Chapter 26
Health, Safety, and the Environment

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Outline

- Risks
- Regulations and Agencies
- Worker Exposure
- Process Safety Management
- Fires and Explosions
- Inherently Safe Design
- Pollution Prevention
- Life-cycle Analysis
- HAZOP

Risk Assessment

- Statistics

OSHA incidence rate

Injuries and illnesses/100 worker years

200,000 hrs @ 2000 hrs/yr

Risk Assessment

- Statistics

FAR (fatal accident rate)

Fatalities/1000 worker lifetimes

10^8 hr

Risk Assessment

- Statistics

Fatality rate

Fatalities/yr/applicable population

e.g., smokers

Risk Assessment

Activity	OSHA Incident Rate (injuries & deaths per 200,000 h)	Fatal Accident Rate (deaths per 100,000,000 h)	Fatality Rate (deaths per person per year)
Working in Chemical Industry	0.49	4	
Staying at Home		3	
Working in Steel Industry	1.54	8	
Working in Construction	3.88	67	
Traveling by Car		57	170 x 10^{-6}
Rock Climbing		4000	40 x 10^{-6}
Smoking (1 pack per day)			5000 x 10^{-6}
Being struck by Lightning			0.1 x 10^{-6}

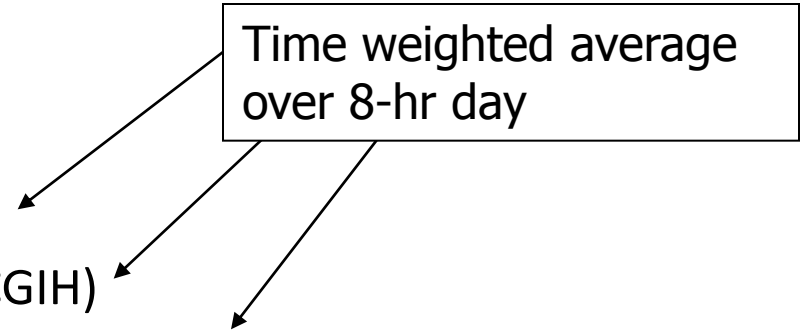
Risk Assessment

- Accident statistics - Table 22.1
- Worst case scenario $\Longleftrightarrow$ HAZOPS
- Role of CHE – to communicate risks to employees, employers, clients, public – <u>Important Public Relations</u>

Regulations and Agencies

- Rules and regulations arise from governmental (OSHA, NIOSH, EPA, DOT, MSHA) and non-governmental agencies (AIChE, API, ASTM, NFPA, etc.)
- Federal government rules are published in the Federal Register (FR) and the Code of Federal Regulations (CFR).
- Important Standards include
  - OSHA Act and Air Contamination Standard – give exposure limits
  - Hazard Communication Standard – “worker right to know” or HazCom. Specifies proper labeling of containers and availability of Material Safety Data Sheets (MSDS).

Worker Exposure



- Workers
  - OSHA
    - **P**ermissible **E**xposure **L**imit
    - **T**hreshold **L**imit **V**alues (ACGIH)
  - NIOSH – **R**ecommended **E**xposure **L**imits
  - **S**hort **T**erm **E**xposure **L**imit – 15 minute exposure
- Public
  - EPA – CAA, CWA, SARA
  - DOT
- MSDS Sheet
  - See Table 22.3

Process Safety Management

- Process Safety Management
  - See 13 components of PSM in Table 22.4
- Process Hazards Management
  - See video – API 750

Fires and Explosions

- Combustion - rapid oxidation
  - At room temp rate usually low
  - Increases rapidly with temperature
  - Below auto-ignition temperature – remove heat and returns to room temperature
- Auto-ignition temperature
  - Above this temperature, combustion is sustained when heat source removed.
  - Energy to heat small region to above A-I temp is called the ignition energy – very small

Fires and Explosions

- Flammability (or explosive) Limits
  - LFL (LEL) – min concentration of fuel in oxidant (usually air) that will support combustion
  - UFL (UEL) - max concentration of fuel in oxidant (usually air) that will support combustion
  - MOC – relates to “inerting”

Fires and Explosions

- Explosion – rapid combustion in which the pressure waves formed propagate the combustion. Waves compresses and heats flammable mixture to its AI temperature.
  - Deflagraton (< speed of sound)
  - Detonation (> speed of sound)
- Vapor cloud explosion
- BLEVE (boiling-liquid expanding vapor-cloud explosion – rapid expansion of vapor can cause a massive shock wave)

BLEVE + VCE = 💣☹

Fires and Explosions

- Runaway reaction
  - Insufficient heat removal from exothermic reaction $\Rightarrow$ LOCA (loss of cooling accident)
  - Use a small or large ΔT for cooling medium?
- Over-pressure
  - Pressure-relief valves
  - Bursting discs

Inherently Safe Design

- Substitution – avoid
- Intensification – use less
- Attenuation – less hazardous conditions
- Containment – do not let out
- Control Leaks – emergency isolation
- Survive Leaks – fire protection, etc.

Pollution Prevention

- Source Reduction
- Recycling – “mass integration”
  - In process
  - On-site
  - Off-site
- Treatment
- Disposal
- Release

Life-cycle Analysis

- "Cradle-to-grave"
  - Raw materials acquisition
  - Manufacturing
  - Use, reuse, maintenance
  - Recycle and waste management

Life-cycle Analysis

- Inventory analysis
  - Material and energy inputs to environment
- Impact analysis
  - Environmental consequences
- Improvement analysis
  - Opportunities to improve environment

HAZOP

- *Hazard and Operability Study*
- Ask: *What if?*
- *"A modified brainstorming technique for identifying and resolving process hazards by considering seemingly unusual occurrences."*

HAZOP

- Guide words used to describe possible deviations in the process
  - No, none, not
  - More of
  - Less of
  - More than, or as well as
  - Part of
  - Reverse
  - Other than

HAZOP

- No, none, not
  - Design intention does not occur
- More of
  - Beyond design intention
- Less of
  - Below design intention

HAZOP

- More than, or as well as
  - In addition to design intention
- Part of
  - Only some of intention present
- Reverse
  - Opposite of design intention
- Other than
  - Other than intended by design

HAZOP

- Intention
  - How process is designed to operate
- Deviation
  - From operating specifications
- Cause
  - How deviation might occur
- Consequence
  - Of deviation with reasonable causes
- Hazard
  - Consequences that could cause dangerous situation

HAZOP Algorithm

- Pick unit and establish design intention
- Pick streams entering
- Apply all guide words – does possible cause exist for given deviation
- For deviation – determine consequences and suggest remedy
- Repeat for all equipment

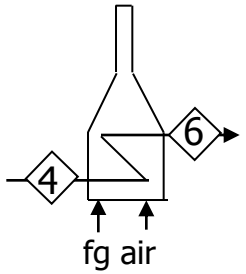
HAZOP Example

- See Table 26.5
  - Shows example of each guide word
  - Shows “correct” tabular form for presentation of results

Table 21.5. HAZOP for the Feed Heater of the Hydrodealkylation (HDA) Process

Process Unit: H-101, Feed Heater, Figure 1.3

Intention: To provide feed to the Reactor (Stream 6) at 600ºC.



Guide Word	Deviation	Cause	Consequence	Action
No	No flow (Stream 4)	blockage in line	Fluid in H-101 overheats	Consider an interlock on fuel gas flow
⇓	No O_2 in combustion products	Rich fuel:air mixture	Unburned fuel and CO in combustion products	None. O2 analyzer with self-checking circuit controls ratio reliably
⇓	⇓	O_2 analyzer malfunction	Potentially rich fuel:air mixture	⇓
⇓	No flow (Stream 6)	Heat tubes burst	Explosion	Interlock with sudden □P drop alarm and shutdown
⇓	No benzene in Stream 6	C-101 not working	Hydrogen:Toluene ratio off to R-101 and loss of hydrogen to fuel gas	Maintain spare compressor C-101
⇓	No fuel gas flow	Supply pipe rupture	Cold shot to R-101, quenching reaction	Interlock with process shutdown
⇓	No flame	Momentary loss of fuel gas	Explosive mixture	Automatic flame detection with re-ignition cycle

Summary

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