Development of a Task Analysis Programme Addressing Safety Critical Tasks at INEOS ChlorVinyls, Runcorn Site

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For many years management of process safety risks at INEOS ChlorVinyls, Runcorn, UK focused on the highest standards of engineered protection, supported by periodic hazard reviews, instrumented protection reviews, etc. However it was recognized that further reduction in process safety risk required application of a similarly rigorous approach to risks resulting from human error. The aim was to identify those errors that could result in process safety consequences, and implement safeguards which reduced the possibility, probability or exposure to such errors.

In 2011, a review of best UK practice, for identifying, reviewing and categorising 'critical tasks' was completed and a model approach identified. A pilot study was conducted on 'identification of critical tasks', using a structured 'brainstorm' approach analogous to Hazard Study 2/ HAZID, and 'task analysis' using Hierarchical Task Analysis and Human Hazop (SHERPA) in 2011 and rolled out in 2012 by an in-house team comprising operating and engineering staff from the plants, facilitated by experienced members of the Site SHE Team. The methodology and example analyses were submitted to UK HSE for review and comment to ensure the methodology delivered both site internal requirements and the regulator's expectation. These studies were supplemented by a 'top down' review of maintenance activities and consideration of a generic list of 'high risk' tasks derived from a review of worldwide process safety incident investigations, provided by HSE. The resulting list of critical tasks was converted to a 5 year program of tasks for more detailed analysis.

This paper presents the methodology used and its application. Synergies with other site initiatives on improvement to operating procedures and compliance and on use of human error analysis within incident investigation are indicated.

Keywords : Task Analysis, SHERPA, Safety Critical Task

Introduction

INEOS ChlorVinyls, Runcorn Site, UK is a large complex manufacturing chlorine, chlorinated methanes and ethylene dichloride for PVC manufacture. It is a 'top tier' COMAH site, which was under ICI ownership before INEOS acquisition in 2001.

Historic Approach to Human Error Management

Engineering

For many years management of process safety risks at Runcorn Site has focused on the highest standards of engineered protection. The possibility of human error resulting in process safety consequences was recognized within the hazard management (predominantly Hazards Study) processes and engineering protection was often provided to 'design out' the risk. Hazard Analysis (quantification) also considered the potential for human error for specific high risk scenarios, generally at the time of new plant design or major upgrade. Periodic retrospective hazard reviews of existing plant applied a Hazards Study based approach focused on process safeguards. Within these studies human error is often considered as causal to scenarios, however risk controls specified are generally hardware. Where identified as necessary, the definition of procedural controls was generally delegated to the commissioning or plant operating team. As a result errors not directly on the engineering line diagram (e.g. during maintenance work, sampling, tanker operations) could take a lower profile.

Upgrade of traditional control rooms to DCS and relocation of some control rooms to a 'Central Control Room' had also enabled Human Interfaces to be redesigned to reduce the risk of Human Error.

More recently the implementation of IEC61511 required the retrospective reassessment of instrumented protection. The methodology considered Human Error both as an initiator of a hazardous event, and where operator response to alarm comprises the instrumented protection system. However the approach took the Human Error to be a fact rather than seeking ways to minimize it.

Historic Approach to Critical Procedures

In parallel with the 'Engineering Approach' outlined above, the site had long recognized that failure to comply with some 'Operating Procedures' could result in process safety consequences. These were designated 'critical procedures' and attracted specific training, validation and refresher training requirements. The consequence of failure defining a procedure as 'critical' was aligned with that for 'registration' of an item of engineering equipment within the site formal integrity management processes. Unfortunately the 'critical operating procedures' approach had some problems:

- where a procedure included a 'critical' step, the whole procedure was designated 'critical'
- within more hazardous plants, a large proportion of operating procedures were designated 'critical'.

This resulted in a lack of focus on truly 'critical' steps, and an unrealistic training load on operating teams.

A More Rigorous Approach

A more rigorous approach to identifying critical procedures had been attempted in one plant area some years previously. This required all tasks to be listed and then reviewed to assign criticality. The work was quickly abandoned when hundreds of tasks were identified, and review work became painfully slow with little perceived value.

In 2010/11 regulatory inspections by Human Factors specialists, aligned with the HSE guidance (ref 1) supported a growing realization that although the engineering approach to Human Error was strong, a more robust people centred approach was required, specifically because :

- further reduction in process safety risk required an approach of similar rigor to that used in engineering design.
- An overhaul of the previous arrangements for Critical Procedures was required to improve focus of the system on those errors that could result in severe process safety consequences.
- HSE required a rigorous, demonstrable approach for site COMAH demonstrations.

The aim was that future arrangements would focus on those errors that could result in severe process safety consequences, and implement safeguards which reduced the possibility, probability or exposure to such errors.

In Search of a Methodology

In 2011, a review of UK practice, for 'task analysis' was completed through discussion with other INEOS UK Sites with a different company heritage (BP rather than ICI) and review of published literature including Refs 2 & 3, with the aim of selecting a methodology for retrospective application at Runcorn. Criteria applied were:

- the methodology should not be too resource intensive, as this would limit the ability to apply it across all plant areas
- a good fit was needed with existing process safety engineering methodologies to allow efficient implementation, and ready understanding and acceptance by the management, technical and engineering teams
- facilitation should be possible by on site personnel, who were practiced in process safety engineering methodologies and /or generally educated in Human Factors, but not require Human Factors Specialists
- the approach should be proven on another site, and have been shared with regulators, to enable a 'fast track' implementation with high confidence of success

A methodology developed at INEOS Grangemouth Site by in-house Human Factors specialists there, was identified as most suitable. Early studies had been completed on site, the regulator had reviewed them and the methodology generally aligned with the just published EI guidance (ref 2) and ref 3. Moreover proformas, training materials and software was readily available and Grangemouth staff agreed to an ongoing 'experience sharing' forum with Runcorn. An overview of the approach is shown in Figure 1.

It was agreed with site senior management, to trial implement the methodology at Runcorn, and share early output with Specialists in HSE before rollout across site

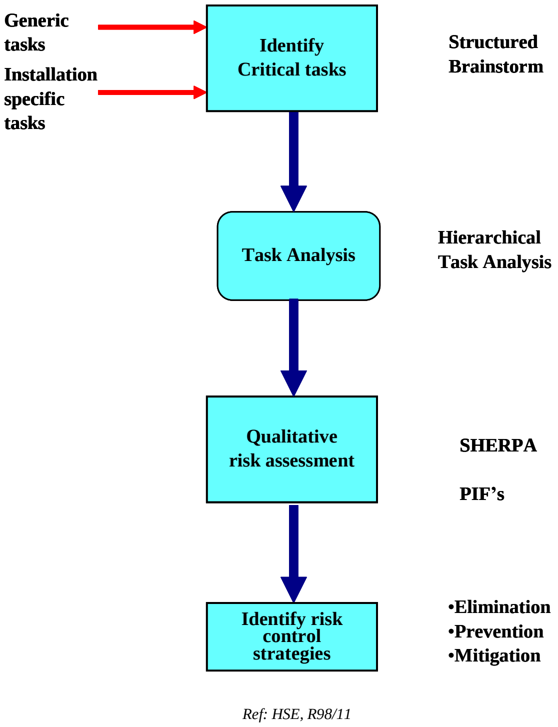
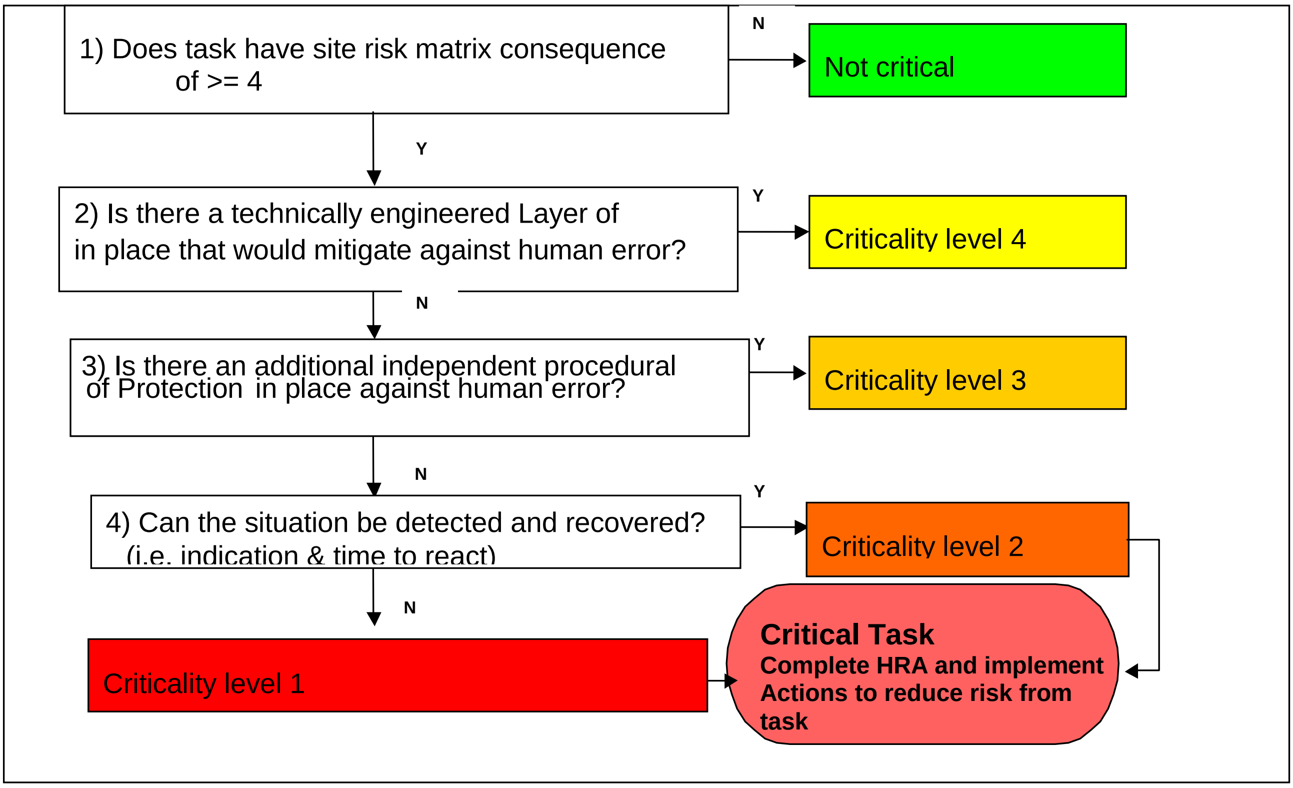


Figure 1 : Task Analysis Methodology (after Ref 3)

Overview of Methodology

Identifying Critical Tasks

Trial applications in 2011 were conducted by site personnel facilitated by a Site Process Safety specialist. A structured brainstorm process modeled on Hazards Study 2/ HAZID was applied to each unit of each plant in turn to identify tasks where error could result in consequences of site severity category 4 or higher (approximately equates to fatality, multiple severe injury, MATTE or worse).



The team identified potentially critical tasks and used a simple decision tree to assign a criticality score (Figure 2) by considering the engineering and procedural controls already in place to prevent a hazardous outcome resulting from the error. Results were recorded in an Excel spreadsheet (Table 1)

Figure 2 : Definition of Criticality During Task Identification

Task	what could go wrong?	Consequenc e Category	consequenc e comments	opportunity to detect & recover from situation?	operator/pro cedural mitigation?	engineering mitigation?	initial criticality	intervention ?	Frequency task is performed	priority f act
VCM storage and pipework										
Preparation for maintenance	- inadequate isolation - inadequate draining/ venting/ purging - inadequate sampling/ testing for breakin	4	Cat 4 Major loss of VCM resulting in fire/ explosion	Limited Retighten bolts, good maintenance practice for breakins, training	no SAF01 checks and check sheets sheet, signed off by team leader but he is not independent	no	2	work control sheets being implemented on PVC8	1 or 2 times/yr, normally during overhauls. Generally pump turnrounds outside overhauls	H
Preparation for maintenance	breakin to wrong equipment	4	Cat 4 Major loss of VCM resulting in fire/ explosion	LImited Retighten bolts, good maintenance	PTW site visit Defect tagging (limited value)	no	3	PTW auditing on plant		
Transfer of VCM to PVC8 from VC3	Not responding to alarm during transfer ;	1	Cat 1 results in overfill of VCM tank on PVC8 - no loss of containment as tank cannot be overpressurised			Several layers of hardwired trips If testing of high level trip requires management	4			
Transfer of VCM to semitech from VC3	Not responding to alarm during transfer ;	4	Cat 4 results in overfill of VCM tank on semitech, can overpressurise tank resulting in failure, with major fire/ explosion	yes operator present at tank during transfer - local emergency stop provided	no	high level trip on tank trips the VCM pump	4			

Table 1 : Example Output from Task Identification Brainstorm Study

The list of critical tasks identified by the brainstorm process above was supplemented by a 'top down' consideration of a generic list of 'high risk' tasks derived from a review of worldwide process safety incident investigations (Table 2).

The HSE (ref 6) was asked to provide illustrative examples of tasks that are generally considered COMAH-critical. Whilst the following list is not exhaustive, and is not necessarily aligned with activities on a specific site, the tasks listed below may help further define the scope for wider implementation:

- process start-up / shut-down (planned and unplanned);
- preparation for intrusive maintenance (including validation of arrangements for safe isolation of plant and equipment and interface with the PTW system);
- conducting an intrusive maintenance task (e.g. repair / replacement of a safety-critical valve), especially when working on a 'live' system; any analysis should explore the effectiveness of associated risk control systems (e.g. measures to prevent moisture ingress; making and proving critical joints);
- returning a system to service following maintenance, including effective integration with other risk control systems (PTW; handback and commissioning; physical line-walking; shift handover; etc.);
- manual charging of an exothermic batch reactor;
- road-tanker loading / unloading (especially toxic and flammable gases);
- bulk tank-to-tank transfers (especially where there is potential for simultaneous filling and discharge, and where there is high reliance on continuous monitoring from a control room);
- manual drum or cylinder filling;
- pigging operations (or equivalent inspection / cleaning / removing blockages in pipelines);
- re-calibration of safety-critical instrumentation;
- inspection and functionality testing of safety-critical trips (with a particular focus on re-instatement to service);
- draining water and other impurities from the base of bulk storage tanks; product sampling;
- operator response to process upset and abnormal conditions (including any diagnosis, planning and action in response to a safety-critical process alarm and relevant follow-up activities);
- first-line emergency response to specific, high-consequence MAH scenarios (e.g. initial response to gas detection alarms; operation of manual valves and manual shut-down systems; operation of 'pen-stock' valves to prevent escalation of a MATTE; availability and usability of emergency PPE and associated emergency equipment; safety-critical communication).

Table 2 : Generic List of COMAH Critical Tasks

Hierarchical Task Analysis

Where a task was considered to be 'criticality 1 or 2' it was prioritized for inclusion in the site 5 year program for more detailed analysis. The first stage of this analysis is to dissemble the task into sub-steps, known as hierarchical task analysis – see 3.3 below.

SHERPA (Systematic Human Error Reduction and Prediction Approach), Ref 4

The application of this 'HAZOP' type review uses error specific guidewords to identify the steps within a critical tasks which are vulnerable to error and the type of possible error. Identifying the type of error (figure 3) that could occur is key to defining the strategy for avoiding that error. A standard proforma (example as Table 3) and keyword list (Table 4) was used.

Task Step	Task	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
1.2.1	Tanker positioned on the designated weighbridge	A6 Misalign	Tanker not positioned on weighbridge correctly - part not on bridge	weighbridge would read below tare weight, and computer would prevent filling	move tanker so on bridge properly	L	M	
		A6 Misalign	Some tankers are only compatable with some of the bridges	tanker would foul steelwork and then the loading gantry could not be lowered	Move to correct bridge	L	L	
1.2.2	Driver to activate the air brakes on the tanker from the Ermeto control box, disabling any free movement of the tanker throughout the loading procedure	A9 Operation omitted	Driver fails to operator lever in ermeto control box	None - air supply to open ermeto valves cannot be fitted without activating the brake lever - operator would complete this action	Operator completes this action instead of driver	L	L	
1.2.3	Operator to take the drivers ignition keys and place into the key box in the control room	A9 Operation omitted	Operator doesn't take keys or fails to put them in the key box	If driver retains the keys, then this removes one of a number of layers of defence against driveaway whilst connected. Main risk would be of driver moving vehicle too early at end of filling, but even then the procedure requires the ermeto lever to be the last thing moved	Operator takes keys at a later stage	L	L	
1.2.4	Operator to check the position of the tanker on the weighbridge and that the loading platform can be lowered without fouling the tanker. Check the wheels are square on the bridge and the back of the	C1 Check omitted	Operator fails to do check			L	M	
		A6 Misalign	Operator doesn't do check properly - as 1.2.1	as 1.2.1- During filling potentially tanker could foul fixed steelwork and weight would not increase as chlroine was filled into it. Potential to overfill the tanker. Would fill into the vent which would trip the liquid in vents detector and SD valves	Would be detected by Weighbridge filling program which would trip the SD valves	L	M	

Table 3 : Example output from SHERPA Analysis

Classification of Human Failures			
Action Errors		**Information retrieval errors**	
	A1 Operation too long/short		R1 Information not obtained
	A2 Operation mistimed		R2 Wrong information obtained
	A3 Operation in wrong direction		R3 Information retrieval incomplete
	A4 Operation too little/too much		R4 Information incorrectly interpreted
	A5 Operation too fast/too slow		
	A6 Misalign	**Information Communication Errors**	
	A7 Right operation on wrong object		I1 Information not communicated
	A8 Wrong operation on right object		I2 Wrong information communicated
	A9 Operation omitted		I3 Information communication incomplete
	A10 Operation incomplete		I4 Information communication unclear
	A11 Operation too early/late		
		Planning Errors	
Checking Errors			P1 Plan Omitted
	C1 Check omitted		P2 Plan incorrect
	C2 Check incomplete		
	C3 Right check on wrong object	**Violations**	
	C4 Wrong check on right object		V1 Deliberate action
	C5 Check too early/late		

Table 4 : Error Guidewords Used in SHERPA Studies

Review of Performance Influencing Factors (PIFs)

HSE publish a list of PIFs (ref 5). A simple proforma was developed for use by the analysis team, immediately after the SHERPA review, to pick up more general human factors issues which might not be identified in the more detailed SHERPA review.

Identification of Error Management Strategies

An understanding of the types of errors (figure 3) during the SHERPA analysis, and discussion on PIFs enabled the team to readily identify error reducing strategies focused on the steps within each task where error had been scored as highest consequence.

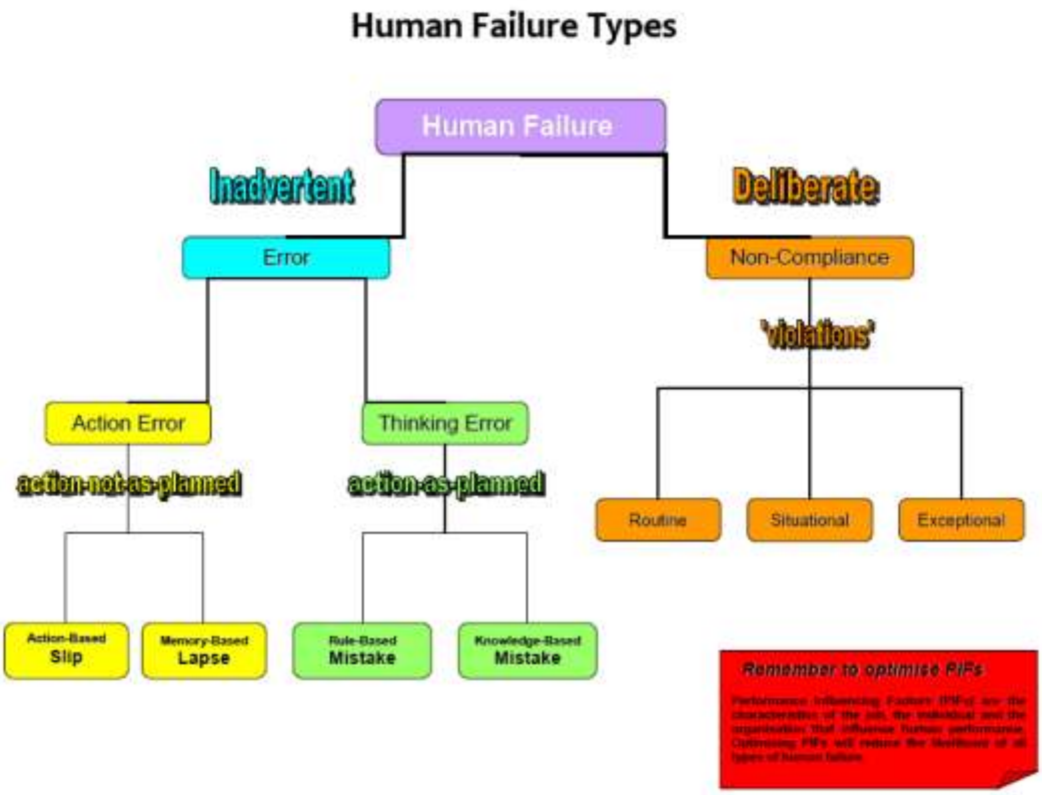


Figure 3: Human Failure Types – courtesy HSE ref 4

Experience from Implementation

Critical Task Identification Brainstorm

Team composition and preparation were key to success with the approach, in particular the involvement of a multi-disciplinary team of Operations, M, EI Engineering, Technical personnel with substantial personal experience of the plant under review.

Technicians bring detailed practical knowledge and experience. However this can lead them to want to work issues at a detailed level. The facilitator needs to ensure that the team does not get bogged down in excessively detailed discussion of each task, but considers it sufficiently to assign scores.

Preparation of the team was important. A short introductory presentation refreshing members in the approach to be used and error types was used ahead of the actual analysis session. This enabled the facilitator to agree in detail what preparation material was required and who would produce it.

Inputs to the review were a general unit description, engineering line diagrams, lists of tasks previously considered critical in operating instructions, critical alarms identified in SIL studies, operator actions noted in COMAH safety reports or retrospective process safety reviews

For a number of identified critical tasks, the realization that the task was critical, in the multidisciplinary forum, enabled the team to quickly see opportunities to reduce risk. These included avoidance of the task, provision of simple engineering protections (e.g. DCS interlock), change of operating instructions (e.g. to require blank flanges to be fitted to a drain point). These 'quick wins' were some of the most valuable outcomes of the whole task analysis process, often resulting is a task becoming much less critical than previously assessed. The Facilitator needs to enable the team to explore such opportunities within the review discussions.

Hierachical Task Analysis

The first stage of dissembling the task into sub elements, known as Hierachical Task Analysis, is useful in setting out the steps to be undertaken in a complex task, in advance of SHERPA analysis. A software tool ('The HTA Tool' – Ref 9) was helpful in doing this. The HTA output is also a very useful format for writing an operating instruction if this does not previously exist. However if a detailed stepwise operating instruction is already available the conversion of this to HTA format was found to have limited value, and in these cases was discontinued after early analyses.

Involvement of a person who actually completes the task in preparation of the HTA, or review/ update of the operating instruction to ensure it accurately represents the task as undertaken is essential.

An on plant 'walkthrough' of the task with the HTA/ Operating instruction is necessary before completion of the SHERPA analysis.

SHERPA Analysis

The SHERPA approach considers each step of the task to determine the consequences of error and the possible nature of error. The process can be somewhat painstaking, but the rigor results in high confidence that issues have been identified. As with any 'hazards study' process the facilitator should focus the team's attention on the steps in the task which are most critical, by considering the consequence of error at each step.

PIF Review

The PIF review provides a simple way of ensuring that more general issues relavent to Human Performance/ Error are recorded. In practice almost all issues will have been raised in discussions during earlier stages of the analysis, but may not have been recorded and appropriate actions considered then. The review is best completed immediately after the SHERPA analysis

Maintenance Tasks

Maintenance tasks are often capable of resulting is serious process safety incidents. However risks are normally controlled by non task specific procedures e.g. Isolation, decontamination, permit to work, ignition source control, confined space entry procedures. Specific engineering hardware controls (e.g. process trips, reliefs, etc.) are not generally possible. These procedures are recognized as critical to process safety and procedural controls (e.g. certification of isolation, independent signoff, etc) are included.

Rather than attempting task specific analysis of maintenance tasks, the list of 'critical tasks' from the plant 'task identification' reviews was therefore supplemented by a 'top down' review of maintenance activities. This was completed with experienced engineering and operating managers against a generic list of these tasks, with the aim of identifying any tasks where the absence of independent procedural controls resulted in a highly critical task. The approach provided a useful challenge/ validation of existing arrangements but did not identify any highly critical tasks for further review.

Control Room Tasks

For control room tasks which required a operator to respond to an alarm, only a very few steps need to be analyzed. The HTA/ SHERPA/ PIF process outlined above did not provide an efficient tool in these cases so a questionnaire based on EEMUA201 appendix 4 (Ref 8) was developed and used effectively.

Proof testing of instrumentation

The testing of SIL designated instrumentation was selected as an exemplar task for fully HTA/ SHERPA review. The process was helpful in identifying those arrangements which are most important to safety with this task. These were:

- the availability of a step by step testing procedure which specifically defines the pass/ fail criteria for each element of the test
- the labeling of equipment items on plant/ at back of panel
- the competence of technicians undertaking the tests, both to undertake the test activities and to know where observations were significant and should be escalated to the engineer
- the involvement of 2 persons in the test activity (generally one in control room/ recording and one in the field)
- the oversight of an engineer to assure competence, diligent test completion and guidance on importance of observations made during tests

A related task (the calibration of on line analysis instruments) was also selected for review. For this task the EEMUA201 appendix 4 (ref 8) questionnaire was trialed as a supplement to the full HTA/ SHERPA/ PIF analysis of a related task (testing of SIL rated instrumented protective systems) to avoid unnecessary duplication. It was concluded that most learning could be 'read across' between these tasks, and that the questionnaire was a helpful and efficient tool.

Task Analysis 5 year program (application of learning across similar tasks)

Approximately 70 high criticality tasks capable of COMAH consequences were identified by the brainstorm analysis, and therefore selected for more detailed HTA/SHERPA/PIF analysis. Based on the trial analyses, each of these would take the full team 1 day, with additional preparation and followup work of approximately 1 man day (plus delivery of identified improvement actions). A schedule completing approximately 1 analysis/ month was judged proportionate which will result in completion of all tasks over a 5-6 year period. A plan for year 1 was drawn up based on the following considerations

- an even spread of analyses across plant areas, to ensure wide engagement of site personnel and facilitate the raising of awareness of the risks of human error, and how these can be mitigated
- a spread of task types to maximize early learning, e.g. learning from analysis of a single road tanker loading/offloading task or response to control room alarm task can be rapidly shared across plants ahead of completion of all analyses
- for some identified critical tasks, improvement actions had been identified to reduce their criticality. Effort to reduce criticality was prioritized above effort to complete detailed analysis of tasks
- for some site wide tasks (e.g. testing of SIL instrumentation) a full analysis could be completed in one plant area, and used as the basis for a review based on 'differences' in other plant areas, thereby improving the efficiency of delivery

At the end of year 1, similar considerations enabled preparation of the year 2 program of analyses.

Facilitator Identification and Competence

The facilitator plays a critical role in each of the task identification, and assessment activities outlined above. Demonstrable competence is therefore important.

The task analysis implementation and task identification studies were lead by the authors, who benefit from long site experience in Process Safety and Operations supplemented by Human Factors training within an H&S Management Diploma program and local training by an external provider. Methodology support was provided by Human Factors specialists at INEOS Grangemouth Site.

The roll out of HTA/ SHERPA analysis to identified critical tasks, using the established methodology, required additional facilitation effort. A job profile was developed for this role, an individual identified and a role specific training and mentored experience program defined.

Considerations in defining facilitator competence requirements are:

- How defined the methodology is for the study to be undertaken : an understanding of human error combined with traditional process safety is required for the task identification activities, due to the less structured nature of the reviews, but SHERPA analysis is a much more prescribed process requiring human error focused competencies
- The level of understanding of human error within the plant/ site team : at an early stage of task analysis implementation, the facilitator may have a role in educating and developing understanding of other team members. As other staff become more familiar with human error issues this role diminishes

Synergies with Other Site Initiatives

The task analysis work described above was undertaken in parallel with other review and improvement work aiming to reduce risk. A number of Synergies with other site initiatives added to the benefits from this work, specifically

1. A pre-existing work stream was reviewing operating instructions and moving these to a standardized format on a central database. This work also required the designation of 'critical procedures' to enable robust implementation of the requirements for training/ validation/ revalidation. The task identification work provided a consistent way of defining the 'critical procedures', and confidence that procedures were in place for all critical tasks. The HTA/ SHERPA reviews identified the specific steps in each instruction that were critical and how these could be improved
2. The conditions contributing to human error resulting in injury/ loss of containment incidents on site were examined more systematically, by use of a proforma based on the HSE PIF list (Ref 5) within incident investigations. This approach supported understanding of why errors had occurred and definition of preventative actions within the incident investigation reports.

Conclusions

A methodology for implementing task analysis on a large and complex existing site was defined, making extensive use of published guidance and experiences elsewhere. The approach selected built upon methodologies well established on site for analysis of engineering systems, which enabled rapid understanding and strong buy-in of management, engineering and technical staff.

Leadership of the initiative and facilitation of studies by experienced members of the site SHE team with strong personal credibility helped ensure that studies were efficiently completed with a number of 'quick wins' identified.

Progressive implementation, initially using on site trials leading to a proportionate and achievable program of analysis was key to obtaining management commitment. Additional synergistic benefits to the operating instructions improvement initiative and to the effectiveness of incident investigations helped maintain this support throughout the implementation.

The implementation of task analysis at Runcorn has already resulted in reduction of risks by reducing task criticality and/or improved risk controls for some identified critical tasks, a more systematic approach to identification and management of critical tasks, improved management understanding of human error as a contributor to major accident risk, and appropriately rigorous methodology for Site COMAH report demonstrations.

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