Operator reliability

taking automation to the next level

Automation and Control for Energy
Manchester, 10-11 may 2011

Luc.de-wilde@total.com

Symptomatic 20st century joke
in the world of Process Automation

Question :

How many resources do you need to run a refinery ?

Answer : Two : one operator and one dog

The operator is there to feed the dog
The dog is there to make sure
that the operator doesn’t touch anything...
The 20th century
Automation Engineers’ heaven:

100% automated plants
No more operators, no more human errors
Infinite workforce productivity

**Just a matter of time and resources…**

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**Just a matter of time and resources … ?**

- **Major investment effort**
  - Digitalize all controls
  - Develop software applications and optimizers
  - 2003, voting systems, UPS, …
  - Fool-proof SIS, Layers of Protection, risk matrix …
  - …

- **In the meantime, human errors continued to happen with evolving diagnosis**
  - ~1970: “Humans are not machines”
  - ~1980: “residual problem from the past, will soon be solved”
  - ~1985: “need more detailed procedures for remaining human interventions”
  - ~1990: “problem to transfer competency to new generation operators”
  - ~1995: “need behavioral program … so that procedures are followed”
  - …
21st century: several wake-up calls

Human Performance Error in operations and maintenance functions = still major risk contributor

Selection of reported accidents and near misses, 2007 - 2009

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-065</td>
<td>Burns by caustic soda during operator intervention at a pump</td>
</tr>
<tr>
<td>2008-026</td>
<td>Worker spread with sulphuric acid</td>
</tr>
<tr>
<td>2008-028</td>
<td>Working on a blind while system still in service</td>
</tr>
<tr>
<td>2008-059</td>
<td>Worker spread with sulphuric acid</td>
</tr>
<tr>
<td>2008-061</td>
<td>Ethylene ship connected to propylene loading arm</td>
</tr>
<tr>
<td>2008-065</td>
<td>Isobutane cloud after rupture of nitrogen hose during startup</td>
</tr>
<tr>
<td>2008-070</td>
<td>Large benzene spill in pipeway</td>
</tr>
<tr>
<td>2008-072</td>
<td>Hot quench oil spread on operator after manometer removal</td>
</tr>
<tr>
<td>2009-014</td>
<td>Large fuel oil spill after contractor opened purge</td>
</tr>
<tr>
<td>2009-020</td>
<td>Fire during furnace startup</td>
</tr>
</tbody>
</table>
Classical (20st century) approach of Automation

Operator = (un)avoidable source of errors and losses

- Human errors are at the origin of many incidents of process safety, reliability, ...
- Automation objective = avoid depending on human intervention
- Technology = a tool to reduce the exposure of the process to human intervention and errors
- Operator error = caused by not following procedures and / or lack of competency

Human error: 2 most observed root causes

« Lack of Competency »
« Not following procedures »

Just aspects of a more complex reality
Humans are not machines…

… so we cannot do anything …

Let's do AT LEAST what we, engineers, do for machinery:

- ensure utilisation in their optimum operating range
- install alarming and overload protection
- ensure long lifetime with a maintenance plan
- design an adapted control scheme to influence their functioning
- use our expertise to constantly enhance their RELIABILITY

= the (‘hard’) science of Human & Organisational Factors

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Human & Organisational Factors: domain

- Basis = brain functioning
  - Handling of conflicting priorities
  - Tunnel effect
  - Types of memory
  - Mental modes of operation
  - …

- Understanding of human error mechanisms and influencing factors

- HARD science: fully quantified

- Applied science: nuclear industry, aviation industry, military…

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3 ways to manage situations

Knowledge based

Demands when an individual faces a completely novel situation. The worker would have to exert considerable mental effort to assess the situation, and after each control action, the worker would need to review its effect before starting further action.

Rules based

Application of rules (IF-THEN form). Situations already experienced by the worker and (or) for which he has been trained.

Skill based

The skill-based mode refers to the smooth execution of highly practiced, largely physical actions in which there is virtually no conscious monitoring. Routine situations that require less attention.
Human Error typology in the Process Industry:
Classification according to CCPS

Active failures

- Slip: Correct but failure in execution
- Mistake: Action as intended but intention was wrong
- Laps: Error in memory recall
- Violation: Intended action that deliberately ignores a known rule, restriction or procedure
- Socio-technical failure: Based on team behaviour

Latent conditions

- Mgt / org. failure: E.g. unclear goal setting, poorly defined responsibilities, tools and interfaces poorly adapted to human capabilities

In combination with active failure, will result in incident

Includes Mgt/ org. failure

Socio-technical Mgt / org. failure

Correct Intent but failure in execution

Error in memory recall

Intended action that deliberately ignores a known rule, restriction or procedure

Based on team behaviour

E.g. unclear goal setting, poorly defined responsibilities, tools and interfaces poorly adapted to human capabilities

... ...

The human ‘control loop’ of the operator

Operator Mental & Physical Activities

Orienting

- Situation Awareness
  - (1) Sensing, Perception, and/or Discrimination
  - (2) Analysis, Interpretation, and/or Projection

Evaluating

- Physical and/or Verbal Response

Acting

- Outputs to Process (SP, OP%, Manual adjustments)

Inputs from Process

- Sensors, analyzers, radars, video, instructions, sounds & smells

External Feedback

- Assessing

Figure from the ASM Consortium
Adaptation of Supervisory Control Activity models of Jens Rasmussen and David Woods - CMA.
Factors which influence the overall intervention success of the operator

Orienting
- Information overload
- Missing information
- Inappropriate level of detail
- Vigilance decrement
- Difficult navigation
- Distracting environment

Evaluating
- Inconsistent information
- Inaccurate information
- Conflicting priorities
- Lack of knowledge
- Inappropriate detail
- Poor information accessibility

Acting
- Inadequate communications
- Deficient / complex procedures
- Fail to follow procedures
- Inappropriate actions
- Inappropriate tools / interface
- Lack of experience
- Inadequate feedback

Assessing
- Lack "big picture" view
- Inaccurate information
- Inadequate information
- Erroneous conclusions

Red = human influencing factors which are directly impacted by available automation technology + already applied in nuclear, aviation, ...

21st century approach of Automation

Operator = unavoidable source of errors and losses
- Human errors are at the origin of many incidents of process safety, reliability, ...
- Automation objective = avoid depending on human intervention
- Technology = a tool to reduce the exposure of the process to human intervention and errors
- Operator error = caused by not following procedures and / or lack of competency

Operator = unique source of safety and reliability
- Unique human contribution = manage abnormal situations (anticipate, detect, respond) in process safety, reliability, ...
- Automation objective = maximize the operator’s impact on his process
- Technology is a tool to boost the Human Reliability of the operator
- Operator error = failure of operational and technical management to adapt work to human characteristics of operator
**Human limitations for reliable alarm response**  
(norm EEUMA, measured by the ASM Consortium as upper bound)

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>Maximum target per operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing alarms</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Background alarms</td>
<td>&lt;10 per hour</td>
</tr>
<tr>
<td>Alarm flooding</td>
<td>&lt;10 in first 10 minutes of upset</td>
</tr>
</tbody>
</table>

Beyond these limits, human operator response is *structurally unreliable*

Allowing such installation to operate without compensating measures is a *management failure*.

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**The role of Operational and Technical Management**  
= installing **Layers of Protection**

Effective alarm management = a vital **Layer of Protection**

*Figure from CCPS website*
Alarm Management: part of Process Safety Culture and Operational Excellence

- Supporting the operator as unique source of safety and reliability
- Operations-centered approach: technology boosts human performance
- Operational professionalism as core competency

Transverse competencies remain THE key element for Automation success in the 21st century
The state-of-the-Art “lab” for technology - enhanced Human Reliability of the Operator: Abnormal Situation Management® Consortium

R&D consortium of 15 companies and universities
• Initially co-funded by US Govt (NIST)
• Jointly invested $50M over 15 years
• Creating knowledge, tools and products designed to prevent, detect and mitigate abnormal situations that affect process safety in the control operations environment

Charter
• Stage 1 (1994-1998) : Research
• Stage 2 (1999-2001) : Prototyping
• Stage 3 (2002-2004) : Development
• Stage 4 (2005-2008) : Deployment

Deliverables
• Technology, prototypes, guidelines, best practices, metrics, application knowledge, workshops, products

R&D domain of the ASM Consortium

Technology to radically enhance the operational teams’ capability to:
• Error-free DETECT indicators and precursors
• Error-free DECIDE on appropriate course of actions
• Error-free RESPOND and execute corrective actions

in order to PREVENT or MITIGATE any abnormal situation

Earlier awareness, more informed response
How?

By focusing on following 7 areas

1. **Understanding ASM** - Focuses on issues that contribute to a better understanding of current incident causes and to prepare for future abnormal situations and to prepare operations teams accordingly.
2. **Management Structure & Policy** - Focuses on the impact of management structure and policy on the ability of operations teams to prevent and respond appropriately to abnormal situations.
3. **Training & Skill Development** - Focuses on the impact of training and skill development on the ability of operations teams to prevent and respond appropriately to abnormal situations.
4. **Communications** - Focuses on communications issues among plant personnel and with the use of technology under normal, abnormal, and emergency situations.
5. **Procedural Operations** - Focuses on all aspects of procedures used to accomplish important tasks at an industrial site, particularly startup/shutdown.
6. **Control Building & Operations Environment** - Focuses on the impact of the control building environment on effective operations.
7. **Process Monitoring Control & Support** - Focuses on process monitoring, control, and support applications for effective operations. It includes such aspects as alarm management and early event detection.

Conclusions:

1. After decades of automation, the human operator’s unique and irreplaceable contribution has become to manage abnormal situations.

2. Automation solutions, interfaces and tools will only be effective if they take into account the ‘hard’ science of Human Factors. This science should become a core competency for automation engineers.

3. The challenge for the Process Automation profession in the 21st century will be, to use technology for a radical enhancement of the operator’s human reliability and his impact on the process in all normal and abnormal situations.

4. The Abnormal Situation Management Consortium plays an essential role in advancing technology to boost the human reliability of the operator. In its pursuit for operational excellence, Total is proud to contribute as a member.
Process Safety is why you do it, …

Reliability is how you pay it!