COOLING TOWER TROUBLESHOOTING MODULE
INSTRUCTOR LESSON PLAN

Overview

Cooling water is supplied to many process units as a means of lowering the temperature of a process gas or liquid for further processing. In the process, the temperature of the cooling water increases. The heated water returns to the cooling tower where the process of evaporation leads to release of heat from the cooling water. The heat is discharged to the atmosphere. Because of their criticality within the process industries, the process technician must have a basic understanding of troubleshooting techniques to recognize and prevent cooling tower inefficiency.

Competency	Performance Standards
Troubleshoot problems with a cooling tower	Performance will be satisfactory when: ☐ Learner recognizes the problem and captures the problem in written form. ☐ Learner evaluates HSE risks involved with continued operation. ☐ Learner recognizes when the HSE hazard/s warrants shutting down equipment. ☐ Learner collects and analyzes data associated with the problem. ☐ Learner rewords problem based on initial observations and reasoning. ☐ Learner identifies possible causes of the problem. ☐ Learner selects most probable cause of the problem, one that explains every observation. ☐ Learner proposes corrective action that is rational and eliminates true cause (when possible). ☐ Learner accurately and completely documents problem and corrective action(s). ☐ Process equipment is stabilized (if simulator-based problem). ☐ System is returned to within $\pm$ 5% of design parameters (if simulator-based problem).
	Conditions: Given a paper-based (P&ID) and/or simulator-based problem, competence will be demonstrated by the completion of troubleshooting steps and subsequent documentation.

Learning Objectives

1. Recall the purpose and types of cooling towers.
2. Recall and discuss problems associated with cooling towers.
3. Describe immediate actions a process technician could take to solve a problem with a cooling tower.
4. Explain the relationship between variables for a specific process under normal operating conditions.
5. Given normal and abnormal operating conditions for a specific process:
   - Recognize the problem.
   - Collect and analyze data associated with the problem.
   - Define the problem.
   - Identify possible causes and the most probable cause of the problem.
   - Evaluate the effect of investigative, compensating and corrective actions.
   - Select an appropriate corrective action.
   - Document the problem and corrective action.

Learning Activities

Time Frame	Learning Activity	Teaching Activity	Instructional Materials	Supplies and Equipment	Notes
	PREVIEW learning objectives and performance standards for this competency.		Learning Plan		
	READ information provided in the Introduction section.		Learning Plan		
	LISTEN to the lecture on the purpose, types of, and problems associated with cooling towers (if provided).	Deliver a brief presentation on towers and associated problems.		Lecture Equipment	Address first two learning objectives.
	REVIEW the process flow, product specifications, equipment specifications, normal operating conditions, and normal design conditions sections for the specified process.	Choose a specific problem/s for learners to solve. Lead discussion of process to assure learners understand all aspects.	Process Description		
	COMPLETE the Self-Check Questions worksheet.	Introduce activity. Review worksheet with learners after completion.	Self-Check Questions worksheet		Reinforce learning objectives 1, 2, and 4.
	BRAINSTORM immediate actions a process technician could take to solve cooling tower problems with a small group of your peers.	Divide learners into groups of 3 to 4. Introduce activity.			
	COMPARE your list of immediate actions for solving cooling tower problems to another group's work.	Write all actions on board or flipchart.			
	LISTEN to instructor expand on actions a process technician could take to solve cooling tower problems.	Lecture on actions not captured and expand on those listed.		Lecture Equipment	Address the third learning objective.

	SOLVE at least one paper-based cooling tower problem including the completion of the Troubleshooting Form.	Choose a specific problem/s for learners to solve. Guide learners as needed during the activity. Do a quick de-brief after activity.	Problem Packet		Information for three Scenarios has been provided for students. Address learning objective 5.
	OBSERVE a normal and/or abnormal condition on the simulator associated with a cooling tower (if simulator is available).	Set up simulation. Guide learners as needed during the activity.		Simulator	
	SOLVE at least one simulator-based cooling tower problem including the completion of the Troubleshooting Form (if simulator is available).	Create a problem/s for learners to solve. Program fault for simulator-based problem. Guide learners as needed during the activity. Do a quick de-brief after activity.	Troubleshooting Form	Simulator	Scenario #1 can also be programmed as a simulator-based exercise. Address learning objective 5.

NOTE: Several websites provide a humidity calculator.

Humidity Calculator

http://bit.ly/WHYkuE

COOLING TOWER TROUBLESHOOTING MODULE
PROCESS DESCRIPTION

Introduction

Cooling water is supplied to many process units as a means of lowering the temperature of a process gas or liquid for further processing. The water is delivered from a cooling tower via supply header to the support side (either tube or shell) of an exchanger in the process area. The circulation of cooling water decreases the temperature of the process fluid and increases the temperature of the cooling water. The heated water returns to the cooling tower via return header where the process of evaporation leads to release of heat from the cooling water. The heat is discharged to the atmosphere.

Cooling towers are classified in a variety of ways—by physical shape, by build, by heat transfer method, by manner of contact between the air and water, by air flow patterns, and by air draft. “Natural-draft cooling towers use the buoyancy of the exhaust air rising in a tall chimney to provide the draft. Mechanical-draft cooling towers rely on power-driven fans to draw or force the air through the tower” (Cooling Technology Institute, 2013).

A number of problems can occur with cooling towers that the process technician may need to address while working within a process unit. Potential problems include high cooling water temperatures, low cooling water supply pressure, and decrease in efficiency.

High cooling water temperature and a subsequent decrease in efficiency may result from equipment failure such as pump or fan malfunction. More often, poor water quality contributes to an increase in water temperature through foaming, scale formation, corrosion, fouling, and biological activity (U.S. Department of Energy, 2013) (Whitfields, 2010).

Additional factors affecting cooling tower efficiency include:

- Ambient temperature increase that exceeds tower design
- Humidity of the air, which affects wet-bulb temperature
- Amount of water surface area available
- Air flow rates through the unit
- High drift rate/high evaporation rate
- Pressure drop across the drift eliminators
- Blowdown rate—incorrect blowdown rate could lead to buildup of solids in the cool water basin and possibly fouling and corrosion of process equipment
- Design changes to process unit/s serviced by cooling tower
- Design changes to cooling tower equipment (e.g., changes to pump and fan design)
- Engineering design (e.g., heat load, range, and approach; configuration of air, and water flows)

In the short term, these problems can create a situation where feed rates are reduced and/or product is lost. If experiencing low cooling water temperature, mechanical integrity may be impacted. If uncorrected, plant shutdown may result.

Process Background

NOTE: This process background description and equipment specifications are specific to the Cooling Tower schematics shown in Figure 1 and Figure 2 and provided courtesy of Simtronics Corporation.

Cooled water is collected in a basin at the bottom of the cooling tower and is pumped to a supply header, which feeds the three process heat exchangers (Figure 1 and Figure 2). The cooling water picks up heat from the process heat exchangers by heat transfer across the surface of metal tubes in shell-and-tube heat exchangers. Warm water from the heat exchangers is collected in a return header and is routed to the top of the cooling tower. The warm return water falls to the basin and is cooled by contact with air drawn through the tower by a motor-driven fan on top of the cooling tower. The internal packing in the cooling tower maximizes contact between the air and the water to ensure maximum heat exchange. Also, evaporation of a portion of the return water occurs in the cooling tower.

Equipment Specifications

The cooling system consists of the cooling tower (CT-101), two cooling water pumps (P-101A and P-101B), and three process heat exchangers (E-201, E-211, and E-221) of varying heat removal capacities.

Cooling Tower – Warm cooling water is returned from the process heat exchangers via the return header and is routed to the top of the cooling tower CT-101 via a hand valve controlled by HIC-103. The warm water is split equally and sent to opposite sides of the same cell of the cooling tower.

Within each cell, falling warm water is contacted with air drawn into the cell by a motor-driven fan located at the top of the tower. When air is drawn in along the outside of each cell the contacting method is known as *cross-flow*. In a cross-flow tower, adjustable louvers are usually installed to allow control of the air flow into the tower. A hand controller, HIC-108, allows adjustment of the louvers' position on the simulator. Only one cell is simulated.

Cooling Water Pumps – The cooling water pumps P-101A and P-101B are identical electric motor-driven centrifugal pumps with a design capacity of 200 GPM at 55 PSIG. Normally only one pump is in operation. The pumps take suction from the basin of the cooling tower CT-101 and deliver cooling water to the three process exchangers via a supply header. The flow of the cooling water to each of the three heat exchangers is regulated by individual temperature controllers on the process streams.

The cooling water supply header pressure is controlled to 50 PSIG by returning a portion of the cooling water back to the cooling tower CT-101. Keeping the supply pressure constant minimizes cooling water flow disturbances to the process heat exchangers. Also, a line is provided off the supply header for sending blowdown water to disposal facilities as needed.

Cooling Water Filter Circuit – The cooling water filter circuit consists of the cooling water filter pump P-102 and the cooling water filter F-101. The circuit circulates water from the basin of the cooling tower through the filter to remove any solids that are suspended in the cooling water. The filtered water is returned to the basin. This ensures that fouling of the cooling tower basin and the process heat exchangers is minimized. P-102 normally circulates 50 GPM of water. The pressure drop across F-101 is approximately 5 PSIG when clean.

Process Heat Exchangers – There are three identically instrumented process heat exchangers that use cooling water to remove heat: E-201, E-211 and E-221. The exchangers are shell-and-tube design with the process flow through the tubes and the cooling water flow through the shell side. The cooling water is taken from the supply header.

Process flow through each of the exchangers is controlled by a flow controller. The process outlet temperature from each heat exchanger is controlled by adjusting the cooling water flow through the heat exchanger. Each of the cooling water valves has a mechanical minimum stop of 10% so that there is always a minimum flow of cooling water through the heat exchanger. This is done to help avoid boiling the cooling water should the process inlet temperature be very high and the cooling water valve is closed for some reason (e.g., positioner failure, poor operation).

The warm cooling water from each heat exchanger is collected by the return header and then routed back to the cooling tower. The return water is normally sent to the top of the cooling tower, but any portion of the return water can also be routed to the basin of the cooling tower if desired (e.g., to regulate the supply temperature in very cold weather).

The return header normally operates at 24 PSIG and 107°F. Normally, all of the return water is returned to the top of the cooling tower with HIC-103 fully open and the basin valve HIC-102 fully closed.

Basic Controls: Cooling Tower – There are no special controls in the cooling tower process. All controllers are single loop configurations.

The flow rate of makeup water to the cooling tower's basin is controlled by FIC-104. The temperature of the makeup water is assumed to be the same as ambient conditions. The level of the cooling tower's basin is indicated on LI-101.

The filtration system flow is indicated on FI-102 and the filter pressure drop is indicated on PDI-103.

Acid solution flow is controlled by FIC-105 and base solution flow is controlled by FIC-106. These solutions are added to the filtration system's return line to the basin. When adding these chemicals, the filter system should be in operation to avoid locally high/low pH situations in the return line.

The supply header pressure is controlled by PIC-101, which sends excess cooling water pumped by P-101A/P101-B back to the cooling tower. The setpoint is normally 50 PSIG. The total flow of cooling water sent to the supply header is indicated on FI-101 and the temperature of the supply water is indicated on TI-101.

Blowdown is taken off the discharge of the cooling water pumps P-101A and P-101B and controlled by FIC-107.

The return header pressure is indicated on PI-102 and the return water temperature is indicated on TI-102. Return water is directed to the top of the cooling tower with HIC-103 or to the basin with HIC-102.

The opening position of the louvers of the cooling tower is adjusted with HIC-108. Maximum air flow is at 100% output. At 0% output, air flow will be at a minimum but will be non-zero to avoid starving the cooling tower's fan. HIC-108 is used to adjust the cooling water supply temperature. However, in very cold weather regulation of the supply temperature to a desired value may not be possible. In this case, some of the return cooling water can be bypassed around the cooling tower by opening HIC-102.

Basic Control: Process Heat Exchangers – All three process heat exchangers, E-201, E-211 and E-221, are identically instrumented as follows:

- FIC-201, FIC-211, and FIC-221 control the process flows through the tube side of the respective heat exchangers.
- TIC-202, TI-212, and TI-222 control the process outlet temperatures by adjusting the cooling water control valve. Note that these vales have a mechanical minimum stop of 10% opening.
- Cooling water flow rates are indicated on FI-202, FIC-212, and FIC-222.
- Process inlet temperatures are indicated on TI-201, TI-211, and TI-221.
- Cooling water outlet temperatures are indicated on TI-203, TI-213, and TI-223.

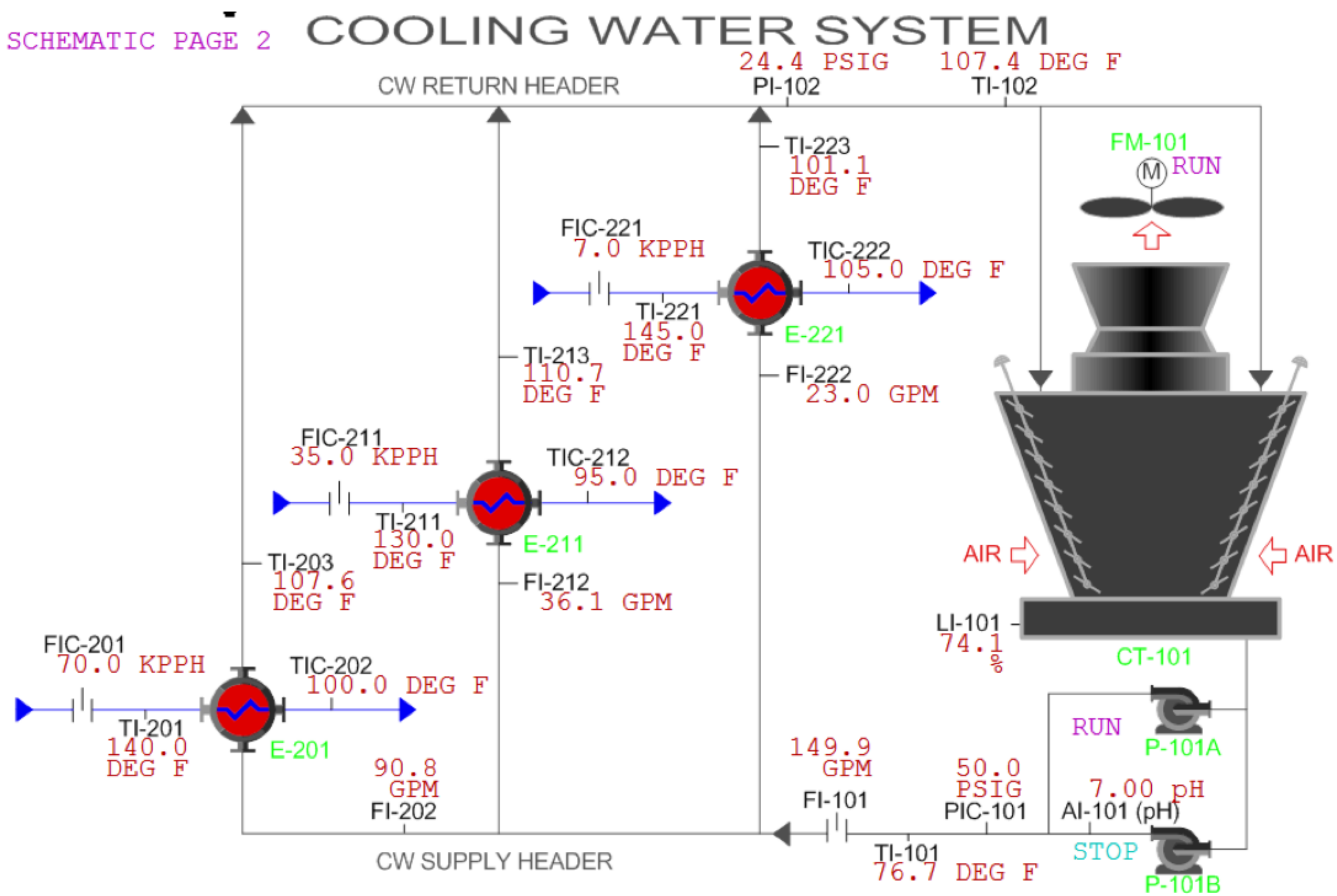

Figure 1. **Cooling Tower Schematic**

Courtesy of Simtronics Corporation

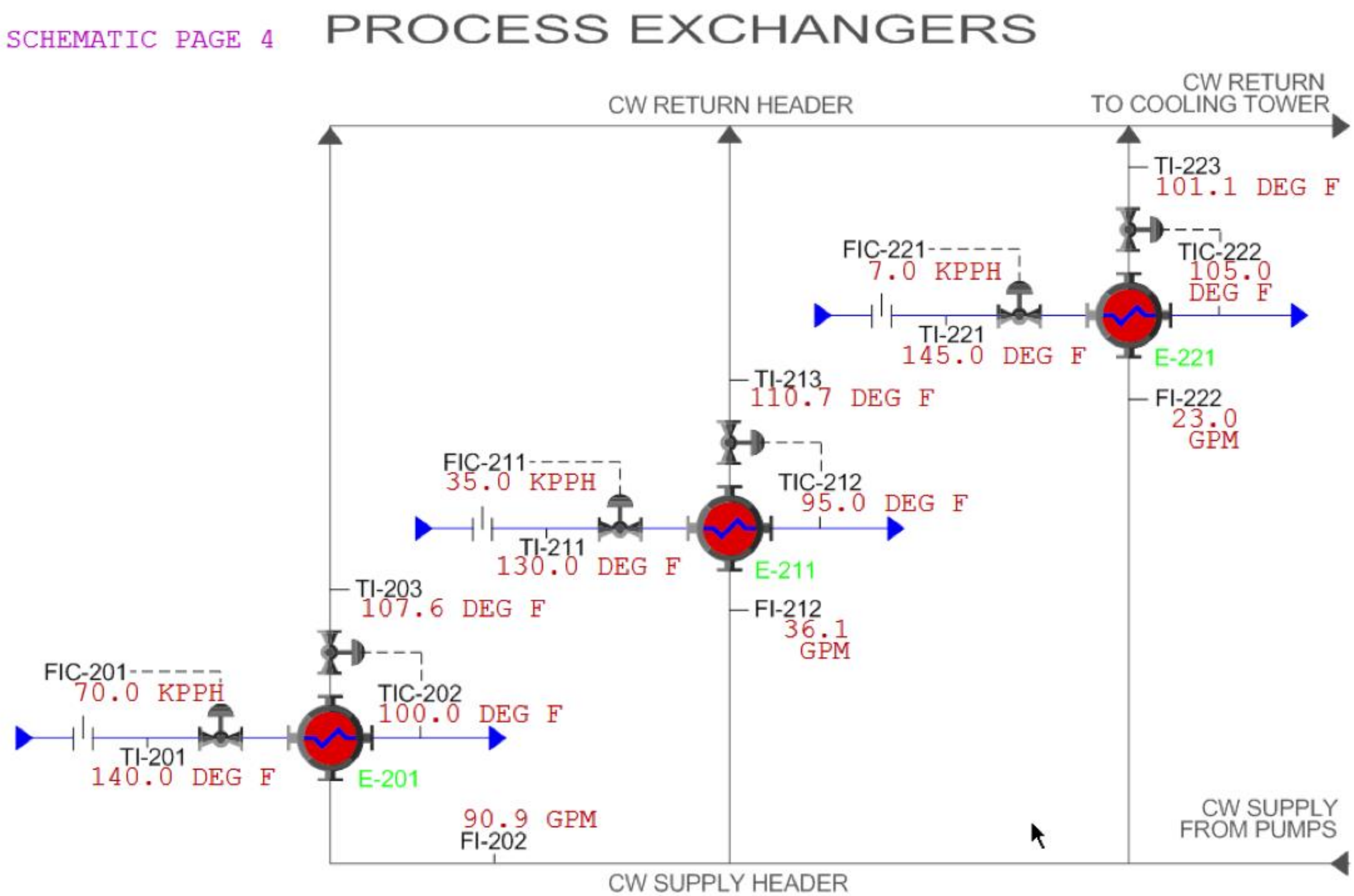

Figure 2. **Process Exchangers Schematic**

Courtesy of Simtronics Corporation

Normal Design Conditions

The warm circulating water returns at approximately 24 PSIG and 107°F under normal operation. The total water circulation flow is normally 150 GPM. Ambient temperature is normally 68°F and its dew point is 60°F. Water from the cooling tower basin is approximately 77°F. Makeup water is added at 3.5 GPM to offset losses. Normal pH is 7.0. The pH of the makeup acid is 4.0; the pH of the makeup base is 10.0.

The following table provides a list of the normal design conditions associated with the specified process.

Table 1. Design Values and Output Percentages for Instrumentation and Equipment at Normal Operating Conditions

Courtesy of Simtronics Corporation

Tag ID	Description	Design Value	Eng. Units	Output Percent
AI-101	SUPPLY pH	7.0	pH	
FI-101	SUPPLY FLOW	149.9	GPM	
FI-102	FILTER FLOW	50.1	GPM	
FI-202	E-201 CW FLOW	90.9	GPM	
FI-212	E-211 CW FLOW	36.1	GPM	
FI-222	E-221 CW FLOW	23.0	GPM	
FIC-104	MAKEUP WATER FLOW	3.5	GPM	27.0
FIC-105	ACID SOLUTION FLOW	0.0	GPM	0.0
FIC-106	BASE SOLUTION FLOW	0.0	GPM	0.0
FIC-107	BLOWDOWN FLOW TO DISP	0.0	GPM	0.0
FIC-201	E-201 PROCESS FLOW	70.0	KPPH	70.0
FIC-211	E-211 PROCESS FLOW	35.0	KPPH	65.0
FIC-221	E-221 PROCESS FLOW	7.0	KPPH	60.0
FM-101	FAN AIR	ON		
HIC-102	BASIN VALVE	0.0	%	0.0
HIC-103	TOWER VALVE	100.0	%	100.0
HIC-108	LOUVER TOWER AIR	50.0	%	50.0
LI-101	BASIN LEVEL	74.1	%	
P-101A	CW CIRC PUMP A	ON		
P-101B	CW CIRC PUMP B	OFF		
P-102	FILTER PUMP	ON		
PDI-103	FILTER PRESSURE	5.2	PSI	
PI-102	RETURN HEADER PRESSURE	24.4	PSIG	
PIC-101	SUPPLY HEADER PRESSURE	50.0	PSIG	68.0
TI-101	SUPPLY HEADER TEMPERATURE	76.7	DEG F	
TI-102	RETURN HEADER TEMPERATURE	107.4	DEG F	

Tag ID	Description	Design Value	Eng. Units	Output Percent
TI-103	AMBIENT TEMPERATURE	68.0	DEG F	
TI-104	DEWPOINT TEMPERATURE	60.0	DEG F	
TI-201	E-201 PROCESS INLET TEMPERATURE	140.0	DEG F	
TI-203	E-201 CW OUTLET TEMPERATURE	107.6	DEG F	
TI-211	E-211 PROCESS INLET TEMPERATURE	130.0	DEG F	
TI-213	E-211 CW OUTLET TEMPERATURE	110.7	DEG F	
TI-221	E-221 PROCESS INLET TEMPERATURE	145.0	DEG F	
TI-223	E-221 CW OUTLET TEMPERATURE	101.1	DEG F	
TIC-202	E-201 PROCESS OUT TEMPERATURE	100.0	DEG F	73.8
TIC-212	E-211 PROCESS OUT TEMPERATURE	95.0	DEG F	75.9
TIC-222	E-221 PROCESS OUT TEMPERATURE	105.0	DEG F	75.8

Cooling Tower Troubleshooting Module
Self-Check Questions

1. Does the cooling tower in Figure 1 have an induced or forced draft fan?

   Induced

2. Figure the delta (Δ) temperature of the cooling water across the tower.

   $\Delta T = (TI\text{-}102) - (TI\text{-}101)$

   $\Delta T = 107.4°F - 76.7°F$

   $\Delta T =$ ***30.5°F***

3. What happens to TI-203 if TI-101 increases?

   a. Increases
   b. Decreases
   c. Stays the same

4. If PIC-101 increases, what happens to PCV-101 output?

   a. Increases – opens valve
   b. Decreases – closes valve
   c. Stays the same

5. If PDI-103 goes into alarm, what happens to FI-102?

   a. Increases
   b. Decreases
   c. Stays the same

6. If FIC-106 decreases, what happens to AI-101?

   a. Increases
   b. Decreases
   c. Stays the same

7. If FIC-107 decreases, what happens to TI-101?

   a. Increases
   b. Decreases
   c. Stays the same

8. If AI-101 increases, which flow should increase?

   a. FIC-104
   b. FIC-105
   c. FIC-106

9. If FM-101 stops, what happens to the air flow?

   a. Increases
   b. Decreases
   c. Stays the same

10. If LI-101 decreases, what happens to FIC-104?

    a. Increases
    b. Decreases
    c. Stays the same

11. If HIC-108 increases, what happens to the air flow?

    a. Increases
    b. Decreases
    c. Stays the same

Cooling Tower Troubleshooting Module
Scenario #1 (Paper or Simulator-based)

Scenario Statement

On July 22nd, the shift supervisor calls from the plant to inquire if there are problems at the cooling tower. It is 4:00 PM in the afternoon and the weather is clear with 94% humidity. The reading on the cooling water inlet supply line at the plant battery limit has increased from 77 to 89°F. Inter-stage and discharge coolers on the compressors in the plant are having trouble with higher discharge pressures on several stages. Flaring could be imminent. Upon investigation, no mechanical problems were found.

Troubleshoot this situation, listing investigative, compensating, and corrective actions on the Troubleshooting Form.

Simulator Programming

The following table includes information needed for you to program the fault for a pump cavitation simulation exercise. The fault has been written for use with Simtronics Corporations' SPM-1010 cooling tower model.

A discussion of fault/s and fault parameters begins on page 70 of Simtronics Corporation's Instructor and Standard DSS-100 User's Guide, Version 6.2. Instructions for creating a new exercise begins on page 75 of the same manual (Simtronics Corporation).

Table 2. Fault Programming information for Scenario #1

Descriptor	Ambient Temp F	**Signal**	102.00	**Rise**	0.50
Status	Idle	**Normal**	68.00	**Start**	01:33
Direction	Fail High	**High**	102.00	**Stop**	00:00:00
Function	slope	**Low**	20.00	**Delay**	07:01
Descriptor	Dew point F	**Signal**	85.0	**Rise**	0.50
Status	Idle	**Normal**	60.000	**Start**	01:46
Direction	Fail High	**High**	85.0	**Stop**	:00:00
Function	slope	**Low**	20.000	**Delay**	03:01

Use Figures 1 and 2 for each scenario if delivering as paper-based exercises. Students may place abnormal readings on a printed copy of each drawing for comparison.

Abnormal Operating Conditions

The process indication values and output percentages for instrumentation and equipment during abnormal operating conditions for Scenario #1 are shown in Table 3.

Table 3. Process Indication Values and Output Percentages for Instrumentation and Equipment During Abnormal Operating Conditions for Scenario #1

Tag ID	Description	Value	Eng. Units	Output Percent
AI-101	SUPPLY pH	7.0	pH	
FI-101	SUPPLY FLOW	166.1	GPM	
FI-102	FILTER FLOW	50.1	GPM	
FI-202	E-201 CW FLOW	90.9	GPM	
FI-212	E-211 CW FLOW	36.1	GPM	
FI-222	E-221 CW FLOW	23.0	GPM	
FIC-104	MAKEUP WATER FLOW	3.5	GPM	27.0
FIC-105	ACID SOLUTION FLOW	0.0	GPM	0.0
FIC-106	BASE SOLUTION FLOW	0.0	GPM	0.0
FIC-107	BLOWDOWN FLOW TO DISP	0.0	GPM	0.0
FIC-201	E-201 PROCESS FLOW	70.0	KPPH	70.0
FIC-211	E-211 PROCESS FLOW	35.0	KPPH	65.0
FIC-221	E-221 PROCESS FLOW	7.0	KPPH	60.0
FM-101	FAN AIR	ON		
HIC-102	BASIN VALVE	0.0	%	0.0
HIC-103	TOWER VALVE	100.0	%	100.0
HIC-108	LOUVER TOWER AIR	50.0	%	50
LI-101	BASIN LEVEL	74.0	%	
P-101A	CW CIRC PUMP A	ON		
P-101B	CW CIRC PUMP B	OFF		
P-102	FILTER PUMP	ON		
PDI-103	FILTER PRESSURE	5.2	PSI	
PI-102	RETURN HEADER PRESSURE	24.4	PSIG	
PIC-101	SUPPLY HEADER PRESSURE	50.0	PSIG	68.0
TI-101	SUPPLY HEADER TEMPERATURE	89.0	DEG F	
TI-102	RETURN HEADER TEMPERATURE	114.0	DEG F	
TI-103	AMBIENT TEMPERATURE	102.0	DEG F	
TI-104	DEWPOINT TEMPERATURE	96.6	DEG F	
TI-201	E-201 PROCESS INLET TEMPERATURE	140.0	DEG F	
TI-203	E-201 CW OUTLET TEMPERATURE	123.0	DEG F	
TI-211	E-211 PROCESS INLET TEMPERATURE	130.0	DEG F	
TI-213	E-211 CW OUTLET TEMPERATURE	117.0	DEG F	

Tag ID	Description	Value	Eng. Units	Output Percent
TI-221	E-221 PROCESS INLET TEMPERATURE	145.0	DEG F	
TI-223	E-221 CW OUTLET TEMPERATURE	112.0	DEG F	
TIC-202	E-201 PROCESS OUT TEMPERATURE	114.0	DEG F	
TIC-212	E-211 PROCESS OUT TEMPERATURE	105.0	DEG F	
TIC-222	E-221 PROCESS OUT TEMPERATURE	117.0	DEG F	

Observation/s

Cooling water temperature is higher.

Compressors discharge pressures are higher.

Cause

Ambient temperature and humidity are high.

Investigative Actions

Visually check the cooling tower water supply and return temperatures to match control room readings

Visually check cooling tower water flows into trough, over packing to ensure flows are appropriate and not blocked

Visually check cooling tower basin level to be in correct operating range

Visually check cooling water supply pump discharge pressure to be in range

Compensating Actions

Ambient temperature and humidity dictate that process units must lower feed rates to compensate for the extreme outside temperature.

Increase air flow through tower if possible.

Add cooler water flow into basin if available

Corrective Actions

Add another cell/bay to the existing cooling tower

TROUBLESHOOTING FORM

1. **Recognize (and write) the problem.**
   *(What **is** happening that should not be or what **is not** happening that should be?)*
   Cooling water temperature is higher. Compressor discharge pressures are higher. ____________

2. **Stabilize the system.**
   (Does it need fixing? Stabilize the unit. Can we keep the unit running? Do we need to shut it down?)
   If compressor discharge cannot be lowered it may need to be shut down. Begin immediate investigation.
   ____

3. **Collect and analyze the data.**
   (Look for changes, differences, readings that have not changed, etc. Write down all observations. After every observation, write down the reason why. Then answer why for each reason.
   Ex. Observation why? because Reasoning why? because Reasoning why? because Reasoning...)

Y N **a.** **Ti-101 cooling water supply temperature increased** ____________
why? Because?______________________________
why? because______________________________
why? because______________________________

Y N **b.** **Fi-101 cooling water supply flow increased** ____________
why? because**Tic-202, 212, and 222 controller outputs increasing**______________
why? Because **Process outlet temperatures are increasing**______________
why? Because?______________________________

Y N **c.** **Ambient temperature is increasing** ____________
why? Because **Summer weather and hottest part of the day**______________
why? because______________________________
why? because______________________________

Y N **d.** **Pump P-101A running correctly and putting up good pressure** ____________
why? because______________________________
why? because______________________________
why? because______________________________

Y N e. **Fan FM-101 running and air is flowing**. ____________
why? because______________________________
why? because______________________________
why? because______________________________

Y N **f.** **Hic-108 louver control responds to change** ____________
why? because______________________________
why? because______________________________
why? because______________________________

Y N **g.** **Dewpoint is increasing** ____________
why? Because **Higher ambient temperature causing humidity to be higher**______________
why? because______________________________
why? because______________________________

Y N h. ______________________________

why? because ______________________________

why? because ______________________________

why? because ______________________________

Y N i. ______________________________

why? because ______________________________

why? because ______________________________

why? because ______________________________

Y N j. ______________________________

why? because ______________________________

why? because ______________________________

why? because ______________________________

4. After initial observations and reasoning, **reword the problem** as specifically as possible.

The cooling water temperature is higher due to increased ambient temperature.

____

5. List **possible causes** of the problem.

Y N **a. Summer heat and time of day**

Y **N** **b. Fan not running correctly**

Y **N** **c. Supply pump not running correctly**

Y N **d. Increased dewpoint creating higher humidity**

Y N e. ______________________________

*****Would each possible cause explain the problem? Circle **Y** or **N** beside each possible cause.

6. List the **most probable cause** of the problem. *(Use your knowledge, experience and best judgment.)*

Higher ambient temperature causing higher cooling water supply temperature

***** Does this cause explain every observation? Circle **Y** or N beside every observation.

7. Determine alternative solutions and select solution.

a. What would be an **investigative** action you could take at this point? What would be the effect?

Check cooling water temperature in the field at the supply – no affect on the process

b. What would be a **compensating** action you could take at this point? What would be the effect?

May need to cut process feed into exchangers – loss of production for plant

c. What would be a **corrective** action you could take at this point? What would be the effect?

Add another cooling tower bay if possible – could lower water supply temperature

d. What will be the **effect** of the above actions? *(Would any of the actions cause other problems?)*

Cutting feed will lower production and could affect downstream customers

____

8. Take the **corrective action** *(if empowered or within your responsibility).*

9. **Follow-up.** *(Was the problem eliminated? Was the "real" cause eliminated? What caused the real cause? You may need to start the problem-solving process again.)*

Summer heat and humidity have a great effect on plant operations, adding cooling tower bays could alleviate the problem or at least minimize the issue during the summer months.

____

10. **Document and share** with others.
(Document problem and actions taken in logbook or report; communicate with others.)

Cooling Tower Troubleshooting Module
Scenario #2 (Paper-based)

Scenario Statement

On August 1^{st}, a new compressor station was placed into service at the existing plant site. Weather conditions are clear with 83% humidity. There are five compressors being used to increase the pressure of methane gas for use in other sections of the process unit.

Exchangers on the discharge of the 2^{nd} and 4^{th} stages of these compressors are shell and tube exchangers with cooling water as the medium for controlling the compressor discharge pressures. Last minute changes in the design of this unit dictated a need for five, as opposed to the original four, compressors to handle the flow of process gas. The plant was also scheduled to go online in mid-March but delays in parts arrival slowed completion of the plant.

Upon starting the 4^{th} compressor and bringing it to full discharge pressure, compressors already on-line began to experience high discharge temperatures with unstable pressures. Cooling tower operators were contacted to ensure there were no problems with their equipment. No mechanical problems were found. The shift supervisor immediately orders a shutdown of compressors #4 and #5.

Troubleshoot this situation, listing investigative, compensative, and corrective actions on the Troubleshooting Form.

Abnormal Operating Conditions

The process indication values and output percentages for instrumentation and equipment during abnormal operating conditions for Scenario #2 are shown in Table 4.

Table 4. Process Indication Values and Output Percentages for Instrumentation and Equipment During Abnormal Operating Conditions for Scenario #2

Tag ID	Description	Value	Eng. Units	Output Percent
AI-101	SUPPLY pH	7.0	pH	
FI-101	SUPPLY FLOW	175.0	GPM	
FI-102	FILTER FLOW	50.1	GPM	
FI-202	E-201 CW FLOW	90.9	GPM	
FI-212	E-211 CW FLOW	36.1	GPM	
FI-222	E-221 CW FLOW	23.0	GPM	
FIC-104	MAKEUP WATER FLOW	3.5	GPM	
FIC-105	ACID SOLUTION FLOW	0.0	GPM	
FIC-106	BASE SOLUTION FLOW	0.0	GPM	
FIC-107	BLOWDOWN FLOW TO DISP	0.0	GPM	
FIC-201	E-201 PROCESS FLOW	70.0	KPPH	
FIC-211	E-211 PROCESS FLOW	35.0	KPPH	
FIC-221	E-221 PROCESS FLOW	7.0	KPPH	
FM-101	FAN AIR	ON		
HIC-102	BASIN VALVE	0.0	%	

Tag ID	Description	Value	Eng. Units	Output Percent
HIC-103	TOWER VALVE	100.0	%	
HIC-108	LOUVER TOWER AIR	50.0	%	
LI-101	BASIN LEVEL	70.0	%	
P-101A	CW CIRC PUMP A	ON		
P-101B	CW CIRC PUMP B	OFF		
P-102	FILTER PUMP	45.0	PSI	
PDI-103	FILTER PRESSURE	5.2	PSI	
PI-102	RETURN HEADER PRESSURE	19.0	PSIG	
PIC-101	SUPPLY HEADER PRESSURE	40.0	PSIG	0.0
TI-101	SUPPLY HEADER TEMPERATURE	76.7	DEG F	
TI-102	RETURN HEADER TEMPERATURE	130.0	DEG F	
TI-103	AMBIENT TEMPERATURE	68.0	DEG F	
TI-104	DEWPOINT TEMPERATURE	60.0	DEG F	
TI-201	E-201 PROCESS INLET TEMPERATURE	140.0	DEG F	
TI-203	E-201 CW OUTLET TEMPERATURE	120.6	DEG F	
TI-211	E-211 PROCESS INLET TEMPERATURE	130.0	DEG F	
TI-213	E-211 CW OUTLET TEMPERATURE	123.0.	DEG F	
TI-221	E-221 PROCESS INLET TEMPERATURE	145.0	DEG F	
TI-223	E-221 CW OUTLET TEMPERATURE	110.0	DEG F	
TIC-202	E-201 PROCESS OUT TEMPERATURE	115.0	DEG F	
TIC-212	E-211 PROCESS OUT TEMPERATURE	105.0	DEG F	
TIC-222	E-221 PROCESS OUT TEMPERATURE	115.0	DEG F	

Observation

The cooling tower is running at or above design capacity.

Cause

The designed size of the cooling tower does not meet facility needs. Cooling tower design would indicate a need for another cell/bay to handle the extra load of a new process unit.

Investigative Actions

Visually check the cooling tower water supply and return temperatures to match control room readings.

Visually check cooling tower water flows into trough, over packing to ensure flows are appropriate and not blocked.

Visually check cooling tower basin level to be in correct operating range.

Visually check cooling water supply pump discharge pressure to be in range.

Compensating Action

Run unit at reduced capacity with three of five compressors on-line.

Corrective Action

Increase capacity of cooling tower by adding 1 or more cells/bays in accordance with the process plant specifications.

TROUBLESHOOTING FORM

1. **Recognize (and write) the problem.**
*(What **is** happening that should not be or what **is not** happening that should be?)*
Compressors #4 and #5 cannot maintain discharge pressures____________________

2. **Stabilize the system.**
(Does it need fixing? Stabilize the unit. Can we keep the unit running? Do we need to shut it down?)
These units will need to be shutdown to prevent equipment damage.__________________

____

3. **Collect and analyze the data.**
(Look for changes, differences, readings that have not changed, etc. Write down all observations. After every observation, write down the reason why. Then answer why for each reason.
Ex. Observation why? because Reasoning why? because Reasoning why? because Reasoning...)

Y N **a.** **Compressors #1 through #3 are running at design parameters**___________
why? Because **All temperatures and pressures are in range**____________________
why? Because **Support systems are in good working order.**____________________
why? Because **Cooling tower is operating at capacity**________________________

Y N b. Compressors #4 and #5 began overheating when placed on line._______________
why? Because **High discharge temperatures causing high discharge pressures**________
why? Because **?**____
why? because____

Y N **c.** **Cooling tower is running at capacity**__________________________________
why? Because **All bays are in service with good supply pressure and supply temperature**___
why? because____
why? because____

Y N d. ____
why? because____
why? because____
why? because____

Y N e. ____
why? because____
why? because____
why? because____

Y N f. ____
why? because____
why? because____
why? because____

Y N g. ____
why? because____
why? because____
why? because____

Y N h. ______________________________

why? because ______________________________

why? because ______________________________

why? because ______________________________

Y N i. ______________________________

why? because ______________________________

why? because ______________________________

why? because ______________________________

Y N j. ______________________________

why? because ______________________________

why? because ______________________________

why? because ______________________________

4. After initial observations and reasoning, **reword the problem** as specifically as possible.

Compressor units #4 and #5 cannot maintain service due to high discharge pressures and temperatures.

5. List **possible causes** of the problem.

Y **N** **a.** **Compressors not placed on line correctly**

Y **N** **b.** **Cooling tower not running appropriately**

Y N **c.** **Cooling tower design not capable of handling all compressors**

Y N **d.** **Plant design changes created a bottleneck with the cooling tower**

Y N e. ______________________________

*****Would each possible cause explain the problem? Circle **Y** or **N** beside each possible cause.

6. List the **most probable cause** of the problem. *(Use your knowledge, experience and best judgment.)*

Change in plant design did not include an enhanced design of the cooling tower creating a bottleneck.

***** Does this cause explain every observation? Circle **Y** or N beside every observation.

7. Determine alternative solutions and select solution.

a. What would be an **investigative** action you could take at this point? What would be the effect?

Complete temperature profile across compressors #4 and #5 and compare to capacity of cooling tower

b. What would be a **compensating** action you could take at this point? What would be the effect?

Run without compressors #4 and #5 until the cooling tower could be modified

c. What would be a **corrective** action you could take at this point? What would be the effect?

Add cooling tower bays to address the lack of capacity

d. What will be the **effect** of the above actions? *(Would any of the actions cause other problems?)*

Compressors #4 and #5 could be run without compromise and methane production could b maximized.

8. Take the **corrective action** *(if empowered or within your responsibility).*

9. **Follow-up.** *(Was the problem eliminated? Was the "real" cause eliminated? What caused the real cause? You may need to start the problem-solving process again.)*

The best solution would be to add bays to the existing cooling tower or, add another cooling tower assembly to fix the root cause.

10. **Document and share** with others.
(Document problem and actions taken in logbook or report; communicate with others.)

COOLING TOWER TROUBLESHOOTING MODULE
SCENARIO #3 (PAPER-BASED)

Scenario Statement

The refinery was shut down in April for its annual maintenance overhaul and was off-line for six weeks to allow for the revamp of several compressors and the associated tower.

During that time, the cooling tower servicing the refinery was shut down for maintenance, equipment cleaning, and replacement. Fans on each cooling tower cell were replaced as was the tray packing and the drift eliminators.

On May 16th, the weather conditions are clear with 83% humidity. The cooling tower was placed on-line without problem. As production began in the refinery, pressures in the distillation tower became hard to control on the overhead condenser. Checks to equipment in the area found no problem but a check to the cooling water supply header at the battery limits showed the pressure to be lower than normal. Cooling tower operators were contacted.

Troubleshoot this situation, listing investigative, compensative, and corrective actions on the Troubleshooting Form.

Abnormal Operating Conditions

The process indication values and output percentages for instrumentation and equipment during abnormal operating conditions for Scenario #3 are shown in Table 5.

Table 5. Process Indication Values and Output Percentages for Instrumentation and Equipment During Abnormal Operating Conditions for Scenario #3

Tag ID	Description	Value	Eng. Units	Output Percent
AI-101	SUPPLY pH	7.0	pH	
FI-101	SUPPLY FLOW	100.0	GPM	
FI-102	FILTER FLOW	37.0	GPM	
FI-202	E-201 CW FLOW	74.0	GPM	
FI-212	E-211 CW FLOW	29.0	GPM	
FI-222	E-221 CW FLOW	17.0	GPM	
FIC-104	MAKEUP WATER FLOW	20.0	GPM	55.0
FIC-105	ACID SOLUTION FLOW	0.0	GPM	
FIC-106	BASE SOLUTION FLOW	0.0	GPM	
FIC-107	BLOWDOWN FLOW TO DISP	50.0	GPM	68.0
FIC-201	E-201 PROCESS FLOW	70.0	KPPH	
FIC-211	E-211 PROCESS FLOW	35.0	KPPH	
FIC-221	E-221 PROCESS FLOW	7.0	KPPH	
FM-101	FAN AIR	ON		
HIC-102	BASIN VALVE	0.0	%	0.0
HIC-103	TOWER VALVE	100.0	%	100.0
HIC-108	LOUVER TOWER AIR	50.0	%	80.0

Tag ID	Description	Value	Eng. Units	Output Percent
LI-101	BASIN LEVEL	23.0	%	
P-101A	CW CIRC PUMP A	ON		
P-101B	CW CIRC PUMP B	OFF		
P-102	FILTER PUMP	38.0	PSI	
PDI-103	FILTER PRESSURE	3.2	PSI	
PI-102	RETURN HEADER PRESSURE	14.0	PSIG	
PIC-101	SUPPLY HEADER PRESSURE	20.0	PSIG	0.0
TI-101	SUPPLY HEADER TEMPERATURE	76.7	DEG F	
TI-102	RETURN HEADER TEMPERATURE	122.0	DEG F	
TI-103	AMBIENT TEMPERATURE	68.0	DEG F	
TI-104	DEWPOINT TEMPERATURE	60.0	DEG F	
TI-201	E-201 PROCESS INLET TEMPERATURE	145.0	DEG F	
TI-203	E-201 CW OUTLET TEMPERATURE	137.0	DEG F	
TI-211	E-211 PROCESS INLET TEMPERATURE	145.0	DEG F	
TI-213	E-211 CW OUTLET TEMPERATURE	135.0	DEG F	
TI-221	E-221 PROCESS INLET TEMPERATURE	150.0	DEG F	
TI-223	E-221 CW OUTLET TEMPERATURE	125.0	DEG F	
TIC-202	E-201 PROCESS OUT TEMPERATURE	128.0	DEG F	100.0
TIC-212	E-211 PROCESS OUT TEMPERATURE	123.0	DEG F	100.0
TIC-222	E-221 PROCESS OUT TEMPERATURE	135.0	DEG F	100.0

Observations

Blowdown valve left open in manual due to turnaround activity.

The ratio of the blowdown flow to the water makeup flow causes the lower basin level and lower supply discharge pressure.

The cooling tower basin level is low.

This results in the lower supply pressure at the process unit battery limits.

Cause

FIC-107 valve output is too high.

Investigative Actions

Visually check the supply pump for discharge pressure, leaks.

Check PIC-101.

Check FIC-107 position.

Visually check the tower basin level.

Visually check the makeup water and blowdown valves for position.

Visually check the return water flow to the top of tower.

Compensating Action

Increase makeup water flow to basin.

Corrective Action

Reduce the blowdown flow to allow the supply pump to return to normal discharge pressure.

NOTE*: Chemical addition and water analysis needs to be closely monitored at this time.*

TROUBLESHOOTING FORM

1. **Recognize (and write) the problem.**
   *(What **is** happening that should not be or what **is not** happening that should be?)*
   High pressure on the distillation column

2. **Stabilize the system.**
   (Does it need fixing? Stabilize the unit. Can we keep the unit running? Do we need to shut it down?)
   Begin immediate investigation into the high pressure situation, possibly lower feed to column temporaily.

3. **Collect and analyze the data.**
   (Look for changes, differences, readings that have not changed, etc. Write down all observations. After every observation, write down the reason why. Then answer why for each reason.
   Ex. Observation why? because Reasoning why? because Reasoning why? because Reasoning...)

Y N **a.** **Pressure increase at the top of the distillation column**
why? Because **?**
why? because
why? because

Y N **b.** **Overhead condenser pressure is unstable**
why? Because **?**
why? because
why? because

Y N **c.** **Support equipment for distillation system checks to be in good working order**
why? because
why? because
why? because

Y N **d.** **Cooling water supply pressure is low**
why? Because **Cooling tower basin level is low**
why? Because
why? because

Y N **e.** **Cooling tower blowdown flow is increased**
why? Because **?**
why? because
why? because

Y N f.
why? because
why? because
why? because

Y N g.
why? because
why? because
why? because

Y N h. ____

why? because____

why? because____

why? because____

Y N i. ____

why? because____

why? because____

why? because____

Y N j. ____

why? because____

why? because____

why? because____

4. After initial observations and reasoning, **reword the problem** as specifically as possible.

Higher distillation system pressure appears to be caused by lower cooling water supply to overhead condenser.

____

5. List **possible causes** of the problem.

Y **N** **a. Cooling water supply pump malfunction**

Y N **b. Cooling tower basin low level has lowered NPSH to supply pump**

Y N **c. Cooling tower makeup water flow is lower than blowdown flow**

Y **N** **d. Too much feed to distillation tower**

Y N e. ____

*****Would each possible cause explain the problem? Circle **Y** or **N** beside each possible cause.

6. List the **most probable cause** of the problem. *(Use your knowledge, experience and best judgment.)*

Cooling tower blowdown flow is too high

***** Does this cause explain every observation? Circle **Y** or N beside every observation.

7. Determine alternative solutions and select solution.

a. What would be an **investigative** action you could take at this point? What would be the effect?

Visually check the cooling tower basin level – no affect

b. What would be a **compensating** action you could take at this point? What would be the effect?

Increase the makeup water flow to the basin – This would help raise the basin level

c. What would be a **corrective** action you could take at this point? What would be the effect?

Lower the blowdown water flow and check the valve at the unit

d. What will be the **effect** of the above actions? *(Would any of the actions cause other problems?)*

This would restore the cooling water pressure and correct the water flow to the process unit.

____

8. Take the **corrective action** *(if empowered or within your responsibility).*

9. **Follow-up.** *(Was the problem eliminated? Was the "real" cause eliminated? What caused the real cause? You may need to start the problem-solving process again.)*

____

____

10. **Document and share** with others.
(Document problem and actions taken in logbook or report; communicate with others.)

Performance Assessment Activity #1
Paper-based Problem

Learner Directions: In this assessment, you will analyze and solve a paper-based cooling tower problem. Your instructor will provide you with the problem scenario and supporting materials. Complete and submit all documentation requested including an Abnormal Operating Conditions table and Troubleshooting Form to your instructor.

Competency: Troubleshoot problems with a cooling tower.

Performance Criteria: Performance will be satisfactory when:

- Learner recognizes the problem and captures the problem in written form.
- Learner evaluates HSE risks involved with continued operation.
- Learner recognizes when the HSE hazard/s warrants shutting down equipment.
- Learner collects and analyzes data associated with the problem.
- Learner rewords problem based on initial observations and reasoning.
- Learner identifies possible causes of the problem.
- Learner selects most probable cause of the problem, one that explains every observation.
- Learner proposes corrective action that is rational and eliminates true cause (when possible).
- Learner accurately and completely documents problem and corrective action/s.

Conditions: Given a paper-based problem (which may include a process description, equipment specifications, normal and abnormal operating conditions and appropriate tools), competence will be demonstrated by the completion of troubleshooting steps and subsequent documentation.

Assessment Strategy: Skill-based Performance Test

Standard: To be determined by the instructor. Example: Satisfactory performance requires learner must meet all criteria on the checklist.

Cooling Tower Troubleshooting Rubric
Paper-based Problem

Competency: Troubleshoot problems with a cooling tower.

Criteria	Scale			
Product				
1. Documentation is accurate.	4	3	2	1
2. Documentation is complete.	4	3	2	1
3. Documentation reflects correct use of terminology.	4	3	2	1
Process				
1. Learner recognizes the problem and captures the problem in written form.	4	3	2	1
2. Learner evaluates and documents HSE risks involved with continued operation.	4	3	2	1
3. Learner recognizes and documents when the HSE hazard/s warrants shutting down equipment.	4	3	2	1
4. Learner collects and analyzes data associated with the problem.	4	3	2	1
5. Learner rewords problem based on initial observations and reasoning.	4	3	2	1
6. Learner identifies possible causes of the problem.	4	3	2	1
7. Learner selects most probable cause of the problem, one that explains every observation.	4	3	2	1
8. Learner proposes corrective action that is rational and eliminates true cause (when possible).	4	3	2	1

Key

4 =	Met and/or surpassed criteria
3 =	Met criteria
2 =	Showed progress toward meeting criteria
1 =	Did not meet criteria

PERFORMANCE ASSESSMENT ACTIVITY #2
SIMULATOR-BASED PROBLEM

Learner Directions: In this assessment, you will analyze and solve a paper-based cooling tower problem. Your instructor will provide you with the problem scenario and supporting materials. Complete and submit all documentation requested including an Abnormal Operating Conditions table and Troubleshooting Form to your instructor.

Competency: Troubleshoot problems with a cooling tower.

Performance Criteria: Performance will be satisfactory when:

- Learner recognizes the problem and captures the problem in written form.
- Learner evaluates HSE risks involved with continued operation.
- Learner recognizes when the HSE hazard/s warrants shutting down equipment.
- Learner collects and analyzes data associated with the problem.
- Learner rewords problem based on initial observations and reasoning.
- Learner identifies possible causes of the problem.
- Learner selects most probable cause of the problem, one that explains every observation.
- Learner proposes corrective action that is rational and eliminates true cause (when possible).
- Learner accurately and completely documents problem and corrective action/s.
- Process equipment is stabilized.
- System is returned to within $\pm$ 5% of design parameters.

Conditions: Given a simulator-based problem (which may include a process description, equipment specifications, normal and abnormal operating conditions and appropriate tools), competence will be demonstrated by the completion of troubleshooting steps and subsequent documentation.

Assessment Strategy: Skill-based Performance Test

Standard: To be determined by the instructor. Example: Satisfactory performance requires learner must meet all criteria on the checklist.

NOTE: If the instructor uses simulator software that includes a performance scoring utility tool, then the instructor may wish to base the standard on the scoring tool. The instructor must describe the performance standards (generally by categories) for learners. Then, the instructor would have multiple options for the performance standard statement. For example, "Satisfactory performance requires learner to score a minimum of 80 for each of the performance category."

Cooling Tower Troubleshooting Rubric
Simulator-based Problem

Competency: Troubleshoot problems with a cooling tower.

Criteria	Scale			
Product				
1. Process equipment is stabilized.	4	3	2	1
2. System is returned to within ± 5% of design parameters.	4	3	2	1
3. Documentation is accurate.	4	3	2	1
4. Documentation is complete.	4	3	2	1
5. Documentation reflects correct use of terminology.	4	3	2	1
Process				
1. Learner recognizes the problem and captures the problem in written form.	4	3	2	1
2. Learner evaluates and documents HSE risks involved with continued operation.	4	3	2	1
3. Learner recognizes and documents when the HSE hazard/s warrants shutting down equipment.	4	3	2	1
4. Learner collects and analyzes data associated with the problem.	4	3	2	1
5. Learner rewords problem based on initial observations and reasoning.	4	3	2	1
6. Learner identifies possible causes of the problem.	4	3	2	1
7. Learner selects most probable cause of the problem, one that explains every observation.	4	3	2	1
8. Learner proposes corrective action that is rational and eliminates true cause (when possible).	4	3	2	1

Key

4 =	Met and/or surpassed criteria
3 =	Met criteria
2 =	Showed progress toward meeting criteria
1 =	Did not meet criteria

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