Considering Human Factors in Process Hazard Analysis

Petroleum Club Romania, September 2015
Objective:

Describe how to consider Human Factors and human failures in Process Hazard Analysis (PHA)

Contents:

- Human factors and human failures in PHA
- Relationship between human factors and human failures
- Approaches to treatment of human failures
- Approaches to treatment of human factors
- Examples, back-up slides
Definitions

**Human Factors**

discipline dealing with the psychological, social, physical, biological and safety characteristics of a user and the system the user is in.

It is sometimes used synonymously with ergonomics, but ergonomics is actually a subset of Human Factors.

**Risk**

'effect of uncertainty on objectives'

(ISO 31000:2009, [2.13])

**Risk Management**

Coordinated activities to direct and control an organization with regard to risk.

(ISO 31000:2009, [2.20])
Definitions:

**Human Factors Analysis and Classification System (HFACS)**

general human error framework originally developed and tested within the U.S. military as a tool for investigating and analyzing the human causes of aviation accidents (Wiegmann & Shapell, 2001)

**Hazard**

'hazard' shall mean the intrinsic property of a dangerous substance or physical situation, with a potential for creating damage to human health and/or the environment

(Seveso III Directive, 2012/18/EU Art. 3 – para. 14)
Definitions:

*Process Hazard Analysis (PHA):*

Process Hazard Analysis (PHA) (or Process Hazard Evaluation) is a set of organized and systematic assessments of the potential hazards associated with an industrial process.

A PHA is directed toward analyzing potential causes and consequences of fires, explosions, releases of toxic or flammable chemicals and major spills of hazardous chemicals, and it focuses on equipment, instrumentation, utilities, human actions, and external factors that might impact the process.

(https://en.wikipedia.org/wiki/Process_Hazard_Analysis)
Definitions:

*Process Hazard Analysis (PHA)*

- PHA is a thorough, orderly, and systematic approach for identifying, evaluating, and controlling the hazards of processes involving highly hazardous chemicals.

- A PHA provides information intended to assist managers and employees in making decisions for improving safety and reducing the consequences of unwanted or unplanned releases of hazardous chemicals.

- The facility shall perform a process hazard analysis on all processes covered by the applicable standards.
WHY?

EU Major Accident Prevention Policy and Safety Management System

- Required by Council Directive 96/82/EC (Seveso II) since June, 2015, Seveso III 2012/18/EU [BACK-UP SLIDES]

- Preparation of a Safety Report to meet the requirements of Council Directive 2012/18/EU Seveso III (Art. 10)

- Among the seven fundamental elements that should be included in the Safety Management System:
  
  PHAs that identify and evaluate the major hazards

- Failures of the management system were shown to have contributed to the cause of over 85% of the accidents reported.
**HOW?**

*Together with the Safety Report, PHA and Risk Analysis must be reviewed and updated every five years or whenever necessary. [BACK-UP SLIDES]*

**Human factors are included in a PHA in two ways:**

- **Human failure is analyzed as a cause of hazard scenarios and**

- **Factors that impact human performance are studied and analyzed**
HOW?

*Human factors* engineering deals with:
- Person-process and person-person interfaces
- How they influence the performance of people

*Human failure* analysis deals with:
- Failures people may make in their interface with an engineered process

These failures and their rates are influenced directly by the human factors engineering design of the process [BACK-UP SLIDES]
HOW?

HUMAN FACTORS MODEL

People  Process  Organization  Environment
HOW?

SYSTEMS VIEW OF HUMAN ERROR

Vulnerability (unforgiving conditions)

Error-inducing environment

Human limitations

Errors with likelihood of significant consequences

Cantemir Mambet
HOW?

How to consider Human Factors and human failures in Process Hazard Analysis (PHA)?
HOW?

SYSTEMS VIEW OF HUMAN ERROR ?????

Examples from other disciplines:

“Structural Engineering is the art of molding materials we do not really understand into shapes we cannot really analyze, so as to withstand forces we cannot really assess, in such a way that the public does not really suspect.”

(Dr. E. H. Brown - Structural Analysis Volume One, 1967)
DIFFERENCE

HUMAN FACTORS
HOW?

*Examples of human factors to include in a PHA:

- Controls and indications:
  - Accessibility
  - Clarity
  - Usability
- Task overload
- Work schedules

*Human factors in PHA does not address ergonomics
EXAMPLES OF CATEGORIES OF HUMAN FACTORS

- People
- Procedures
- Equipment
- Environment
- Management

*Generally, the process industries in EU and US do not use standards and guidelines for human factors

*Some individual companies have developed internal guidelines

*Standards and guidelines exist in other industries
HOW?

EXAMPLES OF CATEGORIES OF HUMAN FACTORS.
GUIDELINES & SAMPLE QUESTIONS

PEOPLE

- What is the educational level of the workforce?
- What is the literacy of the workforce?
- What is the first language of the workforce?
- What is the training level of the workforce?
HOW?

EXAMPLES OF CATEGORIES OF HUMAN FACTORS.
GUIDELINES & SAMPLE QUESTIONS

PROCEDURES

- Who wrote the procedures - engineers or operators?
- What is the reading comprehension level of the operators?
- How long are the procedures? - documents more than about 10 pages intimidate many operators
- Can items be found easily and quickly?
- Are warnings and cautions clearly distinguished?
- How big is the type font?
HOW?

EXAMPLES OF CATEGORIES OF HUMAN FACTORS.
GUIDELINES & SAMPLE QUESTIONS

EQUIPMENT

- Is equipment labeled?
- Are switches and lights on control panels arranged in a logical manner?
- Can key indications be seen from the locations where the adjustments are made?
- Are DCS displays too busy or confusing?
- Do DCS displays correspond to the P&IDs?
HOW?

EXAMPLES OF CATEGORIES OF HUMAN FACTORS.
GUIDELINES & SAMPLE QUESTIONS

ENVIRONMENT

- Is the temperature and humidity comfortable for long-term human working conditions?
- Is it too comfortable?
- Is lighting adequate everywhere it is required?
- What is the noise level?
- What is normal traffic through the workspace - are there distractions?
EXAMPLES OF CATEGORIES OF HUMAN FACTORS.
GUIDELINES & SAMPLE QUESTIONS

**MANAGEMENT**

- Have sufficient resources been made available?
- Are there enough people to perform the required actions in the required times?
- Do direct supervisors have decision-making authority?
- Are decisions made quickly when needed?
HOW?

APPROACHES TO TREATMENT OF HUMAN FACTORS IN A PHA

• Simple checklists
• Auxiliary checklists
• Incorporate explicit human factors study (in HazOp, What-If). Usually it is HAZOP causes or what-if questions that are annotated
• Human factors affect the human failures recorded in the cause or what-if columns
• [BACK-UP SLIDES]
• Separate explicit human factors study
HOW?

SIMPLE CHECKLISTS TREATMENT OF HUMAN FACTORS ISSUES DURING A PHA

- Can be used by the team leader to remind the team of the types of human factors issues that must be considered.
- Entries are made in the PHA worksheet that identify human factors problems and their impact on hazard scenarios.

(more detailed checklist of human factors issues can be used:
  - As a backup for completeness
  - To stimulate the team’s brainstorming
  - As a quality control check

- Similar to the use of checklists of human failures
- The same cautions as before apply
HOW?

EXAMPLE OF SIMPLE CHECKLIST OF HUMAN FACTORS ISSUES

- Operator/process and operator/equipment interface
- Clarity, simplicity, accessibility and usability of controls and indications
- Automatic instrumentation vs. manual procedures
- Number and frequency of tasks operators must perform
- Impacts of extended or unusual work schedules, including shift rotations
- Design of tasks
- Operator feedback
- Communications systems
- Clarity of signs and codes
- Environment
HOW?

GLOBAL VS. LOCAL HUMAN FACTORS ISSUES

• Many human factors engineering issues can be handled on a one-time or global basis
• These issues include:
  – Control room
  – Personnel assignments
  – Work routines
• PHA team leaders must be careful also to consider human factors issues at a local level
  – e.g. The readability of a particular instrument
HOW?

GUIDELINES FOR RECORDING HUMAN FACTORS

• Specify the immediate human factors problem and the underlying cause, as appropriate
  – E.g. Valve difficult to operate due to lack of maintenance
  – Do not need to brainstorm all possible root causes
• Identify the dominant ones
DIFFERENCE

HUMAN FAILURES
(HFACS) based on model developed by J. Reason (Human Error. New York: Cambridge University Press, 1990)

“Swiss Cheese” model for latent and active failure conditions

HOW?

Ill defined Procedures
Labor issues
Low morale

Task allocation
Failure to correct
Willful disregard

Preconditions

Unsafe supervision

Fatigue
Complacency
Loss of Situational Awareness

Crew Actions

Influences from organisation
HOW?

APPROACHES TO TREATMENT OF HUMAN FAILURES

- Simple brainstorming
- Checklists
- Structured brainstorming
- Explicit human failure study
HOW?

SIMPLE BRAINSTORMING

*Human failures* can generally be identified adequately by brainstorming in PHAs as causes of hazard scenarios
- Along with equipment failures and external events

*The team should be questioned* after each deviation or subsystem to determine whether all significant human failures have been identified by considering:
- All the people who are involved
- The various functions they may perform
- The different types of mistakes they may make
**CHECKLISTS**

*Checklists of specific human failures can be used to prompt the team to identify applicable failures.*

*They can range from simple reminder checklists to detailed checklists*

*Use of reminder checklists is a common approach*
EXAMPLE OF CHECKLIST OF SPECIFIC HUMAN FAILURES

- Operator performs an operation when none is required or desired
- Operator performs more than is required
- Operator performs less than is required (incomplete or partial action)
- Operator performs action on the wrong equipment
- Operator performs the reverse or opposite of what is required
- Operator fails to take a reading when required
- Operator makes incorrect reading
- Operator does not believe indications (does not acknowledge alarm, ignores reading)
- Operator inactivates an alarm system for convenience
- Operator ignores out-of-specification test/inspection results and continues to operate with no special or additional protection
- Operator bypasses a trip, interlock, or other safety function for convenience
HOW?

- Reminder checklists need to be kept short if they are to be effective
- PHA teams will become frustrated if they have to repeatedly consider detailed checklists

- Detailed checklists can be used:
  - As a backup for completeness
  - To stimulate brainstorming of human failures when the PHA team needs assistance
  - As a quality control check by the team leader subsequent to a PHA session
HOW?

STRUCTURED BRAINSTORMING OF HUMAN FAILURES IN PHAs

• Human failures can be identified by combining elements of three simple checklists
• Process similar to combining guide words with parameters to generate deviations in a HAZOP study except that three items are combined
• Formula: Person + Facility Aspect + Failure Type = Specific Human Failure

Example: "Operator" + "Procedure" + "Action is not performed" identifies the failure: “Operator does not follow the procedure”

[BACK-UP SLIDES]
HOW TO USE CHECKLISTS IN STRUCTURED BRAINSTORMING

• Must review:
  – List of people to ensure everyone involved has been considered
  – Facility list for completeness of tasks/functions
• Lists are usually similar for different facilities, but not necessarily identical
• **Failure** list assists in ensuring that all types of human failures have been identified for the different ways people interact with the facility
• It is important to understand that items in the three checklists are not combined in a formal, exhaustive way
• The checklists are simply reviewed to identify any combinations that may have been missed by the team brainstorming
HOW?

**EXPLICIT HUMAN FAILURE STUDY**

- It is possible to perform a more detailed analysis that looks at human failures exclusively, in more detail than is possible in a PHA.

- Such studies have been performed routinely in some industries.

- They are not yet common in the process industries.
GUIDELINES FOR RECORDING HUMAN FAILURES

• **Identify underlying causes**
  
  – E.g. pressure gauge is installed incorrectly (teflon tape omitted, cross-threaded, etc.)
  
  – Do not need to brainstorm all possible root causes

• **Identify the dominant ones**
CONCLUSIONS?

• Regulators wants **human failures** and **human factors** to be considered in performing PHAs
• This is routinely done for **human failures** in most PHAs
• **Human factors** engineering issues can also be considered within a PHA
• It is preferable to conduct a separate study prior to the PHA
• There is still uncertainty as to the extent to which **human factors** must be treated to satisfy Regulators
ESSENTIALS OF RISK MANAGEMENT:
1. DON’T DO ANYTHING WRONG TODAY.
2. DON’T DO ANYTHING WRONG TOMORROW.
3. REPEAT.
References

• Institution of Chemical Engineers, European Process Safety Center, 2000 - HAZOP Guide to Best Practice
• Hazard and Operability Studies (HAZOP Studies) – Application Guide, IEC 61882:2001
• 29 CFR 1910.119, OSHA’s Process Safety Management Standard
• 40 CFR Part 68, EPA’s Risk Management Program Rule
• Jeff Kotson, Commander, U.S. Coast Guard, „Risk Management”, Presented to the Air Charter Safety Foundation JSSC 1998
• Cantemir Mambet, Human Factors. Their impact on risk management, Presentation Petroleum Club Romania, June 2013
Back-up slides
PRECAUTIONARY PRINCIPLE

*In the European Union, risk management practice is guided by the precautionary principle:

“The Community has consistently endeavored to achieve a high level of protection, among others in environment and human, animal or plant health. In most cases, measures making it possible to achieve this high level of protection can be determined on a satisfactory scientific basis. However, when there are reasonable grounds for concern that potential hazards may affect the environment or human, animal or plant health, and when at the same time the available data preclude a detailed risk evaluation, the precautionary principle has been politically accepted as a risk management strategy in several fields” (European Commission, 2000)
**SEVESO III**

*EU Major Accident Prevention Policy and Safety Management System, as Required by Council Directive 96/82/EC (Seveso II), now 2012/18/EU Seveso III*

- Preparation of a Safety Report to meet the requirements of Council Directive 2012/18/EU Seveso III (Art. 10)

- The aim of the Seveso II Directive is **two-fold**
  - Firstly, the Directive aims at the prevention of major-accident hazards involving dangerous substances
  - Secondly, as accidents do continue to occur, the Directive aims at the limitation of the consequences of such accidents not only for man (safety and health aspects) but also for the environment (environmental aspect).
SEVESO III

- The scope of the Seveso III Directive applies solely to the presence of dangerous substances in establishments.
- It covers both, industrial "activities" as well as the storage of dangerous chemicals.
  - **Lower tier site**
    - Must comply with Articles 6 and 7 of the Directive.
    - Notification of substance, details of facilities and assessment of immediate environment.
    - Draw up major accident prevention policy.
  - **Upper tier site**
    - Must comply with Articles 6 - 11 of the Directive.
    - Notification of substance, details of facilities and assessment of immediate environment.
    - Produce safety report demonstrating that:
      - A major accident prevention policy (MAPP) and safety management system (SMS) is in place.
      - Major accident hazards have been identified and measures have been taken to limit consequences.
SEVESO III

- Establishments must demonstrate adequate safety and reliability (ALARP)
- Establishments are required to provide sufficient information to Competent Authority to enable decisions to be taken with regard to siting new developments around existing activities
- Requirements for management policies and systems are contained in the SEVESO III Directive
- Failures of the management system were shown to have contributed to the cause of over 85 per cent of the accidents reported.

*Member States require the operator to produce a safety report to:
- Demonstrate that a Major-Accident Prevention Policy (MAPP) and a Safety Management System (SMS) have been put into effect;
SEVESO III

- Demonstrate that major-accident hazards have been identified and that the necessary measures have been taken to prevent such accidents and to limit their consequences
- Demonstrate that adequate safety and reliability have been incorporated into the design, construction, operation and maintenance of any installation, storage facility, equipment and infrastructure connected with its operation which are linked to major-accident hazards inside the establishment.

*The safety report must include information on the:
- Environment of the establishment
- Description of the installation (incl. listing of hazardous substances)
- Risk analysis and prevention methods
- Control and limitation of the consequences of an accident
SEVESO III

*Seven fundamental elements should be included in the Safety Management System*

- Organization and personnel
- Identification and evaluation of major hazards
- Operational control
- Management of change
- Planning for emergencies
- Monitoring performance
- Audit and review

- PHAs that identify and evaluate the major hazards
SEVESO III

- **Safety Report** must be reviewed and updated every five years or
  - At the request of the Competent Authority
  - At the initiative of the operator (voluntary), where justified by
    - New facts
    - New technical knowledge about safety
    - New knowledge about hazard assessment
    - In case of modification of a site (Art. 10)

- Therefore **the PHA and Risk Analysis must be reviewed and updated for the same reasons**
**PHA**

- Process Hazard Analysis (PHA) (or Process Hazard Evaluation) is a set of organized and systematic assessments of the potential hazards associated with an industrial process.

- A PHA provides information intended to assist managers and employees in making decisions for improving safety and reducing the consequences of unwanted or unplanned releases of hazardous chemicals.

- A PHA is directed toward analyzing potential causes and consequences of fires, explosions, releases of toxic or flammable chemicals and major spills of hazardous chemicals, and it focuses on equipment, instrumentation, utilities, human actions, and external factors that might impact the process.

- *There are varieties of methodologies that can be used to conduct a PHA, including but not limited to: Checklist, What if?, What if?/Checklist, Hazard and Operability Study, Failure Mode and Effects Analysis.*
PHA

- PHA methods are qualitative in nature. The selection of a methodology to use depends on a number of factors, including the complexity of the process, the length of time a process has been in operation and if a PHA has been conducted on the process before, and if the process is unique, or industrially common.
- Other methods such as Layer of Protection Analysis (LOPA) [1] or Fault Tree Analysis (FTA) may be used after a PHA if the PHA team could not reach a risk decision for a given scenario.
- In the US, the use of PHAs is mandated by the Occupational Safety and Health Administration (OSHA) in its Process Safety Management regulation for the identification of risks involved in the design, operation, and modification of processes that handle highly hazardous chemicals.
### HUMAN FACTORS WORKSHEET ENTRIES

<table>
<thead>
<tr>
<th>No.</th>
<th>Scenario Description</th>
<th>CAT</th>
<th>Hazards</th>
<th>Consequences</th>
<th>CAT</th>
<th>Safeguards</th>
<th>CAT</th>
<th>Risk Matrix</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Manual valve MV-3 is closed by operator? (HF - Valve is not labeled)</td>
<td>H</td>
<td>3.1. Unable to proceed with reaction</td>
<td>3.1.1. Loss of production - Operability issue only</td>
<td>O</td>
<td>Operator training</td>
<td>TRN</td>
<td>2 3 6</td>
<td>11. Consider switching MV-3 to a motor-operated valve</td>
</tr>
<tr>
<td>4</td>
<td>Pump P-009A or B casing cracks open?</td>
<td>Eq</td>
<td>4.1. Release of acetone to the atmosphere</td>
<td>4.1.1. Potential for employee exposure</td>
<td>E</td>
<td>PM program for pumps</td>
<td>ADM</td>
<td>4 2 8</td>
<td>11. Consider switching MV-3 to a motor-operated valve</td>
</tr>
<tr>
<td>5</td>
<td>Power Failure occurs to Pump P-009A or B?</td>
<td>Ex</td>
<td>5.1. Unable to proceed with reaction</td>
<td>5.1.1. Loss of production - Operability issue only</td>
<td>O</td>
<td>Power supplied through separate buss to each pump</td>
<td>EQ</td>
<td>2 3 6</td>
<td>11. Consider switching MV-3 to a motor-operated valve</td>
</tr>
</tbody>
</table>
## HUMAN FACTORS WORKSHEET ENTRIES

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Causes</th>
<th>Hazard Scenario</th>
<th>Consequences</th>
<th>Safeguards</th>
<th>Risk Matrix</th>
<th>Recommendations</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flow</strong></td>
<td>2. Release of acetone to the atmosphere</td>
<td>2.2.1. Potential for public impact</td>
<td>2.2.1.1. Guard rails</td>
<td></td>
<td>2 1 2</td>
<td>13. Consider public alarm system</td>
<td>SAF</td>
</tr>
<tr>
<td></td>
<td>4. Pump P-009A or B casing cracks open</td>
<td>4.1. Release of acetone to the atmosphere</td>
<td>4.1.1. Potential for employee exposure</td>
<td>4.1.1.1. PM program for pumps</td>
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<tr>
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<td>5.1.1.1. Power supplied through separate buss to each pump</td>
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<td></td>
</tr>
</tbody>
</table>

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Cantemir Mambet
<table>
<thead>
<tr>
<th>QUESTION</th>
<th>A</th>
<th>REMARKS</th>
<th>RECOMMENDATIONS</th>
<th>BY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Are locations of controls and displays based on importance, frequency of use, function and order of use?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Are controls and displays located in the best places for access and use by operators?</td>
<td></td>
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<tr>
<td>3. Are controls and displays that perform different functions distinguished?</td>
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<td></td>
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<tr>
<td>4. Are controls and displays easily identified (by color, labels, demarcation)?</td>
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</tr>
<tr>
<td>5. Are controls and displays that perform common functions grouped?</td>
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<td></td>
<td></td>
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<tr>
<td>6. Are controls and displays that are used together located next to one another?</td>
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<tr>
<td>7. Are controls and displays consistently ordered?</td>
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</tr>
</tbody>
</table>
### Example of Human Factors in a Global Node

<table>
<thead>
<tr>
<th>Causes</th>
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</tr>
</thead>
<tbody>
<tr>
<td>2. SOPs are lengthy</td>
<td>2.1.1. Operators will be discouraged from using procedures</td>
<td>2.1.1.1. None identified</td>
<td>S</td>
<td>16. Consider review of procedures against best practices checklist prior to implementation</td>
<td>OPS</td>
</tr>
<tr>
<td>1. Operators sometimes work two shifts back to</td>
<td>1.1.1. Operator fatigue</td>
<td>1.1.1.1. None identified</td>
<td>L</td>
<td>15. Consider implementing an administrative</td>
<td>MAN</td>
</tr>
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<td>Causes</td>
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</tr>
<tr>
<td>1. Valves are not labeled or differentiated</td>
<td>1.1.1. Valve may be left partially closed or open</td>
<td>1.1.1. None identified</td>
<td></td>
<td>17. Consider labeling valves in line L31-1</td>
<td>OPS</td>
</tr>
<tr>
<td>2. Pressure gage is not easily read by operator</td>
<td>2.1.1. Possible pressure misreading</td>
<td>2.1.1. None identified</td>
<td></td>
<td>18. Review valve labeling throughout the process</td>
<td>OPS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>19. Consider relocating pressure gage on line L31-1</td>
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</tbody>
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## HUMAN FACTORS REVIEW WITHIN WHAT-IF

### EXAMPLE OF HUMAN FACTORS IN A GLOBAL SYSTEM

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</table>

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OPS

MAN

56
**HUMAN FACTORS REVIEW WITHIN WHAT-IF**

**EXAMPLE OF HUMAN FACTORS IN A LOCAL SYSTEM**

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<td>2.1.1. Operator fatigue</td>
<td></td>
<td>2.1.1.1. None identified</td>
<td></td>
<td>L</td>
<td>13. Consider implementing an administration</td>
<td></td>
<td>MAN</td>
</tr>
</tbody>
</table>

Cantemir Mambet
CHECKLISTS FOR BRAINSTORMING HUMAN FAILURES

People
- Operators
- Engineers/Designers
- Maintenance/Testing/Inspection
- Emergency Responders
- Sampling/Lab
- Supervision
- Management
- Contractors
- Material Handlers/Fork Lift Truck Drivers
CHECKLISTS FOR BRAINSTORMING HUMAN FAILURES

Facility
- Process
- Instrumentation
- Controls
- Alarms
- Interlocks
- Shutdowns
- Safeguards

- Safety equipment
- Instructions (verbal)
- Procedures (written)
- Equipment
- Communications
- Emergency response
- Environment
CHECKLISTS FOR BRAINSTORMING  HUMAN FAILURES

Failures
  - Action is not performed
  - Action is performed incorrectly
  - Action is performed in wrong place
  - Action is performed in wrong sequence
  - Action is performed at wrong time
  - Non-required action is performed