General approach to manage occupational Health and safety risks during maintenance activities

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In France, since November 2002 each company must have a document where occupational health and safety risks are identified and analyzed, and mitigation is identified and carried out.

Many documents available (good practices, regulations, indicators, etc.)

but

There is a need for a general approach
Analysis of occupational health and safety risks

- Identification of dangers
  - List of dangers (potential damages)

- Identification of emergency actions

- Analyse and Assessment of risks
  - Prioritized list of risks

- Mitigation of risks
  - List of preventive and/or protective barriers
  - List of emergency actions
Sources of danger

High energies
(provided to, contained in items)
High energies

- which feed the equipment
- obtained by transformation
- stored, potential or residual

- Electric energy
- Pressure energy from fluids (pneumatic energy (compressed air), hydraulic energy (pressurised water), pressurised steam/gas, etc.)
- Potential mechanical energy (mass in height position, spring, …)
- Kinetic energy (masses, surfaces and aggressive forms in motion, projection of material, …)
- Thermal energy (and cooling energy)
- Chemical energy (flammable or explosive products)
- Light or radiation energies (dazzling light, high radiations, …)
- Magnetic energies
- Strong and discontinuous sound energy (detonation, …)
- …
Sources of danger

High energies
(provided to, contained in items)

Toxic or pathogenic products
Toxic or pathogenic products

Used or produced by the equipment or stored in its environment
- Present in the atmosphere (gases, aerosols, vapors, dusts)
- Present on surfaces (liquids, solids)

Characteristics of the product:

- **Paths of toxicity:**
  - Dermal toxicity
  - Toxicity by inhalation
  - Toxicity by ingestion

- **Types of toxicity:**
  - Chemical or physical toxicity (ammonia, hydrochloric acid, ..., mercury, lead, cadmium, ..., asbestos, combustion products, ...)
  - Biological (bacteria (legionella, ...), protozoa (amoebas, ...), prions, viruses, parasites, venoms, toxins)

- **Effects:**
  - carcinogenic, mutagenic, reprotoxic
  - Infections, allergies, diseases
Sources of danger

- High energies (provided to, contained in items)
- Toxic or pathogenic products
- Unsuitable quantity of vital element
Unsuitable quantity of vital element

- Sub-oxygenation or over oxygenation:
  - Confined work areas
  - Work under water
  - Work at high altitude
  - Presence of gas
  - Presence of liquids presenting a danger of drowning
  - Presence of solids presenting a danger of burial
  - Presence of dust presenting danger of asphyxia

- Dangers: anoxia, asphyxia
Sources of danger

- **High energies (provided to, contained in items)**
- **Toxic or pathogenic products**
- **Unsuitable quantity of vital element**

**Energy of the person**

- Elements, situations that can divert the energy of the person against herself
Elements, situations that can divert the energy (potential or kinetic) of the person against herself

- Condition of floors and spaces (slippery floor, uneven floor, obstacles in traffic area, etc.)
- Condition of spaces (congested space, obstacles at human height, protruding or cutting parts, rough surfaces, etc.)
- Differences of level (pits, stairs, elevators, walkways, balconies, ladder, sloping floor, etc.)
- etc.
Sources of danger

- High energies (provided to, contained in items)
- Toxic or pathogenic products
- Unsuitable quantity of vital element
- Work situations (environment, situations, organisation)
- Postures, stress, ...
- Energy of the person
- Elements, situations that can divert the energy of the person against herself
Working environments that may have an impact on **health**

- Atmospheric conditions (weather, humidity, drought)
- Sound ambience (continued)
- Bright atmosphere (insufficient illumination, dazzling illumination)
- Thermal ambience (exposure to high temperatures or low temperatures)
- Vibrations
- Radiation (ionizing, electromagnetic, optical)
- Hyperbaric (>0,1 bar)
- etc.

**Working conditions that may have an impact on health**

- Work on screen
- Uncomfortable positions
- Manual handling operations (mass handling)
- Situations of stress (dangers, time, psychological pressure, etc.)
- Rhythm of work (fatigue, sleep disorders)
- etc.
Working situations that may have an impact on **safety** (pre or post-accident)

- Movement of the person via transportation (road, rail, air, sea/river, ...)
- Circulations of persons or machineries
- Hot points due to the intervention (oxy-cutting, sawing, grinding, welding)
- Projections provided by the intervention (oxy-cutting, grinding, welding, blowing, sandblasting, high-pressure cleaning)
- Equipment incompatible with the characteristics of the intervention area (explosive atmosphere, flammable elements, ...)
- Obstructing the avoidance of a hazard (lack of visibility or audibility, insufficient or faulty measuring equipment, restricted area, fatigue, stress)
- Insufficient means of communication (post-accident hazard)
- Isolated work (post accident hazard)
Analysis of occupational health and safety risks

- Categories of dangers
  - Lists of dangers
- Identification of dangers
- List of dangers (potential damages)
- Analyse and Assessment of risks
- Prioritized list of risks
- Mitigation of risks
- List of preventive and/or protective barriers
- Identification of emergency actions
- List of emergency actions
Risks to personal health & safety - definition

Severity of the dreaded event
Vulnerability of the person
Probability of the dreaded event

Protective barrier (severity)
Protective barrier (vulnerability)
Preventive barrier (probability)
Risks to personal health - definition

Harmful working conditions

Severity of the dreaded event

Vulnerability of the person

Protective barrier (severity)

Protective barrier (exposure)
Severity of danger

- Intensity, amplitude, dose, ...
Causes of accidents

Inadvertent and unexpected events due to external causes to the person

Environmental or working conditions

DANGERS

Inadvertent and unexpected action of the person
Risk Factors for errors and inappropriate actions

Work organization:

- Documentation or procedures that are absent, incorrect, incomplete, not updated, in a foreign language, ...
- Reduced safety conditions (unidentified responsible for access to the intervention zone, lack of risks analysis and mitigation, etc.)
- Failure to identify equipment
- Isolated work
- Co-activity
- Inadequate training and experience (outsourcing, ...)
- Stress, tiredness (working hours, ...)
- etc.
Risk Factors for errors and inappropriate actions

Conditions of intervention:

• Scuba gear, gloves or other bothersome PPE ...
• Restricted area
• Uncomfortable positions, binding postures
• Insufficient lighting, reduced visibility, stroboscopic effect
• Noise prejudicial to communication
• Unsuitable or inadequate tools
• etc.
Scenario of occurrence of the dangerous event

DANGER

Probability of occurrence of the hazardous event

Initial events

Determine scenario of occurrence of the dangerous event and its probability
Vulnerability of the person

Vulnerability - presence → Occurrence

Vulnerability - level → Consequences

PPE / CPE, Barriers, Avoidances, ...

Physical condition of the person

Number of persons simultaneously exposed

Injury

Frequency, Duration of exposure

Distance

Vulnerability

DANGER
Occurrence and consequences of an event

**Frequency of occurrence**
Probability of occurrence of dangerous situation considering experience and preventive risk control (maintenance, operating procedures and control, logistic, organisation, competences, knowledge of dangerous situations and scenarios, ...)

**Severity of danger**
Intensity of danger, dose/amplitude, isolation devices (separation)

**Vulnerability-level**
PPE/CPE, Number of persons simultaneously exposed, safety procedures and devices (lockout, mark-up, signalling, ...), distance to danger, avoidances, Logistic equipment, organisation, competences, ...
Analysis of occupational health and safety risks

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- Identification of emergency actions

R = Sev. @ Vulnerab. @ Proba.
Defence barriers

- Protection to avoid effects of inappropriate actions
- Prevention against the occurrence of a dangerous situation
- Protection to reduce the severity of dangers
- Protection against dangers
- Means to avoid non-use or misuse of protective barriers

**Inadvertent and inappropriate action of the person**

**DANGERS**
Lockout systems: Examples

- **Disconnection**
  - Protection to reduce the severity of dangers

- **Isolation with single valve**

- **Isolation with double valves + purge**

- **Isolation with valve and sealing**
  - Prevention against the occurrence of a dangerous situation

- **Isolation with double valves**

From French Standard NF X60-400
Defense barriers against harmful working conditions

DANGERS

Protection to reduce the severity of dangers

Harmful working conditions

Protection against dangers

Means to avoid non-use or misuse of protection equipment

*PPE, CPE, practices*
Periodic loop of risk ranking

Risk level

- Risk A
- Risk B
- Risk C
- Risk D
- Risk E
- Risk F
- Following risks ...

Actions to control risks

Year n

Risk E
Risk A
Following risks ...

Year n + 1

Risk F
Risk E
Risk D
Risk C
Following risks ...

Year n + 2

Risk D
Risk C
Risk E
Risk F
Following risks ...

Actions to control risks
Assessment of occupational Health and Safety risks

How to quantify the risks to prioritize them?

\[
\text{Risk year } n = \text{Severity} \times \text{Vulnerability} \times \text{Probability}
\]

\[
\text{Risk year } n+1 = \text{year n : Risk quantification} \times \text{New means of Risk control year N+1}
\]

Risk = Frequency x Risk exposure x Severity ??
General model

Class of danger → Danger → Vulnerability → Level of Risk

Frequency of the dangerous situation

Frequency of the danger based on exposure

Presence

Level

Consequences

Severity of the danger
Identification of dangers

List of dangers (potential damages)

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List of emergency actions

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Reduce the consequences of dangers

DANGERS → DANGEROUS EVENT → EFFECTS → FINAL CONSEQUENCES ON THE HEALTH AND SAFETY OF PEOPLE

PREVENTION BARRIERS

• Example: Precautions for the handling of gas cylinders (flammable, oxidizing, corrosive, ...)

PROTECTION BARRIERS

Example:
• PPE/CPE to use
• Knowledge of locations and exposure situations (insulation, roofs, ...)
• Means for testing the atmosphere
• Means of ventilation

TREATMENTS OF EFFECTS (CARE, AID)

First aid for:
• Burns
• Eye damage (objects, chemical)
• Exposure to heat
• Cuts, wounds
• Fractures
• Cardiac arrest
• Respiratory stop
• Electrification,
• Electrocution
• Insect bites etc.
### Implementation for industrial site

**Combination-Cycle Power Plant**

#### Identification of Dangers

<table>
<thead>
<tr>
<th>Work place</th>
<th>Concerned personnel</th>
<th>Activities</th>
<th>Classes of dangers</th>
<th>Dangers</th>
<th>Comments</th>
<th>Protection to reduce the severity of the danger</th>
<th>Protection to reduce vulnerability (distance, PPE, CPE, ...)</th>
<th>Severity of the danger with existing protections</th>
<th>Number of persons exposed simultaneously</th>
<th>Consequences of danger with existing protections</th>
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#### Severity, Vulnerability and Consequences

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<th>Number of persons exposed simultaneously</th>
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#### Danger Occurrence and Exposure to Danger

<table>
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<tr>
<th>Causes of danger</th>
<th>Risk factors</th>
<th>Prevention to reduce inadvertent actions, their effects and failure modes occurrence</th>
<th>Frequency of the dangerous situation (with existing prevention)</th>
<th>Frequency of the dangerous situation based on exposure</th>
<th>Uncertainty on the frequency of the danger</th>
<th>Criticality (level of risk)</th>
<th>Additional control to implement</th>
<th>Residual risk</th>
<th>Emergency actions</th>
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<tr>
<td>Red</td>
<td>Green</td>
<td>Blue</td>
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*Outputs*