Iterating, integrating and improving human factors at two COMAH upper tier sites

Andy Brazier, Consultant, AB Risk Limited, UK. Nick Wise, Gas Storage Business Support Manager, SSE Thermal, UK

SSE Thermal operates two natural gas storage facilities on the east coast of England, both classified as Upper Tier sites under the Control of Major Accident Hazards (COMAH) regulations. Recognising that human factors play a critical role in process safety, the gas storage sites, in 2008, embarked on a long-term plan to embed human factors into the way it manages its safety critical tasks. One of the key objectives has been to implement a proactive, structured approach that integrates with other process safety activities. SSE drafted an internal human factors standard, accompanied by five procedures. These initiatives marked the beginning of a systematic and formalised approach to human factors, which have now reached a level of maturity.

Since 2010, the gas storage sites have implemented annual plans for human factors analysis of critical operations and maintenance tasks. Rigorous prioritisation has proven to be effective at making sure effort has been focused on the areas of most benefit to process safety.

The sites have kept up to date with industry guidance and ensured the adoption of the latest good practices. Increased understanding of human factors within the business and regulator feedback have contributed to an evolved approach that fulfils local and external requirements. Management leadership and commitment have been crucial to securing resources required for external support and individuals' time.

Integrating human factors into wider process safety work has been successful. The sites have, in parallel, implemented five-yearly revalidation of their Process Hazard Reviews (PHRs). Learning from human factors studies is made available to the PHR team and findings from PHR revalidations are fed into the human factors studies. The sites have established a routine of aligning human factors studies with PHR revalidations, ensuring a structured and proactive approach.

Using the output of human factors analyses of safety critical tasks to produce operating and maintenance instructions and associated competency assessment criteria has had practical and cultural benefits. The result is that a single method is agreed as best practice for each of the critical tasks reviewed, which is expected to be followed in practice. Any significant change to the task triggers a revision of the human factors study, instruction and competency profile.

Active involvement of people who perform the task in practice, discipline engineers and process safety specialists takes place in an environment where agreement on best practice is the aim. Clear communication from company leadership supports this by ensuring a common understanding amongst everyone involved. Widening involvement not only allows everyone to have their say but has proven to be a very effective opportunity to learn.

SSE Thermal has aligned its approach to the latest industry best practices. For example workshops are facilitated by human factors specialists with process safety knowledge and attended by personnel familiar with the task. Tasks are described using Hierarchical Task Analysis (HTA) and task walkthroughs are conducted to evaluate Performance Influencing Factors (PIFs).

Findings of human factors studies are documented in detailed reports using a standard template that includes key insights, a review of industry best practices, and a review to confirm risks are managed to As Low As Reasonably Practicable (ALARP).

It has taken time, commitment and resources to evolve a process that works in practice. One outcome has been improved instructions, with a broader impact from integrating human factors into process safety, so that all elements of the risk control hierarchy are thoroughly considered.

This paper will be of interest to companies that are in the process of integrating human factors into their process safety management strategies, offering insights into overcoming challenges, driving cultural change, and demonstrating effective leadership in high-hazard industries.

Key Words: Human factors, task analysis, human reliability, human error, procedures, COMAH, process safety, continuous improvement, lessons learned.

Introduction

This paper was prompted by a conversation between the two authors, which led to the questions: "How did we get here?" and "Is this where we want to be?" A review of old emails and reports revealed that the current programme of work began 15 years ago, building on initial steps taken as early as 2008.

We hope that sharing some insights learned from the way SSE Thermal's gas storage sites have addressed human factors as part of a wider process safety scope may benefit other companies.

The work undertaken has successfully delivered benefits in managing Major Accident Hazard risks. However, we recognise that circumstances continually evolve, and what works today may not tomorrow. By capturing and sharing what we've learned so far, we hope to highlight the important underlying principles that may provide resilience against the inevitable challenges that will come along.

Background

SSE Thermal operates two natural gas storage facilities on the Yorkshire coast. These use subsurface caverns created by leaching voids in a salt layer approximately 1800 metres below ground level. The basic business model is that gas is bought, imported from the grid, compressed, and injected into storage during periods of low demand. It is then sold, withdrawn from storage, dried and exported to the grid during peak demand periods. This helps to balance supply and demand, especially during periods of increased gas usage (typically cold weather) and revenue is generated by price differentials.

The facilities are able to store and process large inventories of flammable gas at high pressure (>200 barg). The degree of hazard means that the sites are Upper Tier under the Control of Major Accident Hazard (COMAH) regulations. COMAH historically emerged in the UK from the EU Seveso directive.

At present, the gas storage facilities are the only Upper Tier COMAH sites operated by SSE.

The COMAH regulations are focused on process safety and the avoidance of major accidents that have the potential for significant harm to people and the environment. They are 'goal setting' regulations, which means the duty holder has primary responsibility to demonstrate that it understands the risks and has implemented the controls necessary to reduce them to As Low As Reasonably Practicable (ALARP), including those risks where human performance impacts on the initiating events or risk controls.

The Health and Safety Executive (HSE) is the safety regulator in Great Britain and typically takes the lead in the safety aspects of the COMAH regulations. It has had a team of human factors specialist inspectors since the mid-1990s, and has generally communicated its expectations by publishing guidance, including the guides referred to by its inspectors, that are freely available to everyone. Although they do not have the status of regulations, duty holders are expected to either follow what the guidance says or be prepared to demonstrate that their alternative approach is at least as effective.

Corporate commitment

SSE is a multi-national company with interests in many different business areas. SSE recognises the importance of Human Factors as part of an integrated Safety, Health and Environmental Management system, with a corporate standard produced in 2008 to provide high-level guidance on expectations across the company. It was recognised early on that there was a greater priority at the gas storage sites to implement Human Factors processes due to the process safety risks and associated regulatory drivers. The learning from implementing these processes at the gas storage sites was then assessed for its relevance elsewhere in the company.

Early timeline

In 2008 a human factors consultancy was engaged to conduct a pilot study at one of the gas storage sites. A human factors analysis of an operating task was carried out. It did a reasonable job of illustrating some human factors techniques, but the benefits in process safety risk management were limited due to undertaking the study as a stand-alone activity.

Also in 2008, in addition to the corporate human factors standard described above, SSE developed five procedures detailing Human Factors requirements for its Gas Storage, Thermal Generation and Renewables businesses:

- Human reliability assessments – methods of identifying and analysing process safety critical operating and maintenance tasks
- Safety-critical communication – identifying and evaluating arrangements in place to ensure systems support people when engaged in safety critical communication (e.g. shift handover, permit to work)
- Fatigue risk management – evaluating shift patterns and hours worked by individuals in safety critical roles
- Alarm handling – ensuring alarms are effective at supporting situational awareness and inform operators of situations requiring their urgent attention
- Integrating human factors into projects – making sure human factors are properly considered from the earliest stages of projects, and appropriate techniques are used to optimise system design.

The standard and procedures have been through several revisions and are now considered as having reached a level of maturity and aligned with latest guidance and good practices.

In 2010 SSE's gas storage sites engaged the services of AB Risk Limited to support the development and implementation of annual plans for human factors analysis of critical operations and maintenance tasks. This collaboration has continued, with other scopes of working undertaken when required (driven by the procedures above).

Keeping focused

Human factors analyses require considerable effort and it is important to focus on where the most benefit will be achieved. For process safety, this is the tasks associated with the major accident hazards and vulnerable to human error. This is

relevant when planning initial analyses of tasks, and for subsequent reviews and updates. If available resources are used to analyse less important tasks, the existing analyses previously carried out for more important tasks may become obsolete if not reviewed routinely.

Creating a task inventory is very useful for understanding the overall scope of human factors and as a basis for prioritisation. SSE's gas storage sites use a two stage approach to prioritise tasks for analysis:

Stage 1 - the consequence rating from the SSE corporate risk assessment matrix identifies tasks linked with the most significant safety and environmental hazards, with input from Process Hazard Reviews (PHR) for each site. This is a fairly crude prioritisation but useful because it creates a link with the PHRs and hence the COMAH Major Accident scenarios, that has long term benefits during subsequent reviews of both PHRs and human factors analyses.

Stage 2 - apply an amended version of the scoring system presented in OTO 092/1999 [HSE 1999] to the tasks identified from the first phase. The tasks with the highest scores are given highest priority for analysis. This scoring system has been found to be effective for the gas storage sites due to the main hazards being fires and explosions. Other scoring systems [CIEHF, 2023] are used elsewhere in SSE where a broader range of hazards exists.

This approach was used to prioritise tasks for initial human factors analysis in 2010. The task inventories and prioritisation have been reviewed several times since, particularly after PHR revalidation, which the gas storage sites carry out every five years. This approach has proven effective for planning human factors studies on an annual and five yearly basis.

Gas storage tasks

The two SSE gas storage sites perform the same function with similar types of equipment. However, they were built decades apart with different technology. This means operations tasks are site specific and required site specific task inventories. However, the number of operations tasks identified at each site was similar at approximately 180 each. Also, the split of priorities was similar for the two sites, with approximately 15% classed as high priority and 30% as medium.

The nature of the tasks at the different sites varies due to the technology. For example, the compressors at the older site require more manual intervention and several normal operating tasks were rated high priority. The same tasks at the newer site have been automated. However, there are additional tasks carried out infrequently with the newer compressors that were rated high priority. Also, the higher level of automation creates more reliance on maintenance tasks, particularly for testing safety systems.

There are some operating tasks common to both sites and given high priority. They include tanker operations (methanol and condensate), and plant isolation and return to service after maintenance.

Maintenance tasks were identified at a more generic level covering both sites. Approximately 200 tasks were included on the list, with 10 rated as high priority. The task of most interest was testing safety instrumented systems (SIS). Although this appeared as one task on the list, there were multiple SIS, with some variations in the test methods. Representative examples of each type of system (e.g. pressure, temperature, flow, level) have been analysed, followed by an evaluation to identify any potential case-specific issues not covered by the generic analyses [Brazier, Wise, Dearden 2022].

Some maintenance tasks were originally rated high priority because they were related to safety critical equipment, but subsequently down rated. This included inspection of non-return valves and restriction orifices installed to mitigate major accident scenarios. Maintenance of these involves removal, inspection and reinstatement. Analysis of these tasks concluded that the main issues were related to making and breaking flanged joints, which is a relatively simple task and within the capability of a suitably competent technician. However, the sites had experienced some incidents related to pipework joints, so it was decided that human factors analysis of flanged and small-bore tubing (SBT) joint making was worthwhile. The findings led to changes in instructions and training. Both sites have seen a noticeable reduction in incidents as a result.

One area that has traditionally been seen as very specialist and possibly not amenable to human factors analysis is work related to the subsurface wells and caverns. Operations tasks are generally very simple, but maintenance involves specialist contractors and is usually managed as a project. However, with multiple caverns, it was clear that tasks are often repeated and the work programmes developed are not fundamentally different to maintenance instructions for above surface. Tasks including wellhead valve testing and maintenance, cavern sonar surveys and replacement of subsurface safety valves (SSSV) are now included in the maintenance task inventory, and human factors studies have been carried out. Also, some significant projects have taken place on several of the cavities in recent years and human factors has been formally included in the planning and development of work packs [Brazier, Wise, Ford 2023]

Integrating human factors into process safety

SSE's gas storage sites have evolved their approach and see significant benefit in maintaining a rolling, five-yearly review of all their process safety analyses. The site PHRs serve as a cornerstone for identifying and assessing major accident hazards, including for the COMAH Safety Reports, and the findings have been fed into human factors studies from the start. However, including the human factors studies into the five-yearly PHR revalidation and COMAH Safety Report review cycle means that information on how human error can initiate events and how best to control the risks can be included in the COMAH Safety Reports, before being fed into the next PHR revalidation process. Over time this approach has led to a more integrated and realistic understanding of how hazards are managed in practice, and better targeting of improvement actions.

A similar approach has been adopted for Layer of Protection Analysis (LOPA). This has led to a higher level of scrutiny of some of the data used in LOPA studies and tasks where a higher human reliability (better than 0.9 per human action) have

been incorporated in the relevant task inventory and prioritised for detailed assessment as described above. The result is a better understanding of where human actions are relied on for the risk reductions required to achieve company targets.

Aligning with operating and maintenance instructions

Operating and maintenance instructions, where available, are always a valuable source of information when analysing tasks. They describe a method of performing a task that has been through a development process. However, experience shows that written instructions do not always fully align with the way tasks are performed in practice and are not always presented as clearly and succinctly as they could be.

Task analysis can be effective at highlighting deficiencies with written instructions, especially when people who perform the task are actively involved in the analysis. If there is a small number of minor issues it is usually possible to update the instruction. However, if the issues are more significant or associated with the overall structure, a full rewrite may be required, and instruction authors may be reluctant to rewrite an instruction which they believe reflects how the task should be done. This may lead to mismatches between the reports documenting the findings of the human factors studies and the task methods described in operating or maintenance instructions.

It was soon recognised that the task analyses were creating a good basis for the instructions. This led to the current situation where the task analyses and instructions are fully aligned (i.e. both describe the task in the same way). This was helped by using task analysis software that can export text to the company standard instruction template.

Another development that has supported adoption of best practice for safety critical tasks has been the development of competency profiles for each task that has been analysed. These are used to assess every person who performs the task and to guide training and assessment of new starters. A competence management specialist has been engaged to create the profiles in consultation with people familiar with the tasks. One benefit of having performed a human factors study is that task steps associated with major accident hazards have been identified, which helps to focus the competency profiles on the most important aspects of the task.

The company has seen practical and cultural benefits in this approach. It has created a clearer focus on the role of instructions and competence in controlling process safety risks, and the quality of instructions is perceived to have improved by everyone, including the people who use them. To maintain this alignment, any significant change to the task triggers a revision of the human factors study, instruction and competency profile. Also, by making instructions more useful to people performing tasks they have become more critical about how they are written. Instead of giving cursory reviews people are willing to engage in discussion about what more can be done to improve the way tasks are performed in practice.

Involving the right people

Human factors analyses have always been carried out in a workshop. Originally all were face to face, which remains the preference for more complex tasks. However, assessing tasks online using Microsoft Teams has proven effective for most tasks and five yearly reviews, although it is still important to undertake a site visit to consider performance influencing factors. Task analysis software has made the task assessment process simple and efficient.

SSE's gas storage sites learned early in the process that carrying out analyses was of little benefit if the right people were not involved. In particular, people who perform the task in practice have to be actively involved, and different opinions on how to perform the task need to be considered. This is achieved by making sure individuals who perform the task attend every workshop, along with discipline engineers and process safety specialists. For operations tasks the minimum is two current members of the operating teams. For maintenance tasks, the pool of people is smaller and the scope for variability less, so one current maintenance technician is considered sufficient if the discipline engineer attending has performed the task in a previous role. The whole process, including chairing workshops, is facilitated by a human factors specialist who has proven facilitation skills and an awareness of process safety. Having a competent scribe has been found to optimise workshops, including the time commitment required from the site personnel. Achieving this level of involvement has required strong support from gas storage site leadership to release SSE personnel to take part and to fund the study leader's time. The quality of the output has justified this.

One aim has been to involve everyone from the pool of operating and maintenance teams in workshops (i.e. not rely on two or three volunteers). Feedback has been good and there is rarely reluctance from people to take part. This approach has helped to create a common understanding of why human factors is important with everyone working towards a common purpose of recognising best practices and putting them into practice. The gas storage leadership team has had a key role in communicating its understanding and expectations. It may not be a coincidence that the site director, who has been very supportive throughout, is a chemical engineer from an operational background.

Involving everyone has given people with less experience of tasks the opportunity to take part. Although they may not have depth of knowledge, they often ask some of the most insightful questions. Also, it has proven to be very useful for their learning. A trainee thanked the organiser at the end of a recent workshop for inviting them because they had learned so much about the job.

Following and developing good practices

It is now fifteen years since the current approach to human factors started. In that time, there has been new or updated guidance, including from Energy Institute [EI 2020] and Chartered Institute of Ergonomics and Human Factors [CIEHF 2023]. SSE Thermal has monitored these developments to ensure its approach is aligned. The conclusion is that the following aspects of the approach achieve this:

- Tasks identified in a systematic way that considers process safety and human factors
- Workshops facilitated by a chartered member of CIEHF
- People familiar with the tasks are actively involved throughout and attend all workshops
- Tasks are described using Hierarchical Task Analysis (HTA)
- A full range of human error types are considered
- Task walkthroughs are conducted to evaluate Performance Influencing Factors (PIFs).

Also, the gas storage sites have looked wider to consider process safety guidance. In particular, the hierarchy of risk controls and demonstrating that risks have been reduced to ALARP. Judgements are included in the reports that are created for each critical task analysed. The fundamental questions being:

- What more could be done to reduce the risk further?
- Why have those actions not been taken?

As an example, the task review for starting up and shutting down the gas compressors at the older site considered why the compressors had not been updated to include the level of automated control at the new site. The answer was that it would be technically very difficult and the only practical solution would be to replace the compressors. There has been decades of experience to show that the existing compressors can be operated safely and so the risk reduction achieved would not justify the cost of replacing the machines solely for this reason. However, if SSE installed new compressors to uprate a site or as part of a new facility, it would include the automation because it is much easier and cheaper to do so at initial installation.

More recently, the gas storage sites have started reviewing industry guidance and good practice related to each task as part of each Human Factors task analysis to ensure it is making its ALARP judgements based on the best available information. For example, for tasks related to subsurface caverns, documents from the Health and Safety Executive, British Standards Institute and Offshore Energy UK have been reviewed to ensure all relevant industry good practice is being considered and followed where appropriate.

Commitment and resources

It has taken considerable time and resources to evolve the process to one that we believe is useful and sustainable. It has required close collaboration across disciplines, consistent leadership support, and a willingness to learn from both successes and challenges. One tangible outcome has been the development of clearer, more practical operating and maintenance instructions. Another has been embedding human factors thinking into the wider process safety risk management process.

This integration has enabled a clearer understanding of how to apply the hierarchy of risk control and layers of protection to reduce risks to ALARP. Active involvement of the people who work at the sharp end gives us confidence that the organisation’s understanding of risk, and the measures in place to control it, accurately reflect the realities of day-to-day activities. Importantly, this is not based solely on theoretical or optimistic analyses, but on evidence that control measures are working as intended and are effective despite inevitable operational pressures and human variability.

Looking ahead, the focus will be on sustaining this progress through routine review, continual learning, and further refinement. There are no short cuts that will do this without resources and clear leadership. However, it is clear that for some tasks it can take several iterations of a task analysis to settle on an agreed best practice for carrying out the task and, after that, subsequent reviews become a validation rather than a development activity.

Conclusions

Companies working in major accident hazard industries cannot claim that human factors is a new idea or that there is no evidence to suggest that it does not apply to what they do. Equally, viewing it as a separate specialist topic or one-off study is not an effective way of optimising the way risks are managed in practice. Based on SSE’s gas storage sites experience, we can see that embedding human factors into a wider process safety scope, leadership understanding of and commitment to human factors, actively involving people involved in tasks, using specialist support and aligning task analyses with operating and maintenance instructions are all critical to success. Finally, continuous review, focused on the most critical tasks ensures that the benefits are sustained.

References

Brazier, A. Wise, N. Dearden, H. SIF Testing – it’s more complicated than you think. IChemE Hazards 32 (2022)

Brazier, A. Wise, N. Ford, N. Human Factors issues and solutions when undertaking major projects on operational site. IChemE Hazards 33 (2023)

Chartered Institute of Ergonomics and Human Factors. How to carry out human factors assessments of critical tasks – guidance for COMAH establishments. CIEHF 2023

Energy Institute. Guidance on human factors safety critical task analysis. Second edition. EI 2020.

Health and Safety Executive. Human factors assessment of safety critical tasks. OTO 1999 092. HSE 1999.