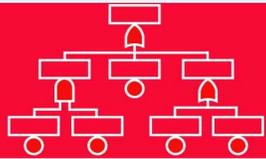

Preliminary Hazard Analysis

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What is preliminary hazard analysis?

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What is PHA?

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PHA scope

PHA procedure

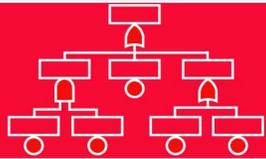
Hazard checklist

Preliminary hazard analysis (PHA) is a semi-quantitative analysis that is performed to:

1. Identify all potential hazards and accidental events that may lead to an accident
2. Rank the identified accidental events according to their severity
3. Identify required hazard controls and follow-up actions

Several variants of PHA are used, and sometimes under different names like

- Rapid Risk Ranking
- Hazard identification (HAZID)



What can PHA be used for?

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1. As an initial risk study in an early stage of a project (e.g., of a new plant).

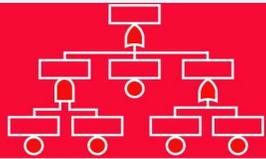
Accidents are mainly caused by release of energy. The PHA identifies where energy may be released and which accidental events that may occur, and gives a rough estimate of the severity of each accidental event. The PHA results are used to (i) compare main concepts, to (ii) focus on important risk issues, and as (iii) input to more detailed risk analyses.

2. As an initial step of a detailed risk analysis of a system concept or an existing system.

The purpose of the PHA is then to identify those accidental events that should be subject to a further, and more detailed risk analysis.

3. As a complete risk analysis of a rather simple system.

Whether or not a PHA will be a sufficient analysis depends both on the complexity of the system and the objectives of the analysis.



PHA scope

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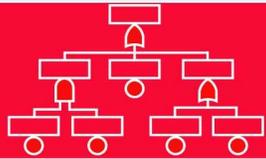
PHA procedure

Hazard checklist

The PHA shall consider:

- Hazardous components
- Safety related interfaces between various system elements, including software
- Environmental constraints including operating environments
- Operating, test, maintenance, built-in-tests, diagnostics, and emergency procedures
- Facilities, real property installed equipment, support equipment, and training
- Safety related equipment, safeguards, and possible alternate approaches
- Malfunctions to the system, subsystems, or software

– Source: MIL-STD 882C



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Frequency classes

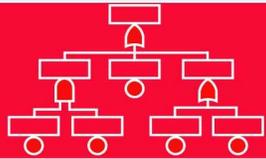
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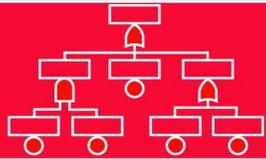
Risk ranking

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1. PHA prerequisites
2. Hazard identification
3. Consequence and frequency estimation
4. Risk ranking and follow-up actions



PHA prerequisites

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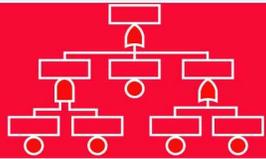
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1. Establish PHA team
2. Define and describe the system to be analyzed
 - (a) System boundaries (which parts should be included and which should not)
 - (b) System description; including layout drawings, process flow diagrams, block diagrams, and so on
 - (c) Use and storage of energy and hazardous materials in the system
 - (d) Operational and environmental conditions to be considered
 - (e) Systems for detection and control of hazards and accidental events, emergency systems, and mitigation actions
3. Collect risk information from previous and similar systems (e.g., from accident data bases)



PHA team

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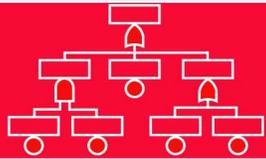
Review

Hazard checklist

A typical PHA team may consist of:

- ❑ A team leader (facilitator) with competence and experience in the method to be used
- ❑ A secretary who will report the results
- ❑ Team members (2-6 persons) who can provide necessary knowledge and experience on the system being analyzed

How many team members who should participate will depend on the complexity of the system and also of the objectives of the analysis. Some team members may participate only in parts of the analysis.



System functions

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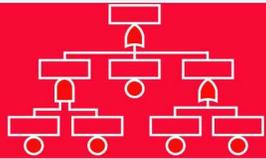
Pros and cons

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Hazard checklist

As part of the system familiarization it is important to consider:

- What is the system dependent upon (inputs)?
- What activities are performed by the system (functions)?
- What services does the system provide (output)?



System breakdown

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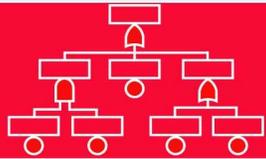
Pros and cons

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To be able to identify all hazards and events, it is often necessary to split the system into manageable parts, for example, into three categories

- System parts (e.g., process units)
- Activities
- Exposed to risk (who, what are exposed?)



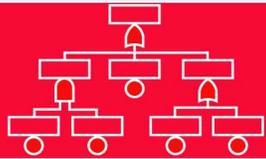
Selection of PHA worksheet

The results of the PHA are usually reported by using a PHA worksheet (or, a computer program). A typical PHA worksheet is shown below. Some analyses may require other columns, but these are the most common.

- Introduction
- PHA procedure
- PHA Main Steps
- Prerequisites**
- Hazard identification
- Frequency
- Severity classes
- Frequency classes
- Risk ranking
- Pros and cons
- Review
- Hazard checklist

System: _____ Operating mode: _____ Analyst: _____
Date: _____

Ref.	Hazard	Accidental event (what, where, when)	Probable causes	Contingencies/ Preventive actions	Prob.	Sev.	Comments



Hazard identification

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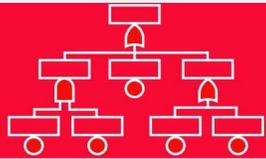
Risk ranking

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Hazard checklist

All hazards and possible accidental events must be identified. It is important to consider all parts of the system, operational modes, maintenance operations, safety systems, and so on. All findings shall be recorded. No hazards are too insignificant to be recorded. Murthy's law must be borne in mind: "If something can go wrong, sooner or later it will".



Hazard checklist

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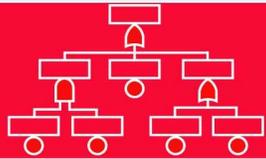
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Hazard checklist

To get a complete survey of all possible hazards it may be beneficial to use a hazard checklist. Several checklists are available in the literature. An example of a checklist (mainly from the standard EN 1050) is given in a separate presentation.



Common sources of hazards

Common sources of hazards are:

- Sources and propagation paths of stored energy in electrical, chemical, or mechanical form
- Mechanical moving parts
- Material or system incompatibilities
- Nuclear radiation
- Electromagnetic radiation (including infra-red, ultra-violet, laser, radar, and radio frequencies)
- Collisions and subsequent problems of survival and escape
- Fire and explosion
- Toxic and corrosive liquids and gases escaping from containers or being generated as a result of other incidents
- Deterioration in long-term storage
- Noise including sub-sonic and supersonic vibrations
- Biological hazards, including bacterial growth in such places as fuel tanks
- Human error in operating, handling, or moving near equipment of the system
- Software error that can cause accidents

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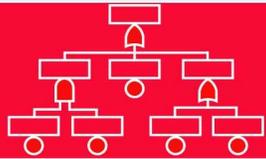
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How to identify hazards?

To identify hazards, you can:

- Examine similar existing systems
- Review previous hazard analyses for similar systems
- Review hazard checklists and standards
- Consider energy flow through the system
- Consider inherently hazardous materials
- Consider interactions between system components
- Review operation specifications, and consider all environmental factors
- Use brainstorming in teams
- Consider human/machine interface
- Consider usage mode changes
- Try small scale testing, and theoretical analysis
- Think through a worst case what-if analysis

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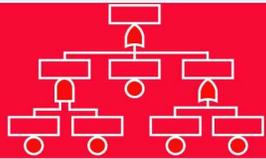
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Additional data sources

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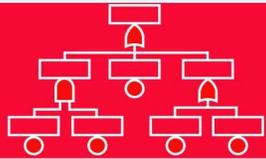
Hazard checklist

To aid prediction of what can happen in the future it is possible to see what actually has happened in the past:

- Accident reports/databases (MARS, Facts, Mhidas, Woad, etc.)
- Accident statistics
- Near miss/ dangerous occurrence reports
- Reports from authorities or governmental bodies
- Expert judgement

A list of accident data sources may be found on:

<http://www.ntnu.no/ross/srt>



Frequency and consequence estimation

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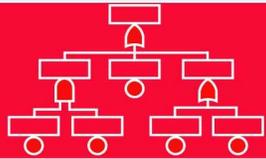
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Hazard checklist

The *risk* related to an accidental event is a function of the frequency of the event and the severity of its potential consequences.

To determine the risk, we have to estimate the frequency and the severity of each accidental event.



Which consequences should be considered?

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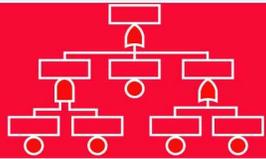
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Hazard checklist

An accidental event may lead to wide range of consequences, ranging from negligible to catastrophic. A fire may, for example, be extinguished very fast and give minor consequences, or lead to a disaster.

In some applications the severity of an *average* consequence of an accidental event is assessed.

In other applications we consider several possible consequences, including the worst foreseeable consequence of the accidental event.



Severity classes

The severity of an event may be classified into rather broad classes. An example of such a classification is:

Rank	Severity class	Description
4	Catastrophic	Failure results in major injury or death of personnel.
3	Critical	Failure results in minor injury to personnel, personnel exposure to harmful chemicals or radiation, or fire or a release of chemical to the environment.
2	Major	Failure results in a low level of exposure to personnel, or activates facility alarm system.
1	Minor	Failure results in minor system damage but does not cause injury to personnel, allow any kind of exposure to operational or service personnel or allow any release of chemicals into the environment.

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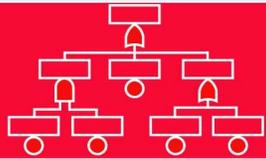
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Frequency estimation

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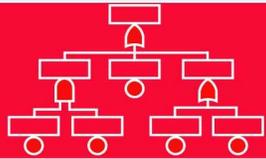
Review

Hazard checklist

When estimating the frequency of an event, we have to bear in mind which consequences we consider.

In some applications we estimate the frequency of each accidental event. To be used in risk ranking, this frequency has to be related to the severity of an *average* consequence of each particular accidental event.

In other applications we consider specific (e.g., worst case) consequences of an accidental event. We must then estimate the frequency that the accidental event produces a specific consequence. This may involve a combined assessment, for example, the frequency of the accidental event, the probability that personnel are present, the probability that the personnel are not able to escape, and so on.



Frequency estimation - (2)

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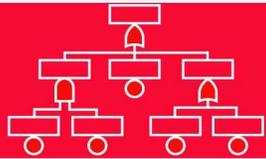
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This means that for each accidental event, we may want to present several consequences with associated frequencies. Consider an accidental event where an operator falls from a work platform of low height. In most cases the consequence of such a fall will be a minor injury (low severity and rather high frequency). In a very seldom case, the fall may result in a fatality (high severity and very low frequency). Both consequences should be recorded in the PHA worksheet.

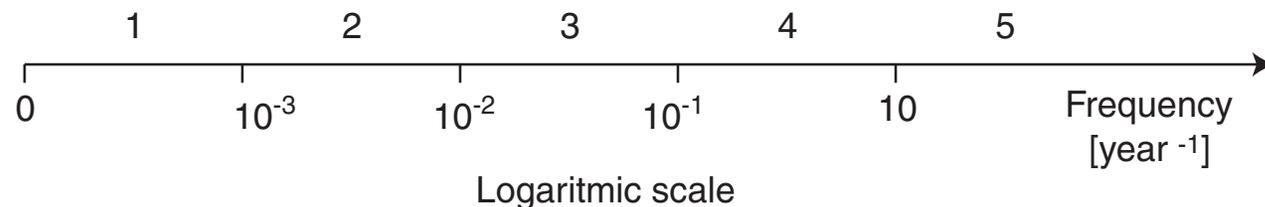
In some applications we may want to present both the frequency of the accidental event and frequencies of various consequences. These may be included in separate columns in a (revised) PHA worksheet.

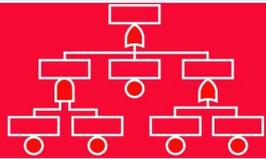


Frequency classes

The frequency of events may be classified into rather broad classes. An example of such a classification is:

1	Very unlikely	Once per 1000 years or more seldom
2	Remote	Once per 100 years
3	Occasional	Once per 10 years
4	Probable	Once per year
5	Frequent	Once per month or more often





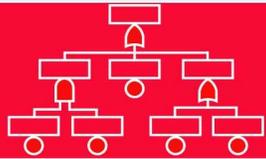
Risk ranking and follow-up actions

The risk is established as a combination of a given event/consequence and a severity of the same event/consequence. This will enable a ranking of the events/consequences in a *risk matrix* as illustrated below:

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- Frequency classes
- Risk ranking**
- Pros and cons
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- Hazard checklist

Frequency/ consequence	1 Very unlikely	2 Remote	3 Occasional	4 Probable	5 Frequent
Catastrophic	Yellow	Red	Red	Red	Red
Critical	Green	Yellow	Yellow	Red	Red
Major	Green	Green	Yellow	Yellow	Red
Minor	Green	Green	Green	Yellow	Yellow

- Acceptable - only ALARP actions considered
- Acceptable - use ALARP principle and consider further investigations
- Not acceptable - risk reducing measures required



Risk levels and actions

Each entry in the PHA worksheet may be given a specific risk level, for example, as (from Norsh Hydro, 2002):

Level	Name	Description
H	High	High risk, not acceptable. Further analysis should be performed to give a better estimate of the risk. If this analysis still shows unacceptable or medium risk redesign or other changes should be introduced to reduce the criticality.
M	Medium	The risk may be acceptable, but redesign or other changes should be considered if reasonably practical. Further analysis should be performed to give a better estimate of the risk. When assessing the need of remedial actions, the number of events of this risk level should be taken into account.
L	Low	The risk is low and further risk reducing measures are not required.

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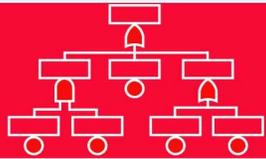
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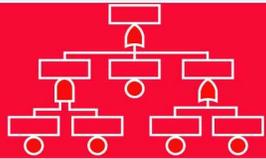
Hazard checklist

Pros:

- Helps ensure that the system is safe
- Modifications are less expensive and easier to implement in the earlier stages of design
- Decreases design time by reducing the number of surprises

Cons:

- Hazards must be foreseen by the analysts
- The effects of interactions between hazards are not easily recognized



Reviewing and revising a PHA

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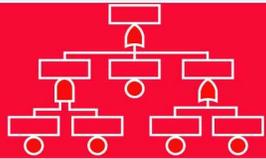
Pros and cons

Review

Hazard checklist

Review/update a PHA whenever:

- The system matures and more is learned about it
- The system equipment is modified
- Maintenance or operating procedures change
- A mishap or near-miss occurs
- Environmental conditions change
- Operating parameters or stress change



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Electrical hazards

Thermal hazards

Thermodynamic hazards

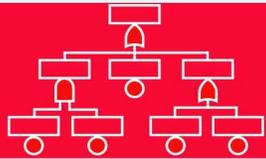
Noise hazards

Vibration hazards

Radiation hazards

Materials/substances hazards

Hazard checklist



Mechanical hazards

Properties of machine parts or workpieces, like:

- (a) Shape
- (b) Relative location
- (c) Mass and stability (potential/kinetic energy)
- (d) Inadequacy of mechanical strength
- (e) Accumulation of energy inside the equipment, e.g.:
 - Elastic elements (springs)
 - Liquids and gases under pressure
 - The effects of vacuum

1. Crushing hazard
2. Shearing hazard
3. Cutting or severing hazard
4. Entangling hazard
5. Drawing-in or trapping hazard
6. Impact hazard
7. Stabbing or puncture hazard
8. Friction or abrasion hazard
9. High pressure fluid injection or ejection hazard

– From EN 1050 (1996)

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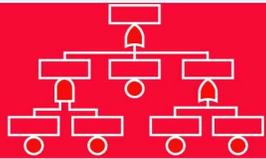
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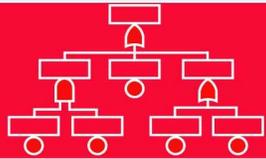
Vibration hazards

Radiation hazards

Materials/substances hazards

1. Contact of persons with live parts (direct contact)
2. Contact of persons with parts which have become live under faulty conditions (indirect contact)
3. Approach to live parts under high voltage
4. Electrostatic phenomena
5. Thermal radiation or other phenomena such as the projection of molten particles and chemical effects from short circuits, overloads, etc.

– From EN 1050 (1996)



Thermal hazards

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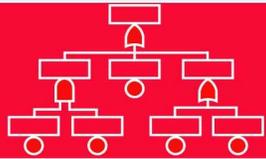
Vibration hazards

Radiation hazards

Materials/substances hazards

1. Burns, scalds and other injuries by a possible contact of persons with objects or materials with an extreme high or low temperature, by flames or explosions and also by radiation of heat sources
2. Damage to health by hot or cold working environment

– From EN 1050 (1996)



Thermodynamic hazards

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Thermodynamic hazards

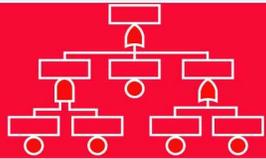
Noise hazards

Vibration hazards

Radiation hazards

Materials/substances hazards

1. Overpressure
2. Underpressure
3. Over-temperature
4. Under-temperature



Hazards generated by noise

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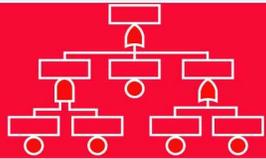
Radiation hazards

Materials/substances hazards

Resulting in:

1. Hearing loss (deafness), other physiological disorder (e.g., loss of balance, loss of awareness)
2. Interference with speech communication, acoustic signals, etc.

– From EN 1050 (1996)



Hazards generated by vibration

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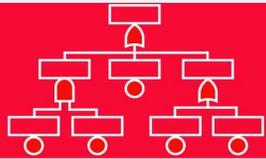
Vibration hazards

Radiation hazards

Materials/substances hazards

1. Use of hand-held machines resulting in a variety of neurological and vascular disorders
2. Whole body vibration, particularly when combined with poor postures

– From EN 1050 (1996)



Hazards generated by radiation

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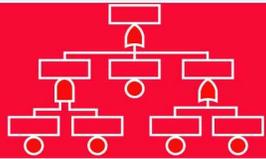
Vibration hazards

Radiation hazards

Materials/substances hazards

1. Low frequency, radio frequency radiation, micro waves
2. Infrared, visible and ultraviolet light
3. X and gamma rays
4. Alpha, beta rays, electron or ion beams, neutrons
5. Lasers

– From EN 1050 (1996)



Hazards generated by materials/substances

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Materials/substance hazards

1. Hazards from contact with or inhalation of harmful fluids, gases, mists, fumes, and dusts
2. Fire or explosion hazard
3. Biological or microbiological (viral or bacterial) hazards

– From EN 1050 (1996)

- Flammables (ignition, fire, explosion/detonation)
- Chemicals (toxicity, corrosion, off-specification)
- Pollutants (emissions, effluents, ventilation)