SYNOPSIS - IEE COLLOQUIUM 'STEMMING THE ALARM FLOOD'

17 June 97

Rev 0 (19/06/97) D C Campbell Brown

HIGHLIGHTS:

- The main messages from the Colloquium on 'Stemming the Alarm Flood' were:
  - problems with alarms are not unique to BP or to the hydrocarbon processing industry
  - the alarm problem in refineries is nowhere near as bad as it is on nuclear power stations
  - there is significant potential to learn from the solutions that others have implemented

- There is significant interest in this area; the Colloquium was full to capacity - with 73 attendees from industry (hydrocarbon, utilities, transport, defence, aerospace), 'solution vendors' , academia and consultancies. Over 30 additional registrants had to be turned away by the organisers, the Institution of Electrical Engineers (IEE).

- The event was 'initiated' in conjunction with an ongoing survey of alarm management practices in the UK power and hydrocarbon processing industries, sponsored by the Health & Safety Executive (HSE) under the aegis of the Electronic Equipment Manufacturers and Users Association (EEMUA).

- The report on UK 'best practices' and guidelines for alarm management will be published in early 4Q 97 by the HSE. As contributors to this report BP will receive a complimentary copy (the intention is to post it on to Lotus Notes).

- The BP paper by Donald Campbell Brown and Manus O'Donnell on 'Alarm Management Experience in BP Oil' was very well received, covering generic problems with DCS alarm systems and the trial of the ProSys Dynamic Configuration Software on the Grangemouth CRU.

- More detail can be provided by Donald Campbell Brown (BP Oil Sunbury) or by any of the other BP attendees (Manus O'Donnell - BPOGR, David Coates - ESS Sunbury, Mervyn Currie - BPX Dyce, or Roy Lord / Rob Tyler - BP Oil Coryton)

ATTENDEES: (if more than one, the number of attendees is shown in brackets)

Hydrocarbon:	ICI (7), BP (6), Shell (4), Allied Colloids (2),
Utilities:	National Power (3), Thames Water (2), Nuclear Electric (2), National Grid, London Electricity, Scottish Power
Transport:	London Underground (6)
Defence:	DERA Farnborough (2), Thomson Marconi Sonar, Siemens Plessey, Thomson Thorn, Rolls Royce & Associates
Aerospace:	Smiths Industries, National Air Traffic Services, TLI Satellite Services
Solution Vendors:	Ametek Panalarm, ProSys, Usability Ltd, ICS, ICIS, Highland Electronics, Elektro Apparateban Olten (2), Peek Measurement, Cogsys, Honeywell HisSpec
Academia:	Univ Strathclyde (2), Univ Dundee (3), Univ Glasgow
Consultants:	Liveware (2), Bransby Automation, Davis Associates, Tekton Engineering, Synergy, InterAction
Unknown/Others:	HSE, Vodafone, NATS, GRTC, Others

DIGEST OF PAPERS:

Papers by Users:

(1) Optimisation of the Sizewell B Alarm System

A report on an ongoing programme to reduce alarm activity at Sizewell B Nuclear Power Station.

(2) Too Much of a Good Thing? Alarm Management Experience in BP Oil

- An overview of BP's current views on what constitutes an effective DCS alarm system, and the barriers that must be overcome before the alarm system can fully support the process operator.
- A report on the 1996 trial of the ProSys Dynamic Configuration Software on the Grangemouth CRU.

(3) Alerts in the Ship Control Centre: The Potential for Expert Systems

- A report on a literature review and experimental study into the possible use of expert systems to support the operator of the propulsion and auxiliary systems on a Type 23 frigate.

(4) Intelligent Surveillance for Nuclear Submarine Propulsion

- A report on the development of an intelligent knowledge based system (IKBS) to improve surveillance of the propulsion unit on UK Naval nuclear submarines.

(5) Handling of Repeating Alarms

- A report on two techniques used by National Power to reduce chattering alarms; automatic shelving on the 10th occurrence in 5 mins, and re-annunciation at the existing position on the alarm display.

Papers by Solution Vendors:

(6) Abnormal Situation Management: A Major US Programme

- A Honeywell overview of the activities and objectives of the ASM Consortium

(7) The Need for Dynamic Configuration & Other Augmentation of Distributed Control Systems

- A review of some of the problems associated with DCS alarm handling systems, and an description of two ProSys software products to reduce alarm floods (DCS) and standing alarms (SAM).

(8) Intelligent Alarm Handling & Analysis

- The application of a Cogsys expert system to reduce alarm floods on a blast furnace.

(9) What an Alarming Condition to be in!

- A very limited overview of key features of the Man Machine Interface (MMI) of alarm systems.

(10) Identifying the Nuisance Alarm

- An overview of the ICS IMAC product that allows alarms to be printed to a PC instead of a printer.

Other Papers:

(11) Alarm Management in the Chemical and Power Industries - A survey for the HSE

- A report on the ongoing study of UK alarm management practice, based on site visits/questionnaires

(12) Alarm Reduction in Nuclear Power Plants: Results of an International Survey

- A report on a 1995 survey into solutions for alarm reduction, focused around a literature search

(13) Blind Panic: Event Rates, Alarm Rates & Multi-modal Interfaces

- A review of current experimental efforts in human psychology, linked to aircraft cockpit design, to determine the components of 'interference' between simultaneous visual and manual tasks.

SUMMARY OF PAPERS:

(1) Optimisation of the Sizewell B Alarm System (N Broadhead, Nuclear Electric)

- A report on an ongoing programme to reduce alarm activity at Sizewell B Nuclear Power Station.
- Alarms at Sizewell are either 'alert' alarms (current average rate 730 per day) and 'information alarms' (current average rate 5970 per day), with a total population of around 11,000 alarms. During March 97, 50% of the alert alarms were generated by just 70 points.
- Alarm activity exhibits a strong diurnal and weekly pattern, revealing that a large number of alarms are generated from routine maintenance.
- Sizewell have already implemented Alarm Significance Logic, which can automatically condition specific Alert or Priority alarms to Information status, depending on the plant state. Alarm grouping is also used (a single group head Alert alarm is initiated if any group member becomes active, the group members being classified as Information alarms), and the operator is provided with a facility for 'alarm shelving' (to allow troublesome repeating alarms to be removed from the alarm list). Without these measures the current average alarm rate would have been around 6500 per day.
- Observations from the ongoing alarm optimisation exercise include:
    - consider alarm necessity - Sizewell operators are used to high Alert alarm activity and resist reduction in the numbers of alarms.
    - stratify alarm presentation
    - one cause, one alarm - rationalisation of the four redundant trains of reactor protection equipment allows a reduction from 696 to 233 alarms
    - properly assign alarm priority, to handle alarm floods
    - focus on alarm stability (ie put mechanisms in place to avoid alarm chatter). A good test is to run the alarm log through a 30 sec filter and measure the reduction in events.
    - relevance at the time of initiation - allow alarms to be demoted from Alert to Information manually as well as automatically (via Alarm Significance Logic)
    - alarm grouping - doesn't have much support from operators, but can be used effectively, particularly where equipment is redundant
    - alarm text messages - must be meaningful

(2) Too Much of a Good Thing? Alarm Management Experience in BP Oil (D Campbell Brown & M O'Donnell, BP Oil)

Part 1 - Generic Problems with DCS Alarm Systems

- An overview of BP's current views on what constitutes an effective DCS alarm system, and the barriers that must be overcome before the alarm system can make a full contribution to supporting the tasks of the process operator. The main conclusions are:
    - there is a growing focus on the behaviour of operator support systems during abnormal situations
    - the alarm system has an important role in assisting the operator to detect process problems and to prioritise his response
    - we need to get it right:
        - understand how the alarm system supports operator objectives
        - define appropriate alarms (not alerts or status information)
        - avoid the pitfalls - misuse, fundamental, practical snd implementation
    - we should measure system performance with comparison metrics
    - we should apply advanced solutions, but not as a 'fix' for bad basic practices

Part 2 - Implementation of Alarm Management at Grangemouth Refinery

- A report on the 1996 trial of the ProSys Dynamic Configuration Software on the Grangemouth CRU.
- Initial feedback includes:
    - the ProSys package is easy to configure, and performed faultlessly

    - there was (and continues to be) considerable operator support for this type of application
    - do not underestimate the effort required by the production asset
    - alarm management is an iterative process
    - consider carefully how to store real time and system event journals
- Analysis of real plant data revealed a reduction of 18% in the number of alarms during one plant trip, and 23.5% during another, as a result of the Dynamic Configuration Software

(3) Alerts in the Ship Control Centre: The Potential for Expert Systems (DM Usher, InterAction Ltd & J M Stallard, Thomson Thorn Missile Electronics)

- A report on a literature review and experimental study into the possible use of expert systems to support the operator of the propulsion and auxiliary systems on a Type 23 frigate.
- The literature review revealed that:
    - there is very little published with regard to marine applications of expert systems. The most research has been done in the nuclear industry, especially in the Far East.
    - most of the relevant expert systems are designed to monitor plant health, advising the operators of developing faults, rather than to analyse alert data following an incident.
    - no operational expert systems for alert handling have been identified
    - people can perform typical expert systems functions adequately, given a good UI design (!)
    - technological trends include hybrid systems (neural nets & fuzzy logic), small dedicated neural nets and model based reasoning.
- The pilot study was performed using a simulator for the Type 23 Frigate propulsion and auxiliary systems, under a 'refuelling at sea' scenario. The conclusions are:
    - in general, expert systems should be used as a decision aid and not for automatic control
    - the most likely candidates for future investigation are model based reasioning, fuzzy logic (perhaps tuned using neural networks) and small artificial neural networks
    - whilst expert systems can support a reduction in manning levels, the skills required of the remaining operators and their degree of training is likely to rise
    - it is vital to understand the implementation problems raised by scaling an expert system to the size and complexity required for a real application

(4) Intelligent Surveillance for Nuclear Submarine Propulsion (P Maskell, Rolls Royce & Associates)

- A report on the development of an intelligent knowledge based system (IKBS) to improve surveillance of the propulsion unit on UK Naval nuclear submarines. A system has been built and tested on a plant simulator, and is ready for a long term evaluation trial.
- A survey in 1992 revealed that this domain suffered from:
    - cognitive overload on operators (reducing numbers of operators, increasing complexity)
    - a simplistic surveillance model (alarms generated from simple threshold comparisons only)
    - poor design of the user interface
    - no account taken of the operator's mental model of the plant
- An IKBS called SURVEX (SURVeillance EXpert) has been built, with a 'user-centred' approach and using G2/Unix for 'rapid prototyping'. This delivers event-driven information on a 'warnings' and a 'surveillance' console, is used to:
    - evaluate over 1500 'channel' (alarm) states - confidence limits, dynamic warning levels, hysteresis
    - evaluate channel suppression - with a base of 1750 rules to determine relevance
    - evaluate warning priority - 10 levels
    - assess system predictions - identify undesirable trends and provide details of an expected event that did not happen
    - handle operator interaction - action and acknowlegement

(5) Handling of Repeating Alarms (E Burnell & C R Dicken, National Power)

- A report on two techniques used by National Power to reduce chattering alarms; automatic shelving on the 10th occurrence in 5 mins, and re-annunciation at the existing position on the alarm display.
- Simple techniques can be used to reduce the size of the problem:
    - choice of alarm limit
    - analogue deadbands
    - double scan validation
    - delayed reset
    - manual shelving - depending on industry background
- At Drax Power Station alarms are 'shelved' automatically if they exceed 10 occurrences in 5 minutes (the basis of these numbers was purely empirical/historical). Additional features are:
    - the 'shelved' alarm is identified on the alarm list by a change in colour
    - the initial period of shelving is 20 mins
    - if the auto-shelving criterion is transgressed during the subsequent on-trial period of 20 minutes, then alarm is auto-shelved again for double the time
    - the auto-shelving time doubles progressively, up to a maximum of 640 minutes
- Another solution that has been employed is to reannunciate a repeat alarm at the same position in the alarm summary list:
    - this prevents repeating alarms from filling the screen and hiding alarms on subsequent pages
    - if the first occurrence is currently 'out of view' (on a hidden page), the repeat alarm is inserted at the bottom of the alarm list
    - the alarm list gives the current state of all alarms, but no longer necessarily in chronological order (although an alternative does preserve the order by removing and reinserting a repeating alarm at the latest point of occurrence)
    - all alarm occurrences are logged to the system journal, which is accessible to the operator

(6) Abnormal Situation Management: A Major US Programme to Improve Management of Abnormal Situations (P Andow, Honeywell HiSpec)

- An overview of the activities and objectives of the ASM Consortium
- Key elements of the programme are the ASM Audits, to aid understanding of the problems and potential solutions, and the AEGIS prototype software.
- The ASM Consortium in the USA brings together, in a four-year programme funded to around $ 17 million by the American Government:
    - industrial users of Distributed Control Systems (BP, Shell, Exxon, Chevron, Texaco, Amoco, Novacor)
    - a multi-disciplinary research team from Honeywell Technical Centre
    - experienced developers from Honeywell Intelligent Automation College
    - the niche expertise of two high technology suppliers (Gensym, Applied Training Resources)
    - a number of Universities (Purdue, Toronto)
- Key findings/observations from a series of ASM audits include:
    - there is a need for a shared understanding of the meaning of 'abnormality' on process plants
    - the most serious incidents involve multiple fatalities, but even events without human injuries can involve considerable costs
    - the cost of abnormal situations is staggering - estimated at 20 bn $ per yr for USA HPI alone
    - plants tend to be designed for normal operation, with insufficient consideration of performance under abnormal situations
    - poor systems integration is typical

    - the MMI tends to be designed for the operator alone, with little consideration of other users
    - the experience needed to improve the operations interface generally exists, but is not utilised
    - operator training, particularly in abnormal situation management, is often inadequate
- The AEGIS software development programme is on schedule, to build an integrated suite of tools:
    - to assist in identifying the current plant status, particularly where this is deviating from the intended state
    - to determine appropriate operating goals for the current situation
    - to plan how the operating goals can be realised
    - to communicate with the operations team in order to obtain information and also to explain the conclusions that have been reached

(7) The Need for Dynamic Configuration & Other Augmentation of Distributed Control Systems for Improved Alarm Management (L Jensen, ProSys)

- A review of some of the problems associated with DCS alarm handling systems, and an description of software products to reduce alarm floods (Dynamic Configuration Software) and standing alarms (Special Alarm Management).
- Dynamic Configuration Software allows alarms to be switched between enable and disable depending on the plant state. Alarm thresholds and priorities (etc) can also be switched.
- A fired heater was quoted as a recent application example for Dynamic Configuration Software, with a reduction from cumulative total of 176 alarms to 14 over three quarters of an hour during a process trip.
- Special Alarm Management software allows the operator to:
    - disable nuisance alarms - either automatically if the point is in alarm for a certain length of time, or immediately for nuisance alarms.
    - realarm specific points - after a certain period of time if the alarm remains active
    - reset/intelligent enable - to reset the disabled point if it clears out of alarm condition for a minimum period of time

(8) Intelligent Alarm Handling & Analysis (S Davison, Cogsys Ltd & J Hamilton, ISC)

- A report on the application of an expert system to reduce alarm flooding on the #6 furnace at BHP Steels Port Kembala blast furnace (a continuous operation, critical production unit with 10,000 I/O on an ABB Advant DCS with 12 operator stations. Alarm floods of up to 500 per minute were reported on an identical process unit).
- The Smart Alarm Analysis Module (SAAM) was developed using the CAKE (Computer Aided Knowledge Engineering package) marketed by Cogsys. A hierarchical structure was established with maximum focus on re-usable components so as to minimise the modelling effort.
- Pattern matching (with confidence levels) against predefined alarm sequences, groups of alarms and patterns of time delays between events were used to issue warnings to the operator, even if the predefined pattern had not completely emerged.
- A rule base was used to allow identification of around 800 root causes of events, with an ability to interrogate the decision tree so as to better understand the reasons for a particular conclusion.

(9) What an Alarming Condition to be in! (G Pochin, Peek Measurement)

- A very limited overview of key features of the Man Machine Interface (MMI) of alarm systems.
- The MMI should:
    - provide clear and simple instruction, in a format that can be clearly understood
    - reduce the potential for confusion
    - use easily understood technology
    - reduce irrelevant information

(10) Identifying the Nuisance Alarm (J Speedie, Industrial Control Software)

- An overview of the IMAC product that allows alarms to be printed to a PC instead of an alarm printer.
- The IMAC software runs on a PC (at the latest release under Windows NT), with the capability for connecting up to 8 serial printer interface lines.
- Applications tools are provided to support analysis of alarm frequency, windowing in time and searches for text strings.
- Data is encrypted to discourage tampering. IMAC has been used on fiscal metering applications, where information is automatically backed up daily to optical drive, for security.

(11) Alarm Management in the Chemical and Power Industries - A survey for the HSE (M Bransby, Bransby Automation)

- A report on the ongoing study of UK alarm management practice, based on site visits and questionnaires
- Sites visited included 4 refineries (including BPOGR), 5 chemical plants, 1 pharmaceutical plant, 1 gas terminal, 3 power stations and 3 HQ engineering organisations (including BP Oil Sunbury).
- There were significant problems on many sites visited, with common issues such as:
    - high average alarm rates, in some cases more than one every two minutes (on average!)
    - alarm floods during upsets
    - many nuisance alarms (repeat alarms or out of service equipment)
    - many alarms of low operational significance
    - operators sometimes accept alarms 'blindly'
- The financial implications of these problems is significant, possibly as much as £ 1 million per site per year in incidents which may have been avoidable with better alarm systems. A number of specific examples were quoted, including Texaco Milford Haven Refinery (£ 200M in plant damage + lost production 2 months total site & 2 months partial site + fines of £ 200K plus legal costs - where problems with alarms was cited as a significant contributing factor)
- There is also a safety implication for poor alarm systems, at least in terms of the demand rate on the ultimate protection system.
- Measurement of alarm system performance is fundamental to any attempt to make improvements
- Solutions to nuisance alarms include:
    - tune alarm limits, deadbands (etc)
    - deal with repeating alarms
    - eliminate from the operator alarm displays those alarms which are no longer of interest
    - Proper prioritisation
    - Suppress alarms from out of service plant
    - suppress alarms according to the plant operating mode
- There have been notable successes on sites where a priority has been placed on solving the problems

(12) Alarm Reduction in Nuclear Power Plants: Results of an International Survey (J Jenkinson, Tekton Engineering)

- A report on a 1995 survey into solutions for alarm reduction, focused around a literature search
- A typical nuclear plant has 5,000 - 10,000 alarmed DPS inputs. There is a serious mismatch between target and actual alarm rates, which are typically:
    - actual during commissioning - 16,000 per 24 hrs
    - actual during early life - 500 per 24 hrs
    - actual alarm flood rate - 600 per min
    - target average alarm rate - 24 per 24 hrs

    - target peak rate - 6 per min
- Alarm system problems include:
    - too many on display
    - high alarm rates (flooding)
    - long-standing alarms
    - spurious and false alarms
    - repeating alarms
    - excess grouping of alarms
    - no action required
    - no defined action
    - wrong recipient
- Solutions include:
    - Organisational - consistent alarm definitions, separate alarm & status information, assign to systems/geographically, systematic classification/prioritisation
    - Systems - fixed boolean logic, dynamic logic (wrt plant state), alarm synthesis/generation, knowledge based systems, neural nets
    - Signal Processing - validation, grouping, coalescing (eg multiple train but same problem), eclipsing (eg remove hi on hihi), dynamic limits, first-out
    - Signal Suppression - plant mode/condition, plant item state, minor/major event
    - Presentation Stage - shelving, dynamic prioritisation, flexible sorting, alarms on data displays, distributed alarm displays.
- Alarm management issues need to be addressed at each step in the plant lifecycle (from conceptual design through to operation)
- Organisational and management issues include
    - parochial - contract responsibilities ('not my problem')
    - geographic - distributed design (no overview of the size of the problem until too late)
    - temporal - long design periods (requires sustained effort)
    - communications - need for a common understanding
    - user involvement - generally not enough at design stage
    - operator task definition - alarms must be designed as a part of the operator's task environment
    - guidelines & design aids - some limited resources are available
    - risk/cost/benefits metrics - are generally not available

(13) Blind Panic: Event Rates, Alarm Rates & Multi-modal Interfaces (M J Cook, C Cranmer & H Pengelly, University of Dundee)

- A review of current experimental efforts in human psychology, linked to aircraft cockpit design, to determine the components of 'interference' between simultaneous visual and manual tasks.
- Previous theory suggests that simultaneous visual tasks (visual input - visual coding - manual output) and verbal tasks (Verbal input - verbal coding - verbal output) do not 'interfere' with each other (cf driving a car whilst holding a conversation).
- Recent laboratory experiments show that this is not true. There is interference between the two, particularly if the subject is required to use his memory for either or both tasks, if the task is complicated or if the event rate is high.
- There is significant cognitive overhead involved in switching between verbal and visual channels - too much switching reduces performance
- A much more effective model has been shown to result if the requirement for verbal output is removed (ie visual input/visual coding and verbal input/verbal coding are used to drive only manual output). The effect of removing manual output (ie verbal output only) has not been evaluated.
- The conclusions for alarm management are:
    - there are reasons related to human psychology for avoiding high event rates

- when workload increases, the cognitive requirements of handling simultaneous visual and auditory input do not interact destructively, but only as long as only manual (and no verbal) output is required
- use functional integration to manage alarms and messages
- use intelligent alarm management which is sensitive to context and event frequency
- where possible, use redundant cueing to qualify alarm status - limit auditory signalling to high priority alarms, to give a faster response
- train operators in pattern recognition - consider how to measure competence and establish training standards