Hazard and Operability (HAZOP) Study

Imagination to

A Scenario…

One family are on a road trip by using a car in the middle of the night. Driver were replying a text message while driving at 100 km/h and it was raining heavily. The car hits a deep hole and one of tire blows. Driver hit the brake, but due to slippery road and car tire thread was thin, the car skidded and was thrown off the road.

Points to ponder

What is the cause of the accident?

What is the consequence of the event?

What can we do to prevent all those things to happen in the first place?

What other possible accidents might happen on the road trip?

Can we be prepared before the accident occurs?

Can we make it more systematic?

Parameter	Guideword	Possible Causes	Consequences	Action	Safeguard
Car speed	Too fast Too slow	Rushing	Skidded when emergency brake	- Slow down - Speed up	-ABS brake system -Safety belt - Air bag
Tire	No thread Less thread	Tire too old, often speeding and emergency break	Car skidded		- Check frequently - Have spare tire
Window visibility	Low Very low	Rain	Cannot see the road		
Car light	Dim No light			-Stop car -Go to nearest garage -Use emergency signal	
Road	With holes Rocky		Breaks the car tire		- Put a signboard -Street lights
Travel time	Night Foggy	No street light			-Travel during daylight

What is HAZOP?

- Systematic technique to IDENTIFY potential Hazard and Operating problems.
- A formal systematic rigorous examination to the process and engineering facets of a production facility.
- A qualitative technique based on "*guide-words*" to help provoke thoughts about the way deviations from the intended operating conditions can lead to hazardous situations or operability problems.
- HAZOP is basically for safety
  - Hazards are the main concern.
  - Operability problems degrade plant performance (product quality, production rate, profit).
- Considerable engineering insight is required - engineers working independently could develop different results.

HAZOP Methodology

- systematically questions every part of a process Or operation to discover qualitatively how deviations from normal operation can occur and whether further protective measures, altered operating procedures or design changes are required.

- The questioning is sequentially focused around a number of guide words which are derived from method study techniques.

- The main advantage of this technique is its systematic thoroughness in failure case identification. The method may be used at the design stage, when plant alterations or extensions are to be made, or applied to an existing facility.

HAZOP Study Procedure

GUIDE WORDS

POSSIBLE CAUSES

DEVIATION (FROM DESIGN AND/OR OPERATING INTENT)

CONSEQUENCES

ACTION(S) REQUIRED OR RECOMMENDEED

Guide Words

NONE	No forward flow when there should be
MORE	More of any parameter than there should be, *e.g.* more flow, more pressure, more temperature, etc.
LESS	As above, but "less of" in each instance
PART	System composition difference from what it should be
MORE THAN	More "components" present than there should be for example, extra phase, impurities
OTHER	What needs to happen other than normal operation, *e.g.* start up, shutdown, maintenance

Guide Words

NONE — *e.g.*, NO FLOW caused by blockage; pump failure; valve closed or jammed : leak: valve open ;suction vessel empty; delivery side over - pressurized : vapor lock ; control failure.

REVERSE — *e.g.*, REVERSE FLOW caused by pump failure : NRV failure or wrongly inserted ; wrong routing; delivery over pressured; back- siphoning ; pump reversed .

MORE OF — *e.g.*, MORE FLOW caused by reduced delivery head ; suction pressurized ; controller failure ; valve stuck open leak ; incorrect instrument reading.

Guide Words

MORE OF	MORE TEMPERATURE, pressure caused by external fires; blockage ; shot spots; loss of control ; foaming; gas release; reaction; explosion; valve closed; loss of level in heater; sun.
LESS OF	*e.g.*, LESS FLOW caused by pump failure; leak; scale in delivery; partial blockage ; sediments ; poor suction head; process turndown.
PART OF	Change in composition high or low concentration of mixture; additional reactions in reactor or other location ; feed change.

Guide Words

MORE THAN	Impurities or extra phase Ingress of contaminants such as air, water, lube oils; corrosion products; presence of other process materials due to internal leakage ; failure of isolation ; start-up features.
OTHER	Activities other than normal operation start-up and shutdown of plant ; testing and inspection ; sampling ; maintenance; activating catalyst; removing blockage or scale ; corrosion; process emergency ; safety procedures activated ; failure of power, fuel, steam , air, water or inert gas; emissions and lack of compatibility with other emission and effluents.

Sequence of Examination

The main elements under consideration are:

- intention
- deviation
- causes
- consequences
  - hazards
  - operating difficulties
- Safeguards/corrective action.

HAZOP Effectiveness

The effectiveness of a HAZOP will depend on:

- the accuracy of information (including P&IDs) available to the team information should be complete and up-to-date.
- the skills and insights of the team members.
- how well the team is able to use the systematic method as an aid to identifying deviations.
- the maintaining of a sense of proportion in assessing the seriousness of a hazard and the expenditure of resources in reducing its likelihood.
- the competence of the chairperson in ensuring the study team rigorously follows sound procedures.

The HAZOP Team

- Chairperson
- HAZOP secretary
- Project Engineer
- Mechanical Design engineer
- Process engineer
- Electrical engineer
- Instrument engineer
- Operations manager
  - Plant Engineer/manager
  - Shift Engineer
  - Chemist

Responsibility of HAZOP Team Members

HAZOP leader

- Plan sessions and timetable
- Control discussion
- Limit discussion
- Encourage team to draw conclusion
- Ensure secretary has time for taking note
- Keep team in focus
- Encourage imagination of team members
- Motivate members
- Discourage recriminations
- Judge importance issues

Checklist for HAZOP Leader

- Always prepare study program in advance.
- Agree on the format or form to be used.
- Prepare follow up procedures.
- Brief members about HAZOP during first meeting.
- Stop the team trying to redesign the process.
- HAZOP is a team exercise. Do not let anybody (including the leader himself to dominate).

Checklist for HAZOP Leader

- If conflict arises, handle with care.
- Avoid long discussions by recording areas which need to be resolved outside meeting.
- Leader must be strong, yet diplomatic.
- Speak clearly. Make you point.
- Better have experience working as team member previously.
- Do not skip anything….some time small things may cause big accident.

HAZOP Secretary

- Take adequate notes
- Record documentations
- Inform leader if more time required in taking notes
- If unclear, check wording before writing
- Produce interim lists of recommendations
- Produce draft report of study
- Check progress of chase action
- Produce final report

Process Engineer

- Provide a simple description
- Provide design intention for each process unit
- Provide information on process conditions and design conditions
- Provide a simple description
- Provide design intention for each process unit
- Provide information on process conditions and design conditions

Mechanical Design Engineer

- Provide specification details.
- Provide vendor package details.
- Provide equipment and piping layout information.

Instrument Engineer

- Provide details of control philosophy.
- Provide interlock and alarm details.
- Provide info on shutdown, safety features.

Plant Engineer or Manager

- Provide information on compatibility with any existing adjacent plant.
- Provide details of site utilities and services.
- Provide (for study on existing plant) any update on maintenance access and modifications.

Shift Operating Engineer or Supervisor

- Provide guidance on control instrumentation integrity from an operating experience view point.
- Provide (for study on existing plant) information on plant stability at the specified control parameters.
- Provide information on experienced operability deviations of hazard potential.

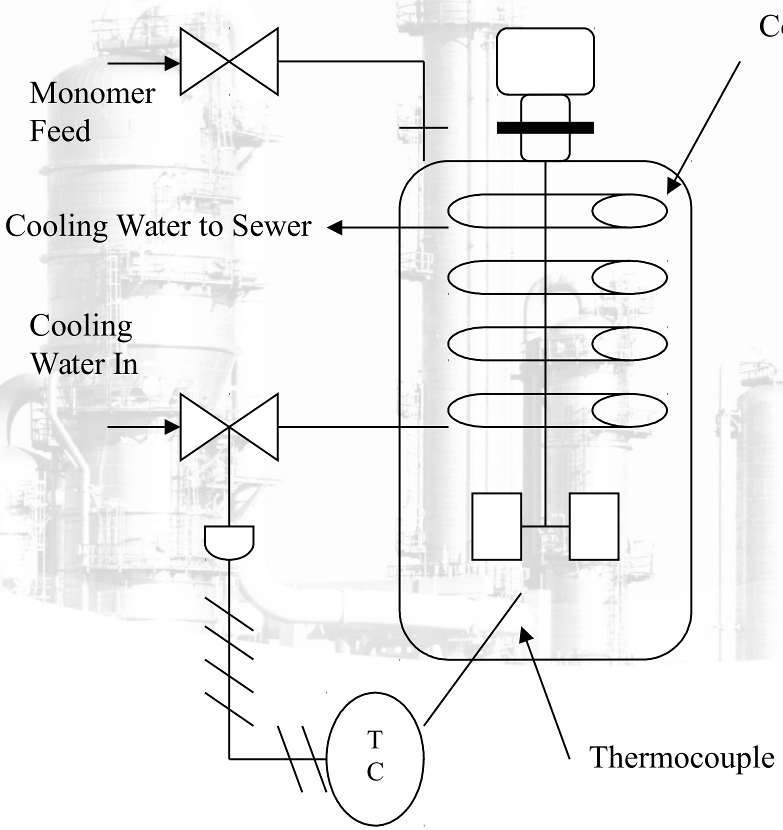
Chemist

- Provide details of process chemistry
- Provide details of process hazards (polymerizations, byproducts, corrosion etc)

Project Engineer

- Provide details of cost and time estimation and also budget constraints.
- Ensure rapid approval if required.

HAZOP Example: Reactor



Refer to reactor system shown.

The reaction is exothermic. A cooling system is provided to remove the excess energy of reaction. In the event of cooling function is lost, the temperature of reactor would increase. This would lead to an increase in reaction rate leading to additional energy release.

The result could be a runaway reaction with pressures exceeding the bursting pressure of the reactor. The temperature within the reactor is measured and is used to control the cooling water flow rate by a valve.

Perform HAZOP Study

HAZOP on Reactor - Example

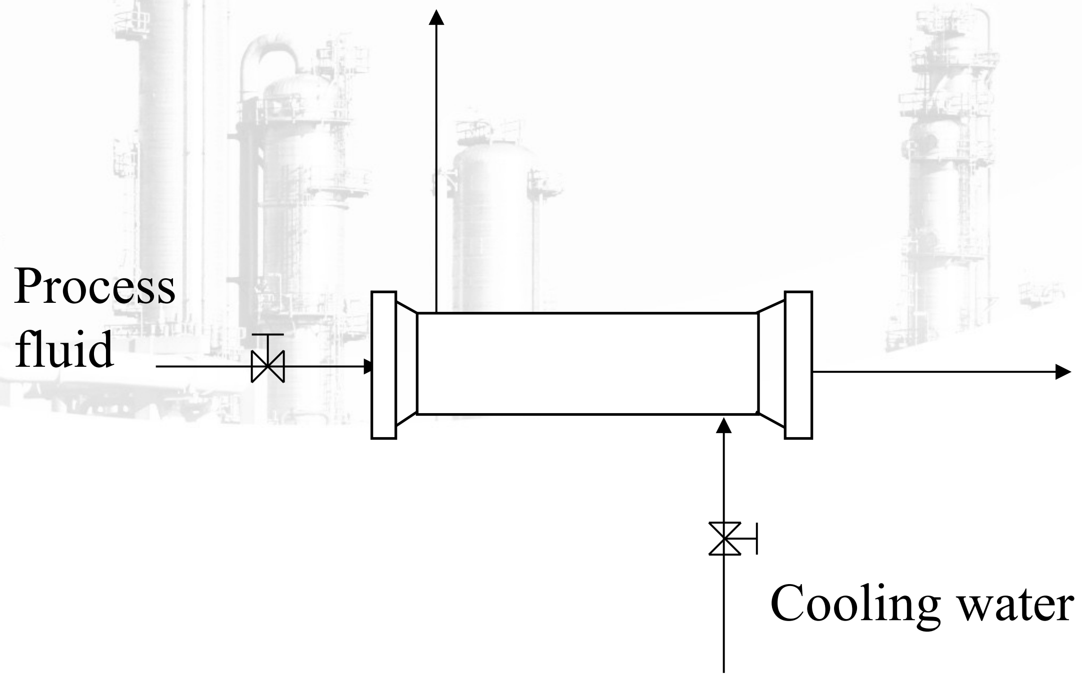
Guide Word	Deviation	Causes	Consequences	Action
NO	No cooling		Temperature increase in reactor	
REVERSE	Reverse cooling flow	Failure of water source resulting in backward flow		
MORE	More cooling flow			Instruct operators on procedures
AS WELL AS	Reactor product in coils			Check maintenance procedures and schedules
OTHER THAN	Another material besides cooling water	Water source contaminated		

HAZOP On Reactor: Answer

Guide Word	Deviation	Causes	Consequences	Action
NO	No cooling	Cooling water valve malfunction	Temperature increase in reactor	Install high temperature alarm (TAH)
REVERSE	Reverse cooling flow	Failure of water source resulting in backward flow	Less cooling, possible runaway reaction	Install check valve
MORE	More cooling flow	Control valve failure, operator fails to take action on alarm	Too much cooling, reactor cool	Instruct operators on procedures
AS WELL AS	Reactor product in coils	More pressure in reactor	Off-spec product	Check maintenance procedures and schedules
OTHER THAN	Another material besides cooling water	Water source contaminated	May be cooling inefffective and effect on the reaction	If less cooling, TAH will detect. If detected, isolate water source. Back up water source?

HAZOP Example: Shell & Tube Heat Exchanger

- Using relevant guide works, perform HAZOP study on shell & tube heat exchanger



HAZOP on Heat Exchanger: Answer 1

Guide Word	Deviation	Causes	Consequences	Action
Less	Less flow of cooling water	Pipe blockage	Temperature of process fluid remains constant	High Temperature Alarm
More	More cooling flow	Failure of cooling water valve	Temperature of process fluid decrease	Low Temperature Alarm
More of	More pressure on tube side	Failure of process fluid valve	Bursting of tube	Install high pressure alarm
Contamination	Contamination of process fluid line	Leakage of tube and cooling water goes in	Contamination of process fluid	Proper maintainance and operator alert
Corrosion	Corrosion of tube	Hardness of cooling water	Less cooling and crack of tube	Proper maintenance

HAZOP on Heat Exchanger – Answer 2

Guide Word	Deviation	Causes	Consequences	Action
NONE	No cooling water flow	Failure of inlet cooling water valve to open	Process fluid temperature is not lowered accordingly	Install Temperature indicator before and after the process fluid line Install TAH
MORE	More cooling water flow	Failure of inlet cooling water valve to close	Output of Process fluid temperature too low	Install Temperature indicator before and after process fluid line Install TAL
LESS	Less cooling water	Pipe leakage	Process fluid temperature too low	Installation of flow meter
REVERSE	Reverse process fluid flow	Failure of process fluid inlet valve	Product off set	Install check valve (whether it is crucial have to check?)
CONTAMINATION	Process fluid contamination	Contamination in cooling water	Outlet temperature too low	Proper maintenance and operator alert

HAZOP Case Study : Distillation Column

HAZOP Case Study : Distillation Colum

Aims:

The purpose of this study is to identify potential hazards and problems in order to reduce the occurrence of hazards which may impact the safety of plant operators and personnel or cause delays in plant operation. Proper consideration of operating pressures, temperatures, and flow rates was crucial to designing a process control system that can anticipate and correct for deviations from safe and ideal conditions. An analysis of each of the main components of the plant’s distillation column (column itself, reboiler, condenser, reflux pump, and feed and product control valves) was performed to determine the necessary controllers, transmitters, and alarms to ensure safe and efficient performance.

Description of Facility

At ideal conditions, the plant operates with a saturated liquid feed mixture of 50 mol/hr of methanol, 50 mol/hr of ethanol, and 50 mol/hr of water, entering a distillation column at 1 atmosphere. The column operates at a reflux ratio of 1.2 with a 1.2 psi pressure drop across the column. 95% of the ethanol fed and at most 5% of the water fed is to be outputted overhead, with the remaining water and entirety of the methanol feed to be taken below. The column is accompanied by feed and product valves, a pump, and reboiler and condenser associated with the distillation process.

Plant Overview

Start-up Procedures

- Begin supplying heat to the distillation column up to the desired operating temperature, then open feed control valve to allow feed mixture to enter distillation column.
- Conditions at start-up must be monitored carefully to ensure the plant safely arrives at its ideal operating conditions. Careful attention must be paid to the temperature and pressure of the distillation column; it must be allowed to safely reach and maintain its operating temperature and pressure before allowing the feed mixture to enter.

Emergency Shutdown Procedures

- All functioning transmitters and controllers report directly to the flow controller of the feed control valve and to the temperature controller of the distillation column. In the event of an emergency shutdown, flow through the feed control valve is stopped and heat ceases to be supplied to the distillation column, allowing the process to empty and cool and reduce the likelihood of an explosion.

Analysis of Main Findings

1. Node Description: Feed control valve

Guide Word	Deviation	Causes	Consequences	Action
More	High Flow	Flow Controller Fault	•Column level, temperature, and pressure increase. •over pressurization of column. Column controls will attempt to correct.	Flow indicator with high flow and temperature alarms, emergency feed shutdown
Less	Low Flow	•Feed Pump Failure •Jammed feed valve	Reduced column temperature and rate of reaction	Flow indicator with low flow alarm.
No	No Flow	•Feed Pump Failure •Jammed feed valve	No reaction	Flow indicator with low flow alarm.

2. Node Description: Distillation Column

Guide Word	Deviation	Causes	Consequences	Action
More	High temperature	Temperature controller fault, reboiler malfunction	Reaction rate increase Pressure increases Off-spec product.	High and low temperature alarm need to be install
Less	Low Temperature	Temperature controller fault, reboiler malfunction	Reduced column temperature and rate of reaction Off-spec product	High and low temperature alarm need to be install
No	Zero temperature	Temperature controller fault, reboiler malfunction	No reaction	High and low temperature alarm need to be install

Guide Word	Deviation	Causes	Consequences	Action
More	High Pressure	Flow controller fault, Temperature	Column level, temperature, and pressure increase. Over pressurization.	Pressure indicator reporting to feed control valve and to Pressure Safety Valve (open-to-air)
Less	Low Pressure	Feed pump failure; jammed feed valve	Reduced column temperature and rate of reaction	Flow indicator with low flow alarm
No	Zero Pressure	Feed pump failure; jammed feed valve	Flow indicator with low flow alarm	Flow indicator with low flow alarm

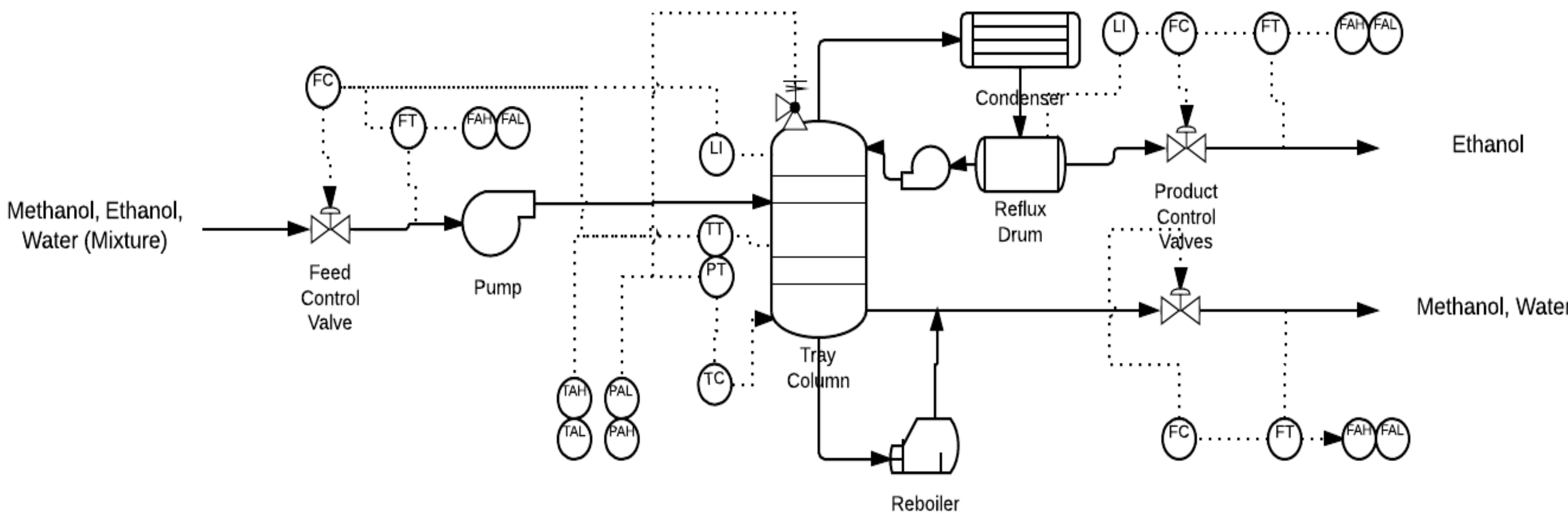
3. Node Description: Product Control Valves

Guide Word	Deviation	Causes	Consequences	Action
More	High Flow	Flow Controller Fault	Column level, temperature, and pressure decrease. Column controls will attempt to correct	Flow indicator with high flow and temperature alarms, emergency feed shutdown
Less	Low Flow	•Feed Pump Failure •Jammed feed valve	Increased column level, temperature, and pressure. Over pressurization. Risk of explosion.	Flow indicator with low flow alarm
No	No Flow	•Feed Pump Failure •Jammed feed valve	Increased column level, temperature, and pressure. Over pressurization. Risk of explosion.	Flow indicator with low flow alarm

Action Arising from the HAZOP

Deviations from proper operating conditions for temperature, pressure, and flow were analyzed in order to develop recommendations for controllers, transmitters, and alarms to monitor and control these parameters during operation. These findings can be found in the Analysis of Main Findings section. The recommended transmitters, controllers, and alarms are indicated in the P&ID. The main hazards include dangerously high temperatures and pressures inside the column, which could result in over pressurization events and explosions if not controlled. The proposed process control system should be implemented and tested before the plant begins normal operation.

PFD With Controls



HAZOP - Hazard and Operability

ATTITUDE CHECK

All of these terms! This stupid table! I hate HAZOPS. Why don't we just learn the engineering?

Consequence

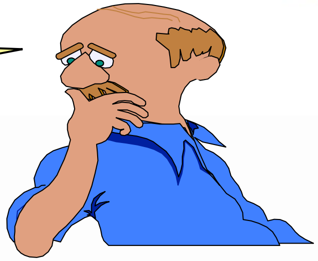
Nodes

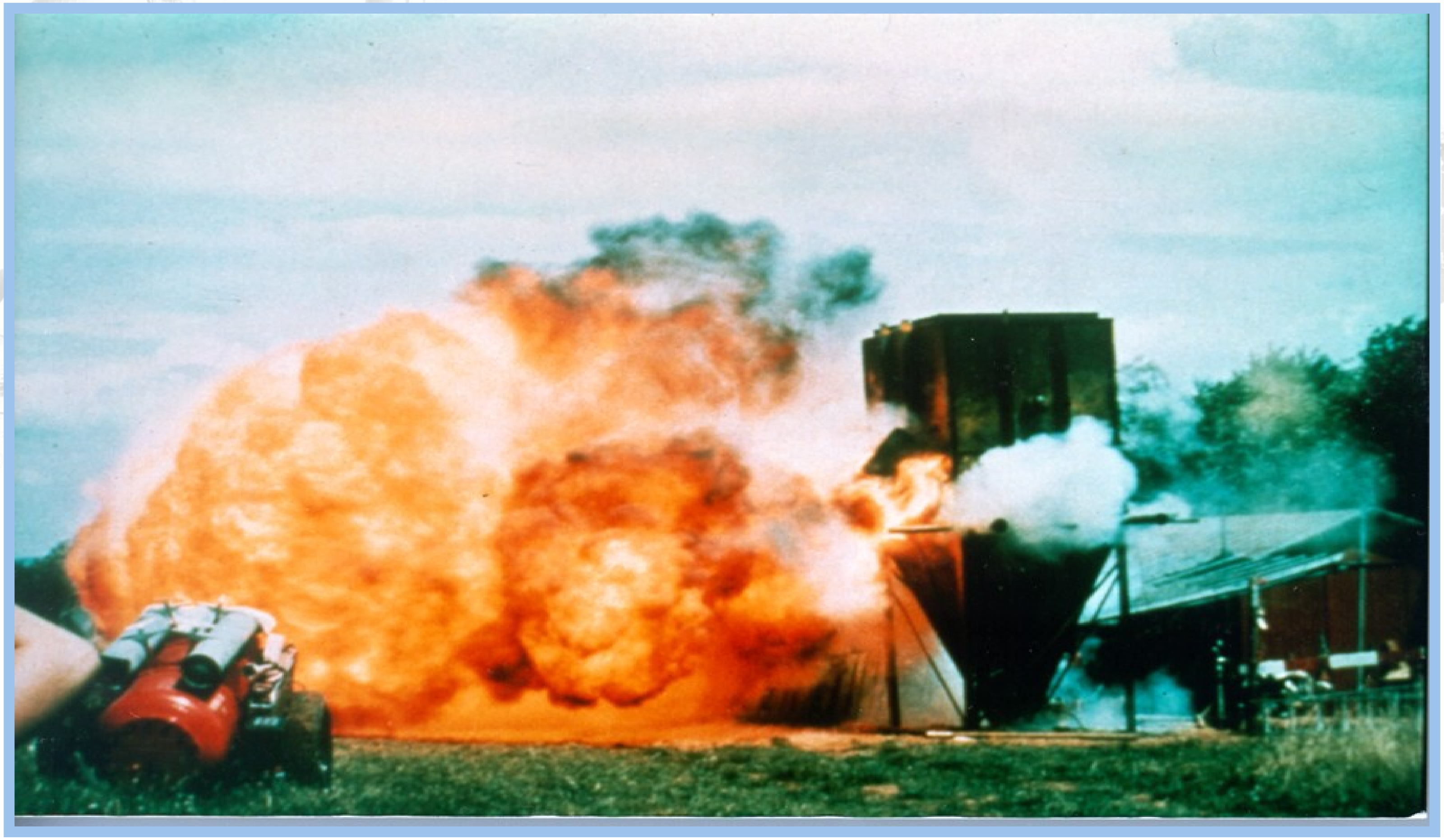
Guide words

Parameters

Deviation

I suppose that I should have done that HAZOP Study!





imagination to innovation

THANK YOU

Questions