

## AN EXPERT USER'S TRIAL OF THE HAZID SYSTEM FOR COMPUTER-AIDED HAZOP EMULATION

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The Hazid computer system has been developed to help reduce the workload involved in Hazop studies of process plants. It uses qualitative propagation to examine the causes and effects of failures within a process, reporting these in a tabular format similar in structure to the traditional Hazop-style report. The system can be used to check on developing process designs, to prepare for a Hazop study, or to quickly analyse the impact of proposed plant modifications. Recent efforts have improved the interfaces of the program to intelligent CAD systems as well as to the end-user, allowing effective browsing and comparison of results. This paper reports on a trial which evaluated whether the software would provide real value to an experienced engineer. The engineer concerned selected a test plant and reviewed the results of Hazid's analysis of this plant. The results were evaluated, both in terms of their correctness and their usefulness in provoking thought and thereby leading to indirect identification of problems. The useability of the software tools and the results produced are also evaluated, and speculative conclusions are offered on how to integrate programs like this into the engineering workflow. In particular, the authors feel that this software may have a significant role to play in supporting the user in preparing a Layer of Protection Analysis (LOPA) for his/her plant design.

**KEYWORDS:** hazard identification, Hazop, case study, Hazid, knowledge-based system.

### INTRODUCTION

The Hazards and Operability (Hazop) study<sup>1-3</sup> is widely regarded as one of the most effective and systematic methods for the identification of process plant hazards at the detailed design stage of a new facility. As a result, it also has the advantage of a distinctive reporting style, suitable for documenting the formal hazard identification activity.

Nevertheless, the study method is time-consuming and expensive, and there has been a significant research effort for many years now, to develop computer-based techniques for reducing the workload of the Hazop study. Some of the software developed in this area has tackled the significant "secretarial", or "information processing" duties surrounding Hazop, producing tools to aid in the conduct and documentation of Hazop studies. In contrast, previous work at Loughborough<sup>4-8</sup> and elsewhere<sup>9-12</sup> has

concentrated on software for performing the hazard identification task itself, using techniques from the Artificial Intelligence toolbox.

One result of this research effort has been the “Hazid” software package developed at Loughborough University, which is now technically mature enough to be commercialized within the process industry. This paper examines a trial of the software, to determine if it produces significant user benefit, from the point of view of an experienced process safety engineer.

### THE COSTS AND BENEFITS OF HAZOP

The development of a P&ID is a relatively slow process with a number of reviews along the way. At each review more detail will be added until the P&ID reaches the level of “Approved for Construction” (AFC). Intermediate stages will include “Issued for Comment” and “Approved for Design” (AFD). The preliminary stage to AFC should be “Approved for Hazop”, when the design is frozen.

The plant drawings can be reviewed 4 and possibly more times during their development. Each review is time and resource consuming — none more so than the Hazop. There are no golden rules for a Hazop, but it is usually assumed that each major piece of hardware will consume about 3 hours of Hazop study time. The number of attendees at a study meeting can be about 6 and the unit cost is about £40 per person per hour (when overheads are rolled into the costing) and possibly more for the leader. The study time is then boosted by the reviews during the writing of the report and the resolution of the issues raised during the study itself. As a measure of the resources required, an offshore oil platform took 70 full days for the Hazop of the process and utilities, 30 days for the drilling, and an undisclosed time for the write-up and the resolution of the issues or questions raised. As team members are taken out of their day-to-day duties the full day must be charged against the study resulting in a total cost of perhaps £250,000 or more for a major project. For a minor change to an existing process the cost will clearly be less, but it is still likely to be a considerable amount.

Despite this expense, the P&ID reviews (including Hazop) may not be highly significant in the budget and the costs should be returned in fewer operating problems and smoother commissioning/start-up. Often more important is the fact that the Hazop is a potential “hold-up” in the process design; for obvious reasons the P&IDs must be frozen until the study is complete, and this can be inconvenient, so the timing and speed of review are of the essence. From this it is clear that a “pre-Hazop” filter is essential. This is where Hazid fits in.

### MOTIVATION FOR THE TRIAL

Current development work on Hazid is concentrating on improving the interfaces to the program, through new tools which allow a user to browse the results of a Hazop analysis interactively, which make the Hazop analysis of a CAD-drawn P&ID more streamlined

and which facilitate the capture of expert knowledge about equipment failure modes in equipment models.

In addition to the more straightforward issues of facilitating these basic input/output operations, the nature of the domain in which Hazid operates makes it highly desirable to test the system and its methods on a realistic end-user.

The intended end-user of Hazid will be an experienced or perhaps a junior engineer, without any knowledge of the internal representations used by Hazid for its knowledge/rules. What is more, such a user will be operating within an organisation which has an “engineering” ethos, rather than a more theory-driven environment. What matters is that the software works, and gives results that provide maximum value for minimum effort on the part of the end-user.

This paper describes a trial that was done to determine the reaction of one of us (Frank Crawley, an engineer with many years practical experience in process safety) to the results produced by Hazid, and to the experience of working with such a tool. Such trials give valuable feedback to the development team, to direct future developments in the direction of the real perceived needs of the users.

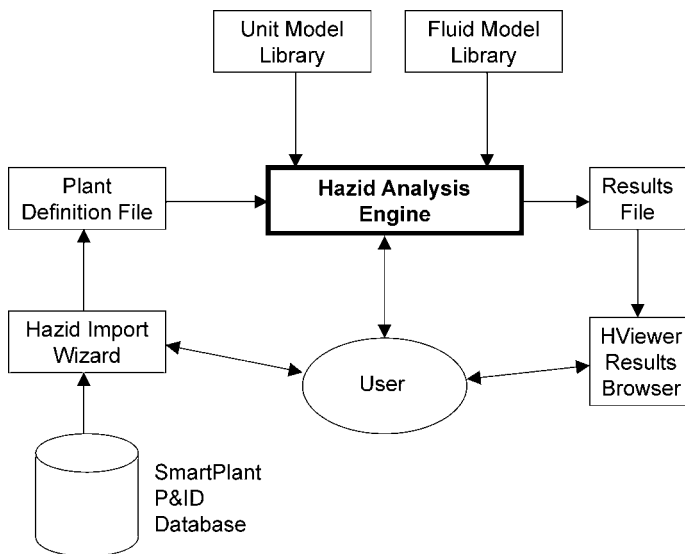
Some of the points raised will be specific to Hazid and this trial, but many lessons can be learnt for future use wherever a knowledge-based system of this nature is being considered, and there are concerns about the useability or appropriateness of the tool for a particular engineering user type.

## **THE HAZID SYSTEM**

Hazid is a loosely-coupled suite of software applications designed around an intelligent knowledge-based system (the “Hazid Analysis Engine”) which provides the ability to emulate Hazop study analyses of process plant designs. The various components of the Hazid system are shown schematically in Figure 1, which emphasises the flow of data in the system and the interaction of the user with the various components.

Hazid is closely integrated with SmartPlant P&ID, an intelligent CAD application marketed by Intergraph, so that the main source of data input to Hazid is via the CAD database of the user’s SmartPlant installation. The user interacts with a tool called the “Hazid Import Wizard”, to control the conversion of data from plant drawings stored in the database to plant definitions in the format required by the Hazid Engine. The Hazop-style analysis of the plant drawing is performed by the Engine, using the Plant Definition File produced by the Wizard and a number of equipment models provided by the “Unit Model Library”. Information on the fluids present in the plant, their flow rates, temperatures and pressures, can also be used in the analysis — the “Fluid Model Library” provides access to physical properties and safety-related data for process materials. The models used in Hazid will be described briefly in the next section.

The user controls the configuration of the analysis, in terms of specifying what should be examined and how the results should be reported. However, the Engine performs its full analysis for the session non-interactively, producing a report file for the Hazid



**Figure 1.** System architecture of the Hazid tool

analysis results. This mode of operation permits the Engine to do a complete and systematic analysis of the plant, without any danger of interruption by the user.

Clearly the user needs to see the results of the analysis at some point, and this is the purpose of the “HViewer Results Browser” tool. When analysis is complete, the Analysis Engine passes control over to HViewer so that the user can look through the report of potential hazards produced by the search. Since the Hazid Results File is produced in a structured XML format, HViewer is able to provide a wide variety of possible views on the report, allowing the user to focus on issues of particular interest, and to investigate the reasoning used by the Engine in predicting each of the hazardous scenarios in the report.

More detailed explanations of the workings of Hazid are given in a number of previous publications.<sup>4–8</sup> The present outline is intended to give enough of an overview to understand what the tool does and how it fits into the user’s engineering workflow.

## MODELS

Although it does qualify as a knowledge-based system (KBS), Hazid is not a traditional rule-based expert system. Instead it operates more as a qualitative simulation tool, in which the events in the process under examination are simulated in order to identify any potential hazards. To support this activity, Hazid makes use of a number of “Unit

Models”, which capture its knowledge about the behaviour of particular types of process equipment.

In the Unit Model Library, Hazid maintains a model for each significant equipment item type, organised around a hierarchy of model types.<sup>5</sup> Each one of these models contains links between process variables within the equipment item, indicating either a direct or a reverse-acting influence of one variable on the other. In addition to these “fault propagation” links, the unit model also includes knowledge about the inherent failure modes of the equipment, and about the potential hazards which can be associated with it. The former are represented as links from an initial “Fault” to a process variable deviation, indicating that if the fault occurs, the given deviation may occur. The latter are represented as links between process variable deviations and final “Consequences”, indicating that if the given deviation occurs, the associated consequence may then result.

When the unit models corresponding to the equipment items in a process are connected to one another, a network is constructed, linking the process variables, faults and consequences together for the whole process. A search algorithm can then be used to trace the possible influences between faults and consequences in the process. In this picture, the faults can be thought of as generating deviations in process variables, which then propagate elsewhere in the plant and cause eventual hazards in other equipment items.

In addition to the definition of Unit Models for equipment items in the process, Hazid also provides for specification of the process materials (fluids) in the plant, and their effect on the hazards which are feasible for that plant. At each point in the process, the identity of the fluid, its flow rate, temperature and pressure may be specified. Given this information, Hazid can use physical properties information stored in the “Fluid Model Library” to determine if certain hazards or initial causes are valid. For example, if a leak occurs from the process, but the fluid concerned is not flammable or toxic, some of the potential hazards, which would otherwise be reported, can be suppressed.

As with any KBS, the power of the Hazid tool lies in the knowledge base that it uses. This translates into the range of equipment modelled in the library, the quality of the propagation link structures in those models, and the quantity of equipment-specific knowledge about failure modes and hazards. To date, the range of equipment covered by the Hazid equipment library is fairly limited, but the models that have been built have a reliable propagation model. Beyond this, expanding the range of knowledge in the unit model library is the task of the users (the process engineering “domain experts”), perhaps in collaboration with the software developers.

## **THE TRIAL METHOD**

The approach used was first to choose an example of a simplified process, with an existing Piping and Instrumentation Diagram, as might be produced for a process modification. The P&ID was redrawn using Intergraph SmartPlant P&ID<sup>®</sup>, which in turn interfaces with

Hazid. The process was then analysed by Hazid, and the results were reviewed by the engineering expert, in order to evaluate the performance of Hazid.

The expert review of Hazid's output can be used to identify weaknesses in the analysis, fix "bugs" with the Hazid models, or to suggest larger-scale improvements in terms of useability enhancements, etc. After some of these problems have been tackled, the analysis and review cycle can be repeated again, to demonstrate improvements and to identify further weaknesses.

The speed with which results can be produced after small changes to the process plant model, the equipment models or the analysis engine itself, make Hazid a very powerful tool for exploratory process design.

## PLANT CHOSEN

The "model" used in the analysis was one devised for the illustration of the Hazop procedure in undergraduate and postgraduate training courses. The Process and Instrument Diagram was constructed to contain a number of real hazards, with the potential to produce events which had occurred in the offshore process industry. As a result the design contained a number of deliberate errors such that Hazid, as with any Hazop practitioner, would produce a suitable return for the efforts.

The model, designed to produce a flow of fuel gas which would supplement the existing fuel gas system (see Figure 2), is that of flow of a light gas rich hydrocarbon stream from the compression system which is heated and fed into a flash separator. The full vapour-liquid equilibrium has not been carried out, so the flows are assessed by operational judgement. The instrumentation and any protective systems were kept to the absolute minimum as a means to achieving a good reward for efforts in training courses, recognising that in a Hazop course a slow rate of problem identification may result in a loss of team motivation.

The "intent" of the process is as follows: 10 m<sup>3</sup>/hr of mixed hydrocarbons (methane to pentane), with a density of 850 kg/m<sup>3</sup> at 30°C and 1.6 MPa are pumped from a three-phase separator (off the P&ID) by the pump P101/2 to 2 MPa, and controlled by FC101. The fluids flow through the interchanger H101 where they are heated to 60°C. The fluids are further heated to 90°C in heat exchanger H102 against a hot water stream. The resulting mixed phase fluids are separated in the two-phase separator T101, and the liquids are rejected under level control by LC101. The hot liquids, at a rate of 8.0 tonne/hr, pass through the interchanger H101 and a cooler (off the P&ID), and enter the oil product route. The gases proceed to cooler H103, where traces of water and heavier hydrocarbons are condensed. Gas, at a rate of 0.5 tonne/hr, leaves the three-phase separator T102 under pressure control (PC101) and enters the fuel gas system. Heavier hydrocarbons (traces) are separated from water in T102, the hydrocarbons are recycled to a lower pressure system through LC103 and the water is rejected to T103 where it is heated by an electrical element, before being rejected to drain. Any dissolved gas, released from the water, is rejected to atmosphere via a flame arrestor. A Hazop has been carried out on this P&ID

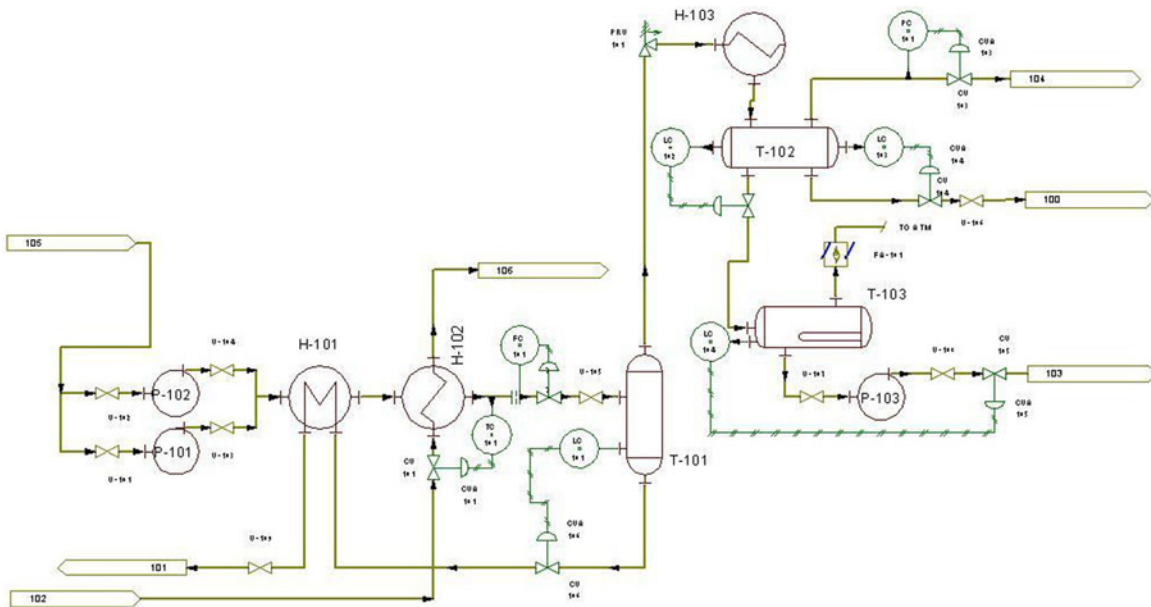


Figure 2. Schematic of test plant

up to T101. At least 35 errors were found, and there are at least 10 more known faults built into the P&ID.

It is fair to note that the quality of this P&ID is poor and that a properly designed P&ID would be to a far higher standard. However this would defeat the objective of the example for training purposes.

## **RESULTS**

### **PERFORMANCE**

Hazid took less than 35 seconds to perform its analysis and produce the report file. The results contained approximately 150 groupings of faults with consequences, reported alongside the process deviation which gave rise to the indicated consequence. The size of the output XML file was approximately 1.30 MB, but this is of little interest, as the only means of looking at the results was through the HViewer application. The quantity of output can more readily be appreciated by noting that the Hazop results table in HViewer filled about 24 screens with a similar density of information to that shown in Figure 3.

Of far more significance than the program run-time is the time spent on preparation of the drawing for analysis, and on reading through the results. In executing a Hazid analysis on this plant, the preparation of the drawing and transfer of data to Hazid took much more time than the actual analysis of the process. The redrawing of the P&ID shown in Figure 2, together with adding the information about fluid operating conditions, took around 3 hours. This was time spent by a single engineer and could be reduced in future with more training and experience of the CAD tools and the drawing preparation method. It is fair to say that redrafting the P&ID would not usually be necessary in a more realistic user context, so this would remove at least half the preparation time just quoted.

The drawing analysed is not a fully detailed P&ID, but does contain a typical number of major items and control loops for a P&ID. As drawn, the plant contains 9 major items (pumps, vessels and heat exchangers), 7 control valves and associated loops, and 9 other valves. In a conventional Hazop study, it would require the team to examine about 8 process “nodes” or lines — which is about typical.

### **SAMPLES**

An example of the output format produced by Hazid is shown in Figure 3. This output is designed to emulate the traditional format used for reporting the results of Hazop study meetings. Some of the columns usually present in such reports are missing, but the overall structure is quite familiar.

Each of the deviations considered by the analysis is given in the leftmost 3 columns of the results table, identifying the equipment tag name, the “port name” identifying where in the equipment item the deviation occurs, and the process deviation guideword composed of the process variable and one of the usual guide words (more, less, no, reverse,



**HAZOP Results Table:**

| Tag Name | Port               | Deviation | Cause  | Consequence [Type, Rank]  | Information | Control | Protections     |
|----------|--------------------|-----------|--|---|-------------|---------|-----------------|
| T101     | interface          | moreLevel | FCV101, valve unintentionally opened more<br>LCV101, valve unintentionally closed completely<br>101, morePressure from sheet connector and less flow<br>LCV101, valve unintentionally closed partially | T101, foaming [none, 0]   |             |         | PRV101          |
|          |                    |           | 101, reverseFlow from sheet connector<br>V109, valve unintentionally closed completely<br>101, noFlow from sheet connector   | T101, foaming [none, 0]   |             |         |                 |
|          |                    |           | OP101, orifice plate removed   | OP101, consider replacement with narrow piping [none, 1]<br>T101, foaming [none, 0] |             |         | PRV101          |
|          |                    |           | 104, 100, lessPressure from sheet connector and more flow<br>LCV103, LCV102, PCV101, valve unintentionally opened more   | T101, foaming [none, 0]   |             |         | FA101<br>PRV101 |
| H102     | S1_at_fst174P_151  | noFlow    | V104, valve unintentionally closed completely  | H102, fouling [op, 2]   |             | TCV101  |                 |
|          |                    |           | FCV101, valve unintentionally closed completely  | H102, fouling [op, 2]   |             |         | PRV101          |
|          |                    |           | V105, valve unintentionally closed completely  | H102, fouling [op, 2]   |             |         |                 |
| H102     | T1_at_fst168WH_163 | moreSolid | 102, moreSolid from sheet connector  | H102, fouling [op, 2]   |             |         |                 |
| H102     | T1_at_fst168WH_163 | lessTemp  | 102, lessTemperature from sheet connector  | H102, unintended condensing [haz_op, 3]   |             |         |                 |
| H102     | coldSide           | moreTemp  | P102, loss of drive  | H102, unintended boiling  |             |         |                 |

**Figure 3.** Typical screenshot of results file view in HViewer

etc.). The “Cause” column gives the potential faults that could give rise to the deviation and the “Consequence” column shows the hazards that could result from the deviation. The 3 columns at the right of the table identify instruments which could serve to prevent or ameliorate the given scenario.

Figure 4 shows an alternative form of display, which is used to browse the report in a more focussed way. Suppose the user wishes to view the possible causes of fouling in heat exchanger H102, perhaps to check whether he/she agrees with Hazid’s reasoning.

flash21042004e.xml - HViewer

File Edit View Options Help

### Filtered Paths

the query: - select all fault paths given that *Consequence = H102, fouling*

| Cause   | Deviation   | Consequence [Type, Rank] |
|---|---|--------------------------|
| V104, valve unintentionally closed completely   | V104 (in_at_fst173P_119), noFlow<br>V104 (out_at_fst173P_135), noFlow<br>fst173P_135 (in_at_V104), noFlow<br>fst173P_135 (out_at_fst173P_134), noFlow<br>fst173P_134 (in_at_fst173P_135), noFlow<br>fst173P_134 (out_at_fst173P_136), noFlow<br>fst173P_136 (in_at_fst173P_134), noFlow<br>fst173P_136 (out_at_H101), noFlow<br>H101 (S1_94_at_fst173P_136), noFlow<br>H101 (S2_93_at_fst174P_151), noFlow<br>fst174P_151 (in_at_H101), noFlow<br>fst174P_151 (out_at_H102), noFlow<br>H102 (S1_at_fst174P_151), noFlow   | H102, fouling [op, 2]    |
| FCV101, valve unintentionally closed completely | FCV101 (in_at_fst176P_157), noFlow<br>fst176P_157 (out_at_FCV101), noFlow<br>fst176P_157 (in_at_OP101), noFlow<br>OP101 (out_at_fst176P_157), noFlow<br>OP101 (in_at_fst176P_166), noFlow<br>fst176P_166 (out_at_OP101), noFlow<br>fst176P_166 (in_at_fst176P_164), noFlow<br>fst176P_164 (out_at_fst176P_166), noFlow<br>fst176P_164 (in_at_fst176P_165), noFlow<br>fst176P_165 (out_at_fst176P_164), noFlow<br>fst176P_165 (in_at_H102), noFlow<br>H102 (S2_at_fst176P_165), noFlow<br>H102 (S1_at_fst174P_151), noFlow | H102, fouling [op, 2]    |
| V105, valve unintentionally closed completely   | V105 (in_at_fst176P_159), noFlow<br>fst176P_159 (out_at_V105), noFlow   |                          |

Figure 4. Filtered output from HViewer showing fault paths

By selecting the filter option, or by clicking on the text in the Cause or Consequence columns, the user can request a summary of all the fault propagation paths resulting in the consequence of interest. This is the view shown in Figure 4. It allows Hazid to give an explanation of its reasoning, and quite often can stimulate thought in the user, so that either the scenario will be accepted as genuinely possible, or some other hazard may be recognised due to the process of “working out” the logic of the fault path.

## EVALUATION

The following comments arose from a careful examination (by the safety engineer expert) of the results produced by Hazid, for the trial plant introduced above.

### Presentation of results

The main problem reported with the presentation of the results was the recording format, which was perceived not to be close enough to the standard format as recommended in the Hazop Guidelines.<sup>1-3</sup> This gave some difficulties in interpreting the results. It also might suggest, to the person analysing the output later, that the study had been carried out either by an inexperienced team or by a computer. The objective should be to produce an output which (as far as possible) appears to have been carried out by a “Human Team”. It is a minor point, but it is important to tailor the results to the “expectation”. This would require a minor reconfiguration of the analysis report produced by Hazid:

| Number | Parameter | Deviation | Cause | Effect | Protective Systems | Actions |
|--------|-----------|-----------|-------|--------|--------------------|---------|
|--------|-----------|-----------|-------|--------|--------------------|---------|

In the above, most of the columns correspond to output that Hazid produces already. Only the “Actions” column is not covered by Hazid and would have to be left blank. It is not desirable for Hazid to suggest actions in any case, as such decisions should be left in the hands of the engineers in charge of the project.

A further problem was that of the order of presentation of results. Traditional Hazop studies tend to examine a drawing by breaking it up into a number of lines, containing a number of equipment items, such as the line transferring fluid from boundary limits at the off-page connector “105” to the vessel “T101” in Figure 2. Then, each of the deviations of process variables are considered for one line before going on to examine others.

Hazid attempts to do something similar, but deviations are defined at every one of its equipment items, so that a lot more detail may be reported than with the usual Hazop study. Hazid identifies process lines, between plant boundaries and major equipment items, then examines the lines in sequence; within each line, the equipment forming the end of the line and its start are processed first, followed by the intermediate equipment items in order. This caused problems at first, seeming to show a random order — until

the engineer understood the logic being used. Nevertheless, the order of examination in the report was still difficult to follow.

Some solution to this problem should be found, as it impacts on the acceptability of the Hazid report. Communicating the logic used to order the report would be a first step, or providing different user options to control the order. However, it can be difficult to come up with a set of rules which can be implemented mechanically, and which produce “natural-looking” Hazop-style reports.

#### Content of results

In the first run of Hazid on this plant, a drawing error was quickly detected by Hazid — the piping connections around the process side of the condenser H103 were incorrectly made at first. This “silly” mistake was quickly corrected and the proper analysis of the plant went ahead as planned. This is an example where Hazid picked up something on the drawing which may not have been noticed until a Hazop meeting was convened — which would certainly be quite an inconvenience.

Once this problem was corrected, the results were better than first expected. The test case was deliberately set as a *bad design* with many errors inbuilt. It is likely that the many inbuilt errors in the P&ID were a further complication for Hazid, which it might not have to deal with normally. It handled the standard parameters of *flow*, *level* and *temperature* with ease but had more difficulty with *pressure*. It would indicate that *higher pressure* might come from a higher pressure in a down stream system. This was not logically correct but on the other hand Hazid was performing correctly as it might be a possible problem under specific conditions. One such could be a drains system. The process engineer is quite at liberty to reject these points in the follow-up analysis.

It should be noted that this type of problem is to be expected with Hazid, which only has a very simple model of the process and cannot easily judge whether the scenario it is considering is one in which the problem is feasible or not. In any Hazid analysis, there will always be a proportion of the results which are found to be inappropriate, after careful examination.

Hazid also did not seem to be programmed to recognise the leakage across potential leak paths as in a heat exchanger. This is a problem area which Hazid *had* been designed to detect, as an initial leakage fault that could give rise to pressure changes and contamination of the low pressure side of the exchanger. However, the particular rule governing this behaviour in Hazid was not working properly at the time of the trial.

#### Useability of Hazid

The most important thing to note under this section is that the “filtering” that would be applied by the team during a real Hazop study is not applied by Hazid. It is a reasonable assumption that an action recorded in a Hazop study has some basis and should be treated with some degree of seriousness. Whereas a Hazop team has a competence to accept that a point under discussion is not an issue, Hazid does not, and must record everything including trivia. Initially the expert found this a little tiresome, until it was recognised that some of the points *were* actually trivia.

Once a more critical mind-set is adopted in reviewing the results from Hazid, it is possible to filter the “real issues” from other “spurious issues”. At present the format of the results would be a little alien to the Hazop facilitator, as mentioned above under “Presentation of Results”. Ideally the results should be in the standard Hazop format such that the analyst does not recognise it as a “computer generated study”. It might be necessary for future users to have a short “familiarisation” course so that the correct mind-set can be encouraged.

The wording used in Hazid to raise issues was sometimes put into a form of short-hand, which made the analysis more difficult than it might have been. Choice of wording is always a problem, and could be readily corrected internally in the Hazid unit models, even by the user, using the “Model Builder” tool also provided with Hazid.

There is no doubt that the use of Hazid would be most effective at the earlier stages of P&ID development. It would be a most suitable tool for the “Preliminary Hazop”, and could well replace it. It is so relatively easy to run that Hazid could be run in parallel with the development of the P&ID and hence speed it up by flagging up possible problem areas — which might take more time for a “human review team”.

If Hazid were interfaced with “Layer of Protection Analysis” (LOPA), it would be a very potent monitor of the development of the “safety features”, and could be used to produce documentation to support a Safety Case. Hazid is not intended to supplant the full Hazop, but it should reduce the costs significantly and reduce the relatively trivial issues raised during the Hazop, which take time to resolve. Hazid would also be an ideal tool for the initial review of a modification. It could then be used to determine if a full Hazard Review was required through an analysis of the results.

#### Likely implications for users

It should be noted that working through the results from Hazid, to separate the important results from the trivial ones, required a concentrated effort on the part of the engineer, and was quite a significant job. This type of solo review was found to be more intense than Hazop-type work, which is team-based and affords more chances to “relax” one’s mind briefly during the course of the study meeting.

The question therefore arises, of whether it is better for one user to analyse the whole report alone, or whether it would be better for two engineers to tackle it together. It seems perhaps that given the browsing capabilities of the HViewer tool (which were not used by our expert in this study), and working in pairs, reviewing the results could be made a much more efficient and less intensive activity.

#### Other lessons learned/points raised

In using SmartPlant P&ID<sup>®</sup> to prepare a drawing for analysis by Hazid, it is imperative to make sure that as many of the icons on the drawing are properly tagged, so that the results which come out of Hazid are intelligible. This is good practice anyway, but is not compulsory in the CAD package. Without tag numbers it is very difficult to make sense of the Hazid results.

Hazid can often predict overpressure events which are not credible for the given failure mode. This is a result of the fact that it models the plant very simply — but Hazid is capable of reasoning about limits of process variable deviations, and this can be more widely used in the equipment models in future, to eliminate many of these “silly” overpressure results.

## DISCUSSION AND FUTURE WORK

The costs and benefits of Hazop have been outlined in the Introduction above — this trial has suggested that, as well as saving time, Hazid can also provide documentation for the paper trail needed to ensure that the process design is auditable.

With Hazid, design reviews can now be carried out as the P&ID is being developed, and can if necessary be used to test and verify alternative design options. This would obviously highlight those areas where there are potential hazards or operability issues — this early stage hazard identification could have major cost implications, in terms of capturing hazards early and also encouraging the choice of inherently safer designs.

It is expected that the use of Hazid prior to Hazop should eliminate about half of the “sillies”, “design omissions” and “non-issues” revealed during the Hazop study, not only saving time and resources, human and financial, but also allowing the Hazop team to focus on the real issues without distraction by the non-issues.

Hazid has other benefits, outside the scope of “new-build” projects. It can be used to screen minor modifications that arise later on, as the process ages, or as technology moves forward. Management of Change procedures require a structured review of the change for potential problems — Hazid can be used as the first level of analysis. It may not eliminate the need for a full review but it will highlight those areas which need attention.

One of the more frequent issues raised in a Hazop is that of the vapour/liquid equilibrium. Usually, the question centres on “What are the composition, temperature and phase at any point in the process?”. This is often a precautionary comment requesting confirmation of data, rather than a challenge to the designer. In turn the question requests a “VLE” analysis, which could be done by a proprietary program such as Aspen Plus<sup>®</sup>. If there were an interface between Hazid and such a program, the results could be automatically interrogated by Hazid and the effects integrated with Hazid’s own report.

One of the potentially more significant outputs of Hazid is that of the “protective systems”. In this trial plant they were deliberately suppressed as design features so as to make the study more rewarding. It would be a reasonably simple task to incorporate an indicative failure to danger (FTD) probability for each protective system in the plant, perhaps by specifying a probability for each class of protective equipment. Given this data, Hazid could then feed information through to the “layer of protection analysis” (LOPA) for use in subsequent risk assessment activities. Once again, Hazid could provide a self-documenting information source for this activity.

This experience of using Hazid on an early-stage trial plant design with almost no alarms suggests the interesting possibility of using Hazid to examine process hazards with a view to developing a minimal instrument set. Only those instruments/protections which

are necessary to make the plant safe and operable need be added. Clearly, such an analysis would have to include a careful assessment of startup, shutdown and maintenance requirements within the process, but it could cut down on the number of redundant instruments installed on the plant.

## CONCLUSIONS

The view from the trial is therefore that Hazid is a very capable system and would be highly suitable for initial hazard identification in a variety of possible use case scenarios. In this respect it could save a lot of time and money which would otherwise be spent on Hazop studies and similar team-based exercises. Although useability issues still remain in the system, many of these can be tackled by managing the user's expectations of what to see and how to read the output report. Finally, it is suggested that the software would benefit from further integration with other engineering software (such as physical property estimation packages), to provide an even richer analysis and save even more engineers' valuable time.

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