

ASSESSING RISK ON AN EXPERIMENTAL DESIGN – HOW TO USE HAZOP AND SIL STUDIES EFFECTIVELY

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A new gas treatment plant has been designed as an experimental facility providing the scale-up experience from the test rig to an operating unit as an interim stage before operating routinely.

The plant has been specified with a wider design margin than the initial operating mode requires, such that potential future operating modes which are as yet undefined can be accommodated. Only the initial operating conditions and absorption fluid have been defined.

Examples of the identified potential changes on the plant include the composition of the feed gas for treatment, the circulating fluid used for gas treatment, the operating temperature and pressure and the dose levels of additives to the system. In addition, the benefit of certain equipment items is to be determined, considering gas treatment effectiveness and energy efficiency.

As part of the project scope a full set of safety studies were completed, including hazard and operability (HAZOP) study and safety integrity level (SIL) assessments using the layer of protection analysis (LOPA) methodology.

The challenge was to complete the HAZOP and SIL studies on a plant where the operating regime was uncertain, the operating modes not yet defined, and flexibility is required to enable the experimental programme to be completed safely.

As no similar facility has been built previously, there was no operating experience on which to base the risk assessments. Initially the operating intent is to have mainly manual operations to facilitate the flexibility required for the trials, but with high levels of instrumentation to provide feedback. The intention was to determine how best to operate the plant and then tune the instruments to suit at the end of the experimental phase of operation.

Completing the studies, in particular the SIL assessment was a challenge. Many of the identified risks related to manual activities and changeover scenarios; the number of these per year to use as the basis for assessments was unknown, so an estimate had to be made. The challenge was to be pessimistic enough such that the SIL assessment would cover the worst case, whilst not unduly penalising the project costs by over-specifying the requirements.

The HAZOP study created a large number of actions as a lot of data was unknown. This lead to a large amount of laboratory work and learning to be built into operating instructions and trial programmes to ensure the data was identified so the actual risk could be quantified and recorded for the future.

The plant is also intended as a base design for future plants, which would have defined operating parameters/feed materials, so some of the equipment and instrumentation may not be applicable. This means that some existing data, layers of protection and indeed some potential hazards may not be valid in these future plants. The recording of all assessments needed to clearly indicate all assumptions made, such that the assessments could be reviewed easily and updated to reflect the actual risks once the experimental phase had finished and to support future plant design.

INTRODUCTION

A gas treatment plant has been designed based on a small test rig, which is still completing trial runs during the detailed design stage of the project. The test rig is also limited in its range of operating modes, but the trials have indicated a potential benefit of running outside of these limits. As a result the design basis for the new plant has been specified with much more flexibility than the test rig.

This plant is intended as a scaled-up experimental unit. The plant will be operated in a range of operating modes, using a variety of absorption fluids, varying feed gas compositions and different additives. A significant level of instrumentation is provided which will enable detailed assessment of these various modes. A rolling 12 - 18 month test programme is planned, with additional cover for the operating team to support decision making and troubleshooting. After this time period a stable operating mode will be established and the plant will operate with the standard operating team, expected to be two or three people.

Despite the expectation of all the various changes to the experimental operational programme, no detailed information was available to define anything other than the initial operational mode (for two different gas compositions), and the design basis for physical conditions specified for the unit. For example, the design pressure has been set at 5 barg, whereas initial operation will be approximately atmospheric. Similarly, the physical and hazardous properties of the initial absorption fluid are defined, but future fluid properties are unknown. However, the limitations, for example, on freezing point, viscosity and corrosiveness will be based on the electric tracing, pump design and material of construction specifications, respectively.

The aim of the new plant is to define what the optimum operating conditions are, which items of non-essential equipment add value, for example by reducing energy consumption, and how to optimally control the plant to maximise gas treatment and minimise releases to air and water. From this understanding the plant will be set up for future operation, and subsequent designs will be justified.

RISK ASSESSMENTS

Whilst risk assessments were completed for the test rig, the potential harm is limited due to the low inventory. When this is scaled up the risks become magnified in respect of the potential for both human and environmental harm.

The preliminary hazard studies completed for the project were limited to the known materials to be handled, with just a mention that these may change. Therefore the hazard and operability (HAZOP) studies for the plant needed to be as detailed as possible, especially as no existing similar facility has been built previously, so there is no existing basis of safety for this technology. However, the individual equipment items within the plant are relatively standard equipment, with nothing novel.

The ideal situation for the client would be that the HAZOP study and the subsequent safety integrity level (SIL) assessment, would be suitable for all potential operating modes of the unit. However, following discussion and the HAZOP study of the initial plant sections, it was evident that this could not be achieved directly; it was not possible to assess the risks of an unknown fluid, operating over a range of conditions. The agreed approach was that the HAZOP study would be conducted based on the planned initial conditions, with highlighted discussions where it was evident, or possible, that subsequent changes could create a different hazard.

HAZOP STUDY

The HAZOP study was completed using a standard technique and adapted guidewords for the process, but also with an additional check at each stage about possible deviations from current documented intent if different operating conditions, absorption fluids or additives were used. Where this was identified, especially if there was a concern about the potential effect, this was noted for future reference. However, it was emphasised that this should not be considered an adequate risk assessment for future changes, especially if the materials handled changed, as the physical and chemical properties of those materials may lead to a completely different hazard which had not been anticipated by the executed HAZOP study.

In addition to typical HAZOP study actions arising, there was some learning for future designs, for example, changing the design temperature for some equipment to make it inherently safer removing the need for a high temperature trip.

Due to the nature of the plant, with significant manual interactions anticipated, the operability aspects of the plant are very important, and were more prominent in the discussions than is often the case.

The environmental considerations are also very important for this facility, as the design basis is to minimise chemical discharges to air and water. Extremely low tolerability targets have been set, which are theoretically possible, but could be easily exceeded through human error or plant upset. The initial manual control basis planned, such that the plant can be used as an experimental facility, in conjunction with the anticipated routine changes to operating conditions, means that the risk of human error in setting control parameters is relatively high.

The ongoing test rig activities, and the fact that there is no existing similar plant, lead to a large number of HAZOP study actions relating to troubleshooting and reference information that needed to be included in operating instructions for the plant, which had yet to be written. Similarly, many questions relating to what would happen to the process when it moved into an abnormal operating regime could not be answered, leading to laboratory or test rig work which needed to be done to verify that this would not lead to a hazardous scenario. Further, it was highlighted that whilst the operation was nominally within the design envelope for the equipment, the potential for instability in the process whilst in manual operation, could lead to repeated trips and restarts. Gaining a good understanding from the experimental programme of how the level controls, for example, would react across interlinked systems in an upset condition would be very important for designing control system parameters for the future.

A very high number of HAZOP study actions were generated, mainly due to the risk assessment highlighting a significant number of unknowns in the scale-up of the process. Whilst the trip systems were in place to nominally prevent the plant moving into an unsafe region, there was potentially a high demand on these protective systems, especially during the initial commissioning and experimental stages. Some vendor packages resulted in high numbers of actions when initially subject to HAZOP study, as the proposed packages were typical, not specific, however these were addressed and revised designs subjected to a repeat HAZOP study to confirm that the final design was suitable.

Many of the actions arising were related to the drains system, which was complicated in order to collect and recycle or dispose of any liquid losses. However, there was the potential for contamination of rain water, for example following a small leak into a bund, which would be sufficient to exceed the release targets.

It was also highlighted that other absorption fluids used could give issues with air contamination targets, for example if they were more volatile or less soluble in water.

The potential for different materials to be handled on the plant did highlight some repeat issues, such as level device design should not be based on density of fluid, as this could change routinely and there was a risk that high level controls, alarms and trips could be compromised if the density factor had not been changed.

In summary, the HAZOP study process could have been more efficient if an operability review had been completed at an earlier stage in the design; however there was a commitment to address actions rapidly, wherever possible. A number of actions are outstanding until the plant is commissioned, but these are operability rather than safety related.

SIL ASSESSMENTS

Following on from the HAZOP study, the scenarios identified as potentially hazardous were subjected to a SIL assessment, using the layer of protection analysis (LOPA) methodology. Again, a standard LOPA was completed, but the uncertainty in how the plant was to be operated, the intention to initially run the plant in manual rather than using automatic control as standard, and the intention to repeatedly change the set points for different parameters led to a huge uncertainty in the values to use for initiating event frequencies for those scenarios relating to mal-operation. In addition, the potential consequences were not always obvious, especially environmentally, because it depended on the actual efficiency of the different abatement systems.

The key challenge for the project team was to estimate conservatively the values to use, whilst not being so pessimistic that the demand on the safety instrumented functions (SIF) resulted in a high SIL classification, and hence added unnecessary cost to the project. As a general rule, if the conservative assessment demanded more than a SIL 2 instrumented system then we would review the assessment, but SIL 1 or SIL 2 systems were accepted.

It was evident from the SIL assessments that more SIFs than would normally be expected were being specified, rather than relying on control system based actions, due to the proposed initial operational mode of the plant and its experimental nature. Where the long term need for such a trip action was questionable, this was recorded in the SIL assessment record, such that the data could be reviewed easily at the end of the experimental phase and the event/failure probabilities adjusted to reflect the operating experience.

Conversely, it was also evident that there are significant levels of instrumentation on the plant, relayed to the control system, intended for comparative data gathering, which would provide back up warnings to the operators. Such highly instrumented plant would not be cost effective for future installations, with only those instruments necessary installed. Therefore, comparative SIL assessments for future plants may have higher SIF demands due to the reduction in alternative alarm information. However, alarms were not always considered as a layer of protection. Due to the expectation that set point would be adjusted routinely, most alarms were designed, following the HAZOP discussions, to be deviation from set point alarms, rather than at specific values. As such these alarms could not be relied on to provide warning of a deviation as a result of operator/set point error, as the set point could be outside the operating envelope. This conflicting use of data available led to involved discussions on valid layers of protection for the plant.

It was not immediately obvious that many of the SIL assessments would be affected significantly by the changes to operating modes and absorption material, as the aim of the SIFs is to ensure that the plant remained within the safe operating envelope. The exception, as highlighted in the HAZOP studies, was that the design basis for the SIFs needed to be fluid independent, especially for level devices, as this was subject to change.

Due to the tight targets for air and water emissions, some potentially hazardous scenario assessments indicated that SIFs were needed to act on analytical output. However, as the emissions were target only and would not lead to direct human harm, or measurable environmental harm, then it was acknowledged that obtaining suitably accurate on-line analytical equipment, with a rapid enough response time was unrealistic. As a compromise it was suggested that the best available equipment should be purchased.

All the SIL assessments were reviewed at least twice, to ensure that all HAZOP study and preliminary SIL assessment actions had been completed and incorporated. Any assumptions and estimates made in the assessments were clearly recorded such that they could be verified and/or adjusted in the future.

CHANGES TO THE INITIAL OPERATING MODE

Despite the original intention to try and make the HAZOP study and SIL assessment applicable to the whole range of potential operating modes for the experimental programme, it was acknowledged by the team that this was unrealistic as the future materials which could be handled were not known.

It was therefore agreed that the HAZOP study and SIL assessments related only to the preliminary operating mode and specified associated materials to be used. For all future changes to the preliminary operating mode covered by the HAZOP study would therefore need to be considered as a change and covered by the company management of change procedure. This would require that the base HAZOP study and SIL assessments were reviewed and verified as either applicable to the new process, or the differences documented and addressed. To aid this, significant detail was written into the documents, in particular any assumptions made.

The risk assessment process was extremely useful as it exposed wide-ranging clarifications required to enable the experimental plant to be operated safely, in an environmentally friendly manner and with as many of the potential operating issues addressed as possible. However, the process also highlighted that the traditional risk assessment processes are not capable of being as flexible as had been hoped: although it is not surprising that the assessments were not capable of determining whether a risk existed from handling a completely undefined material!