

IMPROVING HUMAN FACTORS AND SAFETY IN THE PROCESS INDUSTRIES: 'THE PRISM PROJECT'

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SYNOPSIS

To assist the process industries in improving both its understanding of and application of human factors the European Process Safety Centre has taken the initiative in creating PRISM. This is a 'Thematic Network' which aims to create an extensive European forum within which industry, universities, research centres and practitioners can collaborate to improve the flow of practical experience and fundamental knowledge in human factors. The network has been established with financial support from the European Union Department for Research and Development under its Programme for Competitive and Sustainable Growth.

The network, which started in 2001, will last for 3 years and already has the support of organisations from 14 countries in Europe. These include many major chemical producers as well as universities and research organisations. It also has support from the European Union Joint Research Centre, from CEFIC as part of its 'Sustech' programme and from the Health and Safety Executive (UK). It is being co-ordinated by the European Process Safety Centre with support from The Institution of Chemical Engineers.

Since Human Factors is a very broad field four separate 'Focus Groups' have been established within the network covering

- Cultural and organisational factors
- Optimising human performance
- Human factors in high demand situations
- Human factors as part of the engineering design process

Each of the focus groups has already held a seminar and more are planned. In addition they will produce guidance aimed at meeting industrial needs, all of which will be made available on the Internet.

This paper provides a mid-term review of PRISM, describing what is available and how organisations can gain from and participate in its future activities.

Safety, Human Factors, Emergencies, Safety Culture, Alarms.

INTRODUCTION

It is well known that human factors play an important part in most if not all accidents. This can be seen in both the simplest accidents and in those that involve more complex technical interactions. It is also clear that the adoption of the attitude of 'blame the operator' will fail to lead to improvements in safety and will result in the true causes of accidents, for example the pressures which lead operators and others to make mistakes, never coming to light.

An example is the explosion at the Texaco Refinery in Millford Haven in July 1994. The series of events that lead to this explosion can be traced to a severe electrical storm that affected a number of production units. During the following 4 to 5 hours a fire on one of the units was dealt with, parts of the refinery were shut down and attempts were made to bring all units back on-line.

Eventually a combination of failures resulted in a knock-out drum on a flare line being overfilled followed by the failure of the flare line and the release of 20 tonnes of flammable hydrocarbons. This material ignited, causing a major explosion. In its report into the incident (ref. 23 & 24) the HSE identified important human factors issues as well as failures in safety management systems, plant design and construction. The human factors issues included limitations in the display systems of the distributed control system, which made it difficult for the operators to form a clear overview of the state of the whole unit. The operators were further hindered by the alarm systems where there were a total of 2040 alarms, 87% of which were rated as high priority. In the 10 minutes prior to the explosion a key alarm indicating that the knock-out drum was overfilled was submerged amongst a total of 275 alarms which had to be dealt with by the operators (an average of one alarm every 2 seconds). In fact the operating team had been dealing with alarms at a very high rates since the initial lightning strike, 4 hours earlier.

The above incident demonstrates the very important part which human factors play in both the cause and prevention of accidents alongside the other key elements essential for safe operation.

- Plant and equipment which is safe and suitable for its function.
- Effective systems for the management of safety.
- Properly trained and well motivated staff.

High standards of safety can only be obtained if all the above elements are in place.

Looking back over the last 20 to 30 years it is probably in the first two areas that the most important safety improvements have been made in the process industries. Whilst the drive for further improvements in both hardware and management systems will continue the returns are likely to be lower than in the past. It is for this reason that many companies, including those in the PRISM network, are looking at the scope to obtain further improvements in safety through the greater understanding of 'Human Factors'. This is represented in figure 1.

THE PRISM PROJECT

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The objective of PRISM is.

“The improvement of safety in the European process industries through raising awareness of, and sharing experience in, the application of human factors approaches. In addition the network aims to stimulate the development and improvement of human factor approaches in order to address industry-relevant problems in batch and continuous process industries.”

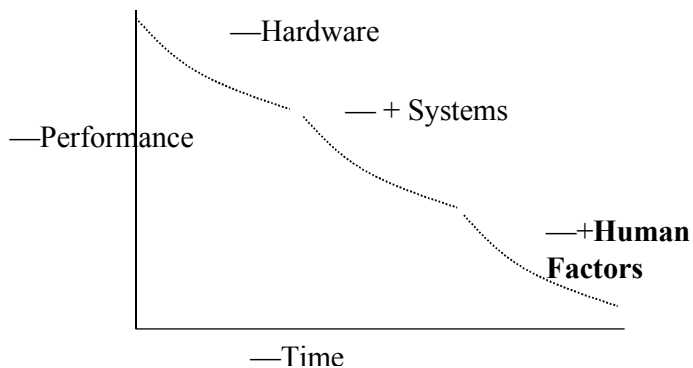


Figure 1. Improvement in safety performance

The network, which will last for 3 years, already has the support of over 100 organisations and individuals from 14 countries in Europe. These include many major chemical producers as well as universities and research centres. It also has support from the European Union Joint Research Centre, from CEFIC as part of its ‘Sustech’ programme and from the Health and Safety Executive (UK). It is being co-ordinated by the European Process Safety Centre with support from The Institution of Chemical Engineers.

This paper provides an overview of progress and achievements of the project at its half way stage.

So how does PRISM operate? It is recognised that the field of Human Factors is a very broad one and for this reason four separate ‘Focus Groups’ have been established within the network.

These cover

- *Cultural and organisational factors*
- *Optimising human performance*
- *Human factors in high demand situations*
- *Human factors as part of the engineering design process*

CULTURAL AND ORGANISATIONAL FACTORS (FOCUS GROUP 1)

This Focus Group is examining topics such as:

- the influence of cultural factors (e.g. national, organisational, and site culture)
- effective behaviour modification programmes
- safety implications of team working (benefits and pitfalls)

This Focus Group is being lead by The Keil Centre (UK) and John Ormond Management Consultants (UK) as Principal Contractors, in conjunction with Solvay (Belgium) and Lyondell (Netherlands) as End-User Advisors. The role of the End-User Advisers is the important one of ensuring that the work of the focus group will be of practical relevance to industry. The topics and deliverables will include:

- A general guide on the application and value of behavioural modification programmes.
- A report on cultural factors in safety management and a guide on identifying and managing key factors
- Information and guidance on the safety implications of team working and their management.

The first Focus Group 1 seminar was held in Edinburgh in January 2002 with the theme 'Improving Safety: Cultural & Organisational Factors'. Approximately 70 delegates from 11 European countries attended to take part in a programme which included both presentations and group work sessions. The presentations included inputs from industry, academics and consultants.

In a paper, 'Benchmarking offshore safety culture' Mearns (1) outlined the results of a 2 year study sponsored by the HSE and involving 14 off-shore operating and support companies. During the study a number of indicators or measures of safety culture were used. In the second year of the study only 1 company showed a reduction in the measure of its safety culture, 3 were about the same and 5 showed an improvement. More importantly the study demonstrated a positive correlation between the measures of safety culture and the lost time injury rate, with low injury rates being associated with adoption of 'Best management practice' More detailed analysis also showed significant differences between year 1 and year 2 in those practices rated as most important by the operators.

In a case study, Joyner (2) explained why bp's Dalmeny and Hound Point tanker loading facility had embarked upon a project to assess and improve the existing strong safety culture. The site had in recent years undergone significant changes with the introduction of new technology, organisational changes including 'enhanced teamwork'. The results had been deemed successful but had been disappointing in safety, with 2 serious incidents occurring early in the year 2000. The study identified a number of areas for improvement, including the need for more face to face communication (not just e-mails), a simpler way of reporting minor incidents and near misses and a need to involve all staff, including management, in the observation and correction of unsafe acts. Of particular interest was the way in which different safety subcultures were found within different occupational groups on the site, which suggests safety culture improvement activities need to be tailored to local circumstances. Overall it was considered that the exercise had increased two-way communication as well as understanding and had provided a sound basis for safety improvement plans.

Having established that there is a link between Safety Culture and safety performance ways of measuring safety culture are necessary. Two techniques have been shared within PRISM. Lardner et al (3) described the 'Safety Culture Maturity' model. The essence of the model is the definition of 5 stages of Safety Culture maturity. These range from Emerging, through Managing, Involving, Cooperating, to Continually Improving. An

essential element of the approach is that, for sustained improvement an organisation needs to assess the level which it is at and then make improvements step-wise through the various levels. Trying to jump steps may lead to failure because the organisation is not mature enough to take the new ideas on board. The model is based on 10 elements of safety culture which are assessed in workshops involving front-line personnel and management from across the whole organisation. Byron (4) separates Safety Culture from Safety Climate which he defines as '*Tangible outputs of the safety culture as viewed by an individual or group at a particular point in time.*'. The HSE has developed a tool designed to provide an assessment of the safety climate through a 71 statement questionnaire, which is distributed throughout the organisation (The questionnaire is available from the HSE website). Byron has emphasised the way in which a survey can reveal important differences in opinion between different groups within an organisation. An example was provided where the workforce strongly agreed with a statement that 'the permit to work system introduced unnecessary delays' whereas the management & supervision disagreed. Further investigation showed the root cause to be a change in the organisation which had reduced supervision resources and introduced the delays in the issue of permits which were causing the concern.

Many organizations have adopted new working methods over recent years with many moving towards self managed work teams. Lardner (5) called on the results of four recent case studies from oil exploration, chemical and offshore gas maintenance industries to illustrate the gains and "tripwires" of teamworking. These showed that the Self Managed Teams had more involvement in risk assessment, safety auditing, monitoring safety indicators, plant design and other key safety issues. Communication, and knowledge of plant and processes, improved and there was greater involvement in planning and problem solving. On the other hand, major changes to roles and responsibilities required careful planning and retraining. The jobs can become more demanding, and the assumption that safety is "always someone else's responsibility" is a potential problem.

Corpe (6) led an interactive sessions which introduced delegates to Smartteams, an internet-based team development resource which was developed specifically for the upstream oil and gas industry. Workshop sessions demonstrated the relevance of this resource to teamworking in all industries, and explained how health and safety benefits had been achieved through participation in teamworking initiatives. Whiting (7) outlined the work which had won a team from Bradwell Power Station the NUMEX 2000 Award for excellence in maintenance in the nuclear industry. They described how a project to refurbish maintenance workshops was used as a vehicle to enhance teamworking and ownership of safety. This project achieved impressive improvements in commercial and health and safety performance within existing budgets

Wright (9) presented some results from a study which identified best practice in involving employees in health and safety. He distinguished between different degrees of employee involvement, and highlighted the health and safety benefits obtained by a number of organisations through effective employee involvement.

In addition fishwick (8) described the approaches being made to small to medium sized organisations in order to prepare the guide on 'Application of Behaviour Improvement Programmes'. At the time of writing this guide is being reviewed by PRISM members.

OPTIMISING HUMAN PERFORMANCE (FOCUS GROUP 2)

This Focus Group is examining topics such as:

- task design
- procedures
- ergonomics
- training
- staff selection
- shift work

This Focus Group is lead by DNV (UK & Norway) as Principal Contractors, in conjunction with Chinoin (Hungary) and Huntsman Polyurethanes (Belgium) as End-User Advisors. The topics and deliverables will focus on:

- The production of best practice guidance for the process industries on task design, including consideration of both cognitive and physical ergonomics issues.
- Best practice guidance on man-machine interface and human computer interaction.
- Best practice guidance for the process industries on the production of effective procedures.
- Guidance on human factors considerations in the training of staff.

Both focus group 2 and focus group 3 will consider many of the issues highlighted by the Texaco incident.

Focus Group 2 held a seminar in Budapest in March 2002.

Although a great deal of time and resources are devoted to the development of procedures in the process industries, less attention is paid to how to ensure compliance once they have been developed. In his paper, Embrey (10) quotes data from the power generation industry which indicates that 46% of all incidents are caused by failure of personnel to follow instructions. When such incidents arise it is important to look for the underlying system failures which may have generated the situation in which the violations are encouraged or condoned. CARMAN (Consensus Approach to Risk MANagement) actively involves the operators in the development of procedures, considers the level of support required for different levels of competence and the interface between training and procedures. The approach has been applied to a major oil & chemical site following a series of dangerous near misses. Following the use of the new approach for over 3 years, surveys have shown significant improvements in a number of areas including a 52% reduction of those who saw the procedures as unworkable

In a verbal presentation, Labudde, shared approaches used by DuPont. Compliance with standard procedures is seen as critical to safe operation and significant time and effort is devoted to training. When a facility is acquired from another operator detailed retraining of staff is undertaken, an exercise which can, in some cases, involve a stoppage of production to ensure that the new approach to safety is adopted. The emphasis does not stop at this point and on-going training is provided to all staff, figures from one site showing 7% of the total manpower hours being devoted to training. DuPont do not see this as a cost but as an investment in safety and product quality.

For plants covered by COMAH (Seveso II), the demonstration that employee training has been carried out effectively is extremely important. Bull, (11) reported on the way in which

Ciba Speciality Chemicals have used a Systematic Approach to Training (SAT) developed by the US Department of Energy. A comprehensive computer system had been implemented to manage the large amount of information involved, and to maintain up-to-date records.

PRISM presentations have also addressed the effectiveness of training. In a paper presented to Focus Group 3, Schaafstal, (12) reported on studies into the effectiveness of the training of Weapons Technicians in the Royal Dutch Navy. Results showed that newly qualified technicians were able to solve only 40% of the problems presented. This led to the redesign of the training course to incorporate a structured approach to trouble shooting, the total length of the course being increased from 6 to 7 weeks. Results were encouraging with the proportion of problems being solved rising to 86%. Following this there was a complete redesign of the course with a greater concentration on trouble shooting, the total duration being reduced to 4 weeks. With this course the proportion of problems solved increased again to 95% indicating an approach which obviously warrants wider consideration.

At the time of writing best practice guidance for small to medium sized operations on 'Training' and 'Preparation of Procedures' are available to PRISM members for comment.

HUMAN FACTORS IN HIGH DEMAND SITUATIONS (FOCUS GROUP 3)

This Focus Group is examining topics such as:

- diagnosis of process upsets
- cognitive (alarm) overload
- emergency response
- control room layout
- abnormal situation management

This Focus Group is led by TNO (Netherlands) as Principal Contractor, in conjunction with ATOFINA (Belgium) and BASF (Germany) as End User Advisors. The topics and deliverables will focus on:

- workload, stress and work environment
- information (alarm) overload
- emergency procedures
- application of virtual reality to human factors
- resource deployment
- the human in the emergency loop

A seminar was held in Soesterberg in May 2002.

The UK Health and Safety Executive have recognised the importance of ensuring that the manning levels in critical situations are sufficient to ensure the safe management of upset and emergency conditions. Contract research carried-out for the Hazardous Installations Directorate of the HSE has led to the development of a socio-technical assessment method to determine areas where the level of manning may be insufficient. This method has been described in a number of places and application in a number of different situations has confirmed its value. This approach has been shared within PRISM by Conlin. (15)

Neerinx & Passenier (16) have developed a model for mental load under high demand situations. This takes into account the level of information processing, the time occupied by the tasks and the number of time set switches (changes to tasks being undertaken). In addition to other applications the model has been found to be useful when applied to high demand situations in the control of ships of the Royal Dutch Navy. (17)

Within the PRISM group there has been a high level of interest in this model together with a recognition that for wide application, more guidance will be needed on the high and low levels of the parameters used in the model.

One of the problems common to all control room situations is 'Alarm Overload'. Herbaux (18) described a practical approach to 'Alarm Management' being applied by Atofina. The approach covered, the establishment of an alarm philosophy, the identification & treatment of 'bad actors', application of advanced techniques such as alarm masking, alarm grouping or the replacement of individual alarms by overviews. The application of this approach to an ethylene plant led to a reduction in the monthly number of alarms from 19000 to 14000. Whilst this level is still considered high the proportion of alarms caused by instrument problems was reduced from 40% to 25% and the number of disabled alarms from 50 to 15. This was seen to represent major progress involving a significant change in mentality whilst it was still recognised that there is scope for further improvement.

High demand situations are not restricted to process plants or naval applications but cover a wide range of industries. Northern Ireland Electricity has recently reorganised its 24 hour emergency processes. This had involved the introduction of new IT support systems, the creation of new job roles, and the development of a revamped incident management centre and emergency response plan. A paper by Hamilton (19) described how human factors integration techniques were applied in the accomplishment of these changes and the lessons learnt from this work.

Other papers presented at this seminar covered, Display Development for Manned Space Missions (20) and Identifying Critical Situations (21). In addition workshop sessions considered future developments in high demand situations and a number of demonstrations were arranged showing the ways in which virtual reality techniques are able to provide assistance.

Within Focus Group 3 a separate sub group lead by Polytechnica Milano are studying the use of Virtual Reality techniques to improve the understanding of human factors. A number of meetings have been held and a survey produced on 'Human Reliability Methods for Safety Assessment & Risk Management' (22) as well as a state of the art report on the use of Virtual Reality. Currently proposals for further work on this topic are being developed.

HUMAN FACTORS AS PART OF THE ENGINEERING DESIGN PROCESS (FOCUS GROUP 4)

The concept of this Focus Group is to take direction/outputs from research and other Focus Groups and consider them in relation to typical engineering design processes in place at both major process industry companies and at SME's.

Current practice is being reviewed with the objective of producing guidelines on how to take human factors into account as part of the engineering design process. In doing this account will be taken of know-how and experience from nuclear, oil and gas and other process operations.

This Focus Group is being led by the Technical University of Berlin (TUB), in conjunction with ExxonMobil (Germany) and Snamprogetti (Italy) as End User Advisers.

SMALLER ORGANISATIONS

Whilst the human factors are clearly seen to be of value in large organisations an important objective of the project is to find the way in which human factors issues are addressed in smaller companies. From this it is hoped to establish what, if any, barriers prevent the application of good practice and to find ways to increase application. To do this contact has been made with a number of smaller companies through national associations of chemical manufactures, including the UK Chemical Industries Association.

Preliminary results indicate a much lower level of interest in the topic and less appreciation of the potential value of human factors. In addition many small organisations appear to be averse to obtaining help from consultants in this field.

CONCLUSIONS

At the time of writing the PRISM network is a little over half-way through its 3 year life. Although much work has still to be accomplished the following conclusions can be drawn.

- Human factors continue to contribute to accidents across all industries,
- Within the process industries improvements in hardware and management systems have lead to significant improvements in safety over recent years. Further improvements in these areas are likely to be much more limited.
- An improved understanding of Human Factors offers the opportunity for further significant benefits to safety.
- Leading companies in the process industries already show a high degree of interest in Human Factors and recognise the value it can provide in improving safety and business performance.
- This interest is shared by a number of smaller companies although the majority have still to be convinced of the value.
- New approaches to Human Factors, such as the assessment of safety culture and techniques to assist in the assessment of manning levels are proving to be of value to industry.
- The PRISM network is meeting its objective in providing an opportunity to share information and experience on Human Factors across Europe.

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APPENDIX I

EXCHANGE OF INFORMATION AND EXPERIENCE

The value of the network lies the opportunity it provides to share experience in the field of human factors as well as the guides and reports which will be produced. This sharing of experience is being accomplished in a number of ways.

Plenary Meetings

There will be two plenary meetings of the entire Network membership during the project. The first plenary meeting was a two-day event was held in June 2001 at the CEFIC offices in Brussels. At this meeting, focus groups outlined their plans of work and organised breakout sessions in order to gain contributions and feedback from all network members. The conclusions from these sessions are being incorporated into the workings of the network.

The final plenary meeting will be held in Prague in June, 2004 as part of the International Symposium on Safety & Loss Prevention in the Process Industries.

Focus Group Seminars

Each of the Focus Groups plans to hold four meetings in total during the project. For each focus group two will be traditional “physical” meetings, eight in total for the whole project, and two will be on-line meetings, hosted at a PRISM web page.

The meetings are open to all who register with the network and the on-line meetings are open to anyone with access to the Internet.

Virtual Conference

A key planned dissemination activity will be a major international Internet-based conference on Human Factors. This event will be used to communicate good practice and roll-out the deliverables at the end of the project. Papers and documents will be down loadable from the conference web site and presenters will be available for on-line discussion. This event will be open to the worldwide online public.

EXPANDING THE MEMBERSHIP OF PRISM

It is the belief of all members of PRISM that work on human factors offers the opportunity for further significant improvements in safety in the process industries. To achieve this there is a need to discuss and share experiences, both good and bad, and find ways to overcome any problems. The network already contains some of the leading consultancies and research organisations in the field of human factors together with operating companies with safety records which are amongst the best in the world.

More members from the process industries, universities and consultancies will be welcome and it is hoped that the combination of meetings in different European countries, together with the use of the Internet will enable everyone with an interest in human factors to participate in one way or another.

More information on how to become a member of PRISM and be kept up-to-date on its future activities can be obtained from the PRISM web-site www.prism-network.org