Resourcing Teams based on Key Project Risks

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Have you ever received a design so over designed that the cost was prohibitive, or have you received a design which when reviewed has identified a hazard that the team did not identify? Do you have a lot of changes in your designs or a large number of changes immediately after starting up a facility (within the first year)? So much focus is on the competence of the front-line worker that often the competence of the engineer is examined in a disproportionately low level of diligence. Plants are becoming more complex however there is a potential that this complexity is not necessary. In this article I will propose a different way of selecting or specifying your engineering team allowing you to be a more competent contract holder or team manager. This methodology helps meet the requirement of IEC 61511 and 61508 and will reduce the inherent risk in designs as well as the cost and schedule. I propose that engineers should be selected to complement each other in terms of experience and international or industrial standard knowledge. This will be based on the key risks of the proposed design. In this way if there is a gap in experience on the risks identified for the new design this can be mitigated by bringing in specialists for training and awareness or it can focus your recruitment. We all know that one engineers 10 years' experience is not equivalent to another's however how can we use things such as chartership, training and technical experience to build the best engineering team for our project?

Introduction

In this article I will argue that it is of utmost importance to ensure that your engineering, commissioning and construction team have the right competence/experience and information to deliver a safe and operable plant. This is not news to anyone (hopefully) however this competence/experience or information I refer to is not the number of years' experience but experience of Standards relevant to your design or experience in managing the main hazards.

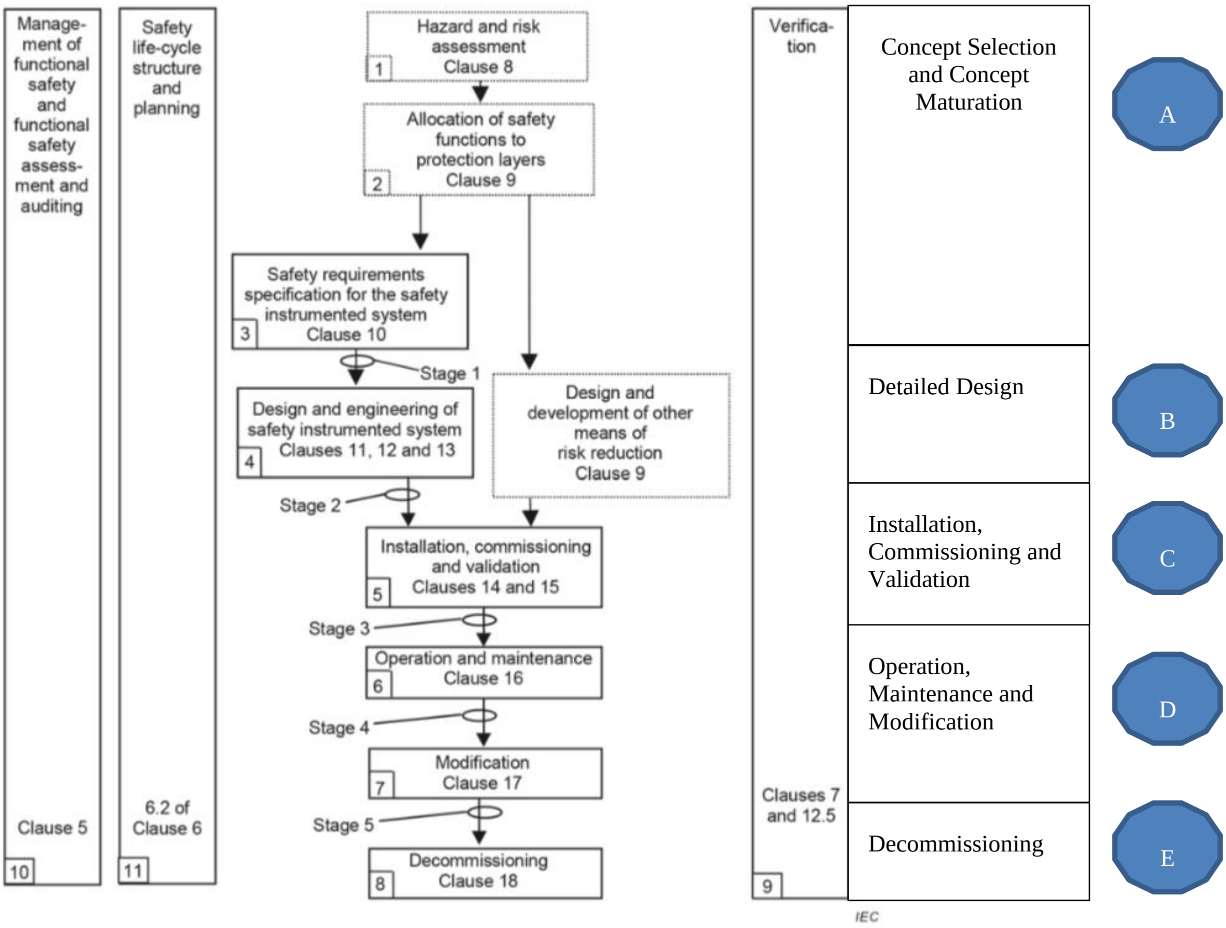
We all know that if we try to buy a 'red car' from a car dealer with no other functional requirement we are likely to leave the showroom with the most expensive red car they have which probably wouldn't fit the dog in. Which is why when doing these big purchases, we spend more time in the evaluation phase than we would say for buying a lettuce. However, when purchasing high value, high hazard sites we are always squeezing the evaluation phase to be shorter and shorter. We also are not very specific when buying. We say we need a senior engineer and 5 junior engineers but not what strengths they need or what mitigations should be in place if they are not there. There is so much focus on making sure they understand the operator's systems/processes in the drivers cab that we often neglect the engine and other safety factors until they are raised by the contractor.

If we could be a more intelligent buyer when setting up our engineering teams, validating our own engineers or when tendering and drawing up a contract we could be sure that the relatively short time we spent in design was well spent and targeted at risk reduction. This would enable us to learn more effectively from industry and embed learnings into design after design. Use of this methodology will help you identify where your big risks are, where your gaps are managing those through the project phases and then in proactively planning to close them. The use of this methodology can help bring structure to CV reviews for contractors, management of personnel changes, contract tendering, contruction and management. This will ultimately lead to stronger designs, fewer changes and more robust engineering teams.

Not only does this methodology provide the benefits above it also brings you in line with application of the revised BS EN 61511. BS EN 61511 covers the safety life cycle for the process sector. This is a supporting Standard for 61508 to ensure effective management of functional safety for electrical equipment. 61511 provides detailed requirements on how to identify the requirement of SIS and design and implement them. In particular requirement 5.2.2 requires that any person working on the project, operating, maintaining, manufacturing or decommissioning is required to be competent to carry out the activities they are accountable for. Over recent years there has been much focus on the frontline making sure they have the tools to do what they need to do. Likely because the majority of any project life is the operating phase and therefore as incidents of this nature generally occur during the operating phase they can be linked back to some human/frontline action. In many incidents, failures in the design can be a contributing factor to the incident. However, as design has already occurred the best remedy is an engineering change. Often learnings are not fed back to the original design team as they are dispersed, and it is a constant struggle to make new projects evergreen.

Basic Structure of Approach

Building on the basic structure in BS EN 61511 (see figure below) I have labelled some project phases which will be used in the following sections to describe the process by which one would use the methodology to ensure a robust engineering team at each stage of the project lifecycle.



Key

→ Typical direction of information flow.

No detailed requirements given in this standard.

Requirements given in this standard.

NOTE 1: Stages 1 through 5 inclusive are defined in 5.2.6.1.4.

NOTE 2: All references are to Part 1 unless otherwise noted.

Figure 7 — SIS safety life-cycle phases and FSA stages

NOTE 2 Information in Figure 7 may flow from operation and maintenance back to the earlier life-cycle stages to reflect tracking of incidents and failures and to verify engineering assumptions.

Figure 1: Safety life cycle from BS EN 61511 with annotation to describe stages used in the body of this article.

As with all projects the start of the project marks an exploration phase where different options (concepts) are explored. In this stage the options explored are often assessed using various hazard and risk assessment techniques. The two techniques I will focus on will be the hazard identification study (HAZID) and the Coarse Hazard and Operability Study (HAZOP) or inherently safer design review. These studies will be completed by the end of Stage A and therefore the first step of the process occurs late in Stage A or just before Stage B.

Stage A – Concept Selection and concept maturation:

For the Hazard and Risk Assessment (HRA) workshops it is imperative that people with the correct competencies are present in the workshop as this will form the foundation of the work for the remainder of the project. Therefore, before commencing these workshops it is important to consider the competence of the individuals entering the workshop and the potential issues that will be identified in the workshop, the perceived technical risks. In a large organisation it is likely that you will be able to identify someone with each of the competencies that are required (for example there is likely a diving expert, offshore mooring or human factors expert) however in a small company this is likely not to be the case. In this case one should try to enlist the help of external specialists. This can be in the form of the workshop facilitator or in the form of some trusted subcontractors (for example if the project requires offshore mooring and the company works with a mooring specialist on other facilities, try to enlist their help in this exercise).

As a project manager this may seem a daunting task especially at this early stage of the project where there are many unknowns. However, a review of the guidewords in preparation for the workshop can help you understand the ‘issues’ which may arise and can help identify the competencies required for the workshops having been given knowledge of the project scope and objectives. If you have already passed this stage and you realised you missed a competency, then ideally one should revisit the workshop with a completed set of competencies. However, this may not be possible so an independent review by a specialist may be able to inform you if there was a glaring omission or a minor one. As every project is different for this stage this is as much as can be done.

Once the workshops have been completed one can start to utilise the framework to develop your detailed design engineering team. Two scenarios warrant higher scrutiny from the perspective of risk management:

1. The first being low consequence high frequency events. These are likely to be events which occur in the installation, construction, commissioning and decommissioning phases. This may be things like welding (especially if there is a large structure) or working at height.
2. The second being high consequence low frequency events. These are likely to be the events which will occur in the operational phase. These are things such as loss of containment resulting in fire or explosion or vessel collision during bunkering of bulk liquids.

To identify these systematically there are several ways in which this can be done. The first is that two columns can be added to the HAZID or HAZOP worksheets which have Yes/No answer, is the hazard identified related to a high frequency activity? Or is it related to a major accident hazard (high consequence event)? Then after the workshop identify which phase of the project this hazard could be realised. Alternatively, both steps could be done in the workshop or both outside. An example worksheet can be seen below.

Table 1: Example table of application of the methodology against scenarios in a fictitious example. NOTE: sufficient detail is included for the purposes of this exercise however the level of detail is not sufficient for normal HAZOP or HAZID quality.

Scenario	**MAH Potential**				**High Frequency**			
	Ops	**Comm**	**Decom**	**Const**	**Ops**	**Comm**	**Decom**	**Const**
Welding super structure for offshore platform could result in injury or fatality from close contact with hot torch or inappropriate usage or storage of welding gasses.						Y	Y	Y
Poor quality welding due to unavailability of competent welders or required quality materials leading to unrevealed flaws in weld metallurgy. Preferential corrosion at weld leading to loss of containment with the potential for fire, explosion (if release in congested area) and in worst case 15 fatalities due to close proximity of office building to pipeline.	Y	Y	Y					
Blocked gas outlet leading to the potential for overpressure of vessel by over 3 times design pressure. Potenial loss of containment, catastrophic failure of vessel, pool fire or flash fire leading to localised environmental damage, potential for up to 2 fatalities and complete facility shutdown until investigated and repaired.	Y	Y						
Working at height when welding upper levels of super structure has the potential for injury or fatality if personnel fall from scaffolding. Potential for dropped objects to impact personnel working on lower levels.							Y	Y
Etc.								

Once the scenarios have been identified two steps should be taken. The first is to assess whether the hazard can be eliminated from the design of the facility. If this is not possible then proceed to the next step. This step will involve the use of a search engine for standards which are going to be used in the development of the project. For example, if API standards are to be used the API catalogue can be used. Alternatively, a facility such as IHS or BSOL can be used which also include search for the body of the standard.

In addition to the industrial standards there are likely to be some company standards which are required. These should be added in the same way. Eventually you will land up with a list of standards and scenarios. This is where the information can now be used to build the engineering team. Interview questions can be formulated from the standards requirements.

Using the examples above we can follow this process:

Scenario 1

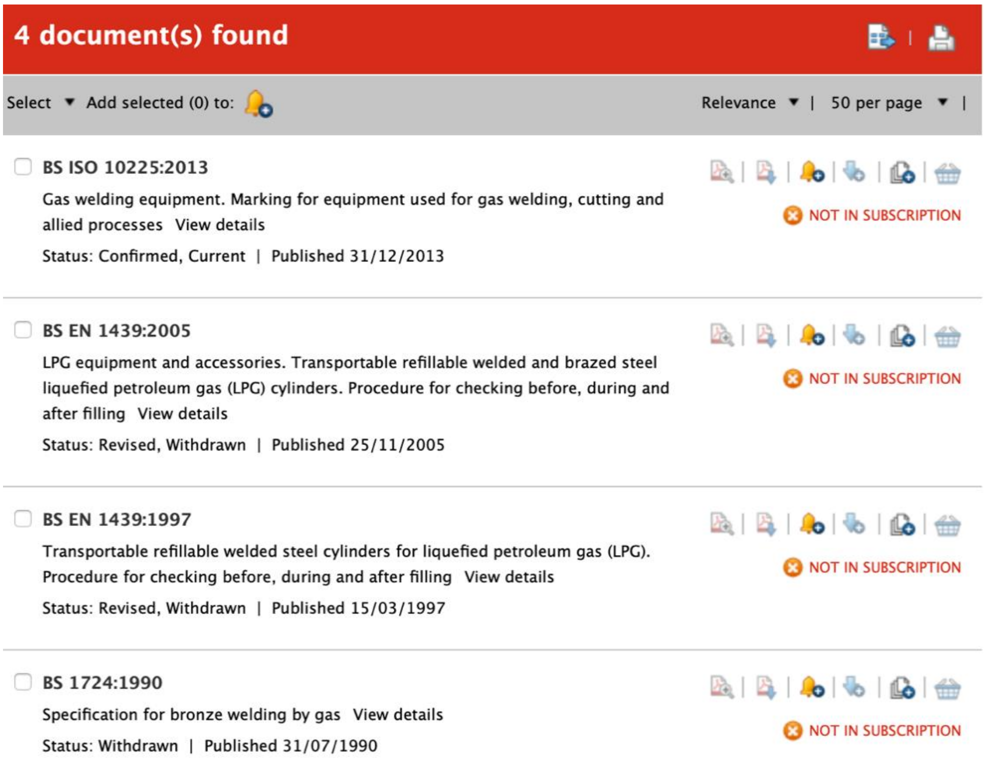
Welding super structure for offshore platform could result in injury or fatality from close contact with hot torch or inappropriate usage or storage of welding gasses.

Can this hazard be eliminated from the design?

Welding is an integral part of how the super structure is to be built and as such this cannot be eliminated. Consultation with the mechanical engineer has identified the potential for elimination of the use of oxy acetylene eliminating the risk associated with acetylene use and storage. Propane will be used instead therefore risks still exist associated with welding gasses.

Which standards could help me?

A search for 'welding propane' has returned the following results. These results are mainly to do with the competence of staff executing the welding which is in line with the risk described in the HRA.



Which interview questions?

The above example has been identified to be realised in the commissioning, construction and decommissioning phases. Therefore, it would be beneficial to ensure that one of the engineers is familiar with welding practices (limitations on sheet size, mechanical stresses during welding etc.) so as to allow minimisation of welding during these project phases. The main roles which will be responsible for effective implementation of the mitigations in these standards would be supervisors, HSE champions, quality assurance and the welders themselves. Therefore, the following questions could be used based on the list above:

- Supervisor: Which standard could be used to help manage the risk associated with propane welding? *Note only one standard is active BS ISO 10225:2013*
- Welder: Can you show me or talk me through some of the checks that you would complete on a propane torch before using it?
  Note: Not knowing the answer to the question does not mean you shouldn't ask it as you may be able to tell from the body language or the confidence in the answer if the person is experienced. Also, when interviewing a trades person you are likely to have the supervisor already on board who will have the knowledge as to whether the answer is correct. You asking this question rather than the

supervisor sends a message that the supervisor can't pull the wool over your eyes and safety is important, reinforcing the efforts you have made on your process safety management.

Scenario 2

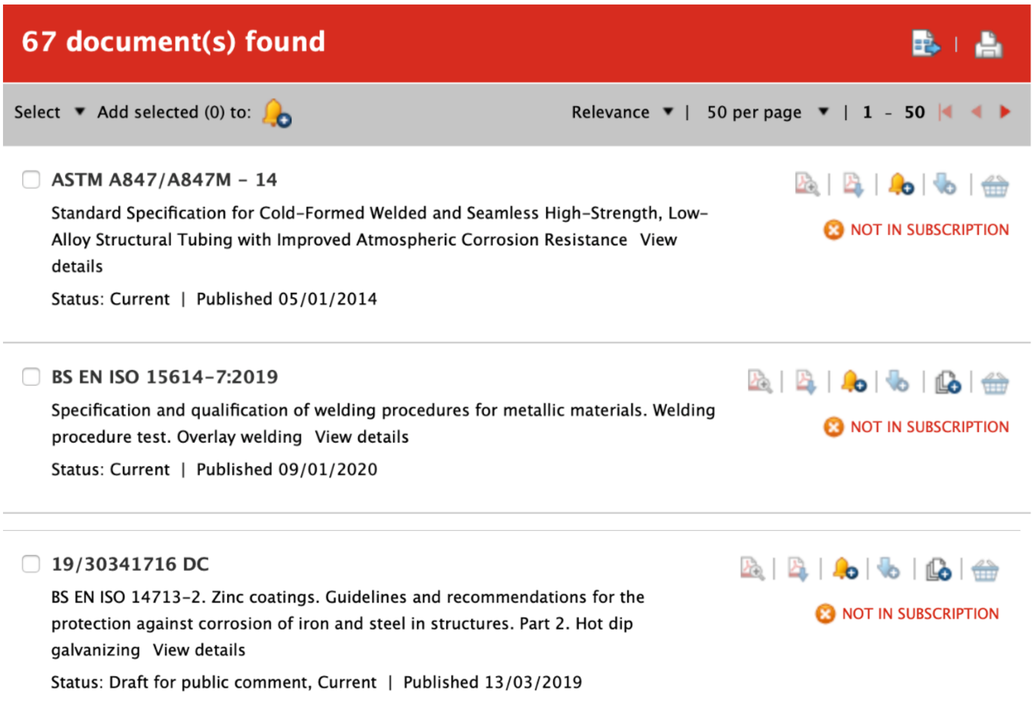
Poor quality welding due to unavailability of competent welders or required quality materials leading to unrevealed flaws in weld metallurgy. Preferential corrosion at weld leading to loss of containment with the potential for fire, explosion (if release in congested area) and in worst case 15 fatalities due to close proximity of office building to pipeline.

Can this hazard be eliminated from the design?

Welding is an integral part of how a facility is to be built from the superstructure to the actual facility. Even if flanged joints are to be used the flanges will have to be welded to the pipework so this hazard cannot be eliminated.

Which standards could help me?

A search for 'weld' returned over 2000 results so in this case I refined the search for 'weld corrosion' which returned only 121. I further refined the results for the ones which are currently active which resulted in 67 standards being listed. For the purposes of the exercise I have made some snips below:



ASTM B757 - 00(2016)
Standard Specification for Nickel-Chromium-Molybdenum-Tungsten-Alloys (UNS N06110) Welded Pipe View details
Status: Current | Published 01/06/2016
NOT IN SUBSCRIPTION

ASTM B804 - 02(2018)
Standard Specification for UNS N08367 and UNS N08926 Welded Pipe View details
Status: Current | Published 01/11/2018
NOT IN SUBSCRIPTION

ASTM B516 - 18
Standard Specification for Welded Nickel-Chromium-Aluminum Alloy (UNS N06699) and Nickel-Chromium-Iron Alloy (UNS N06600, UNS N06601, UNS N06603, UNS N06025, UNS N06045, UNS N06690, and UNS N06693) Tubes View details
Status: Current | Published 01/11/2018
NOT IN SUBSCRIPTION

ASTM B675 - 02(2018)
Standard Specification for UNS N08367 Welded Pipe View details
Status: Current | Published 01/11/2018
NOT IN SUBSCRIPTION

BS EN ISO 28319:2018
Dentistry. Laser welding and filler materials View details
Status: Current | Published 05/06/2018
NOT IN SUBSCRIPTION

BS EN ISO 12944-3:2017
Paints and varnishes. Corrosion protection of steel structures by protective paint systems. Design considerations View details
Status: Current | Published 12/01/2018
NOT IN SUBSCRIPTION

BS EN ISO 14713-1:2017
Zinc coatings. Guidelines and recommendations for the protection against corrosion of iron and steel in structures. General principles of design and corrosion resistance View details
Status: Current | Published 06/07/2017
NOT IN SUBSCRIPTION

Which interview questions?

The above example has been identified to be realised in the commissioning, operation and decommissioning phases, that is when hydrocarbons are present in the facility. This risk is related to two items. The first being welding quality and the second being the potential for utilising the incorrect materials for the metal being welded. The main roles which will be responsible for effective implementation of the mitigations in these standards would be mechanical static engineers, inspection engineers, supervisors, HSE champions and the welders themselves. Therefore, the following questions could be used based on the list above:

- Mechanical Engineer: For the materials normally used in a plant of this nature which welding types or methods would you utilise and why?
  Note: from the standard list it can be seen that there are special processes for various Nickel based alloys, considering that there is mention of welding in the question I would expect the respondent to mention some of the specialty regarding these alloys and if they will be used.
- Inspector: We are welding on several different alloy types including some nickel-based alloys can you walk me through some of the inspection (destructive and non-destructive) methods you may employ and some of the particular care you need to take when completing these tasks?
  Note: Not knowing the answer to the question does not mean you shouldn't ask it as you may be able to tell from the body language or the confidence in the answer if the person is experienced. Also, when interviewing a trade person you are likely to have the mechanical engineer already on board who will have the knowledge as to whether the answer is correct.

It is important to differentiate between knowledge and application of a standard. Often engineers are aware that a standard exists however they are not aware of the content of the standard, the challenges or dilemmas of using the standard or of the interpretation of the standard which is in line with industry best practice. This can lead to over engineering as well as under engineering. That is why asking scenario-based questions in the interview will prove invaluable to allow you to determine the level of competence in the team. Note that identification of a gap of knowledge in an otherwise good candidate should not preclude them from being hired however it should inform their development plan to allow them to best support the project. There are many industrial and internal qualifications which may lead you to believe that the person you are hiring is sufficiently competent to do the role however upon closer examination of the qualifications one would understand that these qualifications are based on the application of engineering principles not on the application of specific standards. There are some exceptions such as the CFSP and the CFSE qualifications which specifically qualify a person in a specific industrial standard (in this case BS EN 61511 and 61508 or other as is specified by their qualifications). However, the other qualifications such as Chartership do mean that the engineers will operate to a certain code of conduct which includes knowing when to ask for help and how to search and apply new standards. Therefore, these qualifications should be valued in the CVs of engineers especially those who are applying for team leader or assurance roles.

You may get to the end of your exercise and think I don’t need a technical or process safety engineer as it is all covered by discipline engineers. This unfortunately is where the above system will need some refinement as 90% of the responsibility of the technical safety engineer is with mitigative measures. Many of these mitigative measures will not be specified in the discipline documents or standards. For example, when designing a vessel the requirement for fire and gas detection may not be present in the standard however it may be best practice in your industry. In addition, the technical safety engineer is instrumental in ensuring the hazard reviews for your project go smoothly and have the correct competence.

Table 2: Example table of the mapping of competencies to scenarios to allow identification of gaps in the engineering design team.

	Scenario 1	Scenario 2	Scenario 3		Scenario 4
Competencies	Welding for the purposes of minimisation	Welding requirements considering different metallurgy	Overpressure protection	Fire protection (drainage and isolation)	Working at height minimisation through construction competence
Team					
Mechanical Static		X			
Rotating	X	X			
Instruments			X (Inst)		
Process			X (Calc)		
Process Safety			X (Scenario ID)	X	
Electrical				X (Ignition Control)	

Standards can be split by departments and at the end of team assembly gaps can be identified in standard knowledge. In the above example you can see that some competencies are found in surprising places such as the mechanical rotating engineer has some understanding of welding which is not typical. Also from the table it can be seen that there is a competence gap in working at height in your engineering team. In this case industry standard training could be employed for the team or a single team member, a specialist could be brought in for an awareness session and then later assurance on the completed work or a new vacancy can be created in the team specifically to close the gap on that area of expertise. When completing workshops if you have identified that the team only have knowledge of a standard and have not previously applied it you can make sure workshop facilitators carry certain competencies or specialists are invited to these critical reviews. In some cases, the team will be an engineering contractor team with client personnel embedded in the team. This systematic application will allow identification of the client expertise needed to compliment the engineering contractor team and it can also help target the tender process.

The information gathered from the assessment can also tell you when you need certain expertise. If the expertise is required in an operation or commissioning it is likely that this expertise will be required in your design team. If the expertise is required in the construction team it can also be helpful to have this expertise in the design team or at least in key reviews in preparation of the construction work scopes.

In all projects it is worth having decommissioning in mind at design however with the acknowledgement that the facility will likely change in the 20 - 40 year life which may potentially impact this. However, if there are special high potential risks in decommissioning it would be worth alerting the team in the design phase so that these can be mitigated or minimised. Note that some of the decommissioning risks will actually be present in the life of the facility. For example, if there are large volumes of fluids in the facility during a turn around these will have to be evacuated to allow for inspections. These risks are the same during maintenance and inspection as during decommissioning.

Stage B – Detailed Design:

All the groundwork will have been completed in Stage A and hopefully you now have a team well equipped to deal with designing your facilities. However, as we all know teams are not static and our initial assessment can be incorrect. Therefore, the matrix developed in Stage A should be revisited regularly, I would recommend at 25%, 50%, 75% and 100% design levels. It is important to maintain the competence to the end of the engineering phase as this is where minor changes to the design may happen and it may undermine the safeguards put in place by the original team. This is also when final assurance takes place which means if the expertise has already departed there is no assurance that the correct standards have been applied to mitigate the risks however this can be mitigated in an effective handover.

Stage C – Installation, Commissioning and Validation:

Many standards actually have requirements for installation and commissioning, and it is important that these requirements have been built into the procedures by the design engineers and that someone who is competent will be able to review the completion of these tasks to mitigate the risks. The potential issues can be for example installation of pressure gauges on a low-pressure trip with non-return valves in the assembly. Thereby rendering the safeguard ineffective in the event of low pressure as the pressure transmitters would be unable to detect the drop in pressure only pressure rise. Another example could be that incorrect gaskets could be installed on a specialised service (for example on an oxygen or oxygen scavenger service) leading to loss of containment within the early life of the facility. Many commissioning and installation errors can remain unrevealed for many years however could cause persistent operating issues. For example, if a heat exchanger was a long lead item and the tube sheet was to be constructed of a certain metal alloy. Actually, this specific alloy was a particularly long lead time and a very similar alloy was available with a shorter lead time. This change was made during the procurement phase to shorten the schedule but not properly assessed. Although the integrity of the exchanger was not compromised the heat transfer coefficient of the new alloy was significantly lower than that of the preferred one and therefore during operation it was never possible to achieve the heat transfer required to ensure the unit operated in optimum conditions leading to significant solvent losses, foaming and enhanced corrosion in other units due to elevated temperatures of operation. This stage is often seen as important however in terms of the initial ‘first oil’ not in terms of the full life of the facility, this is seen to be taken care of by the design and then the subsequent maintenance and operations teams.

Stage D – Operation, Maintenance and Modification:

The design is completed now and so we just need a process engineer, an instrument engineer and a mechanical static engineer right? Well yes and no, again the competence of the team and how they complement each other are critical in ensuring that operations remain within the design envelopes of the equipment and that modifications are completed in compliance with current standards taking into account the original design. Therefore, the matrix developed in stage A (potentially updated after the main HAZOP and any additional HAZID studies) should be used to create the engineering operations team. The team obviously do not need deep application knowledge that was required during design however they need to understand the principles of the standards, the basic contents and when they may be applied. Ideally the design engineers from the project could travel with the facility however it is highly unlikely they will be present for the duration of the life (especially if life is extended to 40 years as many facilities are lately). Therefore, this competence framework should be kept live with training and development requirements built into the teams’ plan. This may be most important at the first 5 year mark when most likely the original operation team change over to a new team. The other part which is often missing in the changeover of personnel is a clear communication of the risks which that engineer manages and how they are currently mitigated. In many cases the outgoing engineer leaves before the new engineer starts. This competency framework can help the engineering or facility manager make sure that the pertinent information is handed over from one party to another even if this is in a written handover document.

Stage E – Decommissioning:

This stage is normally treated as a project in itself. That is, it actually starts off with its own Stage A. If this is not the case the matrix to build the team can be used from the original project Stage A however unless the life of the facility was very short with very few modifications this is unlikely to be sufficiently comprehensive to build the entire team.

Conclusion

With some work utilising the output of the hazard risk assessment the key risks can be used to allow identification of the key personnel with the correct competencies for the job at hand. If they cannot be sourced, then the methodology in this article allow for the identification of gaps in individuals or the entire team allowing structured mitigations to be put in place. This information can be used for personnel change within the early phases of the project as well as during the operations phase. The information gathered in this approach can also be used to inform handover protocols between engineers to ensure that the management of the key risks is consistent and constant throughout the lifetime of the facility.

References

PD CLC IEC/TR 61511, 2019, Functional safety – Safety instrumented systems for the process industry sector, *BSI Standards Publication*, all volumes.

PD CLC IEC/TR 61508, 2019, Functional safety pf electrical/electronic/programmable electronic safety-related systems, *BSI Standards Publication*, all volumes.