation through to refitting is analysed carefully, the hazards identified and the need for special features (including Personal Protective Equipment) is specified. This becomes part of a Management System called "***Permit to Work***" (PtW) (See Part F for a worked example).