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

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The PRISM Human Factors thematic network was established in April 2000 with support from the European Union Directorate General Research & Development under Framework Programme 6. Initially the network comprised 50 companies from 14 countries and since its inception it has grown to have over 200 registered members on the website. Over this period the network has held 7 seminars with a total of approximately 70 presentations being made by 4 focus groups covering

- Organisational & cultural issues
- Improving human performance.
- High demand situations
- Human factors in engineering design

This paper provides an overview of PRISM in order to highlight those areas where human factors techniques are being applied in the process industries and the safety benefits which they provide. The paper also includes an assessment of those areas where further research or development work is necessary.

INTRODUCTION: THE PRISM PROJECT

To assist the process industries in improving both its understanding and application of human factors the European Process Safety Centre took the initiative in creating PRISM. PRISM was a 'Thematic Network' aimed at creating an extensive forum across Europe within which industry, universities, research centres and practitioners could collaborate to improve the flow of practical experience and fundamental knowledge in human factors. It was established with financial support from the European Union Directorate General for Research and Development under its Programme for Competitive and Sustainable Growth.

The objective of PRISM was:

"*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."

So how did PRISM operate? It was recognised that the field of Human Factors is a very broad one and for this reason four separate 'Focus Groups' were established within the network.

These covered

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

In this paper these issued will be addressed starting with human factors in design.

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

The concept of this Focus Group has been to take direction/outputs from research and other Focus Groups and consider them in relation to typical engineering design processes.

This Focus Group was led by the Technical University of Berlin (TUB), in conjunction with ExxonMobil (Germany) as End User Adviser.

Current practice has been 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 has been taken of know-how and experience from nuclear, oil and gas and other process operations.

A seminar was held in Frankfurt in June 2003.

INDUSTRIAL EXPERIENCE

At the present time few companies are applying human factors in the design of process plant. However a survey carried out as part of the PRISM Project showed that 91% of those companies responding saw the need for an increased consideration of HF in design with training and guidelines as the most favoured way of increasing uptake.

Two major companies Exxon Mobil & Shell, have recognized that safety, health and business performance can be improved through the greater application of HF in the design of process plant and have shared their experience through PRISM.

Exxon Mobil in particular have given very strong support to the work of focus group 4. Froehlich (32) outlined some of the costs involved in accidents and advocate a broad approach to the consideration of human factors in design, indicating that whilst much of the information needed to make improvements is known it is not easily available to the designer. To counter this Exxon-Mobil (33) have developed a set of HF techniques and tools to enhance HF considerations within existing project management models. The approach uses a number of tools applied throughout the projects life, from planning (concept) stage, through development & detailed design to construction and start-up. The tools increase the designer's awareness of HF issues enable them to identify those problems which require more detailed consideration. Rensink, (35) has described a similar whole project approach followed by Shell which involves the establishment of a

Project Ergonomics Team (PRET), from project personnel and a HF engineer to ensure the proper handling of HF issues.

DELIVERABLES FROM FOCUS GROUP 4

Focus Group 4 has produced the following deliverables;

- Application Guide on Human factors in Engineering design

This is available on the PRISM website. www.prism-network.org

HUMAN FACTORS IN HIGH DEMAND SITUATIONS (FOCUS GROUP 3)

This Focus Group examined topics such as:

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

The Focus Group was lead by TNO (Netherlands) as Principal Contractor, in conjunction with ATOFINA (Belgium) as End User Advisor.

Seminars were held in Soesterberg, Holland, in May 2002, and Brussels, October 2003.

CONTROL ROOM MANNING

The UK Heath 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 lead 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.(12)

Neerincx & Passenier (13) 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.(14)

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.

The Norwegian Petroleum Directorate have developed a number of standards for offshore control centres, Balfour (34).

High demand situations are not restricted to process plants or naval applications but cover a wide range of industries. Northern Ireland Electricity has recently reorgansied 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 (16) described how human factors integration techniques were applied in the accomplishment of these changes and the lessons learnt from this work.

REDUCTION OF DEMANDS ON CONTROL ROOM OPERATORS

The problem of alarm overload has been addressed by a number of authors. Wilkinson (29) has outlined the way in which the Health & Safety Executive in the UK are encouraging industry to address this problem and illustrated this with references to the explosions which occurred at the Texaco Refinery in Milford Haven and at Exxon, Longford.

Careful design of the operator interface and technical solutions are necessary to ensure that the necessary information is presented and not lost in a flood of alarms and warnings. The most useful guidance on this topic is provided in the Engineering Equipment Manufacturers & Users Association (EEMUA) publication 'Alarm Systems: a guide to design, management and procurement' (30). Andow (31) provided further detailed information on the use of the EEMUA guidance.

In a case study Herbaux (15) described a practical approach to 'Alarm Management' being applied by Atofina. The approach covered, the establishment of an alarm philosophy, the identification & treatment of 'problem alarms', application of advanced techniques such as alarm masking, alarm grouping and 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 was 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.

USE OF VIRTUAL REALITY TECHNIQUES

Within Focus Group 3 a separate sub group lead by Polytechnica Milano studied the use of Virtual Reality techniques to improve the understanding of human factors. The key issues and opportunities have been summarized by Colombo, (36). In addition a survey has been produced on 'Human Reliability Methods for Safety Assessment & Risk Management' (17) as well as a state of the art report on the use of Virtual Reality. Proposals for further work on this topic are still being developed.

DELIVERABLES FROM FOCUS GROUP 3

Focus Group 3 has produced the following deliverables;

- Best Practice Guidance on Human factors in High Demand Situations

- Human Reliability Methods for Safety Assessment & Risk Management
- State of the Art Report on the use of Virtual Reality

These are available on the PRISM website. www.prism-network.org

OPTIMISING HUMAN PERFORMANCE (FOCUS GROUP 2)

This Focus Group has examined topics such as:

- task design
- procedures
- ergonomics
- man–machine and human–computer interface
- training

This Focus Group was lead by DNV (UK & Norway) as Principal Contractors, in conjunction with Chinoin (Hungary) as End-User Advisor.

Focus Group 2 held seminars in Budapest, in March 2002 and in Athens, September 2003, the second of which concentrated on the Control of Major Hazards.

HUMAN FACTORS IN THE CONTROL OF MAJOR HAZARDS

A sound appreciation of human factors is important in the control of major hazards, particularly in the case of batch processing.

Hallett (24) described an approach to the improvement in the control of major hazards which was instigated by Ciba Specialty Chemicals at the request of the Health and Safety Executive, as part of the implementation of the COMAH (Seveso II) regulations. The programme drew on the experience of a consultant to provide training and to develop a structured approach which could be applied by company personnel. The approach built on risk assessments and major accident hazard scenarios which had already been prepared for the COMAH (Seveso II) safety reports. The programme resulted in a number of detailed process improvements and its application has been extended throughout the company.

OPERATING PROCEDURES & TRAINING

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. Embrey (9) reported on a study undertaken at a major major oil & chemical site, following a series of dangerous near misses. The technique, CARMAN (Consensus Approach to Risk MANagement) actively involves the operators in the development of procedures and includes a method for assessing the most appropriate form of support based on risk and task frequency. Following the use of the new approach for over 3 years, surveys showed significant improvements in a number of areas, including a 52% reduction of those who saw the procedures as unworkable.

For plants covered by COMAH (Seveso II), the demonstration that employee training has been carried out effectively is extremely important. Bull, (10) 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, (11) 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. The training course was redesigned 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 further redesign of the course the proportion of problems solved increased again to 95% indicating an approach which obviously warrants wider consider.

INCIDENT INVESTIGATION & PERFORMANCE MEASURES

The investigation of accidents and near misses plays an important part in safety improvement. Although a number of techniques are available for root cause analysis many of these are not very effective in the identification of deficiencies in human factors. Van der Smeede (25) described an approach developed by Exxon which places much greater emphasis on the identification of deficiencies in human factors.

On a related topic Labudde (26) has described the use of performance indicators, leading indicators and metrics in an integrated process management system.

DELIVERABLES FROM FOCUS GROUP 2

As part of the PRISM project best practice guidance has been prepared for small to medium sized operations on

- Training: Application Guide
- Procedures: Application Guide
- Task Design: Application Guide
- Man-Machine- Interface: Application Guide

These are available from the PRISM website. www.prism-network.org

CULTURAL AND ORGANISATIONAL FACTORS (FOCUS GROUP 1)

This Focus Group examined topics such as:

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

The Focus Group was 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 was important in ensuring practical relevance in the work of the focus group.

INDUSTRIAL COMMITMENT

During the course of the project two seminars were held by the focus group, (Edinburgh, 2002 and Manchester, 2003). Presentations at both seminars demonstrated that leading companies see the improvement of human factors as one of the most important ways of maintaining the drive for improved safety in the process industry. A number of case studies demonstrated the value of

- Assessing and improving the safety culture
- Implementing behaviour based safety programmes.
- Improved teamworking

Case Studies shared at the seminars included

- Joyner (2), implementation of 'enhanced teamworking' together with improvements in safety culture and two way communication at an oil terminal facility operated by BP.
- Webb (20), the integration of behaviour based safety programme with other safety activities on a petrochemical site operated by Basell.
- Van der Smeede (18), the application of the Exxon, Safety Excellence Process
- Martinez & Lardner (19), the establishment of a positive safety culture at a new facility in Spain operated by DuPont.
- Finlayson (21), improvements achieved on a fuel reprocessing facility operated by BNFL.
- Doornbos (22), linking a behavior safety programme with improved near miss reporting at petrochemical facilities operated by Lyondell.
- Harvey (23), integration of behavioural approaches to optimize human performance at a nuclear fuel reprocessing facility.
- Whiting (7) work to enhance teamworking and ownership of safety at a nuclear power station.

What are the common themes that can be drawn from these case studies?

- Most of the companies reporting their experience were large companies operating on a multi-national basis.
- All the companies already had effective Safety Management Systems in place.
- In general the safety performance before the introduction of HF based programmes was average for the process industries. In many cases the improvement programmes were introduced to maintain improvement after safety performance had reached a plateau.

- All have reported either very significant improvements in safety performance or the maintenance of 'world class' levels of performance as measured by Lost time Accident Frequency.
- Some companies had used consultants to implement the programmes and others had used their own experience.
- Where external consultants had been used it was seen as important to maintain 'ownership' by local management since there can be difficulties where behaviour based safety programmes are run separately from other safety activates.

SAFETY CULTURE

A 2 year study of 14 offshore operating and support companies sponsored by the HSE ('Benchmarking offshore safety culture' Mearns (1)) 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'

Having established a linkage 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. An essential element of the approach is that, for sustained improvement, an organization needs to assess its level of safety maturity then make improvements step-wise through the various levels. 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 organization.
- Byron (4) described the tool developed by the HSE to assess safety climate through a 71 statement questionnaire, which is distributed throughout the organization (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.

Wright (8) has presented 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.

TEAMWORKING

Many organizations have adopted new working methods over recent years with many moving towards self managed work teams. Lardner (5) has reviewed 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 very 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) has reported on the work of 'Smarteams', an internet-based team development resource which was developed specifically for the upstream oil and gas industry. Another approach to team working widely used in the aviation and maritime sectors is 'Crewe Resource Management'.

BEHAVIOUR BASED SAFETY PROGRAMMES

At both seminars authors reported on the benefits obtained through the implementation of behaviour based safety programmes, including Van de Smeede, Webb, Finlayson, Doornbos & Harvey. In addition Ormond, Woodall & Muuse described experience with one specific approach. These techniques have helped organisations to make very significant improvements in lost time accident performance.

Despite the value of these approaches it is important to be aware of their limitations. Whilst behaviour based safety can lead to significant improvements in Lost Time Accident performance there is no evidence to show that this will automatically lead to improvements in the control of major hazards. **Improvements in this aspect of safety must be targeted at process safety hazards and build on more detailed human factor techniques such as task analysis, covered by PRISM focus groups 2 & 3.**

DELIVERABLES FROM FOCUS GROUP 1

In addition to making all presentations available on the PRISM Website Focus Group 1 has produced the following deliverables.

- Behavior Safety: Application Guide. (37)
  This reviews many of the techniques which have been applied and provides guidance aimed at helping companies intending to implement such programmes. The report includes some consideration of the needs of Small to Medium Sized Organizations.
- Safety Culture: State of Art & Application Guide.(38)
- Team-working: State of Art & Application Guide (39)

These are available from the PRISM website. www.prism-network.org

SMALLER ORGANISATIONS

Whilst the human factors are clearly seen to be of value in large organizations, an important secondary objective of the project was to identify how human factors issues are addressed in smaller companies. The objective was to identify any the barriers which prevent the application of good practice and thus find ways to increase application. To do this contact was made with a number of smaller companies through national

associations of chemical manufactures, including the UK Chemical Industries Association.

The results have indicated a much lower level of interest in the topic and less appreciation of the potential value of human factors. Whilst small organizations are keen to improve safety performance there is reluctance to obtaining help from consultants in this field. If the consideration of HF issues in SME's is to be improved more simple guidance will need to be provided together with smaller, local consultancies.

NAS (NEW ACCESSION STATES)

The enlargement of the European Union in May 2004 is providing an incentive for industries in the New Accession States to improve safety performance. To provide assistance to companies in NAS, an extension to the PRISM project was approved during 2002. The work was coordinated by the Slovakian Technical University. In October 2003 a seminar was held in Bratislava where experience in applying HF techniques to improve safety in the process industries in both Slovakia and other European Countries was compared.

RESEARCH NEEDS

As part of the project PRISM was requested by the European Union to carry-out a survey of 'Research Needs in Human Factors in then Process Industries'. This has been accomplished through

- A website Questionnaire
- Position papers prepared by the Principal Contractors
- Discussion at a workshop at the International Symposium on Process Safety, Prague, 21004.

Based on the above the following conclusions can be drawn.

IMPROVEMENTS IN DISSEMINATION AND APPRECIATION

Although a number of important research needs were identified the majority of those at the workshop considered that the greatest need was to improve the dissemination, appreciation and application of existing techniques amongst practicing engineers & managers. Such guidance needs to cover

- What techniques are available
- The benefits (including case studies)
- When and where the techniques are best applied
- Resource requirements

A number of the guides produced by the PRISM project, for example the 'Behavior Safety: Application Guide' (see 5.5 above) meet the above needs although they are unlikely to be fulfilled by any one series of publications.

Special attention needs to be given the most effective approaches for small to medium sized organisations.

ORGANISATIONS AND THEIR MANAGEMENT SYSTEMS

At present important aspects of an organisations management system, such as 'Safety Culture', 'Teamworking' etc., are often seen as being 'optional add-ons'. Whilst such an approach has its value in concentrating on those areas where improvement is needed, more work needs to be done to develop approaches and systems where human factors issues are fully integrated. This work would need to include

- consideration of the way in which the organisation influences the work of managers, as well as others
- ways in which the human factors expertise within the organisation can be developed & maintained.
- study of the methods used in other industries to improver teamworking
- analysis of those factors which lead to 'team errors', such as those which occurred at Chernoble
- clarifying the key elements of good safety culture and describe practices which can be used to enhance it.

CONTROL ROOMS

Whilst much work has already been carried out on this topic it is still difficult to integrate the hardware and organizational issues which affect performance with the cognitive demands on the operator. There is also a need for

- techniques which can be used by engineers during the limited time available during design
- techniques suitable for existing installations
- better definition of the benefits of simulator training
- dissemination of the business benefits through reduced shutdowns etc.

HUMAN FACTOR TECHNIQUES

As noted in 8.1 it is generally considered that there are enough proven tools available to solve the majority of problems. There is however a need to improve the engineers access to existing techniques and information. The guide produced by Focus Group 4, 'Application Guide on Human factors in Engineering design' (see 2.2 above) meets some of these needs.

TEACHING OF HUMAN FACTORS

In parallel with the dissemination of human factors techniques and experience noted above there is a need to improve formal training of engineers and managers in these issues at both undergraduate and post graduate level.

CONCLUSIONS

What has the PRISM network achieved over its 3 year life? Although much work has still to be accomplished the following conclusions can be drawn.

- Poor Human Factors continues to contribute to accidents across all industries,
- An improved understanding of Human Factors offers the opportunity for a further significant reduction in accidents.
- 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 both safety and business performance.
- This interest is shared by some smaller companies although the majority have still to be convinced of the value.
- The PRISM network has met its objective of raising interest across Europe and providing an opportunity to share information and experience on Human Factors.
- Maintenance of these contacts will accelerate the implementation of good HF practice across Europe. Ways of achieving this need to be considered.
- A number of deliverables aimed at assisting industry in the improvement of human factors have been produced and are available free of charge from the PRISM website.
- Further research will be beneficial but needs to be targeted at meeting industrial problems.

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