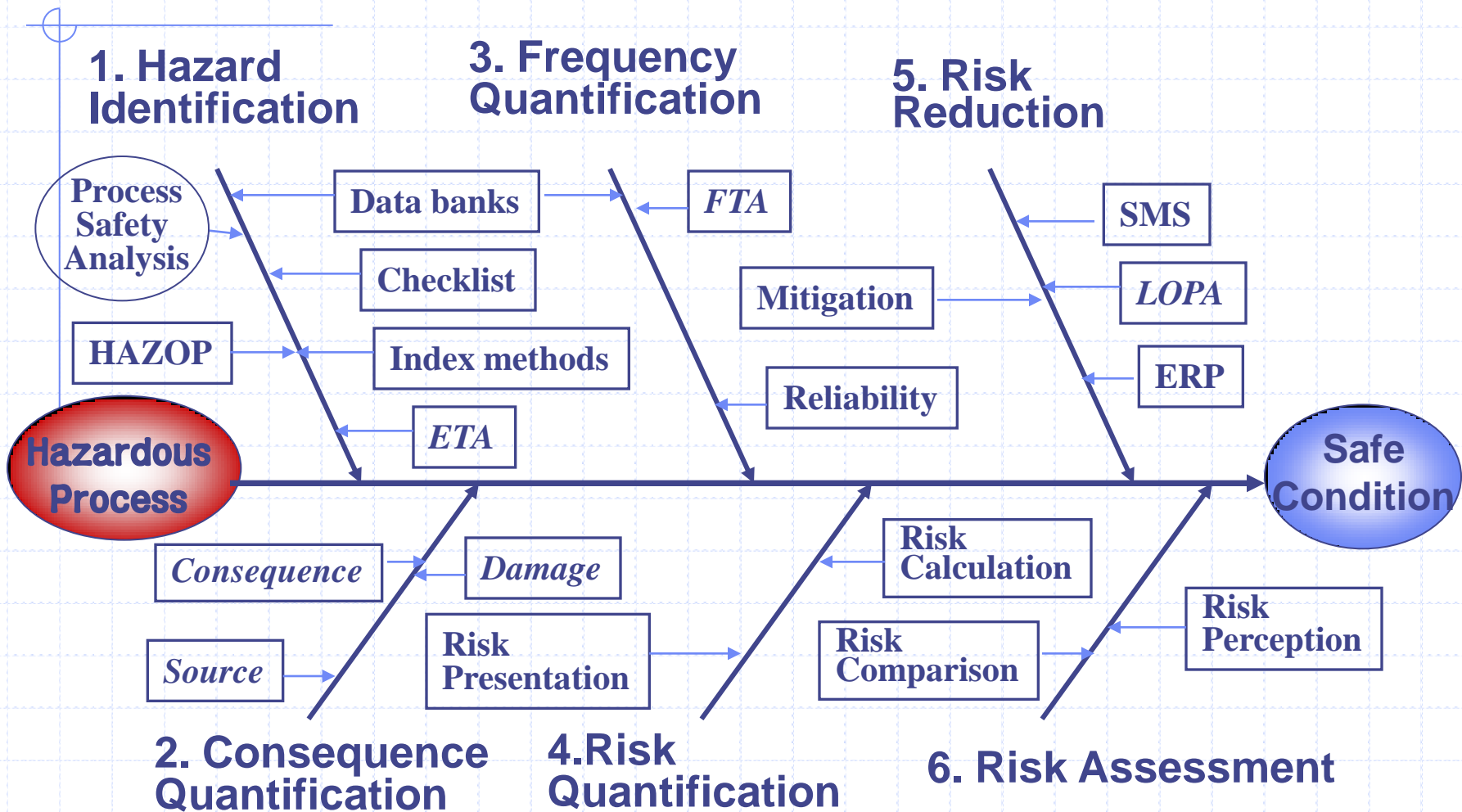


# Qualitative & Quantitative Hazard Analysis

- + Guidelines for Chemical Process Quantitative Risk Analysis, CCPS / AIChE
- + Guidelines for Hazard Evaluation Procedure, CCPS / AIChE

# Risk Analysis Methodology



# Qualitative vs Quantitative



Technique (Tool)	HAZOP What-if FMEA	Quantified FMEA F&EI, CEI	LOPA	ETA	ETA FTA HRA
Simple	Good	Good	Good	Excessive	Excessive
Complex	Poor	Poor	Fair	Fair	Good

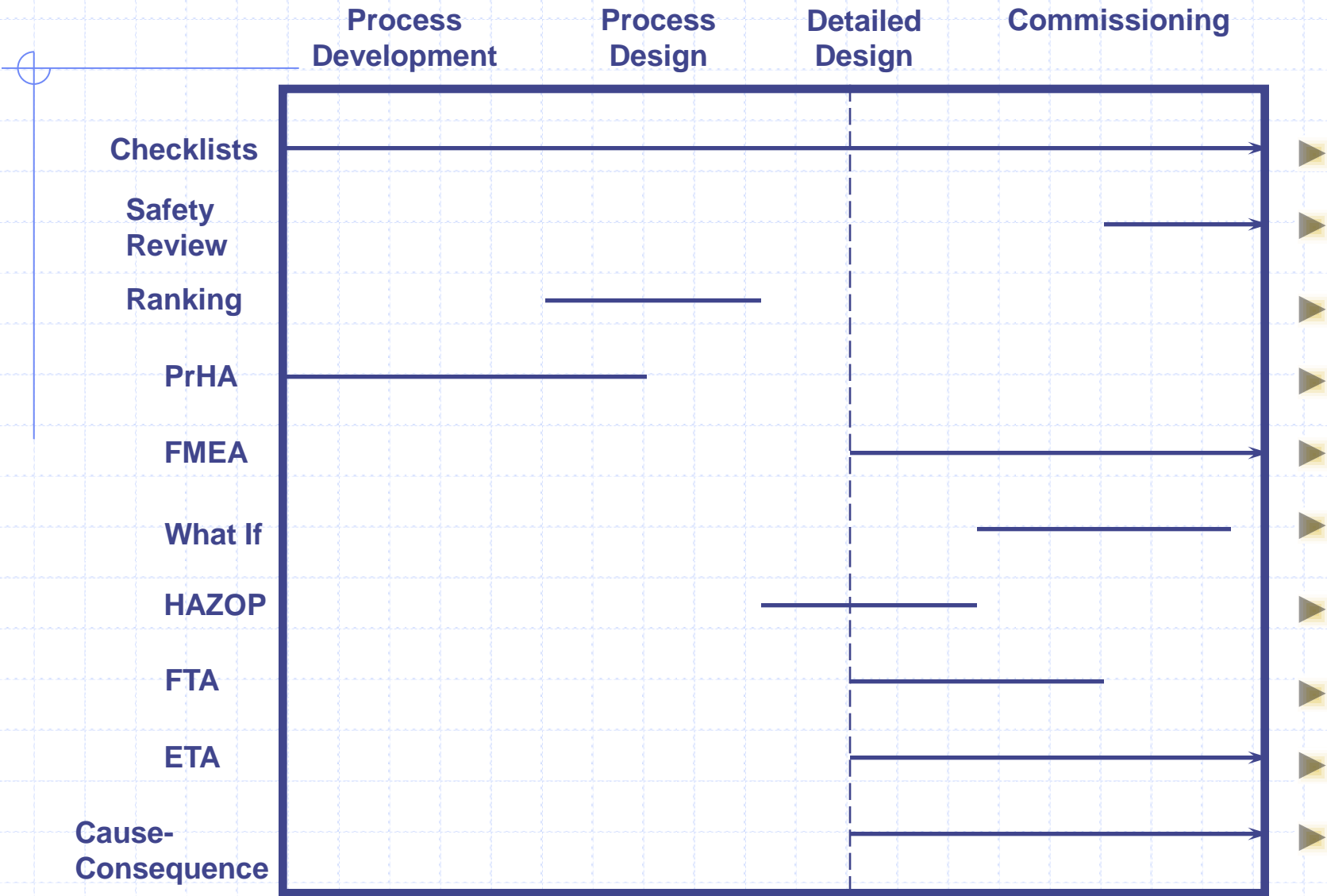
FMEA : Failure Modes and Effects Analysis, F&EI : Dow Fire and Explosion Index  
 CEI : Dow Chemical Exposure Index, HRA : Human Reliability Analysis

# Introduction

- ✚ **Successful hazard evaluation study can be defined as one in which**
  - ✚ **The need for risk information has been met**
  - ✚ **The results are of high quality and are easy for decision makers to use**
  - ✚ **The study has been performed with the minimum resources needed to get job done**

# Hazard Evaluation

- ✦ **Factors influencing the selection of hazard evaluation technique**
  - ✦ Motivation for the study
  - ✦ Type of result needed
  - ✦ Type of information available to perform the study
  - ✦ Characteristics of the analysis problem
  - ✦ Perceived risk associated with the subject process or activity
  - ✦ Resource available and analyst/management preference



	Site selection/ early design state	Design stage of new plants	Operational stage of new and existing plants	Modifications to existing plants
Process system checklist	B	B	A	B
Safety Audit/review	C	C	A	C
Dow and Mond Hazard Indices	C	B	A	C
Preliminary Hazard Analysis	A	C	C	A
Hazard Operability Studies	C	A	B	A
'What if' Analysis	A	C	B	A
Failure Mode and Effect Analysis	C	A	A	B
Fault tree Analysis	C	A	A	B
Event tree Analysis	C	A	A	B
Cause-Consequence Analysis	C	B	A	B
Human Reliability Analysis	C	A	A	B

A : Best suited

B : Could be used

C : last suited (not advised)

# Safety Review

## + Purpose

- + Keeps operating personnel alert to the process hazards
- + Review operating procedures for necessary revisions
- + Seek to identify equipment or process changes that could have introduces new hazard
- + Evaluate the design basis of control and safety system

## + Types of result

- + Qualitative descriptions of potential safety problem and suggested corrective actions

## + Resource requirements

- + P&ID, flowcharts, plant procedures for start-up, shutdown, maintenance and emergencies, hazardous incident reports, process material characteristics












## **+ Overview**

- + Detailed inspection to identify hazardous process design characteristics, plant conditions, operating practice or maintenance activities**
- + Conduct periodic inspection of an operating plant helps ensure that implemented risk management program meet original expectations and standards**
- + Address all plant equipment. Instrumentation, associated utilities, environmental protection facility, maintenance areas and service**

## **+ Preparing for the review**

- + Define which systems, procedures, operations and personnel will be evaluated**
- + Following task should be completed**
  - + Assemble a detailed description of the plant**
  - + Review the known hazards and process history with the review team members**
  - + Review all of the applicable codes, standards and company requirement**
  - + Schedule interviews with specific individual responsible for safe process operation**
  - + Request available records concerning personnel injuries, accident/incident reports, equipment inspection, pressure relief valve testing, safety/health audits etc.**

## Performing the review

-  Obtain and review copies of plant drawing as well as operating, maintenance and emergency procedures
-  Some question that might be addresses are
  -  Is there a system for keeping important process documentation and drawing up-to-date?
  -  Is the equipment in good condition?
  -  Are the pressure relief or other safety property installed, well maintained and properly identified?
  -  Do plant records show the history of inspecting/testing of the equipment and the safety devices?
  -  Are safe practice followed and permits used?



# Checklist Analysis

## + Purpose

- + Ensure that organizations are complying with standard practices

## + Type of results





- + List of questions based on deficiencies or difference
- + Completed checklist contains “yes”, “no”, “not applicable” or “need more information” answer to the question

## + Resource requirement

- + Engineering design procedure, operating practices manual
- + Experiences manager or engineer with knowledge of process



## **Overview**

-  **Experience –based approach**
-  **Use s list of specific items to identify known types of hazards, design deficiencies and potential accident situation**
-  **Can be used to evaluate materials, equipment or process**
-  **Ensure that a piece of equipment conforms with accepted standards and it may also identify areas that required further evaluation**

## **+ Analysis procedure**

### **+ Selecting or developing an appropriate checklist**

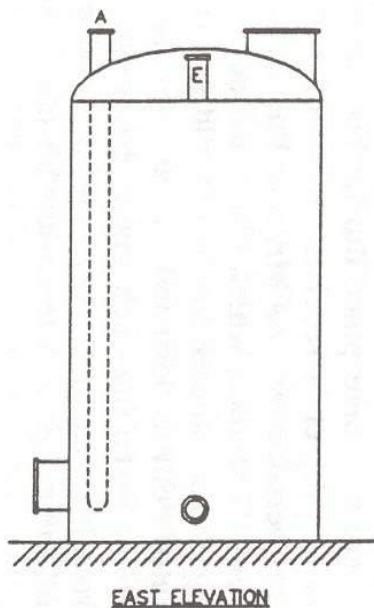
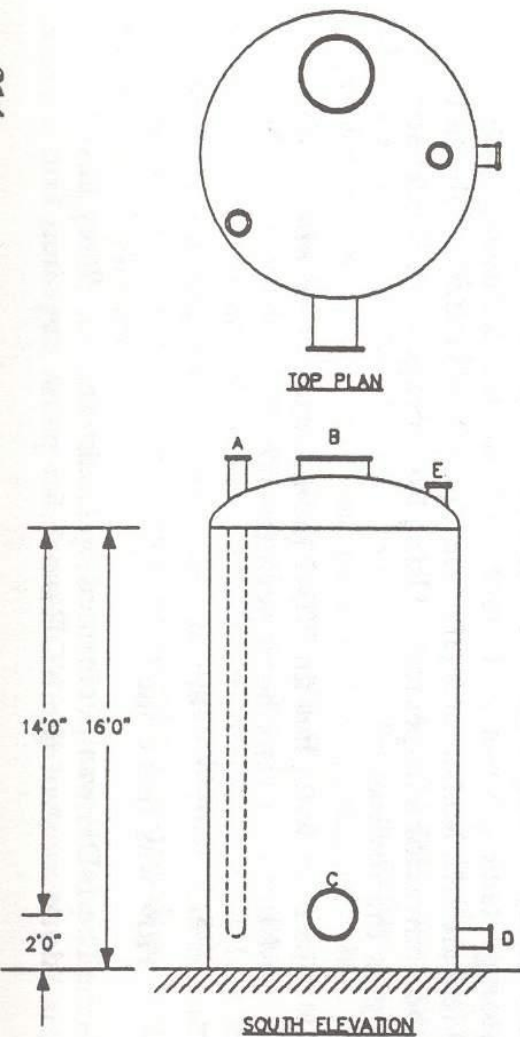
- + Appropriate checklist from available information**
- + Analyst must use his own experience and the information available from authoritative reference to generate an appropriate checklist**

### **+ Performing the review**

- + Include tours and visual inspections of the subject process areas by the HE team members**
- + Reviewer respond to the checklist issues based on observations from site visits, system documentation, interviews with operating personnel and personnel perception**

### **+ Documenting the results**

- + Summarize the deficiencies noted during the tours or meeting and any specific recommendation**



NOZZLE SCHEDULE				DESIGN DATA
MARK	SIZE	TYPE	DESCRIPTION	
A	2"	150#	FILL	DIMEN: 8' DIA. X 16' STR. SIDE CAPACITY: 13,500 GAL DES. PRESSURE SHELL: 50 PSIG OPERATING PRESSURE SHELL: ATMOS DESIGN TEMPERATURE SHELL: 250F OPERATING TEMPERATURE SHELL: 120F TEST PRESSURE SHELL: 100 PSIG SHELL THICKNESS 5/16" MATERIAL OF CONSTR. CARBON STEEL REMARKS: FIBERGLASS LINED
B	20"	150#	MANWAY	
C	16"	150#	MANWAY	
D	2"	150#	DISCHARGE	
E	2"	150#	VENT	

DRAWING NO. H-107	HCl STORAGE TANK	ABC VCM PLANT ANYWHERE, USA	DRAWN BY	DATE	REV	DATE	DESCRIPTION
			DFM	9/8/88			
SCALE: NONE			CHECKED BY	DATE			
			WGB	10/20/88			

Figure 16.1 Schematic of the HCl storage tank.

**Table 16.1 Checklist Analysis Results for the HCl Storage Tank Inspection**

<b>Item To Check</b>	<b>O.K. (Sign and Date)</b>
1. Nondestructive examination (NDE) performed	
a. NDE examiners are ASME-certified	I.M.B. 1/5/89
b. Approved ASME NDE method used	I.M.B. 1/5/89
c. NDE results in engineering file	I.M.B. 1/5/89
2. Postweld heat treatment and hardness testing performed	
a. Postweld heat treatment in accordance with ASME code	I.M.B. 1/5/89
b. Brinell hardness testing performed	I.M.B. 1/5/89
c. Test results in engineering files	I.M.B. 1/5/89
3. Vessel foundation elevation and slope checked	Action Required
4. Vessel material and construction materials in compliance with specifications and job requirements	I.M.B. 1/5/89
5. All welds inspected and tested	I.M.B. 1/5/89
6. All tack welds in vertical joints properly removed	I.M.B. 1/5/89
7. Vessel wall plate in good condition (or properly repaired if damaged) and contains all pertinent information	I.M.B. 1/5/89
8. Vessel hydrotested	I.M.B. 1/5/89
9. Dimensional check of vessel performed	I.M.B. 1/5/89
10. Elevation and orientation of nozzles checked. Vessel is on centerlines, is level, and is properly grouted. Foundation bolts tightened	I.M.B. 1/5/89
11. Ladders and platforms installed as per drawings	I.M.B. 1/5/89
12. Trays level and correct orientation. Downcomer clearance, weir height, drain holes, gaskets, bolts, etc., installed per specification	Not Applicable
13. Internal pipes installed with correct bolts and gaskets	I.M.B. 1/5/89
14. Internal lining intact	Action Required
15. Internal tray manways closed	Not Applicable
16. Packing installed	Not Applicable



# Relative Ranking

## + Purpose

- + Determine the process areas or operation that are the most significant with respect to the hazard of concern in a given study

## + Types of result




- + An ordered list of process equipment, operation or activities

## + Resource requirements

- + Basic physical and chemical data on the substance used in the process or activity



## **Overview**

-  Rank process areas or plant operations by comparing the hazards attributes of chemicals
-  Distinguish between several process areas based on the magnitude of hazards, likelihood of accidents and/or severity of potential accidents
-  Can address fire, explosion and/or toxicity hazards and associated safety, health, environmental and economic effects for a process or activity

**Relative ranking techniques may be used during any phase of a plant or process lifetime to:**

- Identify the individual process areas that contribute most to the anticipated overall hazard and accident attributes of a facility**
- Identify the key material properties, process conditions and/or process characteristics that contribute most to the anticipated hazards and accident of a single area or an entire facility**
- Compare to anticipate hazard and accident attributes of process areas or facilities to other whose attributes are better understood**

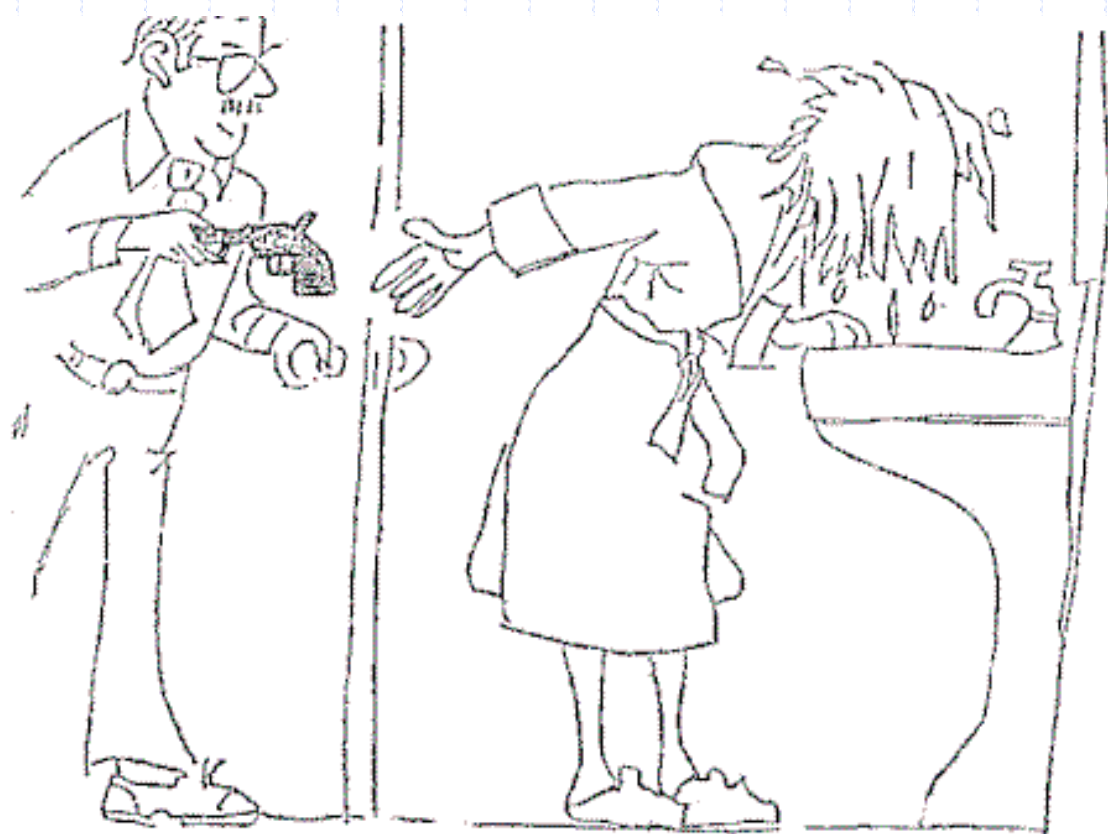
스릴 최고의 그네  
가다가 급정거하면  
바로 사망





*YES! IT'S A WOMAN!!!*

<http://go.to/funpic>



Honey ! Hand me the hair dryer!

## **✚ Considering factor for implementing the relative ranking index**

- ✚ Material properties**

- ✚ Process conditions**

- ✚ Process characteristics and support systems**

  - ✚ Purging, ventilation, cooling, heating etc**

- ✚ System design and construction**

  - ✚ Fire proofing, equipment layout, corrosion resistance etc**

- ✚ Operational activities**

  - ✚ Operator training, written procedures etc.**

- ✚ PSM activities**

  - ✚ Inspection and testing intervals, maintenance activities etc.**

- ✚ Exposure possibilities**

  - ✚ Operation time and frequency, number of operator activities etc.**

## + Summary of relative ranking indexes-1

### + Dow Fire and Explosion Index(F&EI)

- + Rankings of process units can be used
  - + To direct specific safety improvement efforts relating to important parameters used in the F&EI calculation
  - + To identify areas for more detailed hazard evaluation or risk analysis study

### + Mond Index

- + Extension of the Dow F&EI
- + Includes factors that address the toxicity hazards associated with materials in process units

### + Substance Hazard Index(SHI)

- + Way of ranking material hazards defined as “equilibrium vapor concentration(EVC) of a material at 20C divided by an acute toxicity concentration”



## **+ Summary of relative ranking indexes-2**






### **+ Chemical Exposure Index(CEI)**

- + Addresses five types of factors that can influence the effects of release of the material**
  - + Acute toxicity**
  - + Volatile portion of material which could be released**
  - + Distance to areas of concern**
  - + Molecular weight of the substance**
  - + Various process parameters such as temperature, pressure, reactivity and so forth**



# Analysis Procedure

## Preparing for the review

### Information for preparing the analysis

-  Site plan
-  Lists of materials, chemical properties and quantities
-  General process diagram and equipment layout drawing
-  Design and operating data
-  Technical guides for the selected ranking technique

### Performing the review

-  Follow the instruction in the technical guide for that technique to perform the evaluation
-  The calculates risk index should be summarized to facilitate comparisons among the area

### Document the results



백취이미지카페  
<http://cafe.daum.net/guess1976>



# Presentation Content

- + Participation
- + Introduction with an overview and background
- + Literature review
- + Definition of the problem
- + Objective
- + Identification of important issues
  - + Analysis of the problem
  - + Description of fundamentals
  - + Relation to engineering principles
  - + Guidelines for applying the information or experience in engineering situations
  - + Patterns that help determine process safety strategies  
Include applicable government regulations.
- + Conclusions and recommendations

**Table 6.3 Data for the Relative Ranking Example**

Facility	Hazardous Substance	Mass of Chemical in Largest Single Container ( $\times 10^3$ kg)	SHI	Population Within 1-Mile Radius of Facility ( $\times 10^3$ )	LFL (ppm)
Plant A	Chlorine	90	73,000	2	na <sup>a</sup>
	Ammonia	1,000	2,400	2	na
Plant B	Arsine	.01	1,000,000	0.5	na
	Sulfur dioxide	10	10,000	0.5	na
	Ammonia	90	2,400	0.3	na
Plant C	Hydrogen fluoride	30	50,000	3	na
	Chlorine	10	73,000	3	na
Plant D	Propylene oxide	120	3,300	7	28,000
	Sulfur dioxide	10	10,000	7	na

<sup>a</sup>na = not applicable for this example.

**Table 6.4 Results from the Relative Ranking Example**

<b>Facility/Substance</b>	<b>SHI (<math>\times 10^3</math>)</b>	<b>MSHI (<math>\times 10^3</math>)</b>	<b>Rank</b>
Plant A/chlorine	73	1390	1
Plant C/hydrogen fluoride	50	822	2
Plant C/chlorine	73	693	3
Plant D/sulfur dioxide	10	221	4
Plant A/ammonia	2.4	152	5
Plant B/arsine	1,000	50	6
Plant D/propylene oxide	3.3	18	7
Plant B/sulfur dioxide	10	16	8
Plant B/ammonia	2.4	11	9

**EXHIBIT A**

**FIRE AND EXPLOSION INDEX**



LOCATION ANYWHERE USA DATE 2/10/94

PLANT VCM PLANT - SITE #1 PROCESS UNIT 150 PSIG PVC EVALUATED BY DD REVIEWED BY AD  
**MATERIALS AND PROCESS**

MATERIALS IN PROCESS UNIT  
VCM WATER DISPERSANTS INITIATOR  
 STATE OF OPERATION: START-UP  SHUT-DOWN   NORMAL OPERATION  
 BASIC MATERIAL(S) FOR MATERIAL FACTOR: VCM

MATERIAL FACTOR (SEE TABLE I OR APPENDICES A OR B) Note requirements when unit temperature over 140 F) 21

1. GENERAL PROCESS HAZARDS	PENALTY	PENALTY USED
BASE FACTOR →	1.00	1.00
A. EXOTHERMIC CHEMICAL REACTIONS (FACTOR .30 to 1.25)		<u>0.5</u>
B. ENDOTHERMIC PROCESSES (FACTOR .20 to .40)		<u>—</u>
C. MATERIAL HANDLING & TRANSFER (FACTOR .25 to 1.05)		<u>0.5</u>
D. ENCLOSED OR INDOOR PROCESS UNITS (FACTOR .25 to .90)		<u>—</u>
E. ACCESS	.35	<u>0.2</u>
F. DRAINAGE AND SPILL CONTROL (FACTOR .25 to .50) <u>Gals.</u>		<u>0.25</u>
GENERAL PROCESS HAZARDS FACTOR (F <sub>1</sub> ) →		<u>2.45</u>
<b>2. SPECIAL PROCESS HAZARDS</b>		
BASE FACTOR →	1.00	1.00
A. TOXIC MATERIAL(S) (FACTOR 0.20 to 0.80) <u>Nh = 2</u>		<u>0.4</u>
B. SUB-ATMOSPHERIC PRESSURE (1 - 500 mm Hg)	.50	<u>—</u>
C. OPERATION IN OR NEAR FLAMMABLE RANGE <input type="checkbox"/> INERTED <input type="checkbox"/> NOT INERTED		
1. TANK FARMS STORAGE FLAMMABLE LIQUIDS	.50	
2. PROCESS UPSET OR PURGE FAILURE	.30	<u>0.3</u>
3. ALWAYS IN FLAMMABLE RANGE	.80	
D. DUST EXPLOSION (FACTOR .25 to 2.00) (SEE TABLE II)		<u>—</u>
E. PRESSURE (SEE FIGURE 2) OPERATING PRESSURE <u>75</u> psig RELIEF SETTING <u>100</u> psig		<u>0.32</u>
F. LOW TEMPERATURE (FACTOR .20 to .30)		<u>—</u>
G. QUANTITY OF FLAMMABLE/UNSTABLE MATERIAL: QUANTITY <u>13000</u> lbs., H <sub>c</sub> = <u>8000</u> BTU/lb		
1. LIQUIDS, GASES AND REACTIVE MATERIALS IN PROCESS (SEE FIG. 3)		<u>0.16</u>
2. LIQUIDS OR GASES IN STORAGE (SEE FIG. 4)		
3. COMBUSTIBLE SOLIDS IN STORAGE (SEE FIG. 5)		
H. CORROSION AND EROSION (FACTOR .10 to .75)		<u>0.1</u>
I. LEAKAGE - JOINTS AND PACKING (FACTOR .10 to 1.50)		<u>0.3</u>
J. USE OF FIRED HEATERS (SEE FIG. 6)		<u>0.1</u>
K. HOT OIL HEAT EXCHANGE SYSTEM (FACTOR .15 to 1.15) (SEE TABLE III)		<u>—</u>
L. ROTATING EQUIPMENT	.50	<u>0.5</u>
SPECIAL PROCESS HAZARDS FACTOR (F <sub>2</sub> ) →		<u>3.18</u>
UNIT HAZARD FACTOR (F <sub>1</sub> x F <sub>2</sub> - F <sub>3</sub> ) →		<u>779</u>
FIRE AND EXPLOSION INDEX (F <sub>2</sub> x MF - F & E <sub>1</sub> ) →		<u>164</u>

**Figure 18.3** Fire and explosion index calculations for low-pressure PVC reactor site #1.



LOSS CONTROL CREDIT FACTORS

<b>1. Process Control (C<sub>1</sub>)</b>			
<b>.98</b> ✓ a) Emergency Power	.98	f) Inert Gas	.94 to .96
b) Cooling	.97 to .99	g) Operating Instructions/ Procedures	.91 to .99
c) Explosion Control	.84 to .98	✓ h) Reactive Chemical Review	.91 to .98 <b>.91</b>
<b>.98</b> ✓ d) Emergency Shutdown	.96 to .99		
e) Computer Control	.93 to .99		
C <sub>1</sub> Total <u><b>0.87</b></u> *			

<b>2. Material Isolation (C<sub>2</sub>)</b>			
<b>.96</b> ✓ a) Remote Control Valves	.96 to .98	✓ c) Drainage	.91 to .97 <b>.95</b>
b) Dump/Blowdown	.96 to .98	d) Interlock	.98
C <sub>2</sub> Total <u><b>0.91</b></u> *			

<b>3. Fire Protection (C<sub>3</sub>)</b>			
a) Leak Detection	.94 to .98	f) Sprinkler Systems	.74 to .97
b) Structural Steel	.95 to .98	g) Water Curtains	.97 to .98
c) Buried Tanks	.84 to .91	h) Foam	.92 to .97
<b>.97</b> ✓ d) Water Supply	.94 to .97	✓ i) Hand Extinguishers/Monitors	.95 to .98 <b>.97</b>
e) Special Systems	.91	j) Cable Protection	.94 to .98
C <sub>3</sub> Value <u><b>0.94</b></u> *			

Credit Factor = C<sub>1</sub> X C<sub>2</sub> X C<sub>3</sub> = **0.74** Enter on Line D Below

UNIT ANALYSIS SUMMARY

A-1. F & EI	<u><b>164</b></u>	
A-2. Radius of Exposure	<u><b>137</b></u> ft.	
A-3. Value of Area of Exposure	_____	\$MM _____
B. Damage Factor	_____	
C. Base MMPD (A-3 X B)	_____	\$MM _____
D. Credit Factor	_____	
E. Actual MMPD (C X D)	_____	\$MM _____
F. Days Outage (MPDO)	_____	_____ days.
G. Business Interruption Loss (BI)	_____	\$MM _____

\* Product of all factors used.

Figure 18.4 Radius of exposure calculations for low-pressure PVC reactor site #1.