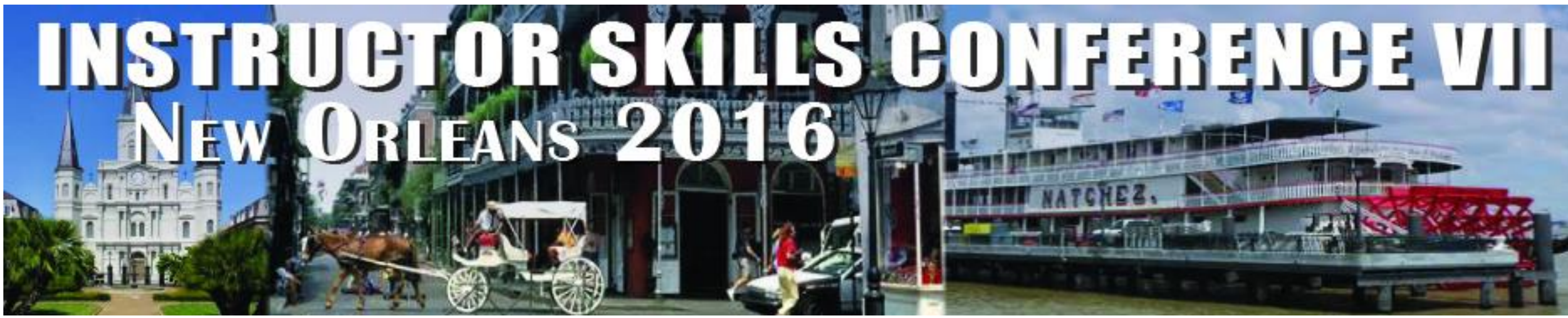
Exercises for Developing Critical Thinking Skills for Operators



September 22nd 2016

Simulation Solutions, Inc.
Donald Glaser
Matthew Garvey

Abstract

Various unique styles of training exercises are discussed that promote critical thinking skills for PTEC Students and Plant Operators. A focus is placed on exercise delivery and development.

Outcomes

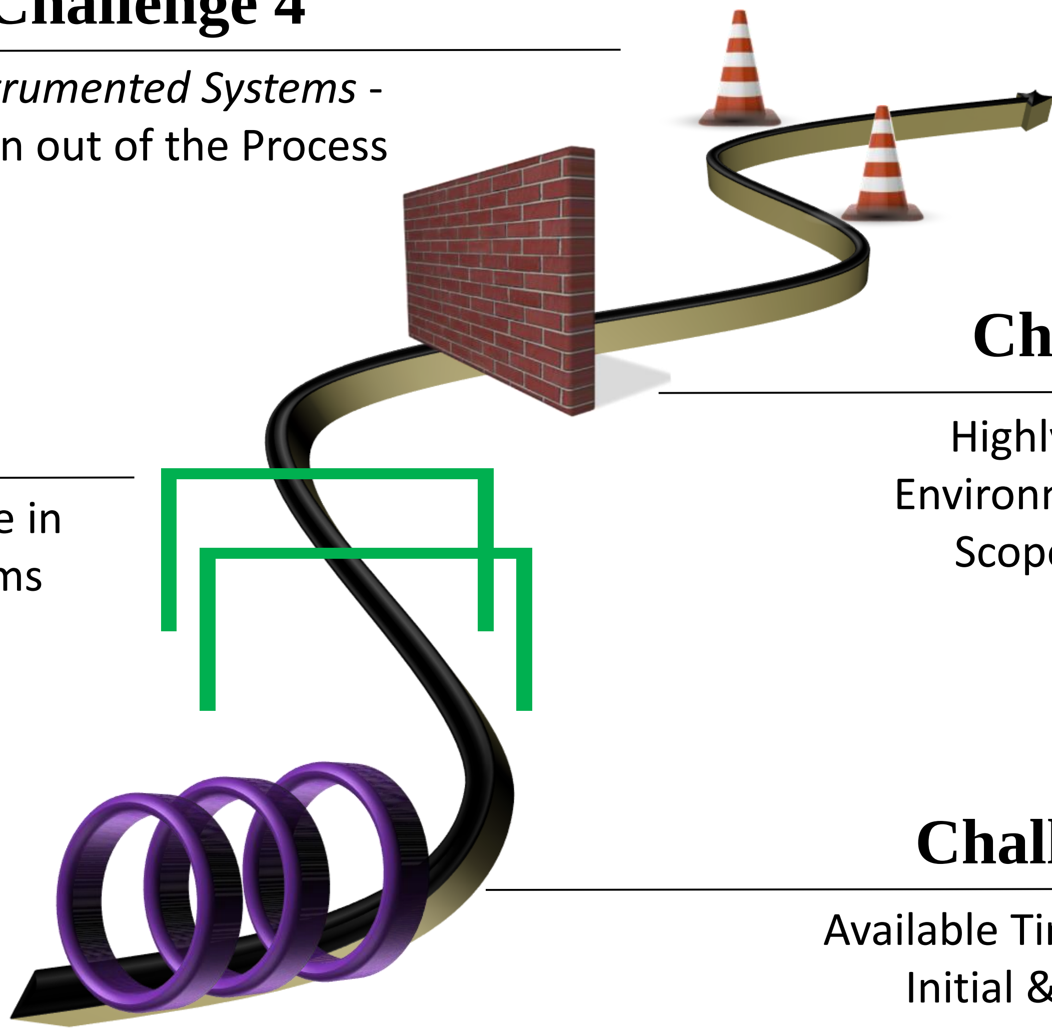
Help Training Instructors and Plant Training Departments to develop and deliver exercises that promote critical thinking skills

Challenges Affecting Operator Performance

Operator Performance

Challenge 4

Safety Instrumented Systems -
Being Taken out of the Process



Challenge 3

Highly Stressful Work Environment – Increases in Scope/Responsibility

Challenge 2

Continued Increase in Automation/Alarms

Challenge 1

Available Time for Training Initial & Refresher

Changing Role of the Operator: Operator of the Past

- In depth knowledge of process and machine operations, as well as the systems that enable the process.
- Often learned from previous operators, sometimes through trial and error.
- Great deal of step-by-step knowledge within an operator’s specific responsibilities

Changing Role of the Operator: Today's Operator

- Multi-faceted employee with drastically increased responsibilities

- Need the ability to reason, plan and solve problems quickly. Operators needs to be comfortable with growing Automation and be able to use these tools to decipher data and solve problems.

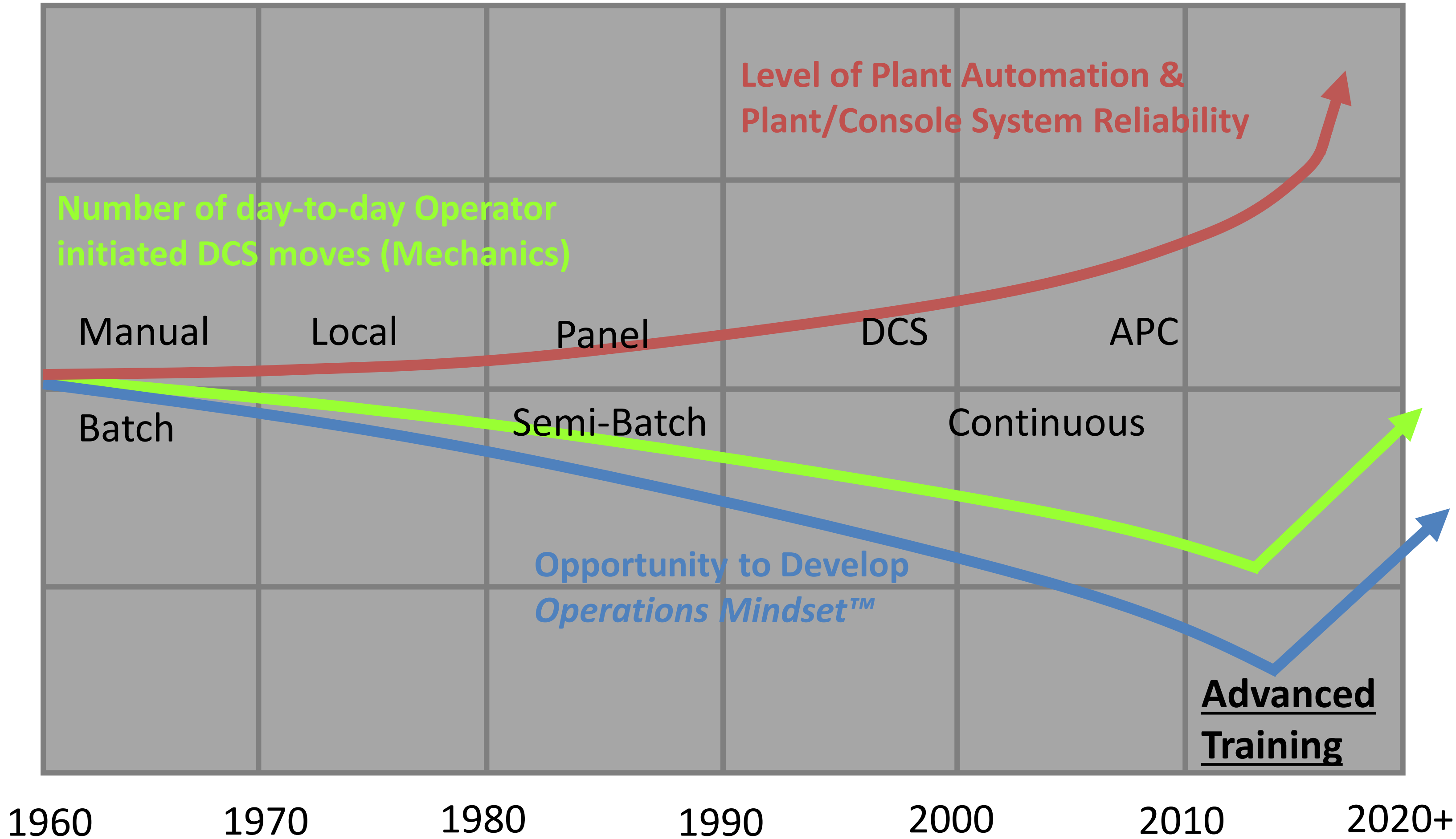
- Advanced features such as alarms, historical trending, and predicative analysis are helping operators process information

Changes in the Role of Operators

YESTERDAY'S OPERATOR	TODAY'S OPERATOR
→ Follow the process based on predefined procedures	→ Make objective decisions based on real-time data
→ Work within a linear, functional role	→ Work within a cross-functional organization
→ Maintain compliance with set standards	→ Contribute to driving process changes
→ Make independent decisions based on training	→ Leverage institutionalized knowledge

©"The Changing Role of the Operator", GE 2010

Advanced Levels of Automation Prevent Control Room Operators from Developing both Mechanics and an *Operations Mindset*™



"There are two especially important situations that can lead to the escalation of an abnormal situation."

1. An Operator believes a process measurement that is incorrect

Incorrect Reading

Escalation

2. An Operator disbelieves a process measurement that is correct

Correct Reading

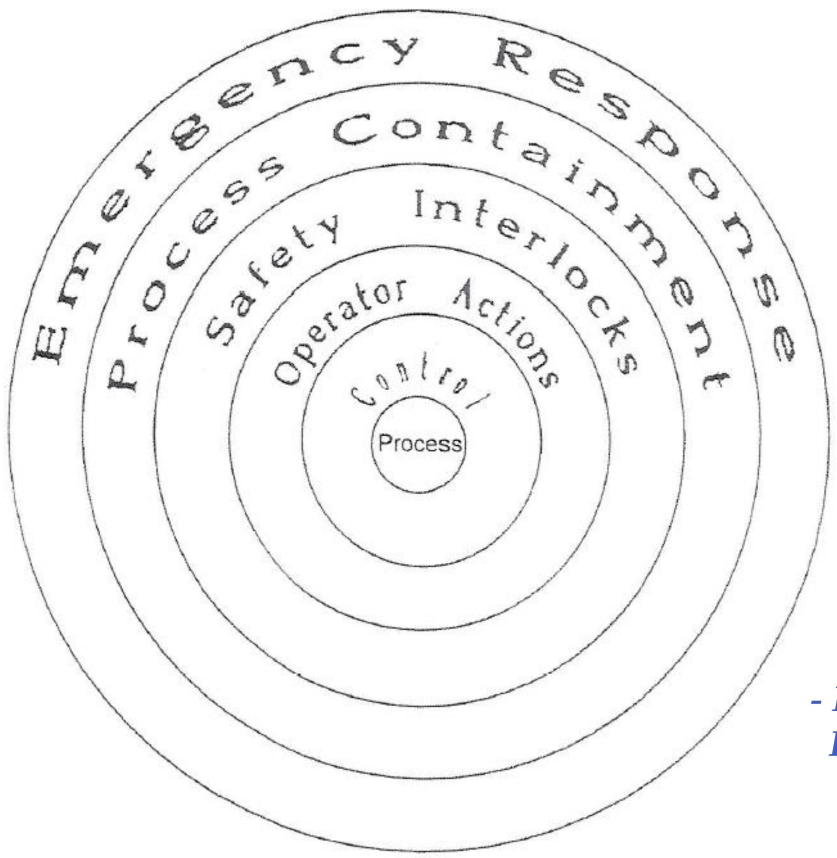
Escalation

– Improving the Operator's Capabilities During Abnormal Conditions, Kenenth F. Emingholz, Exxon.

Legacy Layers of Protection from 1995

Figure 1

Layers of Process Protection



- Improving the Operator's Capabilities During Abnormal Operations

Layers of Protection Analysis: Shift in Operator Intervention

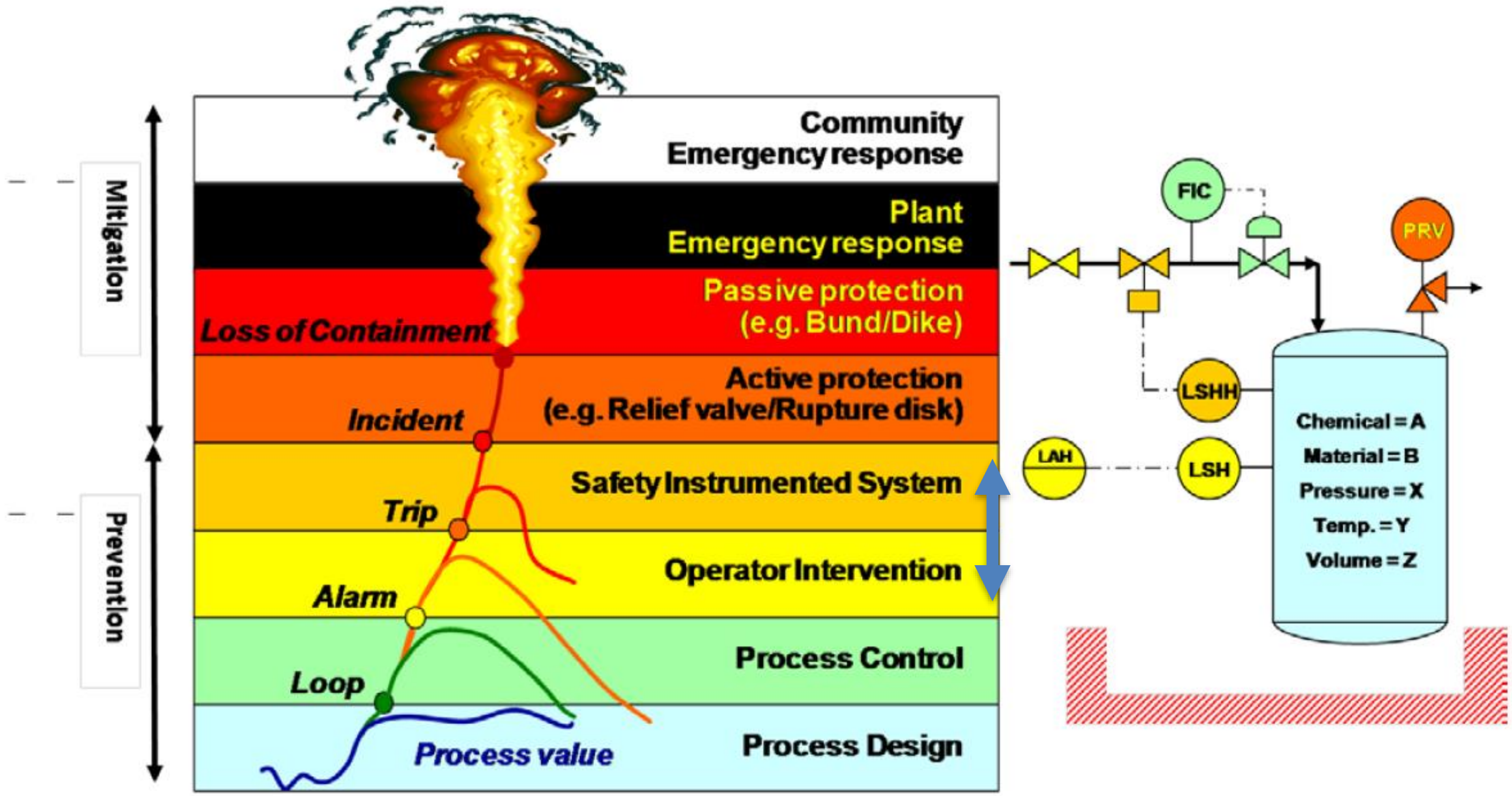


Figure 3. Layers of Protection and Their Impact on the Process

Increase in Emergency Shutdown System Automation

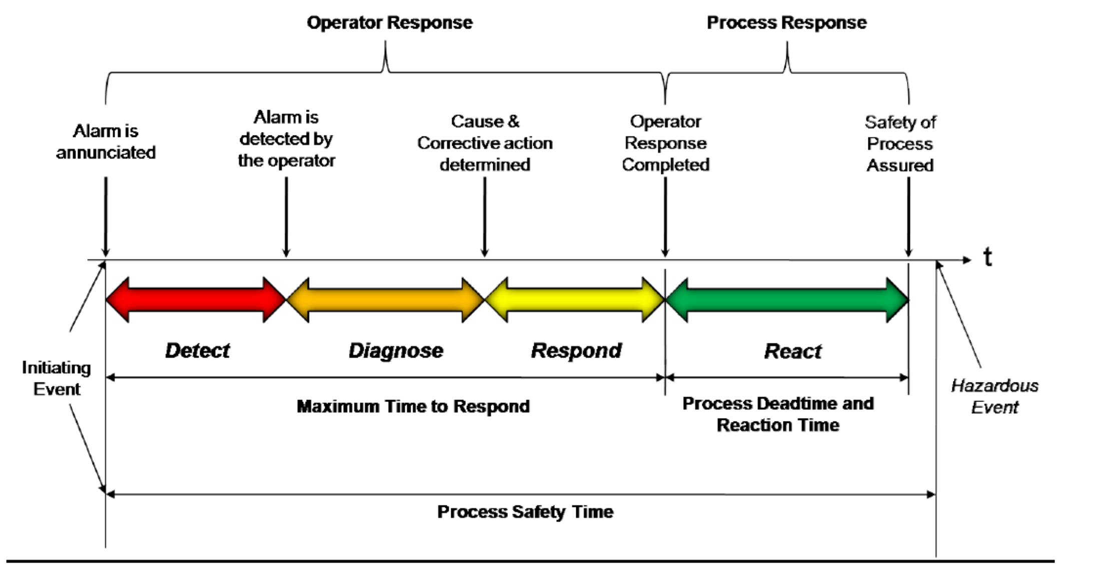


Figure 6. Operator Response Timeline

Operator response time should be considered up-front during design. Creating a situation where an operator has only a few minutes to ***detect***, ***diagnose,*** and ***respond*** increases the probability for failure and means that they cannot be a significant safety layer. One company has set a threshold requirement of 10 minutes, meaning any alarm which has a process safety time of less than 10 minutes cannot be claimed as a layer of protection (PFD = 1.0).

<u>Cited Sequence</u>

1. Alarm
2. Operator Intervention “within 10 minutes or less”
3. Trip

<u>Evolving Sequence</u>

1. Alarm
2. Trip
3. Operator Intervention if the trip/automated controls fail to respond properly

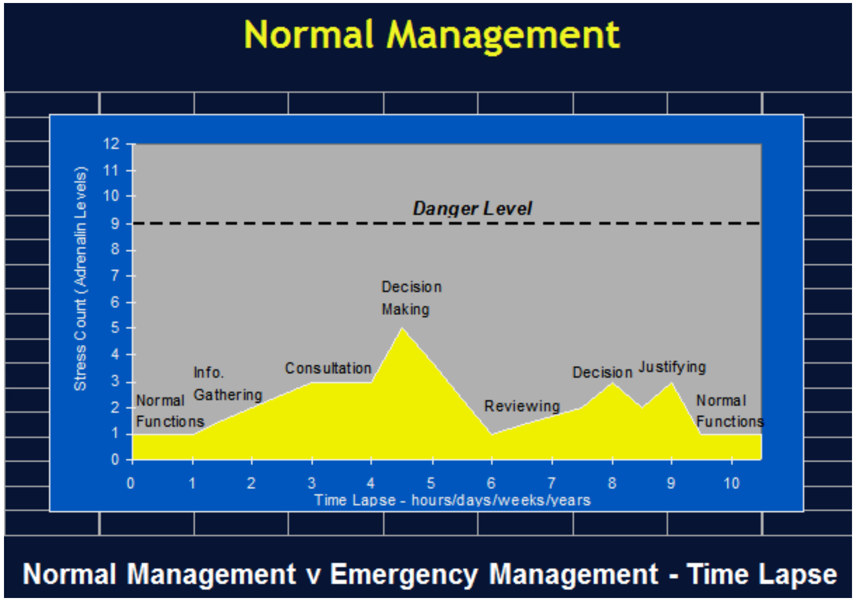
©Exida, 2009

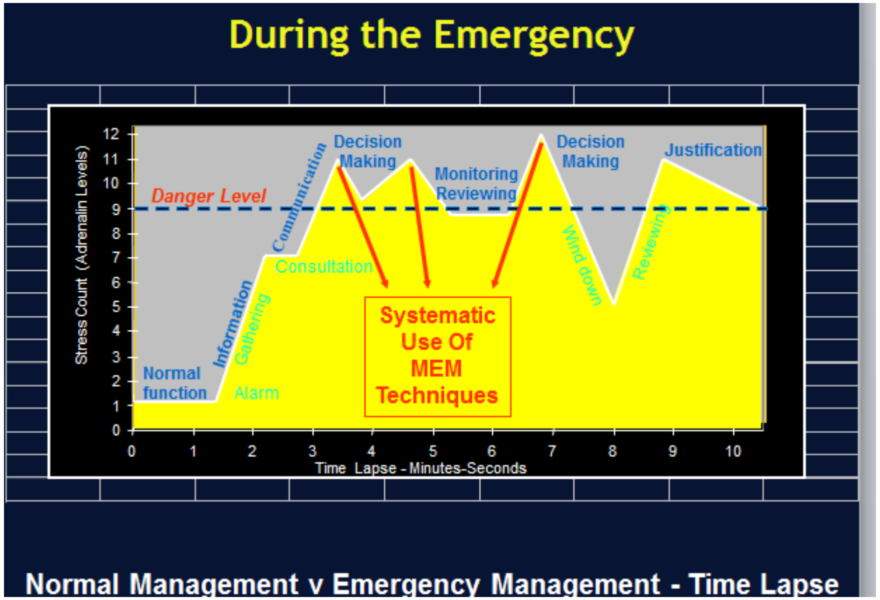
Typical actions from Safety Instrumented Systems:

- Shutdown of part systems and equipment
- Isolate hydrocarbon inventories
- Isolate electrical equipment
- Prevent escalation of events
- Stop hydrocarbon flow
- Depressurize / Blowdown
- Emergency ventilation control

Safety Instrumented Systems Increasing

How Does Stress Affect Decision Making?

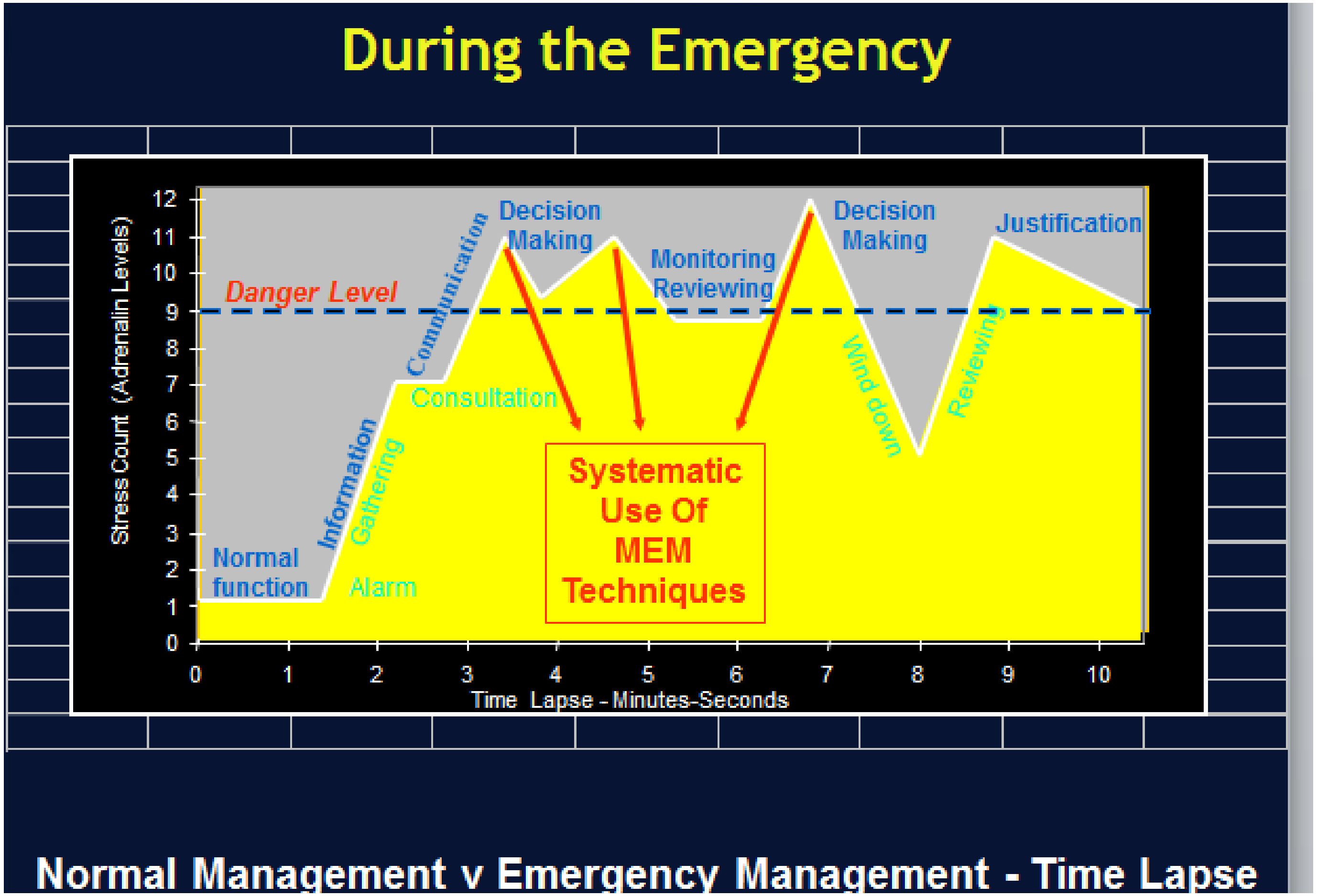




MEM Techniques = Major Emergency Management Techniques

Qatar International Safety Centre, 2013

How Does Stress Affect Decision Making? (Continued)



MEM Techniques = Major Emergency Management Techniques

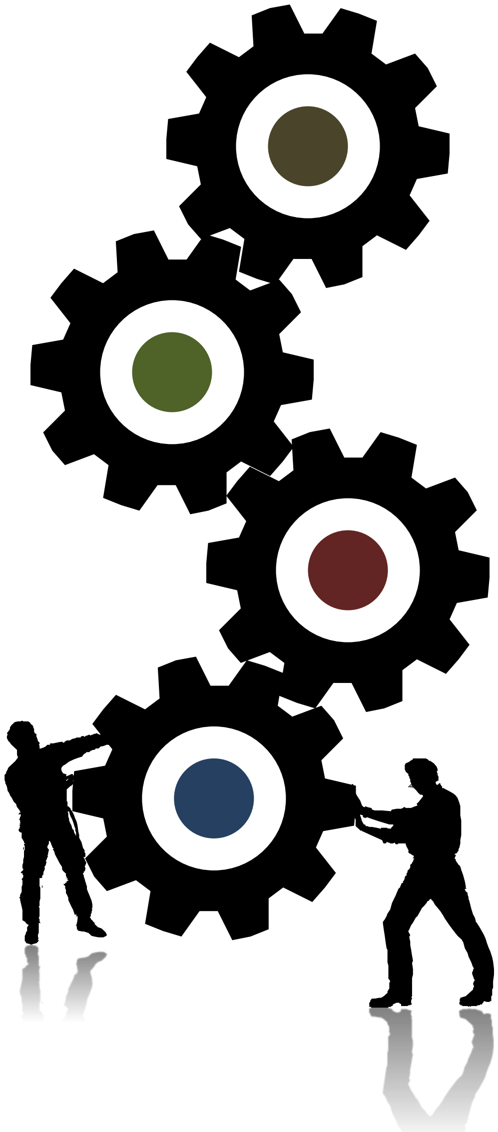
Operations Jobs are Complex
A Suggested Competency Model

Operating Mechanics & *Operations Mindset*

- **Operating Mechanics** – The "hands on" skills required to successfully execute and complete an Operations task(s).

- ***Operations Mindset*** –The "mentality" or "mindset" of an Operator during preparation, execution, and completion of an Operations task(s).

Operating Mechanics

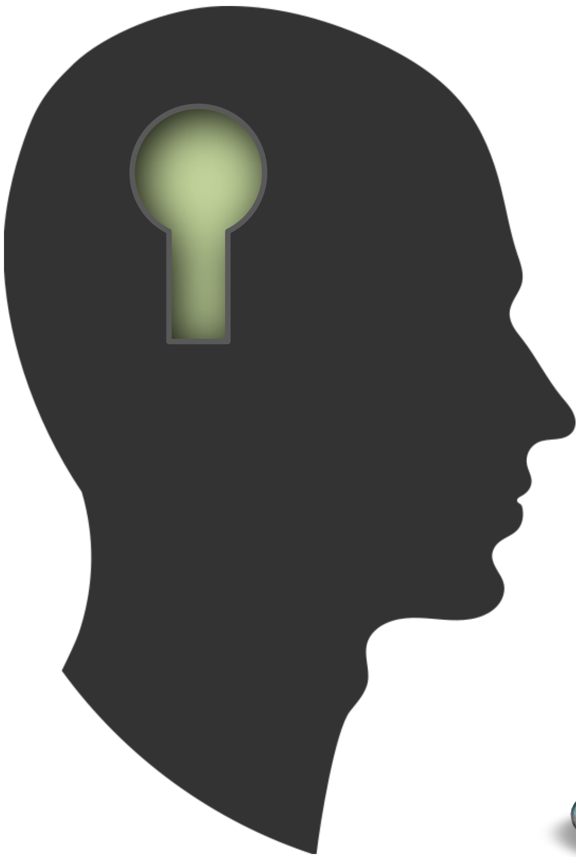


1. Familiarity with DCS Interface and basic Plant Equipment.

2. Ability to Follow procedures as written.

3. Fast, Calculated Response when dealing with routine plant moves (Sparing a Pump).

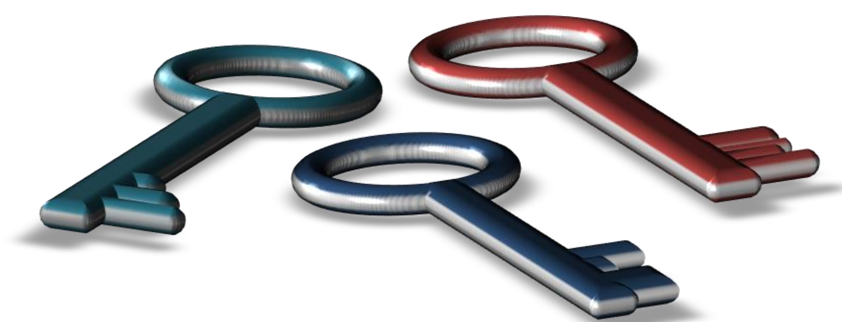
Operations Mindset



1. Have an Expectation of Results before making a change in the Plant.

2. Be able to Understand and perform parallel procedures.

3. Monitor Plant responses using Alarms, Trends, & Alerts with an understanding of Upstream & Downstream effects.

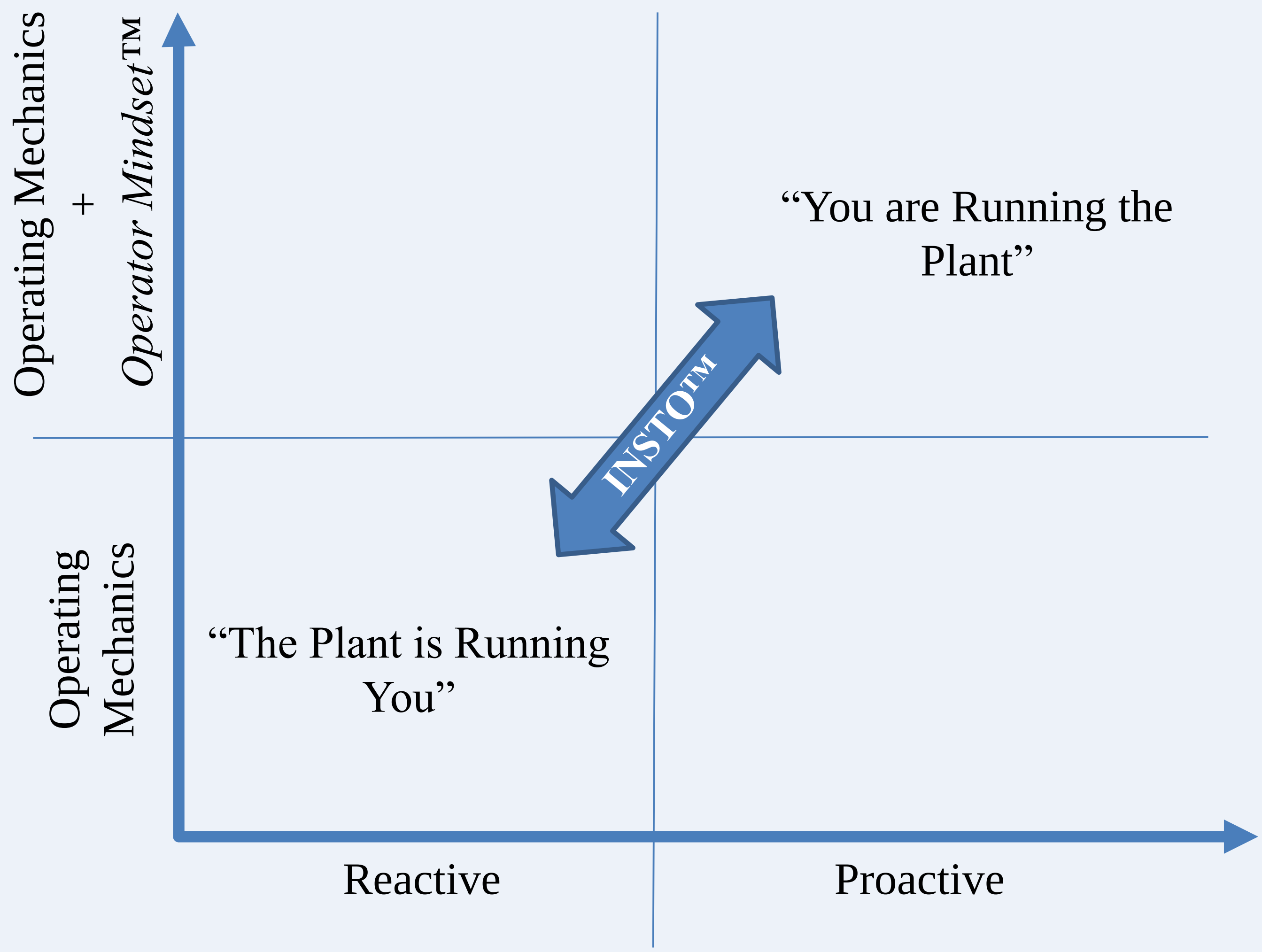


Operating Mechanics + *Operations Mindset* = High Skill Operator

Operating Mechanics

Operations Mindset™

Operating Mechanics vs. *Operations Mindset*



Grafting an *Operations Mindset* to New Operators

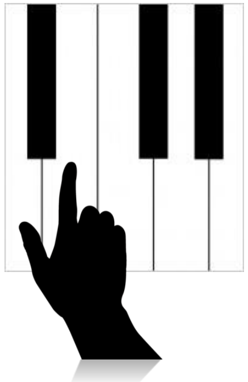
"Old School" Operator
Numerous Opportunities for Experiential Learning

"New School" Operator
Vastly Different Circumstances

Relating Musical Ability to Operating Ability

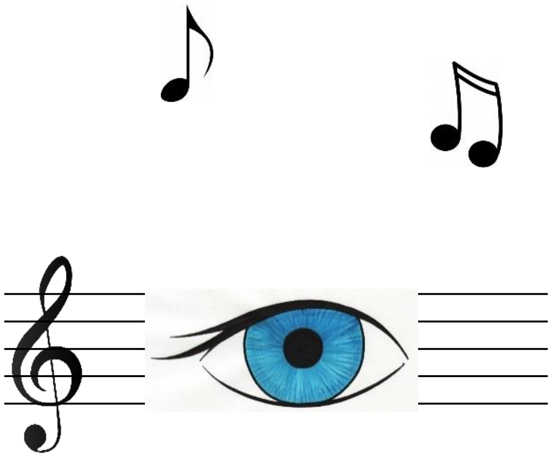
Play Music by Ear

Operators are "naturally gifted" in the troubleshooting process.



Rote Memorization

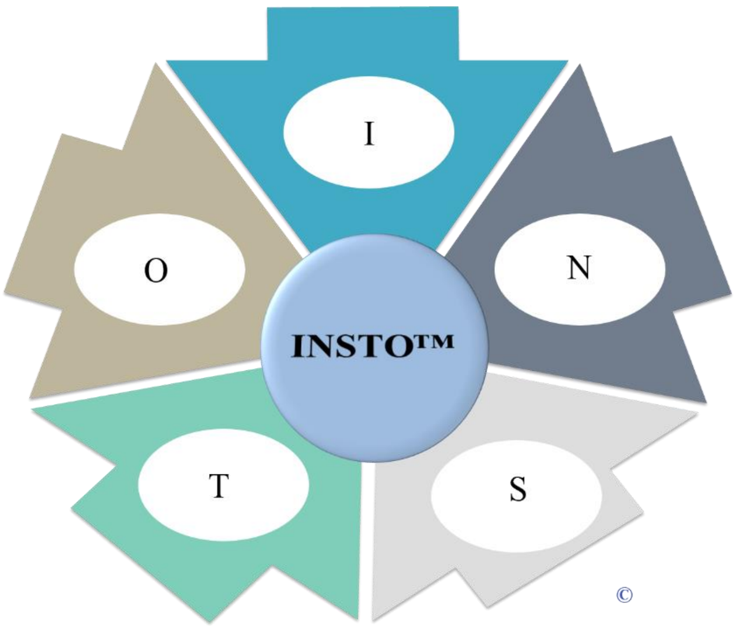
Operators repeatedly practice a limited number of known upsets.



Sight Read Music

Operators develop skills to face an upset they have never faced before with an *Operations Mindset™.*

Classroom Methodology – INSTO
5 Phases of Simulator Training



I. **I**dentification – Location of equipment and controls

II. **N**ormal Operations – How things work - Expected responses

III. **S**tart-up and **S**hut-down

IV. **T**roubleshooting and Upsets

V. **O**ptimization and **O**perating Strategies

Training Emphasis

Traditional

- 2-3 days of Training is Sufficient
- Procedure-Driven
- Answers versus Understanding
- Speed over Contemplation
- All problems have a Single Quick Fix
- Drilled Responses are possible to Master with Limited Practice
- Once Learned, Never Forgotten
- Refresher Training is a Luxury

INSTO

- 2-3 days is a start!
- Critical Thinking Skills are key
- Answers + Understanding
- “Thinking Fast and Slow”
- Quick Fix = A Repair
- Mastery takes considerable time and effort
- Forgetting Curve/”Use it or Lose It”
- Refresher Training is Required
- Lifelong Learning in the Control Room

Minds-On/Hands-On

"Minds-On"

"Hands-On"

Identify the Problem

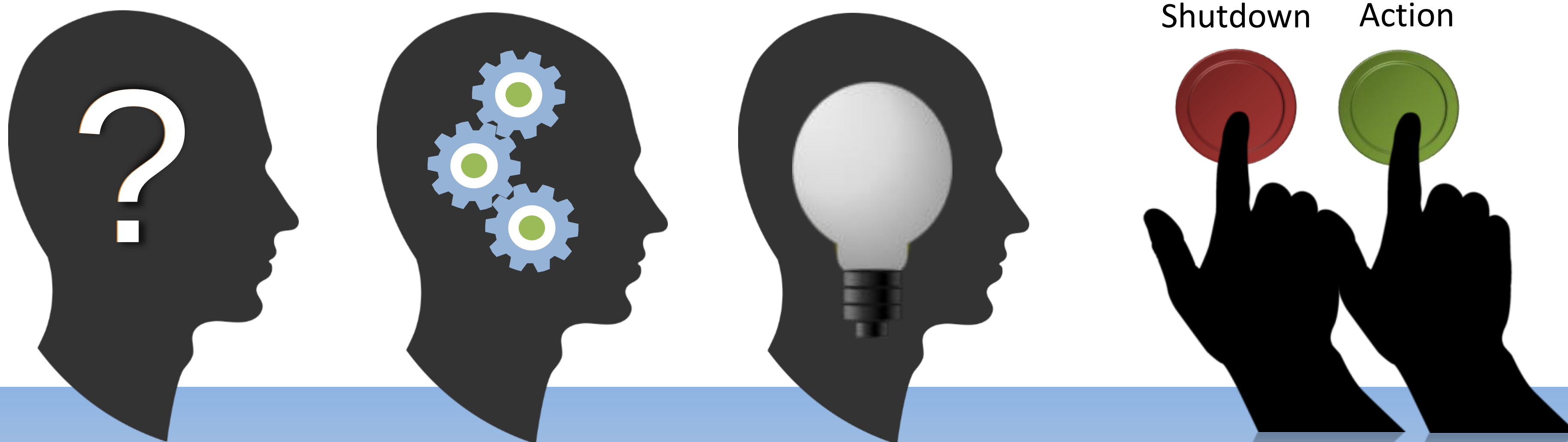
Troubleshooting Process

Propose a Cure

Taking Action

Safe Shutdown

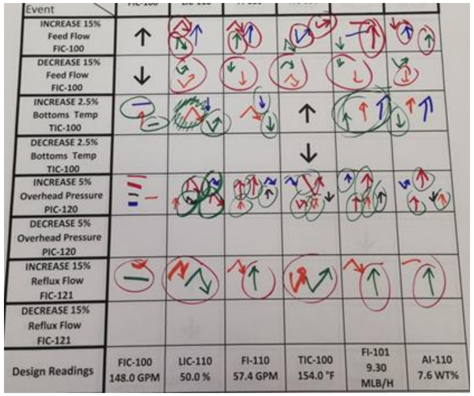
Corrective Action



Habits of a Systems Thinker

Makes meaningful connections within and between systems

What-If Questions



Event						
INCREASE 15% Feed Flow FIC-100						
DECREASE 15% Feed Flow FIC-100						
INCREASE 2.5% Bottoms Temp TIC-100						
DECREASE 2.5% Bottoms Temp TIC-100						
INCREASE 5% Overhead Pressure PIC-120						
DECREASE 5% Overhead Pressure PIC-120						
INCREASE 15% Reflux Flow FIC-121						
DECREASE 15% Reflux Flow FIC-121						
Design Readings	FIC-100 148.0 GPM	LIC-110 50.0 %	FI-110 57.4 GPM	TIC-100 154.0 °F	FI-101 9.30 MLB/H	AI-110 7.6 WT%

Seeks to understand the big picture

[Start Up & Shut Down Scrambles]

START UP SCRAMBLE **DISTILLATION**

Directions: Arrange the Startup Procedure in the correct order.

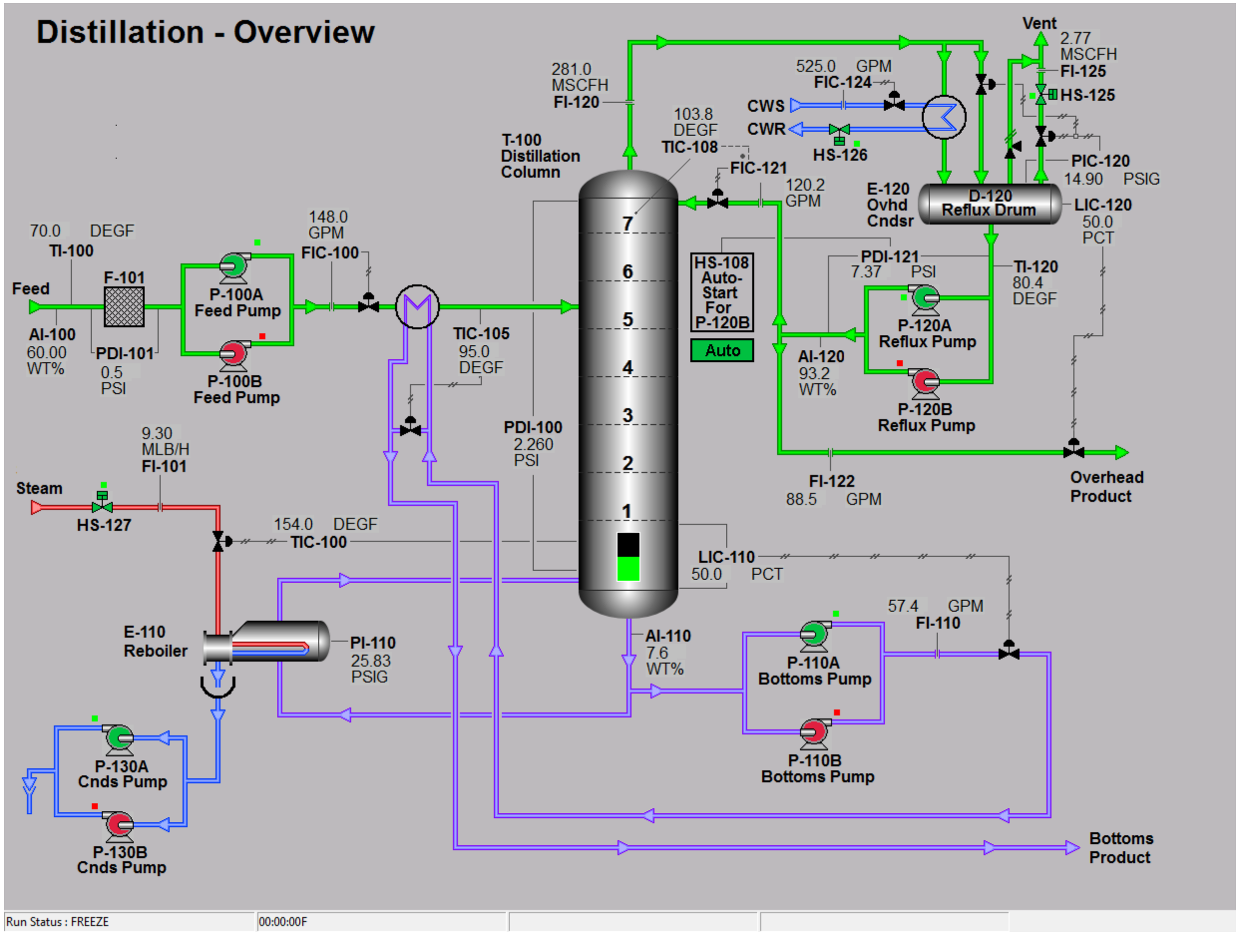
A. Establish vapor flow
B. Start reflux flow
C. Start steam flow
D. Start feed flow
E. Start cooling water
F. Establish a base level
G. Establish top Pressure control
H. Take off bottoms product
I. Establish reflux drum level
J. Take off top product
K. Open vent valve

Pays attention to accumulations and their rates of change

Start Up Procedures

4. **Outside Operator:** Monitor the Bottoms Level controller LIC-110 and verify that the level is rising as feed enters. When level reaches 60%, turn off P-100A and notify Console Operator. (Level will appear on Gauge at 40%) 	___/___/___
5. **Console Operator:** Manually adjust the output of Feed Flow controller FIC-100 to 0%, stopping feed flow.	___/___/___

Exercise Agenda



1. Startup Scramble 2. Trend Match 3. Troubleshooting Cause & Effect

Start Up Scramble Exercise

- Reorder the scrambled steps of a Distillation Column Start Up Procedure.

- The scramble exercise allows Trainees or Operators a chance to look at an overview of the procedure before starting the process.

- Discussion are held on which steps <u>must</u> be done before others in terms of safety and sequence.

START UP SCRAMBLE

DISTILLATION

Directions: Arrange the Startup Procedure in the correct order.

A. Establish vapor flow

B. Start reflux flow

C. Start steam flow

D. Start feed flow

E. Start cooling water

F. Establish a base level

G. Establish top Pressure control

H. Take off bottoms product

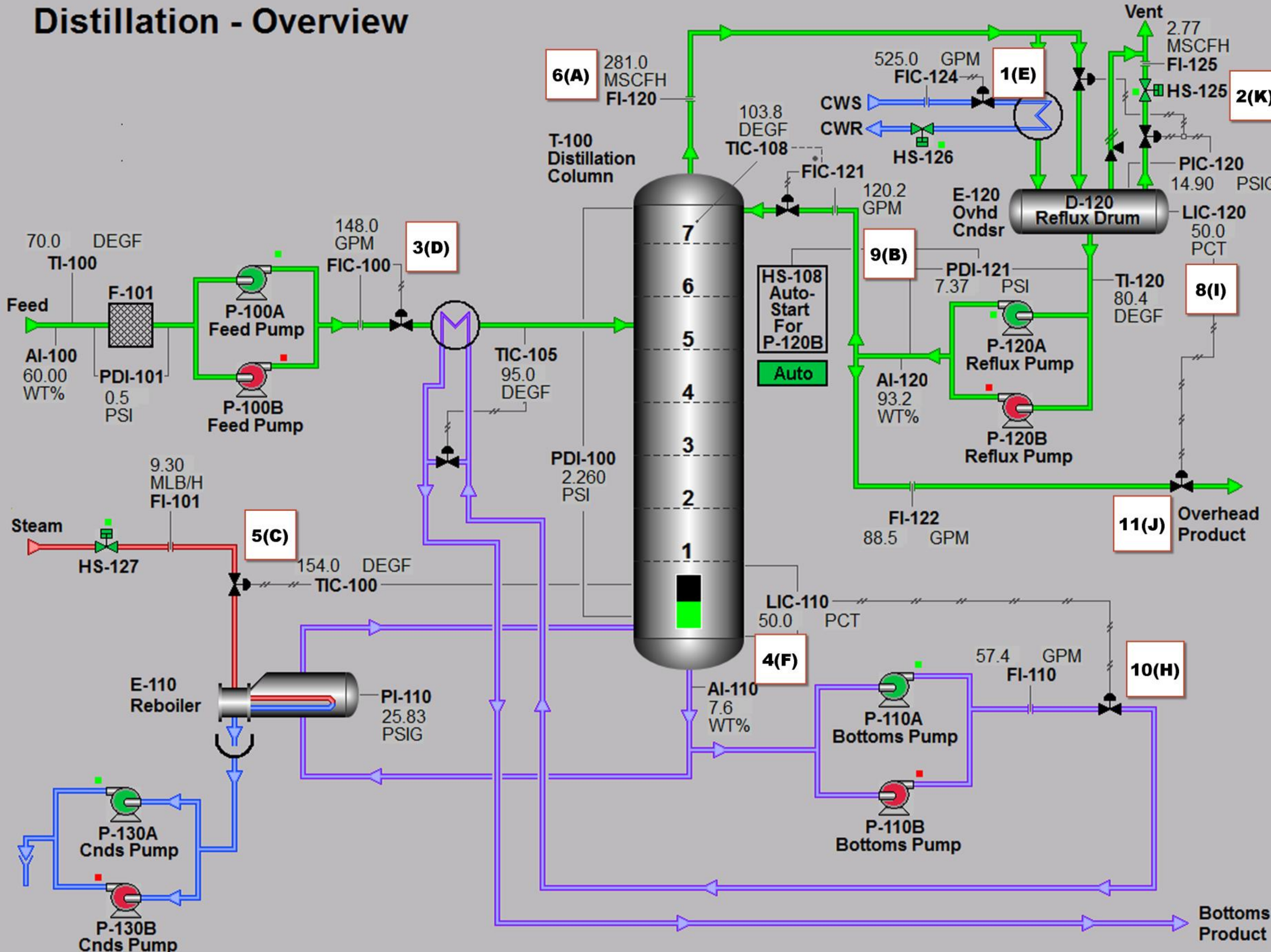
I. Establish reflux drum level

J. Take off top product

K. Open vent valve

Name																		
1.																		
2.																		
3.																		
4.																		
5.																		
6.																		
7.																		
8.																		
9.																		
10.																		
11.																		

Distillation - Overview



Distillation Startup - Safety Errors

- Starting Steam Before Cooling Water
- Failing to Open Vent Valve before Starting Steam
- Starting Steam Before Establishing a Base Level

Distillation Startup - Sequence Errors

- Take Bottoms Product Off before Level is Established
- Claiming Overhead Vapor Flow before Starting Steam
- Starting Reflux Flow Before Reflux Drum Level is Established

Provide a path for vapors prior to establishing heating

Blocked Damper

Safe Operations

Establish a sufficient level prior to heating

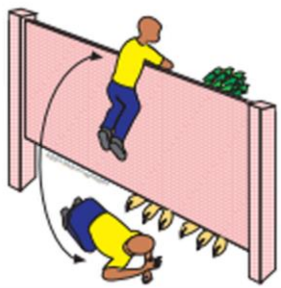
Heat before enough liquid

Safe operation

Considers an issue fully and resists the urge to come to a quick conclusion

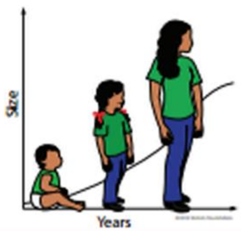
Repair vs Troubleshooting

Changes perspectives to increase understanding

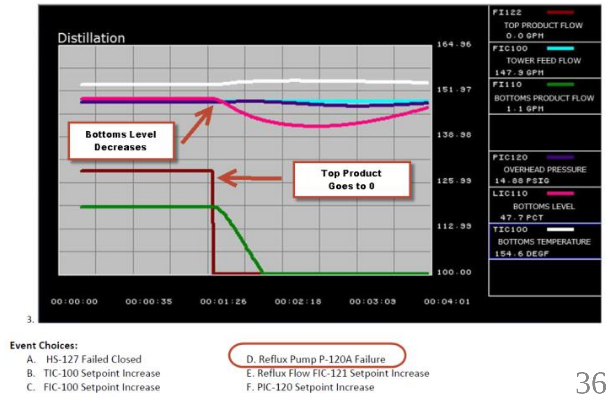


“Think EQ.U.I.P.P.E.D” Exercise

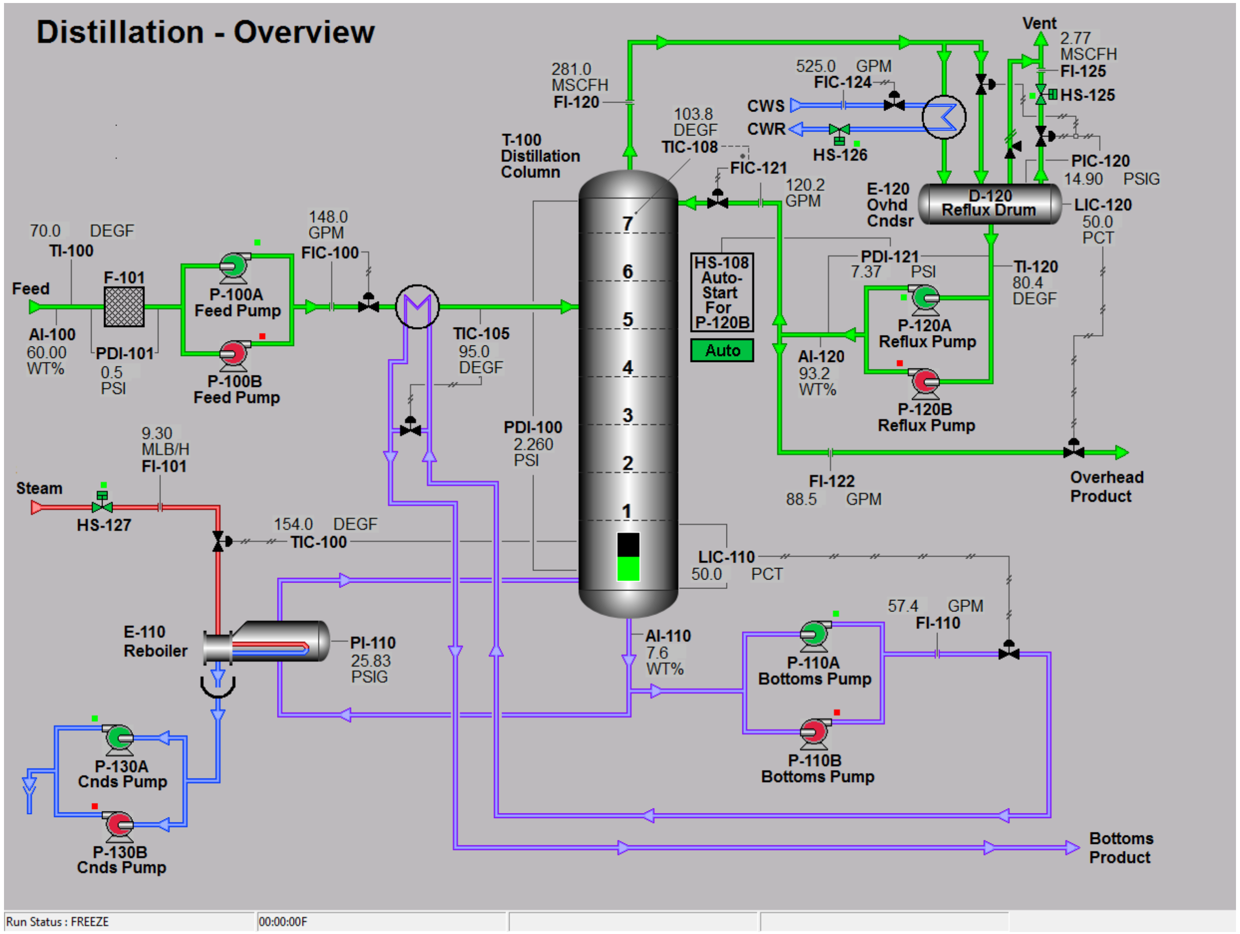
Observes how elements within systems change over time, generating patterns and trends



Trend Match Exercise



Exercise Agenda



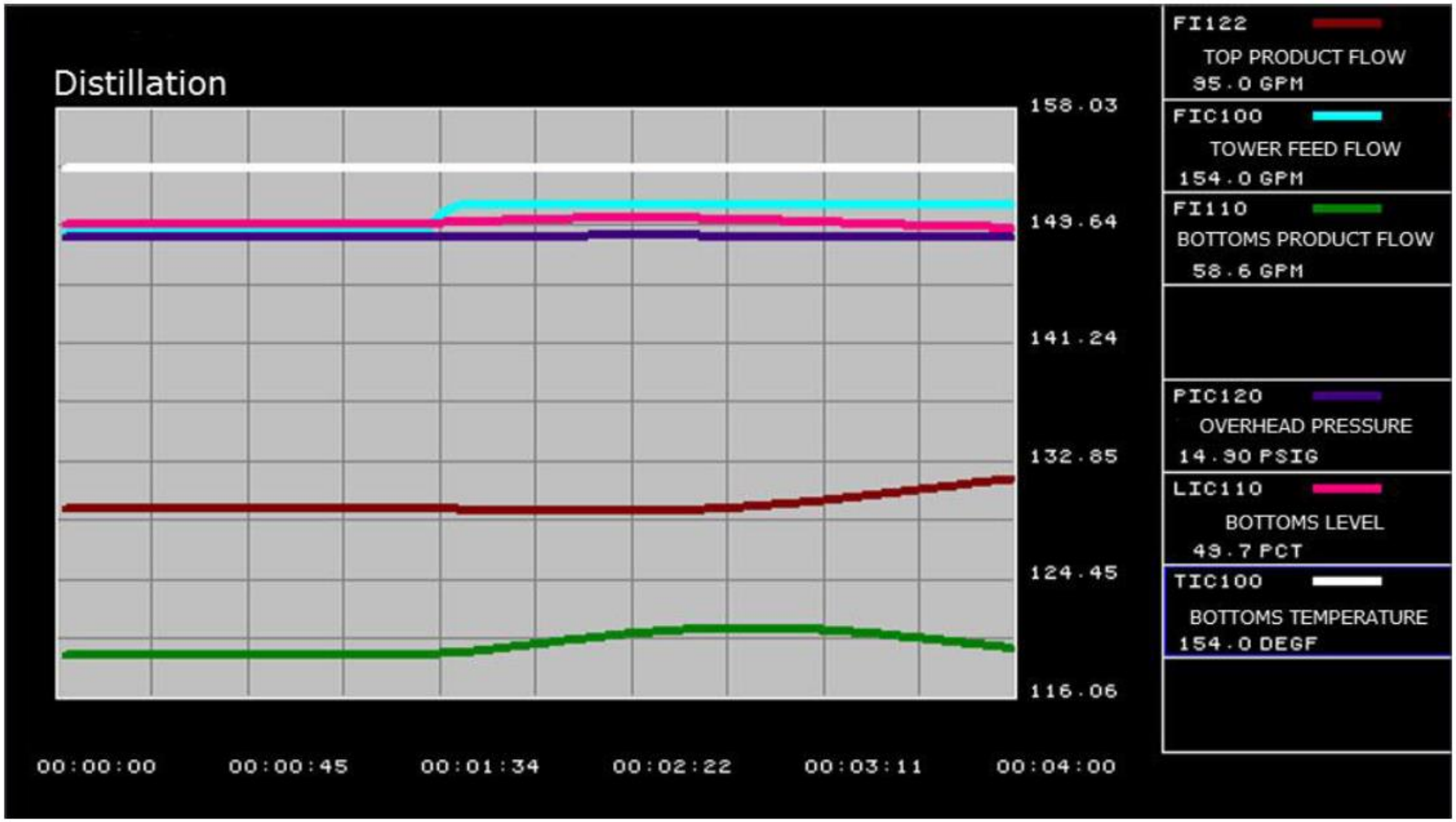
1. Startup Scramble **2. Trend Match** 3. Troubleshooting Cause & Effect

Trend Match Exercise

- Circle the Event under each Trend that correlates to the process responses in that Trend.

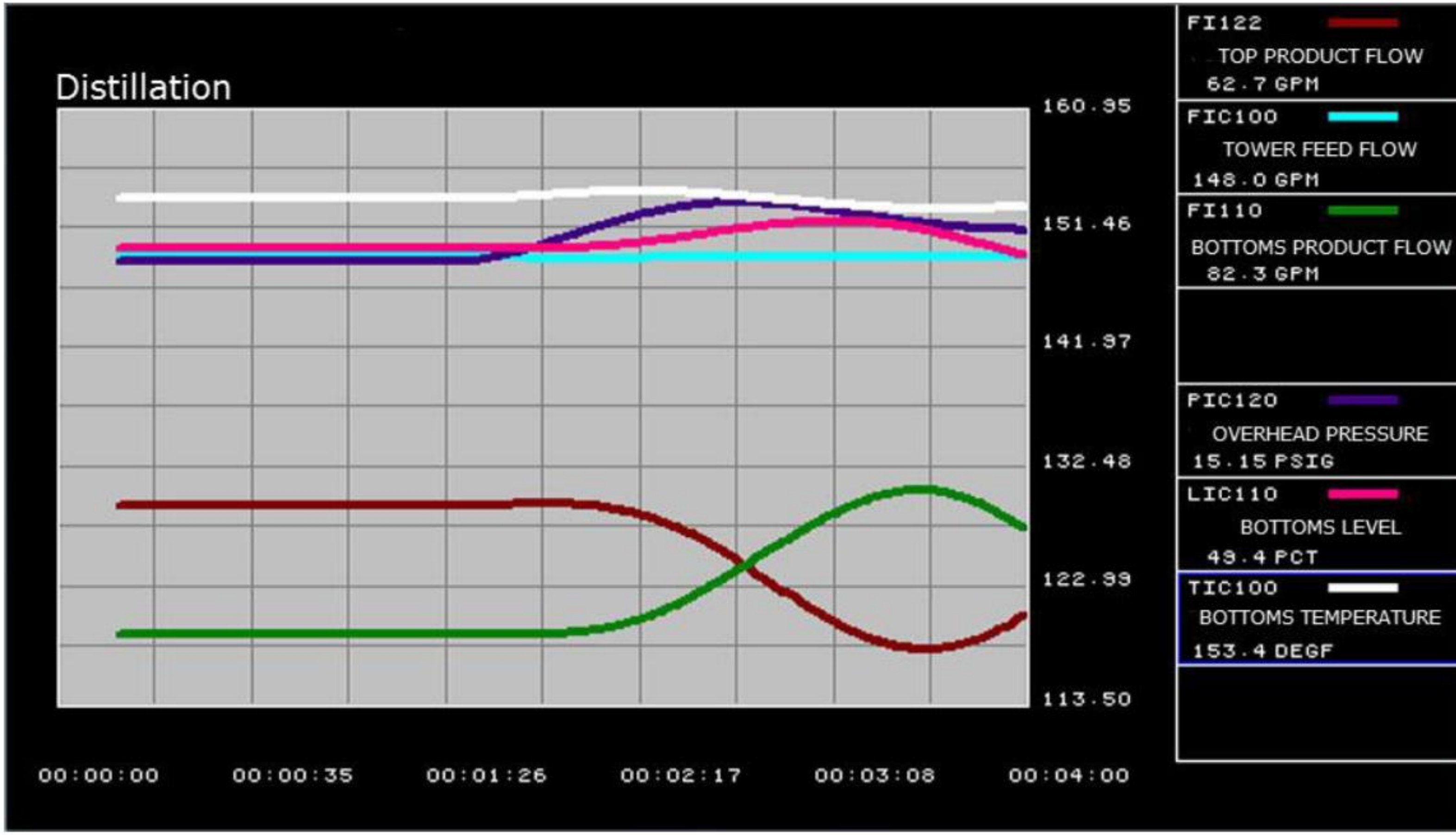
- Four of the Six options are used once, Two of the options are not used.

- This same technique can be used in the Control Room or Classroom with common upsets, past accidents, or near misses.

1. 

Event Choices:

A. HS-127 Failed Closed
B. TIC-100 Setpoint Increase
C. FIC-100 Setpoint Increase
D. Reflux Pump P-120A Failure
E. Reflux Flow FIC-121 Setpoint Increase
F. PIC-120 Setpoint Increase

2. 

Event Choices:

A. HS-127 Failed Closed

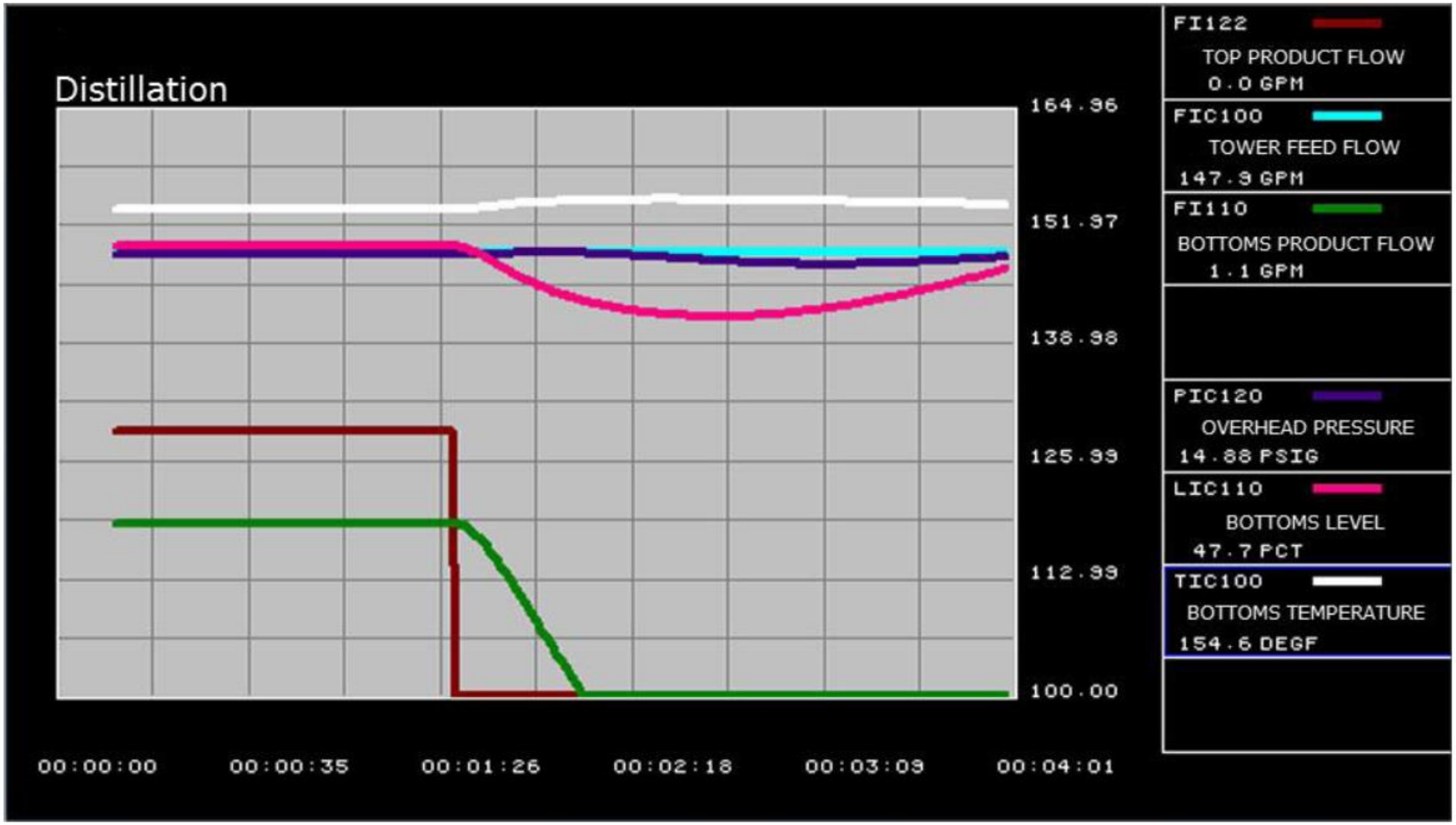
B. TIC-100 Setpoint Increase

C. FIC-100 Setpoint Increase

D. Reflux Pump P-120A Failure

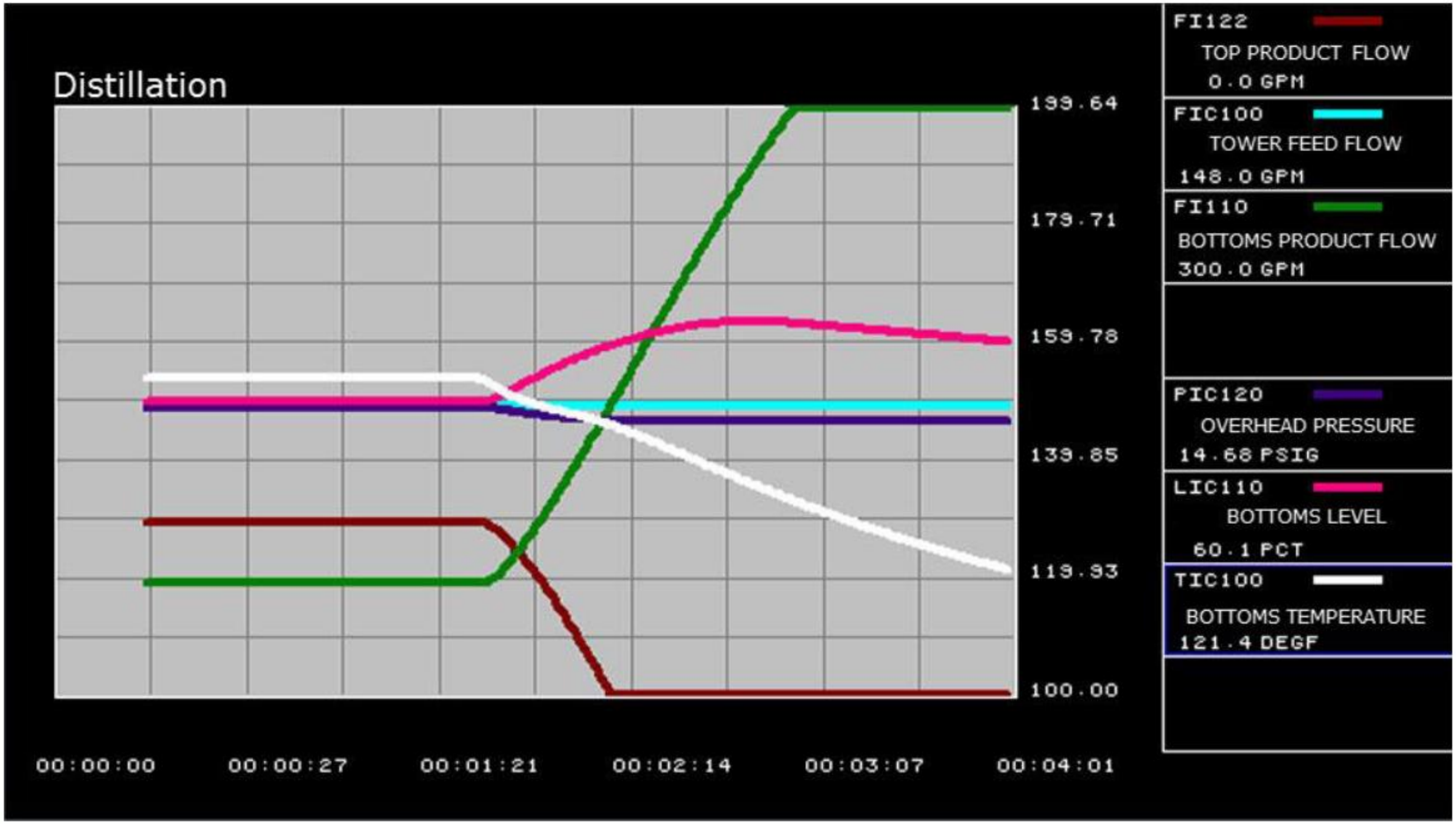
E. Reflux Flow FIC-121 Setpoint Increase

F. PIC-120 Setpoint Increase

3. 

Event Choices:

A. HS-127 Failed Closed
B. TIC-100 Setpoint Increase
C. FIC-100 Setpoint Increase
D. Reflux Pump P-120A Failure
E. Reflux Flow FIC-121 Setpoint Increase
F. PIC-120 Setpoint Increase



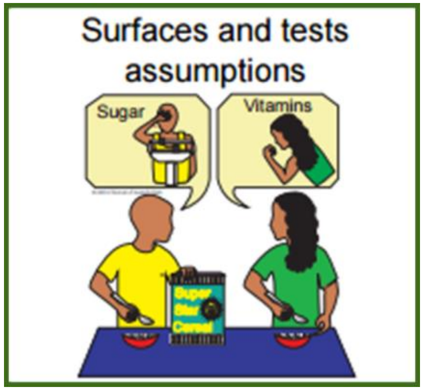
4.

Event Choices:

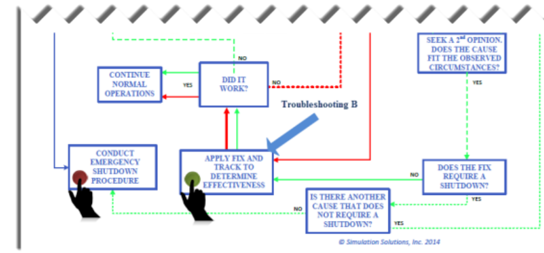
A. HS-127 Failed Closed
B. TIC-100 Setpoint Increase
C. FIC-100 Setpoint Increase
D. Reflux Pump P-120A Failure
E. Reflux Flow FIC-121 Setpoint Increase
F. PIC-120 Setpoint Increase

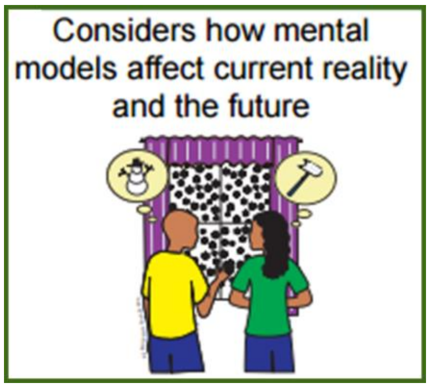
Trend Match Recap

- Look for the first or “sharpest” move of any Instrument on the Trend.
- Choose a potential event that matches that Trend.
- Cross Validate selection by confirming each Instrument on the Trend matches that event.

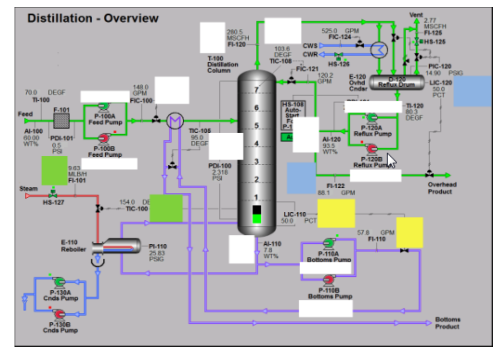


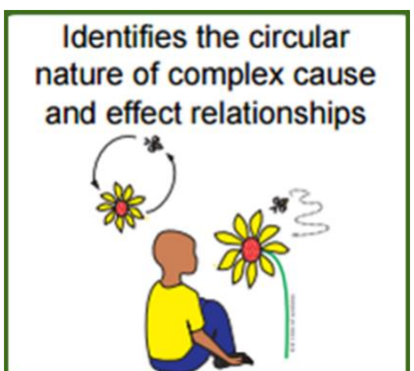
Troubleshooting Guide
“Track Fixes”



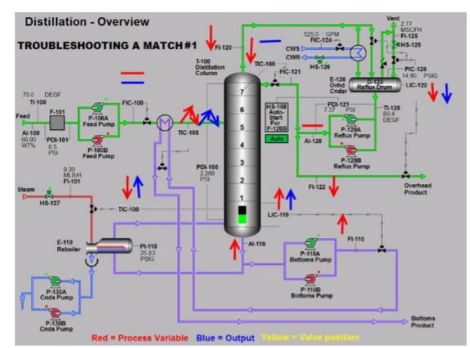


Troubleshooting A
“Groupings”





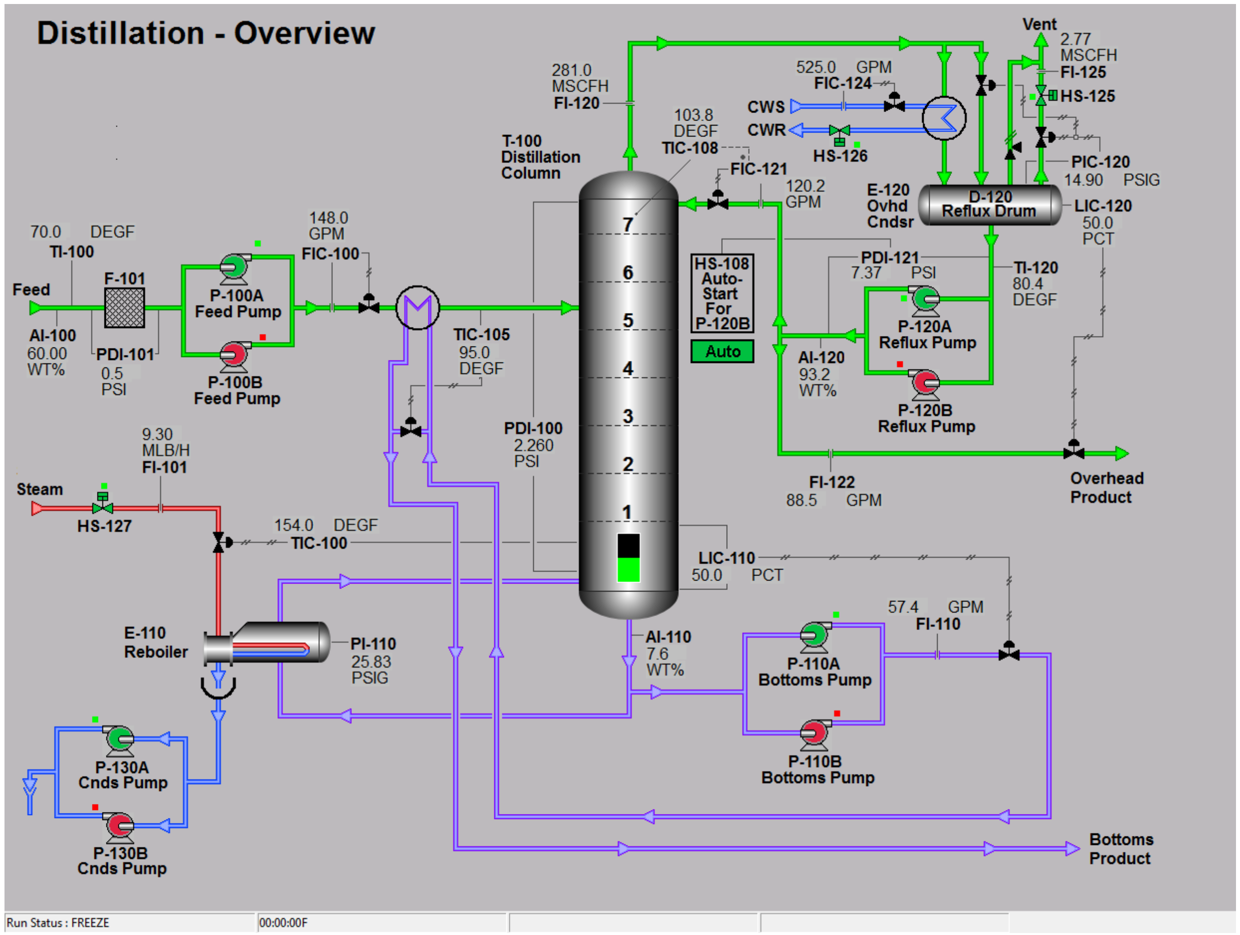
Troubleshooting A
Cause and Effect Match



Circle the Correct Answer:

A. Pump P-120A Fails (no auto-start)
B. Vent Block Valve HV-125 Fails Closed
C. Cooling Water Block Valve HV-126 Fails Closed
D. Reflux Valve FCV-121 Fails Open
E. Pump P-110A Failure
F. Steam Block Valve HV-127 Fails Closed

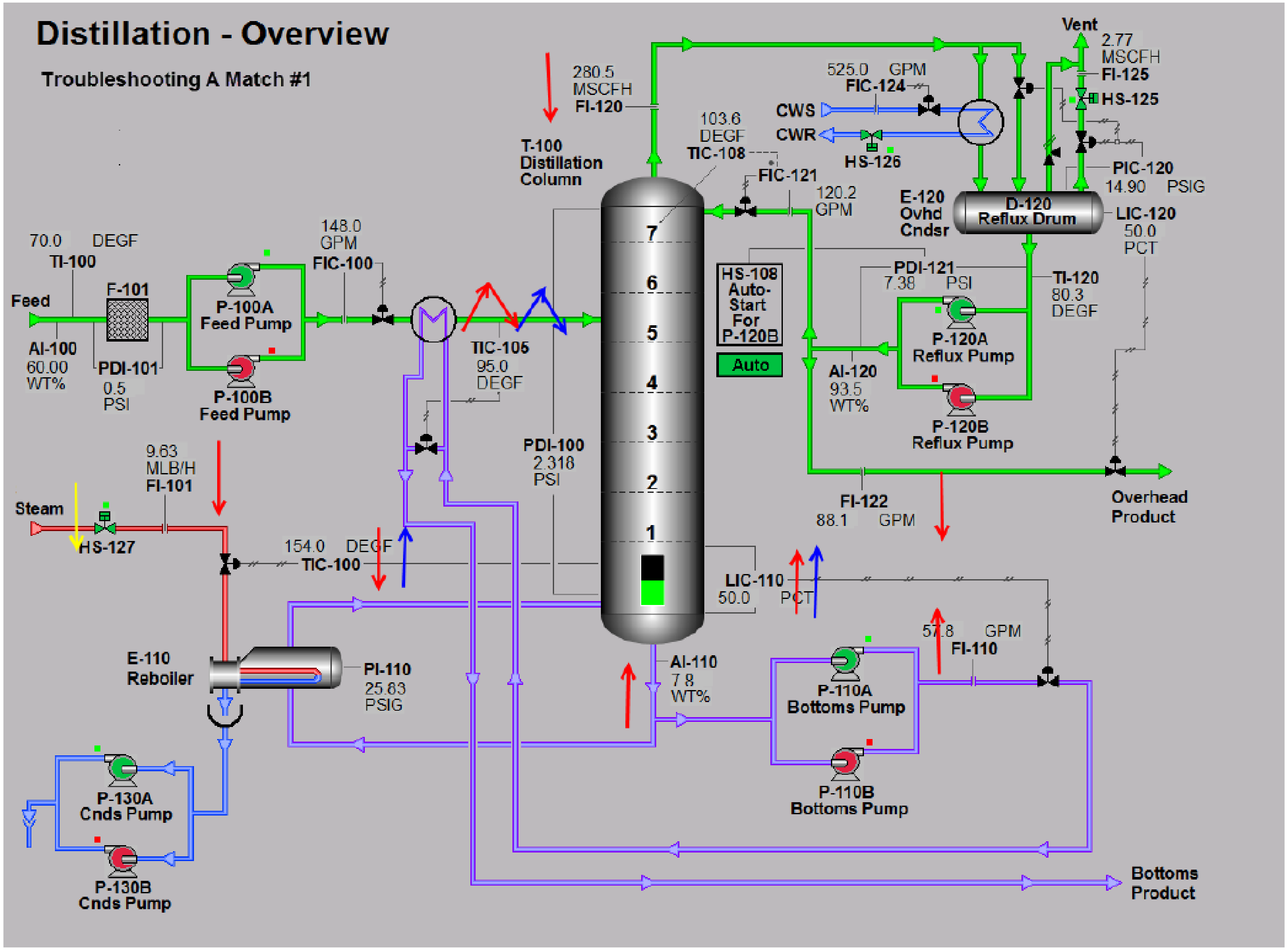
Exercise Agenda



1. Startup Scramble 2. Trend Match **3. Troubleshooting Cause & Effect**

Cause and Effect Match Exercise

- Circle the Event under each Schematic that correlates to the PV and Output Responses in that Schematic
- Four of the Six options are used once, Two of the options are not used
- This same technique can be used in the Control Room or Classroom with common upsets, past accidents, or near misses



Circle the Correct Answer:

A. Pump P-120A Fails (no auto-start)

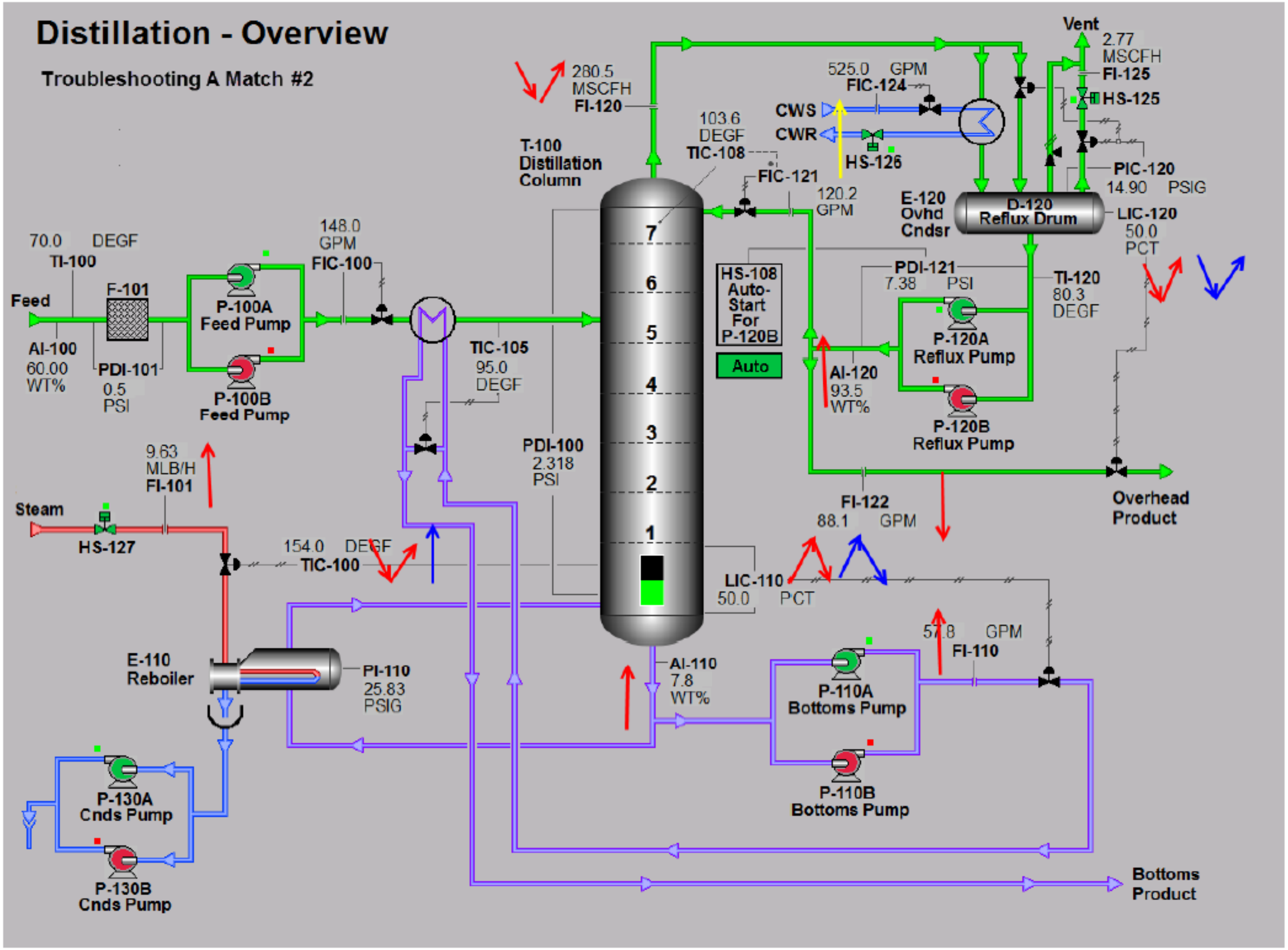
B. Vent Block Valve HV-125 Fails Closed

C. Cooling Water Block Valve HV-126 Fails Closed

D. Reflux Valve FCV-121 Fails Open

E. Pump P-110A Failure

F. Steam Block Valve HV-127 Fails Closed



Circle the Correct Answer:

A. Pump P-120A Fails (no auto-start)

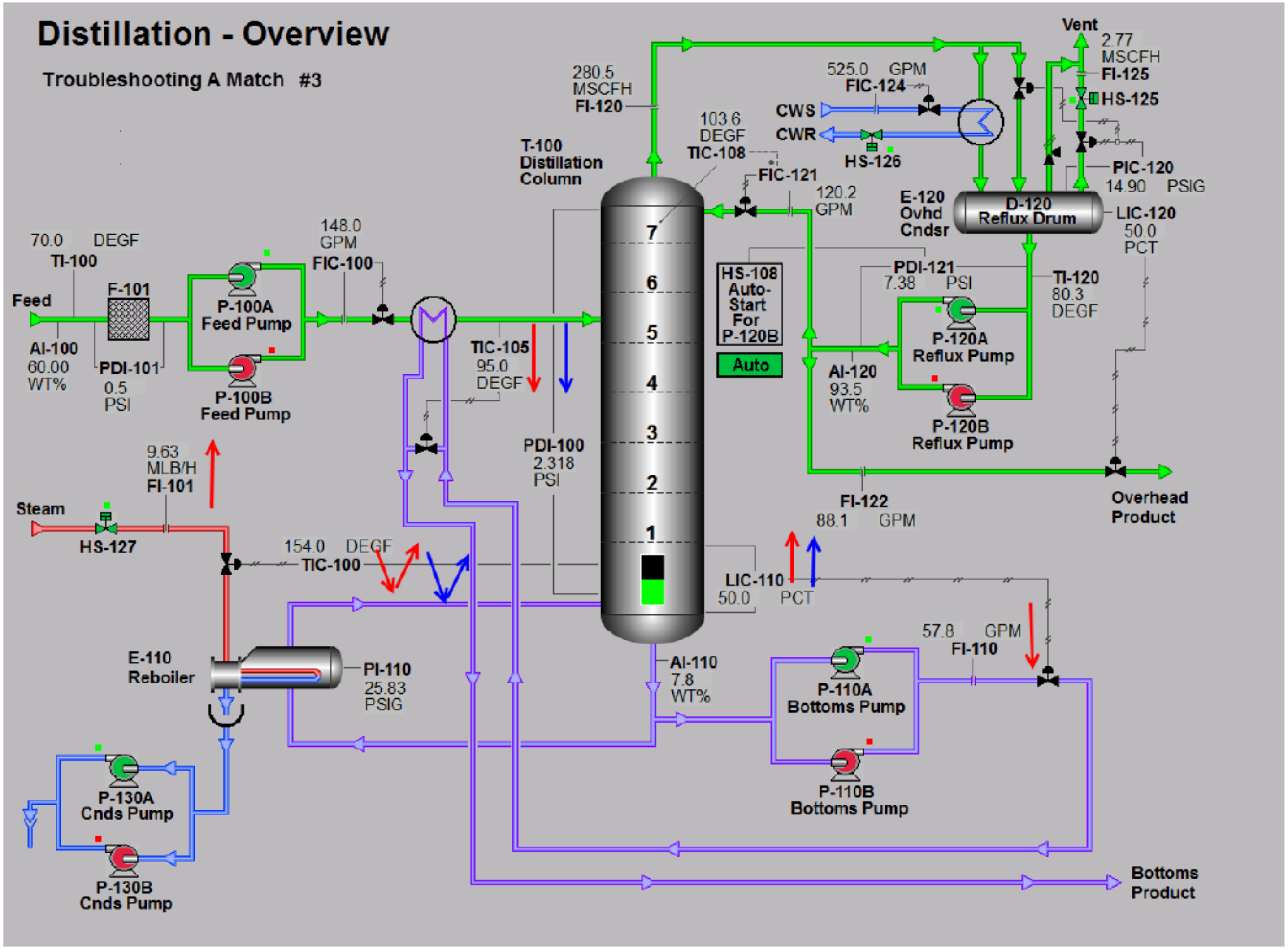
B. Vent Block Valve HV-125 Fails Closed

C. Cooling Water Block Valve HV-126 Fails Closed

D. Reflux Valve FCV-121 Fails Open

E. Pump P-110A Failure

F. Steam Block Valve HV-127 Fails Closed



Circle the Correct Answer:

A. Pump P-120A Fails (no auto-start)

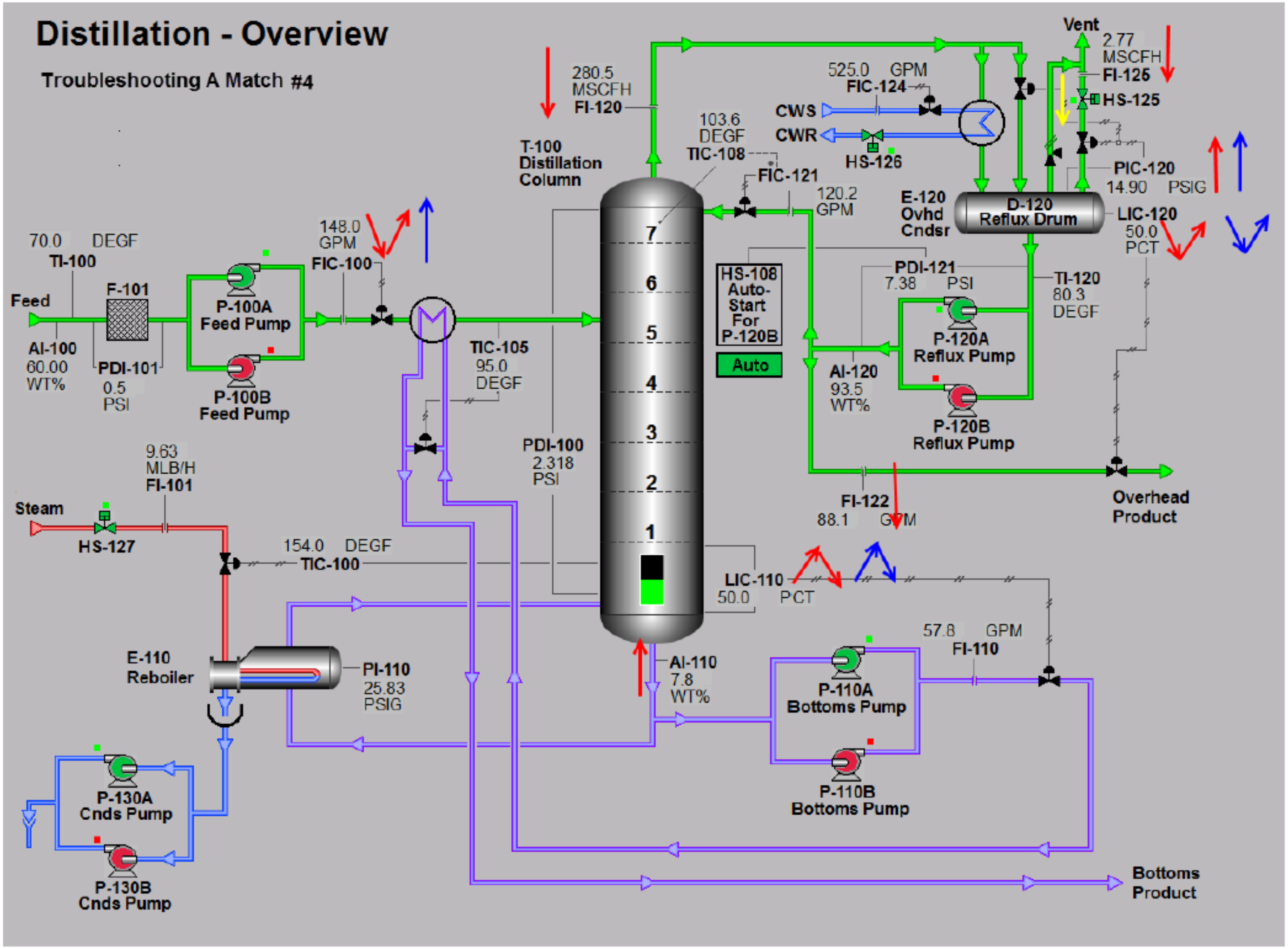
B. Vent Block Valve HV-125 Fails Closed

C. Cooling Water Block Valve HV-126 Fails Closed

D. Reflux Valve FCV-121 Fails Open

E. Pump P-110A Failure

F. Steam Block Valve HV-127 Fails Closed



Circle the Correct Answer:

A. Pump P-120A Fails (no auto-start)

B. Vent Block Valve HV-125 Fails Closed

C. Cooling Water Block Valve HV-126 Fails Closed

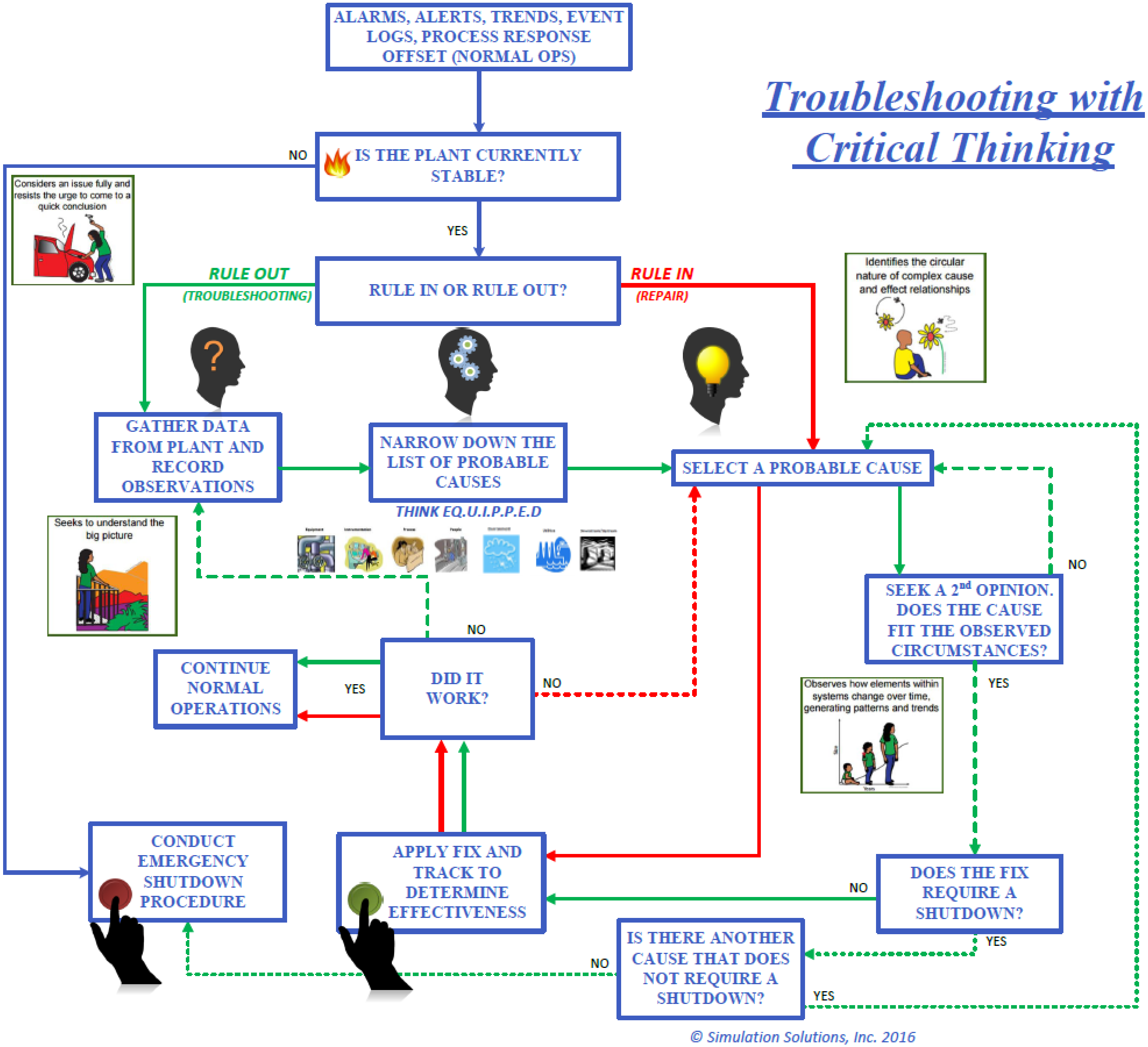
D. Reflux Valve FCV-121 Fails Open

E. Pump P-110A Failure

F. Steam Block Valve HV-127 Fails Closed

Troubleshooting Cause & Effect Match Recap

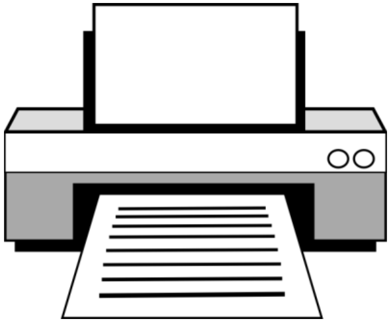
- Look for key disturbances in the plant.
- Check if any Controller PV and Output are incongruent from normal conditions.
- Select a probable event, and cross-validate selection by confirming each Instrument on the schematic matches the event.



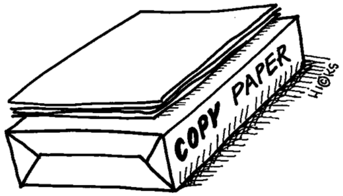
Troubleshooting with Critical Thinking
ALARMS, ALERTS, TRENDS, EVENT LOGS, PROCESS RESPONSE OFFSET (NORMAL OPS)
IS THE PLANT CURRENTLY STABLE?
NO
YES
Considers an issue fully and resists the urge to come to a quick conclusion
RULE OUT (TROUBLESHOOTING)
RULE IN OR RULE OUT?
RULE IN (REPAIR)
Identifies the circular nature of complex cause and effect relationships
GATHER DATA FROM PLANT AND RECORD OBSERVATIONS
NARROW DOWN THE LIST OF PROBABLE CAUSES
THINK EQ.U.I.P.P.E.D
SELECT A PROBABLE CAUSE
Seeks to understand the big picture
SEEK A 2nd OPINION. DOES THE CAUSE FIT THE OBSERVED CIRCUMSTANCES?
NO
YES
NO
CONTINUE NORMAL OPERATIONS
YES
DID IT WORK?
NO
Observes how elements within systems change over time, generating patterns and trends
CONDUCT EMERGENCY SHUTDOWN PROCEDURE
APPLY FIX AND TRACK TO DETERMINE EFFECTIVENESS
DOES THE FIX REQUIRE A SHUTDOWN?
NO
YES
IS THERE ANOTHER CAUSE THAT DOES NOT REQUIRE A SHUTDOWN?
NO
YES
© Simulation Solutions, Inc. 2016

Using Control Room Resources to Create “Paper & Pencil” Exercises

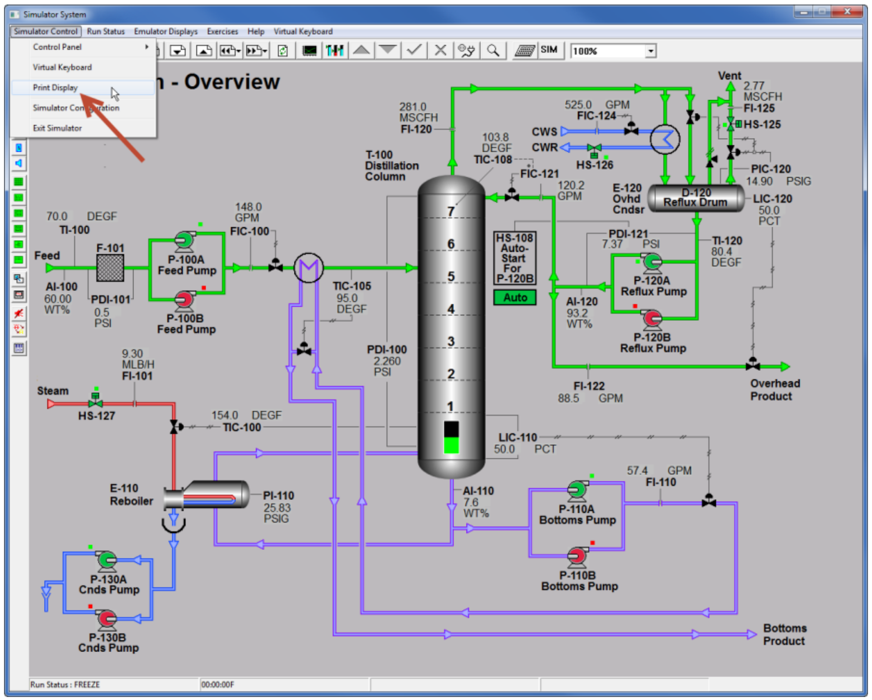
+

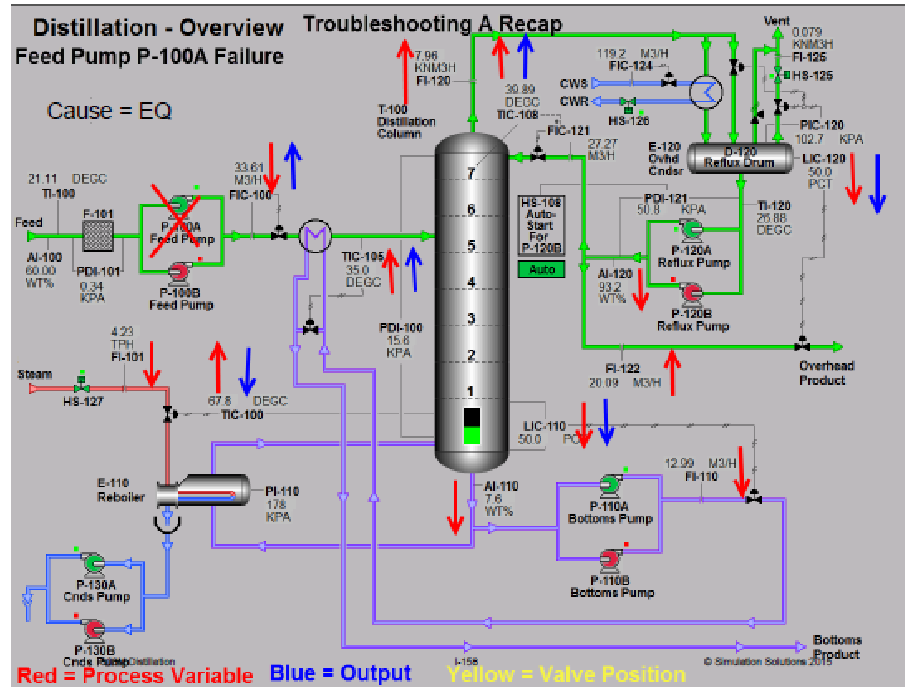


+



“What-If” and “Troubleshooting A”





Print DCS Screen.

→

Q: What If you make a process change, or a certain piece of equipment fails?

→

Operator Draws Arrows predicting Controller Responses.

→

Supervisor reviews answers.

Startup, Shutdown, and Troubleshooting B Scrambles

START UP SCRAMBLE **DISTILLATION**

Directions: Arrange the Startup Procedure in the correct order.

A. Establish vapor flow

B. Start reflux flow

C. Start steam flow

D. Start feed flow

E. Start cooling water

F. Establish a base level

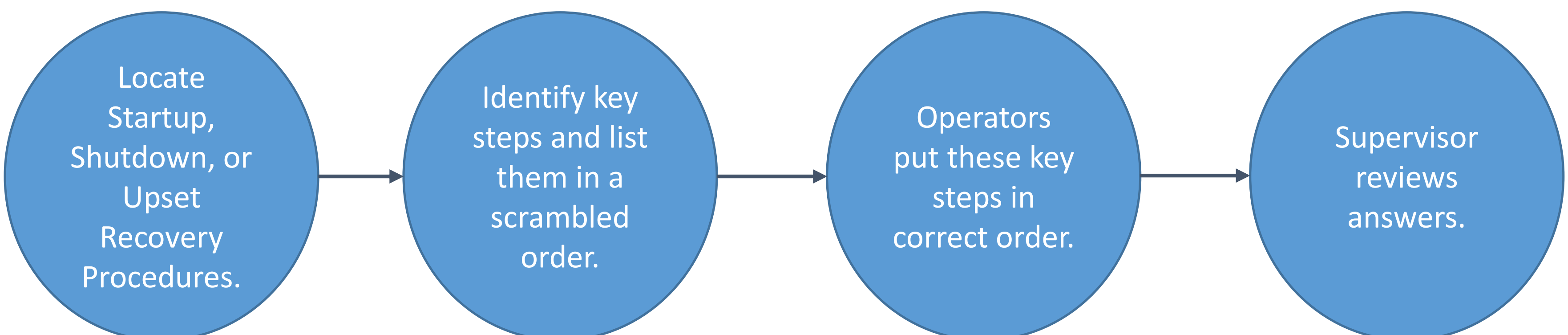
G. Establish top Pressure control

H. Take off bottoms product

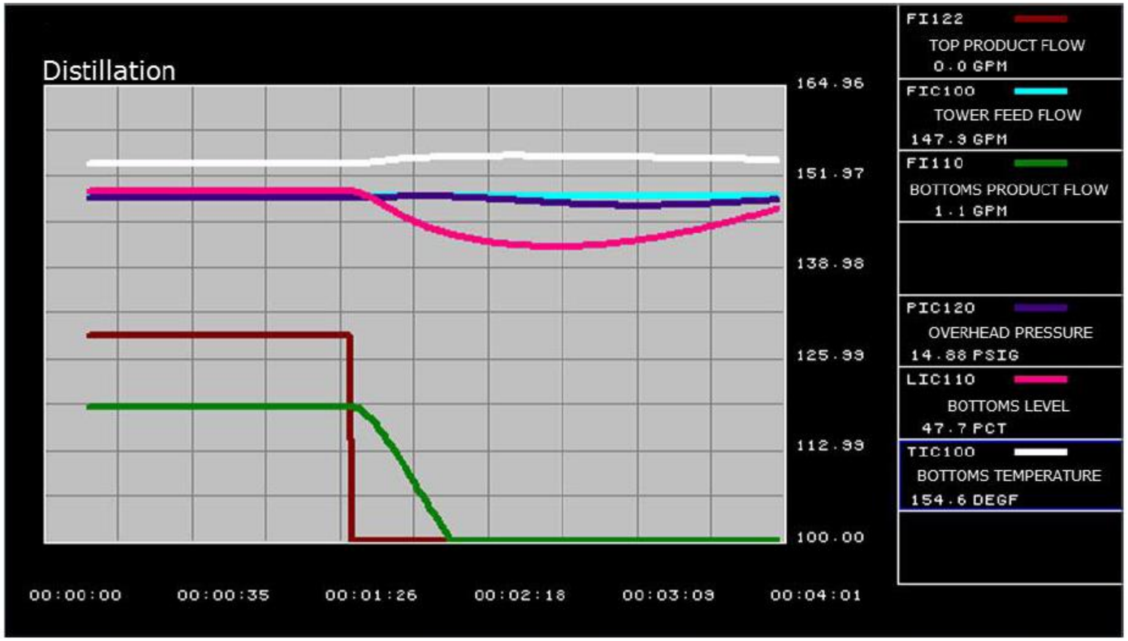
I. Establish reflux drum level

J. Take off top product

K. Open vent valve



Trend Match



3.

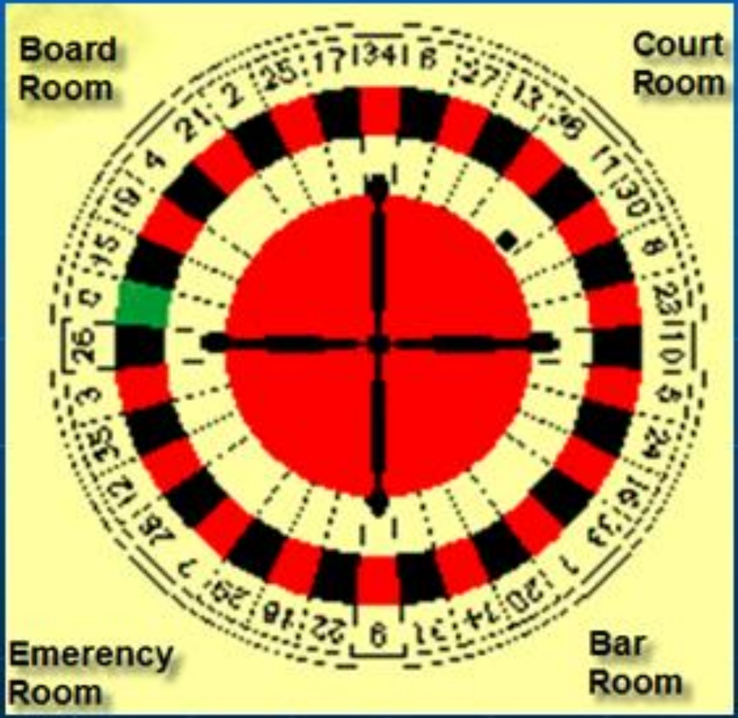
Event Choices:

A. HS-127 Failed Closed
B. TIC-100 Setpoint Increase
C. FIC-100 Setpoint Increase
D. Reflux Pump P-120A Failure
E. Reflux Flow FIC-121 Setpoint Increase
F. PIC-120 Setpoint Increase

Print trend windows for 4 Different Events → Include an Answer Bank below each trend. → Operator matches each trend to the correlating event. → Supervisor reviews answers.

Refining Industry Challenges…If not resolved….

- Increased plant accidents
- Loss of production
- Downgrade of product and/or re-run
- Increase in releases and equipment damage damage
- Employee turnover and low morale leading to poor performance



References

- *The Changing Role of the Operator: Engaging and Supporting the Operator of Today Into the Future with Advanced Software Capabilities,* General Electric®, 2010.

- *Improving the Operator's Capabilities During Abnormal Operations,* Kenneth F. Emigholz, Exxon®, 1995.

- *Saved by the Bell: Using Alarm Management to make Your Plant Safer,* Exida®, 2009.

Thank you!

Donald C. Glaser
dglaser@simulation-solutions.com

Simulation Solutions, Inc.
Shrewsbury, NJ 07702
www.simulation-solutions.com

732-389-5400