USING HAZOP TO IDENTIFY AND MINIMISE HUMAN ERRORS IN OPERATING PROCESS PLANT

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This joint paper between Tracerco and ABB outlines some of the benefits from carrying out a HAZOP Study focusing on Human Interaction with process plant.

Tracerco wished to conduct a hazard study of their existing High Pressure Injection System (HP Injection Rig) to understand how to improve the design and minimise the impact of human errors when operating the system. The HP Rig is used to inject tracer material into a client's process to allow measurements to be taken. The Rig can be used to inject liquid into a dual phase flow line, liquid into a gas line or liquid into a liquid line.

Traditional HAZOP is good at checking the hardware design for an existing system but is best adapted if you are aiming to identify and minimise the potential for human operational errors.

By using this approach, this paper highlights some of the simple, practical, low cost measures that were identified during the study, to improve the design and also minimise the possibility of human error when operating the HP Injection Rig.

KEYWORDS: Human Error, HAZOP

BACKGROUND

Tracerco have developed a High Pressure Liquid Injection Rig, see Figure 1, to inject radioactive tracer material into a client's process. The velocity of the injected active material within the client's process equipment is then measured, by the use of externally mounted radiation detectors, to give a detailed understanding of liquid movements. This type of investigation is used to 'see inside' the process plant in real time, to verify process conditions and also equipment integrity. This technique is typically used for distillation column studies, reactor system trouble shooting, vessel inspection and heat exchanger leak testing.

Use the HP Injection Rig requires the following additional equipment: backing nitrogen supply, hand operated liquid pump, pressure rated hoses, non return valve, and a customer supplied double block and bleed valve arrangement.

Operating the HP Injection Rig broadly follows these steps: (1) Positioning & connection, (2) System leak test, (3) Transfer active material, (4) Inject & monitor, (5) Depressurise, (6) Purge and dismantle. Tracerco use short half-life isotopes (typically 36 hours) for injection into client processes when carrying out their investigations.

Operation of the HP Injection Rig and associated equipment follows well defined procedures, as outlined in Figure 2. This is essentially a manual operation requiring extensive training and experience to be able to carry out the operation safely and effectively. Each operation of the rig may require multiple injections.

Tracerco wished to conduct a hazard study to assist their understanding of how to improve the design, and minimise the potential for human errors, while using the HP Injection Rig on a client's site.

HAZOP APPROACH CONSIDERING HUMAN INTERACTIONS

A conventional HAZOP approach[1] would consider a section of process plant on a node by node basis, and apply a series of deviation guidewords to help reveal any undesirable effects or hazards. This is would be carried out as a team exercise by those with suitable knowledge and experience of the process plant being studied.

By way of illustration, consider a simple tank as shown in Figure 3. A node may be selected by the team comprising of the outlet valve from the tank. Applying a guideword such as 'No Flow' might identify the possibility of the valve being left closed leading to tank overflow. As there appears to be no means of preventing the undesired event of tank overflow, the team may conclude that some form of high level protection might be appropriate.

However this approach does not directly address the identified initiating cause of leaving the manual valve closed. What is required is an alternative approach which focuses on the manual tasks involved in operating this section of the plant.

By considering the plant procedure that describes how the tank is operated, it is possible to focus on the potential errors that could be made by someone operating the tank. Typically a step in the procedure is selected as a node in this type of HAZOP, rather than a selection of plant hardware. A series of guidewords is then used which focus on potential failures that could be made at each operational step, such as; part completion, omission, repetition,

[1]Ref [1] IChemE – "Hazop Guide to Best Practice".

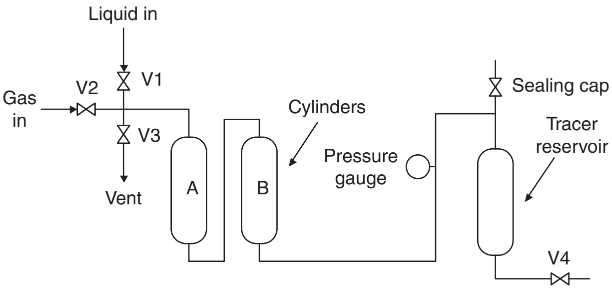

Figure 1. High Pressure Injection Rig

mistiming etc. The guidewords for Human HAZOP are different from those used in normal HAZOP.

In the tank example, applying this form of guidewords to the selected step in the procedure, (operating the tank valve) would aid the HAZOP team in identifying the different types of potential operational error that could occur. The team could then also consider ways of making these errors less likely, for example, 'missing out the step'. The team might offer some alternative solutions such as; installing an interlocking the valve so it is not possible to move to the next step in the procedure, ensuring the status of the valve is clearly visible from the handle position to assist in error recovery, and improving the environment so operator distractions are kept to a minimum etc. An example of how this may be recorded is shown in Figure 4.

The HP Injection Rig is essentially a manual operation. Human HAZOP was chosen as the best approach

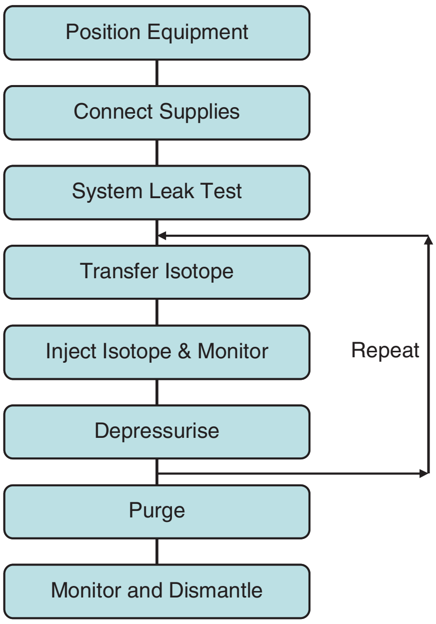

Figure 2. Operating procedure

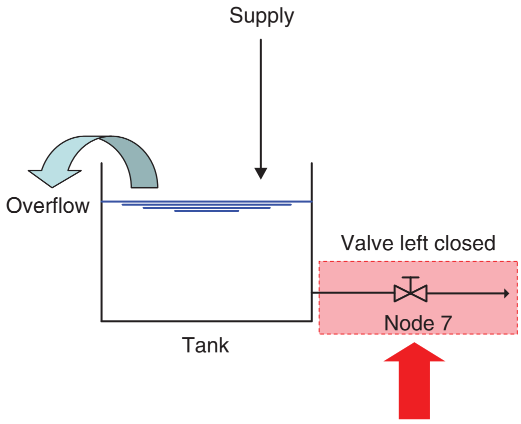

Figure 3. Tank example node selection

for understanding how to improve the HP Rig design, and minimise the impact of human errors during its operation.

PREPARATION AND NODE SELECTION

Before carrying out this form of HAZOP, it is essential to have a clear, accurate procedure that describes exactly what is carried out in operating the section of process plant under consideration. This is necessary in order to select the nodes that are to be studied, prior to conducting the HAZOP as illustrated in Figure 5.

It may also be necessary to break the individual procedural steps down into smaller elements. Typically it is worth considering before the study, which steps in the overall procedure are likely to prove most hazardous, should operational human errors occur. If the consequences from failure of a given step are not significant, then it is probably not efficient use of time to break that step down into any further detail.

A technique such as task analysis may be used to help break down the steps in the overall procedure, as illustrated in Figure 6. This allows the team to consider the effect of failures in the selected step where the consequences are significant.

Item/ Line/ Stage	*Deviation*	*Causes*	*Effect or Hazard*	*Preventative or Corrective Measures (error recovery)*	*Action Required*
Node 7 - step 3 close valve BB	Operation omitted	Human error missing step in procedure due to memory lapse, distraction etc.	Tank Overflows	None	Install interlocking valve so not able to move to next step in sequence
					Change valve type so handle clearly indicates position (error recovery)
					Ensure valve is clearly labelled and easily visible (to other Operators)
					Consider how to improve environment to minimise Operator distractions
					Improve training package & auditing of operational procedure
					Re-organise shift work program so this becomes a routine skill practised by all Operators

Figure 4. HAZOP considering human interactions

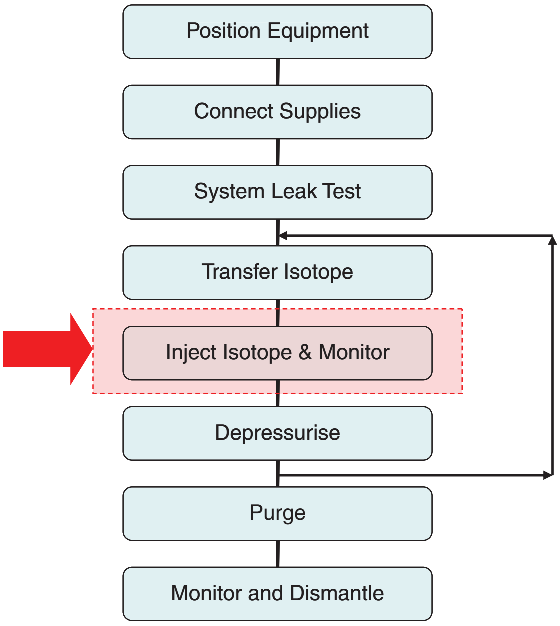

Figure 5. Operating procedure node selection

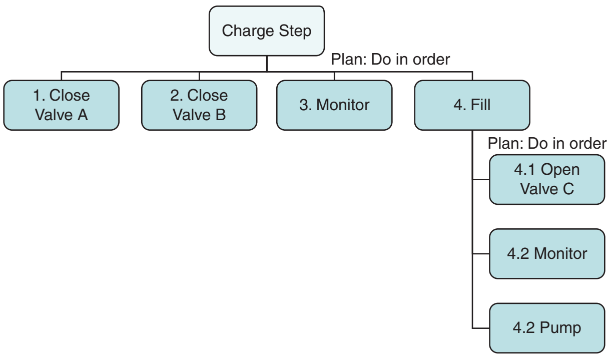

Figure 6. Task Analysis

HUMAN ERROR

Before discussing the results from this HAZOP, it is worth considering some simplified classifications of human error[2], to assist in understanding some of the study outcomes.

Figure 7 illustrates a simplified model of the steps that are undertaken when operating a typical item of process plant. The first opportunity for making an error is at the recognition stage. It is necessary to recognise that some form of action is required, in this case the need to close a valve. Secondly there is a mental processing step where a decision has to be made based on the data from the recognition phase. Finally there is an action phase where there is interaction with the process equipment. Only after successful completion of all of these will the desired outcome be achieved e.g. closing the valve. Errors can be made at any of these stages, and it is helpful if the HAZOP team is aware of this type of simplified model of human behaviour to aid their understanding and help with identification of potential solutions.

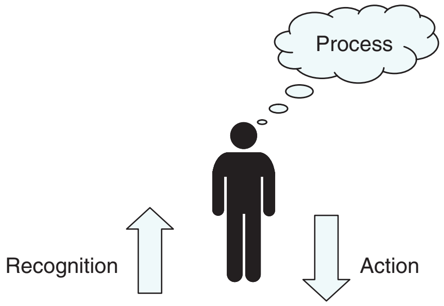

Figure 7. Human Error

Another useful classification of human error is shown in Figure 8. Human errors can be typically divided into unintended and intended actions. Unintended actions tend to be described as slips or lapses, and are largely carried out by subconscious mental processes when we are operating in a skill based 'auto-pilot' mode. Skill based mode implies that an activity is well practised and intuitive, such as making a cup of white coffee. If someone pointed out that you had made a slip and forgotten to add milk to the coffee, then you would immediately recognise the issue, assuming the original target was to make them a cup of white coffee.

Intended actions tend to be associated with mistakes. You would typically not be aware that an error had occurred. Mistakes tend to be associated more with rule or knowledge based activities, where we are learning how to carry out an unfamiliar task or activity. Because of this we tend to be less reliable than when we are operating in a skill based mode.

This simplified model implies that to achieve a higher reliability in executing a task successfully, the activity needs to become skill based through design and routine practice.

Awareness of these simplified models of human behaviour is beneficial for the HAZOP team. They assist in understanding and help in brainstorming to identify causes of error and potential solutions.

RESULTS

By using the approach described above, the HAZOP team identified a number of simple, low cost, changes that could be made to minimise the potential for human errors, when operating the HP Injection Rig. The following are some of the team's findings:

(1) Tracerco have a number of HP Injection Rigs which have been constructed over a period of several

[2]Ref [2] Reason – "Human Error".

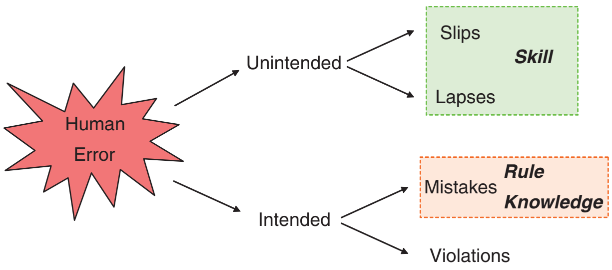

Figure 8. Classification of Human Errors

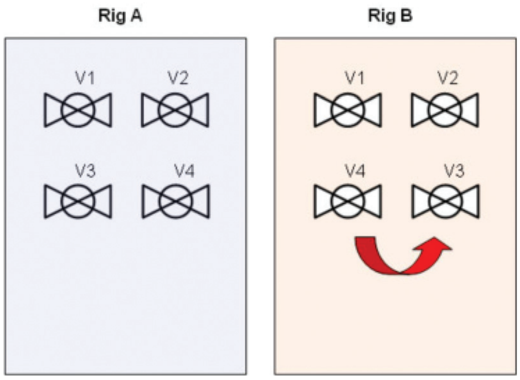

Figure 9. Inconsistent valve position

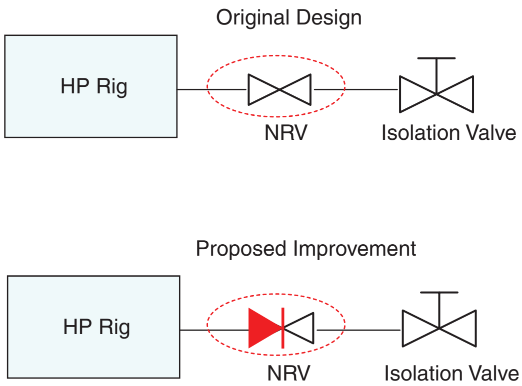

Figure 10. Marking of NRV direction

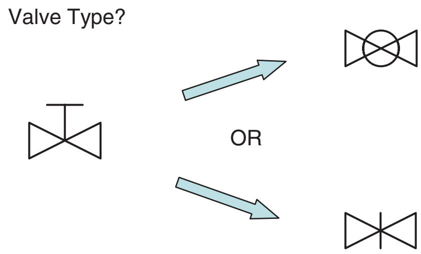

Figure 11. Choice of valve type

years. Not all the Rigs are identical in layout, as illustrated in Figure 9.

On some rigs, valves V3 and V4 are reversed. This invites errors to be made, as a typical investigation is a repetitive activity requiring a sequence of injections of tracer material. Operation of the rig can be classed as a ‘skill based’ activity[3] carried out by experienced, trained personnel. Therefore it is particularly unhelpful to have valves positioned in alternative orientations on differing rigs. It was a relatively simple, low cost exercise to ensure consistency in the layout of valves on all the HP Injection Rigs.

(2) A non-return valve (NRV) is used as one protective measure to prevent backflow from the client’s process into the HP Rig. One of the first activities on reaching a client’s site is to assemble the HP Rig installation in preparation for a pressure test and ‘dummy’ injection. The original NRVs have little or no clear marking on the valve body to indication the correct orientation, as illustrated in Figure 10. Again it was a relatively simple exercise to mark the existing NRVs to minimise the potential for installing the valve in the wrong orientation. This also makes the error more visible[4] so that this could be detected and corrected before proceeding to a pressure test.

[3]See Figure 8.
[4]See Figure 7.

(3) The choice of valve type is also another way, identified by the HAZOP team, of reducing the potential for making operational errors, as shown in Figure 11.

Some valves are used solely for isolation, where it is desirable to have a quick operating valve, such as ‘quarter turn’. For this design of valve, valve position is often clearly indicated by the orientation of the handle. Other valves are used solely for venting purposes where their function is quite different. The pressure within the HP Rig must to be vented in a controlled manner, calling for a very different design of valve.

By ensuring that the valve type is appropriate for the type of function required, this minimises the potential for operating valves too quickly. It also has the benefit of clearly differentiating between the various valves, making incorrect valve selection less likely[4].

(4) The HAZOP team identified the benefits of using colour coding to help reduce the possibility of installation errors. For example, uniquely colour coding the hoses that are used to connect up each of the gas and liquid supplies to the HP Rig.

(5) The HAZOP team also suggested that the screw cap on the injection vessel, as shown in Figure 12, could be made more visible. If the cap were missing due to an error, then its absence would be easier to notice if the cap were brightly coloured. By highlighting the absence of the screw cap, this increases the likelihood of spotting and correcting the error[4]. This was another low cost solution which helps to minimise the potential for human error.

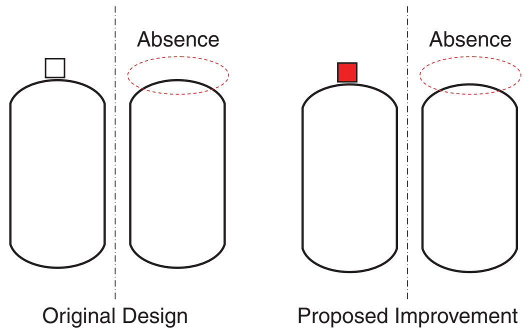

Figure 12. Colour coding screw cap

Many of the HAZOP team's findings are similar of those highlighted by Trevor Kletz in his book[5] "An engineer's view of human error".

CONCLUSIONS

An adapted form of HAZOP, which considers the hazardous steps in an operating procedure, is one effective approach to identifying and minimising the potential for human errors.

As with any form of Hazard Study, preparation is essential to ensure that the study is efficient and effective. It is necessary to have a clear, accurate procedure that details the human interactions with process plant; this enables selection of the nodes for this type of study. The key steps where human error can lead to significant consequences can then be studied by the HAZOP team in more detail.

Human error is highly influenced by the design of equipment and the operational procedures. It is therefore possible to make the situation more error tolerant by careful consideration of the equipment design and its operation by personnel.

By using this approach, the HAZOP team were able to identify some simple, practical, low cost measures to improve the design and minimise the potential for human error, when operating the HP Injection Rig.

REERENCES

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[5] Ref [3] Kletz – "An engineer's view of human error".