THE INSTITUTE OF PETROLEUM

HUMAN factors no2

briefing notes

For background information on this series of publications, please see Briefing Note 1 - Introduction

ALARM: *a signal to an operator (a sound - usually with a flashing light and a message) indicating a problem requiring the operator's attention.*

alarm handling

Case studies

1. On 25th September 1998, explosions at an Australian gas plant killed two people, injured eight others and cut the gas supply to Melbourne for two weeks. Investigations showed, among other things, that operators routinely ignored alarms in the plant control room. At a rate of 300-400 a day, and 8 500 during one incident (12 alarms every minute), the operators had little choice.

Source: Lessons from Longford, Andrew Hopkins CCH Australia Ltd. Sydney, (2000) ISBN 1 86468 422 4

2. In 1994 lightning caused a plant upset leading to fires and explosions at an oil refinery. Twenty-six people were injured. Damage amounted to £48 million. The company was prosecuted and fined £200 000.
   One reason plant operators could not control the event was because there were too many alarms to deal with. (275 in the 11 minutes before the accident). Also, the alarms were poorly presented.

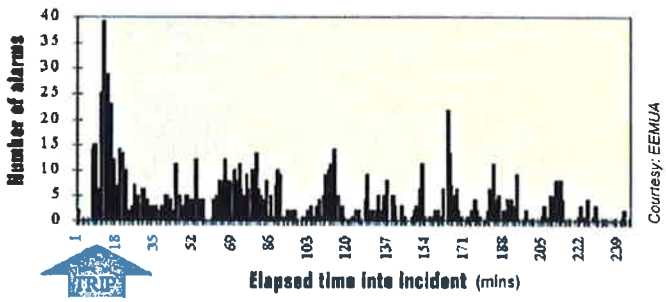
Source: www.hse.gov.uk/hid/land/comah/level3/a58dee.htm

3. In a petrochemical plant, 85% of all alarm activity came from nine alarms. In seven days, one alarm was activated 921 times. The average alarm rate was one a minute. There were 30 'standing' (permanently on) alarms.
   By reviewing the problem and making changes, the company removed 25% of alarms and changed another 15% of them. Average alarm rate was reduced by 26% and standing alarms to eight.

Source: reference 3

Why alarm handling?

Poorly-designed alarm systems may hinder rather than help the operator and may result in failure to identify a need to act, or failure to select an effective course of action, especially in emergency conditions. But systems can be redesigned by physically changing them or by training the operator to use the alarms. Companies should consider changes to improve responses to alarms and therefore improve safety.



Source: reference 2

Does your company have problems with alarms?

1. Are some alarms too quiet compared to background noise?
2. Are some alarms so loud that they startle operators and make it hard for them to think or to hear what anyone is saying?
3. Are too many alarms activated during a typical shift, even if there isn't a major problem?
4. When there is a problem, do hundreds of alarms activate and does one alarm seem to set off others until there are just too many to deal with?
5. Are a lot of them not really alarms; they're always there or come up because of maintenance or are some definitely false alarms?
6. Although alarms can be reset, do they just keep coming back?
7. Do alarm lists seem to be arranged in no obvious logical order or are they mixed with other information?
8. Do alarm messages go off computer screens before anyone has a chance to read them?
9. Is it hard for operators to decide which alarm to deal with first when a lot come in at once?
10. Is it often not clear what caused an alarm?
11. Do operators not always know what to do about a particular alarm?
12. Is the wording of some important alarm messages unclear?

If the answer to any of the above is 'yes', then you need to take action!

What can I do about it?

You can't control what you can't measure. Also, it's difficult to get management's attention without some data to illustrate the problem. So, the first thing to do is to 'measure' the problem:

i. Ask control room or workstation operators, either face to face, or by giving out a question sheet, to find out what experiences they have had with alarms in your company. You could base some questions on points 1 to 12 above, or there is a sample questionnaire in reference 2 Appendix 12.

ii. Find out how many alarms: go off in a typical shift; went off after the last fault on the plant; are 'standing' alarms (always on or repeatedly come up)
   You might need printouts from alarm logs to get information for ii). The reference documents listed on the next page will give an idea of what is acceptable or not.

iii. Draw the information to the attention of company management. Advise them of the benefits of improving alarm systems in reduced plant upsets and down-time, better motivated personnel, etc.

A company policy/strategy/standard on alarm management should be adopted. Guidance in reference 2 can help.

What should my company do about it?

It is reasonable to expect that anyone who needs to take action in response to an alarm will:

- Be able to see and hear the alarm under all conditions
- Quickly understand what caused the alarm and how serious it is
- Know from training or instructions what to do next and in what order
- Have enough time to take action
- Realise when the situation has returned to normal.

But the operator should not:

- Be 'swamped' by lots of irrelevant alarms that come up quickly
- Have certain alarms activated permanently or coming up very frequently
- Be startled by the alarm or be unable to hear/concentrate because of it.

Your company should make sure that alarms are designed to modern guidelines such as that published by EEMUA (reference 2).

Courtesy: Colin Curwood

Api Energia gasification plant

Your findings might show that your alarm systems meet the above broad 'standard'. If not, then your company will need to consider the information provided and make changes to improve alarm handling. It is worth noting that operators facing as few as 10 alarms a minute in an emergency will quickly abandon the alarm list to reduce stress. They will then find a way to solve the problem without using the alarms. If alarms are ignored in this way, they might as well not be there and could result in incorrect actions that could compromise the safety of the plant. It may also be prudent to assess staffing levels to ensure that alarms can be managed during plant disturbances (see briefing note No.3, *Organisational change*).

As case study 3 showed, methods are available for improvement. Volume and brightness settings can be changed. Software systems can be re-designed, for example, to filter out those that are not required, show the correct priority for each alarm, etc. Even systems that are not based on VDUs/computers can be changed, for example, adjusting the sensitivity of some of the sensors, disabling alarms connected to out of service plant, ensuring that each alarm is justified, and so on.

Some changes will require long-term effort by the company to make a significant difference, with an initial step of establishing exactly what the problems are. However, some 'quick wins' - ways of making short-term enhancements - are possible as outlined above. Again, the EEMUA Guide (reference 2) can provide information on other possible ways of improving alarm handling.

The benefits should be obvious - improving alarm systems makes it easier for operators to interpret alarms and take correct and timely action and both reduce their stress and the likelihood of error. This allows better control of processes and helps avoid accidents. An editorial in Hydrocarbon Processing supports this:

> "3 - 15% in lost capacity can be attributed to lack of control during abnormal operating modes (i.e. plant incidents and transition events). A typical plant can save approximately $3,500,000 per year by providing good control during plant incidents and transition events such as startups, feed changes, etc."
> *Source*: Hydrocarbon processing, March 2002, 81 (3)

Useful reference information

1. *Better alarm handling*, Chemical Information Sheet 6 (2000) HSE Books (HSE Books website www.hsebooks.co.uk)
2. *Alarm systems, a guide to design, management and procurement*, Engineering Equipment & Materials Users Association publication No 191 (1999) ISBN 0 8593 1076 0.
3. *The management of alarm systems* Bransby, M. L. and Jenkinson, J., HSE Contract Research Report 166 HSE Books (1998) ISBN 0 7176 1515 4.
4. *The explosion and fires at the Texaco Refinery, Milford Haven, 24 July 1994: A report of the investigation by the Health and Safety Executive into the explosion and fires on the Pembroke Cracking Company Plant at the Texaco Refinery, Milford Haven on 24 July 1994*, HSE Books (1997) ISBN 0 7176 1413 1.

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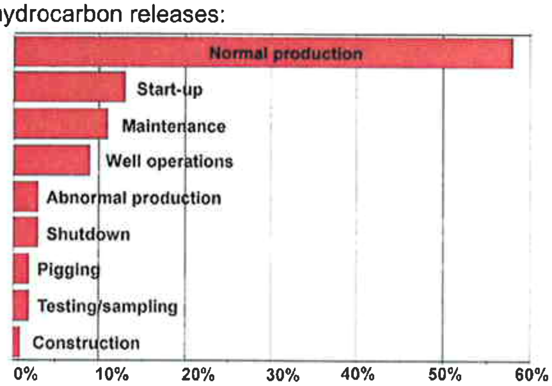
MAINTENANCE ERROR: *failing to perform a task or performing it incorrectly during routine testing/checking, servicing or breakdown repair. Result - the equipment malfunctions or the error causes damage to plant or personnel.*

maintenance error

Case studies

1. "Gas was released from a flange on a vent line which was overpressured when a compressor relief valve vented. A block valve in the vent line was found to be closed. **The valve had been left shut by mistake following maintenance two weeks previously**."
"....inspection/condition monitoring was identified in nearly a third of all incidents, suggesting that **checking and maintaining** the condition of the plant was one of the most important ways of preventing leaks."

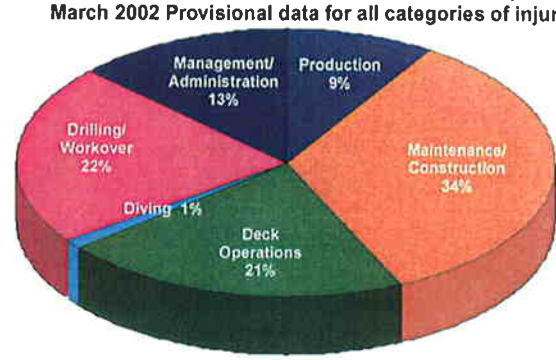
2. Maintenance error is a significant contributor to hydrocarbon releases:



Source of 1 and 2: OSD Hydrocarbon release reduction campaign: Report on the hydrocarbon release incident investigation project 1/4/2000 to 31/3/2001 HSE Offshore Technology Report 2001/055

3. A gas compressor was being re-started after corrective maintenance. The train was slowly being pressurised when a leak was noticed around the recycle pipeline on the scrubber skid. The scrubber had been cooling down from normal operating temperatures. It is suspected that thermal expansion and contraction had loosened bolts on one of the flanges resulting in the release. A new maintenance routine has been created to check the torque settings after significant maintenance work.
Source: Step Change, SADIE record number 237: www.stepchangeinsafety.net

Severity of injury and work process environment, April 2001-March 2002 Provisional data for all categories of injury



Source: HSE Offshore Injury and Incident Statistics 2001/2002 (provisional data) www.hse.gov.uk/hid/osd/hsr1002/

Are you aware of any of the following problems with maintenance in your company?

1. Are lots of items of equipment difficult to maintain - hard to get at or strip down?
2. Do maintenance crews often have problems finding or using the right tools or spares?
3. Is there little or no checking of jobs in progress or when completed to make sure they're carried out properly?
4. Is there no priority rating of jobs - do maintenance crews just do the next one on the list?
5. Have fitters had problems where electricity or pressurised pipes haven't been isolated properly?
6. Are some maintenance procedures out of date or just poorly written so that they don't relate to the equipment in its current state?
7. Are conditions usually less than ideal for doing maintenance tasks - it's hot, noisy or cramped?
8. Is there any evidence that sometimes fitters take shortcuts on a job, especially when pushed for time?
9. Would it be easy to work on the wrong system - things look similar, labelling and P&IDs are poor?
10. Are lots of maintenance jobs badly planned?
11. Could protection of the fitter or anyone near the job be improved (guards, warnings, PPE, isolation methods, etc)?
12. Are contractor procedures and processes rarely monitored to ensure they meet company standards?

If the answer to any of the above is 'yes', then you need to take action.

What can I do about it?

If anyone to your knowledge is experiencing problems with maintenance work, you need to be clear what the problems are and inform management.

i. Ask people, either face to face, or by giving out a question sheet, to find out what experiences they have had with maintenance errors or near misses. You could base some questions on points 1 to 12 above, or the points raised on page 2. Also, reference 1 contains a useful 'workforce questionnaire'.

ii. Find out especially:
- Which maintenance tasks are the most physically difficult to carry out
- If systems for reporting problems are working properly
- If procedures, permits or other safeguards are adequate and are being used.

iii. Draw the information to the attention of company management.

What can my company do about it?

A key feature of maintenance work is that it typically involves isolating process streams of dangerous substances then stripping down and rebuilding a system, often removing or disabling safety systems to do this. On the other hand, it could be as simple as changing a fuse in a plug. Irrespective of the work undertaken, it is a human activity and maintenance quality is dependent upon the performance of the people who undertake it.

A human error in this process can lead directly to injury (of the fitter or someone nearby) or a major accident. More seriously, it can mean that the system malfunctions at a later date, for example, leading to loss of containment of dangerous substances. These undetected deficiencies are also known as 'latent failures'. If it is a safety related system that fails, this could cause more extensive injury or damage. Piper Alpha was the starkest example of a maintenance error within the petroleum industry. There are many examples of disasters outside the industry in which maintenance errors were the root cause, for example, those that took place at Flixborough, Bhopal and Clapham Junction. To help avoid such disasters, companies should establish a maintenance policy and programme and should clearly define roles and responsibilities for maintenance.

Courtesy: Furmanite

Furmanite leak sealing

Management responsibility

The factors that can lead to human error in maintenance are basically the same as for other types of job. To avoid such errors and encourage good performance in maintenance work, it is important that your company should, as a minimum, make sure that there are:

- Enough competent people to carry out maintenance work and to check work done
- Adequate supplies of spares and consumables
- Good communications so that maintenance crews (and others who might be affected by maintenance - including contractors) know what work has to be done and where (particularly important at shift handover)
- In relation to the above point, a good permit to work system is crucial and should be developed against formal safety analyses so that major hazards, as well as personal/occupational safety are considered
- Contingency plans; for example, if a job looks as if it might overrun, or if other problems arise
- Systems for investigating problems that occur and for making improvements
- Structured processes to identify and assess human error potential in safety critical maintenance tasks (and to reduce this potential)

The company should also ensure as far as possible that:

- Maintenance tasks are realistic and achievable
- All maintenance work is carefully planned and scheduled including unscheduled maintenance tasks
- Particular attention is given to whole plant shutdowns where the company has to manage a large number of contractors, work under permit and in which many safety systems may be taken out of service
- The design of equipment to be maintained, and its location, doesn't encourage errors
- Suitable tools and equipment (including safety equipment) are provided for the work
- Working conditions are tolerable (e.g. enough light, not too noisy or too hot or cold, well ventilated and clean)
- Written instructions, permits, diagrams and other paperwork, and labels are clear and up to date
- The impact of any proposed change in maintenance is assessed
- Up to date standards are adopted (see *Useful reference information*)

Maintenance had highest numbers of both major and over 3-day injuries amongst main disciplines in 1999-2000.
Source: HSE OTO Report 700/2001

Useful reference information

1. *Improving maintenance: A guide to reducing human error* Human Factors in Reliability Group HSE Books (2000) ISBN 0 7176 1818 8
2. *Dangerous maintenance - A study of maintenance accidents and how to prevent them* HSE Books (1992) ISBN 0 11 886347 9
3. *Maintenance - reducing the risks* A Joint Industry/HSE Seminar & Workshops 17/18 January 2001 Aberdeen Exhibition & Conference Centre HSE OTO 007/2001 HSE Books (2001) ISBN 0 7176 2075 1. Step Change in Safety website: www.stepchangeinsafety.net
4. *Level 3 guidance for the assessment of COMAH safety reports - technical measures document: maintenance procedures* HSE-HID website: www.hse.gov.uk/hid/land/comah/level3/index.htm

THE INSTITUTE OF PETROLEUM

HUMAN factors no8

briefing notes

For background information on this series of publications, please see Briefing Note 1 - Introduction

ERGONOMICS: *Ergonomics is about 'fit': the fit between people, the things they do, the objects they use and the environments they work, travel and play in. If good fit is achieved, the stresses on people are reduced. Source: the Ergonomics Society website:* www.ergonomics.org.uk *Proper attention to ergonomics will improve usability, comfort, productivity, reliability and well-being.*

ergonomics

What's the problem?

'Ergonomics' and **'human factors'** mean roughly the same thing, but ergonomics usually refers to the 'physical' aspects of work. For example: lifting and carrying; posture when working (whether standing up or seated); the layout and design of equipment; the effect of temperature, lighting and noise on work performance. Bad ergonomic design can mean that the employee: suffers discomfort at work; develops health problems from long term exposure to physical stresses; might be prone to making costly and possibly dangerous errors.

Case studies

Note: Work related sickness in the UK costs around £11 billion every year - much of this due to back injury.

Source: Ergonomics Society website: www.ergonomics.org.uk

1. A large petroleum, chemical and pharmaceuticals company began an ergonomics improvement programme to reduce worker injuries and illness. Employees participated by reporting early symptoms of ergonomic problems and compiling statistics on injuries and illnesses. This produced a significant decline in ergonomics-related injuries and lost work time. In one year, workers' compensation costs were reduced by 35%.

Source: OSHA Ergonomics - Possible solutions: www.osha.gov/SLTC/ergonomics/

2. During operation of a petrochemical plant, a reactor vessel burst due to it becoming over-pressurised because excess water had affected the reaction. A further explosion occurred as the contents of the vessel ignited, causing fires and propelling fragments of the plant over a large area. Six people were injured, one of whom later died. The VDU that the operators were using did not display vessel pressure. If it had, operators might have been able to take corrective action.

Source: Case studies: www.hse.gov.uk/hid/land/comah/level3/

3. In a plant producing ammonia from natural gas, operators activated three safety valves in error. Pipework vibrated so severely that it cracked a weld and opened flanges. Gas escaped and caught fire destroying much of the plant. Fortunately, no-one was injured. The error occurred because of improper labelling and positioning of push-buttons used to operate the valves.

Source: Ammonia Plant Safety, Vol.27 39-44 1987, American Institute of Chemical Engineers (AIChE)

Courtesy: Gavan Goulder

Testing mice and keyboards - ChevronTexaco's 'ergolab'

Are you aware of any of these problems in your company?

1. Is your company poor at giving training or advice on lifting and carrying heavy items?
2. Do members of the workforce get pains in their arms, legs, back or neck when they use certain tools or do certain jobs?
3. Are maintenance (or other) jobs made more difficult because of the location and layout of the equipment or through having to work in an 'awkward' position?
4. When a job involves operating controls, is it sometimes unclear to the user what some of the controls do and what will happen when operated?
5. Could a control be easily operated accidentally - by knocking into it, or through confusion (caused by poor positioning or labelling)? Would it be dangerous if this happened?
6. Are some controls and display devices difficult to reach or see, or to understand how groups of controls and displays relate to each other?
7. Could a lot of the displays give more or better information to the user?
8. Are computer systems difficult to use: to put information or command into, or to get information out of?
9. Are any of the areas where people work so badly lit (too bright or dark), or noisy, or too hot or cold, or cramped that they can't do the job properly?
10. Do management seem to give low priority to doing anything about reported 'ergonomic' problems?

If the answer to any of the above is 'yes', then you need to take action!

What can I do about it?

Many ergonomic problems are obvious. Some can only be pointed out by people close to the job (typically, operators, fitters and supervisors). Ask people, either face to face, or by giving out a question sheet, to find out what ergonomic problems they have had. You could base some questions on points 1 to 10 above, or there are ideas for questions in reference 1 (sections on posture, controls, displays and environment).

i. Find out whether:
   - Anyone has experienced unusual symptoms (pain or discomfort) that might have been caused by physical work
   - Anyone has actually or nearly made an error because of bad design of equipment (controls, displays, tools, computer systems) or because of environmental conditions (temperature, lighting, noise, vibration).

ii. Draw the information to the attention of company management.

What should my company do about it?

You may have heard the expression, 'ergonomically designed', maybe in an advert or in a magazine. There is no strict definition of this term, but it generally means that designers of a workplace, tool or piece of equipment have taken the trouble to gather information on typical users - their size, strength, abilities and expectations - and designed the item to suit. They may even have carried out tests with a group of users to make sure that what they have designed is acceptable. No system will be perfect, though. In any group, some people find certain equipment difficult to use or in the wrong place; others will have no problem. Your company should, however, be aware of the more serious problems and be prepared to change a design or to change the way people work to reduce the risk of discomfort, injury/health problems or errors.

Management responsibility

Management need to act on problems caused by bad ergonomics and improve working conditions and equipment. But, people working with poorly designed devices do get used to them and 'adapt'. Managers should get specialist advice and decide whether to change such systems or 'leave well alone'. Four ergonomic aspects need to be considered: musculo-skeletal problems; problems with displays; problems with controls; workplace and working environment.

Musculo-skeletal problems

Aches, pains and other discomfort arising from physical work, often where power tools are used. The phrases 'Repetitive Strain Injuries' (RSIs) and 'Work Related Upper Limb Disorders' (WRULDs) are also used. The company should:

- Ensure that equipment is fit for use and does not produce excessive strain or vibration
- Where equipment cannot be changed, provide additional protection or support equipment to reduce the problem
- Review tasks that force or encourage employees into an uncomfortable posture for long periods (stooping, kneeling, crouching, twisting, stretching, bending etc) or where heavy or awkward loads need to be lifted and carried
- Schedule work and rest breaks to minimise any negative health effects caused by equipment operations.

Problems with displays

A display is any device that provides information to the operator. Displays are mainly 'visual' and include: status lights; dials; digital readouts; pen recorders; VDU screens and mimic boards. 'Audible' displays are pre-recorded messages or tones. Note that the advice given here is similar to that for controls. The company should:

- Provide the correct type of display for the information to be passed (e.g. **not** a 'pointer and dial' if you need to take an exact reading - a numeric display would be better for this)
- Displays should work as the user expects them to - e.g. a pointer moving clockwise or to the right means an increase in flow, temperature or pressure etc.
- Group displays logically, that is, put all the displays for one system near to each other and in the order they are to be used
- Put the display devices near to any associated controls (e.g. if a control increases flow, put it adjacent to the flow gauge)
- Label each display and use colour or other coding to enhance displays (e.g. show danger zones on dials, but don't rely on this as the only warning of danger).

Problems with controls

A control is anything that is used to operate a system (switches, levers, handles, wheels, knobs, sliders, keyboards, joysticks, etc). The company should:

- Provide the correct type of control for the job to be done - e.g. a foot pedal if a lot of force needs to be applied, switches or selector knobs for making settings
- Controls should work as the user expects them to - e.g. pushing a switch down turns the machine on, turning the wheel on a valve anti-clockwise opens it. Exceptions, e.g. reverse threads, should be made clear
- Group controls logically - put all the controls for one system near to each other and arranged in the order they are to be used and according to frequency of use, if possible
- Put controls where they can be easily reached and operated: protect any that should not be accidentally operated (cover with a flap, put in a recess or make the operation a double action - e.g. release with a key then turn)
- Label each control so that it is clear what it does and what the movement is required to operate it (e.g. 'Emergency Shut Down'; 'Open flap and push down to operate'). Use appropriate colour coding, e.g. red buttons to stop).

Workplace and working environment problems

Physical work space and conditions. The company should:

- Control temperature - not too warm to cause drowsiness and not too cold to affect use of tools or equipment
- Control air movement - to provide fresh air and cooling if needed
- Control vibration - to prevent annoyance, injury or effects on vision
- Control lighting - not too dark to see but not too bright to cause 'glare' (bright spots)
- Control noise - to allow good communications and reduce annoyance
- Control workspace - not too cramped to cause discomfort or injury, (e.g. where using PPE or other safety equipment) and equipment within easy reach and not spread over a large area.

Useful reference information

1. *The guide to reducing human error in process operations* Human Factors in Reliability Group, SRD Association (1991) ISBN 0 8535 6357 8.
2. *Level 3 guidance for the assessment of COMAH safety reports - technical measures document: control room design* HSE-HID website: www.hse.gov.uk/hid/land/comah/level3/index.htm
3. *Safe use of work equipment: Provision and use of work equipment regulations 1998 Approved code of practice and guidance* HSC 2nd edition (1998) HSE Books ISBN 0 7176 1626 6.
4. *Reducing error and influencing behaviour* HSE HSG48 2nd edition HSE Books (1999) ISBN 0 7176 2452 8.
5. *Upper limb disorders in the workplace* HSE HSG60 2nd edition HSE Books (2002) ISBN 0 7176 1978 8.
6. *Understanding ergonomics at work* HSE IND(G)90(L) 2nd edition HSE Books (2003)
7. *Manual handling: solutions you can handle* HSE HSG115 HSE Books (1994) ISBN 0 7176 0693 7.
8. *Ergonomic design of control centres* ISO 11064-200 (in 14 parts).