HEAT EXCHANGER TROUBLESHOOTING MODULE
LESSON PLAN

Overview

Heat exchangers are used in facility systems to control a fluid's temperature "by adding or removing thermal energy" (Bartlett, 1996, p. 18). In essence, the equipment heats, cools, condenses, or evaporates a fluid. Heat exchangers are important to a facility's economic viability in that they use energy (heat) that might otherwise be wasted. Because of their criticality within the process industries, the process technician must have a basic understanding of troubleshooting techniques to recognize equipment problems and prevent further losses in production.

Competency	Performance Standards
Troubleshoot problems associated with a heat exchanger	**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 root 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 ± 5% of design parameters (if simulator-based problem) **Conditions:** Given a paper-based and/or 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.

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Learning Objectives

a. Recall the purpose and types of heat exchangers.

b. Identify and discuss fluid flow, pressure drop, and leakage problems associated with heat exchangers.

c. List observations a process technician could make given a scenario involving heat exchanger fluid flow and pressure drop problems.

d. Explain the relationship between variables for a specific process under normal operating conditions.

e. 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 root cause of the problem
- evaluate the effect of investigating, compensating and correcting 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 and types of heat exchangers and problems associated with the equipment (if provided).	Deliver a brief presentation on heat exchangers and associated problems		Lecture Equipment	Address first two learning objectives
	BRAINSTORM with a small group of your peers the observations you would make given a scenario involving fluid flow restriction and leakage problems with a heat exchanger.	Create scenario for activity Divide learners into groups of 3 to 4 Introduce activity			Address the third learning objective
	COMPARE your list of observations to another group's work.				
	PARTICIPATE in a class discussion regarding the observations.	Capture observations on board or flipchart		Board or Flipchart	
	REVIEW the process description, equipment specifications, schematics, and normal operating conditions for Processes A and B.	Choose a specific problem/s for learners to solve Lead discussion of process to assure learners understand all aspects	Process Description		Have students write normal operating values for Processes A and B directly on the Figures 1 and 3, respectively.

TIME FRAME	LEARNING ACTIVITY	TEACHING ACTIVITY	INSTRUCTIONAL MATERIALS	SUPPLIES AND EQUIPMENT	NOTES
	COMPLETE Self-Check Questions worksheet.	Introduce activity Review worksheet with learners after completion	Self-Check Questions worksheet		Reinforce learning objectives 1, 2 and 4
	SOLVE at least one paper-based problem associated with heat exchangers 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 six incidents have been provided for students Address learning objective 5
	OBSERVE a normal and/or abnormal heat exchanger condition on the simulator (if simulator is available).	Set up simulation Guide learners as needed during the activity		Simulator	
	SOLVE at least one simulator-based heat exchanger problem including the completion of the Troubleshooting form (if simulator is available).	Create a specific problem/s and set up simulation 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	Address learning objective 5

HEAT EXCHANGER TROUBLESHOOTING MODULE
INCIDENT #1 (PAPER-BASED)

Incident Statement

A control room operator (CRO) calls you on the radio to say that the steam low flow alarm (FAL-102) to the EX-101 heater has sounded. List investigative actions that you should take at this point.

Investigative Actions

Look at PI-102, steam inlet pressure. Low pressure combined with low flow alarm would indicate a problem at the steam source. If normal then –

Look at FCV-102 valve position. Report to CRO and perhaps stroke valve. Have CRO take to 100% open. If the valve goes wide open and the flow doesn't increase then-

Check the outlet (condensate) gauges to see if they are within normal parameters. Also, look at the outlet gauges on the "water side" to see if they are within normal parameters.

Have the CRO contact the unit from where the steam comes to learn if any issues are present there.

Walk the steam line backwards toward the source to check for any leaks or open drains/vents.

Finally, call the instrumentation department/technician to check the low flow alarm.

HEAT EXCHANGER TROUBLESHOOTING MODULE
INCIDENT #2 (PAPER-BASED)

Incident Statement

While making rounds, you notice that the inlet water pressure gauge of the heat exchanger reads 55 psi instead of the normal 100 psi. List investigative actions that you should take at this point.

Investigative Actions

Check the gauge block valve to ensure it is fully open. Stroke the block valve if possible to make certain it is open fully.

Check the PI-101 outlet gauge to see if that is also reading low. If it is, that may indicate a pump problem. Or perhaps the pump suction blocked or the source of water to the suction is inadequate. If PI-101 is normal and the pump seems ok, then -

Look at the outlet FCV-101 position. Has it failed open? Call the CRO and have the valve stroked open and closed. Does the valve move? Does the valve go fully closed? When closed, does the pressure rise on the water line?

Look at the exchanger, check for leaks on the tube side flanges/heads.

Lastly, if everything checks out fine, have the gauge replaced to see if that is helpful.

HEAT EXCHANGER TROUBLESHOOTING MODULE
INCIDENT #3 (PAPER-BASED)

Incident Statement

The operating shift is half way through the night and is recording process readings and lab data results. Readings on the exit of both the shell and tube side of the exchanger have changed but none are in alarm state. Downstream users of the condensate stream notice some foaming of the water.

Using information for Process A, troubleshoot the situation. Complete the Troubleshooting Form, listing investigative, compensative, and corrective actions.

Cause

Tube leak on the caustic wash water flow into the shell side.

Investigative Actions

Check the local pressure gauges on the outlets of both the shell and tube sides of the exchanger.

Run a physical pH sample to ensure the meter is operating properly.

Visually look at FCV-101 to compare its position to the controller's output signal.

Visually check TI-103 in the field for comparison.

Compensative Actions

Reject the condensate to the process sewer or a standby tank.

Reduce the caustic wash water flow if possible.

Shut down the unit or bypass the exchanger.

Corrective Actions

Plug or replace the leaking tube.

HEAT EXCHANGER TROUBLESHOOTING MODULE
INCIDENT #4 (PAPER-BASED)

Incident Statement

While making rounds, you notice the extraction steam flow pressure gauge is reading low. List investigative actions that you should take at this point.

Investigative Actions

Check the local boiler feedwater temperature indicator downstream of the feedwater heater to ensure it has decreased. Compare local reading to control room reading.

Check with the control room to determine if extraction steam flow was changed.

Visually check the area piping for steam leaks.

HEAT EXCHANGER TROUBLESHOOTING MODULE
INCIDENT #5 (PAPER-BASED)

Incident Statement

A control room operator calls on the radio to say the feedwater pressure has dropped off substantially at the inlet to the feedwater heater. The operator requests that you investigate and report your findings.

Investigative Actions

Check the outlet pressure at feed pump 1 to compare the inside reading with the outside pressure gauge reading.

Check the pump operation.

Check the condenser level.

Look for leaks between the pump and feedwater heater.

Check instrumentation.

HEAT EXCHANGER TROUBLESHOOTING MODULE
INCIDENT #6 (PAPER-BASED)

Incident Statement

A control room operator calls on the radio to say the feedwater pressure has dropped off substantially at the inlet to the feedwater heater. The control board operator notices a decrease in speed of the steam turbine.

Using information for Process B, troubleshoot this situation. Complete the Troubleshooting Form, listing investigative and compensative actions.

Cause

Steam jets are fouled.

Investigative Actions

Visually check the sight glass on the condenser.

Visually check the local control level on the condenser.

Check the local temperature and pressure gauges to match control room indications.

Check the steam jets located at the top of the condenser to be in working order.

Check the local tachometer on the local turbine panel board.

Check cooling water flow and temperature to the condenser.

Compensative Actions

Ask CT operator to put another cell in service.

Increase cooling water flow.

Increase steam flow to steam jets.

Corrective Actions

Restore cooling water flow.

Clean steam jets.

HEAT EXCHANGER TROUBLESHOOTING MODULE
SELF-CHECK QUESTIONS

1. Explain the relationship between temperature, pressure and the state of a fluid.

   A fluid can be in a liquid or gaseous state. Temperature and pressure work together to determine the state of a fluid. For example, at ambient conditions, water will be in a liquid state. At higher temperatures, water can be in a gaseous state (steam). However, at higher pressures, water must be even hotter to become steam.

2. List four examples of heat exchangers used in your everyday life.

   Examples of heat exchanges include refrigerators, air conditioners, furnaces, hot water heaters, and car radiators.

3. List five observations made and/or readings taken by an operator on the exchangers shown in Figures 1 and 3 during regular shift rounds.

   — Leaks from vessel, pipes, flanges, valves, or instrumentation
   — Inlet pressures
   — Outlet pressures
   — Inlet temperatures
   — Outlet temperatures
   — Valve positions
   — Irregular sounds
   — Vibrations
   — Smells
   — Flows

4. List three impacts of severe fouling in heat exchangers.

   — Corrosion
   — Leaks
   — Equipment shutdown
   — Tube replacement
   — Reduced heat transfer
   — Reduced flow through tubes
   — Off-spec product
   — Reduced profitability

5. List three causes of leakage in heat exchangers.

   — Vibrations
   — Thermal expansion and fatigue
   — Extreme temperatures (freezing)
   — Improper assembly
   — Incorrect exchanger selection
   — Incompatible gasket material
   — Exchanger design flaw
   — Component failure (e.g., tube, plate)

6. List four impacts of exchanger tube failures.

   — Lost production
   — Contaminated products
   — Additional energy usage
   — High repair costs
   — Environment release impacts
   — Fire
   — Fatality
   — Fines (e.g., OSHA) and regulatory sanctions
   — Explosion

7. In Figure 1, what happens to TI-101 if TI-102 decreases?

   b. Decreases

8. In Figure 1, what happens to PI-103 if FIC-102 increases?

   a. Increases

9. In Figure 1, what happens to TI-102 if TI-100 increases?

   c. Remains the same

10. In Figure 1, what happens to PI-100 if FIC-101 increases?

    b. Decreases

11. In Figure 1, what happens to TI-103 if PI-103 decreases?

    c. Remains the same

12. In Figure 1, what happens to PI-101 if PI-100 decreases?

    a. Increases

13. In Figure 1, what happens to PI-102 if FIC-102 decreases?

    b. Decreases

14. In Figure 1, what happens to PI-100 if FIC-102 increases?

    c. Remains the same

15. On June 10, 2008 at 4:30 PM, maintenance workers replaced a burst rupture disk associated with a heat exchanger at The Goodyear Tire and Rubber Company facility in Houston, Texas. In their reactor process line, ammonia is used as the coolant within heat exchangers to regulate temperature. Ammonia pressure within the heat exchanger is maintained at 150 psig. "Each heat exchanger is equipped with a rupture disk in series with a pressure relief valve (both set at 300 psig) to protect the heat exchanger from excessive pressure. The relief system vents ammonia vapor through the roof to the atmosphere" (Figure 4) (U.S. Chemical Safety Board, 2011, p. 4).

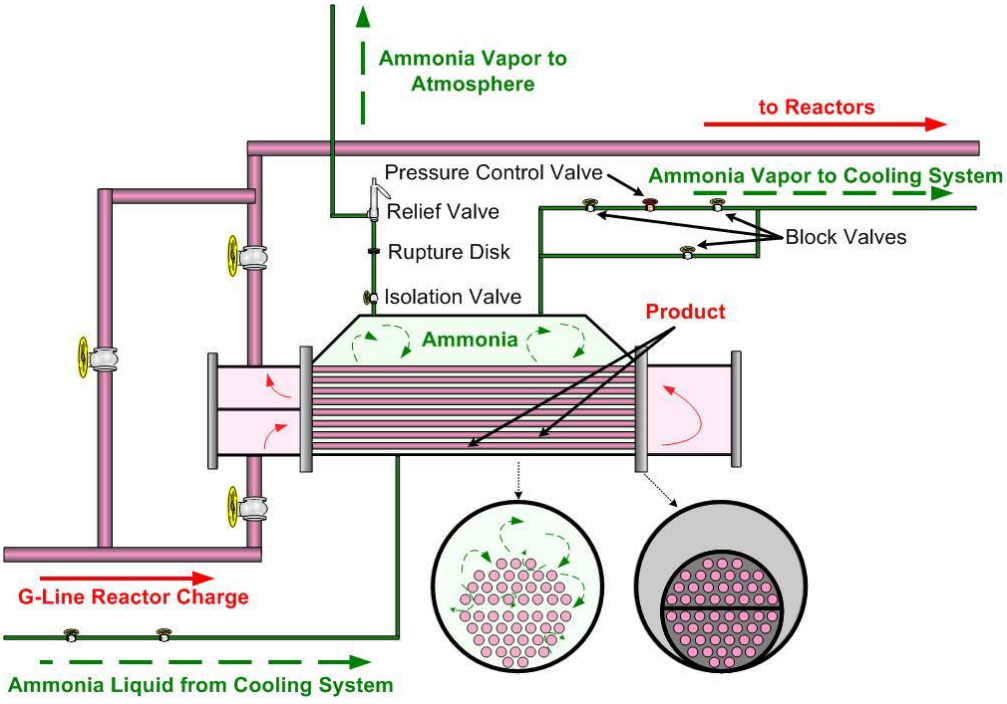

Figure 4. Ammonia Heat Exchanger
Courtesy of the U.S. Chemical Safety Board (2011)

Thirty minutes prior to replacement, process technicians “closed an isolation valve between the heat exchanger shell (ammonia cooling side) and a relief valve” (U.S. Chemical Safety Board, 2011, p. 2). After the replacement, the isolation valve remained closed.

The following morning at 6:30 AM, a process technician “closed a block valve isolating the ammonia pressure control valve from the heat exchanger. The operator then connected a steam line to the process line to clean the piping” (U.S. Chemical Safety Board, 2011, p. 2).

Predict what could happen in this situation and provide your rationale for why it would happen.

- **As steam flows through the tubes, the temperature of the liquid ammonia in the shell increases.**
- **The pressure in the shell increases.**
- **The pressure could not safely vent because of closed valves.**
- **At some point, the heat exchanger will rupture.**
- **Ammonia will be released.**
- **Personal injury and/or death may result.**

To see what actually happened, visit the U.S. Chemical Safety Board links below.

Heat Exchanger (Photo)

http://1.usa.gov/WQzojI

Case Study Report

http://1.usa.gov/12lirSC

PERFORMANCE ASSESSMENT ACTIVITY #1
PAPER-BASED PROBLEM

Learner Directions: In this assessment, you will analyze and solve a paper-based heat exchanger 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 heat exchanger.

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 root 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: TBD – Example: Satisfactory performance requires learner must meet all criteria on the checklist.

HEAT EXCHANGER TROUBLESHOOTING RUBRIC
PAPER-BASED PROBLEM

Competency: Troubleshoot problems with a heat exchanger.

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 root 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 simulator-based heat exchanger problem. Your instructor will provide you with the problem scenario and supporting materials. Complete and submit all documentation requested including a Troubleshooting form to your instructor.

Competency: Troubleshoot problems with a heat exchanger.

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 root 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: TBD

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.”

HEAT EXCHANGER TROUBLESHOOTING RUBRIC
SIMULATOR-BASED PROBLEM

Competency: Troubleshoot problems with a heat exchanger.

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 root 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