HUMAN FACTORS INTEGRATION FOR A NEW TOP TIER COMAH SITE — OPTIMISING SAFETY AND MEETING LEGISLATIVE REQUIREMENTS

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The successful integration of human factors (HF) into the design, construction and operation of any hazardous installation is essential in order to optimise operability and personal safety. It is also critical for ensuring that the risks of a major accident are as low as reasonably practicable (ALARP). Furthermore, it is a requirement under the COMAH Regulations to identify and address any HF issues for the site.

In September 2002, Atkins Consultants began working with a client to address HF for a new chemical plant being built in the UK. This had been prompted by HF specialists within the HSE who, in reviewing the pre-construction safety report, identified a number of areas where specialist HF input was required. The work Atkins conducted on behalf of the client involved the development and implementation of a human factors integration plan (HFIP) to specify how HF activities would be integrated within the project lifecycle. The areas covered included operator selection and training, control room design, DCS interface assessment, human error analysis, procedure review and workload assessment.

This paper describes HSE's role in assessing and promoting HF for COMAH sites, and details the analyses conducted by Atkins to satisfy the requirement of the regulator, ultimately helping to optimise plant safety. It highlights the advantages of ensuring human factors issues are considered from an early stage in plant design.

HSE & COMAH

THE CONTROL OF MAJOR ACCIDENT HAZARDS REGULATIONS 1999

The main aim of the COMAH Regulations is to prevent and mitigate the effects of those major accidents involving dangerous substances, such as chlorine, liquefied petroleum gas, explosives and arsenic pentoxide which can cause serious damage/harm to people and/or the environment. The COMAH Regulations treat risks to the environment as seriously as those to people. The COMAH Regulations are enforced by a new joint competent authority (CA) consisting of the HSE and the Environment Agency in England and Wales and the HSE and the Scottish Environment Protection Agency in Scotland.

The regulations place duties on the CA to inspect activities subject to COMAH and prohibit the operation of an establishment if there is evidence that measures taken for prevention and mitigation of major accidents are seriously deficient. It also has to examine safety reports and inform operators about the conclusions of its examinations within a reasonable time period.

These regulations mainly affect the chemical industry, but also some storage activities, explosives and nuclear sites and other industries, where threshold quantities of dangerous substances identified in the regulations are kept or used.

The substances which cause the duties to apply are detailed in Schedule 1 of the regulations, as are the quantities which set two thresholds for application. Operators of sites that hold large quantities of dangerous substances ('top tier' sites) are subject to more onerous requirements than those of 'lower tier' sites.

The Regulations include a general duty on operators to take **'all measures necessary'** to prevent major accidents or limit their consequences. The phrase 'all measures necessary' is effectively the same standard as 'so far as is reasonably practicable'. 'All measures necessary' is a new term and applies to both lower tier and top tier establishments. This is general duty on all operators and underpins all the regulations. It is a high standard and applies to all establishments within scope.

Operators should therefore be able to show that they have looked at ways of avoiding the hazards or reducing them at source through the application of the principles of inherent safety. Clearly, it is more likely to be reasonably practicable to take measures to avoid or reduce process hazards at source during the design stage of new plant and equipment and as early as possible during the design process. It is at this stage that assessors need to look for evidence of the use of principles of inherent safety to remove or reduce hazards to people and the environment.

Even so, risks will remain, and the overall demonstration that 'all necessary measures' have been taken should be based on the principle of reducing risk to a level As Low As is Reasonably Practicable (ALARP) for human risks and using the Best Available Technology Not Entailing Excessive Cost (BATNEEC) for environmental risks. This is usually achieved by the adoption of good practice – for example from ACoPs, recognised standards and industry guidance. The ideal should always be, wherever possible, to avoid a hazard altogether.

Furthermore, the regulations require the operator to **demonstrate** to the CA that all necessary measures have been taken to comply with the requirements of the Regulations. There are therefore requirements to take all measures necessary and to demonstrate that this has been done. Operators should therefore be able to demonstrate that they:

- have identified the possible hazards of their operation and;
- have considered options for reducing the risks arising from these hazards.

Inspectors will need to balance what is technically feasible against the costs and benefits of implementing the protective measures, and may need to obtain advice from discipline specialists in making this judgement, particularly in cases where there is no established industry good practice.

SAFETY REPORTS

Top tier COMAH sites must submit a written safety report to the CA. A safety report is a document prepared by the site operator and provides information to demonstrate to the CA that all measures necessary for the prevention and mitigation of major accidents have been taken. The safety report must include:

- a policy on how to prevent and mitigate major accidents;
- a management system for implementing that policy;
- an effective method for identifying any major accidents that might occur;
- measures (such as safe plant and safe operating procedures) to prevent and mitigate major accidents;
- information on the safety precautions built into the plant and equipment when it was designed and constructed;
- details of measures (such as fire-fighting, relief systems and filters) to limit the consequences of any major accident that might occur; and
- information about the emergency plan for the site, which is also used by the local authority in drawing up an off-site emergency plan.

Safety reports are available to the public via the competent authority registers, subject to safeguards for national security, commercial and personal confidentiality.

ASSESSMENT OF SAFETY REPORTS

Assessment of the safety report is part of an overall enforcement strategy for top tier COMAH sites. Information gained from assessing the safety report will be used to inform the inspection plan for a particular operator or a particular establishment. Similarly, information gained from inspection or investigation will be used to inform the safety report assessment.

The COMAH Safety Report Assessment Manual (SRAM) is the primary source of reference. Included in the manual are guiding principles for assessment, procedures to be followed during assessment and criteria for assessment. Assessment of a safety report is by a team of competent assessors from both the HSE and the environment agencies. The assessment process is managed by a nominated Assessment Manager and assessment is against criteria given in the Manual. In assessing a safety report, the CA examines the information in the report and comes to conclusions about whether the purposes of safety reports have been met.

The CA will identify in its assessment conclusions any matters for inclusion in the CA's inspection programme concerning certain installations, parts of installations or activities at an establishment which relate to preventing or controlling a major accident. In completing its conclusions, the CA will prepare inspection plans for COMAH issues to cover the period until the planned date for the completion of the assessment of the next safety report. The inspection plan will be influenced by other factors as well as the conclusions of the assessment team.

Unless there are requests for confidentiality for parts of the safety report, both the safety report and the CA's conclusions are made available to the public.

REQUIREMENTS FOR NEW SITES

Operators planning to build new top tier establishments must submit the part of the safety report relating to design and construction to the CA prior to the start of construction and wait for the CA's response before starting to build safety critical parts of the establishment. The balance of information is submitted before the start of operation using dangerous substances. The combined contents of the Pre-Construction Safety Report (PCSR) and Pre-Operation Safety Report (POSR) will, therefore, contain sufficient information to fulfil the purposes of a safety report submitted by an operator of an existing establishment.

The pre-construction submission should address plant design, construction, and commissioning using non-dangerous substances. The start of operation is taken to be the first time that dangerous substances are introduced into the plant and will include commissioning if dangerous substances, in any quantity, are used at that stage.

The pre-construction submission should focus on 'front-end' design. It should cover conceptual design issues such as selection of process options, dangerous substances, etc. The submission should also identify the major accident scenarios, the philosophy of prevention, control and mitigation, and a demonstration that an effective safety management system will be in place.

The CA will form a judgement on whether all hazards have been identified and, as far as possible, whether adequate safety and reliability have been built into the design with respect to major accident prevention, control and mitigation.

In assessing the elements of a PCSR the CA has an opportunity to influence the design and construction proactively, rather than require changes to installations once they have been constructed. New establishments offer the best opportunity to apply the principles of inherent safety, i.e. the removal or reduction of a hazard at source, from the start of the design process. Once a plant has been built it is difficult retrospectively to apply inherent safety principles except to the design of modifications. An operator cannot commence construction of an establishment until he has received the CA's conclusions on its examination of the PCSR.

At the pre-operation submission stage, the CA will have particular interest in:

- any changes made to the design and construction since the pre-construction submission;
- whether the plant as built and commissioned using non dangerous substances meets the design intent;
- the proposed extent of commissioning using dangerous substances;
- operational systems of prevention, control and mitigation, and management systems to complete the information requirements of a safety report.

An operator cannot start operation of an establishment until he has received the CA's conclusions on its examination of the POSR. If there is evidence of serious deficiency at the pre-operation stage in any of the measures taken, or proposed, for the prevention or mitigation of major accidents, the CA is required by the COMAH Regulations to prohibit operation of those parts of any installation where the measures are seriously deficient.

HSE's ROLE IN ASSESSING HUMAN FACTORS

It is generally now understood that the prevention of major accident hazards depends to a large degree upon managing human performance. It is therefore essential that appropriate consideration is given to human factors.

Human factors have a very wide scope in major hazard work — they are often referred to as 'the thread' that runs through the safety management system, the organisation for safety, and the culture of a site.

Studies have shown that up to 90% of accidents are attributable to some degree to human failures. For many of these major accidents the human failure was not the sole cause but one of a number of causes, including technical and organisational failures, which led to the final outcome. It is also worth noting that the prevention of major accidents depends to a large degree upon human reliability at all COMAH sites, no matter how automated.

HSE expect the parts that people play in protection, prevention, potential initiation, and recovery from major accidents to be addressed with the same degree of rigour that we traditionally expect for process and engineering issues.

Yet to date most COMAH safety reports do not address human factors with any degree of rigour. A common example is that reports include alarms amongst the safety critical control systems described, and tell us how electro-mechanical reliability is assured, but don't address the reliability of the person in the control room without whose effective response the whole system fails.

The Human Factors Team in the Hazardous Installations Directorate (HID) of HSE has carried out a substantial number of field visits and provided associated support for advice and enforcement (including expert witness work) over the last five years. Members of the Human Factors Team are involved in a wide range of activities, including:

- inspecting major hazard sites (oil, chemical and gas),
- assessing safety reports,
- investigating accidents and incidents,
- providing expert testimony on a wide range of human factors issues,
- promoting human factors in the major hazard industries,
- producing guidance for industry,
- training non-specialist HSE inspectors in human factors.

Human factors is often seen as a rather nebulous concept and so it is convenient to unpack the subject into a series of discrete topics. A 'top ten' has emerged from the experience of the Human Factors Team, over a number of years, as those which have most often been raised by Regulatory Inspectors as requiring specialist input. Failures in these areas are also often identified as being important contributory factors in the causes of major accidents. These topics have been accepted by industry as the key ones for which improvements are needed. The topics range from broad, high level issues e.g. staff competence, to those covering detailed specific subjects e.g. fatigue risks and alarm handling.

A CASE STUDY

A company from the Far East (Company X) have built a new top-tier COMAH site located within the boundaries of an existing chemical company. The plant is owned, operated and maintained by Company X, with feedstocks, utilities and services provided by the existing chemical company. The new plant produces chemicals based upon existing technology from facilities in the Far East and the USA. Site hazards include flammable and toxic raw materials/products.

The regulation of this site was complicated by the fact that the company managements' first language was not English and they had little experience of UK major hazard legislation.

The Pre-Construction Safety Report (PCSR) was assessed by a team of mechanical, electrical, process safety and control & instrumentation specialists. The results of the assessment were communicated to the site. Assessment of the pre-construction COMAH Safety Report concluded that human factors had not been considered. The HID Human Factors Team was then contacted to provide the company with advice regarding HSE's expectations on these issues for the Pre-Operation Safety Report (POSR).

The role of the Human Factors Team was to ensure that these issues were considered throughout the project to encourage inherently safety design. The objective was to assist the company in designing-out human performance problems and to increase the likelihood that human failures would be detected. The advantages of considering human factors early in the design are several:

- Changes are easier and cheaper;
- It encourages the awareness of human factors at senior management level;
- The organisation can reduce costs long term by increasing efficiency, improving product quality, reducing absenteeism, and preventing personal injuries and major accidents.

HSE met with the company and their main contractor in order to ensure that human factors were addressed in the pre-operation safety report and onwards. At this meeting, a presentation was provided on 'what HSE expects' and the site were provided with a draft guidance note on human factors in design. Issues that should be considered at this stage include:

- Maintenance of plant and equipment;
- Workload and staffing levels;
- Allocation of function;
- Emergency Shutdown philosophy;
- Control room philosophy;
- Selection and training of operators;
- Inclusion of human factors in risk assessment.

For example, human failures in maintenance can have disastrous consequences and are a significant cause of major accidents. Common problems include replacing components in the wrong order, omitting components; using incorrect replacement components (e.g. grade of oil, gasket, filter) or leaving tools inside equipment.

Maintenance failures can be prevented at an **engineering** level by:

- Reducing the complexity of the plant;
- Making equipment accessible (e.g. not requiring ladder access, ensuring parts to be maintained are front-facing);
- Allowing sufficient working space around equipment;
- Providing sufficient task lighting;
- Designing equipment so that components cannot be incorrectly assembled;
- Making removal of equipment easy (e.g. providing a mechanical aid to make it a one-man job);
- Effective labeling/colour-coding of plant & equipment;
- Standardization of components (filters/gaskets/bolts); Control of spare parts/materials.

Maintenance failures can be prevented at an **human** level by:

- Adequate competence;
- Adequate procedures, instructions and job aids (e.g. diagrams);
- Suitable Permit to Work system.

If it is not feasible to prevent maintenance failure, consideration should be given to increasing the likelihood that failures are detected. This may be achieved by:

- Designing equipment to increase the visibility of breaches (e.g. sight glasses to identify lack of lubrication);
- Supervision and monitoring;
- Auditing.

The HSE approach in this intervention was to be supportive. The site was having to address a wide range of issues for non-specialists in short timescales, with little guidance available on human factors in design. Where appropriate, HSE suggested that expert human factors assistance was required. Rather than stipulate specific controls, HSE required that general principles/goals were to be met — for example, operator competence could be achieved by several means. HSE required the site to demonstrate that the arrangements would ensure and maintain competency and suggestions were provided to assist in this demonstration.

HUMAN FACTORS INTEGRATION

Following the intervention of HSE described above, the site operators contracted Atkins to provide human factors (HF) support to the project. After initial consultation with the client, a Human Factors Integration Plan (HFIP) was developed for the site. HFIPs are routinely used across a wide range of industrial applications as a structured means of demonstrating that the range of relevant HF issues have been identified and considered for major projects. Different sections relate to specific technical areas, commonly including:

- Personnel selection and training to ensure that operators are competent for the range of normal and emergency operational scenarios. This should focus on specific tasks which are critical in terms of safety (e.g. manual activation of ESD system), and for which there may be gaps in competency, particularly for tasks that are infrequently performed.
- Procedure design to ensure procedure content, layout and presentation comply with best practice and thus ensure are able to be used and understood by operators, particularly in relation to safety critical operations.
- Operator workload assessment in order to ensure that sufficient competent personnel are available to undertake routine tasks, and also to respond to minor upsets and major emergencies.
- Workplace (or control room) design. This ensures that operators are positioned such that tasks, particularly those relating to communications, are facilitated. Environmental conditions in the work place are also considered (e.g. lighting, noise and heating), including the environment both within the control room and outside on the plant where critical tasks (e.g. manual isolation) require sufficient lighting for example.
- Workstation layout, specifically the positioning of equipment on and around the workstation to ensure that it is visible and within easy reach of the operators who will use it.
- Workstation design in terms of physical dimension, including seating. This aims to minimise the risk of operator discomfort and related musculo-skeletal problems such as back and shoulder complaints.
- Human-machine interface design, including alarms, to ensure that operators are provided with the appropriate information/displays and controls required to undertake tasks, and that these are presented and laid out in an appropriate manner. This aspect is particularly important for safety critical tasks such as those associated with process upsets, where a good interface is required to support the operator in detecting, diagnosing and responding to process deviations.
- Human error analysis involving the identification and assessment (qualitative and/or quantitative) of potential operator errors that could cause of contribute to a major accident hazard scenario (e.g. maintenance error causing stand-by pump to be unavavilable).
- Shift design and fatigue. It is widely recognised that fatigue can negatively impact upon human performance (see Reference 1 for example), and is often cited as a factor in incident and accidents (e.g. Zeebrugge ferry disaster). Consequently it is necessary to ensure that the risks of fatigue associated with the design of staff rosters is managed adequately.

Depending upon the stage the project is at when the HFIP is developed, details can be provided in terms of what has already been done in terms of HF, along with the information on planned activities. In this case, work was already progressing in some areas, notable personnel selection and training, whereas other areas had not, because of the early stage, been addressed. In consultation with the client, HF activities were agreed, planned and documented in the HFIP. This was included in the Pre-Operational Safety Report (POSR) to provide a useful reference for HSE inspectors reviewing the safety case submission.

Throughout the project, the HFIP served to guide the integration of HF into the project. The basis for the specified analyses was task information. This is essential for any HF analysis since it is not possible to assess the adequacy of equipment design, for example, without an understanding of how the operators are going to use it. In existing operational environments (e.g. existing sites), task information is relatively simple to obtain through observation and discussions with task experts. For this work, however, it was much more difficult to obtain task information because the site was new. In addition, the HF work commenced at an early stage within the project's development when there was only a small number of staff working on site with operational experience. As such there was a high degree of reliance on a limited number of personnel and on information obtained from procedures and site visits to a 'sister' production site in the USA. This meant that the early HF analyses could only be completed at a high level; these became increasingly more detailed as more information became available.

The analyses conducted highlighted a number of HF issues which were able to be resolved with minimal impact on cost and timescales. Some of these are discussed below.

PROCEDURES

Procedures are frequently cited in safety reports as a means of mitigating risks due to human error. Specifically, it is often considered that the likelihood of operator error is minimized by the existence of a procedure specifying how a task should be performed correctly. Of course this assumes that the procedure will be available to the operator, that it will be read, and that the contents will be readily understood. In order to ensure these aspects, it is essential that procedures are designed in line with best practice. In particular:

- The content should be simple, detailing what tasks should be done, how they should be carried out, when they should be done, and who should do them.
- The procedures should be written in simple language that the operators will readily understand.
- The procedures should be laid out so that they are easy to read. If possible, flow diagrams should be used to illustrate task sequences.

In the case of this site, procedures were being developed for commissioning the plant, and also for its operation and maintenance post-commissioning. Given the importance of these procedures, it was necessary to review a sample to identify any HF deficiencies, and so make recommendations for improvements, taking account of accepted standards, guidelines and best practice relating to procedure design. These are summarized below:

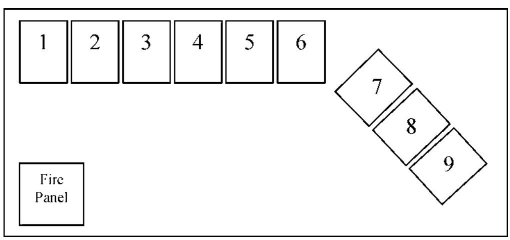
- It was recommended that the procedures should be modified to include diagrams and flow charts where possible to aid navigation through the procedure, particularly where there were numerous steps involved (e.g. preparation for start-up).

- Where levels, set-points and other conditions are specified, the relevant values should be included. An example of where this was not the case was in the commissioning procedure for the steam condensate system, which stated *"Switch the control valve V014B0LC back to automatic control at the pre determined set point"*.
- Where relevant, information on feedback provided by the system at different points should be provided in the procedures.
- All valves and other components that feature in the procedure should be identified by a unique label (as opposed to *"the 24 inch butterfly valve"*).
- Where procedure includes an instruction to check a parameter, instructions should be provided on action to be taken if the parameter is out of range. For example, where the commissioning procedure for the steam condensate system stated *"Check that the pressure gauge P041B0PG is showing a positive value"*, there should have been guidance on what the operator should do if this was not the case.

CONTROL ROOM DESIGN, EQUIPMENT PROVISION AND WORKSTATION LAYOUT

The new site was to be controlled and monitored primarily from a central control room which was to be staffed by 2 operators (Area A operator and Area B operator). In order to optimize performance in the control room (and so minimize risk and optimize safety), it was necessary to review the equipment to be provided to these operators, and assess control room and workstation layout.

It was proposed that a total of 9 workstations would be provided in the control room, as illustrated below.



Consoles 1–6 each housed a DCS system (display and keyboard) which could be configured to suit operator requirements. Console 7 housed a CCTV display and keyboard for controlling this. A second CCTV display (but no keyboard) was to be provided on Console 8. Console 9 was to be used for the hard-wired annunciator display and shutdown controls. The layout was reviewed against human factors best practice (see Reference 2 for example) in order to identify and make recommendations to address any deficiencies.

On initial assessment of this proposal, the location of the CCTVs and annunciator/shutdown controls on one end of the whole array of displays caused concern in terms of availability to both operators. However, from the emerging task information, it was established that the CCTV was only to be used by one operator (Area A) who would be positioned in front of consoles 4–6. In addition, it was confirmed that the annunciator/shutdown panel would not need to be operated within seconds as first thought. This meant that, should the panel need to be operated by the Area B operator (in front of consoles 1–3), the expected delay in this due to the location of the panel did not represent a risk to safety. Consequently the proposed layout was considered acceptable.

However, other deficiencies were identified associated with the console layout and other aspects of the control room. Recommendations to address these were made, some of which are summarised below:

1. There was a lack of spare desk space for administrative tasks. It was recommended that desk space be provided close to each operator for the purposes of writing (e.g. in the log book) and resting reference documents (e.g. procedures). A new blank console was recommended as this could also be used to locate the telephones and radios which were also proposed in the HF review.
2. A single telephone had been proposed for use by both operators. This was not considered adequate as it may compromise effective communications to and from the control room in upset conditions or in an emergency. It was recommended therefore that two telephones be provided. In addition, a separate emergency phone was recommended to allow immediate access to operators in the event of an emergency.
3. Adjustable lighting was to be provided in the control room, and the range of variability was considered to be adequate. However, experience shows that control room operators typically prefer lighting levels to be maintained at a relatively low level in order to facilitate viewing of CCTV and DCS screens, particularly at night. For this reason, additional task lighting was recommended to facilitate reading and writing tasks.
4. Given the lack of detailed task information at the stage of the control room assessment, it was not possible to assess the adequacy of the positioning of the fire panel. Depending on how this was to be used it may have been necessary to relocate it to a position that was more visible and accessible to both operators. Specifically, if the operators were required to monitor the panel visually, the panel needed to be in front of the operators rather than behind them. Similarly, if the panel needed to be operated quickly, it was suggested that the panel should be moved closer to both operators.
5. A standard PC was to be provided for use by the operators in accessing the company's email system. One potential location for this was the control room. However, as this may present problems in terms of distraction, it was recommended that this PC was located elsewhere, providing it did not need to be used in conjunction with equipment in the control room (e.g. DCS).

DCS

The DCS review was an important part of the HFIP and aimed to identify and address human factors deficiencies related to the DCS system used by control room operators. Such deficiencies, if not addressed, can increase the likelihood of error, particularly when operators are under stress. The DCS review involved an assessment of screen shot samples and design specifications, and a review of a prototype system. Where deficiencies were identified, Atkins worked with the DCS designers to resolve the issue. In all cases, operators were consulted on proposed revisions to ensure that user requirements were being met. The main issues arising in the review are discussed below.

Alarms

A common safeguard against a critical event in an accident scenario is operator action, where the operator is prompted to take corrective action after being notified by an alarm. In order for this safeguard to be effective, it is essential that the operator is able to detect and understand the nature of the alarm. Deficiencies in alarm system design have contributed to a number of major accidents, for example Three Mile Island and Texaco Milford Haven (see Reference 3). A common problem is 'alarm flooding', in which a large number of alarms are presented to an operator within a short period of time. In these cases it is difficult for an operator to determine what the root of the problem is, and many of the alarms will be irrelevant. For example, in the case of a site-wide power failure, it is not necessary for the operator to be informed of related (and in most cases expected) sub-system failures.

To avoid alarm flooding, alarms on this site were prioritised according to EEMUA standards (Reference 4), taking account of the severity of events to which the alarms relate. HF advice, based on accepted best practice (see Reference 5 for example) was then used to determine the most appropriate way of representing alarm priority to the operator via the DCS. Specific issues were as follows:

1. Deficiencies were identified in relation to the colours initially proposed to indicate priorities (as detailed below).

Alarm Priority	**Proposed Colour**	**Revised Colour**
Emergency	Red	Red
High	Magenta	Yellow
Low	Yellow	White

   Specifically, it was considered that red and magenta are too similar to enable the operator to differentiate emergency and high alarms, particularly given the importance of alarms in the emergency category. Consequently, the company implemented a revised colour scheme, based on HF advice and operator preferences, but taking account of the constraints within the DCS system in terms of colour availability.
2. Another issue relating to the alarm system concerned the LEDs provided on the keyboard to indicate the presence of an alarm. Despite there being 3 different alarm priorities, only 2 LEDs were available, which flashed to indicate unacknowledged alarms across the process but are otherwise stable. As it was not feasible to modify the keyboard, Atkins were asked how the three priority groups should be grouped. Advice was also sought on the appropriate colours to use for the LEDs. In consultation

with operational personnel, it was agreed that a red LED would be used for emergency and high alarms, with white being used for low priority.

3. A further area of concern related to the indication of unacknowledged alarms. In line with standard practice, these are readily identifiable from the alarms summary page (through the use of flashing indicators). However, if this screen is not displayed on one of the available DCS screens, the only visual indication of an unacknowledged alarm is the flashing LED on the keyboard. Given the criticality of alarm detection, this was considered inadequate. Consequently, as this was a fundamental feature of the DCS system that could not be changed, it was recommended that it be a standard operational policy to have at least one screen displaying the alarm summary permanently.

Symbols and labels

It is good HF practice to ensure that symbols and labels are used consistently and are well presented on the DCS screens (see Reference 6 for guidance in this area). Although most DCS systems use standard symbols for components such as valves and pumps, labelling can be more problematic. Relevant issues for both symbols and labels include size and position relative to item to which they refer. Within this project, recommendations for the DCS system included suggestions to increase font size for labels, and to ensure that they were consistently located. In addition, the following two specific labelling issues were highlighted.

- The proposed means of displaying vessel level (see Figure 1a) was not optimal as it was not possible to determine the level at a glance without reading the label. On the basis of HF advice, the level indication was modified, as shown in Figure 1b.
- A small number of cases of flashing text were identified and subsequently modified. Use of flashing text is not good practice as it means that the information detailed is not visible for some of the time.

Colour

The legibility of information is affected by the use of colour. In particular, it is necessary to ensure sufficient contrast between colours, and the colours used must be meaningful to operators. A relevant consideration for this project was the use of the colour red. In many Far Eastern cultures, red is seen as positive and is not associated with danger.

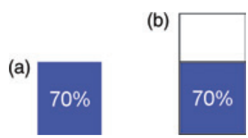


Figure 1.

There were a number of instances where red had been proposed inappropriately on the DCS. Following HF advice, these aspects were re-coloured.

CONCLUSIONS

Within the UK, the COMAH regulations require that top-tier sites produce a safety case to demonstrate that the risks associated with the site are ALARP. This is assessed by the joint Competent Authority who must accept the safety case before construction and operation can commence. Demonstration of the ALARP argument requires consideration of human factors. Despite this requirement, for some companies there can be a reluctance to incorporate HF into major design projects and this can be explained by a number of factors. Although the perceived cost and extended timescales are likely to be partly responsible, there is also a lack of understanding of the benefits provided by HF and a misunderstanding of what is involved and how this impacts on budget and timescales. Some companies have been known to ask 'Why Bother?'.

This paper has demonstrated that in the case of this new UK site, HF input was able to identify potential problems in the design and proposed operation of the plant that could have compromised safety and process efficiency. Because HF input was integrated from a relatively early stage in the design process, the company was able to address these issues and implement recommended design changes. Had these requirements not been identified until later in the project, they may have been prohibitively costly, or unachievable within the project timescales.

The work was accepted by the Health & Safety Executive as part of the POSR, enabling the plant to be commissioned according to plan. It is concluded, therefore, that if initiated early enough within a project lifecycle, HF is a key discipline for new builds within the major hazards industries. It should be noted, however, that HF input can also be used to provide added value to existing sites. Because of this, HSE is actively promoting HF within these sectors and aims to ensure interventions are educational, positive and supportive.

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