Session 4: Cooling Water Systems

Prepare to Teach

Session Overview

Session 4 provides students with a thorough description of cooling water systems, including purpose, components, theory of operation, and safety and environmental concerns. Students are given a variety of activities to help them understand how these systems work.

Class Preparation Checklist

1. ☐ Contact vendor for cooling water system video (Betz, Exxon Nalco, Calgon, Drew, etc.).
2. ☐ Grade homework collected during previous session.
3. ☐ Familiarize yourself with materials to be presented in this session.
4. ☐ Make copies of handouts as needed (see Appendix).
5. ☐ Arrange for flipchart easel, flipchart paper, and markers OR chalkboard and chalk.
6. ☐ Arrange for overhead projector and overheads, if used.
7. ☐ Arrange for VCR and television to show video.
8. ☐ Bring texts or other materials to be used in this course.

Objective(s)

Learning Objectives

1. Describe the purpose of cooling water systems.
2. Identify the basic equipment components found in cooling water systems.
3. Explain the purpose of equipment components found in cooling water systems.
4. Define terms associated with cooling water systems.
5. Explain the cooling water system theory of operation.
6. List variables that must be controlled to ensure proper operation of the cooling water system.
7. Describe factors that affect normal cooling water system operation.
8. Identify cooling water system instrumentation.

9. Trace flows through a cooling water system on a PFD.

10. Discuss the specific safety, health and environmental concerns associated with the cooling water system.

Agenda

Activity	Estimated Time
1. Agenda	5
2. Learning Objectives	5
3. Homework Collection and Review	5
4. Cooling Water Systems Vendor Video	Varies
BREAK	10
5. Cooling Water System	50
BREAK	10
6. Lab/Classroom Activities	50
7. Summary and Wrap-Up	10

Background

1. Cooling water systems are the final water system presented in this course. Cooling water systems (with or without cooling towers) are essential to facility operations. They remove heat from process streams and equipment.

2. Vendor videos are available to provide additional information on how cooling water systems operate. It may require time to order/receive a video; therefore, advanced planning is necessary. Up to 35 minutes are available in the agenda to show a video and conduct a discussion over the video contents. It will be necessary to adjust the remaining session time according to the length of the video.

Begin Lesson

1. Agenda

Time: 5 minutes

Agenda: Explain what you intend to accomplish in today's class.

DISPLAY
SLIDE #1

OR

Write today's agenda on the flipchart or whiteboard.

2. Learning Objectives

Time: 5 minutes

DISPLAY
SLIDE #2 - 4

OR

Write today's objectives on the flipchart or whiteboard.

Discuss the lesson's objectives with the learners in order to provide them with clear-cut guidelines for what is to be learned during the instructional session.

3. Homework Collection

Time: 5 minutes

1. Collect the Service/Utility and Waste Water Systems Review Sheet assigned for homework at the end of the previous session. Review any questions students may have to ensure they have mastered the concepts covered during the session.

2. Return the graded homework assignment collected during the previous session.

4. Cooling Water Systems Vendor Video

Time: Varies

Show the vendor video. Follow up the video with a discussion of the main points to ensure students understand the operation of cooling water systems.

Instructional Strategy

Videos appeal to both visual and auditory learners and are therefore recommended to provide an additional means to convey this information. The video should not replace a thorough explanation of the components and operating principles of cooling water systems by the instructor.

Break 10 minutes

5. Cooling Water Systems

Time: 50 minutes

1. Have students continue taking notes on the Water Systems Worksheet from Session 2 as you present this material.

DISPLAY

SLIDE #5 - 6

OR

Write slide contents on the flipchart or white board.

2. Describe the purpose of cooling water systems:
   - Remove heat from process streams using circulating water.

3. Define terms associated with the system:
   - **Cycle of concentration** is the concentration of chemical blowdown and metals due to evaporation solution
   - **Blowdown** is a continuous removal of water from the circulating system that prevents dissolved solids from concentrating to form scale
   - **Makeup water** is service/utility water added to the system to make up for evaporated water; maintains proper system levels
   - **Biocides** are used to control algae and fungi growth within the cooling tower
   - **Water analysis** is performed on water samples to ensure correct levels of chemical injection
   - **Fouling** is an accumulation of unwanted matter on heat transfer surfaces

- **Corrosion** is damage to metal equipment and piping caused by oxygen and other dissolved gases entrained in the water
- **Latent heat** is the amount of energy required to evaporate liquid
- **Sensible heat** is the heat content due to temperature
- **Convected heat** is a type of heat transfer in which gas or liquid is used to remove heat from another heat source
- **Dewpoint** is point where vapor condenses to liquid
- **Wet bulb temperature** is the temperature at which, when at constant pressure, no evaporation occurs in a closed system, the vapor pressure in the air is equal to the liquid vapor pressure, and the mass at the vapor state is equal to the mass in liquid state
- **Dry bulb temperature** is the air temperature as measured by a dry-bulb thermometer
- **Approach** is the difference between actual temperature of the cooled water and the wet bulb temperature
- **Heat capacity** is the amount of energy required to increase one pound of water one degree

DISPLAY

SLIDES #7 - 8

OR

Provide simplified flow diagrams of a cooling tower and exchanger-type systems on the flipchart or white board.

4. List and discuss the components associated with cooling water systems and the purpose of each component:
   - Cooling tower – device used to remove heat from water through evaporation
   - Basin – collection point at bottom of tower
   - Pumps – maintain circulation through exchangers and back to tower
   - Exchangers – equipment through which cooling water flows for heat transfer; used to cool other process liquids
   - Water supply source – river, city water authorities, etc.

5. Describe how typical cooling water systems operate. Include a discussion of how the arrangement of the equipment impacts operation of the system.
   - Loop system
   - Hot water enters troughs at top of cooling tower; water flows downward, being evenly distributed through nozzles, where it contacts packing below; cool air is forced through air inlet louvers where it contacts the water and removes heat by direct contact (sensible heat) and the process of evaporation.

DISPLAY

SLIDES #9 - 10

OR

Provide drawings to illustrate cooling tower principles of operation.

6. Describe the following types of cooling towers used and how their design relates to the efficient operation of the system:
   - **Atmospheric towers** use counterflow of air traveling up against falling water to cool the water; uses drift eliminators to reduce water loss from wind velocity increases
   - **Forced draft cooling towers** use fans on the bottom of the tower to produce air flow used in the tower
   - **Induced draft towers** use fans on top of the tower to provide efficient heat transfer
   - **Counter flow** occurs when air moves vertically as water falls downward
   - During **cross flow**, the air moves horizontally across the water

7. Identify process variables associated with the system control. Use a P&ID to identify system instrumentation and explain how the instrumentation is used to control the system.

8. List and discuss factors that affect the efficient operation of Cooling Water Systems:
   - **Tower design** – type of tower affects the economics of the system (water loss, evaporation, etc.)
   - **Water contamination** – may foul or corrode equipment
   - **Mechanical problems** – may create need for shutdown
   - **Loss of pump** – affects circulation
   - **Loss of fan** – affects ability for proper cooling/evaporation
   - **Wind velocity** – may cause system water loss
   - **Humidity** – affects bulb temperature of water
   - **Temperature** (ambient and water) – affect ability of process steams to be adequately cooled
   - **Foaming** – caused by concentrations of dissolved solids or contamination; can be minimized by increasing blowdown or using anti-foam agents
   - **Air flow** – adequate air flow is necessary for proper evaporation
   - **Water flow and distribution** – affects ability for water to cool properly
   - **Deposits** - form suspended solids and cause plugging/fouling
   - **Corrosion** – affects metal equipment and pipes
   - **Tube plugging/scaling/fouling** – affects efficiency of equipment
   - **Wood decay** – plugs exchanger tubes
   - **Silt and debris** – plug exchanger tubes

9. Identify safety/environmental hazards associated with the system. Discuss the use of hydrocarbon leak detectors and fire protection equipment.
   - Atmospheric contaminants
   - Foaming
   - Chemicals

Break 10 minutes

6. Lab/Classroom Activities

Time: 50 minutes

Lab Activity:

Select an appropriate lab activity from the Lab Activity Section of the Instructor's Guide.

OR

Have students access the URL listed below and complete the Cooling Water Systems Activity Sheet (see Appendix). This activity will help them learn the difference between once-through, open evaporative recirculating, and closed non-evaporative recirculating cooling towers.

http://lorien.ncl.ac.uk/ming/pservices/cpe214p1.htm

Alternative Classroom Activities:

1. Have each student complete the Cooling Water System P&ID Activity (see Appendix) either independently or in small groups. Discuss the answers together as a class.

2. Have students break into pairs or small groups and brainstorm possible advantages and disadvantages of each type of system. Have them share their thoughts with the entire class, capturing their thoughts on a flipchart. Have students complete the Cooling Water Systems Activity Sheet (see Appendix) from the classroom discussion.
   Note: This activity is listed as homework. Use the activity only once.

8. Summary and Wrap-Up

Time: 10 minutes

1. Use the following discussion questions to summarize cooling water systems:
   - What is the purpose of cooling water systems?
     - ✓ to remove heat from process streams
   - List the three common types of systems.
     - ✓ open evaporative recirculating, closed non-evaporative recirculating, once-through

- Explain the difference between forced draft and induced draft towers.
  - ✓ forced draft: fans are located on bottom section of tower, all process air is introduced by the fans, the fans circulate vertically against the flow of the water, they have higher velocities but are less efficient
  - ✓ induced draft: fans are on top of the toper, air flow is slower but through evaporation is more efficient, the air can be crossflow or counterflow
- Explain the difference between counterflow and crossflow towers.
  - ✓ counterflow moves the air vertically across the downward falling water; crossflow moves air horizontally across the downward falling water
- List factors that can impact efficient operation of the cooling water system.
  - ✓ tower design, water contamination, mechanical problems, loss of pump or fan, wind velocity, humidity, temperature (ambient and water), foaming, air flow, water flow/distribution, deposits, corrosion, tube plugging/fouling, wood decay, silt and debris
- Explain how a cooling water system operates.
  - ✓ hot water transfers heat to cooler air as it passes through the tower; the majority of heat transfer in the tower is caused by evaporation; the cooling water circulates through process equipment (like tube/shell exchangers) to cool process flow

2. Conclude Water Systems by asking students to recall the different water systems studied in Sessions 2 – 4. Capture these systems on the flipchart. Have students review their Water Systems Worksheet and ensure they have completed each section. Answer any questions they may have over the information on the worksheet.

3. Assign homework: Have each student complete the Cooling Water Systems Comparison Sheet (see Appendix):
   - open evaporative recirculating
     - ➢ cooling water evaporates; approximately 1%; makeup water required
     - ➢ used in refinery cooling tower systems
     - ➢ advantages: less water required than others; enhanced corrosion control is feasible
     - ➢ disadvantages: higher capital cost than once-through; large cooling towers may be unacceptable; system purge may pose environmental problems
   - closed non-evaporative recirculating
     - ➢ cooling water is cooled in a secondary (air) heat exchanger; no evaporate, no makeup
     - ➢ examples include compressor jackets and car radiators
     - ➢ advantages: water remains clear; cooling water temperature above 100° is possible
     - ➢ disadvantages: high capital cost; limited by air temperature
   - once-through
     - ➢ cooling water passes through heat exchanger once; used when plenty of inexpensive cool water is available and adequate facilities for disposal of warm water exist
     - ➢ used in power plants that dump water into river
     - ➢ advantages: no cooling tower system; no water treating
     - ➢ disadvantages: corrosion, fouling, water waste, thermal pollution of waterway