**UA STAR
MASTERY EXAM**

**Pipe Fitter
Study Guide**

International Pipe Trades Joint Training Committee, Inc

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ACKNOWLEDGEMENTS

FORWARD

The International Pipe Trades Training Committee and the United Association Training Department have developed the following Study Guide to assist you in locating information in UA textbooks, which relate to the 11 categories and 28 tasks identified during the DACUM (Develop A CurriculuM) process administered by Ferris State University. The DACUM is an in-depth job and task analysis, which serves as the base for the UA STAR exam.

The 12 categories and 44 tasks identified during the DACUM are included in this Study Guide so that you see, first-hand, the results of the study and the items that you can expect to encounter on the UA STAR exam. Each category and task is numbered, and each task is broken into a number of smaller jobs, which a pipe fitter would be expected to perform in order to complete the task.

> **Below each task you will find an underlined paragraph that looks like this and contains general reference to UA textbooks.**

You will find that the UA STAR exam is a comprehensive exam. It is designed to test the knowledge of the experienced pipe fitter. As such, this Study Guide is not intended to be a reference for the inexperienced pipe fitter to use in preparing for the exam. It is not expected that the inexperienced pipe fitter will be able to successfully compete the exam based on the Study Guide and the information contained in UA textbooks.

It is expected that the UA STAR test candidate is the pipe fitter who has completed the UA training and has gained several years of experience in the field. Many of the tasks and jobs identified in the DACUM are those, which can only be learned by doing. The test candidate, who expects to achieve success on the UA STAR exam by merely using the Study Guide to locate information in textbooks, will likely be disappointed.

It is recognized that even the best pipe fitter does not work in all areas of the industry. Further, some knowledge can be forgotten through lack of use. As such, it is recommended that you study a number of UA textbooks in preparing for the UA STAR exam. A list is provided below this paragraph. These texts were cited throughout the Study Guide. You may wish to review those texts where you feel you need knowledge. In addition, there are many other excellent books on the market, which can serve as reference for you. They are far too numerous to list. You may know of some of them or even own them. Feel free to use them in your studies.

UA textbooks use as reference in this Study Guide

Advanced Plan Reading and Related Drawing
Air Conditioning
Gas Tungsten Arc-Welding
Hydronic Heating and Cooling
Instrumentation and Process Control
Job Safety and Health
Pipe Bending
Pipe, Fittings, Valves, Supports and Fasteners
Oxy-Fuel Cutting and Welding and Shielded Metal-Arc Welding
Pneumatic Controls
Pumps
Refrigeration (2 volume set)
Related Mathematics
Related Science
Rigging
Soldering and Brazing
Steam Systems
Piping Handbook and Offset Formulas

Some UA textbooks contain questions, which provide excellent practice material and act as a learning tool. If you spend time and answer the questions at the back of the texts successfully, you will improve you chances of success on the UA STAR exam.

This Study Guide also contains practice questions. All questions are multiple choices, with four possible answers. Most questions contain explanations for each of the correct and incorrect answers. The questions are designed to help you review some of the material that you will need to know when taking the exam.

The UA STAR exam is a tough test. With some hard work, you can be successful in passing it. Good luck!

Category A: **Piping and Tubing**

Task 1.   **Cut and join steel, chromium and stainless pipe**

Measure steel pipe
Cut steel with torch
Cut with saws (band, hack, reciprocation, etc.)
Cut with pipe cutters
Lift with proper lifting equipment
Join steel pipe to steel using flanges, welding, thread
Join steel pipe to copper using dielectric fittings and thread
Join pipe using grooved ends

Prepare ends of pipe appropriately per joining process and properly fit them
Identify percentage of chrome in pipe in order to determine proper cutting method

Reference
Information of these procedures can be found:
         Pipe, Fittings, Valves, Supports and Fasteners
         Oxy-Fuel Cutting and Welding and Shielded Metal-Arc Welding

Task 2.   **Cut and join copper pipe and tubing**

Measure copper pipe
Cut using various methods: tubing cutter, saws, etc.
Identify class of copper piping and tubing (K, L, M, etc.)
Join copper to various pipes: copper, brass, steel, etc.
Join using various methods: soldering, brazing, welding, thread, compression,
                              dielectric, flaring,etc.
Prepare ends appropriately including cleaning and reaming
Bend copper tubing

Reference
Information of these procedures can be found:
         Soldering and Brazing

Task 3:   **Cut and join plastic pipe**

Measure pipe
Cut using various methods: tubing cutter, saws, etc.
Identify types of plastic piping (PVC, CPVC, ABS, etc.)
Join plastic to various pipes: copper, brass, steel, etc.
Join using various methods: gluing, welding, thread, etc.
Prepare ends appropriately including cleaning

Reference
Information of these procedures can be found:
        Related Science

Task 4:   **Hang pipe using pipe hangers, supports, anchors, guides and fasteners**

Identify various types of pipe hangers and clamps: clevis, roller, beam, etc.
Use various pipe guides
Install pipe anchors
Identify types of joints: welded, screwed, flanged, etc.
Cut using various methods: tubing cutter, saws, etc.
Identify class of copper piping and tubing (K, L, M, etc.)
Join copper to various pipes: copper, brass, steel, etc.
Join using various methods: soldering, brazing, welding, thread, compression,
                              dielectric, flaring,etc.
Prepare ends appropriately including cleaning and reaming
Bend copper tubing

Reference
Information of these procedures can be found:
        Pipe, Fittings, Valves, Supports and Fasteners

Task 5:   **Install expansion joints**

Identify various expansion joints
Identify need for expansion joints
Properly install and anchor expansion joints

Reference
Information of these procedures can be found:
Related Science
Steam Systems
Hydronic Heating and Cooling

Task 6:   **Install valves**

Identify types of valves: gate, globe, ball, relief, check, butterfly, mixing,
                                diverting, control, etc.
Select appropriate valve for the application: positive shut-off, throttling, etc.

Reference
Information of these procedures can be found:
Pipe, Fittings, Valves, Supports and Fasteners

Task 7:   **Perform pipe fabrication**

Determine scope of job
Secure and interpret appropriate drawing of sketch
Create scaled drawing
Create templates if necessary
Measure pipe
Join piping material as specified
Identify location
Install pipe

Reference
Information of these procedures can be found:
Advanced Plan Reading and Related Drawing
Piping Handbook and Offset Formulas

Category B: **Blueprint Reading**

Task 8:   **Identify piping symbols**

Identify size of piping
Identify direction of flow
Identify valves, fittings, etc.

Task: 9   **Interpret blueprints**

Identify basic blueprint symbols
Identify basic mechanical symbols: valves, motors, etc.
Identify welding symbols: fillet, butt, etc.
Identify common architectural symbols: walls, doors, etc.
Interpret blueprints
Identify different types of drawings: orthographic, isometric, etc.

Reference
Information of these procedures can be found:
Advanced Plan Reading and Related Drawing

Category C: Mathematics and Measurement

Task: 10   **Perform basic math operations for pipe fitters**

Identify correct math formulas for given problems
Use of: calculator, compass, protractor, ruler, etc.
Calculate: volumes, areas, pressure, force, mechanical advantage, etc.
Calculate piping problems: fitting take-offs (90°, 45°, odd angles),
        Equal spread offsets, unequal spread offset, rolling offsets, etc.
Measure: elevations, pipe diameters, pipe schedules, etc.
Reading: ruler, tape measure, transit, level, etc.

Reference
Information of these procedures can be found:
Related Math
Piping Handbook and Offset Formulas

Task: 11   **Demonstrate knowledge of related science**

Volume, density, force, pressure, thermal expansion, heat, temperature, buoyancy,
Specific weight, absolute pressure, standard temperature and pressure, specific heat,
Heat transfer: conduction, convection and radiation

Reference
Information of these procedures can be found:
Related Science

Category D: Safety

Task: 12   **Demonstrate knowledge of high-pressure safety**

    Identify potential hazards
    Locate cause
    Take corrective action

<u>Reference</u>
    Information of these procedures can be found:
        Job Safety and Health

Task: 13   **Demonstrate knowledge of OSHA regulations**

    Identify: potential hazards
    Demonstrate: applicable regulation
    Comply: with regulations
        confined spaces, lock-out tag-out, fall protection, rigging
        scaffolding and ladders, trenching, personal protective equipment,
        electrical safety, proper storage and handling of hazardous materials,
        hot-work permits, accident reports, etc.

<u>Reference</u>
    Information of these procedures can be found:
        Job Safety and Health

Task: 14   **Demonstrate knowledge of basic safety principles**

    Identify potential hazards, personal protective equipment required
    Comply with shop and equipment safety rules
    Apply basic emergency and first-aid techniques
    Use of tools, equipment, materials, etc.

    <u>Reference</u>
    Information of these procedures can be found:
        Job Safety and Health

Category E: Rigging

Task: 15   **Operate lifting and moving equipment**

       Operate: chain falls, jacks, portapowers, pry bars, come-alongs, etc.

       <u>Reference</u>
       Information of these procedures can be found:
           Rigging

Task: 16   **Perform rigging**

       Determine: weight of the load to be lifted, appropriate lift points
       Select lifting devices: slings, chokers, block and tackle, come-along,
           Tag lines, chain hoist, etc.
       Identify: hazards (electrical lines, populated work areas, accessibility,
           Damaged lifting equipment, etc.)
       Perform proper communication with crane operator: (hand signals,
           Radio contact, etc.)

       <u>Reference</u>
       Information of these procedures can be found:
           Rigging

Category F: Steam Systems

Task: 17   **Install steam traps**

       Identify: piping requirements for each type of trap
       Identify: different traps (impulse, inverted bucket, float, thermostatic, etc.)

       <u>Reference</u>
       Information of these procedures can be found:
           Steam Systems
           Related Science

Task: 18　　　**Install condensate piping and tanks**

Identify: function and operation (condensate pumps, traps, etc.)
Identify: parts of steam piping system (mains, drips, expansion joints, risers, etc.)
Identify: types of heat transfer equipment (convectors, exchangers, coils, etc.)
Maintain: piping, valves, traps, etc.
Install: piping and tanks

Reference
Information of these procedures can be found:
　　　　Steam Systems
　　　　Related Science

Task 19:　　　**Install gaskets in steam systems**

Identify: proper gaskets, bolts, nuts, and flanges
Lubricate: bolts and flanges if required
Install gaskets and make up flanges

Reference
Information of these procedures can be found:
　　　　Steam Systems

Category: G　　　　Instrumentation and Pneumatic Controls

Task: 20　　　**Install industrial instrumentation system components**

Install: regulators, valves, filters, tubing, fittings, solenoids, sensors, transmitters,
　　　　Transducers, controllers, orifice plates, flow meters, control valves,
　　　　Air compressors, pressure reducing stations, etc.

Reference
Information of these procedures can be found:
　　　　Instrumentation and Process Control

Task: 21　　　**Install pneumatic controls**

Install: air compressors, pressure reducing valves, tubing, thermostats, controllers,
　　　　Transmitters, etc.

Reference
Information of these procedures can be found:
　　　　Pneumatics

Category H: Welding

Task 22:   **Perform brazing**

Demonstrate proper procedures for brazing
Clean and prepare pipe and fittings
Use flux if required
Braze copper to copper, dissimilar metals

Reference
Information of these procedures can be found:
    Soldering and Brazing

Task 23:   **Perform SMAW and GTAW welding**

Identify: welding procedures, welding theories, correct polarities,
Select: filler rod, purge gas (if required)
Prepare ends
Perform welding procedure

Reference
Information of these procedures can be found:
    Oxy-Fuel Cutting and Welding and Shielded Metal-Arc Welding

Task 24:   **Perform soldering**

Identify proper soldering theory
Demonstrate proper methods of setting up equipment
Clean and prepare pipe and fittings
Perform solder technique

Reference
Information of these procedures can be found:
    Soldering and Brazing

Category I: Hydronics

Task: 25   **Install boilers**

Differentiate between steam and hot water boilers
Identify types of steam boilers
Identify types of hot water boilers
Identify pipe required
Identify system components
Identify importance of eccentric reducers
Identify operation of boilers

Identify types of fuels
Connect hot water boiler: supply and return piping, valves,
       Water make-up, expansion tanks, etc.
Connect steam boiler: supply and return piping, valves, gages, etc.

Reference
Information of these procedures can be found:
       Steam Systems
       Hydronic Heating and Cooling

Category J: Refrigeration and Air Conditioning

Task: 26   **Install chillers**

Identify different types of compressors: centrifugal, scroll, rotary, etc.
Identify different types of evaporators: flooded, dry
Identify different types of condensers: air-cooled, water-cooled, evaporative
Identify different types of metering devices: needle valve, thermostatic expansion
       Valve, high-side float, low-side float, etc.
Install valves and accessories of chillers: oil separators, mufflers, solenoid valves,
       Dryers, sight glasses, pressures relief valves, etc.
Select piping requirements for chillers

Reference
Information of these procedures can be found:
       Refrigeration

Task: 27   **Install cooling towers**

Identify types of cooling towers: forced draft, induced draft, natural draft and
       Spray towers
Install tower components: fan motors, wet decks, balancing valves, etc.

Reference
Information of these procedures can be found:
       Refrigeration

Category K: Pumps

Task: 28   **Install pumps**

Identify classifications: positive and non-positive displacement
Identify types of positive displacement pumps: piston, reciprocating,
       Rotary, etc.
Identify types of non-displacement pumps: centrifugal

Install: piping, flex connections, gaskets, gages, flanges, valves, etc.

Reference
Information of these procedures can be found:
       Pumps

Study Guide Questions

Category A: **Piping and Tubing**

1. What type of copper tubing joint requires the use of a ferrule?

A. Welded
B. Compression
C. Soldered
D. Beaded

2. What type of copper tubing is not identified by color on the tubing itself?

A. Soft tempered
B. Hard drawn
C. Extra hard
D. Annealed

3. The pipe fitting which makes a 180° turn is called a/an _____:

A. eighth bend.
B. lateral fitting.
C. return fitting.
D. elbow.

4. The final step in the galvanizing of pipe is to dip the pipe into a bath of molten_____:

A. mercury.
B. aluminum.
C. antimony.
D. zinc.

5. Which of the following is not a reason to use stud bolts instead of machine bolts for bolting flanged piping joints?

A. The stud bolt is more easily removed if corroded.
B. The stud bolt is stronger than a machine bolt of the same size and material.
C. Confusion with other bolts at the job site is avoided.
D. Stud bolts in the less frequently used sizes and materials can be readily
   made from round stock.

6. Where should the pressure enter a globe valve?

A. Over the seat.
B. Depends on the desired action if the disc or plug becomes detached from the stem.(fail open or fail closed)
C. Does not matter.
D. Under the seat.

7. In a piping installation allowing for expansion in two directions, how should the anchor(s) and guide(s) be positioned relative to each other?

A. Anchor, guide, anchor.
B. Anchor, anchor, guide.
C. Guide, anchor, guide.
D. No guides are required.

8. What are 3 fuel gases used for heating pipe or tubing?

A. Acetylene, propane, and argon.
B. MAPP, acetylene, and propane.
C. Argon, MAPP. and acetylene.
D. Propane, argon, and MAPP.

9. The purpose of the foot switch on a power-operated pipe cutting and threading machine is to:

A. control the speed of the motor.
B. leave the operator's hands free to hold the pipe.
C. act as safety device to shut of the motor if the operator's foot is removed from the switch.
D. reverse the rotation of the motor.

10. Which of the following is not a reason for using cutting oil when threading pipe?

A. To protect the threads from rust.
B. To reduce friction.
C. To remove heat.
D. To prevent metal chips from adhering to the dies

**11.When is it safe to remove the old packing from a valve that is under pressure?**

A. When the valve is completely open.
B. When the valve is completely closed.
C. When the valve is back seated.
D. Never.

12. The color code for type "K" copper tube is:

A. Blue
B. Green
C. Red
D. Yellow

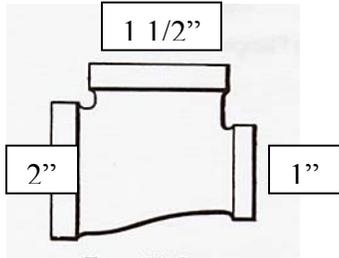**13. Identify the copper fitting shown in the figure below.**

A. Coupling adapter
B. CX FM adapter
C. CX M adapter
D. Dielectric adapter
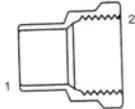
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14. The correct way to order the reducing tee shown in the figure below is?

A. 1" x 1 ½" x 2"
B. 1 ½" x 1" x 2"
C. 2' x 1 ½" x 1"
D. 2" x 1" x 1 ½"

15. Which of the follow types copper tube has the smallest wall thickness?

A. M
B. DWV
C. K
D. L

16. What type of pipe hanger is shown below?

A. Double eye nut
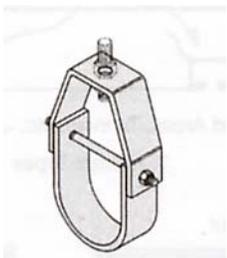B. Clevis
C. Split ring hanger
D. Double bolt pipe clamp

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17. The proper name for the clamp shown below is:

A. Top beam
B. "J" hook
C. Swivel adjuster
D. Socket
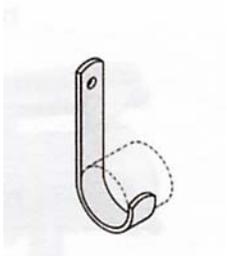
18. The proper name for the hanger shown below is:

A. Ring swivel.
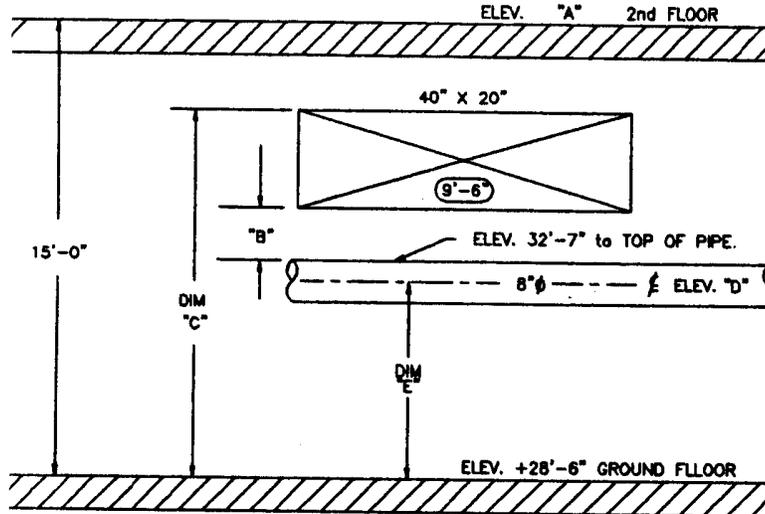B. Band.
C. Clevis.
D. Split.

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Category B: Blueprint Reading

FOR QUESTIONS 1 – 4 CALCULATE THE MEASUREMENTS FOR DIMENSIONS IN THE DRAWING BELOW:

1. The correct measurement for elevation "A" is:
A. 15'-0"
B. 15'-6"
C. 42'-6"
D. 43'-6"

2. The correct measurement for dimension "B" is
A. 3'-9"
B. 5'-5"
C. 32'-3"
D. 38'

3. The correct measurement for dimension "C" is
A. 11'-2"
B. 15'
C. 39'-8"
D. 15'

4. The correct measurement for elevation "D" is:
A. 3'-8 11/16"
B. 5'-4 11/16"
C.   32'-2 11/16"
D. 38'

5. The type of drawing that views a building by looking directly at the front, top and side is referred to as a/an _____ drawing.

A. true isometric
B. orthographic
C. oblique
D. cabinet

6. The type of drawing that most closely resembles an object as the eye would see it is referred to as a/an _____ drawing.
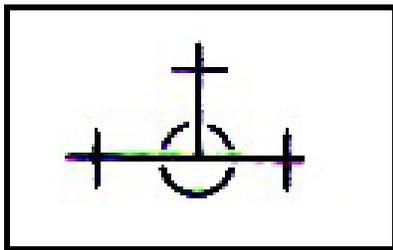
A. true isometric
B. orthographic
C. oblique
D. cabinet

7. The symbol below represents a:
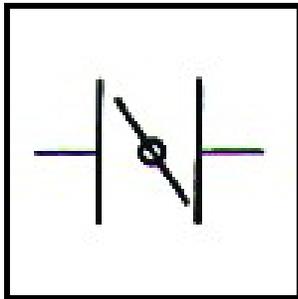
A. Flanged swing check valve.
B. Screwed angle check valve.
C. Screwed butterfly valve.
D. Flanged butterfly valve.

8. The symbol below represents a:

A. Screwed tee side outlet away from you.
B. Screwed tee outlet towards you.
C. Flanged tee outlet away from you.
D. Flanged tee outlet towards you.

Category C: **Mathematics and Measurement**

1. Which of the following constants are used when working with circles and areas?

A. 3.1416, .7854 and 14.7.
B. .7854, 14.7 and .01745.
C. 14.7, .01745 and 3.1416.
D. .01745, 3.1416 and .7854.

2. How many 2" pipes can be supplied from a 6" header?

A.3
B.6
C.9
D.12

3. If the arc length for 90° = 1.57 x radius, find the outside arc of a standard 14" long radius weld ell.

A. 13-15/16"
B. 23-15/16"
C. 33-15/16"
D. 43-15/16"

4. Which is the correct formula for the area of a circle?

A. .7854 x D^2
B.   πd^2
C. 3.1416 x D
D. .7854 x r^2

5. Convert 8" to hundredths of a foot.

A. .27'
B. .47'
C. .67'
D. .87'

6. To figure the end-to-end measurement of a piece of pipe when the end-to-center measurement is known the:

A. pipe make-up must be added to the end-to-center measurement.
B. pipe make-up must be subtracted from the end-to-center measurement.
C. take-off must be added to the end-to-center measurement.
D. take-off must be subtracted from the end-to-center measurement.

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7. What is the Mechanical Advantage of a device when the Resistance is 100 lbs. and the Effort is 5 lbs.?

A.   20
B.   20 lbs.
C.   20 ft./lbs.
D.   500 lbs.

8. Using the formula, Celsius = (Fahrenheit degrees - 32) ÷ 1.8, find the Celsius degrees if the Fahrenheit reading is minus 40.

A. 4.44
B. 40
C. -40
D. 44.4

9. If the travel of a 45°offset is known, what formula can be used to find the advance?

A. Travel ÷ .707
B. Travel x 1.414
C. .707 x Travel
D. Travel x .414

10. When water changes to steam at atmospheric pressure it expands _____ times its original volume.

A. 17
B. 170
C. 1,700
D. 17,000

11. The specific weight of mercury is:

A. .0361
B. 13.6
C. 29.921
D. 34.16

12. Name three methods of transferring heat.

A. Conduction, convection and radiant.
B. Thermodynamic, conduction and convection.
C. Radiant, thermodynamic and conduction.
D. Convection, radiant and thermodynamic.

13.The anode rod used in a hot water heater to protect it from corrosion is made of:

A. Calcium.
B. Magnesium.
C. Aluminum.
D. Boron

14. A neutral reading on a PH scale is _____.

A. 4.1
B. 7.0
C. 9.8
D. 12.4

15. .433 psig is equal to how high of a water column?

A. 1'
B. 2'
C. 3'
D. 4'

16. One cubic foot of water weighs?

A. 40 pounds
B. 62.4 pounds
C. 144 pounds
D. 231 pounds

17. Standard atmospheric pressure at sea level is _____:

A. 0 psia
B. .491 psia
C. 2.31 psia
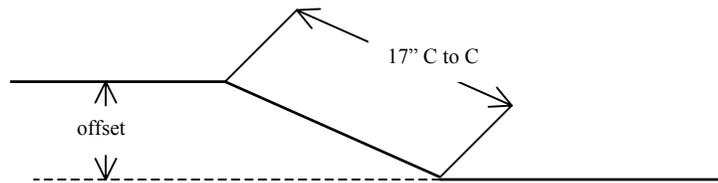D. 14.7 psia

18. One gallon of water weighs _____:

A. 1 pound
B. 2.31 pounds
C. 8.33 pounds
D. 10.6 pounds

19. An increase in pressure will cause the boiling point of water to _____:

A. Increase.
B. decrease.
C. remain the same.
D. expand.

20. What is the C-to-C measurement of the 45° offset in the drawing below?

A. 10"
B. 12"
D. 14 ½"
D. 24"

17" C to C

offset

21. What is the capacity in gallons of a water storage tank that measures 30" in diameter by 80" in length?

A. 2400 gallons
B. 1041 gallons
C. 600 gallons
D. 244 gallons

22. Which of the following is the decimal equivalent of 5/8"?

A. .625
B. .580
C. .400
D. .375

23. The weight of 47 gallons of water is _____:

A. 108.5 pounds
B. 203 pounds
C. 376 pounds
D. 391.5 pounds

Category D: **Safety**

1. Which of the following are not acceptable as part of a personal fall arrest system?

A. Shock absorbers.
B. Dee rings.
C. Body belts
D. Harnesses

2. Which of the following methods of access to a scaffold is prohibited?

A. Climbing the cross braces.
B. Using job made ladders.
C. Using a manufacturer's approved clamp-on ladder.
D. Using frames with built-in ladders.

3. What is the minimum safe clearance between cranes and energized power lines operating at 50kV or below?

A. 2 feet.
B. 10 feet
C. 15 feet
D. 18 feet

4. Which of the following is a key element of a comprehensive safety and health program?

A. Drug and alcohol testing.
B. Record keeping.
C. Pre-employment physicals.
D. Hazard prevention and control.

5. Ladders with visible defects, such as broken rungs, cracked side rails, or broken steps must be:

A. Tagged and removed from service.
B. Repaired with #9 wire.
C. Used with care.
D. Used only on small jobs.

6. The only entity that has the responsibility and authority to appoint the competent person is:

A. the job steward.
B. the job superintendent.
C. the employer.
D. OSHA.

7. Which of the following is not an essential element necessary to produce an ordinary fire?
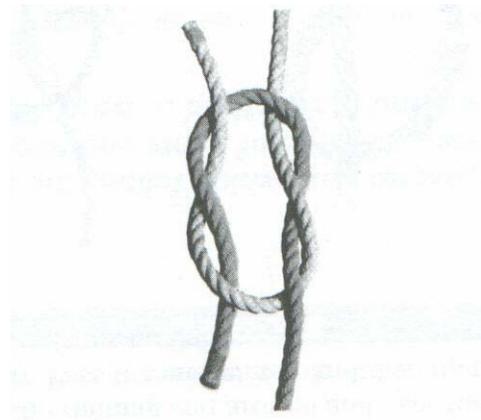
A. Fuel
B. Hydrogen
C. Heat
D. Oxygen

Category E: Rigging

1. Which of the elements of a wire rope aid in absorbing "Shock Loads"?
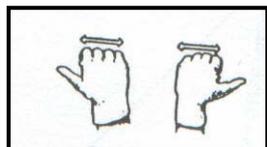
A. The strand
B. The wire
C. The core
D. The rope

2. Identify the knot below.

A. Pipe
B. Clove
C. Square
D. Granny

3. Identify the hand signal below

A. Extend boom
B. Dog everything
C. Travel forward
D. Swing load

Category F:　　　　　　　**Steam Systems**

1. The pipe that connects the steam header to the boiler return connection is the:

A. Equalizing line
B. Down feed line
C. Wet return
D. Boiler return

2. A thermostatic steam trap that fails in the closed position would cause a heating unit to become:

A. Steam bound
B. Waterlogged
C. Superheated
D. Vapor locked

3. The device that controls the pressure in a low pressure steam boiler is called a:

A. Pressuretrol
B. Aquastat
C. Thermostat
D. Thermocouple

Category: G　　　　　　　**Instrumentation and Pneumatic Controls**

1. A diamond on an instrumentation loop diagram encloses information concerning:

A. Calibration
B. Action
C. Range
D. Set point

2. Which type of orifice plate is designed to measure flow of liquids containing solids?

A. Segmental
B. Eccentric
C. Concentric
D. Vented

3. Which component in a closed control loop is the primary element?

A. Controller
B. Control Valve
C. Sensor
D. Converter

Category H: Welding

1. The main cause of undercutting is:

A. Too low of a current setting
B. Too slow of a travel rate
C. Too long of an arc
E. Too fast of a travel rate

2. What is the function of the covering on the electrodes during the process of "Shielded Metal-Arc Welding"?

A. To provide an oxygen barrier.
B. To stabilize and direct the force of the arc
C. To gather impurities in the form of slag.
D. All of the above

3.When arranging weld coupons for testing position 6G:

A. Axis of pipe should be vertical
B. Axis of pipe should be horizontal
C. Axis of pipe should be on a 45 degree
D. Axis of pipe not of importance

4. Both soldered and brazed joints are made by heating a properly prepared joint to the proper temperature and the flowing of a filler metal by means of:

A. Capillary action
B. Tinning action
C. Wetting action
D. Coalescence action

Category I: Hydronics

1. **When changing pipe sizes in the horizontal supply or return lines of a two-pipe hot water heating system use:**

A. Concentric reducers

B. Concentric reducing bushings

C. Eccentric reducers, flat on top

D. Eccentric reducers, flat on bottom

2. **A triple-duty valve is installed:**

A. On top of a hot water heating boiler

B. In the bottom connection of the compression tank

C. In the hot water heating pumps suction piping

D. In the hot water heating pumps discharge piping

Category J: Refrigeration and Air Conditioning

1. **An oil separator is required on systems using:**

A. Ammonia
B. CFC-12
C. HCFC-22
D. Brine

2. **In the cooling cycle, which component throttles the flow of refrigerant?**

A. Evaporator
B. Condenser
C. Compressor
D. Expansion Device

Category K: Pumps

1. If a pump is operating under static suction lift conditions, a _____ may be installed in the suction line to avoid losing the pump's prime each time the pump shuts off.

A. strainer

B. globe valve

C. foot valve

D. suction diffuser

2. In Fig. 1. what will the static pressure be at position 1 on the suction gage when the pump is off, if the suction gage position 3 reads 69.5 PSIG and the discharge gage position 4 reads 100 PSIG when the pump is on?

A. 25.98 PSIG

B. 30.5 PSIG

C. 69.5 PSIG

D. 100 PSIG

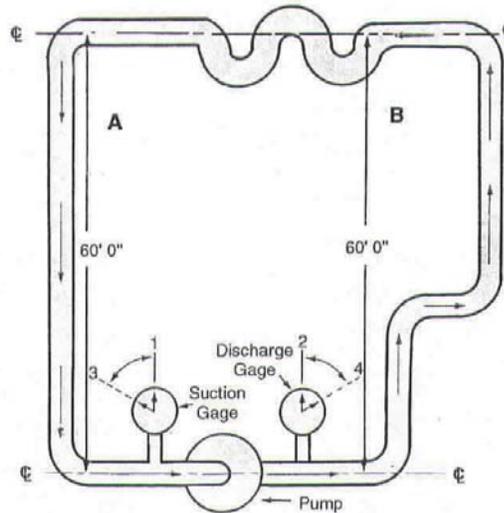

Fig. 1

3. A valve on the suction side of the pump should be:

A. Before the strainer and fully open.

B. After the strainer and fully open.

C. Before the strainer and throttled to the GPM requirement.

D. After the strainer and throttled to the GPM requirement.

Answer Key

Category A: **Piping and Tubing**

1. B
2. A
3. C
4. D
5. B
6. B
7. C
8. B
9. C
10. A
11. D
12. B
13. B
14. D
15. B
16. C
17. B
18. C

Category B: **Blueprint Reading**

1. D
2. B
3. C
4. C
5. B
6. A
7. D
8. A

Category C: **Mathematics and Measurement**

1. D
2. C
3. D
4. A
5. C
6. D
7. A
8. C
9. C
10. C
11. A
12. A

13. B
14. B
15. A
16. B
17. D
18. C
19. A
20. B
21. D
22. A
23. D

Category D: **Safety**

1. C
2. A
3. B
4. D
5. A
6. C
7. B

Category E: **Rigging**

1. C
2. D
3. A

Category F: **Steam Systems**

1. A
2. B
3. A

Category: G   **Instrumentation and Pneumatic Controls**

1. D
2. A
3. C

Category H: **Welding**

1. D
2. D
3. C
4. A

Category I: **Hydronics**

1. C
2. D

Category J: **Refrigeration and Air Conditioning**

1. A
2. D

Category K: **Pumps**

1. C
2. A
3. A

Energy Calculations

$Q_{(Total)} = 4.5 \times CFM \times \Delta h$

$Q_{(Latent)} = 4840 \times CFM \times \Delta g$

$Q_{(Sensible)} = 1.10 \times CFM \times \Delta T$

$Q = BTUH$

Δh = difference in enthalpy

Δg = difference in grains of moisture

ΔT = difference in temperature

Heat transfer

$BTUH = LB. \times \Delta T \times Specific\ heat$ (for any substance)

$BTUH = CFM \times \Delta T \times 1.08$ (for standard air)

$BTUH = GPM \times \Delta T \times 500$ (for water)

Force exerted by a round diaphragm with a pressure applied and measured in psig

$Force = Area \times Pressure$

$= sq.in. \times \dfrac{pound}{sq.in.}$

$= \pi r^2 \times psig$

Pressure conversions

1 psi = 2.31 feet of head

1 psi = 27.7 in. w.c.

1 psi = 2.04 in. Hg.

1 atmosphere = 34 feet of head

1 atmosphere = 29.9 in. Hg.

1 atmosphere = 14.7 psi

    w.c. = water column

    in. Hg. = inches Mecury

Air pressure in ducts

$V = 4005\sqrt{VP}$

$VP = \left(\dfrac{V}{4005}\right)^2$

Airflow in duct:

$Q = A \times V$

    Q = CFM

    A = Cross sectional area of duct (ft2)

    V-Velocity of air (feet per minute – FPM)

    VP = inches water gage, "WG

Mixed air temperature (MAT)

$MAT = OAT \times \%OA + RAT \times \%RA$

Percent of outside air

$\%OA = \dfrac{RAT - MAT}{RAT - OAT}$

MA=Mixed air

OA=Outside air

RA=Return air

Hydronic Pressure (Total Head)

Total Head = Static Head + Friction Head + Velocity Head

Static Head

Static Head = Static Discharge Head - Static Suction Head
(calculated distance above pump as positive, distance below pump as negative)

Velocity Head (VH)

$VH = \dfrac{V^2}{2g}$

    g = 32.2 ft/sec^2 (acceleration due to gravity)

    V = Velocity of liquid

Total Dynamic Head

TDH = (DSH-SSH)+(DVH-SVH)

    TDH = Total dynamic head

    DSH = Discharge static head

    SSH = Suction static head

    DVH = Discharge velocity head

    SVH = Suction velocity head

Flow Coefficient (Cv) rating of valve

$Cv = \dfrac{Q}{\sqrt{H}}$

Q = flow rate in gpm

H = head loss (pressure drop) in PSI

Cv = flow coefficient with valve wide open, equal to gpm of flow at a 1 PSI pressure drop across the valve. Cv decreases as the valve closes.

Temperature conversions

$°F\ (Fahrenheit) = °C \times \dfrac{9}{5} + 32$

$°C\ (Celsius) = (°F - 32) \times \dfrac{5}{9}$

$°R\ (Rankine) = °F = 460$

$°K\ (kelvin) = °C = 273$

Ohm's Law

Volts = Amps x Ohms

  or

E=I x R

Watt's Law

Watts = Volts x Amps

  or

P = E x I

Energy formula

W = P x t

Formula Circle for Ohm's and Watt's Laws
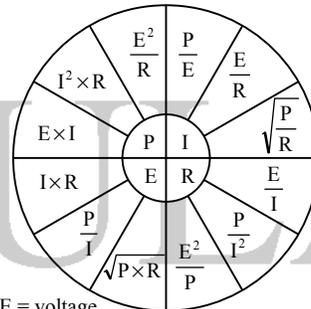
E = voltage

I = current (amps)

P = power (watts)

R = resistance (ohms)

W = energy (kWh, or kilowatt-hour)

t = time (hours)

Sum of resistance

Series circuits

$R_T = R_1 + R_2 + R_3$

Parallel circuits

$R_t = \dfrac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}}$

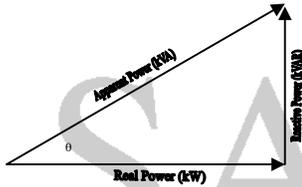**Sum of capacitance (C)**

Series circuits

$C_t = \dfrac{1}{\dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}}$

Parallel circuits

$C_T = C_1 + C_2 + C_3$

Power factor calculations

$$\text{Power Factor} = \frac{\text{true power (kW)}}{\text{apparent power (kVA)}} = \cos\theta$$

$$3\text{ - phase apparent power (kVA)} = \frac{\text{Volts}\times\text{Amps}\times 1.73}{1000}$$

$$\text{single phase apparent power (kVA)} = \frac{\text{Volts}\times\text{Amps}}{1000}$$

$$\text{Re active power (kVAR)} = \sqrt{\text{kVA}^2 - \text{kW}^2}$$

Percent of motor load

$$\%\text{ load} = \frac{\text{MA} - 0.5\text{NPA}}{0.5\text{NPA}}\times\frac{\text{MV}}{\text{MPV}}$$

MA = Measured amps
MPA = Nameplate amps
MV = Measured volts
MPV = Nameplate volts

Transformer voltage/winding calculation

$$E_S = E_P\times\frac{N_S}{N_P}$$

E_S = secondary voltage
E_P = primary voltage
N_S = number of secondary turns
E_P = number of primary turns

Brake horsepower of a fan

$$\text{Bhp} = \text{NPhp}\times\frac{\text{MA}}{\text{NPA}}\times\frac{\text{MV}}{\text{MPV}}\times\text{LF}$$

NPHP = Nameplate horsepower
MA = Measured amps
NPA = Nameplate amps (FLA)
MV = Measured volts
NPV = Nameplate volts
LF = Load factor (by table)

Brake horsepower of a pump

$$\text{Bhp} = \frac{\text{GPM}\times\text{TDH}}{3960\times\text{Eff}}\times\text{specific gravity}$$

$$\text{Bhp} = \frac{\text{kW}\times\text{Eff}}{0.746}$$

$$\text{Pump efficiency} = \frac{\text{Total head}\times\text{GPM}}{3960\times\text{Bhp}}\times\text{specific gravity}$$

TDH = Total dynamic head
Eff = Pump efficiency
kW = real input power

Speed Calculation

Calculate new sheave diameter, changing motor sheave

$$\text{Dia}_{\text{new}} = \text{Dia}_{\text{old}}\times\frac{\text{RPM}_{\text{new}}}{\text{RPM}_{\text{old}}}$$

Compression ratio (R)

$$R = \frac{\text{Absolute discharge pressure}}{\text{Absolute suction pressure}}$$

Calculate new sheave diameter, changing fan or pump sheave

$$\text{Dia}_{\text{new}} = \text{Dia}_{\text{old}}\times\frac{\text{RPM}_{\text{old}}}{\text{RPM}_{\text{new}}}\quad\textbf{Fan Laws}$$

$$\text{CFM}_{\text{new}} = \text{CFM}_{\text{old}}\times\frac{\text{RPM}_{\text{new}}}{\text{RPM}_{\text{old}}}$$

$$\text{SP}_{\text{new}} = \text{SP}_{\text{old}}\times\left(\frac{\text{CFM}_{\text{new}}}{\text{CFM}_{\text{old}}}\right)^2$$

$$= \text{SP}_{\text{old}}\times\left(\frac{\text{RPM}_{\text{new}}}{\text{RPM}_{\text{old}}}\right)^2$$

$$\text{BHP}_{\text{new}} = \text{BHP}_{\text{old}}\times\left(\frac{\text{CFM}_{\text{new}}}{\text{CFM}_{\text{old}}}\right)^3$$

$$= \text{BHP}_{\text{old}}\times\left(\frac{\text{RPM}_{\text{new}}}{\text{RPM}_{\text{old}}}\right)^3$$

Pump Laws

$$\text{GPM}_{\text{new}} = \text{GPM}_{\text{old}}\times\frac{\text{D}_{\text{new}}}{\text{D}_{\text{old}}}$$

$$= \text{GPM}_{\text{old}}\times\frac{\text{RPM}_{\text{new}}}{\text{RPM}_{\text{old}}}$$

$$\Delta\text{P}_{\text{new}} = \Delta\text{P}_{\text{old}}\times\left(\frac{\text{GPM}_{\text{new}}}{\text{GPM}_{\text{old}}}\right)^2$$

$$= \Delta\text{P}_{\text{old}}\times\left(\frac{\text{D}_{\text{new}}}{\text{D}_{\text{old}}}\right)^2$$

$$= \Delta\text{P}_{\text{old}}\times\left(\frac{\text{RPM}_{\text{new}}}{\text{RPM}_{\text{old}}}\right)^2$$

$$\text{BHP}_{\text{new}} = \text{BHP}_{\text{old}}\times\left(\frac{\text{GPM}_{\text{new}}}{\text{GPM}_{\text{old}}}\right)^3$$

$$= \text{BHP}_{\text{old}}\times\left(\frac{\text{D}_{\text{new}}}{\text{D}_{\text{old}}}\right)^3$$

$$= \text{BHP}_{\text{old}}\times\left(\frac{\text{RPM}_{\text{new}}}{\text{RPM}_{\text{old}}}\right)^3$$

General Gas Law

$$pV = mRT$$

Boyle's Law and Charles' Law

$T_1 p_2 = T_2 p_1$ (Charles' Law with constant volume)

$T_1 V_2 = T_2 V_1$ (Charles' Law with constant pressure)

$p_1 V_1 = p_2 V_2$ (Boyle's Law with constant temperature)

p=absolute pressure in pounds per square foot
V=volume in cubic feet
m=mass in pounds
R=gas constant of the particular gas (foot-pounds per pound per degree Rankine)
T=absolute temperature in degrees Rankine

Gas	R	Gas	R
Air	53.5	Hydrogen	765.9
Ammonia	90.5	Nitrogen	55.1
Carbon dioxide	35.1	Oxygen	48.3
Carbon monoxide	55.1	Sulfur dioxide	24.1