

# Educational Modules in Process Design and Operability

**AIChE Annual Meeting**  
**Session on CACHE Corporation**

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**And McMaster Advanced Control Consortium**

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**McMASTER**  
**UNIVERSITY**

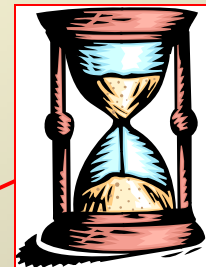


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# GOALS OF THE PRESENTATION

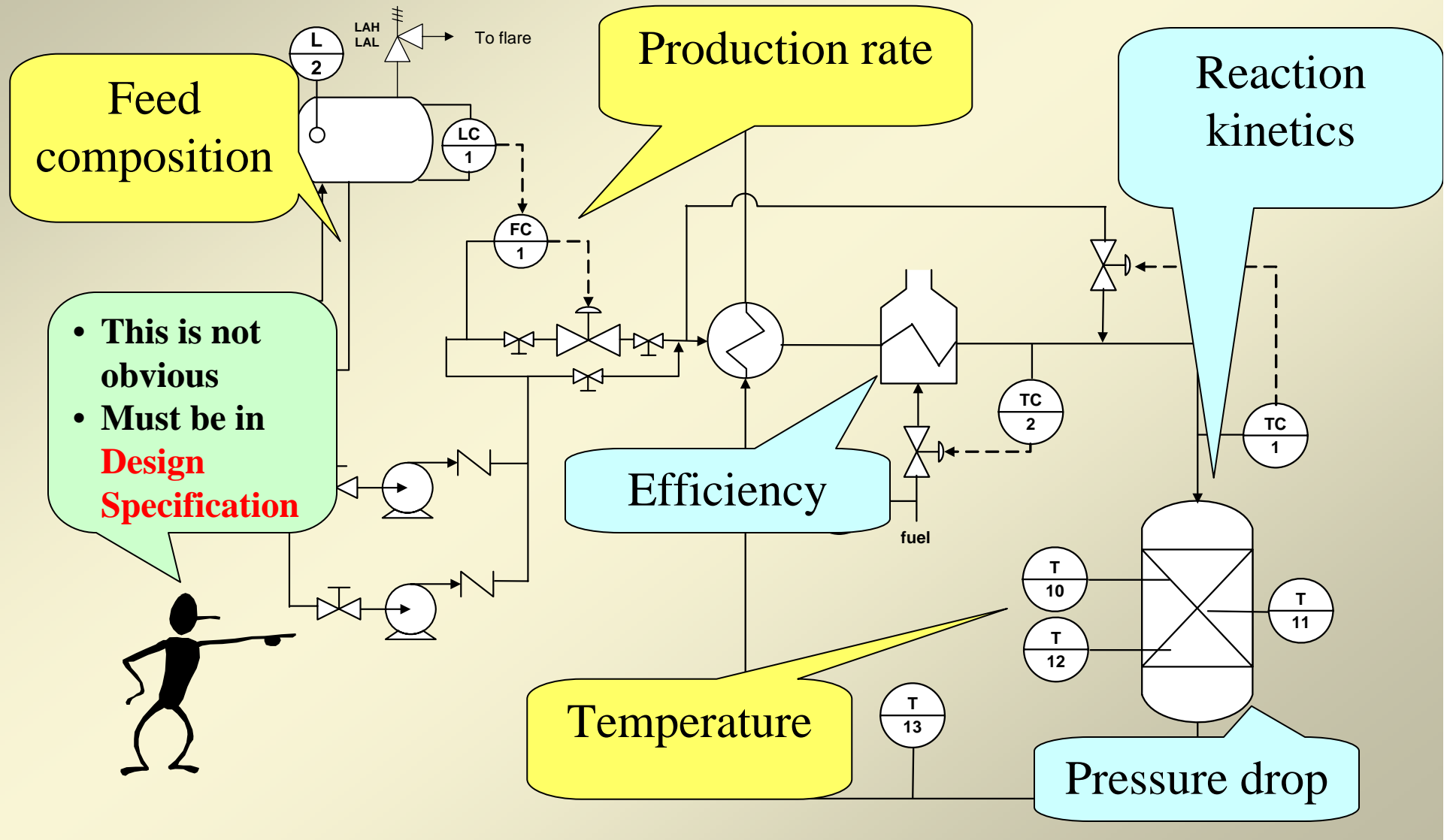
- Provide a (not the) definition of operability
  - A taxonomy of issues
- Demonstrate that operability is not a collection of “tricks”
  - Improves teaching of **fundamentals**
  - Motivates students to **learn/apply**
- **Whet your appetite**, refer to **WEB** site for expanded coverage
- Introduce project to develop and share educational materials



**Too  
little  
time!**

# DESIGN IS NOT FOR A *SINGLE POINT*

BECAUSE OF **VARIABILITY** AND **UNCERTAINTY**

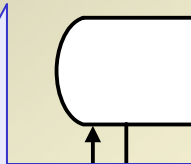


**Key Operability  
issues**

1. Operating window
2. Flexibility/  
controllability
3. Reliability
4. Safety &  
equipment  
protection
5. Operation  
during  
transitions
6. Dynamic  
Performance
7. Efficiency
8. Monitoring &  
diagnosis

**IS THIS**

Feed to



**Key Operability Topics**

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## Key Challenge

**How do we enable students to solve complex problems with multiple objectives?**

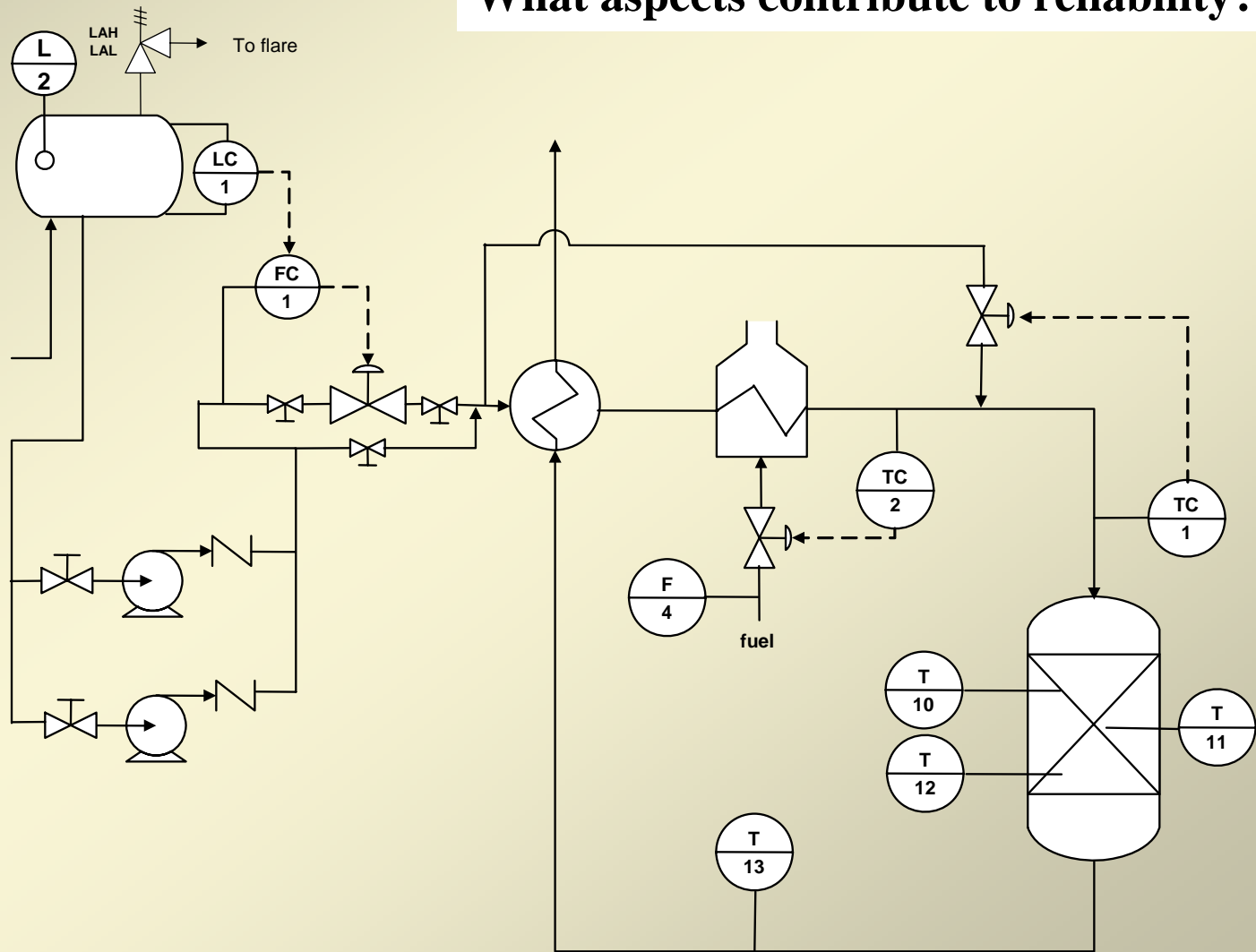
- **Provide superstructure for knowledge**
- **Link to technology basics**
- **Show compelling, practical examples (within the students grasp)**
- **Provide supporting professional skills**
- **Encourage (require) students to **investigate, discover and evaluate issues in real processes****

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# RELIABILITY

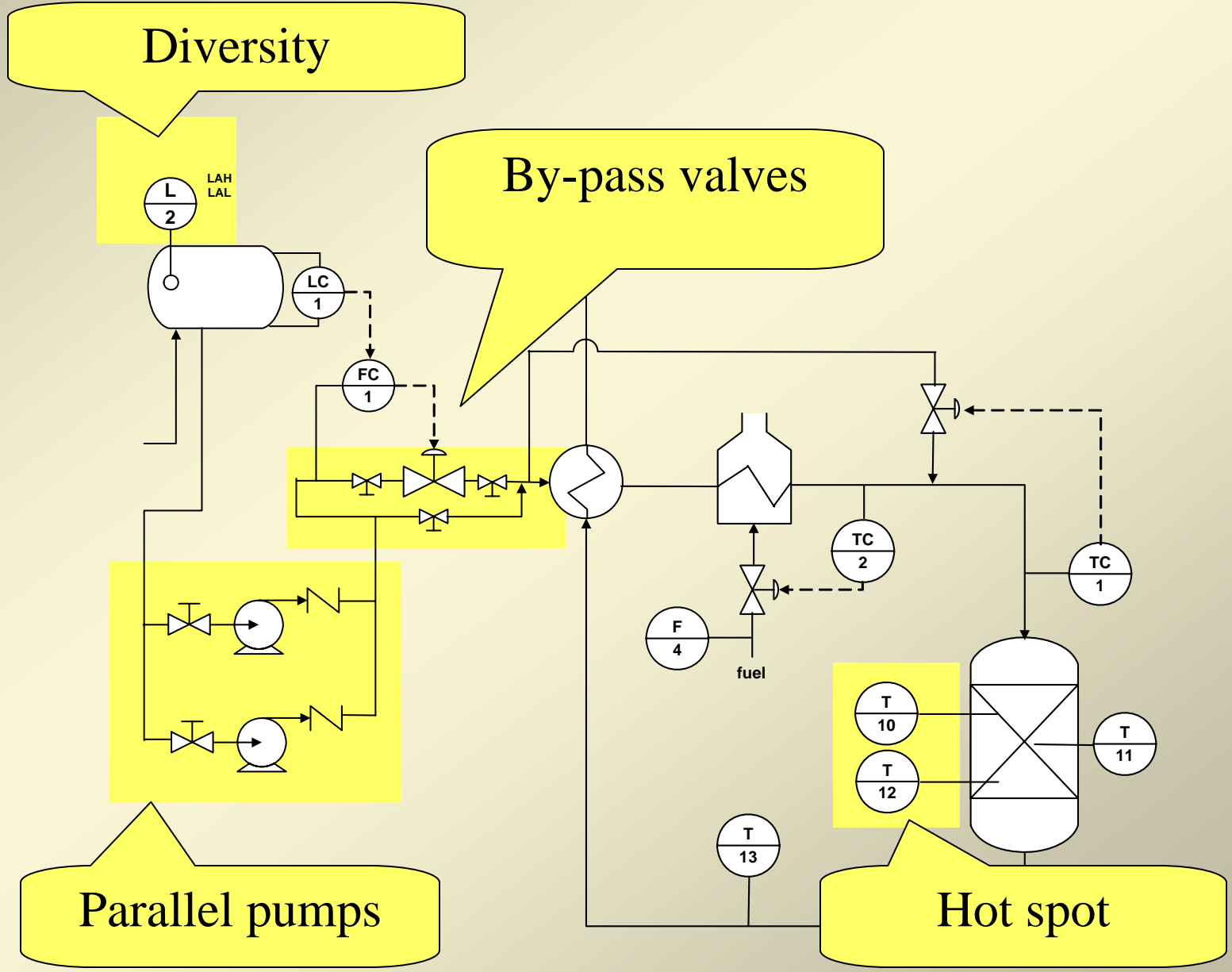
What aspects contribute to reliability?



**Key Operability issues**

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# RELIABILITY

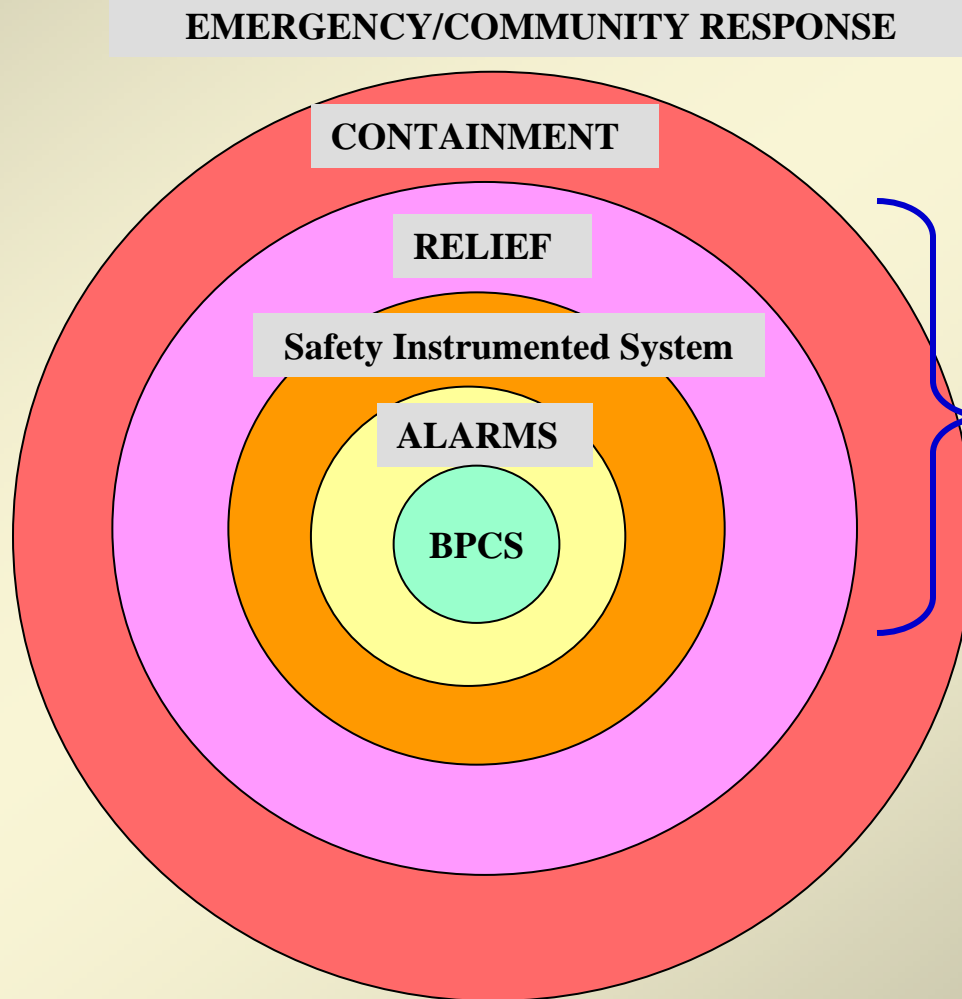


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# SAFETY & EQUIP. PROTECTION

## Layers of Safety Protection



- Concentrate on the first four layers
- Stay close to the process

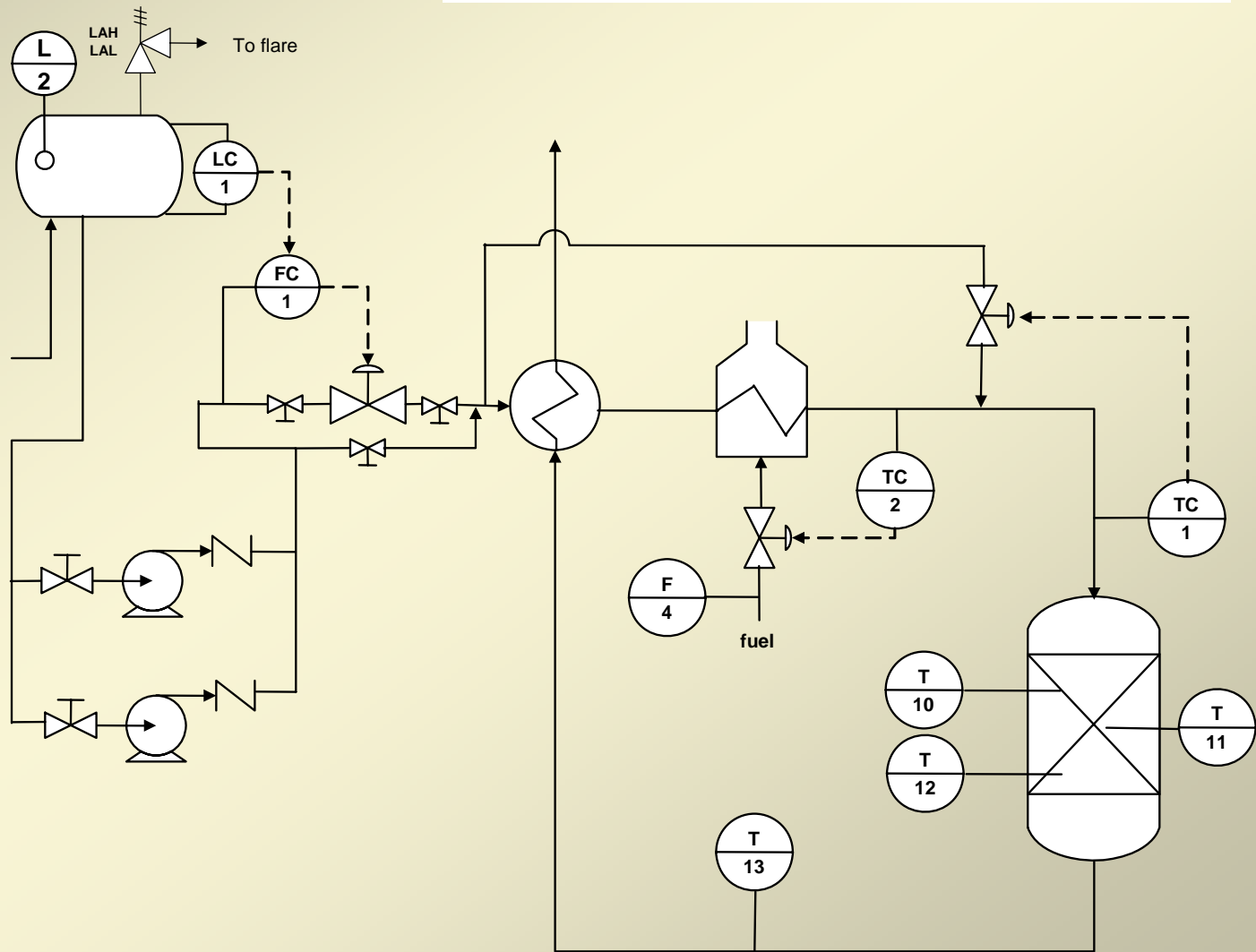


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# SAFETY & EQUIP. PROTECTION

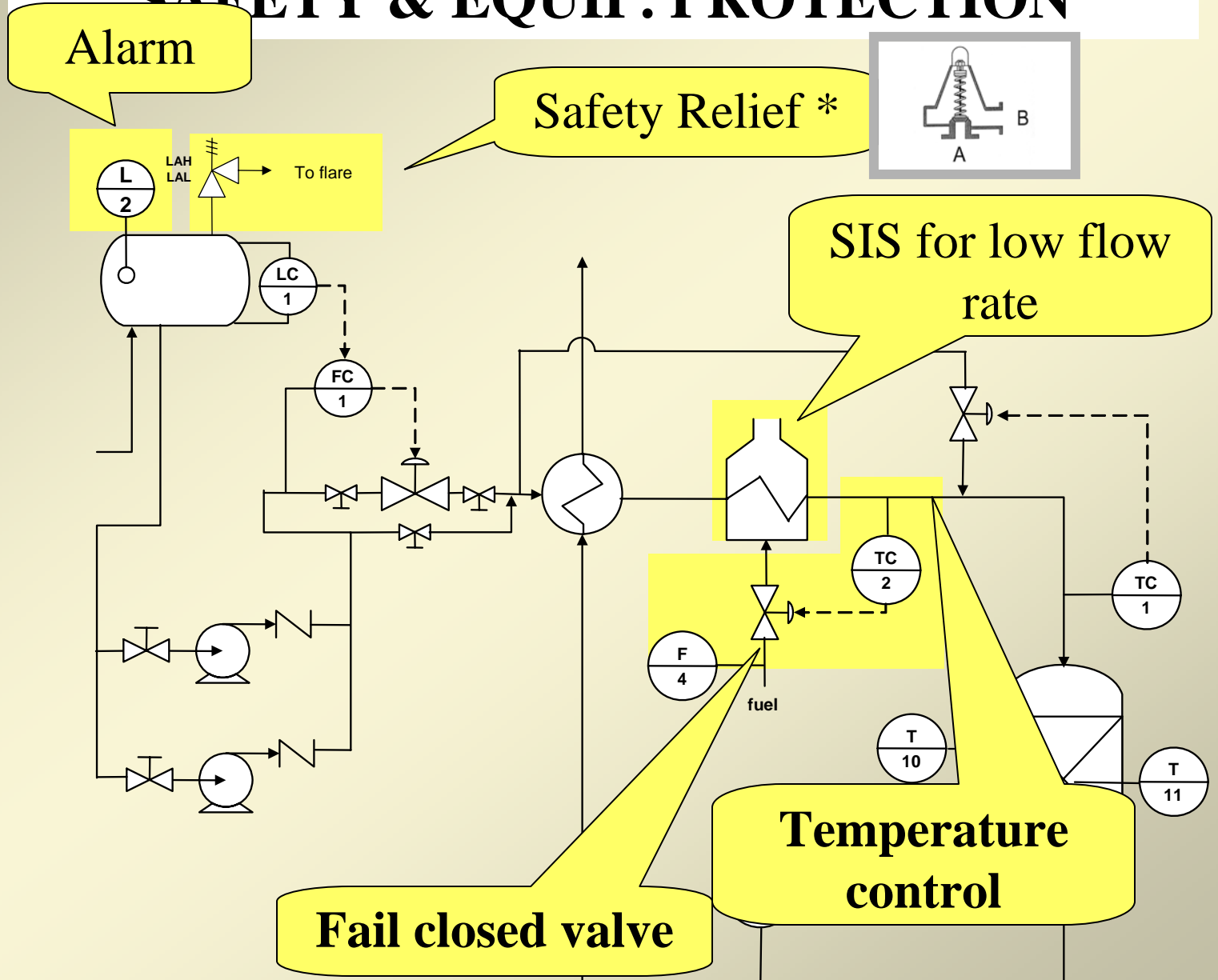
What aspects contribute to safety?



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# SAFETY & EQUIP. PROTECTION



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# SAFETY & EQUIP. PROTECTION



**HAZOP method provides a structured manner for safety analysis (using qualitative analysis)**

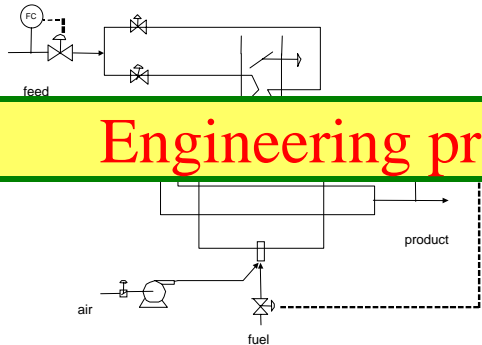
Unit: Fired heater Note the specific location

Node: air pipe after compressor and valve      Parameter: Pressure

| Guide Word | Deviation                          | Cause  | Consequence  | Action   |
|------------|------------------------------------|--|--|--|
| lower      | Low pressure in the fuel pipe node | Stoppage of power to motor or turbine turning the compressor | Uncombusted fuel in the fire box – danger of explosion<br><br>Uncombusted fuel – wasted fuel | SIS based on the rotation of motor shaft *   |
|            |                                    | Break of coupling between motor and compressor               | “  | SIS based on rotation of compressor shaft*   |
|            |                                    | Failure of compressor, e.g., bending of blades               | “<br>(plus danger from flying metal)   |  |
|            |                                    | Failure of air valve due to failure                          | “  | Fail open valve  |
|            |                                    | Any of the above   | “  | SIS that measures the flow of air after the pipe and activates the shutdown if the flow is too low |
|            |                                    | Closure of air valve due to poor decision by operator        | “  | Air flow controller with ratio to fuel flow  |

**Principles**

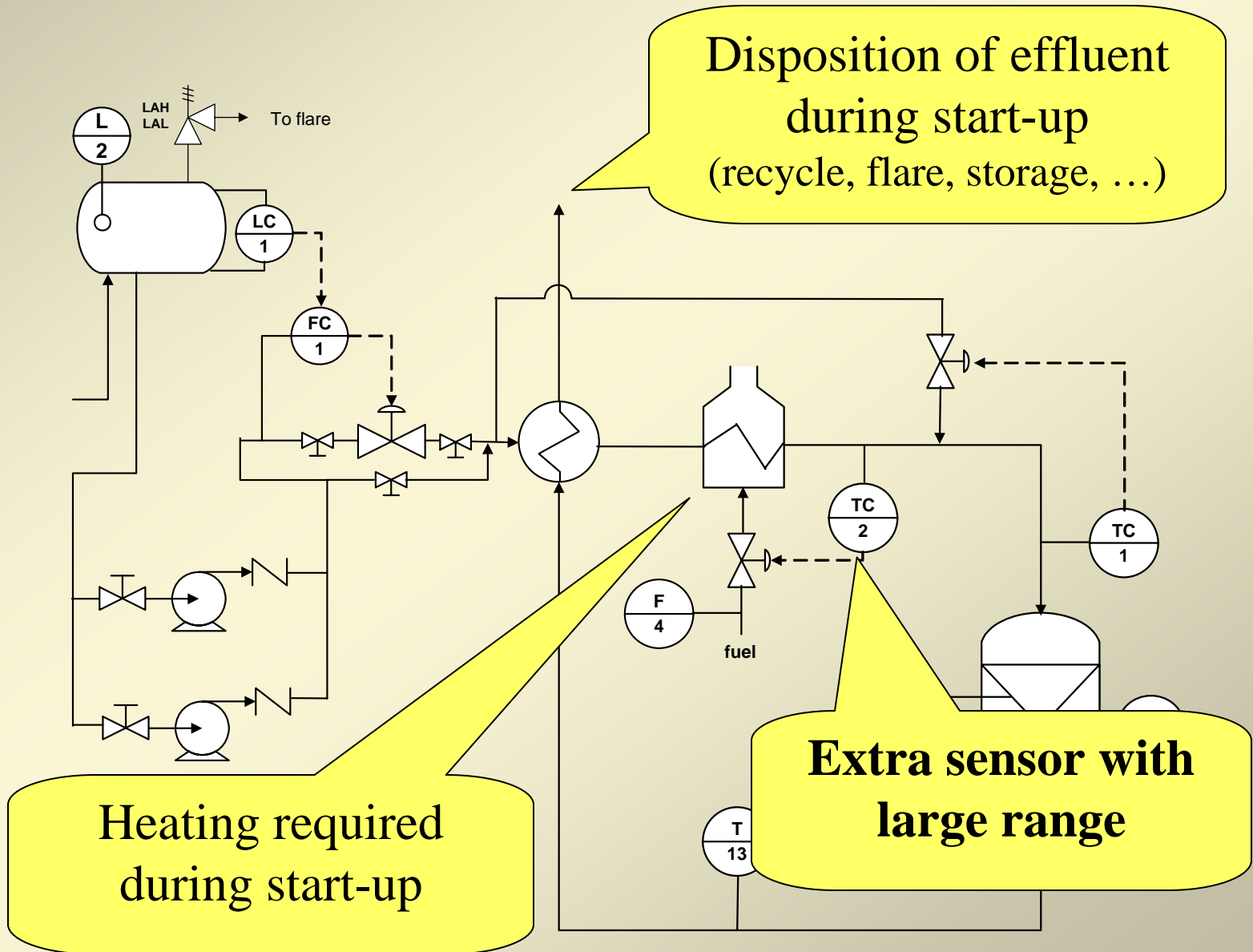
**Engineering practice**



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# OPERATION DURING TRANSITIONS

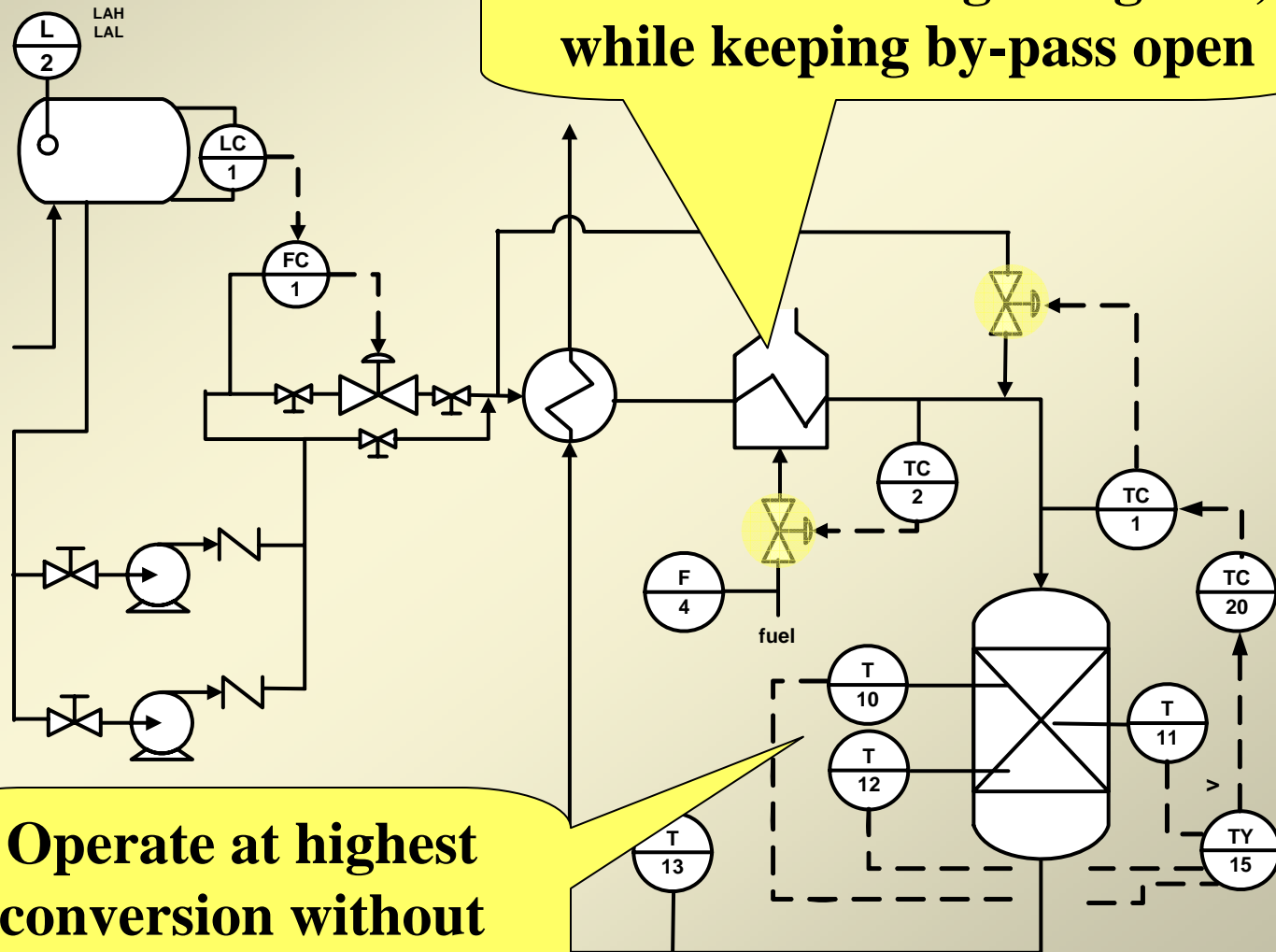


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# EFFICIENCY & PROFIT

**Minimize heating using fuel, while keeping by-pass open**



**Operate at highest conversion without excess temperature**

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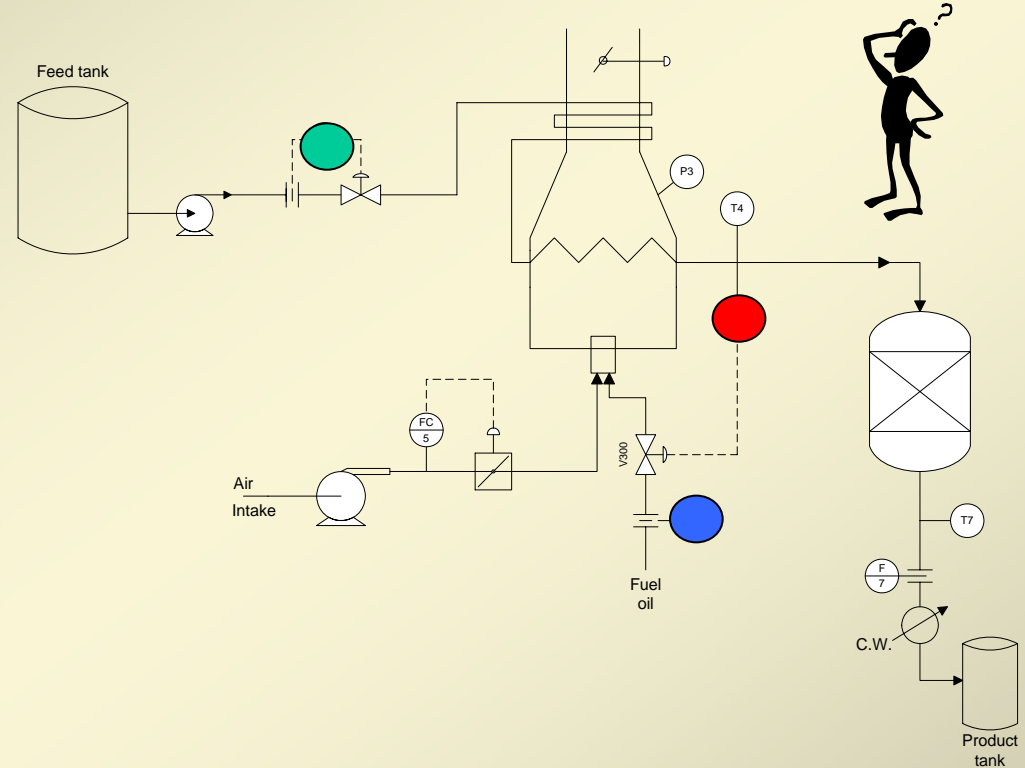
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# MONITORING & DIAGNOSIS

**Systematic Problem Solving Method!**

**Process Trouble Shooting**

1. Engage
2. Define
3. Explore

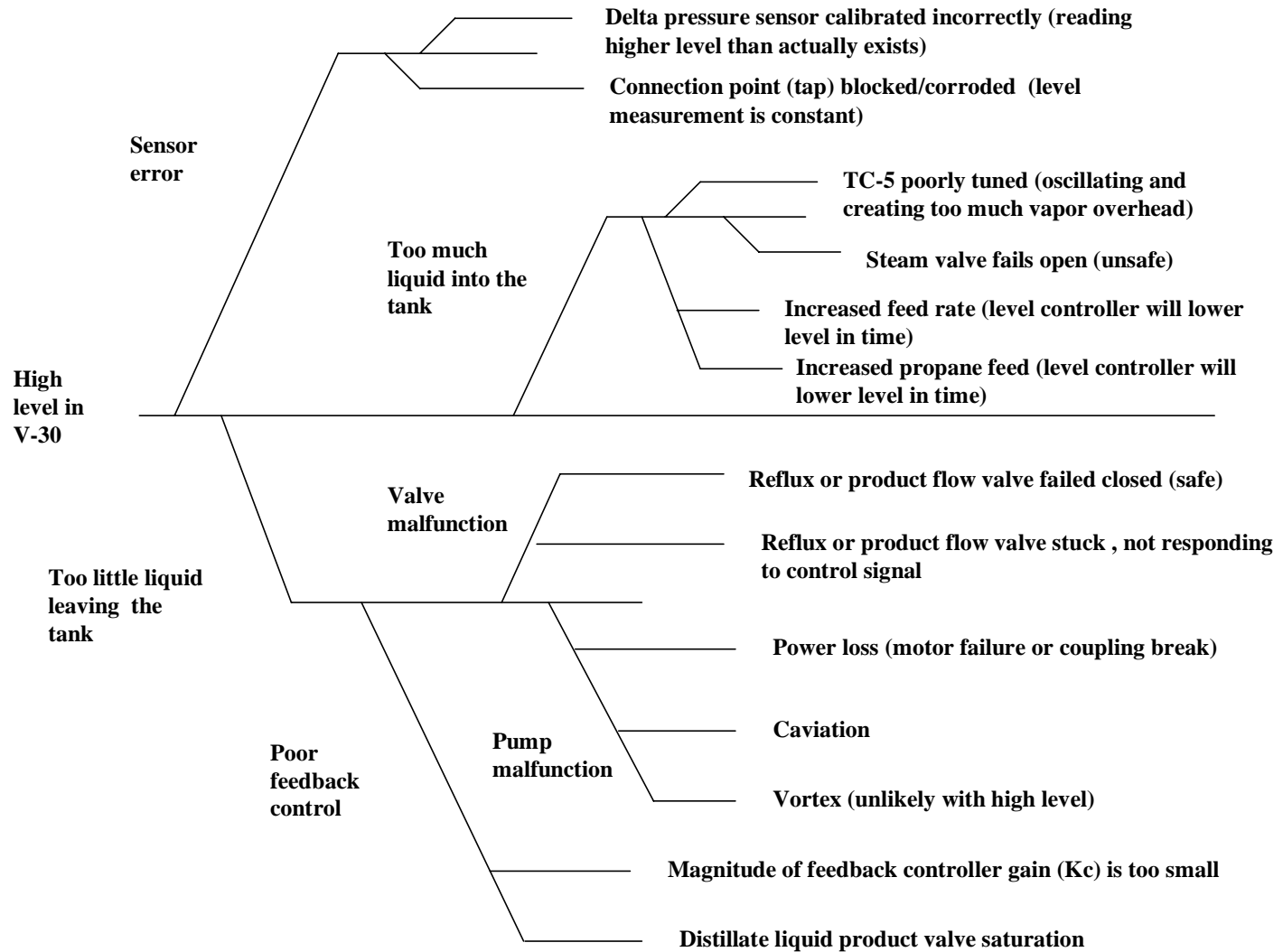


| Hypothesis                                    | Initial information                            | Diagnostic Action  |
|---|--|--|
| T sensor drift                                | Neutral  | Check with temperature at exit of reactor                                  |
| Fuel valve is stuck open                      | Disprove<br>(Temperature would increase)       | Place flow controller in manual and make small change to controller output |
| Feed rate causing T decrease<br>(TC too slow) | Disprove<br>(previous changes were controlled) | -----  |

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# FISHBONE DIAGRAM FOR MONITORING & DIAGNOSIS



# INSTRUCTOR'S EXPERIENCES

- **Any problem-based teaching style will likely satisfy needs**
- **Heavy load to develop**
- **Operability involves generic topics that are applicable to essentially any process (would have to be modified for product design). See sample projects from previous years.**

- Ammonia reactor and separation loop
- Milk powder evaporators and fluid bed drier
- Municipal water purification plant
- Desalination plant by reverse osmosis
- Ice cream production
- Penicillin production (reactor and separation)
- Refrigeration and cooling tower plant
- Boiler feed water treatment and storage
- Kraft pulp digester
- Wine production



# STUDENTS' EXPERIENCES

## The Good

- Students enjoyed the problem solving tasks (e.g., HAZOP and Trouble Shooting)
- Defined diverse projects & found good operability issues



## The Bad

- Difficulty recognizing causes of variability and uncertainty
- Challenge to “work backwards”: effect → cause



The Ugly To much (open-ended) work!



# Educational Modules in Process Design and Operability

- Integrate **Robust design/process operability** in the capstone design course
- No instructor has experience with all issues
- Limited educational material is available that is accessible to undergraduates

Project to establish a portal for **robust design/ process operability**, with educational materials for public use



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# Educational Modules in Process Design and Operability

## For each topic

- A Chapter in pdf format
- Class materials (powerpoint, tutorials)
- Cogent process examples for undergraduates
- Links to resources for problem solving

## To integrate materials

- An introductory chapter
- Several process examples



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# Educational Modules in Process Design and Operability



**We would appreciate comments, criticism,  
suggestions at any time, now or by email.**

Expanded copy of white paper and power point lessons are available at  
**[www.pc-education.mcmaster.ca/operability\\_home.html](http://www.pc-education.mcmaster.ca/operability_home.html)**