Risk*topics*

Which Hazard Analysis?

Issue No. 10, October 1998

Risk Engineering

Where standard solutions are the exception

ZURICH

Hazard Analysis Methodologies
A Selection Guide

Purpose

There are an overwhelming number of different hazard analysis methods in use today with acronyms such as HAZOP, FMEA, HACCP, and, of course, ZHA. Consequently, it is often difficult to select the most appropriate method for a given situation. The main purpose of this guide is to provide a systematic decision process for selecting the most suitable method. It concludes with a chart comparing the methodologies along with a brief overview of each method.

Systematic selection process

Step 1: Perform a gross hazard analysis. A gross hazard analysis is a large scope overview of the risks facing a company. This “broad strokes” technique can help identify major vulnerabilities and hazards and then prioritize those that merit further attention and analysis. A gross hazard analysis also has the advantage of being able to look at a much wider variety of hazards and vulnerabilities that other more strictly process-oriented methodologies such as HAZOP cannot. This is particularly important when non-process oriented hazards such as product failure are of interest. Both the What-if/Checklist and the ZHA serve well as gross hazard analysis methodologies. While the What-if/Checklist approach requires the least amount of team leader training and is the quickest to accomplish, it generally produces less detailed and comprehensive re-sults than the ZHA.

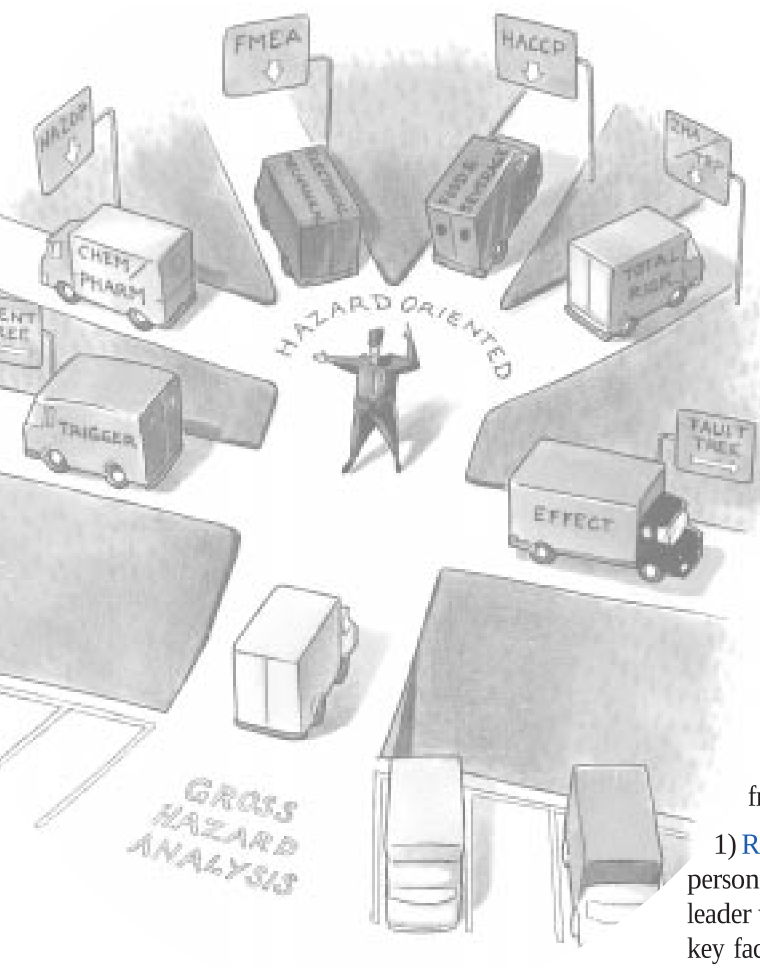
Step 2: Review results of the gross hazard analysis: After completing the analysis, the team can review the results and identify the key hazards, trigger, and effects that the analysis yielded. This step determines what methodology would be appropriate if additional analysis is warranted. For example, suppose a team performed a gross hazard analysis using the ZHA on a slurry gel explosive manufacturing process. The team reviewed the results and reached three key conclusions which are summarized in the chart at the bottom of this page. Please note that the most commonly identified significant hazards, triggers, and effects are not necessarily related to one another. In other words, they do not constitute a “scenario”.

Step 3: Determine appropriate methodology for more detailed analyses: The team concluded that each of these three issues merited further analysis and investigation. Next they must select the appropriate methodology for each issue:

- *Hazard: aluminum powder used as a sensitizing agent.* The aluminum is introduced into the slurry before the final mixing and packaging process. The team decided that the aluminum introduction and mixing process required a more detailed study. Because this process is a chemical one, they chose HAZOP as the appropriate vehicle. *Note: In other types of processes, FMEA or HACCP may be more appropriate. A more detailed ZHA or TRP may also be suitable, particularly for industries that do not have a specific methodology or where the hazards or vulnerabilities are not process-oriented.*

Naturally, the team need not limit themselves to only identifying one common hazard, trigger, and effect of interest. They may be several in each category that merit further investigation.

Zurich Hazard Analysis		
Hazard	**Trigger**	**Effect**
Most commonly identified significant hazard:	Most commonly identified probable trigger:	Most commonly identified severe effect:
Aluminum powder used as a sensitizing agent	Failure of solution tank differential pressure gauge	Explosion in mixing tank



The team is interested in developing a more comprehensive picture of all the possible scenarios leading to such an explosion. Therefore, they decided to develop a **fault tree** with "explosion in the mixing tank" as the top event. This selection process is summarized in the diagram at the bottom off this page.

- *Trigger: Failure of solution tank differential pressure gauge*. The pressure gauge serves as an operational input into the solution mixing process. Its failure could lead to a variety of consequences depending on the stage of the process at the time of failure. In this situation, where the team wishes to further study the potential consequences of a specific initiating event (or trigger), an event tree analysis is appropriate.
- *Effect: Explosion in mixing tank.* An explosion in the mixing tank was a common effect resulting from a variety of hazards and triggers.

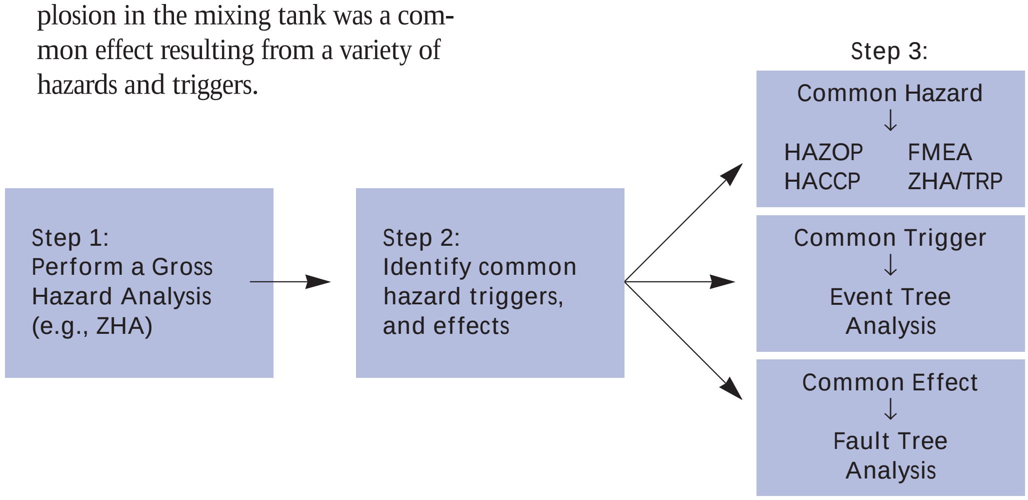
Comparison of the methodologies

One can compare the methodologies from two perspectives:

1) Resource Perspective: The availability of personnel, time, documentation, and a team leader with expertise in the methodology are key factors that influence the selection process.

2) Scope Perspective: The type of industry (e.g., chemical), the need for quantitative results, the breadth of risks being considered, and the size and complexity of the analysis scope also narrow down the prospective analysis techniques.

On the next page is a chart that summarizes the differences amongst the methodologies for key resource and scope criteria. The following pages provide a brief overview of each methodology.



References:
– Center for Chemical Process Safety, Guidelines for Hazard Evaluation Procedures, 2nd ed., New York, New York, 1992.
– Zurich Risk Engineering, Teamleader's handbook for the Zurich Hazard Analysis, Zurich, Switzerland, 1998.
– FSIS Food Safety Education and Communications Staff, http://www.sis.usda.gov/OA/haccp/haccpq@a.htm

Comparison of Hazard Analysis Methodologies

	Criterion	Explanation	What-if/ Checklist	ZHA/TRP	FMEA	HACCP	HAZOP	Event Tree Analysis	Fault Tree Analysis
resource perspective	Team Approach	Does the method rely on a team approach or is it done by an individual?	Team	Team	Team	Team	Team	Individual	Individual
	Documentation	To what extent are drawings, procedures and records needed for an effective analysis?	Minimal	Moderate	Extensive	Extensive	Extensive	Extensive	Extensive
	Time Required	How much time is needed approximately to perform the analysis?	Minimal (less than a day)	Moderate (couple days)	Moderate (week)	Moderate (week)	Extensive (week or more)	Extensive (week or more)	Extensive (week or more)
	Team Leader Expertise	How much training is required for the facilitator to lead a competent analysis?	Minimal training	Moderate training	Moderate training	Moderate training	Moderate training	Extensive training	Extensive training
scope perspective	Quantitative or Qualitative	Can the result be quantitative or or only qualitative?	Qualitative	Qualitative / quantitative	Qualitative	Qualitative	Qualitative	Qualitative/ quantitative	Qualitative/ quantitative
	Inductive or Deductive	Is the analysis forward looking (inductive) or backward looking (deductive)?	Inductive	Inductive	Inductive	Inductive	Inductive	Inductive	Deductive
	Breadth of Hazards considered	How wide a variety of hazards or vulnerabilities can be evaluated?	Could be very wide	Could be very wide	Physical hazards	Physical hazards	Physical hazards	Could be very wide	Could be very wide
	Process Specific	Is the process geared toward a specific type of process or industry?	No	No	Electrical/ mechanical	Food/ agriculture	Chem/ pharm/ petro/ nuclear	No	No
	Gross/Specific Hazard Analysis	Is the methology geared toward a more general site-wide analysis or specific processes and operations?	Gross	Gross or specific	Specific	Specific	Specific	Very specific	Very specific
	Single versus multiple failures	Does the method emphasize single failures in isolation or is it geared toward multiple failures in combination?	Single	Single	Single	Single	Single	Multiple	Multiple

A few words on quantification: One important characteristic of the event tree and fault tree analysis methodologies is that they are capable of generating quantitative results. Capable is emphasized because it is not absolutely necessary to quantify results when using these two techniques. Once the logic trees are developed, more often than not, an analyst can reach conclusions regarding the key potential effects or triggers without defining numerical probabilities. Quantification requires considerable effort and need only be done when the qualitative results are inconclusive or the analysis results are being used in conjunction with a risk-based cost-benefit analysis where quantification is essential.

TRP is primarily a qualitative approach, however, the team can quantify the probability and severity for scenarios of interest (within ranges) to assist in the modeling process which typically follows TRP.

Summary of Methodologies

Here is a summary of the most popular hazard analysis methodologies used in our network today. Each summary includes a brief example of a hypothetical analysis.

Storage of raw materials, products and intermediates

Storage Tanks	Design, Separation, Inerting, Materials of Construction	____
Dikes	Capacity, Drainage	____
Emergency Valves	Remote Control-Hazardous Materials	____
Inspections	Flash Arresters, Relief Devices	____
Procedures	Contamination Prevention, Analysis	____
Specifications	Chemical, Physical, Quality, Stability	____
Limitations	Temperature, Time, Quantity	____

Materials handling

Pumps	Relief, Reverse Rotation, Identification, Materials	____
Ducts	Explosion Relief, Fire Protection, Support	____
Conveyors, Mills	Stop Devices, Coasting, Guards	____
Procedures	Spills, Leaks, Decontamination	____
Piping	Ratings, Codes, Cross-Connectors, Materials	____

(source: Adapted from A.F. Burk, “What-If/Checklist – A Powerful Process Hazards Review Technique,” presented at the AIChE Summer National Meeting, Pittsburgh, PA, August 1991.)

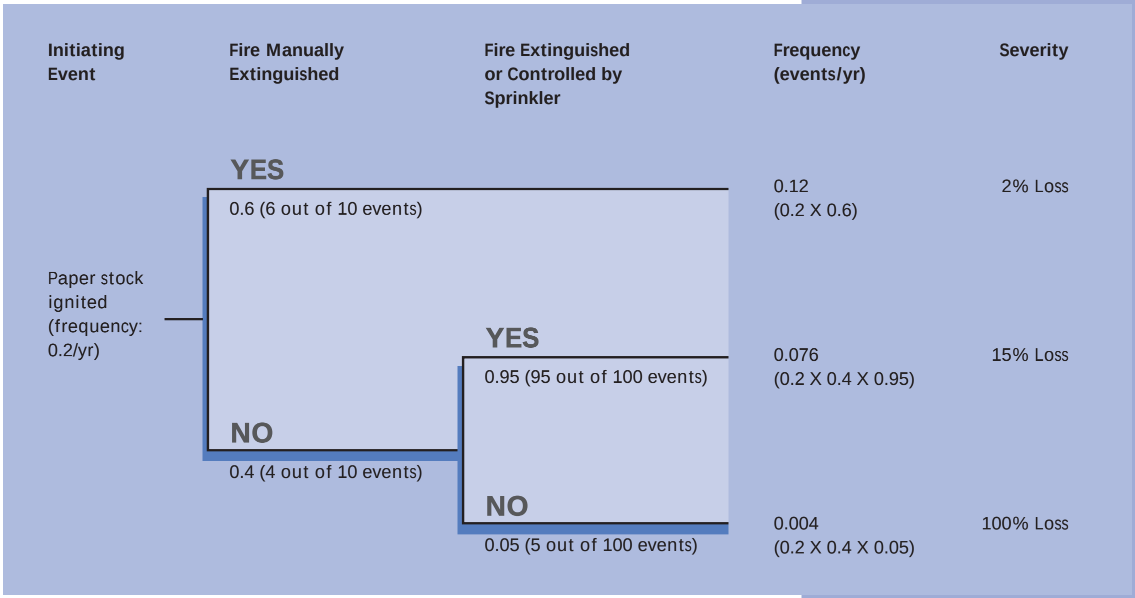
Sample Checklist Excerpt

Event Tree Analysis (ETA)

- Generates multiple scenarios from an “initiating” event (forward-reasoning logic technique)
- Systems modelled must be well defined
- Ideally used for locations with multiple protection and operating systems
- Frequency and/or probability of events can be quantified

Why ETA?

- To model sequences of events; e.g. of operational failures and responses



What-If/ Checklist

- Combines the brainstorming-oriented What-If analysis methodology with the systematic features of the Checklist analysis method.
- Requires relatively little teamleader training and is the quickest analysis method to perform.
- This method usually concentrates on a less detailed level than other process-oriented techniques such as FMEA.

Why What-If/ Checklist?

- To perform gross hazard analyses on relatively simple systems

Zurich Hazard Analysis (ZHA)

Total Risk Profiling (TRP)

- Can be applied at any stage of the product or system life cycle and to the depth required
- Structured brainstorming using "pathways» (the route the analysis team follows; e.g. gas or water flow through the boiler) and "ticklers" (thought-provoking words such as "contamination") as guidelines
- Uses team approach with input from people with expert knowledge of scope analyzed
- Only teamleader needs to have expertise in the analysis methodology
- Risks can be prioritized without being numerically quantified
- A variation of the ZHA called Total Risk Profiling (TRP) can identify a broader range of vulnerabilities that can impact a company's balance sheet.

Why ZHA or TRP?

- To identify hazards in almost any area, including property, liability, employee safety, company image, environmental issues, and overall financial performance etc.

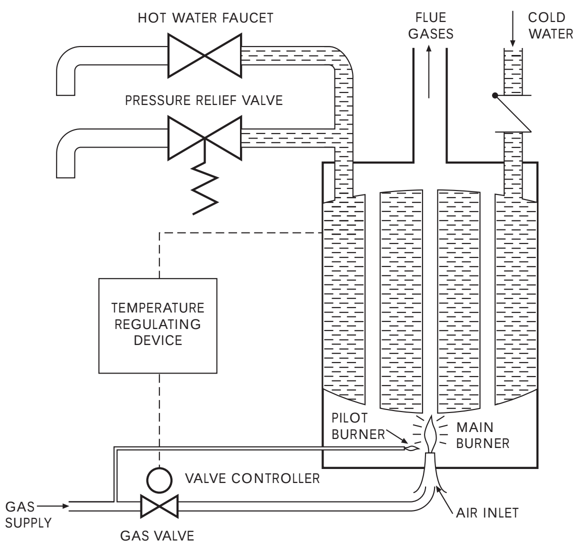
Zurich Risk Engineering	HAZARD ANALYSIS REPORT Company: Hydrolysmus Inc. Project: Domestic Hot Water Boiler

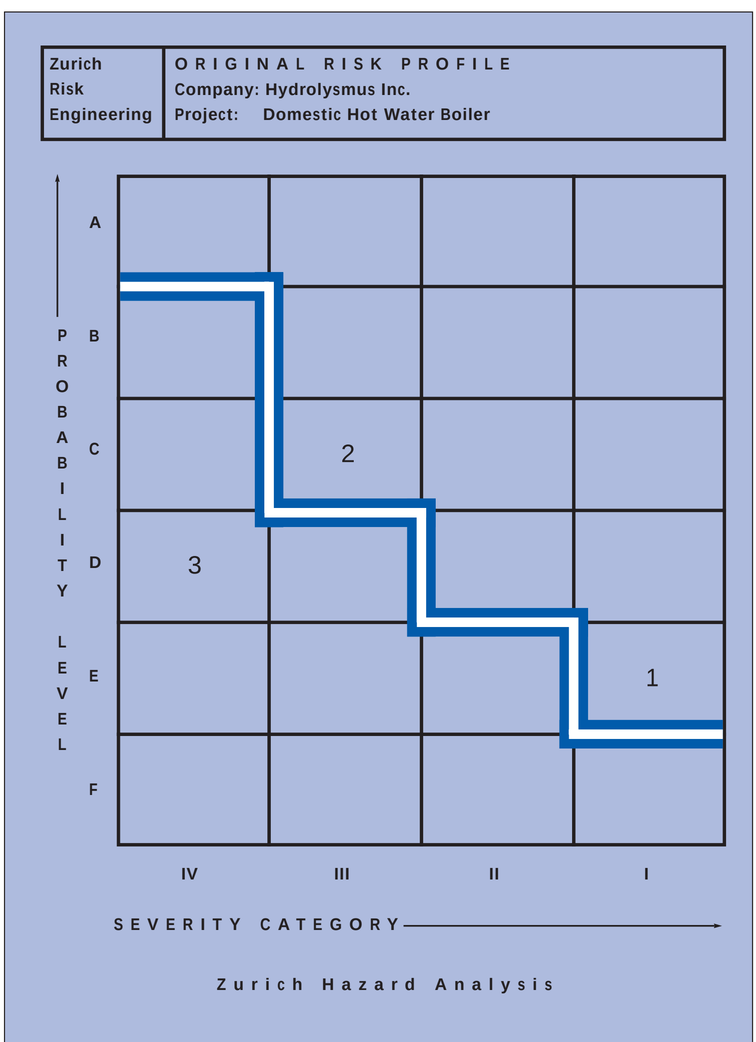
All records sorted by number

No.	Severity	Probability	Hazard	Trigger	Effect	Corrective Action
1	I	E	Flammable gas supply to the burners	Gas supply is temporarily interrupted Flame is extinguished Unignited gas fills chamber + Ignition	Explosion Loss of boiler Significant property damage to house Occupant is killed	Install low gas pressure shut-off valve requiring manual re-set Provide electronic ignition and flame monitor tied to gas shut-off valve
2	III	C	Water supply flowing in heated boiler tubes	Water has high calcium content Calcium builds up on the tube walls and reduces heat transfer	Overheating of tube resulting in damage to boiler Leakage of hot water Loss of boiler use	Install water softener De-calcify boiler tubes at regular intervals Monitor water quality
3	IV	D	Electronic gas valve controller	Controller fails to open gas valve at the appropriate time (basic failure)	No gas is sent to the burner and no hot water is produced	

Severity Category	Probability Level
I Catastrophic II Critical III Marginal IV Negligible	A Frequent B Moderate C Occasional D Remote E Unlikely F Almost Impossible

Zurich Hazard Analysis


HOT WATER FAUCET
FLUE GASES
COLD WATER
PRESSURE RELIEF VALVE
TEMPERATURE REGULATING DEVICE
PILOT BURNER
MAIN BURNER
VALVE CONTROLLER
GAS SUPPLY
GAS VALVE
AIR INLET


Zurich Risk Engineering
ORIGINAL RISK PROFILE
Company: Hydrolysmus Inc.
Project: Domestic Hot Water Boiler
PROBABILITY LEVEL
A
B
C
D
E
F
2
3
1
IV
III
II
I
SEVERITY CATEGORY
Zurich Hazard Analysis

Failure Modes and Effects Analysis (FMEA)

- "Bottom-up" approach; i.e. it follows through initial fault conditions, failures, or errors to their various possible outcomes
- Component-oriented method
- Can be applied by individual or by team
- System modelled needs to be well defined
- Only suitable for modelling "one-event" failures (where single cause leads to the event)
- Results are strongly dependent on analyst's understanding of the failure modes
- Effects of failure modes can be quantified

Why FMEA?

- To identify which failures in a system can lead to undesirable situations
- Particularly suited to electrical and mechanical processes

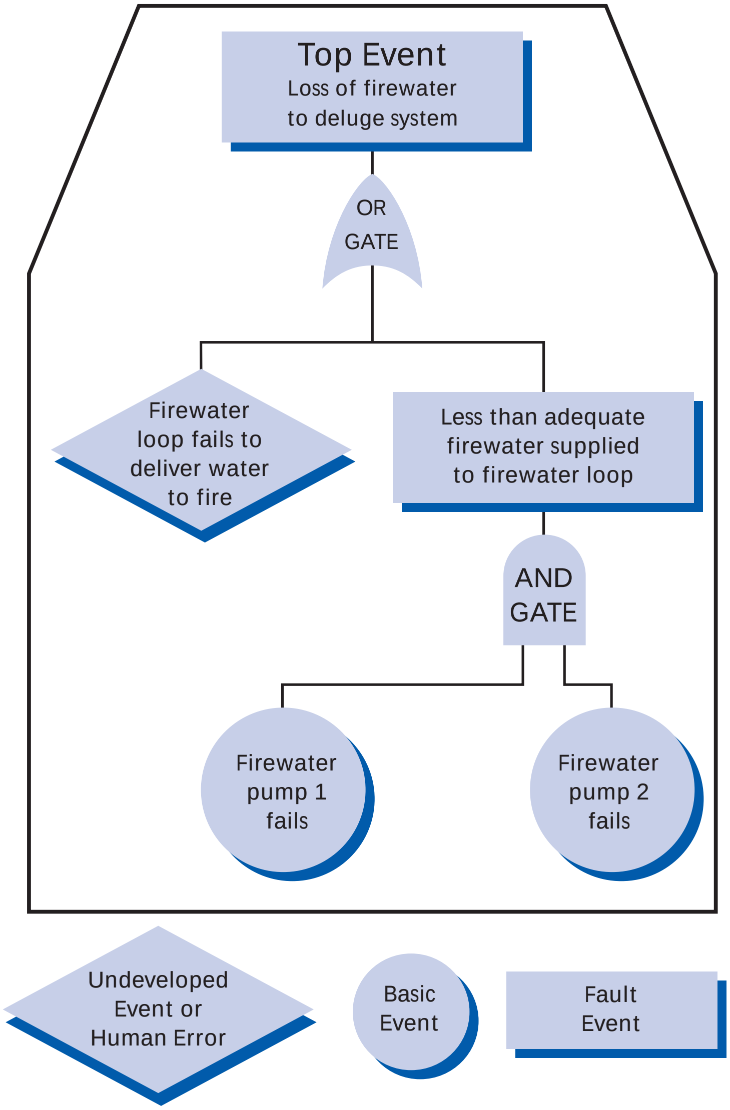
#	Component Description	Failure Mode	Effect	Means of Detection and Safeguards	Actions and Recommendations
1	Master cylinder for brakes in auto	No brake fluid	No braking when main brake pedal is pressed	Emergency brake lever/ handle	Add fluid level indicator
		Piston sticks in closed position	Brakes lock		Scheduled inspection and maintenance every 12 months
2	Impact sensor in auto airbag system	No signal to airbag on impact	Airbag doesn't inflate No protection for driver	System malfunction warning light	Include redundant sensors
		Spurious signal to airbag	Airbag inflates at the wrong time	2 out of 3 «voting» logic for airbag deployment	Add sensor testing to 20,000 km service schedule

Fault Tree Analysis (FTA)

- "Top - down" approach; i.e. FTA works back from the undesired or "top event" to the contributing causes (backward reasoning logic technique)
- Used for modelling specific failures
- Requires skilled analyst
- System modelled needs to be well defined
- Suitable for modelling "one-event" failures (where single cause leads to top event)
- Suitable for modelling "multiple-event" failures (several causes must occur simultaneously for top event to happen)
- Human errors and "common-cause" failures (common to more than one basic event) can significantly influence results
- Frequency and/or probability of the undesired event can be quantified

Why FTA?

- To identify the causes of top events
- To evaluate the economic justification for carrying out improvements to a system

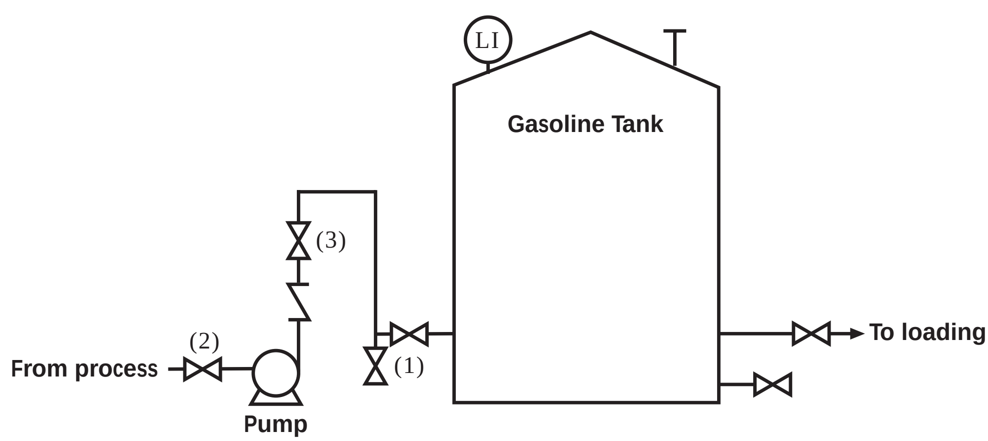


Hazard & Operability Studies (HAZOP)

- Structured brainstorming, using “guide words”; see table below
- Provides a structure for asking “what if” questions to possible deviations from the design: “What if there is NO flow when in fact the design calls for forward flow?”
- Usually applied to piping and instrumentation diagrams (P&IDs)
- Uses team approach with input from people with experience in specific types of equipment

Why HAZOP?

- To identify deviations from normal operating conditions or procedures
- To identify operational problems
- Particularly suited to chemical, pharmaceutical, petrochemical, and nuclear processes.



Guide Words	Deviations	Possible Causes	Consequences	Action Required
LESS OF	Less flow	Loss of hydrocarbon from process to tank via drain valve (1) on pump discharge	Pollution of soil Fire risk	Drain should be plugged or blinded (seldom used)
MORE OF	More flow	Failure of level indicator (LI)	Tank overfills and hydrocarbon is spilled on the ground	Install independent high level alarm
NONE	No flow	Either pump suction valve (2) or discharge valve (3) closes and pump overheats	Damage to electric motor Fire risk	Review operating procedure to ensure all valves between process and tank are open before initiating a transfer

Hazard Analysis and Critical Control Points (HACCP)

- A methodology developed specifically for the food and beverage industry
- Focuses on many physical hazards including biological, chemical, and/or mechanical hazards
- Critical control points are established to prevent, reduce levels, or eliminate such hazards
- Critical limits are established to separate acceptable from unacceptable conditions

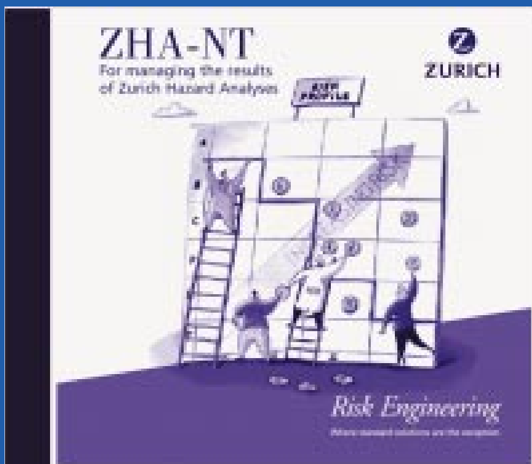
Why HACCP?

- To perform detailed hazard analyses on food and beverage processes and identify critical process limits that require periodic monitoring

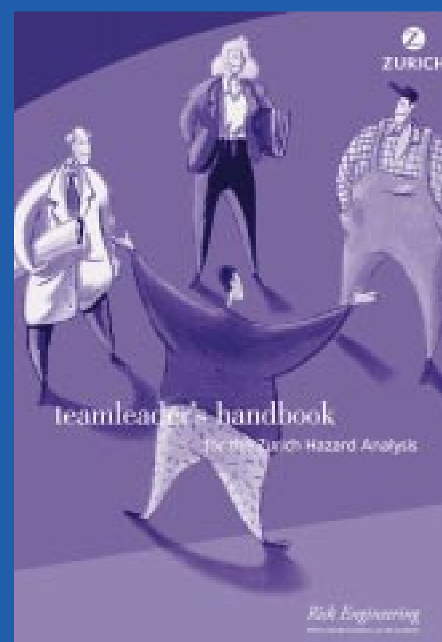
Hazard Details	Monitoring Procedures	Critical Limits	Frequency	Corrective Action	Responsible	Monitoring Document
Brush in salt water	Regular visual check from production staff	No damage to brushes	Ongoing	Rework potentially contaminated product and replace damaged brushes	Main Supervisor	Process Monitoring Manual
Chilling 4 to 5 days at 2° C. Cold burning of crab surface	Check during chilling that Daily plastic cover is in place	Plastic cover to be in place without any opening	Daily	Remove potentially contaminated product for rework Ensure cover is applied	Production Supervisor	Process Monitoring Manual
Freezing room temperature	Check temperature of freezing room	Min. –31.5° Max. –28.5° (Celsius)	Daily	Check temperature with standard thermometer	Main Supervisor	Temperature Monitoring Manual

Disclaimer

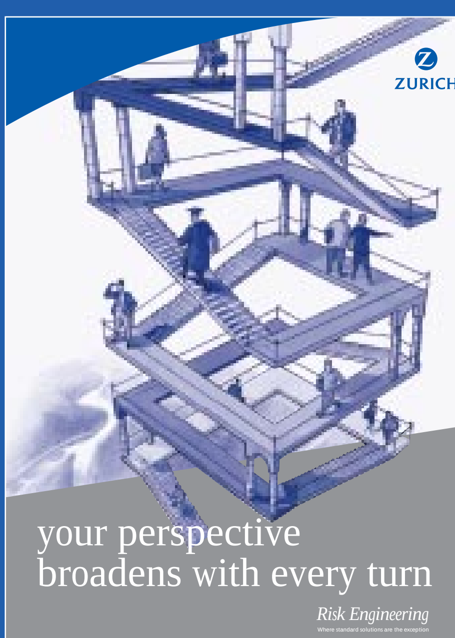
Zurich Risk Engineering has a number of tools and services to help you manage your risks. They are based on Zurich's proprietary hazard analysis methodology, the Zurich Hazard Analysis:



Imagine having one tool to consistently manage all your risks at every location, and being able to keep track of them as they change. ZHA-NT, the new risk management software, makes all your risks instantly visible!



This new handbook is the authoritative guide to performing hazard analyses. It is based on the popular Zurich Hazard Analysis methodology and includes a discussion of hazard analysis fundamentals as well as details on properly defining the scope of an analysis and choosing a team.



Learn the ZHA methodology and practice it within your own company! The Zurich Risk Engineering Course will provide you with the training and practice to become a ZHA teamleader.

For further information contact your local Risk Engineering Office or:

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Zurich Insurance Company
Risk Engineering

Mythenquai 10
8022 Zurich
Switzerland

Telephone +41 (0)1 625 39 51
Fax +41 (0)1 625 26 00

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