

054402 Design and Analysis

LECTURE 12: HAZARD AND OPERABILITY (HAZOP) STUDIES

Daniel R. Lewin
Department of Chemical Engineering
Technion, Haifa, Israel

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OUTLINE

This lecture, and next week's lecture:

- ☆ Provide motivation for performing a HAZOP/HAZAN study on a process
- ☆ This lecture provides instruction on how to carry out a HAZOP analysis
 - HAZOP is a technique for identifying hazards without waiting for an accident to occur.
- ☆ Next lecture, we will learn about the tools and methods used in a HAZAN analysis
 - HAZAN is a technique for estimating the probability and consequences of a hazard.

Sources:

T. Kletz, *HAZOP and HAZAN*, 3rd Ed., IChemE (1992)

T. Kletz, *Learning from Accidents in Industry*,
Butterworths (1988)

T. Kletz, *What Went Wrong?*, 2nd Ed., Gulf Publishing Co. (1988)

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FEED SECTION OF PROPOSED OD PLANT

- ❶ What can go wrong ?
- ❷ What will be the consequences?
- ❸ How often will it occur ?
- ❹ How can it be prevented ?
- ❺ Is the cost of prevention justified ?

PG	Pressure guage	LIC	Level controller	FRC	Flow controller
FI	Flow indicator	PIC	Press. controller	RF	Relief flare
TR	Temperature rec.	ROP	Restriction plate		

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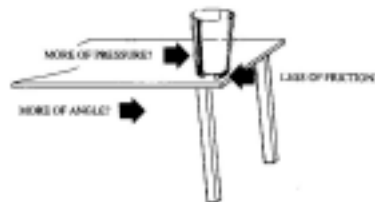
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FROM "AN ATLAS OF SAFETY THINKING"

The ideas expressed in this section are best summarized in the following frames.

1. I identify what can go wrong.



The first and most important stage in any hazard study is to identify the most important things that can go wrong and produce accidents or operating problems.

A HAZOP is a systematic procedure to analyze the hazards associated with each process pipeline, applying the following guide words: NONE, MORE OF, LESS OF, REVERSE, OTHER THAN, PART OF, MORE THAN.

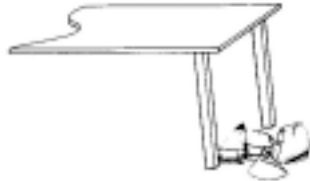
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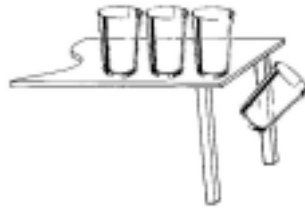
FROM "AN ATLAS OF SAFETY THINKING"

2. How big will the consequences be?



We need to know the consequences to employees, members of the public, plant and profits, now and in the long term.

3. How often will it occur?



We need to know how often the hazard is likely to occur (HAZAN).

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FROM "AN ATLAS OF SAFETY THINKING"

4. Prevention.



How can we prevent the accident occurring, or make it less probable or protect people from the consequences?

5. What should we do?



We should compare the risk (that is, the probability times the consequence) with generally accepted codes and standards or with the other risks around us.

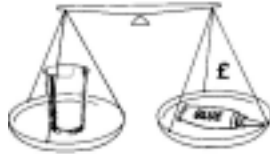
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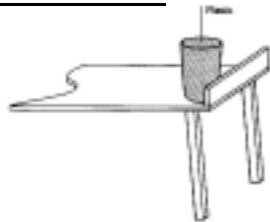
FROM "AN ATLAS OF SAFETY THINKING"

6. Is it worth the cost?



We should also compare the cost of prevention with the cost of the accident to see if the remedy is 'reasonably practical' or we should look for a cheaper solution.

7. Prevention 2.



Perhaps our method of prevention has disadvantages, and better methods can be suggested. We should answer this question before a table is made and a glass ordered.

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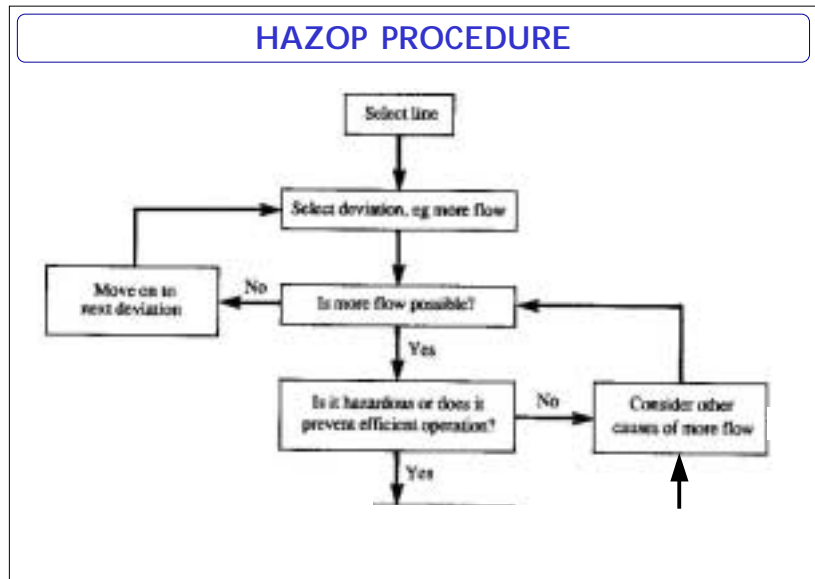
DEVIATIONS GENERATED BY GUIDE WORDS

Guide Word	Deviations
NONE	No forward flow when there should be: i.e. no flow
MORE OF	More of any relevant physical property than there should be: e.g. higher F, higher T, higher P.
LESS OF	Less of any relevant physical property than there should be: e.g. lower F, lower T, lower P.
REVERSE	Flow in the reverse direction than that expected
PART OF	Composition of system different than it should be: e.g. ratio different, or component missing.
MORE THAN	More components present than there should be: e.g. extra phase present, or impurities.
OTHER THAN	What else can happen apart from NOC: e.g. start-up, shut-down, failure of services...

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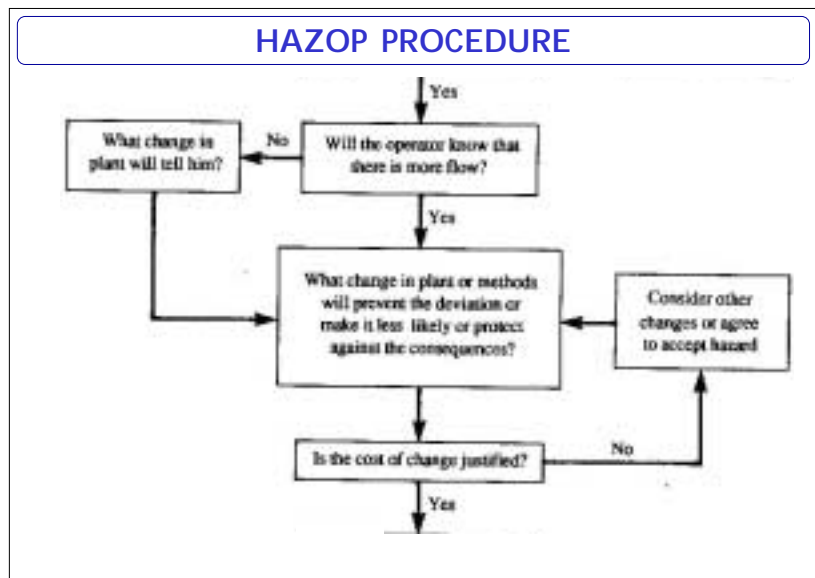
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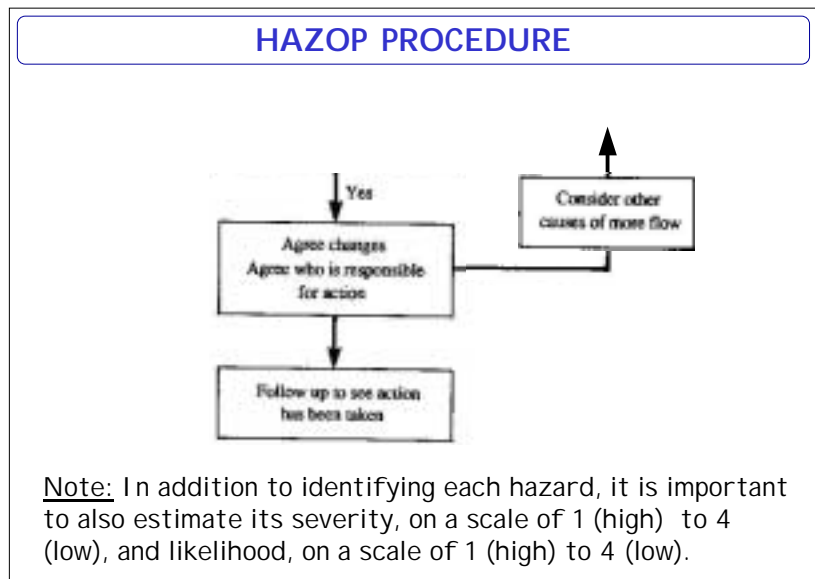
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HAZOP PROCEDURE - SEVERITY

Severity	Significance
1	High - Fatality/serious injury hazard or hazard leading to loss of >6 months production or loss greater than \$10M
2	Medium High - Injury hazard or hazard leading to loss of 1-6 months production or loss between \$1-10M
3	Medium Low - Minor injury hazard or hazard leading to loss of 1-4 weeks production or loss between \$0.1-1M
4	Low - No injury hazard or hazard leading to loss of <1 weeks production or loss less than \$100,000

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HAZOP PROCEDURE - LIKELIHOOD	
Likelihood	Significance
1	High - Hazard expected more than 1/year
2	Medium High - Hazard expected several times in the plant life.
3	Medium Low - Hazard not expected more than once in the plant life.
4	Low - Hazard not expected at all in the plant life.

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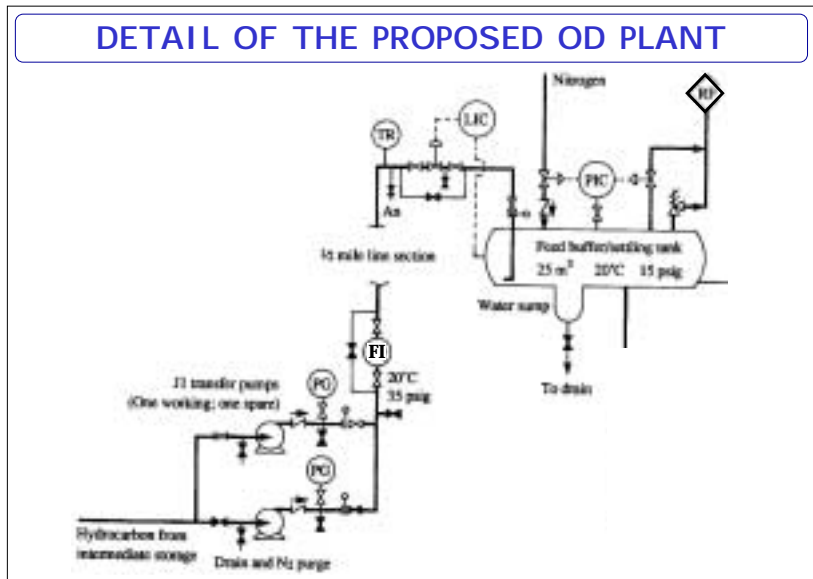
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HAZOP PROCEDURE - RISK RANKING																										
	Severity																									
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1	D	D	C	A																						
2	D	C	B	A																						
3	C	B	A	A																						
4	B	A	A	A																						
Likelihood																										
Ranking	Significance																									
A	Acceptable risk level.																									
B	Almost acceptable risk level. Acceptable if suitably controlled by management. Should check that suitable procedures and/or control systems are in place.																									
C	Undesirable risk level. Must be reduced to level B at the most by engineering or management control.																									
D	Unacceptable risk level. Must be reduced to level B at the most by engineering or management control.																									

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HAZOP STUDY ON PROPOSED OD PLANT

Guide Word	Dev'n	Possible Causes	Consequences	Action Required	S	L	R
NONE	No Flow	(1) No HC available at intermediate storage.	Loss of feed to reactor. Polymer formed in HEX with no flow.	(a) Ensure communication with intermediate storage operator. (b) Install low level alarm on settling tank LIC.	3	2	B
		(2) J1 pump fails.	As for (1).	Covered by (b).	3	2	B
		(3) Line blockage, isolation valve closed in error, or LCV fails shut.	As for (1). J1 pump overheats.	(c) Install kickback on J1 pumps. (d) Check design on J1 pump strainers.	3	2	B

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HAZOP STUDY ON PROPOSED OD PLANT							
Guide Word	Dev'n	Possible Causes	Consequences	Action Required	S	L	R
NONE	No flow	(4) Line fracture.	As for (1). HC discharged into area adjacent to public highway.	Covered by (b). (e) Institute regular patrolling and inspection of transfer line.	2	2	C
MORE OF	More flow	(5) LCV fails open or LCV bypass open in error.	Settling tank overfills. Danger of spillage of HC. Fire hazard.	(f) Install high level alarm on LIC and check sizing of relief opposite liquid overfilling. (g) Institute locking off procedure for LCV bypass if not in use.	2	2	C

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HAZOP STUDY ON PROPOSED OD PLANT							
Guide Word	Dev'n	Possible Causes	Consequences	Action Required	S	L	R
MORE OF	More flow	(5) LCV fails open or LCV bypass open in error.	Incomplete separation of water phase in tank, leading to problems in reactor section.	(h) Extend J2 pump suction line to 12" above tank base.	3	2	B
	More pressure	(6) Isolation valve closed in error or LCV closes with J1 pumping.	Transfer line subject to full pump delivery or surge pressure. Possibility of fracture and release of HC.	(j) Covered by (c) except when kickback blocked or isolated. Check line and FI. Install a PG upstream of LCV and an independent PG on settling tank.	2	1	D

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HAZOP STUDY ON PROPOSED OD PLANT							
Guide Word	Dev'n	Possible Causes	Consequences	Action Required	S	L	R
MORE OF	More pressure	(7) Thermal expansion in isolated valve section due to fire or strong sunlight.	Line fracture and possible release of HC.	(k) Install thermal expansion relief on valve section.	2	2	C
	More temp.	(8) High intermediate storage temperature.	High pressure in transfer line and settling tank.	(l) Check whether there is adequate warning of high temperature at intermediate storage. If not, install.	2	2	C

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HAZOP STUDY ON PROPOSED OD PLANT							
Guide Word	Dev'n	Possible Causes	Consequences	Action Required	S	L	R
LESS OF	Less flow	(9) Leaking flange of valved stub not blanked and leaking.	Material loss adjacent to public highway.	Covered by (e) and the checks in (j).	2	2	C
	Less temp.	(10) Winter conditions.	Water sump and drain line freeze up.	(m) Lag water sump down to drain valve and steam trace valve and drain line downstream.	4	1	A
REVERSE	Not applicable (n/a)						

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HAZOP STUDY ON PROPOSED OD PLANT							
Guide Word	Dev'n	Possible Causes	Consequences	Action Required	S	L	R
PART OF	High water concentration in stream.	(11) High water level in intermediate storage tank.	Water sump fills up more quickly. More chance of water phase passing to reaction section.	(n) Arrange for frequent draining off of water from intermediate storage. Install high interface level alarm on sump.	4	1	A
	High concentration of lower alkanes or alkenes in stream.	(12) Disturbance on distillation columns immediately upstream of intermediate storage tank.	Higher system pressure.	(p) Check that settling tank and piping, including relief valve, will cope with sudden inflow of more volatile HCs.	4	1	A

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HAZOP STUDY ON PROPOSED OD PLANT							
Guide Word	Dev'n	Possible Causes	Consequences	Action Required	S	L	R
MORE THAN	Organic acids present	(13) As for (12).	Water sump fills up more quickly. More chance of water phase passing to reaction section.	(q) Check suitability of materials of construction.	4	1	A
OTHER	Maintenance.	(14) Equipment failure, flange leak, etc.	Line cannot be completely drained or purged.	(r) Install low-point drain and N ₂ purge point downstream of LCV. Also N ₂ vent on settling tank.	4	1	A

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WHO CARRIES OUT A HAZOP ?

A HAZOP team for a new process consists of the following members:

- ☆ PROJECT or DESIGN ENGINEER – Often a MechE. Responsible for keeping costs within target. He/she will want to minimize changes, but at the same time wants to find out now rather than later if there are any unknown hazards or operating problems.
- ☆ PROCESS ENGINEER – Usually a ChemE. The person who drew developed the flowsheet.
- ☆ COMMUNICATING MANAGER – Usually a ChemE. He/she will have to start-up and operate the plant, and will be in favor of any changes that will make life easier.
- ☆ INSTRUMENT DESIGN ENGINEER – A modern plant contains sophisticated control and trip systems, and HAZOPs often result in even more instrumentation.
- ☆ RESEARCH CHEMIST – If new chemistry is involved.
- ☆ INDEPENDENT CHAIRMAN – An expert in the HAZOP technique, but not the plant. If he/she is not a representative of the plant safety department, one needs to be present.

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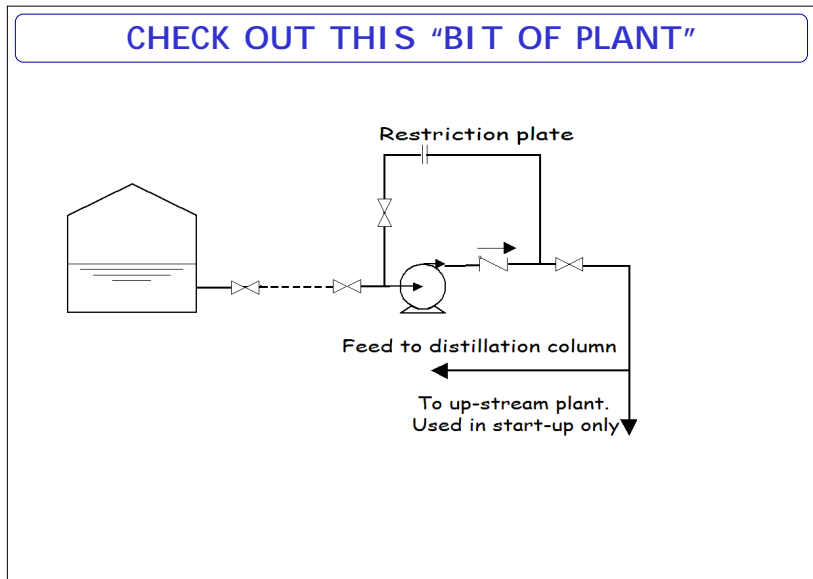
TRACKING ACTION ON HAZOP

Ref. No.	Operating Deviation	Action notes and queries	Action by	Follow-up review comments
a	No flow	Ensure communication with intermediate storage operator.	CM	
b		Install low level alarm on settling tank.	IDE	
c		Install kickback on J1 pumps.	DE	
d		Check design on J1 pump strainers.	DE	
e		Institute regular patrolling and inspection of transfer line.	CM	
f	More flow	Install high level alarm on LIC.	IDE	

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HAZOP STUDY ON "BIT OF PLANT"

Guide Word	Dev'n	Possible Causes	Consequences	Action Required	S	L	R

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CHECK OUT THIS "BIT OF PLANT"

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SUMMARY

On completing this week's materials, you should be able to carry out a HAZOP analysis:

- Applying the guide words systematically to identify the most important hazards affecting each line in the process.
- Categorizing each hazard according to its severity, likelihood and cost.
- Realizing that a HAZOP analysis is an ongoing process that needs to be documented and followed up.

Next lecture, we will learn about the tools and methods used in a HAZAN analysis, which is a technique for estimating the probability and consequences of a hazard.

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