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IDENTIFIERS *Stationary Engineering; *Steam; Steam Power Plant Operators

ABSTRACT

This learning module, one in a series of 20 related training modules for apprentice stationary engineers, deals with steam. Addressed in the individual instructional packages included in the module are the following topics: steam formation and evaporation, types of steam, and steam transport and purification. Each instructional package in the module contains some or all of the following: a lesson goal, performance indicators, a study guide, a vocabulary list, an introduction, instructional text, an assignment, a job sheet, a self-assessment activity, a post-assessment instrument, answers to the post-assessment instrument, and a list of recommended supplementary references. (MN)

APPRENTICESHIP

# STATIONARY ENGINEERS

## RELATED TRAINING MODULES

14.1 - 14.4 STEAM.

## STATEMENT OF ASSURANCE

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## STATEMENT OF DEVELOPMENT

THIS PROJECT WAS DEVELOPED AND PRODUCED UNDER A SUB-CONTRACT FOR THE OREGON DEPARTMENT OF EDUCATION BY LANE COMMUNITY COLLEGE, APPRENTICESHIP DIVISION, EUGENE, OREGON, 1984.

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# APPRENTICESHIP

## STATIONARY ENGINEERS
## RELATED TRAINING MODULES

### COMPUTERS

1.1 Digital Language
1.2 Digital Logic
1.3 Computer Overview
1.4 Computer Software

### SAFETY

2.1 General Safety
2.2 Hand Tool Safety
2.3 Power Tool Safety
2.4 Fire Safety
2.5 Hygiene Safety
2.6 Safety and Electricity

### DRAWING

3.1 Types of Drawings and Views
3.2 Blueprint Reading/Working Drawings
3.3 Scaling and Dimensioning
3.4 Machine and Welding Symbols

### TOOLS

4.1 Measuring, Layout and Leveling Tools
4.2 Boring and Drilling Tools
4.3 Cutting Tools, Files and Abrasive
4.4 Holding and Fastening Tools
4.5 Fastening Devices

### ELECTRICITY/ELECTRONICS

5.1 Basics of Energy
5.2 Atomic Theory
5.3 Electrical Conduction
5.4 Basics of Direct Current
5.5 Introduction to Circuits
5.6 Reading Scales
5.7 Using a V.O.M.
5.8 OHM'S Law
5.9 Power and Watt's Law
5.10 Kirchoff's Current Law
5.11 Kirchoff's Voltage Law
5.12 Series Resistive Circuits
5.13 Parallel Resistive Circuits
5.14 Series - Parallel Resistive Circuits

5.15 Switches and Relays
5.16 Basics of Alternating Currents
5.17 Magnetism

HUMAN RELATIONS

6.1 Communications Skills
6.2 Feedback
6.3 Individual Strengths
6.4 Interpersonal Conflicts
6.5 Group Problem Solving, Goal-setting and Decision-making
6.6 Worksite Visits
6.7 Resumes
6.8 Interviews
6.9 Work Habits and Attitudes
6.10 Wider Influences and Responsibilities
6.11 Personal Finance
6.12 Expectations

TRADE MATH

7.1 Linear - Measure
7.2 Whole Numbers
7.3 Addition and Subtraction of Common Fraction and Mixed Numbers
7.4 Multiplication and Division of Common Fractions and Whole and Mixed Numbers
7.5 Compound Numbers
7.6 Percent
7.7 Mathematical Formulas
7.8 Ratio and Proportion
7.9 Perimeters, Areas and Volumes
7.10 Circumference and Wide Area of Circles
7.11 Area of Planes, Figures, and Volumes of Solid Figures
7.12 Graphs
7.13 Basic Trigonometry
7.14 Metrics

HYDRAULICS

8.1 Hydraulics - Lever
8.2 Hydraulics - Transmission of Force
8.3 Hydraulics - Symbols
8.4 Hydraulics - Basic Systems
8.5 Hydraulics - Pumps
8.6 Hydraulics - Pressure Relief Valve
8.7 Hydraulics - Reservoirs
8.8 Hydraulics - Directional Control Valve
8.9 Hydraulics - Cylinders
8.10 Hydraulics - Forces, Area, Pressure
8.11 Hydraulics - Conductors and Connectors
8.12 Hydraulics - Troubleshooting
8.13 Hydraulics - Maintenance

REFRIGERATION

9.1 Refrigeration - Introduction
9.2 Refrigeration - Compressors
9.3 Refrigeration - Temperature Controls
9.4 Refrigeration - Condensers and Evaporation
9.5 Refrigeration - Purge, Evacuate, Recharge
9.6 Refrigeration - Troubleshooting

MACHINE COMPONENTS

10.1 Machine Components - Shafts
10.2 Machine Components - Bearings
10.3 Machine Components - Seals and Gaskets
10.4 Machine Components - Chain Shafts
10.5 Machine Components - Belts and Pulleys

LUBRICATION

11.1 Lubrication - Introduction
11.2 Lubrication - Standards and Selection of Lubricants

BOILERS

12.1 Boilers - Fire Tube Types
12.2 Boilers - Watertube Types
12.3 Boilers - Construction
12.4 Boilers - Fittings
12.5 Boilers - Operation
12.6 Boilers - Cleaning
12.7 Boilers - Heat Recovery Systems
12.8 Boilers - Instruments and Controls
12.9 Boilers - Piping and Steam Traps

PUMPS

13.1 Pumps - Types and Classification
13.2 Pumps - Applications
13.3 Pumps - Construction
13.4 Pumps - Calculating Heat and Flow.
13.5 Pumps - Operation
13.6 Pumps - Monitoring and Troubleshooting
13.7 Pumps - Maintenance

STEAM

14.1 Steam - Formation and Evaporation
14.2 Steam - Types
14.3 Steam - Transport
14.4 Steam - Purification

TURBINES

15.1 Steam Turbines - Types
15.2 Steam Turbines - Components

15.3 Steam Turbines - Auxillaries
15.4 Steam Turbines - Operation and Maintenance
15.5 Gas Turbines

COMBUSTION

16.1 Combustion - Process
16.2 Combustion - Types of Fuel
16.3 [illegible]on - Air and Fuel Gases
16.4 [illegible]on - Heat Transfer
16.5 Combustion - Wood

FEEDWATER

17.1 Feedwater - Types and Equipment
17.2 Feedwater - Water Treatments
17.3 Feedwater - Testing

GENERATORS

18.1 Generators - Types and Construction
18.2 Generators - Operation

AIR COMPRESSORS

19.1 Air Compressors - Types
19.2 Air Compressors - Operation and Maintenance

MISCELLANEOUS

20.1 Transformers
21.1 Circuit Protection
22.1 Installation - Foundations
22.2 Installation - Alignment
23.1 Trade Terms

# STATIONARY ENGINEER
## SUPPLEMENTARY REFERENCE DIRECTORY

Note: All reference packets are numbered on the upper right-hand corner of the respective cover page.

| Supplementary Packet # | Description | Related Training Module |
|---|---|---|
| 12.1 | Correspondence Course, Lecture 1, Sec. 2, Steam Generators, Types of Boilers I, S.A.I.T., Calgary, Alberta, Canada | 12.1 Boilers, Fire Tube Type |
| 12.2 | Correspondence Course, Lecture 2, Sec. 2, Steam Generators, Types of Boilers II, S.A.I.T., Calgary, Alberta, Canada | 12.2 Boilers, Water Tube Type |
| 12.3 | Correspondence Course, Lecture 2, Sec. 2, Steam Generators, Boiler Construction & Erection, S.A.I.T., Calgary, Alberta, Canada | 12.3 Boilers, Construction |
| 12.4 | Correspondence Course, Lecture 4, Sec. 2, Steam Generators, Boiler Fittings II, S.A.I.T., Calgary, Alberta, Canada | 12.4 Boilers, Fittings |
| 12.4 | Corresondence Course, Lecture 4, Sec. 2, Steam Generators, Boiler Fitting I, S.A.I.T., Calgary, Alberta, Canada | 12.4 Boilers, Fittings |
| 12.5 | Correspondence Course, Lecture 10, Sec. 2, Steam Generation, Boiler Operation, Maintenance, Inspection, S.A.I.T., Calgary, Alberta, Canada | 12.5 Boilers, Operation |
| 12.7 | Correspondence Course, Lecture 3, Sec. 2, Steam Generation, Boiler Details, S.A.I.T., Calgary, Alberta, Canada | 12.7 Boilers Heat Recovery Systems |
| 12.8 | Refer to reference packet 14.3/12.8 | |
| | | PUMPS |
| 13.1<br>13.2<br>13.4<br>13.6<br>13.7 | Correspondence Course, Lecture 9, Sec. 2, Steam Generator, Power Plant Pumps, S.A.I.T., Calgary, Alberta, Canada | 13.1 Types & Classification<br>13.2 Applications<br>13.4 Calculating Heat & Flow<br>13.6 Monitoring & Troubleshooting<br>13.7 Maintenance |
| 13.3<br>13.5 | Correspondence Course, Lecture 6, Sec. 3, Steam Generators, Pumps, S.A.I.T., Calgary, Alberta, Canada | 13.3 Construction<br>13.5 Operation |

| Supplementary Packet # | Description | Related Training Module |
|---|---|---|
| 14.3<br>12.8 | Correspondence Course, Lecture 6, Section 3, Steam Generators, Steam Generator Controls, S.A.I.T., Calgary, Alberta, Canada | 14.3 Steam, Transport<br>12.8 Boilers, Instruments & Controls |
| 14.4 | Correspondence Course, Lecture 11, Section 2, Steam Generators, Piping II, S.A.I.T., Calgary, Alberta, Canada | 14.4 Steam, Purification |
| 15.1 | Correspondence Course, Lecture 1, Sec. 4, Prime Movers & Auxiliaries, Steam Turbines, S.A.I.T., Calgary, Alberta, Canada | 15.1 Steam Turbines, Types |
| 15.2 | Correspondence Course, Lecture 4, Sec. 3, Prime Movers, Steam Turbines I, S.A.I.T., Calgary, Alberta, Canada | 15.2 Steam Turbines, Components |
| 15.3 | Correspondence Course, Lecture 2, Sec. 4, Prime Movers & Auxiliaries, Steam Turbine Auxiliaries, S.A.I.T., Calgary, Alberta, Canada | 15.3 Steam Turbines, Auxiliaries |
| 15.4 | Correspondence Course, Lecture 6, Sec. 3, Prime Movers, Steam Turbine Operation & Maintenance, S.A.I.T., Calgary, Alberta, Canada | 15.4 Steam Turbines, Operation & Maintenance |
| 15.5 | Correspondence Course, Lecture 8, Sec. 3, Prime Movers, Gas Turbines, S.A.I.T., Calgary, Alberta, Canada | 15.5 Gas Turbines |
| 16.2 | Boilers Fired with Wood and Bark Residues, D.D. Junge, F.R.L., O.S.U. 1975 | 16.2 Combustion Types of Fuel |
| 16.2 | Correspondence Course, Lecture 5, Sec. 2, Steam Generators, Fuel Combustion, S.A.I.T., Calgary, Alberta, Canada | 16.2 Combustion Types of Fuel |
| 16.3 | Correspondence Course, Lecture 5, Sec. 2, Plant Services, Fuel & Combustion, S.A.I.T., Calgary, Alberta, Canada | 16.3 Combustion, Air & Fuel Gases |
| 17.1 | Correspondence Course, Lecture 12, Sec. 3, Steam Generation, Water Treatment, S.A.I.T., Calgary, Alberta, Canada | 17.1 Feed water, Types & Operation |
| 17.2 | Correspondence Course, Lecture 12, Sec. 2, Steam Generation, Water Treatment, S.A.I.T., Calgary, Alberta, Canada | 17.2 Feed water, Water Treatments |

| Supplementary Packet # | Description | Related Training Module |
|---|---|---|
| 17.3 | Correspondence Course, Lecture 7, Sec. 2, Steam Generators, Boiler Feed Water Treatment, S.A.I.T., Calgary, Alberta, Canada | 17.3 Feed Water, Testing |
| 18.1 | Correspondence Course, Lecture 2, Sec. 5, Electricity, Direct Current Machines, S.A.I.T., Calgary, Alberta, Canada | 18.1 Generators, Types & Construction |
| 18.1<br>18.2 | Correspondence Course, Lecture 4, Sec. 5, Electricity, Alternating Current Generators, S.A.I.T., Calgary, Alberta, Canada | 18.1 Generators, Types & Construction<br>18.2 Generators, Operation |
| 19.1 | Corrspondence Course, Lecture 5, Sec. 4, Prime Movers & Auxiliaries, Air Compressor I, S.A.I.T., Calgary, Alberta, Canada | 19.1 Air Compressors, Types |
| 19.1<br>19.2 | Correspondence Course, Lecture 6, Sec. 4, Prime Movers & Auxiliaries, Air Compressors II, S.A.I.T., Calgary, Alberta, Canada | 19.1 Air Compressors, Types<br>19.2 Air Compressors, Operation & Maintenance |
| 20.1 | Basic Electronics, Power Transformers, EL-BE-51 | 20.1 Transformers |
| 21.1 | Correspondence Course, Lecture 7, Sec. 5, Electricity, Switchgear & Circuit, Protective Equipment, S.A.I.T., Calgary, Alberta, Canada | 21.1 Circuit Protection |
| 22.1 | Correspondence Course, Lecture 10, Sec. 3, Prime Movers, Power Plant Erection & Installation, S.A.I.T., Calgary, Alberta, Canada | 22.1 Installation Foundations |

## RECOMMENDATIONS FOR USING TRAINING MODULES

The following pages list modules and their corresponding numbers for this particular apprenticeship trade. As related training classroom hours vary for different reasons throughout the state, we recommend that the individual apprenticeship committees divide the total packets to fit their individual class schedules.

There are over 130 modules available. Apprentices can complete the whole set by the end of their indentured apprenticeships. Some apprentices may already have knowledge and skills that are covered in particular modules. In those cases, perhaps credit could be granted for those subjects, allowing apprentcies to advance to the remaining modules.

We suggest the the apprenticeship instructors assign the modules in numerical order to make this learning tool most effective.

## SUPPLEMENTARY INFORMATION

## ON CASSETTE TAPES

Tape 1: Fire Tube Boilers - Water Tube Boilers and Boiler Manholes and Safety Precautions

Tape 2: Boiler Fittings, Valves, Injectors, Pumps and Steam Traps

Tape 3: Combustion, Boiler Care and Heat Transfer and Feed Water Types

Tape 4: Boiler Safety and Steam Turbines

NOTE: The above cassette tapes are intended as additional reference material for the respective modules, as indicated, and not designated as a required assignment.

# 14.1

STEAM -- FORMATION AND EVAPORATION

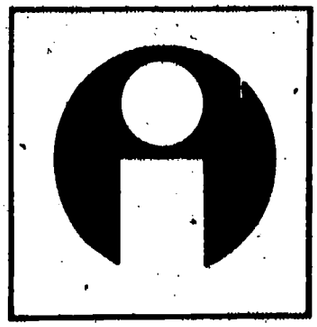
## Goal:

The apprentice will be able to describe steam formation and evaporation.

## Performance Indicators:

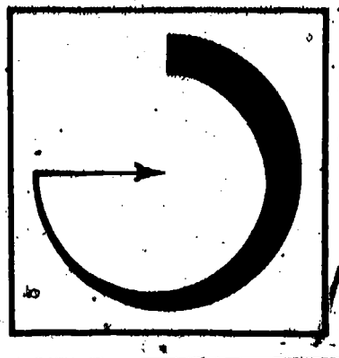
1. Describe temperatures for steam formation.
2. Describe types of heat.
3. Describe formation of steam.
4. Describe evaporation.

# Study Guide



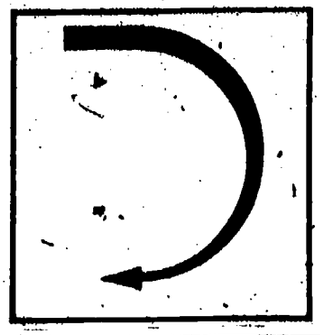
* Read the goal and performance indicators to find what is to be learned from package.
* Read the vocabulary list to find new words that will be used in package.
* Read the introduction and information sheets.
* Complete the job sheet.
* Complete the self-assessment.
* Complete the post-assessment.

# Vocabulary



* Celsius scale
* Condensation
* Evaporation
* Fahrenheit scale
* Latent heat
* Latent heat of fusion
* Latent heat of evaporation
* Saturation temperature
* Sensible heat
* Temperature of evaporation
* Temperature of vaporization
* Vapor

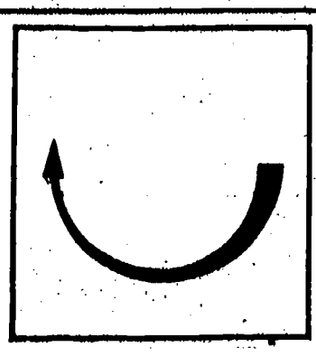
# Introduction



Steam formation requires water to be changed from a liquid to a vapor state. This requires that water be heated to the boiling point. Two types of heat are used in converting water to steam. One is a sensible heat that raises the temperature to boiling and a latent heat that will change the state of water without further rise in temperature.

The apprentice should have a theoretical understanding of the steam formation process.

# Information



## Temperatures

Heat is used to convert solids into liquids and liquids into gases. Steam is regarded as a vapor instead of a gas because it does not follow all of the rules of gaseous behavior. The process of converting water to steam requires 100°. The Fahrenheit scale which is common to American thought has a freezing point of 32° and a boiling point of 212°. Regardless of the measuring scale, water must reach boiling point before steam is produced.

The boiling point will vary at different elevations above sea level. Also, the boiling point will vary with the pressures that are placed upon the liquid. The 100° C is based on atmospheric pressure. Liquids under pressure will boil at a range of temperatures which are controlled by the pressure. Water will boil at high altitudes much quicker than at sea level.

## Types of Heat

Sensible heat is heat that can be sensed and measured with a thermometer. Latent heat is a hidden heat that may cause a state of change in another substance without changing the temperature of the substance. If ice is being changed into its liquid state, the melting temperature is 0°C. As the ice continues its melting, the temperature will remain at 0°C until it is water. When latent heat is used to convert a solid to a liquid, it is called the latent heat of fusion.

If latent heat is applied to water at 100°C, the water will change to a vapor state. The water will continue to boil at 100°C. The heat that converts liquids to a vapor form is called the latent heat of evaporation.

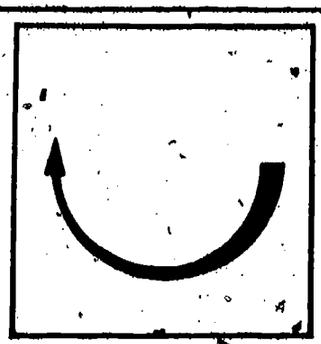
## Formation of Steam

Water is heated to the boiling point with sensible heat. After boiling point, the latent heat changes the water into steam. Steam is formed at the boiling point temperature. That temperature may be more or less than a 100°C, depending on the pressure in relation to atmospheric pressure. That boiling point is called the temperature of vaporization or temperature of evaporation or saturation temperature. That is the temperature at which steam formation takes place.

## Evaporation

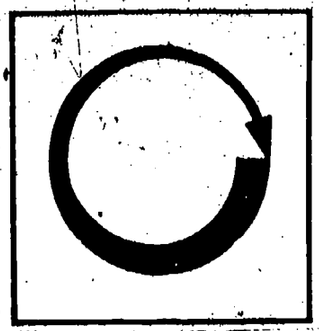
If we set a pan of water in the sun, it will slowly disappear through evaporation. If we add heat to the pan, the water will evaporate much quicker.

# Information



In the process of evaporation, the water simply turns into vapor form and floats away. In steam production, the process of evaporation is controlled by steam generation equipment. Condensation is the opposite of evaporation. As the vapor cools, it is converted back to a liquid state.

# Assignment



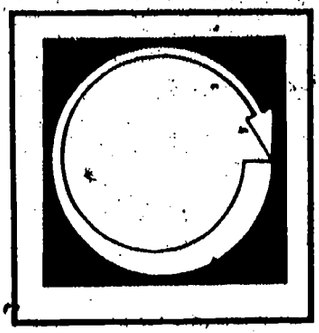
* Complete the job sheet.
* Complete the self-assessment and check answers..
* Complete the post-assessment and ask the instructor to check answers.

# Job Sheet

CHECK BOILING TEMPERATURE

* Obtain a Celsius scale thermometer that records beyond 100°C.
* Place a teapot of water on the burner and place thermometer in water so that it can be read. (Note temperature of water.)
* Light burner and bring water to boiling point. (Note temperature.)
* Allow water to continue boiling for 10 minutes. (Note temperature.)
* Which temperature readings show sensible heat?
* Which temperature readings show latent heat?
* What is the boiling point of water?

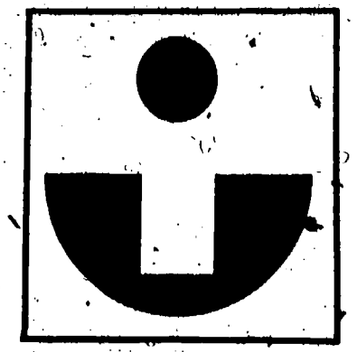
# Self Assessment



MATCH THE FOLLOWING TERMS AND PHRASES.

| | | |
|---|---|---|
| _____ | 1. Celsius scale | A. Changes liquid to gas |
| _____ | 2. Fahrenheit scale | B. Changes solid to liquid. |
| _____ | 3. Latent heat | C. Boiling point 100°. |
| _____ | 4. Latent heat of fusion | D. Changing of liquid to vapor. |
| _____ | 5. Sensible heat | E. Boiling point 212°. |
| _____ | 6. Latent heat of evaporation | F. Freezing point on Celsius. |
| _____ | 7. Temperature of evaporation | G. Hidden heat that changes forms of substances with changing in temperature. |
| _____ | 8. Condensation | H. The boiling point after adjustment for pressure. |
| _____ | 9. Evaporation | I. The opposite of evaporation. |
| _____ | 10. 0° | J. Heat that can be sensed or measured. |

# Self Assessment Answers



C 1.

E 2.

G 3.

B 4.

J 5.

A 6.

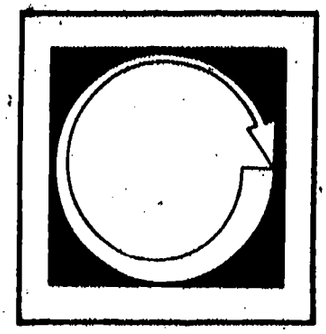
H 7.

I 8.

D 9.

F 10.

# Post Assessment



1. The _____ scale has a freezing point of 32° and a boiling point of 212°.

2. The _____ scale has a freezing point of 0 and a boiling point of 100°.

3. The exact point at which water boils is determined by the _____ on the water.

4. Steam is regarded as a _____ because it does not behave by the rules of most gases.

5. A heat that can be sensed and measured is called _____ heat.

6. A hidden heat that changes water to steam without increasing the temperature is called _____ heat.

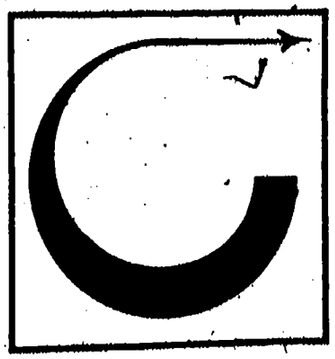
7. A heat that converts a solid into a liquid is called the latent heat of _____.

8. The exact boiling point where steam is formed is called the temperature of _____.

9. _____ is the opposite of evaporation.

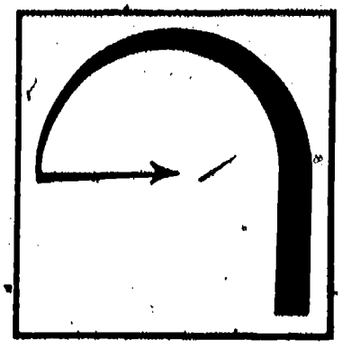
10. The vaporization of a liquid is called _____.

# Instructor Post Assessment Answers



1. Fahrenheit
2. Celsius
3. Pressure
4. Vapor
5. Sensible
6. Latent
7. Fusion
8. Vaporization or evaporation or saturation
9. Condensation
10. Evaporation

# Supplementary References



* Select own reading material for this package.

INSTRUCTIONAL LEARNING SYSTEMS

# 14.2

STEAM -- TYPES

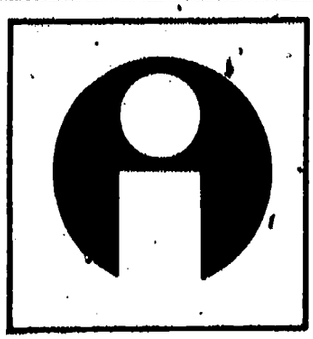
## Goal:

The apprentice will be able to describe types of steam.

## Performance Indicators:

1. Describe saturated steam.
2. Describe dry steam.
3. Describe wet steam.
4. Describe superheated steam.
5. Describe steam tables.

# Study Guide



* Read the goal and performance indicators to find what is to be learned from package.
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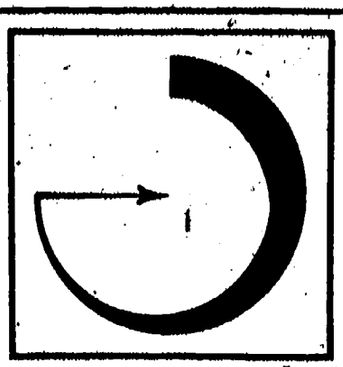
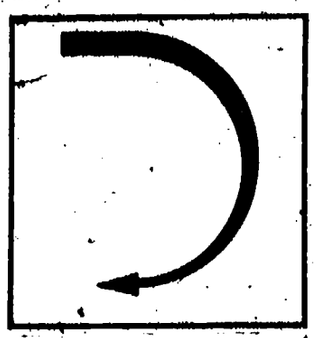
* Complete the job sheet.
* Complete self-assessment.
* Complete post-assessment.



# Vocabulary

* Dry saturated steam
* Saturated steam
* Steam tables
* Thermodynamic properties
* Wet steam

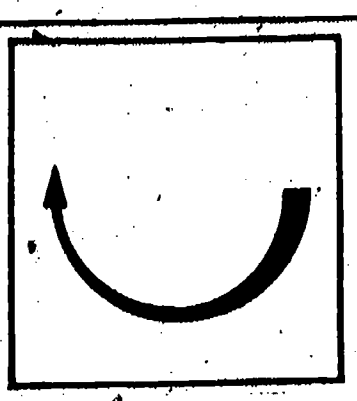
# Introduction



Although all steam is formed at the temperature of evaporation, it will differ in its thermodynamic properties. These differences can affect the efficiency of plant operation unless they are understood.

Some steam has heavy concentrations of suspended water particles which can create problems for turbine blades. Most plants use superheaters to raise the temperature of the steam beyond the temperature of evaporation. An operator must understand the basic types of steam in order to deal with its applications in power production.

# Information



Water turns to steam when heated to a 100°C at atmospheric pressure. This boiling point temperature is the saturation temperature. The saturation temperature will vary according to the pressure on the water.

Saturated Steam

Saturated steam is steam at the temperature of saturation or evaporation. It is steam that has just undergone conversion from the liquid to a vapor state.

Wet Steam

Saturated steam with particles of water suspended within the steam is called wet steam.

Dry Saturated Steam

Saturated steam without suspended water particles is called dry saturated steam.

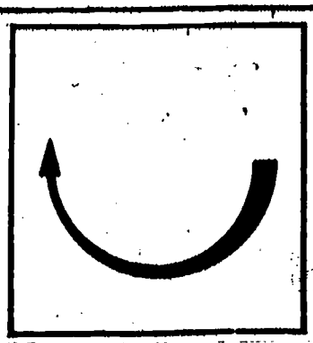
Superheated Steam

Steam cools and starts reverting to water. This creates a wet steam that is undesirable. To avoid wet steam, saturated steam is heated beyond the temperature of saturation. Steam with temperatures higher than saturation levels is called superheated steam. Superheated steam is used in turbines so that erosion of blades by wet steam can be avoided.

Steam Tables

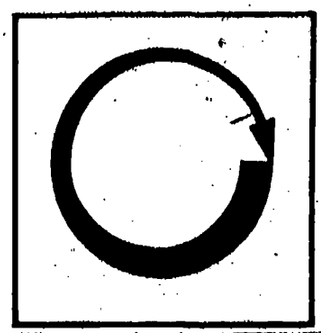
The properties of steam will vary with the pressure. Steam tables have been developed to show the thermodynamic properties of steam at various pressures. The thermodynamic properties include volume, latent and sensible heat values, relationships of heat and pressure and internal energy values of steam. Steam tables are available for saturated and superheated steam. The operator must know how to read the steam tables and interpret the information for practical applications. The following steam table shows the saturation temperatures under pressures ranging from 1/4 pound to 3206 pounds absolute.

# Information



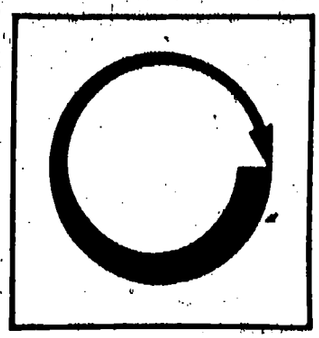
| PRESS. ABS. | TEMP. °F | PRESS. ABS. | TEMP. °F | PRESS. ABS. | TEMP. °F | PRESS. ABS. | TEMP. °F | PRESS. ABS. | TEMP °F | PRESS. ABS. | TEMP. °F |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.25 | 59.30 | 50 | 281.01 | 240 | 397.37 | 430 | 451.73 | 780 | 510.86 | 1900 | 628.58 |
| 0.50 | 79.58 | 60 | 292.71 | 250 | 400.95 | 440 | 454.02 | 775 | 514.59 | 2000 | 635.82 |
| 0.75 | 92.29 | 70 | 302.92 | 260 | 404.42 | 450 | 456.28 | 800 | 518.23 | 2100 | 642.77 |
| 1.0 | 101.74 | 80 | 312.03 | 270 | 407.78 | 460 | 458.50 | 825 | 521.79 | 2200 | 649.46 |
| 1.5 | 115.69 | 90 | 320.27 | 280 | 411.05 | 470 | 460.68 | 850 | 525.26 | 2300 | 655.91 |
| 2.0 | 126.08 | 100 | 327.81 | 290 | 414.23 | 480 | 462.82 | 875 | 528.66 | 2400 | 662.12 |
| 2.5 | 134.44 | 110 | 334.77 | 300 | 417.33 | 490 | 464.93 | 900 | 531.98 | 2500 | 668.13 |
| 3.0 | 141.48 | 120 | 341.25 | 310 | 420.35 | 500 | 467.01 | 925 | 535.24 | 2600 | 673.94 |
| 4.0 | 152.97 | 130 | 347.32 | 320 | 423.29 | 520 | 471.07 | 950 | 538.42 | 2700 | 679.55 |
| 5.0 | 162.24 | 140 | 353.02 | 330 | 426.16 | 540 | 473.01 | 975 | 541.55 | 2800 | 684.99 |
| 7.0 | 176.85 | 150 | 358.42 | 340 | 428.97 | 560 | 478.85 | 1000 | 544.61 | 2900 | 690.26 |
| 9.0 | 188.28 | 160 | 363.53 | 350 | 431.72 | 580 | 482.58 | 1100 | 556.31 | 3000 | 695.36 |
| 11.0 | 197.75 | 170 | 368.41 | 360 | 434.40 | 600 | 486.21 | 1200 | 567.22 | 3100 | 700.31 |
| 13.0 | 205.88 | 180 | 373.06 | 370 | 437.03 | 620 | 489.75 | 1300 | 577.46 | 3200 | 705.11 |
| 14.6 "0" GAGE PRESS | 212.00 | 190 | 377.51 | 380 | 439.60 | 640 | 493.21 | 1400 | 587.10 | 3206 | 705.40 |
| 15 | 213.03 | 200 | 381.79 | 390 | 442.12 | 660 | 496.58 | 1500 | 596.23 | 3300 | 705.40 |
| 20 | 227.96 | 210 | 385.90 | 400 | 444.59 | 680 | 499.88 | 1600 | 604.90 | 3500 | 705.40 |
| 30 | 250.33 | 220 | 389.86 | 410 | 447.01 | 700 | 503.10 | 1700 | 613.15 | 4000 | 705.40 |
| 40 | 267.25 | 230 | 393.68 | 420 | 449.39 | 720 | 506.25 | 1800 | 621.03 | 5000 | 705.40 |

# Assignment



* Complete job sheet.
* Complete the self-assessment and check answers.
* Complete the post-assessment and ask the instructor to check your answers.

# Job Sheet



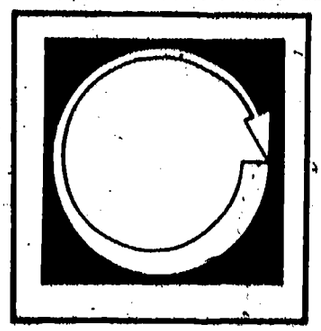
Using a saturated steam table, find the saturation temperatures at the following pressures.

1. 14.6 pounds
2. 40 pounds
3. 420 pounds
4. 1600 pounds
5. 3206 pounds

What is atmospheric pressure at sea level?

What is absolute pressure?

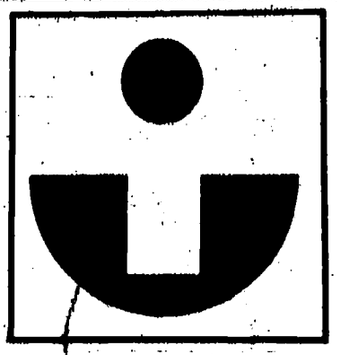
# Self Assessment



Match the following terms and phrases.

| | | |
|---|---|---|
| ____ | 1. Saturated steam | A. Steam with temperatures higher than temperature of evaporation. |
| ____ | 2. Dry steam | B. Steam with suspended water particles. |
| ____ | 3. Superheated steam | C. Steam without suspended water particles. |
| ____ | 4. Wet steam | D. Shows thermodynamic properties of steam. |
| ____ | 5. Steam tables | E. Steam at temperature of evaporation. |

# Self Assessment Answers



E 1.

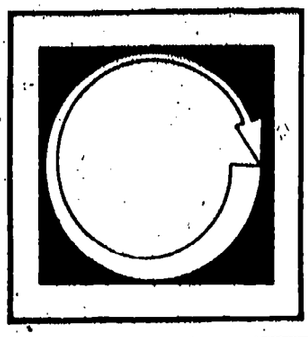
C 2.

A 3.

B 4.

D 5.

# Post Assessment



1. Where can an operator find the thermodynamic values of steam at various levels of pressure?

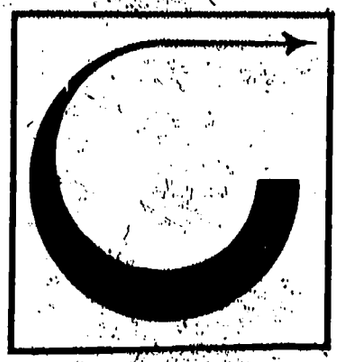
2. Why is superheated steam used for turbine operation?

3. What is saturated steam called when it has water particles suspended within the steam?

4. What is steam called when at the temperature of evaporation?

5. What is the temperature of evaporation at atmospheric pressure?

# Instructor Post Assessment Answers



1. Steam tables

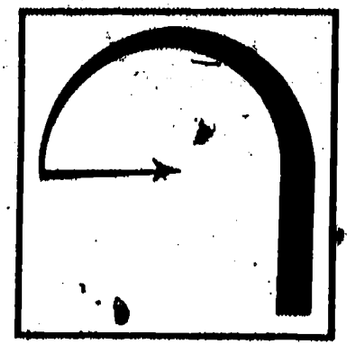
2. Prevent erosion of turbine blades by wet steam.

3. Wet steam

4. Saturated steam

5. 100°C

# Supplementary References



* Saturated Steam Tables provided by instructor or from reference library.

INSTRUCTIONAL LEARNING SYSTEMS

# 14.3

STEAM -- TRANSPORT

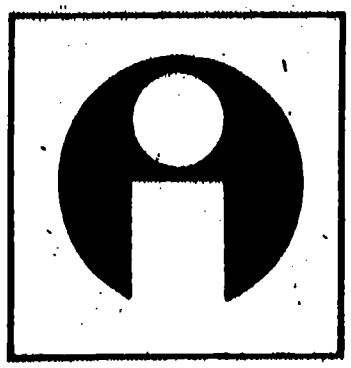
## Goal:

The apprentice will be able to describe steam transport.

## Performance Indicators:

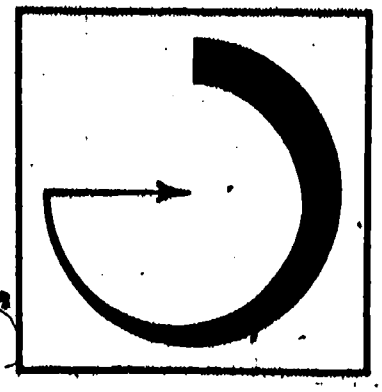
1. Describe condensate removal.
2. Describe piping, pipe insulation and valve control.
3. Describe separators and traps.

# Study Guide



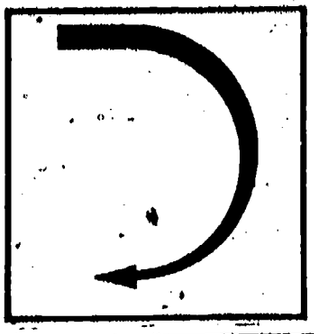
* Read the goal and performance indicators to find what is to be learned from package.
* Read the vocabulary list to find new words that will be used in package.
* Read the introduction and information sheets.
* Complete the job sheet.
* Complete self-assessment.
* Complete post-assessment.

# Vocabulary



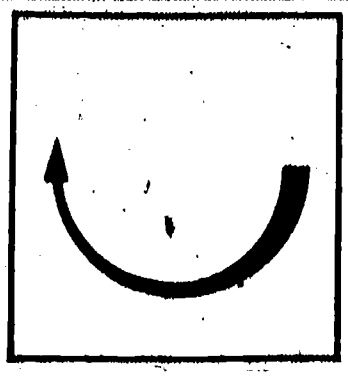
* Drip or drain line
* Insulation
* K value
* Steam separator
* Steam trap
* Thermal conductivity
* Water hammer

# Introduction



This package briefly describes the movement of steam through piping and provisions for removing condensate from the steam line. Other packages have dealt with the specifics of piping, steam purification and valves. Although these items are important to the transport of steam, they will not be repeated in detail in this package.

# Information



The transport of steam through piping must be carefully controlled. Water must be continually drained from the steam. The presence of water in the steam will create the condition known as water hammer. Water hammer can cause an explosion in the lines and equipment damage. Air and carbon dioxide must also be removed from the lines. Drainage must be provided for all types of steam including superheated steam. Any cooling of the steam produces condensate which can damage turbines and other equipment. Drains and drip lines must be installed at all points where condensate is likely to collect.

Drip or Drain Lines

Drip or drain lines should be installed at natural drainage points such as:

* At the ends of mains
* Ahead of risers
* Ahead of expansion joints and bends
* Ahead of valves and regulators

A drip leg should be provided at each drainage point. The drip leg should be the same diameter as the pipe. The drip leg allows gravity drainage of water from the steam flow.

Water Hammer

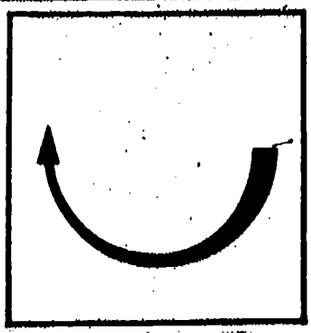
Water hammer is a condition in the line that results in shock waves that resemble hammer blows. It usually occurs in steam lines as a result of condensate in the line. The water or condensate tends to trap pockets of steam. The cooler water condenses the steam which creates a pressure pocket. Equalization of this pressure pocket causes shock waves in the pipe.

Most water hammer can be avoided by installing drains, drip pockets and traps to remove the condensate from the steam lines. Steam valves should be opened slowly, with drain valves open, allowing the line to warm up. Hot steam in a cold line can create condensate and water hammer.

Pipe Insulation

Power plant pipe is covered with insulation to prevent heat loss and condensation. The insulation is also a safety feature to protect employees from getting burns. The material should be of high insulation value and able to withstand corrosion. Insulation materials are selected on the basis of their thermal conductivity K value. The K value indicates the amount of heat that will

# Information



be transmitted through a material. Since insulation is the exact opposite of conductivity, the lower the K value of a material, the better is its insulating quality. Some common insulating materials and their K values are:

| | |
|---|---|
| * Plastic foams | .09 - .28 K |
| * Glass fiber | .29 - .35 K |
| * Magnesia | .35 - .42 K |
| * Calcium silicate | .37 - .60 K |
| * Asbestos | .37 - .72 K |
| * Reflective metal | .58 - .66 K |
| * Diatomaceous silica | .70 - .80 K |

Valves

Several types of valves are used in the transport of steam. Valves are selected according to their specific functions in the movement of steam. Valves have been discussed in detail in other packages on boiler piping and boiler fittings.

Pipe

There are many types and sizes of pipe in a power plant. Pipe is selected to withstand specific conditions of pressure, temperature and resistance to corrosion. Pipe construction is discussed in a package on boiler piping and will not be repeated here. The selection of the proper diameter pipe and pipe material is important to safe and efficient operation of a steam plant.

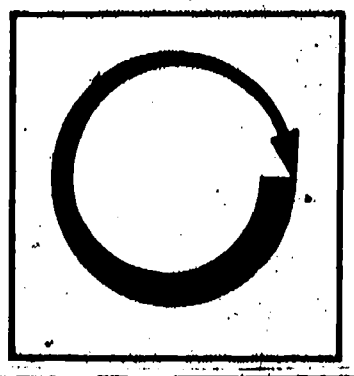
Steam Separators and Steam Traps

Steam separators remove condensate from steam. They are commonly called steam purifiers. The separators are designed with baffles or centrifugal devices that separate the water from the steam to prevent water hammer and erosion caused by wet steam.

A steam trap is a device which removes water from steam separators and steam lines without the loss of steam. Several types of traps are used for this purpose.

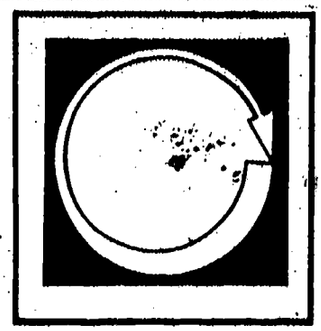
A more detailed treatment of steam purifiers and steam traps is included in the next package of this series -- Steam Purification.

# Assignment



* Read page 1, 20-34 in supplementary reference.
* Complete the self-assessment and check your answers.
* Complete the post-assessment and have the instructor check your answers.

# Self Assessment



1. List 3 places where drip or drain lines should be installed?

2. What causes water hammer in steam lines?

3. How can water hammer be prevented?

4. On insulation materials, what does the K value mean?

5. Which of the following insulation material have the best insulation quality?

   * Asbestos .5 K
   * Glass fiber .3 K

# Self Assessment Answers

1. At end of mains, ahead of risers, ahead of expansion joints and bends, ahead of valves and regulators.

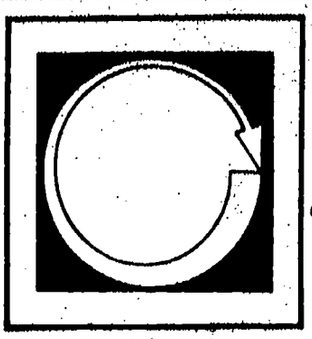
2. Condensate

3. Removing condensate from steam lines and warming up lines before steam flow.

4. Thermal conductivity

5. Glass fiber. The lower value is best.

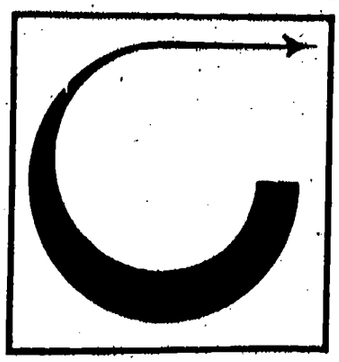
# Post Assessment



Match the following terms and phrases:

| | | | |
|---|---|---|---|
| _____ | 1. Water hammer | A. | Thermal conductivity |
| _____ | 2. Drip leg | B. | Device for removal of water from separators |
| _____ | 3. K value | C. | Steam purifier |
| _____ | 4. Steam trap | D. | Should be installed at each drainage point |
| _____ | 5. Steam separator | E. | Caused by condensate in steam line |

# Instructor Post Assessment Answers



E 1.

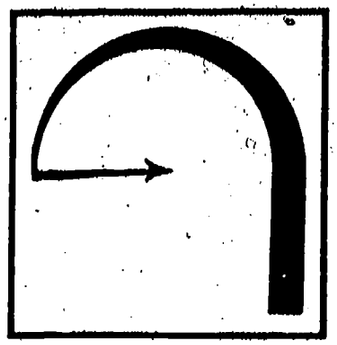
D 2.

A 3.

B 4.

C 5.

# Supplementary References



* Correspondence Course. Lecture 11, Section 2, Second Class. Steam Generators. Southern Alberta Institute of Technology. Calgary, Alberta, Canada.

INSTRUCTIONAL LEARNING SYSTEMS

# 14.4

STEAM -- PURIFICATION

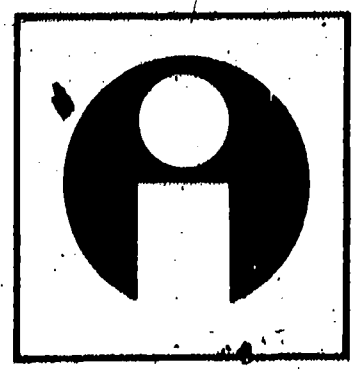
## Goal:

The apprentice will be able to describe the process of steam purification.

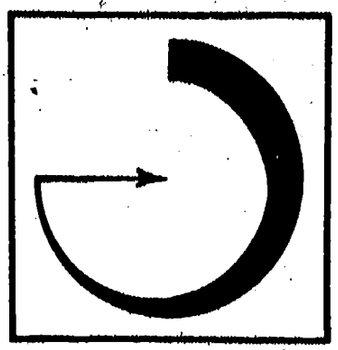
## Performance Indicators:

1. Describe steam separation.
2. Describe steam scrubbers.
3. Describe superheaters.
4. Describe steam traps.

# Study Guide



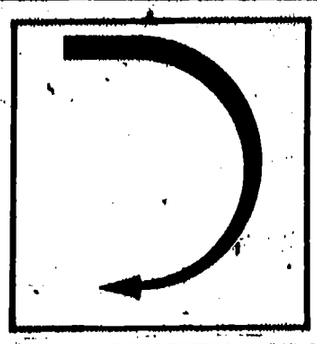
* Read the goal and performance indicators to find what is to be learned from package.
* Read the vocabulary list to find new words that will be used in package.
* Read the introduction and information sheets.
* Complete the job sheet.
* Complete self-assessment.
* Complete post-assessment.



# Vocabulary

* Baffle type separator
* Balanced pressure trap
* Ball float trap
* Centrifugal type separator
* Controlled disc trap
* Inverted bucket trap
* Liquid expansion trap
* Mechanical traps
* Metallic expansion trap
* Scrubber elements
* Sediment separator
* Steam scrubber
* Steam separator
* Superheater
* Thermodynamic traps
* Thermostatic traps
* Tilting disc impulse trap

# Introduction



The purity of steam that enters the turbine will determine its efficiency of operation and its machine life. Steam purification refers to the removal of condensate from steam.

Several pieces of specialized equipment contribute to the purification process. Essentially, steam separators, scrubbers and superheaters remove the moisture from steam. Steam traps collect and dispose of the condensate without a loss of steam. Although steam separators are commonly referred to as purifiers, scrubbers, superheaters and traps are vital to completion of the purification process.

# Information

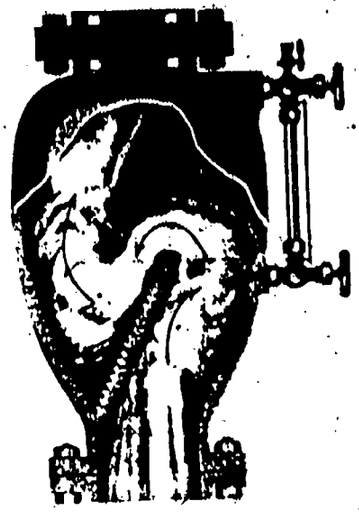
Steam purification refers to the removal of condensate from the steam along with air and carbon dioxide. As steam flows through a pipe it tends to cool and condense. This produces condensate (water) which can cause a rupture of the piping due to water hammer or cause erosion damage to the turbine blades. The major piece of equipment for steam purification is the steam separator.

Steam Separators

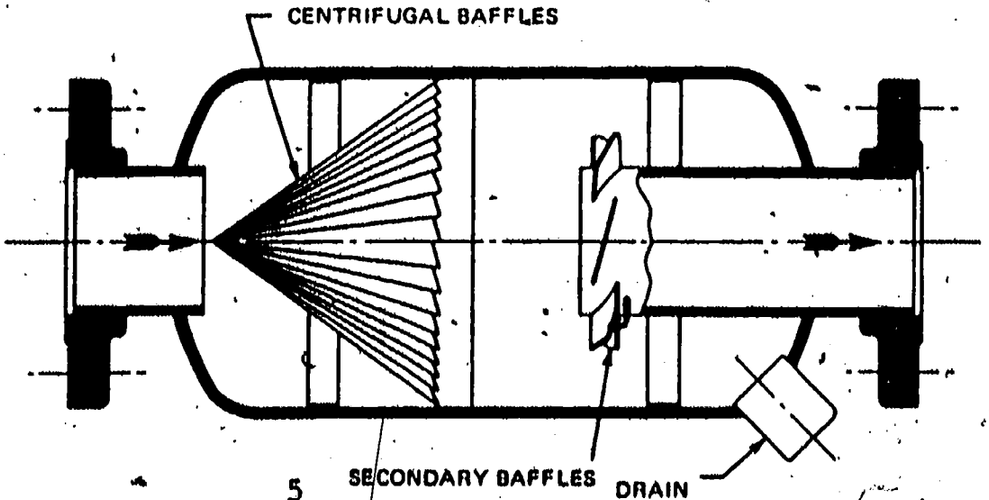
There are two basic types of steam separators:

1. Baffle type
2. Centrifugal type

The baffle type steam separator is usually located in the main steam drum and is part of the drum internals. It has corrugated baffles and walls which collect moisture and reverses the steam flow. The reversal of steam flow slings the water particles out of the steam.



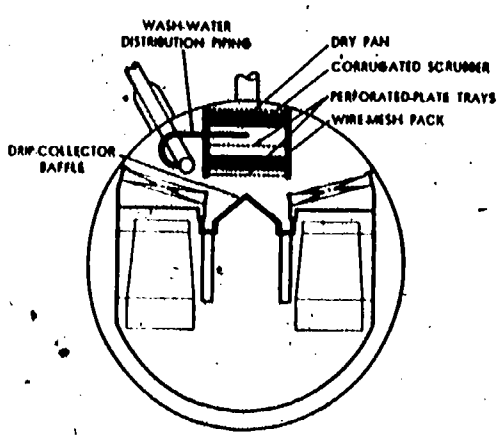
The centrifugal type separator uses centrifugal baffles to swirl the steam which tosses the water particles to the side walls. The separated water drains out. The purified steam passes through the baffles to the outlet.



# Information

## Steam Scrubbers

A second stage of purification is performed by steam scrubbers. A scrubber consists of corrugated steel plates or scrubber elements. The scrubber elements are closely arranged and overlap slightly. The steam is forced to change directions as it passes over the corrugated sections of the scrubber. Moisture and solids that escaped through the separator are thrown out of the steam flow. The water drains out and the steam moves upward to the outlet.



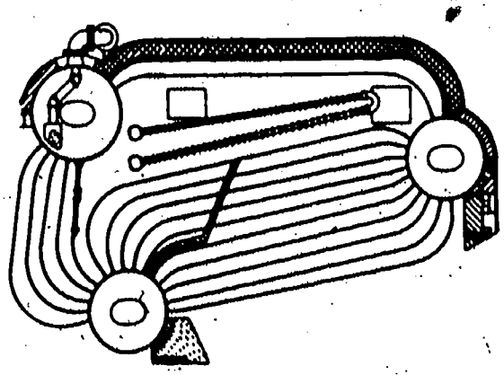

Steam Washer

## Superheater

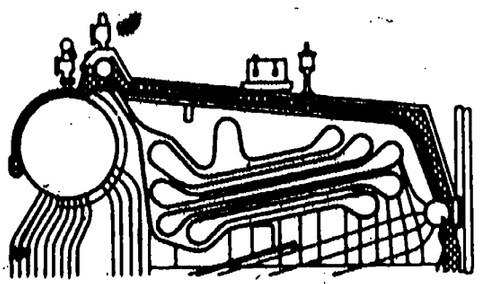
After the saturated steam leaves the drum it is piped to a specialized heating surface that is called a superheater. The superheater wrings all remaining moisture from the steam by heating the steam well beyond the temperature of saturation. This is the third stage of the purification process. A superheater consists of several parallel tube circuits that run between headers.

Superheaters are classified according to the way in which they receive heat -- radiant, convection or a combination. They can be classified according to the location of the headers -- overdeck, interdeck, interbank and intertube. Some superheater arrangements are shown below and on the next page.

# Information



Drainable overdeck superheater employing a system of fins for extending surface



This combined radiant and convection superheater, arranged in overdeck position, has extra large radii at the bends

## Steam TRAPS

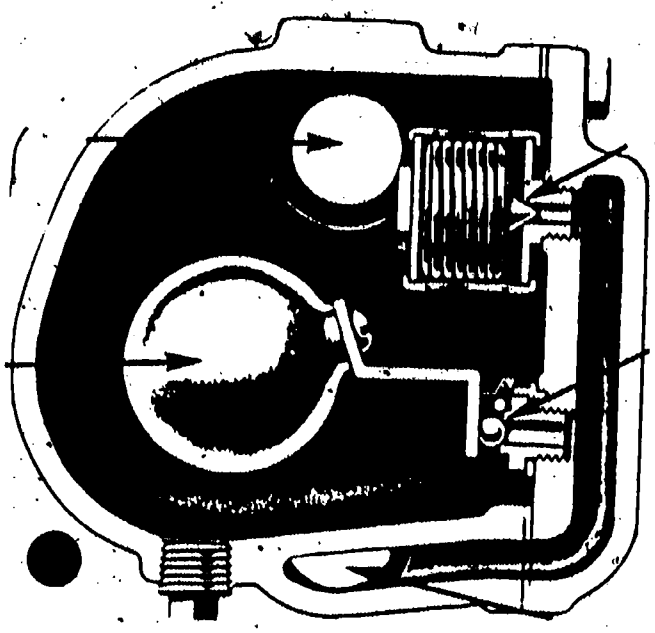
Steam traps are an important part of the steam purification process. The water removed in separation must be drained off without allowing steam to escape at the same time. Several types of traps have been devised to remove the water from separators and lines. These are classified according to the principles of operation.

1. Mechanical Traps
   a. Ball float type
   b. Inverted bucket type
2. Thermostatic Traps
   a. Balanced pressure type
   b. Liquid expansion type
   c. Metallic expansion type
3. Thermodynamic Traps
   a. Tilting disc impulse type
   b. Controlled disc trap

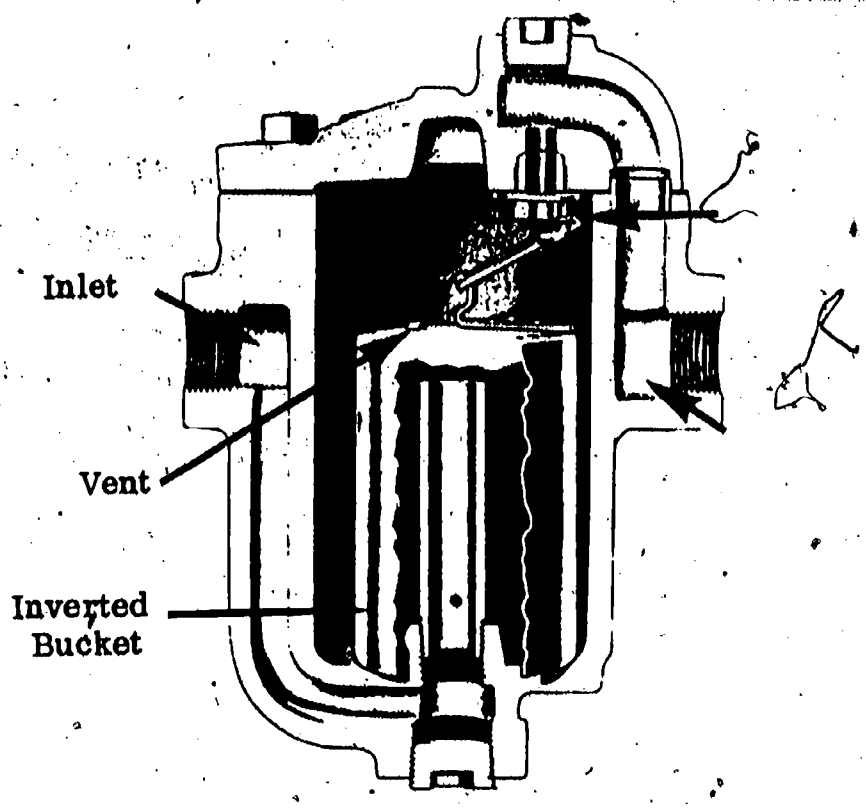


The mechanical traps operate by a float mechanism which responds to the difference in densities of steam and water. Both the ball float and inverted bucket traps operate on mechanical principles.

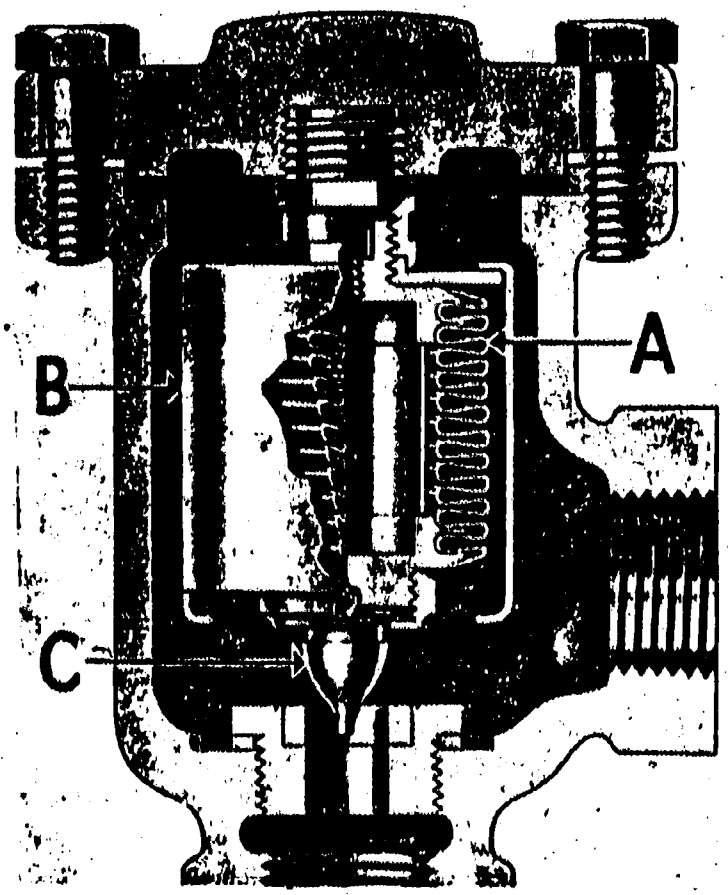
# Information



Ball Float Trap

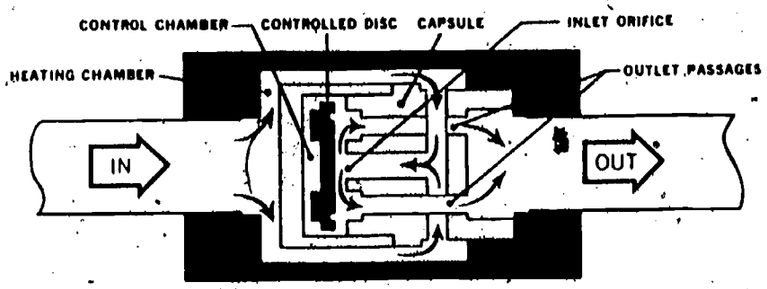



The thermostatic trap operates on the difference in temperature between water and steam. The hot condensate enters the trap and heats an alcohol mixture that is encased in the trap. The heating of the alcohol causes increased pressure and the discharge valve closes. As the condensate cools, the pressure will be reduced to open the valve. A balanced pressure trap is shown.



# Information

Thermodynamic traps respond to the heat of the steam and condensate. A controlled disc trap diagram is featured below.

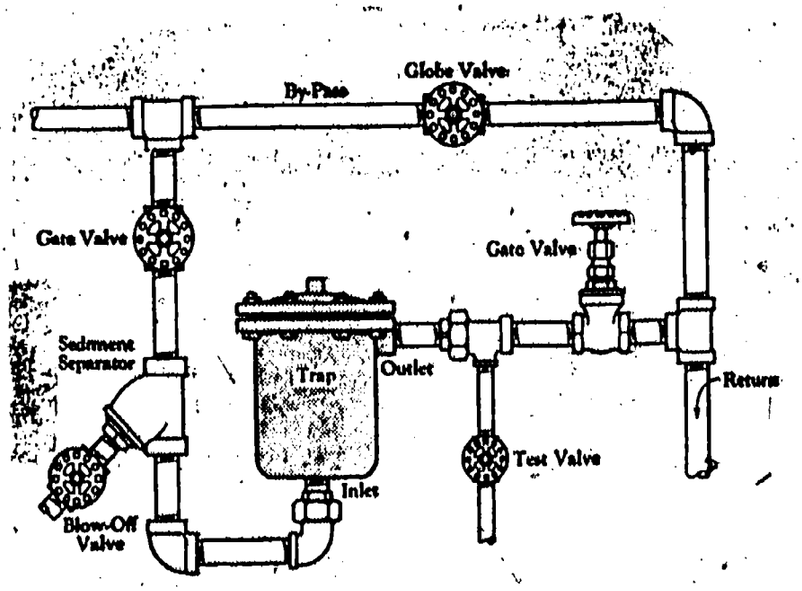



Sediment Separator

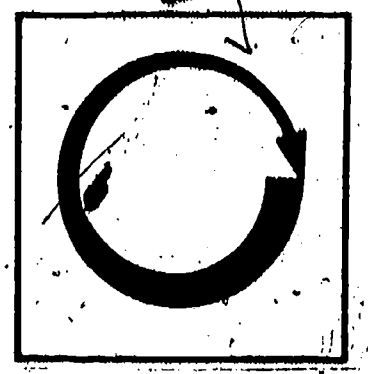
Some provision must be made for keeping scale deposits from fouling up the steam traps. The traps should be fitted with strainers to screen out debris.

Trap Piping

The installation of traps should allow for clean out and repair. A typical arrangement for trap piping is shown in the following diagram.

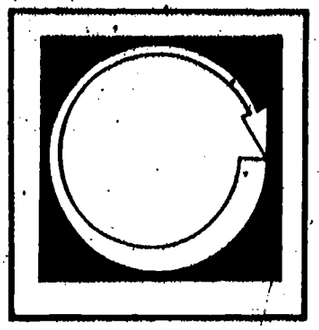


# Assignment



* Read pages 1 - 15 in supplementary reference.
* Complete self-assessment and check answers.
* Complete post-assessment and have instructor check answers.

# Self Assessment



Match the following terms and phrases.

| | | |
|---|---|---|
| ____ | 1. Steam purification | A. A type of superheater |
| ____ | 2. Baffle type | B. Second stage of purification |
| ____ | 3. Balanced pressure | C. First stage of purification |
| ____ | 4. Inverted bucket | D. Removal of condensate from steam. |
| ____ | 5. Tilting disc impulse | E. Third stage of purification |
| ____ | 6. Convection type | F. A thermodynamic trap |
| ____ | 7. Steam scrubber | G. A type of steam separator |
| ____ | 8. Steam separator | H. A mechanical trap |
| ____ | 9. Superheater | I. Corrugated steel plates |
| ____ | 10. Scrubber element | J. A thermostatic trap |

# Self Assessment Answers

D 1.

G 2.

J 3.

H 4.

F 5.

A 6.

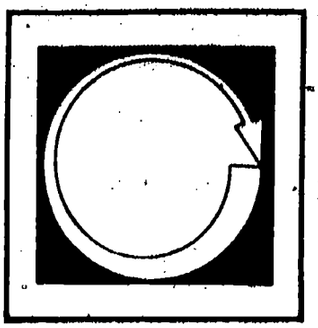
B 7.

C 8.

E 9.

I 10.

# Post Assessment



1. List two major types of steam separators.

2. Where are steam separators usually located in the steam plant?

3. What is steam purification?

4. What equipment is used in the second stage of steam purification?

5. What are the corrugated steel plates of a scrubber called?

6. What is the name of the specialized heating surface that takes over the third stage purification of steam?

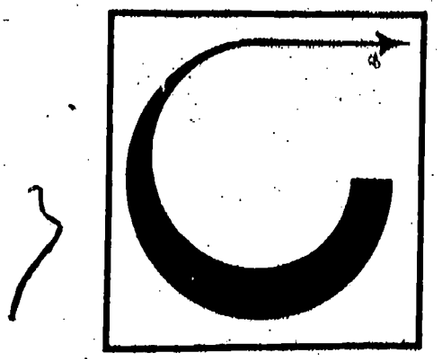
7. List three types of thermostatic traps.

8. List two types of mechanical traps.

9. List two types of thermodynamic traps.

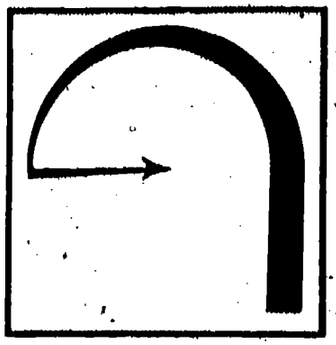
10. List three types of superheaters based on the way they receive heat.

# Instructor Post Assessment Answers



1. Baffle, centrifugal
2. Steam drum
3. Removal of condensate
4. Steam scrubbers
5. Scrubber elements
6. Superheater
7. Balanced pressure, liquid expansion, metallic expansion
8. Ball float, inverted bucket
9. Tilting disc impulse, controlled disc
10. Radiant, convection and combination

# Supplementary References



* Correspondence Course. Lecture 11, Section 2, Second Class. Steam Generators. Southern Alberta Institute of Technology. Calgary, Alberta, Canada.