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ABSTRACT

This publication is the concluding text in a four-part curriculum for air conditioning and refrigeration. Materials in Book 4 are designed to complement theoretical and functional elements in Books 1-3. Instructional materials in this publication are written in terms of student performance using measurable objectives. The course includes six units. Each unit contains some or all of the basic components of a unit of instruction: performance objectives, suggested activities for teachers, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. Units are liberally illustrated and are planned for more than one lesson or class period of instruction. Information for the teacher includes an instructional/occupational analysis of air conditioning and refrigeration, a list of tools and equipment needed, and a list of references. Topics covered by the six units are the following: gas furnaces, electrical heating systems, residential cooling systems, heat pump systems, balance points, and hydronics. (KC)

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AIR CONDITIONING AND REFRIGERATION BOOK IV

by

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and

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PREFACE

Air Conditioning and Refrigeration, Book IV, is the concluding text in MAVCC's four-part curriculum for air conditioning and refrigeration. Materials in *Book IV* are designed to complement theoretical and functional elements in Books *I*, *II*, and *III*.

As with *Book III*, this text is smaller in size and lower in price, and it's economy, in both cases, should lend to its ready compliance with current demands in the classroom for comprehensive materials that are adaptable to long-range programs as well as speciality programs with industry and adult education.

As sugested in the forward, rapid technical advancements in the air conditioning and refrigeration industry will bring demands for new skills. Your suggestions for classroom materials to serve this volatile transitional period will serve to help MAVCC in its continuing effort to answer the needs of classroom and industry.

Ann Benson
Executive Director
Mid-America Vocational Curriculum
Consortium

FOREWORD

The 1980's promise advancement in solar energy technology and alternative fuel sources. Many of these advancements will confront air conditioning and refrigeration technicians with the challenge of modifying existing heating and cooling systems to meet new demands for energy savings and economy.

Modern gas furnaces are built with energy-saving heat exchangers, but older gas furnaces can be modified with electric ignition devices that promote economy. Heat pump systems have been around a long time, but design changes present new demands for articulate installation and professional service. *Air Conditioning and Refrigeration, Book IV,* attempts to address problems that will be faced by technicians in a transitional industry on the premise that rapid advancements in the industry will demand an even better command of basic system installation and service skills.

The success of this publication is due, in large part, to the capabilities of the personnel who worked with its development. The technical writers have numerous years of industry as well as teaching and writing experience. Assisting them in their efforts were representatives of the air conditioning and refrigeration professions who brought with them technical expertise and the experience related to the classroom and to the trade. To assure that the materials would parallel the industry environment and be accepted as a transportable basic teaching tool, other organizations and industry representatives were involved in the developmental phases of the manual. Appreciation is extended to them for their valuable contributions to the manual.

This publication is designed to assist teachers in improving instruction. As this publication is used, it is hoped that the student performance will improve and that students will be better able to assume a role in their chosen occupation. Every effort has been made to make this publication basic, readable, and by all means usable. Three vital parts of instruction have been intentionally omitted: motivation, personalization, and localization. These areas are left to the individual instructors who should capitalize on them. Only then will this publication really become a vital part of the teaching-learning process.

Instructional materials in this publication are written in terms of student performance using measurable objectives. This is an innovative approach to teaching that accents and augments the teaching/learning process. Criterion referenced evaluation instruments are provided for uniform measurement of student progress. In addition to evaluating recall information, teachers are encouraged to evaluate the other areas including process and product as indicated at the end of each instructional unit.

It is the sincere belief of the MAVCC personnel and all those members who served on the committee that this publication will allow the students to become better prepared and more effective members of the work force. If there is anything that we can do to help this publication become more useful to you, please let us know.

David Merrill, Chairman
Board of Directors
Mid-America Vocational Curriculum Consortium

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TABLE OF CONTENTS

USE OF THIS PUBLICATION

Instructional Units

Air Conditioning and Refrigeration, Book IV, includes 6 units. Each instructional unit includes some or all of the basic components of a unit of instruction: performance objectives, suggested activities for teachers, information sheets, assignment sheets, visual aids, job sheets, tests, and answers to the test. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help determine:

A. The amount of material that can be covered in each class period
B. The skills which must be demonstrated
   1. Supplies needed
   2. Equipment needed
   3. Amount of practice needed
   4. Amount of class time needed for demonstrations
C. Supplementary materials such as pamphlets or filmstrips that must be ordered
D. Resource people who must be contacted

Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Following is a list of performance terms and their synonyms which may have been used in this material:

Name	Identify	Describe
Label	Select	Define
List in writing	Mark	Discuss in writing
List orally	Point out	Discuss orally
Letter	Pick out	Interpret
Record	Choose	Tell how
Repeat	Locate	Tell what
Give		Explain

Order	Distinguish	Construct
Arrange	Discriminate	Draw
Sequence		Make
List in order		Build
Classify		Design
Divide		Formulate
Isolate		Reproduce
		Transcribe
		Reduce
		Increase
		Figure

Demonstrate	Additional Terms Used	
Show your work	Evaluate	Prepare
Show procedure	Complete	Make
Perform an experiment	Analyze	Read
Perform the steps	Calculate	Tell
Operate	Estimate	Teach
Remove	Plan	Converse
Replace	Observe	Lead
Turn off/on	Compare	State
(Dis) assemble	Determine	Write
(Dis) connect	Perform	

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

Suggested Activities for the Instructor:

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. Duties of instructors will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

Information Sheets

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

Transparency Masters

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. (NOTE: To overcome the noise of an overhead projector, some teachers have a tendency to speak too loudly, so it is always best to stand away from the projector when discussing transparencies.)

Assignment Sheets

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledges which are necessary prerequisites to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

Job Sheets

Job sheets are an important segment of each unit. In most situations, the instructor should be able to demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.

Test and Evaluation

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

Test Answers

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.

AIR CONDITIONING AND REGRIGERATION BOOK IV

INSTRUCTIONAL ANALYSIS

Job Training: What the Worker Should Be Able To Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)

UNIT I: GAS FURNACES

1. Terms
2. Types of gas fires furnaces and their applications
3. Components of a gas burner assembly
4. Types of gas valves and their characteristics
5. Components of a combination electric gas valve
6. Characteristics of a heat exchanger
7. Advancements in heat exchanger technology
8. Characteristics of a draft diverter
9. Types of blower assemblies
10. Components of a control system
11. Functions of a transformer
12. Types of thermostats and their functions
13. Limit switch operation
14. Fan switch operation
15. Combination fan-limit switch operation
16. Pilot light operation
17. Thermocouple operation

INSTRUCTIONAL ANALYSIS

Job Training: What the Worker Should Be Able To Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
	18. Pilot safety operation
	19. Potential sources of thermo-couple failure
	20. Potential sources of fan switch failure
	21. Potential sources of transformer failure
	22. Potential sources of high limit switch failure
	23. Potential sources of gas valve failure
	24. Potential sources of fan relay trouble
	25. Blower section failure and component sources
	26. Potential sources of heat exchanger failure
	27. Potential sources of pilot safety
	28. Factors needed to determine gas pipe sizing
	29. Energy conservation devices designed for retrofitting
	30. Set back thermostats and their uses
	31. Intermittent ignition systems and their uses
	32. Vent dampers and their uses
	33. Trace high and low voltage circuits of a gas furnace

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INSTRUCTIONAL ANALYSIS

Job Training: What the Worker Should Be Able To Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
	34. Construct wiring diagrams for gas furnaces
	35. Size gas piping
36. Install, start, and adjust a gas furnace	
37. Disassemble, inspect, and reassemble a gas furnace	
38. Perform maintenance on a gas gurnace	
39. Troubleshoot a gas furnace on a "no heat" complaint	
40. Install a retrofit package to replace a standing pilot with a cycling pilot	

UNIT II: ELECTRICAL HEATING SYSTEMS

Job Training: What the Worker Should Be Able To Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
	1. Terms
	2. Types of electrical heating systems
	3. Differences in types of electrical heating systems
	4. Components of electrical heating systems
	5. Causes of common failures of electrical heating components
6. Install, start, and check an electrical heating unit	
7. Disassemble, inspect, and reassemble an electric furnace	
8. Troubleshoot an electric furnace	
9. Perform maintenance on an electric furnace	

AIR CONDITIONING AND REFRIGERATION BOOK IV

INSTRUCTIONAL ANALYSIS

Job Training: What the Worker Should Be Able To Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)

UNIT III RESIDENTIAL COOLING SYSTEMS

1. Terms
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3. Electrical components of an air conditioner
4. Processes in the cooling cycle
5. How the cooling cycle is completed
6. What happens with fan on continuous operation
7. Compressor motor failures and ways they can be detected
8. Compressor failures and ways they can be detected
9. Failures in condensing sections and their possible causes
10. Functions of low side section components in an air conditioner
11. Problems of low side sections and their causes
12. Steps in using a charging table
13. Rule of thumb for working without a charging table

14. Trouble shoot an air conditioner condenser section on a "no cooling" complaint
15. Perform maintenance on an air conditioner
16. Use a charging table to check the charge in a capillary cooling system

AIR CONDITIONING AND REFRIGERATION BOOK IV

INSTRUCTIONAL ANALYSIS

Job Training: What the Worker Should Be Able To Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)

UNIT IV: HEAT PUMP SYSTEMS

1. Terms
2. Components of a heat pump
3. Differences between the operation of a 4-way reversing valve in the heating mode and cooling mode
4. Operation of a heat pump in the defrost mode
5. Components of a heat pump indoor section
6. Characteristics, advantages, and disadvantages of heat pump systems
7. Differences between components of indoor sections of heat pumps and low side sections of air conditioners
8. Common component failures of heat pumps in the cooling mode
9. Proper installation of an electric strip heater
10. Special precautions for replacing reversing valves
11. Major rules for good heat pump operation
12. Trace operational circuits for a heat pump in the cooling mode
13. Trace operational circuits for first stage heating in a heat pump

INSTRUCTIONAL ANALYSIS

Job Training: What the Worker Should Be Able To Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
	14. Trace operational circuits for a heat pump in the defrost mode
	15. Trace operational circuits for second stage supplementary heat in a heat pump
16. Wire a control system for a heat pump	
17. Troubleshoot a heat pump indoor section in the cooling mode	
18. Perform maintenance on an indoor section of a heat pump in the cooling mode	
19. Troubleshoot a heat pump on a "no cooling" complaint	
20. Troubleshoot a heat pump outdoor section on an "insufficient cooling" complaint	
21. Perform maintenance on an outdoor section of a heat pump in the cooling mode	
22. Troubleshoot supplemental heat on a heat pump	
23. Perform maintenance on heat pump supplemental heating	
24. Troubleshoot a heat pump on a "no heat" complaint when compressor will not run	
25. Troubleshoot a heat pump on a "no heat" complaint when compressor runs but cycles on compressor overload	
26. Troubleshoot a heat pump on an "insufficient heat" complaint when compressor will run	

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AIR CONDITIONING AND REFRIGERATION BOOK IV

INSTRUCTIONAL ANALYSIS

Job Training: What the Worker Should Be Able To Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)

UNIT V: BALANCE POINTS

Job Training: What the Worker Should Be Able To Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
	1. Terms
	2. COP of a direct electrical heating element and the COP of a heat pump
	3. COP of a heat pump at given design conditions
	4. Balance points and their relation to COP
	5. Balance points and typical stages in heating continuity
	6. Factors needed to plot balence points
	7. Heat pump performance curve
	8. Plot balance point #1 from given design conditions
	9. Plot additional balance points from given design conditions
	10. Procedure for sizing a heat pump on the cooling load
	11. Adventages of controlled heating stages
	12. Installation considerations related to heat pump performance
	13. Size a heat pump on the cooling load
	14. Plot balence points for a heat pump at given design conditions
	15. Locate equipment to obtain maximum COP from a heat pump

AIR CONDITIONING AND REFRIGERATION BOOK IV

INSTRUCTIONAL ANALYSIS

Job Training: What the Worker Should Be Able To Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)

UNIT VI: HYDRONICS

1. Terms
2. Basic types of hydronic systems
3. Classifications of hydronic systems with their temperature-pressure characteristics
4. Common types of hydronic system designs
5. Hydronic system designs and their advantages and disadvantages
6. Design water temperature
7. Terminal units and design water temperature drop
8. Design water flow rates through circuits
9. Flow rates through terminal units and tubing sizes
10. Placement of terminal units
11. Terminal units, their characteristics and uses
12. Steps in the selection and sizing of terminal units
13. Fuels, ratings, and selection of boilers
14. Advantages and disadvantages of types of residential expansion tanks

INSTRUCTIONAL ANALYSIS

Job Training: What the Worker Should Be Able To Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
	15. Steps in the selection of residential expansion tanks
	16. Types, designs, and sizing of residential pumps
	17. Factors in the selection of residential pumps
	18. Steps in selection of residential pumps
	19. Factors affecting pipe sizing
	20. Procedure for selection of pipe sizes
	21. Hydronic specialities, their characteristics and uses
	22. Steps in designing a hydronic system
	23. Lay out a series loop single circuit hydronic system with boiler located under floor of dining room
	24. Select boiler and expansion tank
	25. Make a trial selection of pump and select pipe size for series loop system

AIR CONDITIONING AND REFRIGERATION BOOK IV

TOOLS AND EQUIPMENT LIST

Hammer
Aviation snips
Scratch awl
Screwdrivers
Nut drivers
Electric drill and bits
Service technician's tool pouch
Flashlight
Oil can with #10 oil
Volt-ohm-ammeter
Millivolt meter
Manometer
Combustion test kit
Thermometer
Refrigeration thermometer or thermometer feeler bulb
Suction or compound gauge
Gauge manifold
Inspection mirror with swivel attachment on 12" handle
Shop rags
Gloves
Duct tape
Metal screws
Gas furnace as selected by instructor
Gas furnace with standing pilot as selected by instructor
Cycling pilot retrofit package as selected by instructor
Cooling system as selected by instructor
Electrical heating system as selected by instructor
Heat pump trainer or heat pump system as selected by instructor

REFERENCES

(NOTE: This is an alphabetized list of references used in completing this text.)

Althouse, Andrew D., and Carl H. Turnquist and Alfred F. Bracciano. *Modern Refrigeration and Air Conditioning.* South Holland, IL: The Goodheart-Willcox Company, Inc., 1975.

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Parallel and Series Pump Application, Bulletin No. TEH 1065. Bell & Gossett Division, ITT.

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Russell, Allen. *Getting Started in Heating and Air Conditioning.* Birmingham, MI: Business News Publishing Co., 1974.

GAS FURNACES
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify types of gas furnaces and problems associated with their components, and list energy saving devices used in retrofitting. The student should also be able to install, service, and maintain a residential gas furnace. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and jobs sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to gas furnaces with their correct definitions.
2. Match types of gas furnaces with their applications.
3. Identify components of a gas burner assembly.
4. Match types of gas valves with their characteristics.
5. Identify components of a combination electric gas valve.
6. Select true statements concerning the characteristics of a heat exchanger.
7. Select true statements concerning advancements in heat exchanger technology.
8. Select true statements concerning the characteristics of a draft diverter.
9. Identify types of blower assemblies.
10. Complete a list of components of a control system.
11. Describe the functions of a transformer.
12. Match types of thermostats with their functions.
13. Select true statements concerning limit switch operation.
14. Select true statements concerning fan switch operation.
15. Select true statements concerning combination fan-limit switch operation.
16. Describe pilot light operation.
17. Describe thermocouple operation.
18. Describe pilot safety operation.

19. Select true statements concerning potential sources of thermocouple failure.

20. Complete a list of potential sources of fan switch failure.

21. Complete a list of potential sources of transformer failure.

22. Select true statements concerning potential sources of high limit switch failure.

23. Differentiate between two potential sources of gas valve failure.

24. Select true statements concerning potential sources of fan relay failure.

25. Match potential blower section failure with component sources.

26. Differentiate between two potential sources of heat exchanger failure.

27. Select true statements concerning potential sources of pilot safety failure.

28. Complete a list of factors needed to determine gas pipe sizing.

29. Complete a list of energy saving devices designed for retrofitting.

30. Select true statements concerning set back thermostats and their uses.

31. Select true statements concerning intermittent ignition systems and their uses.

32. Select true statements concerning vent dampers and their uses.

33. Trace the high voltage and low voltage ciruits of a gas furnace.

34. Construct wiring diagrams for gas furnaces.

35. Size gas piping.

36. Demonstrate the ability to:

    a. Install, start, and adjust a gas furnace.

    b. Disassemble, inspect, and reassemble a gas furnace.

    c. Perform maintenance on a gas furnace.

    d. Troubleshoot a gas furnace on a "no heat" complaint.

    e. Install a retrofit package to replace a standing pilot with a cycling pilot.

GAS FURNACES
UNIT I

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Discuss and demonstrate the procedures outlined in the job sheets.

VII. Show the class examples of ladder diagrams for gas furnace wiring circuits and explain the symbols used to denote specific components that are needed for the assignment sheets.

VIII. Invite a factory representative or a local contractor to talk to the class concerning new techniques in furnace and component construction and their relation to energy conservation.

IX. Invite the local building inspector to discuss construction codes and other regulations concerning furnace installation and service; be sure to ask about codes concerning vent damper retrofits.

X. Invite a local or area contractor who works with solar heating applications to talk to the class concerning area activities in complete or passive solar heating systems.

XI. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Upflow Gas Furnace
2. TM 2--Counterflow Gas Furnace
3. TM 3--Horizontal Gas Furnace
4. TM 4--Lowboy or Basement Gas Furnace

5. TM 5--Components of a Gas Burner Assembly

6. TM 6--Components of a Combination Electric Gas Valve

7. TM 7--Gas Furnace Heat Exchanger

8. TM 8--Amana Heat Transfer Module (HTM®)

9. TM 9--Types of Blowers

D. Assignment sheets

1. Assignment Sheet #1--Trace the High Voltage and Low Voltage Circuits of a Gas Furnace

2. Assignment Sheet #2--Construct Wiring Diagrams for Gas Furnaces

3. Assignment Sheet #3--Size Gas Piping

E. Job sheets

1. Job Sheet #1--Install, Start, and Adjust a Gas Furnace

2. Job Sheet #2--Disassemble, Inspect, and Reassemble a Gas Furnace

3. Job Sheet #3--Perform Maintenance on a Gas Furnace

4. Job Sheet #4--Troubleshoot a Gas Furnace on a "No Heat" Complaint

5. Job Sheet #5--Install a Retrofit Package to Replace a Standing Pilot with a Cycling Pilot

F. Test

G. Answers to test

II. References

A. Althouse, Andrew D., and Carl H. Turnquist and Alfred F. Bracciano. *Modern Refrigeration and Air Conditioning.* South Holland, IL: The Goodheart-Willcox Company, Inc., 1975.

B. Lang, Paul V. *Principles of Air Conditioning.* Albany, NY 12205: Delmar Publishers, 1972.

GAS FURNACES
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Gas pressure regulator--A device for adjusting gas line pressure to the pressure specified by the appliance manufacturer

B. Pilot safety control--An electric switch which prevents a gas valve from opening unless a pilot light is present

C. Solenoid valve--An electrical device that controls the flow of gas; can be millivolt, 24V, or 115V depending on application

(NOTE: A solenoid valve is normally closed and opens when the circuit is completed.)

D. Orifice inserts--Plugs threaded into gas burner manifolds; their small, precisely drilled holes meter precise amounts of gas to individual burners

E. Primary shutter--An adjustable opening on a gas burner which meters the amount of air to mix with the gas in order to produce a proper flame

F. Pilot runner (crossover igniter)--A small opening in a gas burner which diverts a small amount of gas to the vicinity of the pilot flame to assist in a quick, even lighting of all burners in a gas furnace

G. Thermocouple--Serves as a safety device on gas furnaces to cut off the gas supply in the event of loss of flame in the pilot light

H. Fan relay--An electrical device in a furnace blower assembly that energizes the blower from a remote location

I. Bonnet--An air collection chamber

J. Gas valve--An electrically operated valve that controls the flow of gas

K. Retrofit--To remodel or repair; in air conditioning and refrigeration it generally means replacing older system components with new components that conserve energy

II. Types of gas furnaces and their applications

A. Upflow--Installed where headroom is not a problem (Transparency 1)

(NOTE: When installed in closets, upflow furnaces require special clearances from combustible materials.)

INFORMATION SHEET

B. Counterflow--Installed where basement or crawl space cannot be used, and supply ducts are located under the floor (Transparency 2)

(NOTE: When a counterflow furnace is installed on a combustible floor, it requires a special supply adapter.)

C. Horizontal--Installed in crawl space or attic where headroom is limited (Transparency 3)

(NOTE: Heat exchangers in horizontal furnaces are subjected to greater stress than heat exchangers in other furnace types.)

D. Outdoor--Installed outside and ducted into the house

(NOTE: Because these units are usually a combination furnace-air conditioner, they are called "package units," and they are usually vented by a draft inducer instead of gravity.)

E. Lowboy--Installed in basements where headroom is limited (Transparency 4)

(NOTE: Lowboy furnaces have horizontal heat exchangers.)

F. Gravity--Installed in basements, and frequently used to convert furnaces from coal to gas operation

(NOTE: Supply ducts in a gravity type furnace should be installed as nearly vertical as possible and all ducts should be as large as possible because gravity systems have no blowers.)

III. Components of a gas burner assembly (Transparency 5)

A. Gas valve (instantaneous, slow opening, or combination electric)

B. Pilot burner gas supply

C. Burner manifold with orifice inserts

D. Primary air shutter and locking screw

E. Ribbon, slot, or jet burner ports

F. Pilot runner or crossover igniters

G. Pilot burner and thermocouple assembly

H. Tap for manometer use in adjusting gas pressure

IV. Types of electric gas valves and their characteristics

A. Instantaneous--Opens instantly when energized

B. Slow opening--Opens after a lapse of one to thirty seconds when energized

INFORMATION SHEET

G. Combination--Combines other gas burner assembly components such as pressure regulator, pilot gas valve, and pilot safety

V. Components of a combination electric gas valve (Transparency 6)

A. Pilot shut off valve

B. Main gas line shut off

C. Pilot gas adjustment

D. Gas pressure regulator adjustment

E. Pilot gas connection

F. Thermocouple connection (with built-in electromagnetic pilot safety control)

G. Electrical terminals to control circuit

VI. Characteristics of a heat exchanger (Transparency 7)

A. Constructed to provide efficient heat transfer from flames to room air while keeping flue gases separate from room air

B. Composed of units called "clamshells"

C. Each clamshell designed to transfer a specific amount of heat per hour of operation

D. Each clamshell has one burner

VII. Advancements in heat exchanger technology (Transparency 8)

A. Advanced heat exchangers operate with power combustion, an intermittent ignition system that eliminates the need for a standing pilot

B. Advanced heat exchangers eliminate "up the flue" heat losses

INFORMATION SHEET

C. Advanced heat exchangers eliminate "off cycle" heat losses common with conventional gas furnaces and do not add heat to the air conditioning load

Example: The Amana EPCG series systems has a heat transfer module (the HTM is a registered trademark of Amana) which utilizes a system liquid for rapid heat transfer. The Amana HTM has a stainless steel burner which through more than 19,000 tiny flames emits super-heated gas which then pases through hundreds of steel fins. The heat is then transferred through tubes embedded in the fins as a water-ethylene glycol solution is pumped through the tubes. This system liquid leaves the embedded tubes at about 180°F and is carried through the copper tubing loops of the indoor coil. When the coil reaches a temperature of 124°F, the indoor blower automatically starts moving air through the coil to provide heat to the conditioned space. Amana reports fuel utilization efficiencies of up to 86%, or up to 33% better than standard gas furnaces with pilot lights.

(NOTE: The example given is not intended to endorse product; it was selected because it demonstrates significant advancement in heat exchanger technology.)

VIII. Characteristics of a draft diverter

A. Constructed to collect flue gases from upper opening of heat exchanger and funnel them into the vent without pulling excess air over the flames

B. Constructed to be open to the atmosphere

C. Induces unheated air into vent pipe to reduce temperature of flue gases

D. Prevents wind that enters the vent pipe from blowing out the pilot

IX. Types of blower assemblies (Transparency 9)

A. Direct drive

1. Approximately 1050 rpm on high speed

2. Supported by motor shaft

3. Variable speed requires a multi-speed motor

B. Belt drive

1. Motor is usually 1725 rpm

2. Blower wheel is supported by shaft and bearings

INFORMATION SHEET

3. Variable speed is obtained by varying the setting of a split pulley

(NOTE: Blower assemblies are constructed to pull air through the return air ducts and filter, and push air through the heat exchanger and supply ducts; they require careful adjustment to produce enough volume and velocity to maintain comfort at design conditions.)

X. Components of a control system

A. Transformer

B. Thermostat

C. Electric gas valve

D. Limit switch

E. Fan switch

F. Combination fan-limit switch

G. Pilot light

H. Thermocouple

I. Pilot safety

XI. Functions of a transformer

A. Reduces supply voltage to 24 volts

B. Furnishes power for control circuit

XII. Types of thermostats and their functions

A) Heat only thermostats

1. Consist of one switch which closes on a drop in temperature

2. Have only a heat anticipator

3. May have a set back energy conservation feature

B. Heat and cool thermostats

1. Temperature operated heating switch closes on drop in room temperature

2. Temperature operated cooling switch closes on increase in room temperature

INFORMATION SHEET

3. Manually operated fan switch closes circuit to fan relay
4. Have both heating and cooling anticipators
5. May have a set back energy conservation feature

XIII. Limit switch operation

A. Opens on temperature rise

B. Senses bonnet temperature

C. Set at 180 to 200 degrees

D. Interrupts circuit to gas valve or transformer

E. May be separate or combined with fan switch

F. Designed to shut off gas supply to burners if furnace overheats

G. In some models will bypass fan switch to bring on blower while furnace is overheated

XIV. Fan switch operation

A. Closes on temperature rise

B. Senses bonnet temperature

C. Adjustable "on" switch approximately 100 to 180 degrees

D. Adjustable "off" switch approximately 20 to 80 degrees cooler than "on" switch

(NOTE: Some manufacturers use an electric fan switch with time delay to permit furnace to heat before closing blower circuit; this switch does not sense furnace bonnet temperature.)

E. All types of fan switches for gas furnaces are designed to close supply circuit to blower motor when furnace is hot

F. May be combined with limit switch

XV. Combination fan-limit switch operation

A. Combines complete set of fan switches

B. Contains pre-set high limit switch

1. May control gas valve on 24 volts

INFORMATION SHEET

2. May control transformer supply circuit on house current of 115 volts

(CAUTION: Combination fan-limit switches are frequently converted from 115 volt to 24 volt operation and vice versa through the high limit switch; this must be recognized during service work to prevent destruction of the gas valve.)

XVI. Pilot light operation

A. Small flame lights main bu[illegible] when gas valve opens

B. Furnishes heat to thermocouple tip

XVII. Thermocouple operation

A. Converts heat from pilot into an electric current which controls the pilot safety

B. Connects electrically to pilot safety

XVIII. Pilot safety operation

A. Opens control circuit to gas valve in event pilot light fails

B. May be incorporated into combination gas valve or installed as a separate device

XIX. Potential sources of thermocouple failure

A. May fail to generate enough voltage to hold open the gas valve or pilot safety

B. Tip may be burned out because pilot flame is too hot

C. May not be getting enough heat from pilot flame

1. Not properly positioned in pilot flame

2. Soot build up insulates thermocouple

XX. Potential sources of fan switch failure

A. Contacts stick together making fan run all the time

B. Fan switch temperature setting becomes unreliable causing fan to come on too soon or too late

(NOTE: In attic installations, the fan will come on in the summer if attic temperature rises above fan switch set point.)

INFORMATION SHEET

XXI. Potential sources of transformer failure

A. May burn out either in the primary or secondary windings

B. Usually fails for no apparent reason

XXII. Potential sources of high limit switch failure

A. Normally closed switch that is faulty will not open in presence of unsafe temperature

B. Usually very reliable, but might be prevented from operating because of external causes

1. Switch cover jammed against moving plate

2. Wires touching because of burned insulation

XXIII. Potential sources of gas valve failure

A. Usually fails because it will not open

B. Rarely fails because it will not close

XXIV. Potential sources of fan relay failure

A. Contacts stick together causing blower to run all the time

B. Fails to close when 24 volts is applied

C. Contacts fail to close fan circuit

XXV. Potential blower section failure and component sources

A. Blower motors

1. Bearing seizure because of improper oiling

2. Burned out or shorted motor windings

B. Blower bearings

1. Destroyed because of improper oiling

2. Destroyed because of excessive belt tension

C. Blower belts

1. Cracked, frayed, or broken

2. Too loose

3. Too tight

INFORMATION SHEET

D. Aluminum split pulleys--Can seize to motor shaft and cannot be pulled off without destruction

E. Blower wheels out of balance

1. Balance weight has come off

2. Can only be rebalanced at the factory

F. Blower wheel--Running backwards because of improper replacement

G. Blower speed

1. Creates excessive noise

2. Causes temperature stratification resulting in cold spots and hot spots in the room

3. Drawing too much current and blowing fuses

4. Providing inadequate cooling after air conditioning has been added

(NOTE: This condition usually has to be corrected by replacing motor with a higher horsepower motor to facilitate the demand for added air volume.)

XXVI. Potential sources of heat exchanger failure

A. Soot build up between clamshells

1. Usually identified by flames spilling out front of furnace

2. Flames frequently cause extensive damage to wires and electrical components

3. Requires tearing down furnace and cleaning between clamshells with wire and vacuum cleaner

(NOTE: A vacuum cleaner hose fitted with a soft copper tube is a handy tool to pick up soot and rust.)

B. Cracked heat exchanger

1. Starts as hairline cracks in sharper bends at bottom of clamshells

2. Cracks open wider in presence of heat from burner flames and create a potential hazard for occupants

3. Should be suspected when customer complains of pilot light blowing out

INFORMATION SHEET

4. Identified by visual inspection with flashlight and small mirror

(NOTE: It is frequently necessary to pull the burner assembly and blower assembly to properly examine a heat exchanger.)

XXVII. Potential sources of pilot safety failure

A. Usually evidenced by failure to open gas valve after replacement of thermocouple

B. Kills power to gas valve unless operating properly with adequate thermocouple voltage

C. On furnaces without 100% shut-off gas valves

XXVIII. Factors needed to determine gas pipe sizing

A. Specific gravity and Btu per cubic foot heating value of gas supply

B. Btuh rating of gas outlet

(NOTE: This information is either on the rating plate or in manufacturer's specifications.)

C. Distance from the gas meter to the appliance outlet

D. Maximum capacity of pipe related to cubic feet of gas per hour (Figure 1)

INFORMATION SHEET

Maximum Capacity of Pipe in Cubic Feet of Gas per Hour
(Based upon a Pressure Drop of 0.3 Inch Water Column
and 0.6 Specific Gravity Gas)

FIGURE 1

Length in Feet	Nominal Iron Pipe Size, Inches 1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4
10	132	278	520	1,050	1,600	3,050	4,800	8,500	17,500
20	92	190	350	730	1,100	2,100	3,300	5,900	12,000
30	73	152	285	590	890	1,650	2,700	4,700	9,700
40	63	130	245	500	760	1,450	2,300	4,100	8,300
50	56	115	215	440	670	1,270	2,000	3,600	7,400
60	50	105	195	400	610	1,150	1,850	3,250	6,800
70	46	96	180	370	560	1,050	1,700	3,000	6,200
80	43	90	170	350	530	990	1,600	2,800	5,800
90	40	84	160	320	490	930	1,500	2,600	5,400
100	38	79	150	305	460	870	1,400	2,500	5,100
125	34	72	130	275	410	780	1,250	2,200	4,500
150	31	64	120	250	380	710	1,130	2,000	4,100
175	28	59	110	225	350	650	1,050	1,850	3,800
200	26	55	100	210	320	610	980	1,700	3,500

Example: To determine the required pipe size of each section and outlet in the piping system in Figure 2, assume the gas to be used has a specific gravity of 0.65 and a heating value of 1,000 Btu per cubic foot.

To select the right pipe size for each section and appliance outlet, begin by dividing the Btuh rating for each output by the Btu rating of the gas supply to get the cfh (cubic feet per hour) each appliance will consume when operating. This means the water heater at outlet A would have a cfh of 30 (30,000 divided by 1,000); outlet B would be 3 cfh, outlet C, 75 cfh; and outlet D, 136 cfh.

To properly size the total system, start with the outlet with the largest cfh, the furnace at outlet D. Since it will require 50 feet of pipe large enough to supply 136 cfh, refer to the table in Figure 1. Under the "Length in Feet" column find 50, then cross the table until the proper pipe size is found. 1/2" will not handle the cfh, 3/4" will not handle it, so outlet D requires 1" pipe. By continuing with the outlet that requires the next highest cfh, each outlet and each section can be easily sized. Section 3 requires 1" pipe, section 2 requires 3/4" pipe, and section 1 requires 1/2" pipe.

INFORMATION SHEET

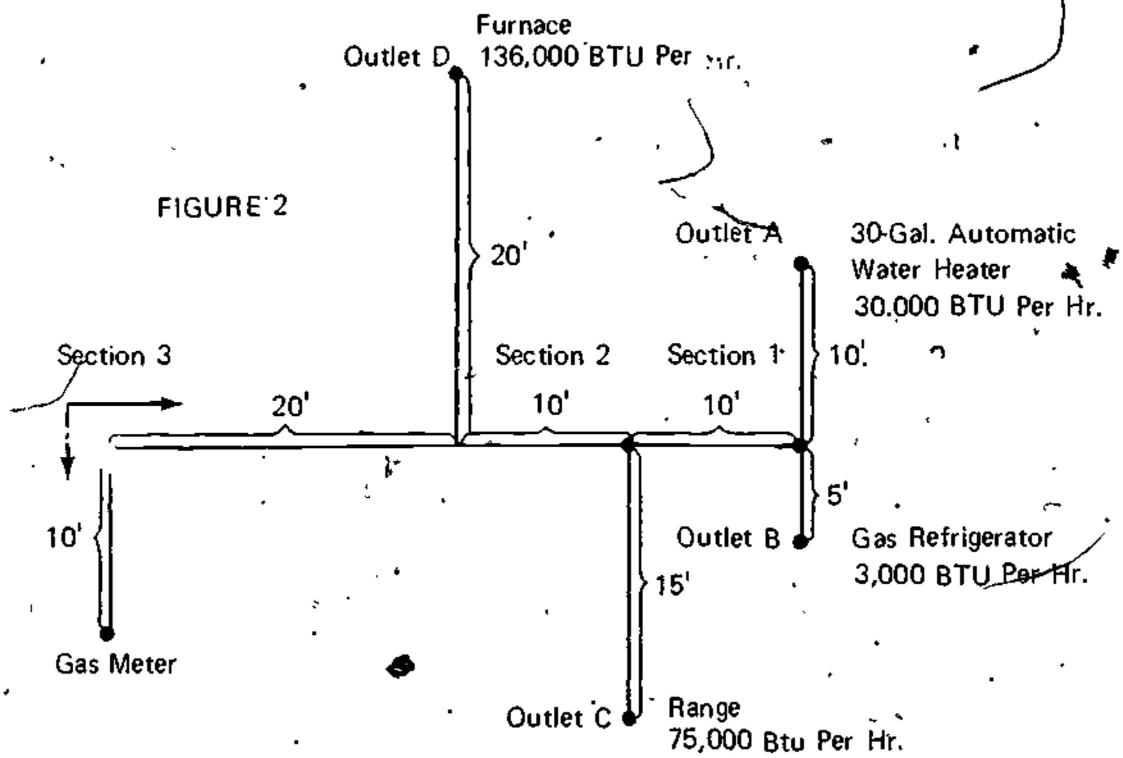


FIGURE 2

XXIX. Energy conservation devices designed for retrofitting

A. Set back thermostats.

B. Intermittent ignition systems

C. Vent dampers

XXX. Set back thermostats

A. Designed to let structure drop to a lower room temperature at night

B. Reduces heat loss because of lower temperature differential

C. Reduces fuel consumption because of reduced heat loss

D. Can be manually operated by occupant upon retiring or getting up

INFORMATION SHEET

E. Can be fully automated with clock operation providing manual override on weekends

(NOTE: Modern clock thermostats give set back temperature night and day if desired, and they also permit a structure to drift to a higher temperature to help reduce heat gain in summer.)

XXXI. Intermittent ignition systems and their uses

A. Eliminates cost of fuel to pilot flame

B. Can operate from a direct spark ignition, proven-pilot ignition, or cycling-pilot ignition

(NOTE: Refer to Job Sheet #5 for illustrations of a cycling-pilot ignition.)

C. Good proven-pilot or cycling-pilot systems are built with a "redundant" safety system which requires that the pilot light be proven with an electric or an electro-mechanical sensor before gas will flow to the main burners

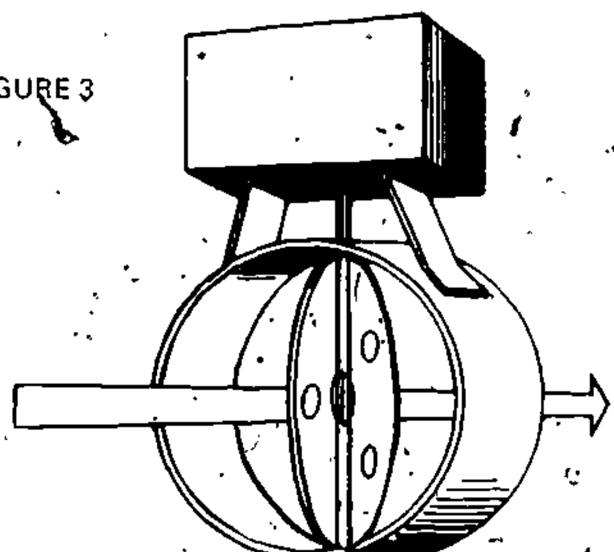
D. Are being incorporated into many new furnace designs

(CAUTION: Applications for intermittent ignition systems are different for natural and LP-gas; manufacturer's installation specifications should be followed carefully on retrofit applications, and it is sometimes necessary to contact the furnace manufacturer to make sure the furnace can be retrofitted with the intermittent system.)

XXXII. Vent dampers and their uses

A. Are designed to stay open while burner is operating in order to vent combustion gases (Figure 3)

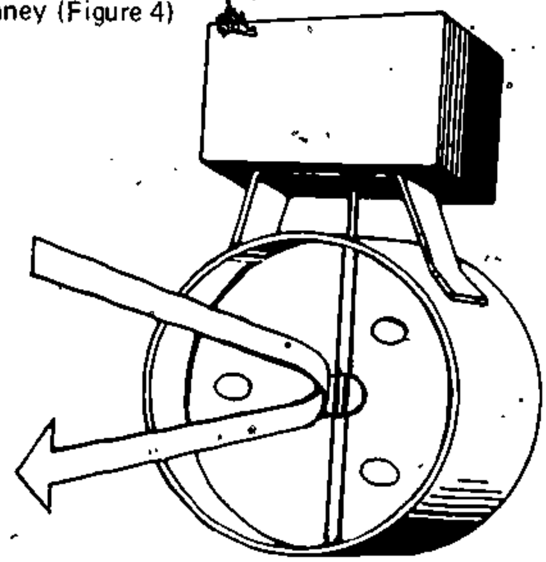
FIGURE 3



INFORMATION SHEET

B. Are designed to close when burner shuts off to stop heat from escaping up the flue or chimney (Figure 4)

FIGURE 4

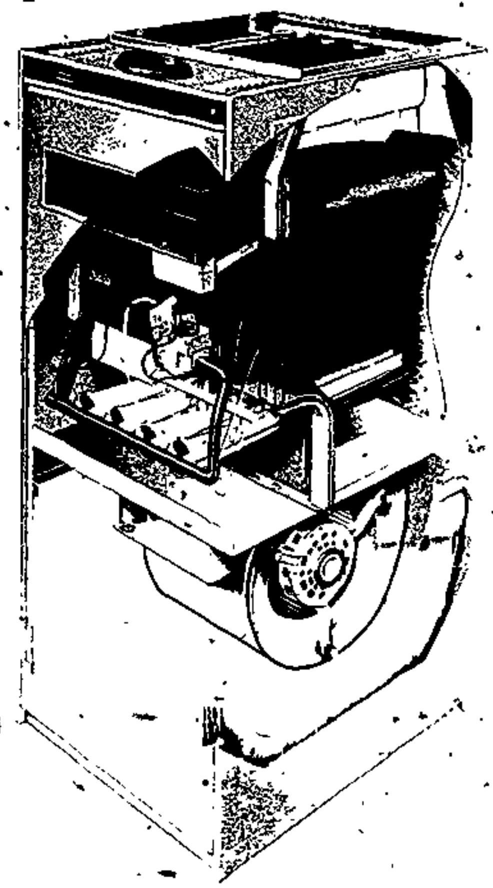


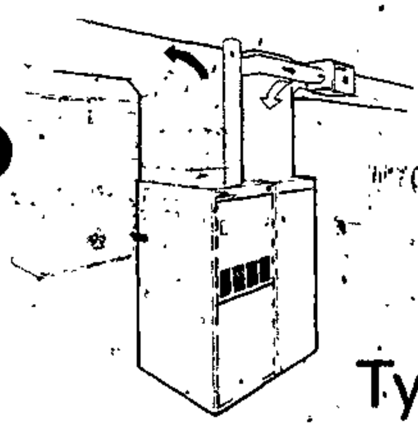
C. Are relatively easy to install, but should only be installed by a licensed contractor

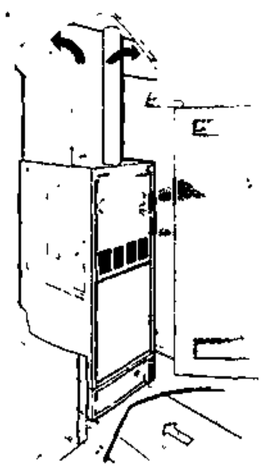
(CAUTION: Vent dampers can be both health and fire hazards if they fail to open when the furnace is operating, and some furnace warranties are voided if vent dampers are added; always check warranties to be safe, and always check local codes for regulations governing vent damper retrofit applications.)

D. Some manufacturers are building furnaces with control wiring installed for adding a vent damper

Upflow Gas Furnace





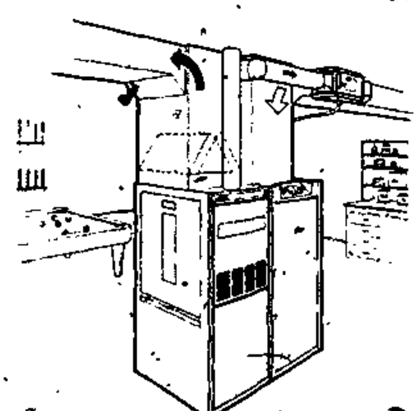


Typical Applications

Basement Installation
With Cooling Coil,
Electronic Air Cleaner and Humidifier.

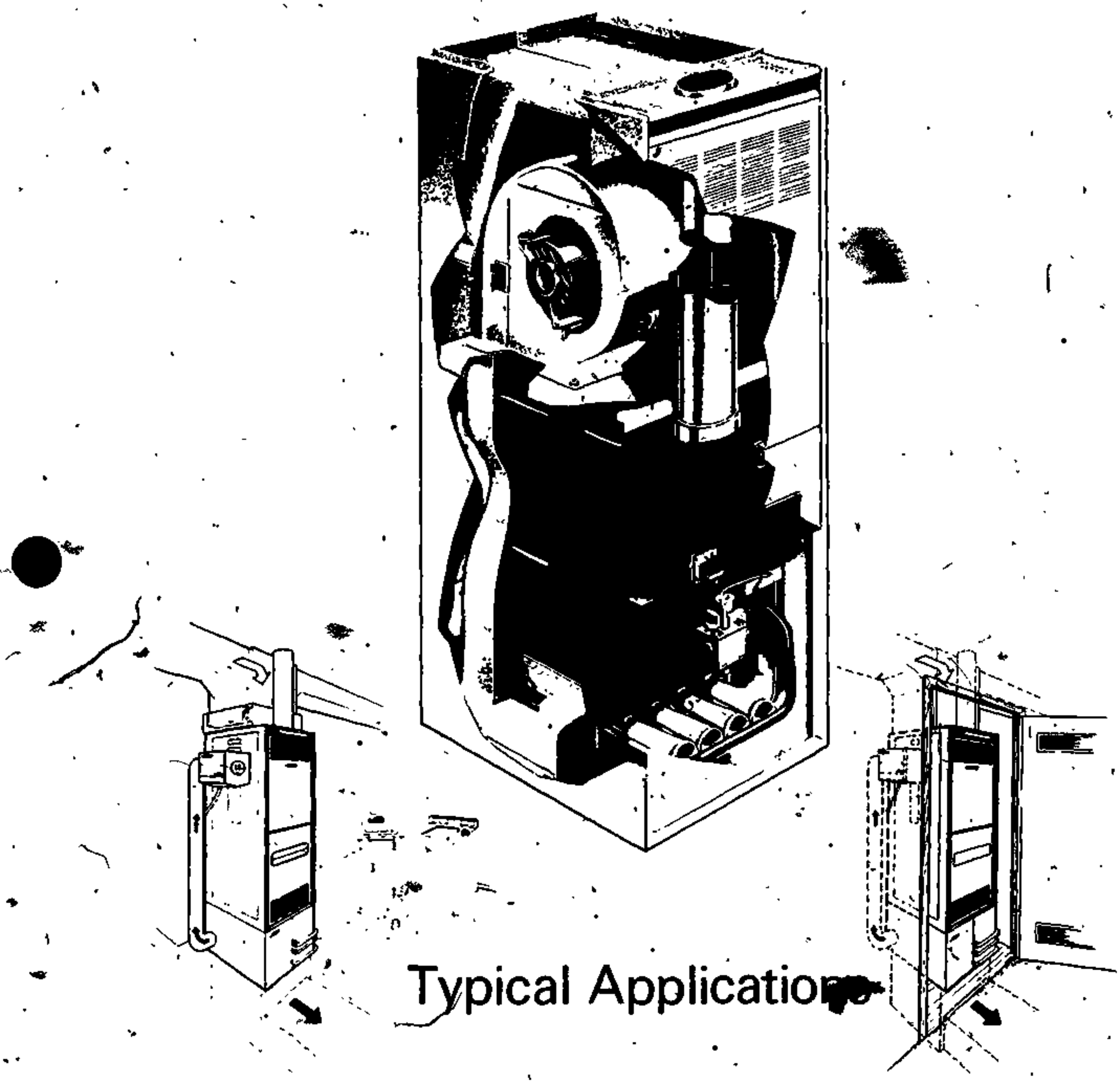
Closet Installation
With Cooling Coil
and Electronic Air
Cleaner

Basement Installation With
Cooling Coil, Return Air
Cabinet and Power
Humidifier



(Courtesy of Lennox Industries Inc., Dallas, Texas)

Counterflow Gas Furnace



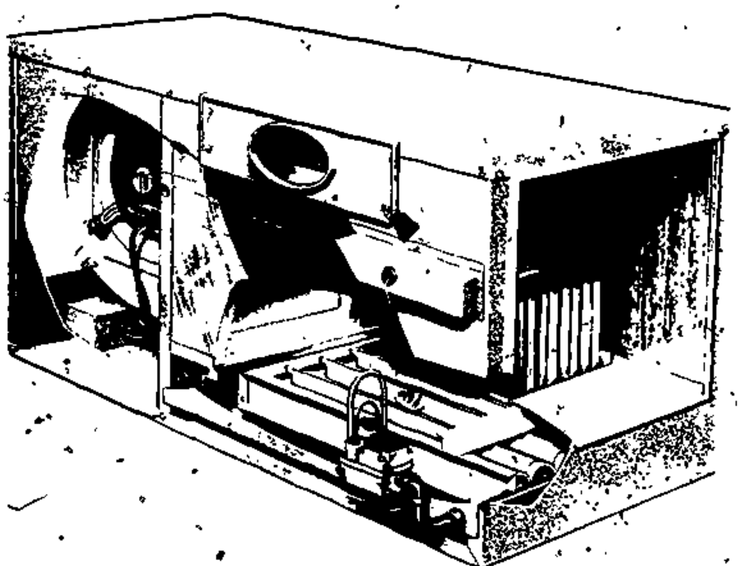
Typical Applications

Utility Room Installation With Cooling Coil, Electronic Air Cleaner and Humidifier

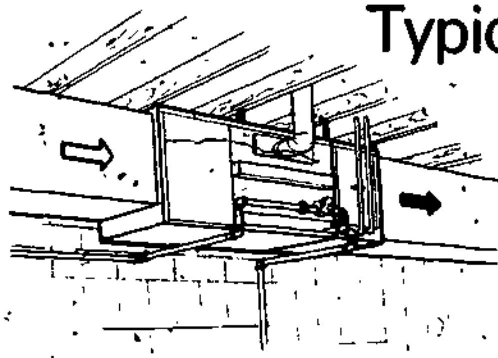
Closet Installation With Cooling Coil and Humidifier

(Courtesy of Lennox Industries Inc., Dallas, Texas)

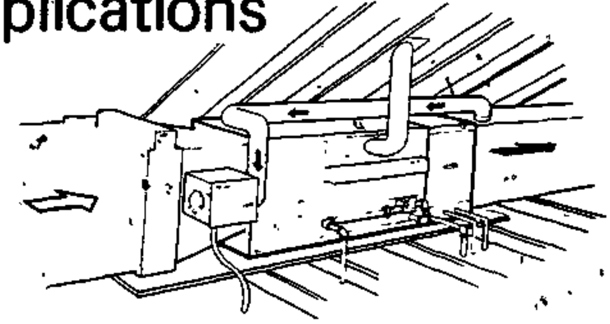
Horizontal Gas Furnace



Typical Applications

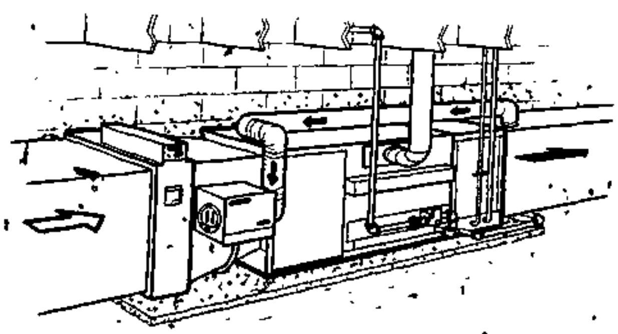


Basement Installation With Cooling Coil



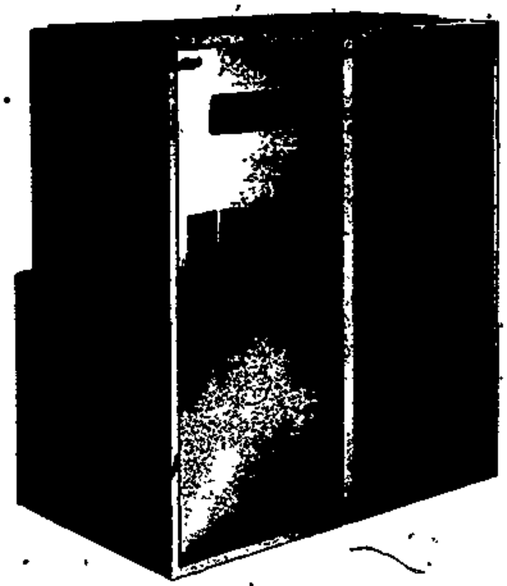
Attic Installation With Cooling Coil, Electronic Air Cleaner and Automatic Humidifier

Crawl Space Installation With Cooling Coil, Electronic Air Cleaner and Automatic Humidifier

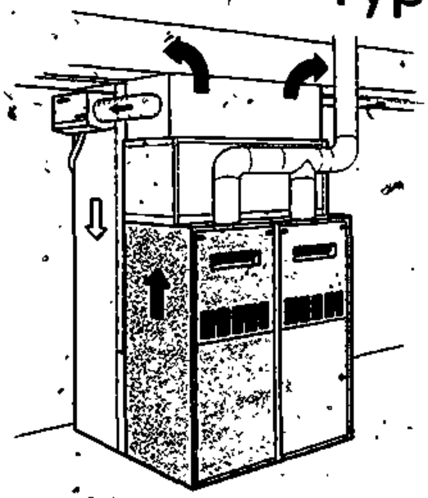


(Courtesy of Lennox Industries Inc., Dallas, Texas)

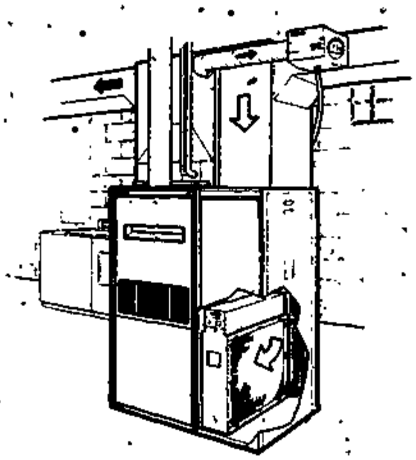
Lowboy or Basement Gas Furnace



Typical Applications



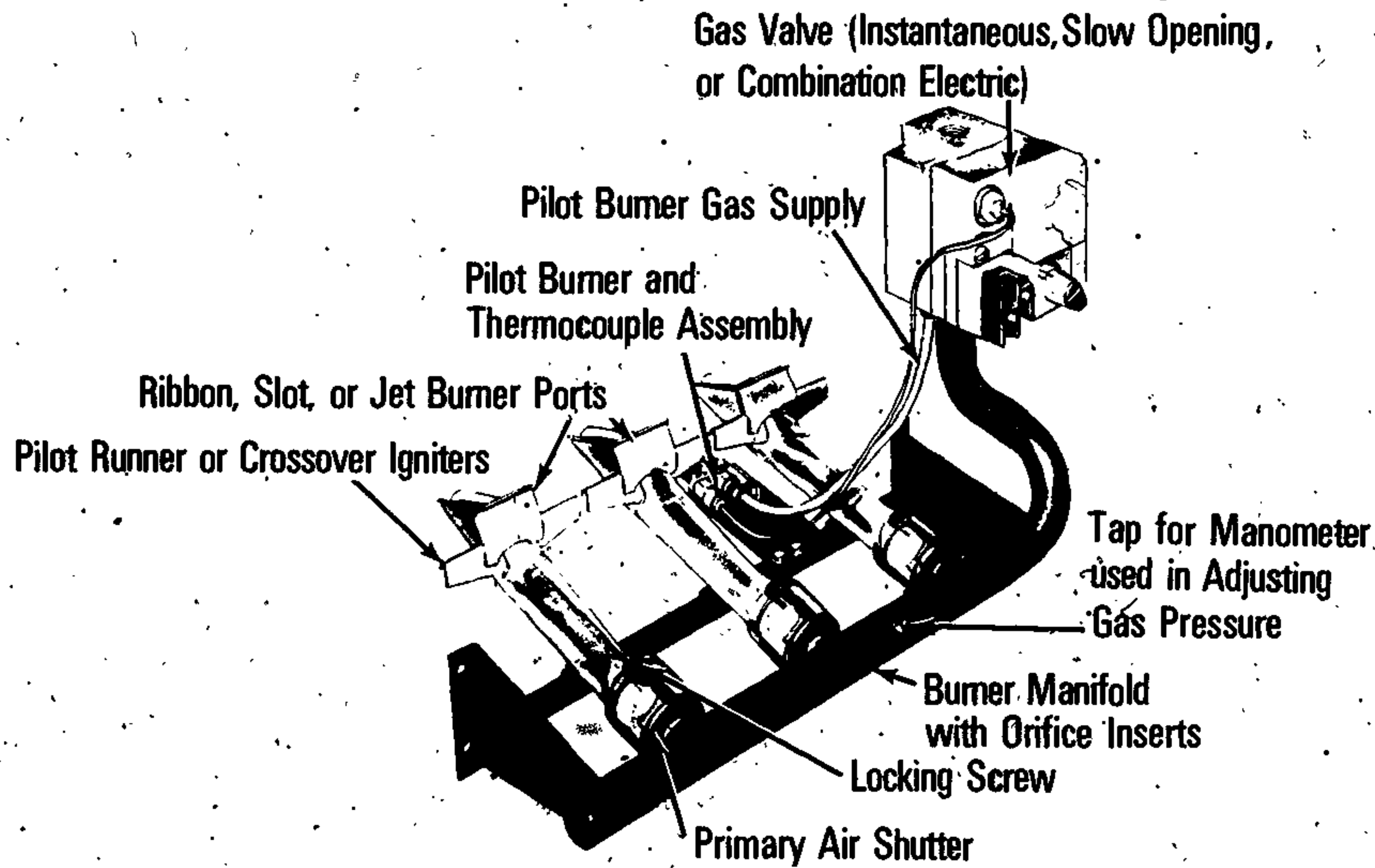
Basement Installation
With Cooling Coil and Humidifier



Basement Installation
With Cooling Coil, Humidifier, Return Air Cabinet And Electronic Air Cleaner

(Courtesy of Lennox Industries Inc., Dallas, Texas)

Components of a Gas Burner Assembly



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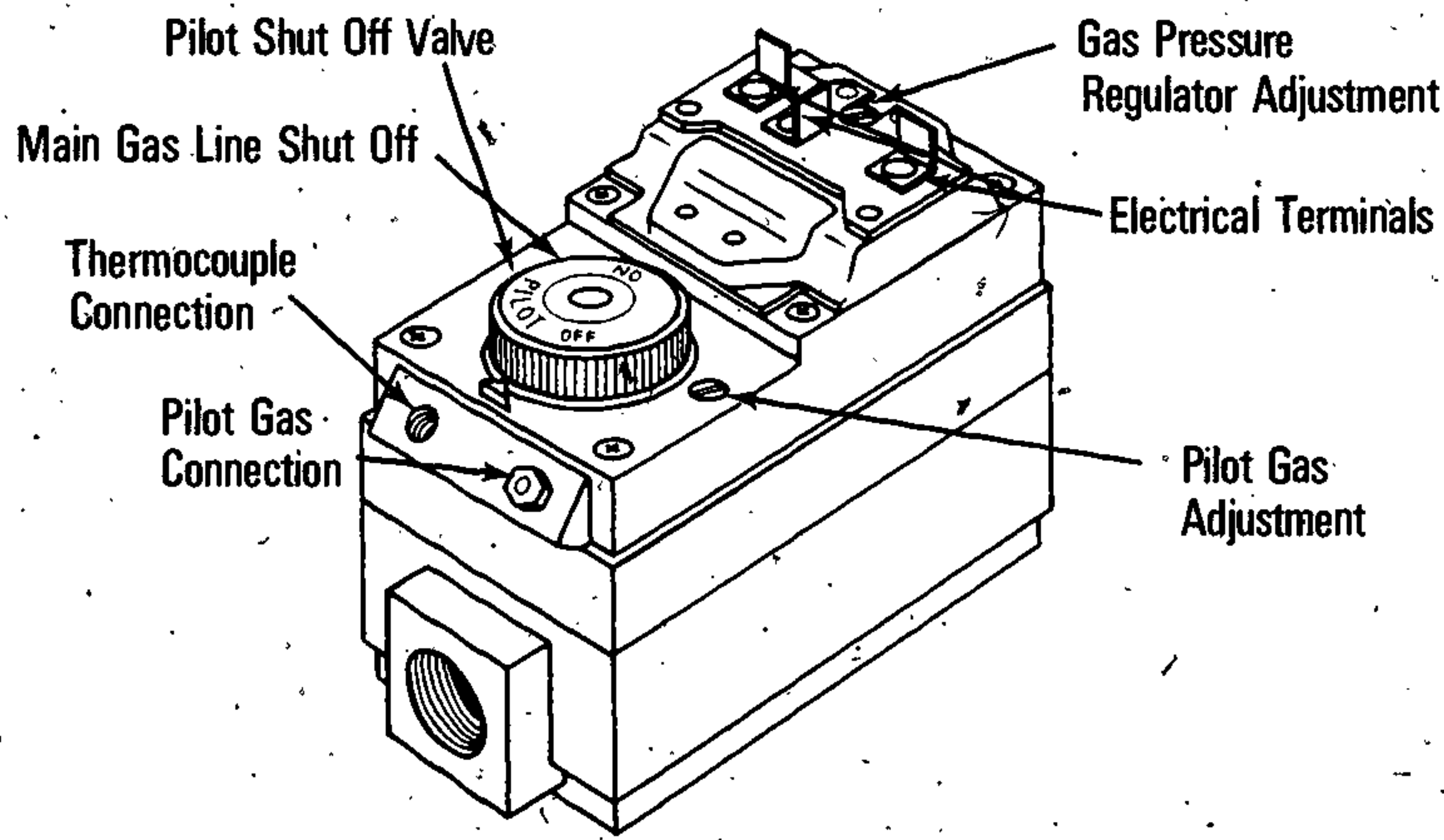
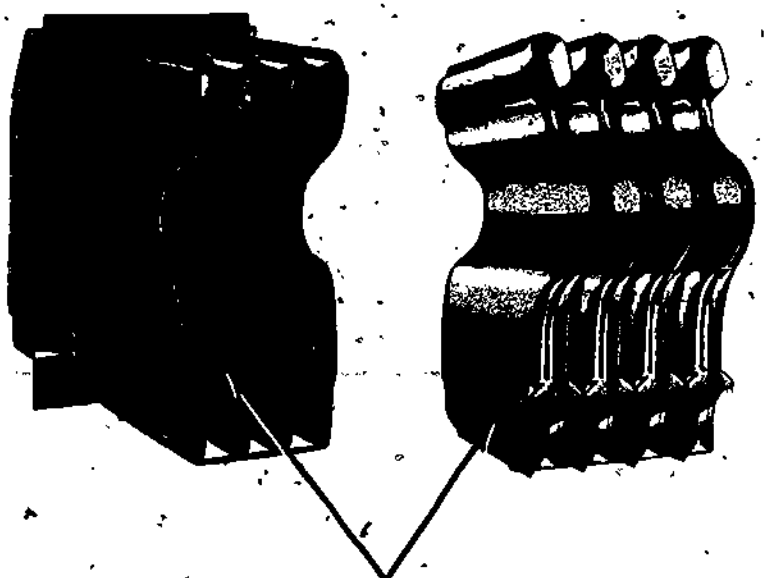
Components of a Combination Electric Gas Valve

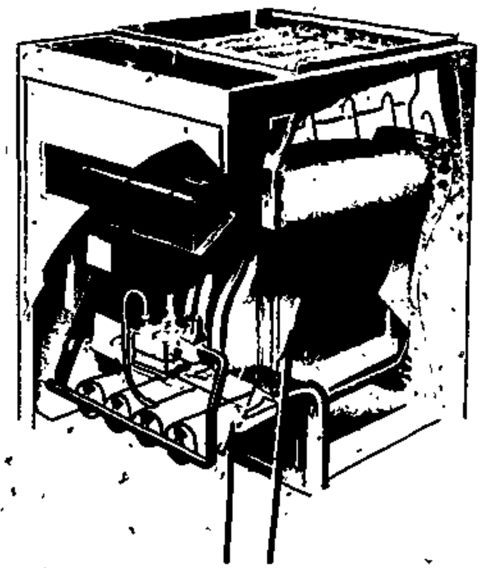


(Courtesy Prentice-Hall, Inc.)

Gas Furnace Heat Exchanger



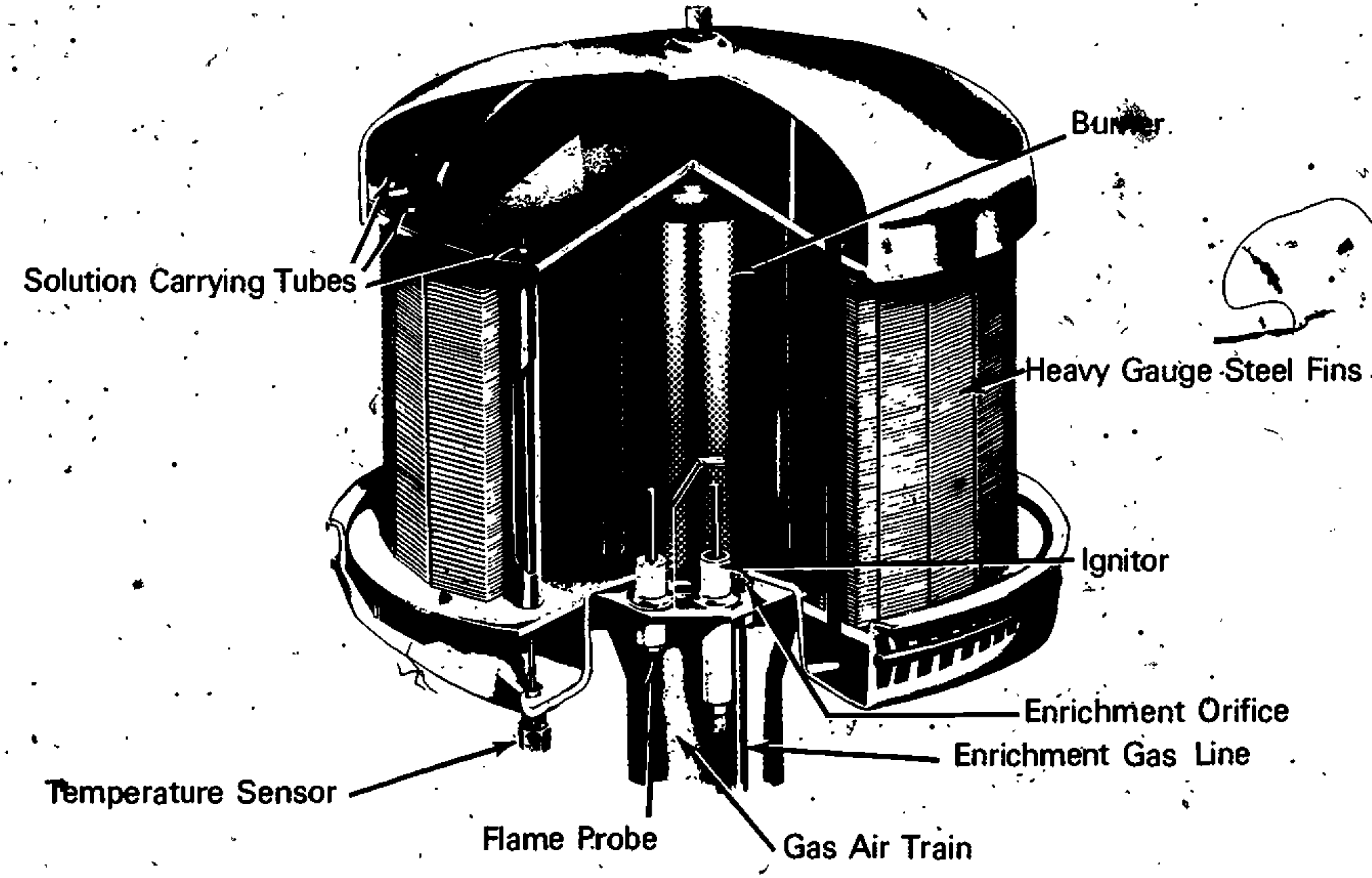
Clamshells



Each Clamshell Has One Burner

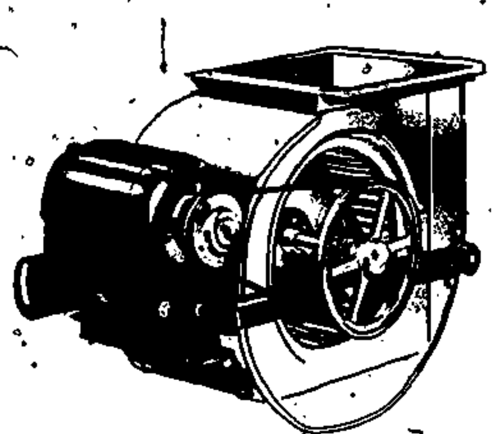
(Courtesy of Lennox Industries Inc., Dallas, Texas)

Amana Heat Transfer Module (HTM®)

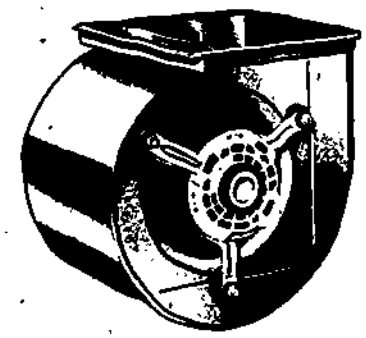


(Courtesy Amana)

Types of Blowers



Belt Drive



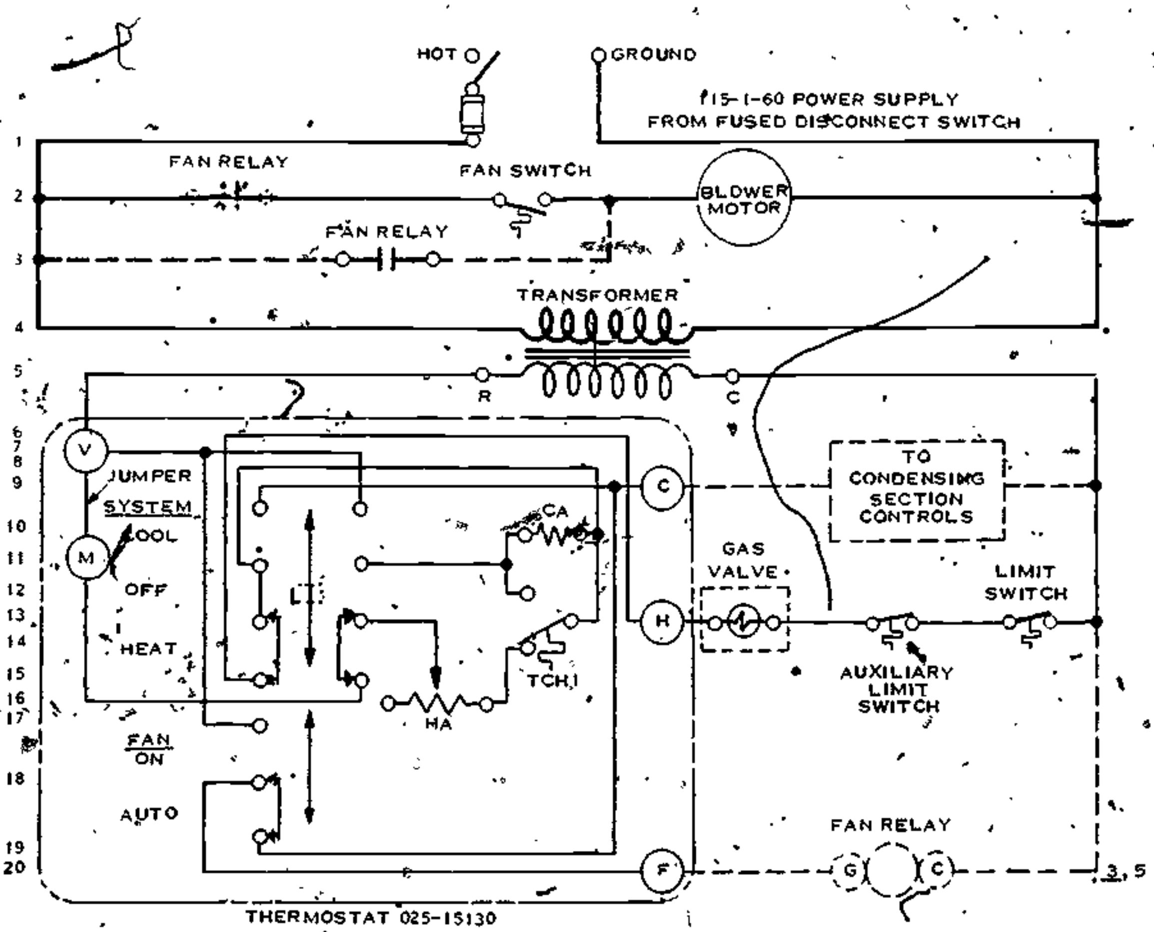
Direct Drive

(Courtesy of Lennox Industries Inc., Dallas, Texas)

GAS FURNACES
UNIT I

ASSIGNMENT SHEET #1--TRACE THE HIGH VOLTAGE AND LOW VOLTAGE CIRCUITS OF A GAS FURNACE

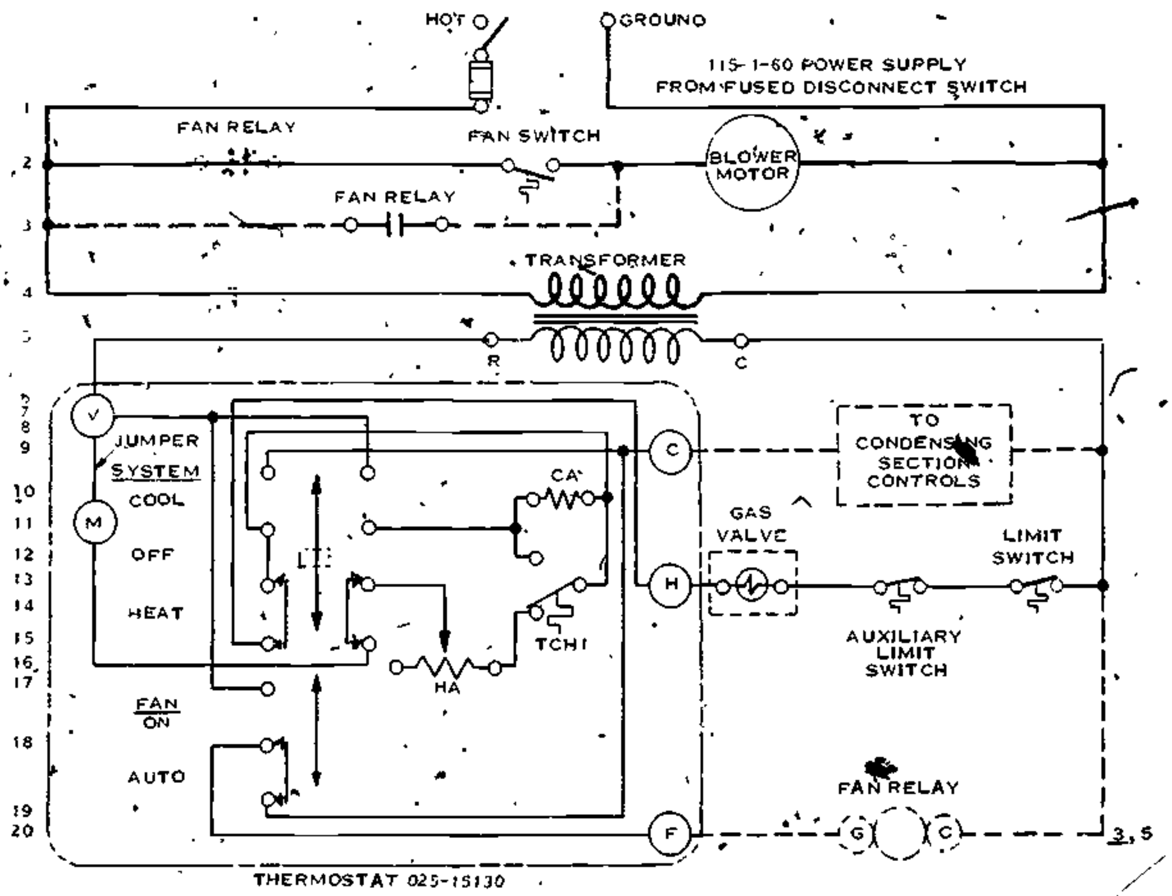
A. Use a dark colored pencil on the following schematic to trace the high voltage circuit while the thermostat calls for heat.



NOTE: COOLING CIRCUIT DOTTED IN.

ASSIGNMENT SHEET #1

B. Use a dark colored pencil on the following schematic to trace the low voltage circuit while the thermostat calls for heat.



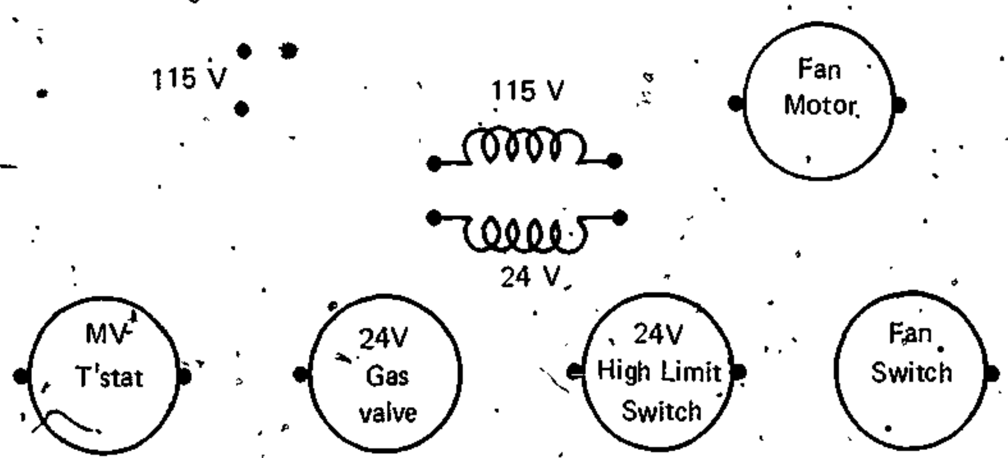
NOTE: COOLING CIRCUIT DOTTED IN.

GAS FURNACES
UNIT I

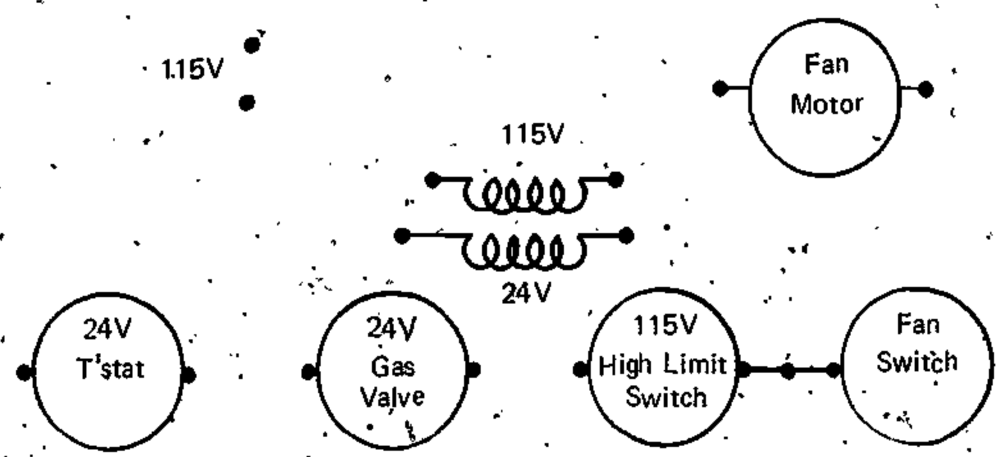
ASSIGNMENT SHEET #2--CONSTRUCT WIRING DIAGRAMS FOR GAS FURNACES

Directions: Draw lines representing wires connecting electrical components of a gas furnace in the following conditions:

A. "Heating Only" furnace with 24V high limit

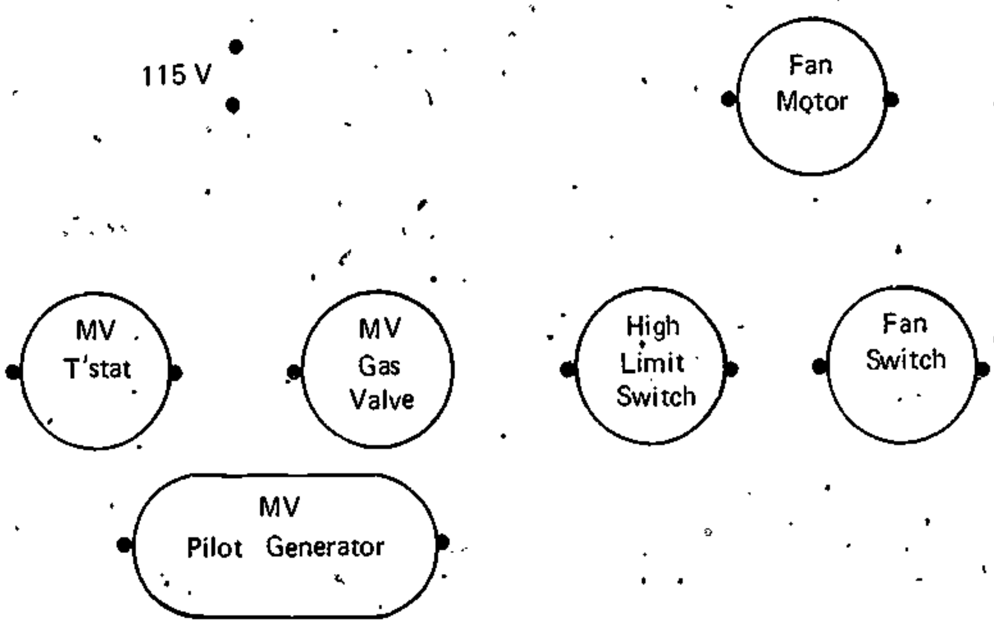


B. "Heating Only" furnace with 115V high limit



ASSIGNMENT SHEET #2

C. "Heating Only" furnace with millivolt gas valve

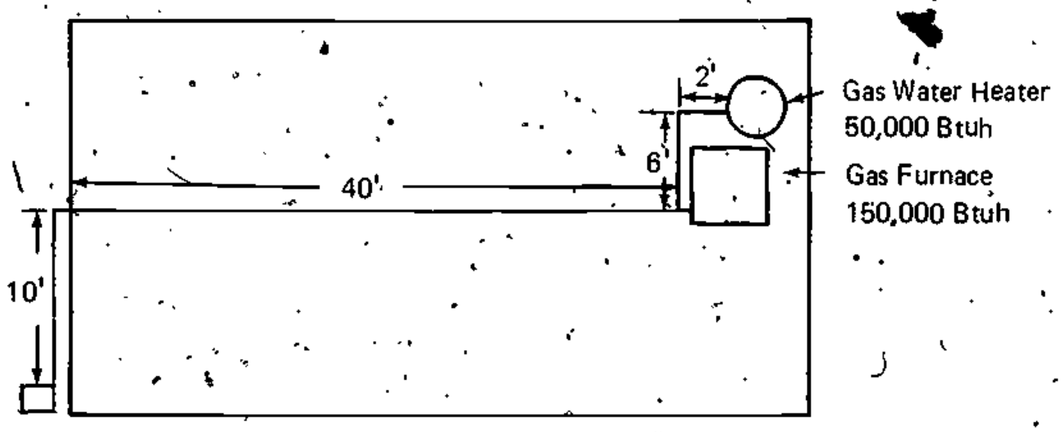


GAS FURNACES
UNIT I

ASSIGNMENT SHEET #3--SIZE GAS PIPING

Directions: Assuming a situation where a gas supply has a specific gravity of 0.65 and a heating value of 1,000 Btu per cubic foot, size the gas piping required for appliance outlets in the following diagram.

(NOTE: Use the table in Figure 1, Objective XXVIII.)



A. Pipe size from meter to furnace should be ______________________

B. Pipe size from furnace to water heater should be ______________________

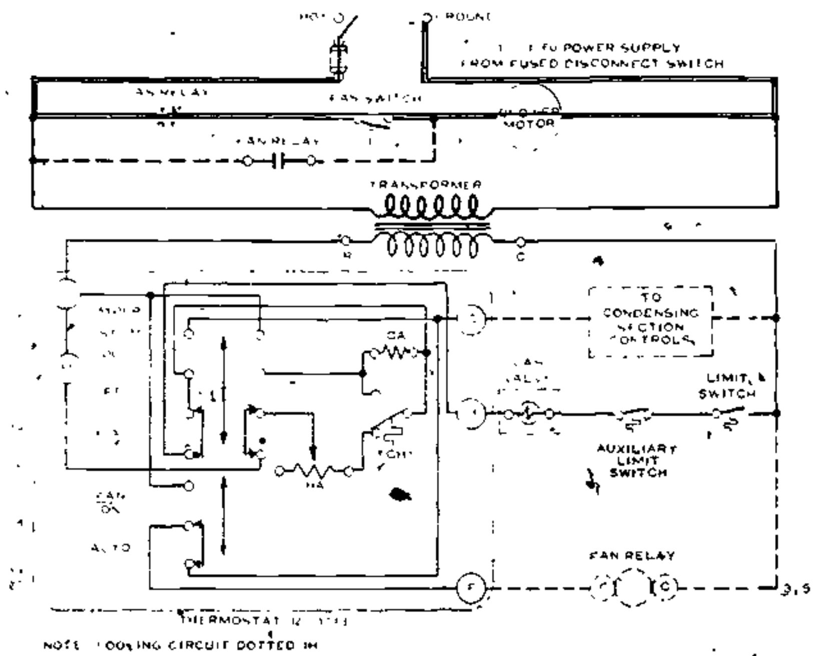
C. Indicate procedure used for each calculation ______________________

GAS FURNACES
UNIT I

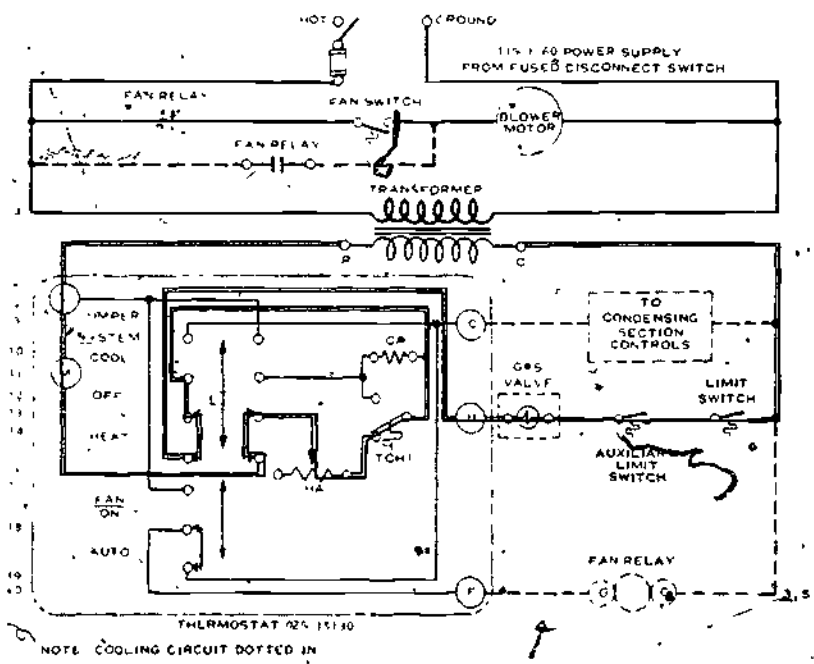
ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

a.

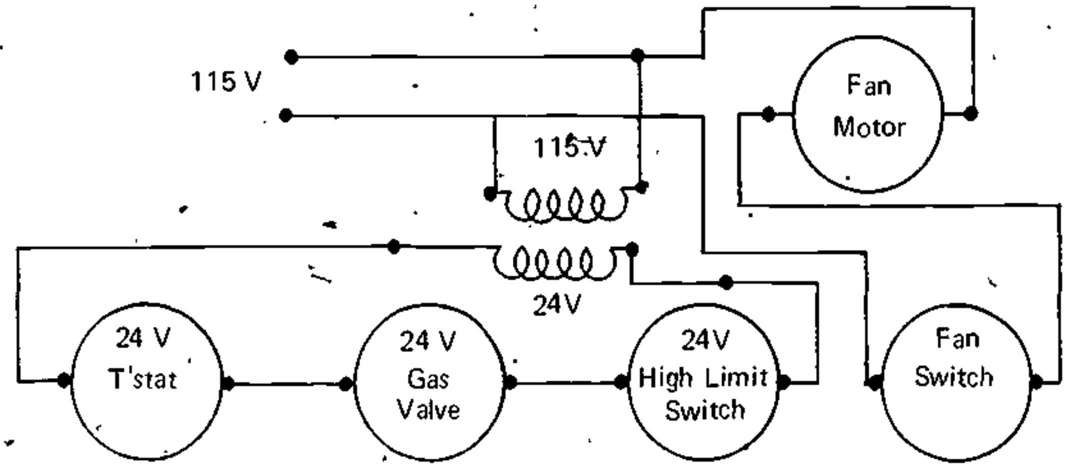


b.

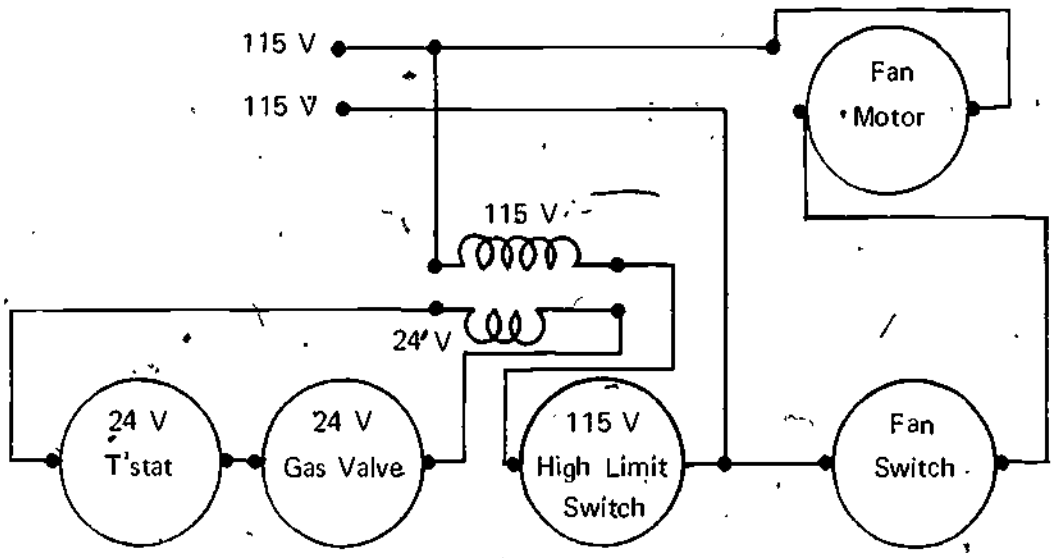


Assignment Sheet #2

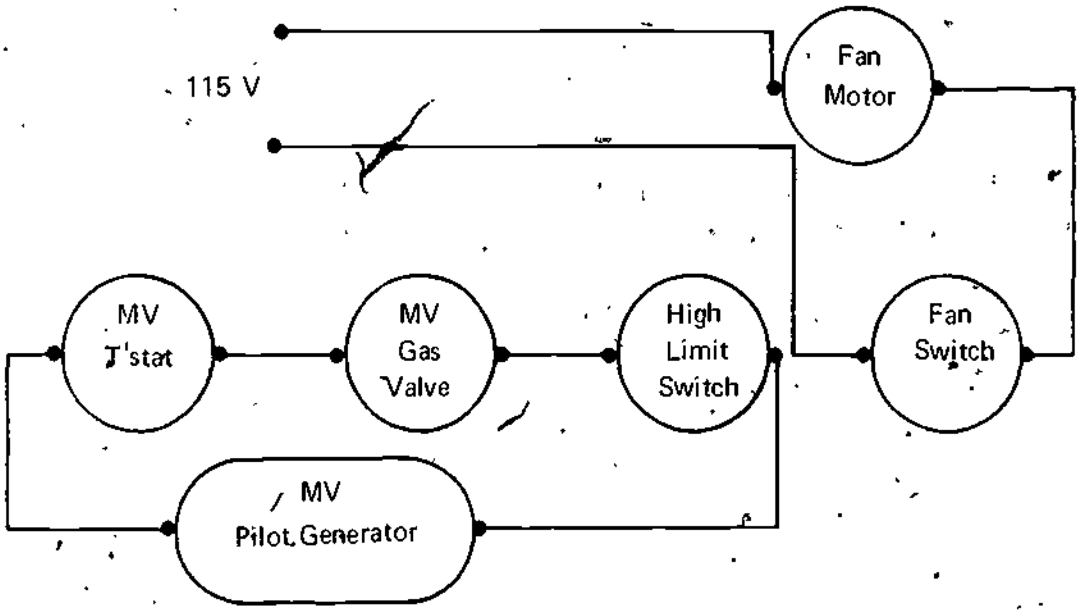
a.



b.



c.



Assignment Sheet #3

a. 1"

b. 1/2"

c. For furnace: $\frac{150{,}000 \text{ Btuh}}{1{,}000 \text{ Btu}}$ = 150 cfh for 50' = 1" pipe

For water heater: $\frac{50{,}000 \text{ Btuh}}{1{,}000 \text{ Btu}}$ = 50 cfh for 8' = 1/2" pipe

GAS FURNACES
UNIT I

JOB SHEET #1--INSTALL, START, AND ADJUST A GAS FURNACE

I. Tools and equipment:

A. Hammer

B. Aviation snips

C. Electric drill

D. Service technician's tool pouch

E. Volt-ohm-ammeter

F. Manometer

G. Combustion test kit

H. Gas furnace as selected by instructor

II. Procedure:

A. Remove crating from around furnace

B. Set furnace in location

C. Adapt and fasten plenum to top of furnace cabinet

D. Adapt and fasten return air ducts to furnace cabinet

E. Install gas flex connection to gas main behind main gas cock

F. Attach gas flex connection to gas supply port on furnace

G. Connect low voltage thermostat wires to proper terminals on furnace

H. Set thermostat and connect

I. Connect power supply cord to proper terminals on furnace electrical system

J. Adapt and connect vent piping

K. Provide proper combustion air supply

L. Turn on gas cock, check and bleed lines

M. Light pilot

N. Place thermostat in "OFF" position

JOB SHEET #1

O. Connect power supply

P. Set thermostat calling and observe lighting of main burner

Q. Check and adjust furnace combustion if necessary

R. Install manometer on manifold and check and adjust gas pressure

S. Drill hole in flue

T. Insert tube of combustion tester in flue and check for CO_2 content and combustion efficiency

(NOTE: When using a combustion test kit, follow directions carefully.)

U. Close hole in flue with sheet metal screw

V. Use amp meter to check blower motor load for tolerance

W. Disconnect blower and check high limit control

X. Block pilot flame and check pilot safety

Y. Clean up tools and area and put tools away

GAS FURNACES
UNIT I

JOB SHEET #2--DISASSEMBLE, INSPECT, AND REASSEMBLE AN UPFLOW GAS FURNACE

I. Tools and equipment:

A. Service technician's tool pouch

B. Flash light

C. Oil can with #10 oil

D. Manometer

E. Combustion test kit

F. Upflow gas furance as selected by instructor

II. Procedure:

A. Disconnect power source

B. Close gas cock and disconnect gas piping

C. Remove vent piping

D. Remove blower plenum door or panel

E. Remove two holding screws on the blower and motor and slide the blower assembly out

F. Remove gas manifold

G. Remove burners from compartments

H. Remove all screws from heat exchanger and slide the exchanger out from the covering chamber

I. Inspect heat exchanger with flashlight to determine whether or not there are any cracks

(NOTE: If cracks appear in a heat exchanger, it should be replaced; for this job sheet it is assumed the heat exchanger has no cracks.)

J. Clean heat exchanger before reassembling

K. Clean motor and blower assembly

L. Oil motor and blower if required

M. Reassemble components by repeating steps H through A in reverse

N. Set thermostat to call for heat and run furnace through a complete cycle

JOB SHEET #2

O. Check and adjust gas and air mixture until it produces a blue flame

P. Install manometer on manifold and check and adjust gas pressure

Q. Drill hole in flue

R. Insert tube of combustion tester in flue and check for CO_2 content and combustion efficiency

(NOTE: When using a combustion test kit, follow directions carefully.)

S. Close hole in flue with sheet metal screw

T. Shut down furnace

U. Clean up tools and area and put tools away

JOB SHEET #3

HH. Remove thermometer

II. Return thermostat to proper setting

JJ. Clean up tools and area and put tools away

GAS FURNACES
UNIT I

JOB SHEET #3--PERFORM MAINTENANCE ON A GAS FURNACE

I. Tools and equipment:

A. Service technician's tool pouch

B. Small mirror with swivel attachment on 12" handle

C. Flashlight

D. Dial thermometer

E. Gas furnace as selected by instructor

II. Procedure:

A. Disconnect furnace power source

B. Clean and lubricate blower and motor bearings

(NOTE: Some motors and bearings are sealed and do not require field lubrication.)

C. Check belt for slipping or wear if it is a belt-type blower

D. Inspect filters and clean if necessary

E. Remove burners

(CAUTION: If it is necessary to remove the burner assembly in order to remove the burners, it is important to close the gas cock on the gas meter side on the union.)

F. Inspect bottom of entire heat exchanger for cracks

(NOTE: Sometimes the blower has to be removed in order to see every bit of the heat exchanger.)

G. Tap rust and soot out of burners

H. Remove any accumulation of rust and soot from the bottom of firebox

(NOTE: A service technician should have an industrial type vacuum cleaner available to remove heavy accumulations of rust and soot.)

I. Remove, inspect, and clean the pilot assembly and pilot orifice

J. Replace burners and other components removed to inspect heat exchanger

K. Relight pilot and observe pilot flame

L. Return gas cock to "ON" position

JOB SHEET #3

M. Reconnect power source to furnace

N. Allow pilot safety to reset

O. Turn off gas to pilot and check to see if pilot safety locks out main gas valve

P. Relight pilot

Q. Set room thermostat to heat and raise temperature to call for heat

R. Observe action of gas valve.

S Observe height, color, and evenness of flame

T Adjust burner air shutters to produce blue flame with little or no yellow flame

U Remove a sheet metal screw in the vicinity of the limit switch and insert dial thermometer

V. Continue observing flames until blower energizes, then note temperature of thermostat

W Examine flames for any change in motion while blower is operating

(NOTE: Hairline cracks in heat exchangers frequently open up under operating temperatures and escaping air will move or blow the flames.)

X. Open furnace disconnect switch

Y. Remove a blower motor wire from fan switch and insulate the bare wire

Z. Close the furnace disconnect switch and fire the burners

AA. Observe, with blower stopped, the temperature of the thermometer as the furnace begins to overheat

BB. Note the action of the high limit switch

(NOTE: The gas valve should close before the furnace bonnet temperature reaches 200°F.)

CC. Open furnace disconnect switch and reconnect the blower

DD. Close furnace disconnect

EE. Observe temperature at which the fan starts

FF. Set thermostat to a setting lower than room temperature

GG. Observe temperature at which the fan stops

GAS FIRED FURNACES
UNIT I

JOB SHEET #4--TROUBLESHOOT A GAS FURNACE ON A "NO HEAT" COMPLAINT

I. Tools and equipment

A. Service technician's tool pouch

B. Volt-ohm-ammeter

C. Millivolt meter

D. Gas furnace as selected by instructor

II. Procedure

A. Check power source with voltmeter

B. Set room thermostat above room temperature

C. Check output of 24v transformer for voltage

D. Check 115 volt circuit from panel through disconnect to transformer if the transformer is dead

(NOTE: Some low voltage transformers are fused with a low amperage (3.2A) through the secondary circuit.)

F. Check proper adjustment and alignment of pilot flame

G. Identify type of gas valve

(NOTE: If gas valve does not open, then the thermocouple is probably bad.)

H. Check thermocouple with millivolt meter

I. Disconnect 24 volt wires from gas valve and test for voltage

J. Establish 24 volts available at valve, then if valve does not open it is bad

(NOTE: A shorted gas valve will usually burn up a transformer, and remember that some slow opening and closing gas valves take up to 20 seconds to open after applying 24 volts.)

K. Establish 24 volts not present at the gas valve, then check continuity through 24 volt circuit

(NOTE: A few limit switches have to be manually reset after tripping.)

JOB SHEET #4

L Check for open high limit switch

(NOTE: An open high limit switch usually results from insufficient air volume through the furnace, and this may result from a clogged filter, a bad fan belt, or a bad blower motor.)

M Restore all high and low voltage continuity and ready all controls for operation

N Fire the furnace and check the thermocouple

O Check the fan switch and operating temperatures

P Check the limit switch temperature

(NOTE: Do not rotate the dial of a fan or limit switch.)

Q Clean-up tools and area and put tools away

GAS FURNACES
UNIT I

JOB SHEET #5 - INSTALL A RETROFIT PACKAGE TO REPLACE A STANDING PILOT WITH A CYCLING PILOT

I. Tools and equipment

A. Service technician's tool pouch

B. Volt-ohm-ammeter

C. White-Rodgers 21D18 retrofit package or equivalent

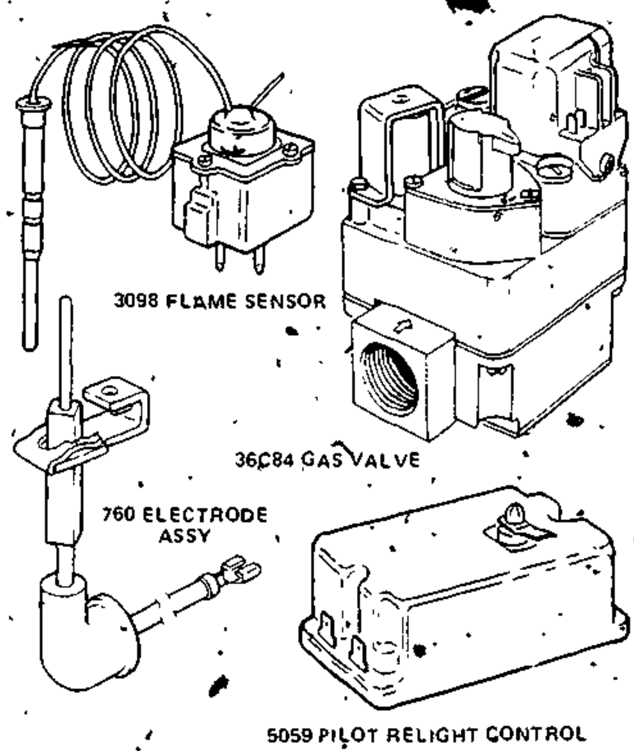
D. Gas furnace with standing pilot as selected by instructor

(NOTE: The procedures and illustrations in this job sheet are reprinted with the permission of the White-Rodgers Division, Emerson Electric Co. The procedures and components used are designed to reflect the essential elements in converting a standing pilot light into an energy-saving intermittent ignition system and no endorsement of product or procedure is intended.)

II. Procedure

A. Check Retro-Fit package to make sure flame sensor, gas valve, electrode assembly, and relight control are included (Figure 1)

FIGURE 1



JOB SHEET #5

B. Complete the following checks before shutting off gas and power

1. Cycle system to insure operating and limit controls are functioning properly

2. Check for other possible furnace/boiler malfunctions; ie., cracked heat exchanger, blocked flue, cracked boiler sections, and evidence of leaks

3. Check incoming supply voltage and 24 volt transformer output. Be sure transformer capacity is adequate. This control system requires 15 VA for proper operation

4. Observe pilot flame pattern to determine best location for ignition electrode placement

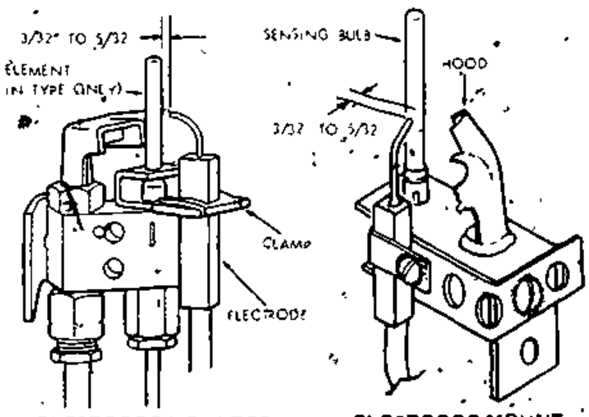
5. Visually check size and length requirements of present control system to insure Retro-fit components will fit in the space provided

C. Turn off gas and electrical power to the system

D. Remove existing gas valve and thermocouple and any other components used in existing system but not required for conversion application; i.e., on a single function control system, remove the gas solenoid, pilot stat., and pressure regulator

E. Insert bulb of Mercury Flame Sensor into pilot burner in place of thermocouple (Figure 2)

FIGURE 2



ELECTRODE MOUNTED WITH SLIP-ON BRACKET

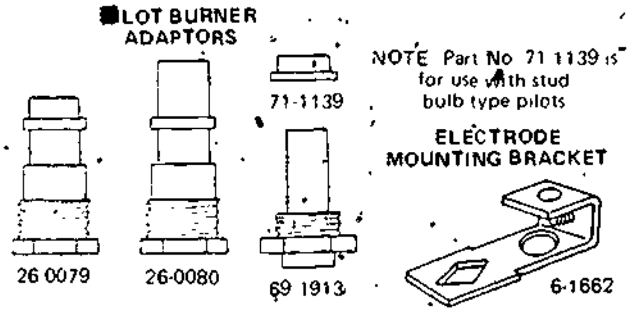
ELECTRODE MOUNT UTILIZING PERFORATED STRAP.

JOB SHEET #5

F. Secure Flame Sensor using the pilot burner adapters supplied with Retro-Fit package (Figure 3)

(NOTE: Check Figures 10 through 16 for demonstrations of typical applications.)

FIGURE 3



G. Double check pilot burner for correct placement

(CAUTION: UNDER NO CIRCUMSTANCES should the existing pilot burner be relocated, or an existing factory-installed shield be altered; if pilot burner replacement is necessary, use only a pilot burner approved for the appliance; if the pilot or main burner have to be removed to properly locate ignition electrode, be sure they are replaced in the EXACT location of factory installation.)

H. Locate 760 series electrode on pilot burner as shown in Figure 2

I. Slip mounting bracket over flame sensor bulb to form a 3/32" to 5/32" spark gap and be sure spark gap is in pilot gas stream

K. Cut off excess electrode if it is too long

(CAUTION: Be sure rod is NOT close to appliance chassis to prevent electrode from arcing to ground; if electrode cannot be mounted with the slip-on mounting bracket due to pilot burner placement, remove ceramic from slip-on bracket and use a brass perforated strap and "U" clamp to mount electrode assembly as shown in Figure 2.)

JOB SHEET #5

L. Double check assembly; flame must NOT IMPINGE on ceramic insulator or the ceramic will be damaged

1. When positioning electrode, spark should jump through pilot gas stream to Flame Sensor bulb. Electrode rod must remain in pilot flame after gas has been ignited. (Electrode rod is part of 59 Relight control flame detection circuitry.)

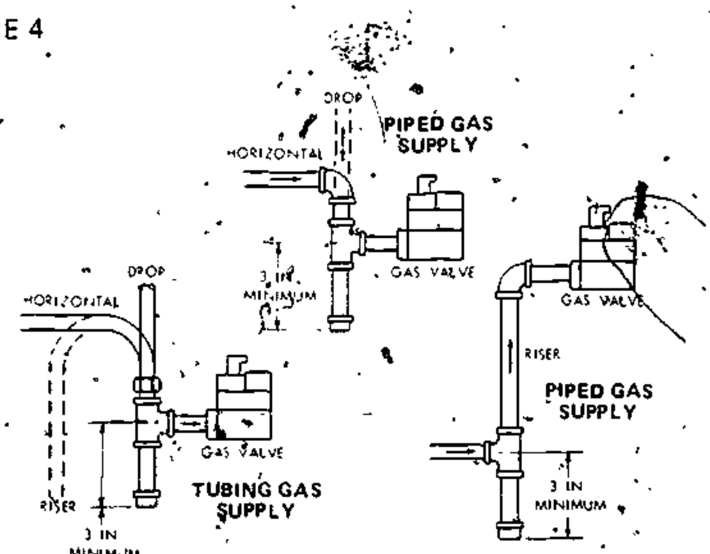
2. When adjusting/bending electrode rod, use two pair of pliers to prevent bending or twisting at the point electrode enters ceramic insulator

M. Mount 36C84 gas valve on supply pipe; valve may be mounted in any position, except upside down; direction of gas flow is indicated by arrow stamped on pipe boss (Figure 4)

1. Where possible, new, properly chamfered and clean pipe should be used. If old pipe is used, be sure it is clean and free of rust and scale

2. Be sure threaded end of pipe is free of burrs and chips. Sparingly apply approved pipe dope to the first three or four pipe threads. Applying pipe dope to the first three or four threads will prevent chips from passing onto internal valve parts since pipe dope will collect and retain metal chips that are formed as the pipe is threaded into valve body

FIGURE 4



TYPICAL GAS SUPPLY PIPING
(BE SURE A DRIP LEG IS ALWAYS INCLUDED.)

JOB SHEET #5

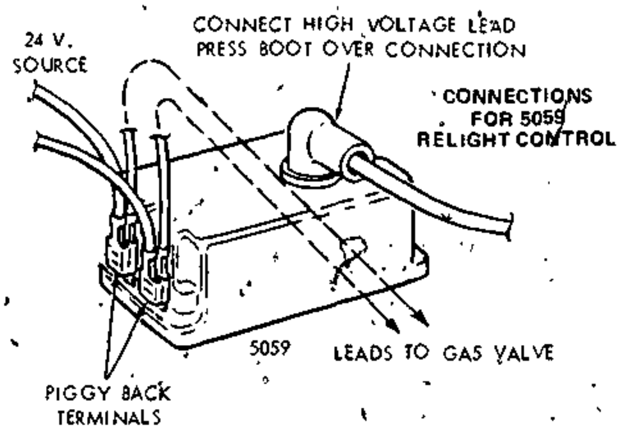
N. Attach pilot tubing to gas valve. Install fitting into pilot gas tapping, turning until finger-tight; insert clean deburred tubing all the way through the fitting; holding the tubing securely, slowly tighten fitting until a slight "give" is felt, then tighten 1 1/2 additional turns

O. Mount the 5059 Pilot Relight control in an area on the appliance where it will not be affected by roll out flame, flame heat, or radiant heat; maximum ambient-temperaure is 150°F

1. Be sure metal to metal contact is made between mounting hole standoffs on Relight control and mounting surface

2. Connect high voltage lead to terminal on top of Relight control, after feeding lead through angled insulation boot; press boot over connection. Avoid excessive strain on ignition cable to prevent cable from being pulled out of ceramic (the ignition cable is held in the ceramic by a push-on connector); see Figure 5

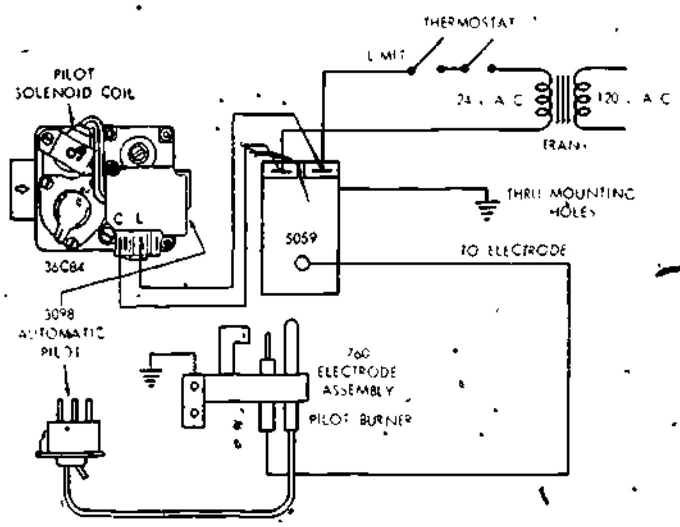
FIGURE 5



JOB SHEET #5

P. Attach leads from terminals "C" and "L" on the gas valve using 1/4" female spade connectors and route these leads to the 5059 Relight Control; attach 1/4" piggy-back spade terminals to the leads and attach them to the male spade connections to the Relight control; see Figures 5 and 6 -

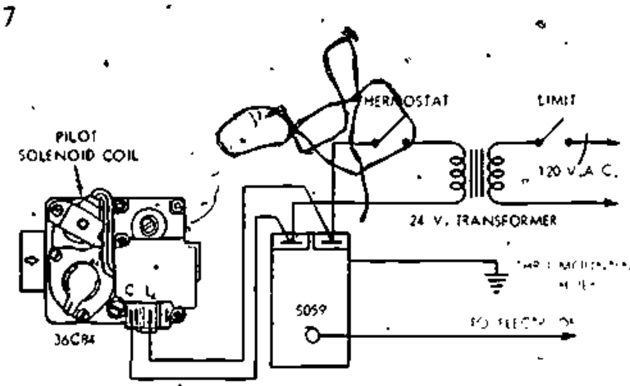
FIGURE 6



TYPICAL LOW VOLTAGE WIRING

Q. Modify procedure if replacing a 24-volt gas valve; attach wires previously connected to OLD gas valve to the piggy-back terminals on the 5059 Relight control; if replacing other control configurations, refer to Figures 6 through 9 for typical wiring.

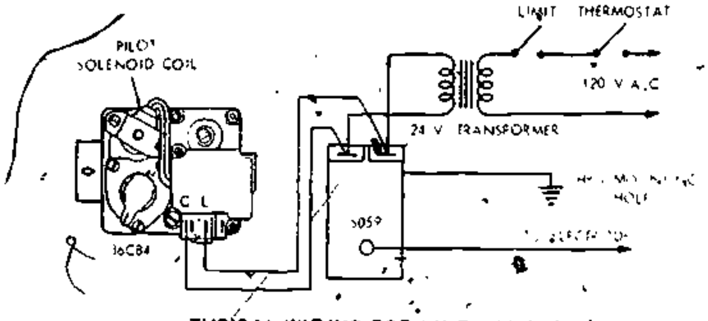
FIGURE 7



TYPICAL WIRING FOR LOW VOLTAGE
THERMOSTAT AND LINE VOLTAGE LIMIT

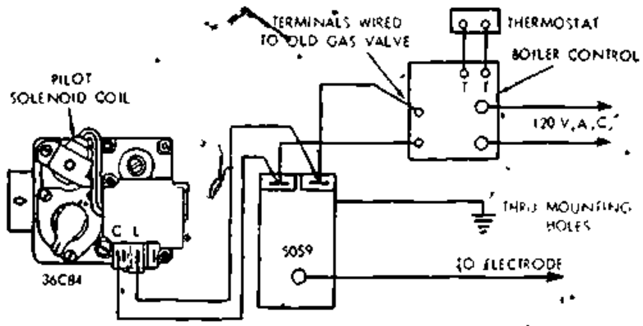
JOB SHEET #5.

FIGURE 8



TYPICAL WIRING FOR LINE VOLTAGE THERMOSTAT AND LIMIT

FIGURE 9



TYPICAL BOILER CONTROL WIRING

JOB SHEET #5

R. Check to be sure the limit control IS NOT accidentally wired OUT of the CIRCUIT

S. Inspect all old wiring for damage, loose connections, etc; secure all wiring to chassis or piping with electrical/friction tape or plastic wire-wraps

T. Carefully extend capillary coil from pilot burner to prevent kinks or other damage; capillary should be stretched only far enough to reach gas valve; excess capillary should remain coiled to prevent damage

U. Use soap solution to leak-check piping to gas valve

V. Adjust heat anticipator on room thermostat for .6 amps current draw

(CAUTION: Do not jumper or accidentally short terminals on 5059 Relight control: room thermostat heat anticipator could BURN OUT!)

W. Turn on power to appliance. Adjust room thermostat to call for heat

X. Check 5059 Relight control, it should begin sparking

Y. Make sure sparking occurs between ignition electrode and Mercury Flame sensor or pilot hood, in the middle of the gas stream; the spark gap must be 3/32" to 5/32"; if electrode placement is not correct, disconnect power, and re-position electrode

Z. Turn gas cock on valve to ON position

AA. Turn on power to appliance to energize system; two to five minutes will be required to bleed air through the valve and pilot line; once gas is present at the pilot, leak-check the pilot line with soap solution

BB. Check to see that sparks from the Relight control stop as soon as pilot flame is established; if sparking does not stop, make sure ignition electrode is in pilot flame and metal standoffs on 5059 Relight control are grounded

CC Allow about 45 seconds for pilot flame to heat Mercury Flame sensor; Flame sensor will then switch main valve ON and main burner will ignite

DD. Use soap solution to leak-check the piping to the main burner

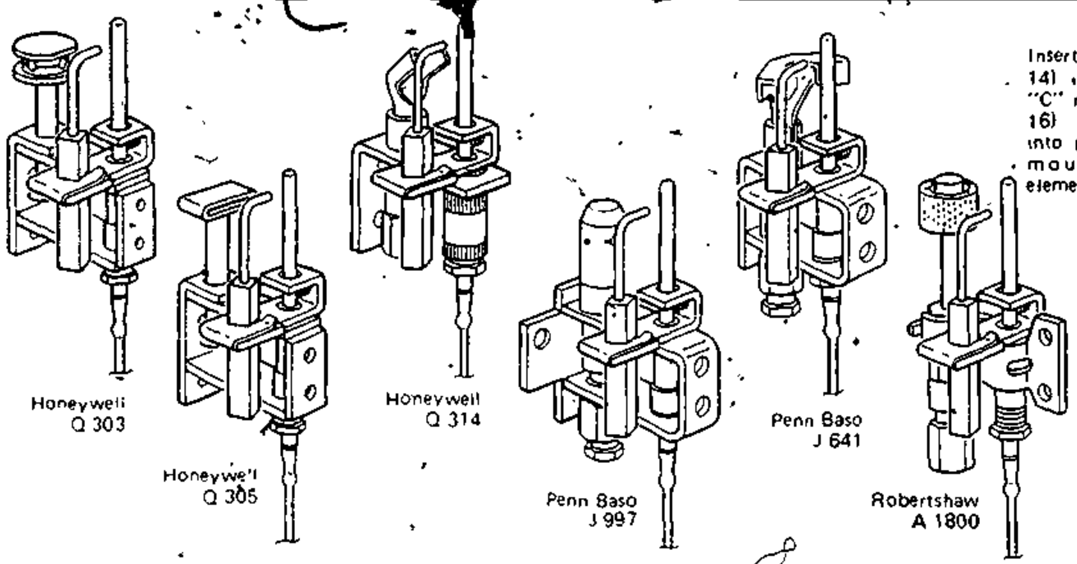
EE. Cycle the system a number of times to insure smooth ignition and proper operation

FF. Place new "LIGHTING INSTRUCTIONS" over existing instructions; clean area to accept adhesive backed label; remove protective backing and attach label

GG. Clean up area and return tools

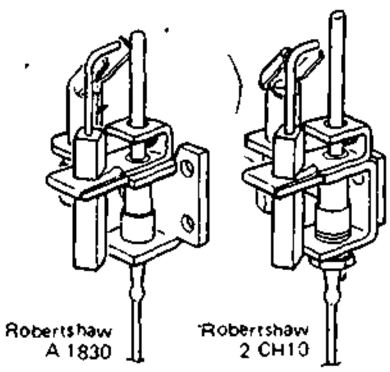
JOB SHEET #5

Typical Pilot Burner Applications



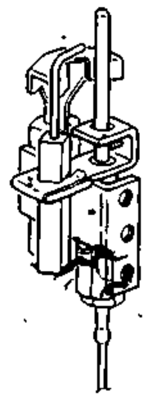
Insert adaptor (26 0079, Fig. 14) into pilot bracket. Place "C" ring in groove "A" (Fig. 16). Slide mercury element into place. Position electrode mounting bracket over element.

FIGURE 10



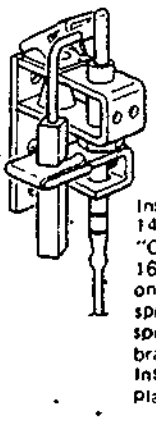
Insert adaptor (26-0079, Fig 14) into pilot bracket. Place "C" ring in groove "B" (Fig 16). Slide mercury element into place. Position electrode mounting bracket over element.

FIGURE 11



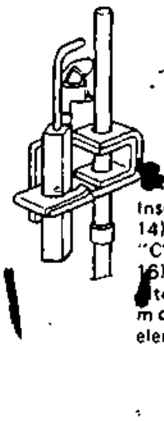
Insert Adaptor (26-0080) into pilot bracket. Place 'C' ring in groove 'A' (Fig 14). Slide mercury element into place. Position electrode mounting bracket over element.

FIGURE 12



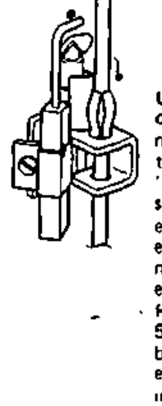
Honeywell
Q 308

Insert adaptor (69 1913, Fig 14) into pilot bracket. Place "C" ring in groove "C" (Fig 16). Invert mounting bracket on electrode assembly (remove spring retainer, invert, reinstall spring clip), drop mounting bracket over mercury element. Insert mercury element into place.



ITT
26T1320

Insert adaptor (26-0080, Fig 14) into pilot bracket. Place "C" ring in groove "A" (Fig 16). Slide mercury element into place. Position electrode mounting bracket over element.



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26T0306

Use standard thermocouple clamp and sleeve to mount mercury element. Slide thermocouple clamp to groove 'A', Fig 16. Perforated strapping is used to position electrode assembly. Bend electrode so spark will jump to mercury element and electrode tip will be in pilot flame. Gap must be 3/32" to 5/32". Excess electrode may be cut off. Both mercury element and electrode must be in pilot flame.

FIGURE 13

JOB SHEET #5

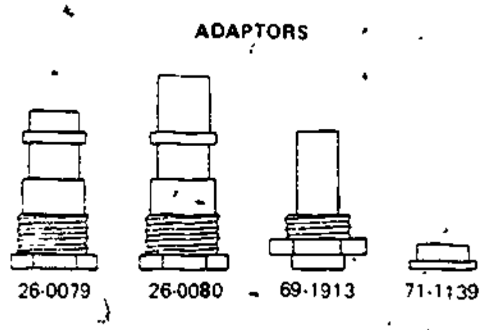


FIGURE 14

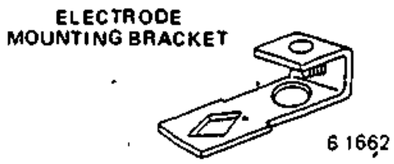


FIGURE 16

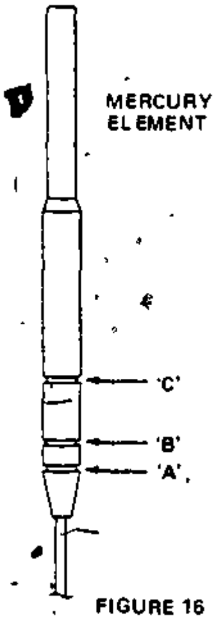


FIGURE 16

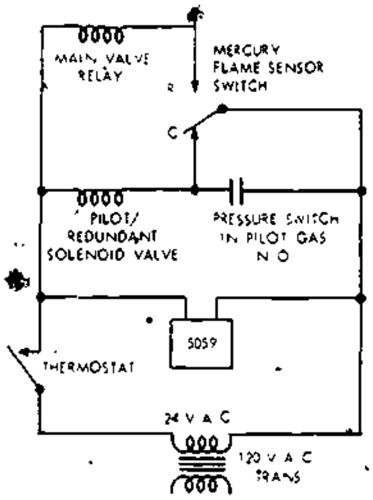
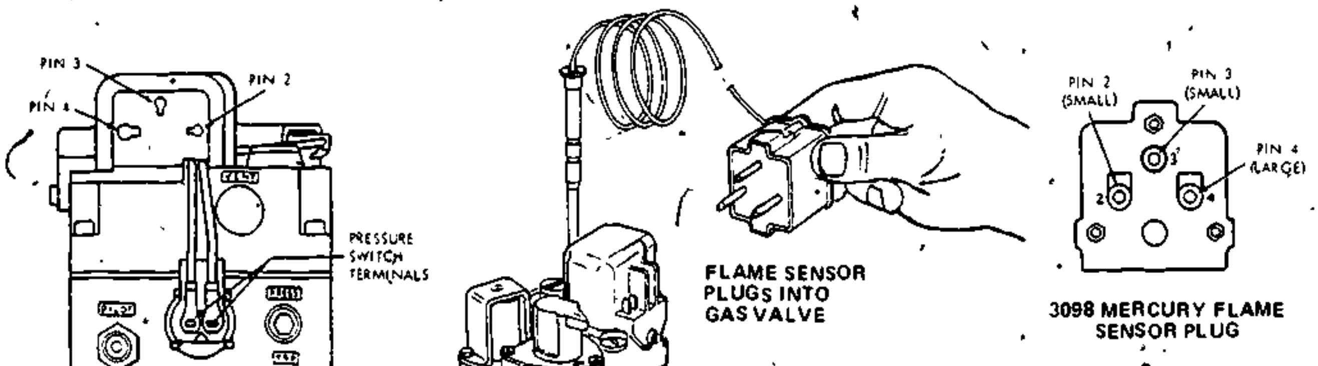


FIGURE 18



Flame Sensor Action

Pins 4 and 3:
Continuity when Cold

Pins 4 and 2:
Continuity when Hot

FIGURE 17

GAS FURNACES
UNIT I

NAME ______________________________

TEST

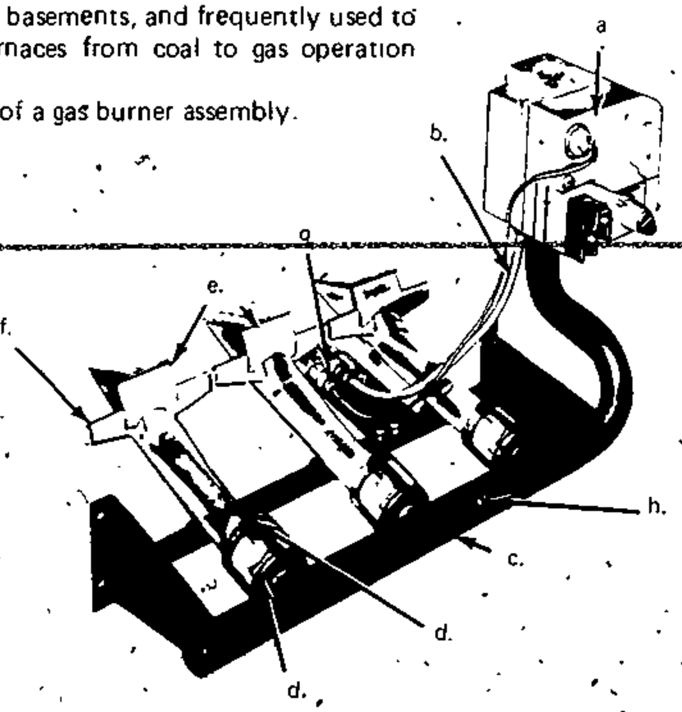
1. Match the terms on the right with their correct definitions.

_____ a. A device for adjusting gas line pressure to the pressure specified by the appliance manufacturer	1. Bonnet
_____ b. An electric switch which prevents a gas valve from opening unless a pilot light is present	2. Gas valve
_____ c. An electrical device that controls the flow of gas; can be millivolt, 24V, or 115V depending on application	3. Fan relay
_____ d. Plugs threaded into gas burner manifolds; their small, precisely drilled holes meter precise amounts of gas to individual burners	4. Gas pressure regulator
_____ e. An adjustable opening on a gas burner which meters the amount of air to mix with the gas in order to produce a proper flame	5. Thermocouple
_____ f. A small opening in a gas burner which diverts a small amount of gas to the vicinity of the pilot flame to assist in a quick, even lighting of all burners in a gas furnace	6. Pilot safety control
_____ g. Serves as a safety device on gas furnaces to cut off the gas supply in the event of loss of flame in the pilot light	7. Retrofit
_____ h. An electrical device in a furnace blower assembly that energizes the blower from a remote location	8. Primary shutter
_____ i. An air collection chamber	9. Solenoid valve
_____ j. An electrically operated valve that controls the flow of gas	10. Orifice inserts
_____ k. To remodel or repair; in air conditioning and refrigeration it generally means replacing older system components with new components that conserve energy	11. Pilot runner

2. Match types of gas furnaces on the right with their applications.

______a. Installed where headroom is not a problem	1. Lowboy
______b. Installed where basement or crawl space cannot be used, and supply ducts are located under the floor.	2. Gravity
______c. Installed in crawl space or attic where headroom is limited	3. Upflow
______d. Installed outside and ducted into the house	4. Counterflow
______e. Installed in basements where headroom is limited	5. Horizontal
______f. Installed in basements, and frequently used to convert furnaces from coal to gas operation	6. Outdoor

3. Identify components of a gas burner assembly.



a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

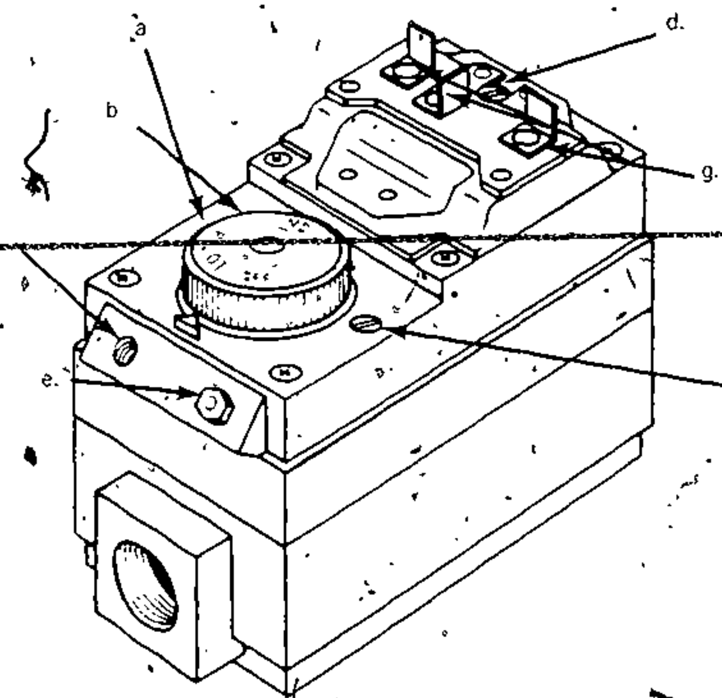
g. ______________________________

h. ______________________________

4. Match types of gas valves on the right with their characteristics.

_____	a. Opens instantly when energized	1.	Slow opening
_____	b. Opens after a lapse of one to thirty seconds when energized	2.	Instantaneous
_____	c. Combines other gas burner assembly components such as pressure regulator, pilot gas valve, and pilot safety	3.	Combination

5. Identify components of a combination electric gas valve.



a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

g. ____________________

6. Select true statements concerning the characteristics of a heat exchanger by placing an "X" in the appropriate blanks.

_____a. Constructed to provide efficient heat transfer from flames to room air while keeping flue gases separate from room air

_____b. Composed of units called "clamshells"

_____c. Each clamshell designed to transfer a specific amount of heat per hour of operation

_____d. Each clamshell has triple burners

7. Select true statements concerning advancements in heat exchanger technology by placing an "X" in the appropriate blanks.

_____a. Advanced heat exchangers operate with power combustion, usually a direct spark ignition that eliminates the need for a standing pilot

_____b. Advanced heat exchangers eliminate "up the flue" heat losses

_____c. Advanced heat exchangers eliminate "off cycle" heat losses common with conventional gas furnaces and do not add heat to the air conditioning load

8. Select true statements concerning the characteristics of a draft diverter by placing an "X" in the appropriate blanks.

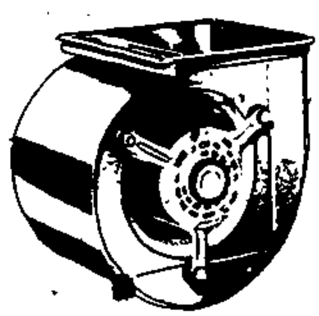
_____a. Constructed to collect flue gases from upper opening of heat exchanger and funnel them into the vent without pulling excess air over the flames

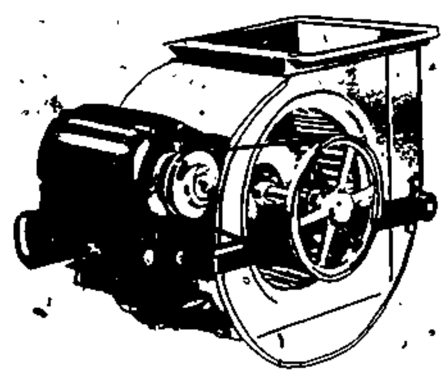
_____b. Constructed to be closed to the atmosphere

_____c. Induces unheated air into vent pipe to reduce temperature of flue gases

_____d. Prevents wind that enters the vent pipe from blowing out the pilot

9. Identify the two types of blower assemblies shown in the following illustrations.





a. ______________________ b. ______________________

10. Complete a list of components of a control system.

    a. Transformer

    b.

    c.

    d.

    e.

    f.

    g. Pilot light

    h. Thermocouple

    i. Pilot safety

11. Describe the functions of a transformer.

    a.

    b.

12. Match the types of thermostats on the right with their functions.

______ a.	1) Consist of one switch which closes on a drop in temperature	1.	Heat only thermostats
	2) Have only a heat anticipator	2.	Heat and cool thermostats
	3) May have a set back energy conservation feature		
______ b.	1) Temperature operated heating switch closes on drop in room temperature		
	2) Temperature operated cooling switch closes on increase in room temperature		
	3) Manually operated fan swtich which closes circuit to fan relay		
	4) Have both heating and cooling anticipators		
	5) May have a set back energy conservation feature		

13. Select true statements concerning limit switch operation by placing an "X" in the appropriate blanks.

_____a. Opens on temperature rise

_____b. Senses bonnet temperature

_____c. Set at 180 to 200 degrees

_____d. Interrupts circuit to gas valve or transformer

_____e. May be separate or combined with fan switch

_____f. Designed to shut off gas supply to burners if furnace overheats

_____g. In some models will bypass fan switch to bring on blower while furnace is overheated

14. Select true statements concerning fan switch operation by placing an "X" in the appropriate blanks.

_____a. Closes on temperature rise

_____b. Senses bonnet temperature

_____c. Adjustable "on" switch approximately 100 to 180 degrees

_____d. Adjustable "off" switch approximately 20 to 80 degrees cooler than "on" switch

_____e. All types of fan switches for gas furnaces are designed to close supply circuit to blower motor when furnace is hot

_____f. May be combined with limit switch

15. Select true statements concerning fan-limit swtich operation by placing an "X" in the appropriate blanks.

(NOTE: For a statement to be true, all parts of the statement must be true.)

_____a. Combines complete set of fan switches

_____b. Contains pre-set high limit switch

1) May control gas valve on 115 volts

2) May control transformer supply circuit on house current of 230 volts

16. Describe pilot light operation.

a.

b.

17. Describe thermocouple operation.

    a.

    b.

18. Describe pilot safety operation.

    a.

    b.

19. Select true statements concerning potential sources of thermocouple failure by placing an "X" in the appropriate blanks.

    (NOTE: For a statement to be true, all parts of the statement must be true.)

    _____ a. May fail to generate enough voltage to hold open the gas valve or pilot safety

    _____ b. Tip may be burned out because pilot flame is too hot

    _____ c. May not be getting enough heat from pilot flame

    1) Not properly positioned in pilot flame

    2) Soot build up insulates thermocouple

20. Complete a list of potential sources of fan switch failure.

    a.

    b. Fan switch temperature setting becomes unreliable causing fan to come on too soon or too late

21. Complete a list of potential sources of transformer failure.

    a.

    b. Usually fails for no apparent reason

22. Select true statements concerning potential sources of high limit switch failure by placing an "X" in the appropriate blanks.

    (NOTE For a statement to be true, all parts of the statement must be true.)

    _____ a. Normally closed switch that is faulty will not open in presence of unsafe temperature

    _____ b. Usually very reliable, but might be prevented from operating because of external causes

    1) Switch cover jammed against moving plate

    2) Wires touching because of burned insulation

23. Differentiate between two potential sources of gas valve failure by placing a "U" beside the statement that usually causes gas valve failure and an "R" beside the statement that rarely causes gas valve failure.

_____ a. Will not open

_____ b Will not close

24. Select true statements concerning potential sources of fan relay failure by placing "X" in the appropriate blanks.

_____ a. Contacts stick together causing blower to short out

_____ b. Fails to close when 24 volts is applied

_____ c Contacts fail to close fan circuit

25. Match component sources on the right with potential blower section failure.

_____ a 1) Bearing seizure because of improper oiling	1. Blower belts
2) Burned out or shorted motor windings	2. Blower wheels out of balance
_____ b 1) Destroyed because of improper oiling	3. Aluminum split pulleys
2) Destroyed because of excessive belt tension	4. Blower speed
_____ c. 1) Cracked, frayed, or broken	5. Blower wheel
2) Too loose	6. Blower motors
3) Too tight	7. Blower bearings
_____ d. Can seize to motor shaft and cannot be pulled off without destruction	
_____ e 1) Balance weight has come off	
2) Can only be rebalanced at the factory	
_____ f Running backwards because of improper replacement	
_____ g. 1) Creates excessive noise	
2) Causes temperature stratification resulting in cold spots and hot spots in the room	
3) Drawing too much current and blowing fuses	
4) Providing inadequate cooling after air conditioning has been added	

26 Differentiate between potential sources of heat exchanger failure by placing an "S" beside statements related to soot buildup between clamshells and a "C" beside statements related to a cracked heat exchanger.

_____a. Should be suspected when customer complains of pilot light blowing out

_____b. Identified by visual inspection with flashlight and small mirror

_____c. Usually identified by flames spilling out front of furnace

_____d. Flames frequently cause extensive damage to wires and electrical components

_____e Starts as hairline cracks in sharper bends at bottom of clamshells

_____f. Cracks open wider in presence of heat from burner flames and create a potential hazard for occupants

_____g. Requires tearing down furnace and cleaning between clamshells with wire and vacuum cleaner

27 Select true statements concerning potential sources of pilot safety failure by placing an "X" in the appropriate blanks.

_____a. Usually evidenced by failure to open gas valve after replacement of thermocouple

_____[illegible] power to gas valve unless operating properly with adequate thermo-[illegible]le voltage

_____c. On [illegible]rnace without 100% shut-off gas valves

28. Complete a list of factors needed to determine gas pipe sizing.

a. Specific gravity and Btu per cubic foot heating value of gas supply

b.

c.

d. Maximum capacity of pipe related to cubic feet or gas per hour

29. Complete a list of energy saving devices designed for retrofitting.

a. Set back thermostats

b.

c.

30. Select true statements concerning set back thermostats and their uses by placing an "X" in the appropriate blanks

______a. Designed to let structure move to a higher room temperature at night

______b. Reduces heat loss because of lower temperature differential

______c. Reduces fuel consumption because of reduced heat loss

______d. Can be operated only by a timer

______e. Can be fully automated with clock operation providing manual override on weekends

31 Select true statements concerning intermittent ignition systems and their uses by placing an "X" in the appropriate blanks.

______a. Eliminates cost of fuel to pilot flame

______b. Can operate only from a direct spark ignition

______c. Good proven-pilot or cycling-pilot systems are built with a "redundant" safety system which requires that the pilot light be proven with an electric or an electro-mechanical sensor before gas will flow to the main burners

______d. Are being incorporated into many new furnace designs

32 Select true statements concerning vent dampers and their uses by placing an "X" in the appropriate blanks.

______a. Are designed to stay open while burner is operating in order to vent combustion gases

______b Are designed to close when burner shuts off to stop heat from escaping up the flue or chimney

______c. Are relatively easy to install, and can be installed by anybody

______d. Some manufacturers are building furnaces with control wiring installed for adding a vent damper

33 Trace the high voltage and low voltage circuits of a gas furnace.

34. Construct wiring diagrams for gas furnaces

35. Size gas piping

GAS FURNACES
UNIT I

ANSWERS TO TEST

1. a. 4 e. 8 i. 1
   b. 6 f. 11 j. 2
   c. 9 g. 5 k. 7
   d. 10 h. 3

2. a. 3 d. 6
   b. 4 e. 1
   c. 5 f. 2

3. a. Gas valve
   b. Pilot burner gas supply
   c. Burner manifold with orifice inserts
   d. Primary air shutter and locking screw
   e. Ribbon, slot, or jet burner ports
   f. Pilot runner or crossover igniters
   g. Pilot burner and thermocouple assembly
   h. Tap for manometer use in adjusting gas pressure

4. a. 2
   b. 1
   c. 3

5. a. Pilot shut off valve
   b. Main gas line shut off
   c. Pilot gas adjustment
   d. Gas pressure regulator adjustment
   e. Pilot gas connection
   f. Thermocouple connection
   g. Electrical terminals to control circuit

6. a, b, c

7. b, c

8. a, c, d

9. a. Direct drive
   b. Belt drive

10. b. Thermostat
    c. Electric gas valve
    d. Limit switch
    e. Fan switch
    f. Combination fan-limit switch

11. a. Reduces supply voltage to 24 volts
    b. Furnishes power for control circuit

GAS FURNACES
UNIT I

ANSWERS TO TEST

1. a. 4 e. 8 i. 1
   b. 6 f. 11 j. 2
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6. a, b, c

7. b, c

8. a, c, d

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   b. Belt drive

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    c. Electric gas valve
    d. Limit switch
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    f. Combination fan-limit switch

11. a. Reduces supply voltage to 24 volts
    b. Furnishes power for control circuit

33. Evaluated to the satisfaction of the instructor

34. Evaluated to the satisfaction of the instructor

35. Evaluated to the satisfaction of the instructor

36. Performance skills evaluated to the satisfaction of the instructor

33. Evaluated to the satisfaction of the instructor

34. Evaluated to the satisfaction of the instructor

35. Evaluated to the satisfaction of the instructor

36. Performance skills evaluated to the satisfaction of the instructor

ELECTRICAL HEATING SYSTEMS
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify components of an electrical heating system and list areas of potential problems in electrical sequencing and relay equipment. The student should also be able to install an electric furnace and perform periodic maintenance on an electrical heating system. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to electrical heating systems with their definitions.
2. Identify types of electrical heating systems.
3. Differentiate between types of electrical heating systems.
4. Complete a list of components of electric heating equipment.
5. Select true statements concerning causes of common failures of electric heating equipment components.
6. Demonstrate the ability to:
   a. Install, start, and check an electrical heating unit.
   b. Disassemble, inspect, and reassemble an electric furnace.
   c. Troubleshoot an electric furnace.
   d. Perform maintenance on an electric furnace.

ELECTRICAL HEATING SYSTEMS
UNIT II

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Show the class samples of electric furnace sequencers; they don't have to be in serviceable condition.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM 1--Duct Heater

      2. TM 2--Upflow Electric Furnace

      3. TM 3--Horizontal Electric Furnace

   D. Job sheets

      1. Job Sheet #1--Install, Start, and Check an Electrical Heating Unit

      2. Job Sheet #2--Disassemble, Inspect, and Reassemble an Electric Furnace

      3. Job Sheet #3--Troubleshoot an Electric Furnace

      4. Job Sheet #4--Perform Maintenance on an Electric Furnace

   E. Test

   F. Answers to test

11. Reference--Russell, Allen. *Getting Started in Heating and Air Conditioning.* Birmingham, MI: Business News Publishing Co., 1974.

ELECTRICAL HEATING SYSTEMS
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Nichrome--An alloy used extensively as a heat source for electric heat as in electric ovens and toasters

B. Contactor--A relay capable of opening and closing power circuits of high amperage

C. Line voltage--Voltage used in residential electric heating

D. Sequencer--A time delay device

E. Fan relay--A relay which operates a furnace blower, frequently incorporated as the first stage of a sequencer in an electric furnace

F. Power lugs--Heavy duty fittings for connecting power wires to a high amperage appliance such as an electric furnace

G. Fusible link--A backup safety device designed to melt and open the circuit on an electric furnace at a temperature higher than the limit

H. High limit switch--A safety device which opens the circuit when there is excessive temperature rise (usually a snap-disc type)

II. Types of electrical resistance heating systems (Transparencies 1, 2, and 3)

A. Duct heaters

B. Electric furnaces

III. Characteristics of electrical heating systems

A. Duct heaters (Transparency 1)

1. Composed of nichrome wire coil strung through insulators

2. Placed in a heating duct with remote blower

3. Equipped with line voltage controls

a. Contactor switch

b. Line voltage high limit safety (fusible link)

4. Equipped with low voltage controls

a. Contactor coil

b. Low voltage high limit safety (click action switch)

INFORMATION SHEET

5. Installed four feet downstream from cooling coil unless approved for use as integral part of equipment

B. Electric Furnace (Transparencies 2 and 3)

1. Composed of one or more nichrome wire heating elements

2. Consists of self-contained complete system with:

a. Blower assembly

b. Electric heating elements

c. Line voltage and low voltage controls vary with manufacturer

IV. Components of electric heating equipment

A. Blower assembly

B. Heater element assembly

1. Nichrome wire coils installed through insulators in path of air stream

2. Fusible link in line voltage circuit of heater coil exposed to radiant heat of heater element

3. High temperature limit controls vary with manufacturer

C. Electric heat circuits and controls

1. Low voltage fan circuit

a. Transformer

b. Thermostat

c. Fan relay coil or sequencer heater

2. Line voltage fan circuit

a. Blower motor

b. Fan relay contacts or sequencer contacts

c. Fuse, 15 amp

INFORMATION SHEET

3. Low voltage heater circuits

   a. Transformer

   b. Thermostat

   c. Contactor or sequencer coil

   d. High limit switch

4. Line voltage heater circuit

   a. Heater Element

   b. Fusible link

   c. Contactor contacts or sequencer contacts

   d. Fuse

V Causes of failures of electric heating equipment components

A Heating element circuit open

1. Melted fusible link

2. Nichrome wire burned in two because of:

   a. Dirty filter

   b. Undersized ductwork

   c. Dirty cooling coil

   d. Broken insulator

B. Burned out sequencer

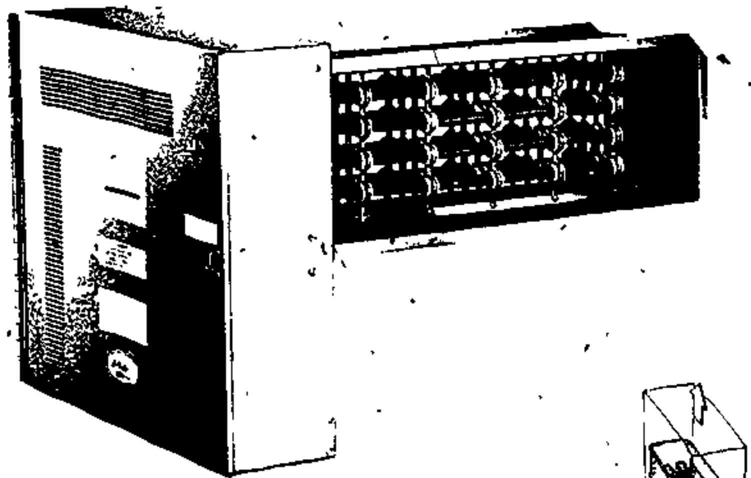
C. Stuck limit switch

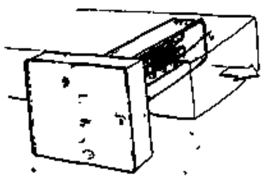
D Burned out transformer

E Loose connections

(CAUTION: When aluminum wire is found in an electrical heating unit, it should be removed and replaced with copper wire.)

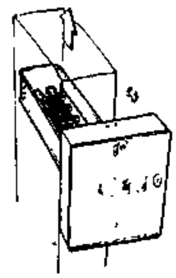
Duct Heater



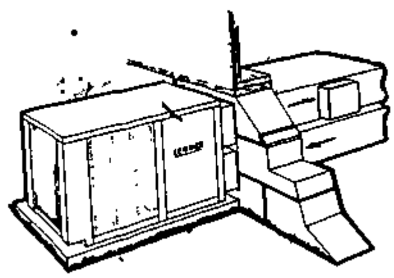


Horizontal Duct Installation

Typical Applications



Vertical Duct Installation

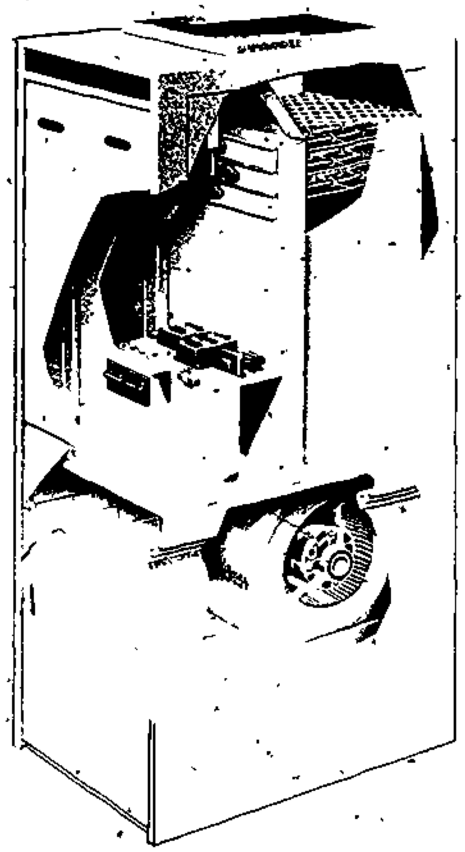


Installed With Single Package Heat Pump or Single Package Air Conditioner

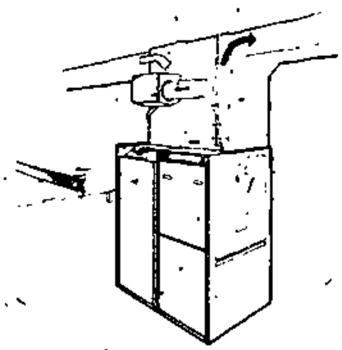
Zone Installation With Centrally Located Filter Unit

(Courtesy of Lennox Industries Inc., Dallas, Texas)

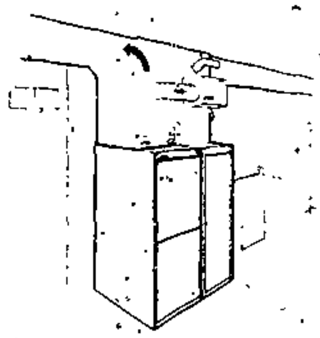
Upflow Electric Furnace



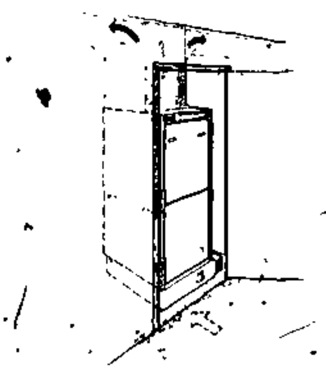
Typical Applications



Basement Installation
With Cooling Coil,
Electronic Air Cleaner
and Power Humidifier



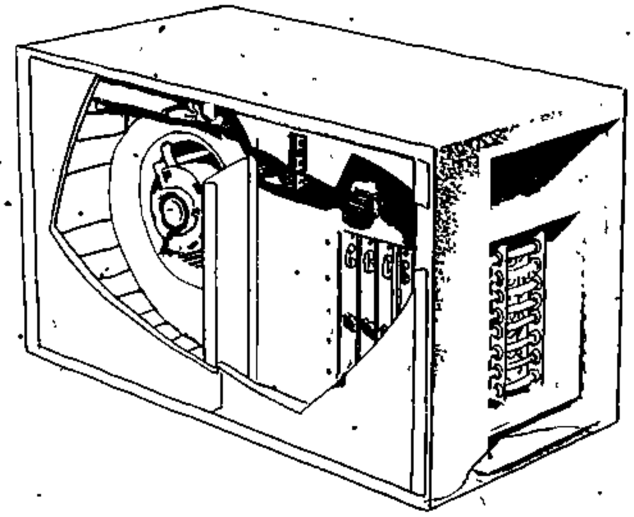
Basement Installation
With Cooling Coil,
Return Air Cabinet
and Power Humidifier



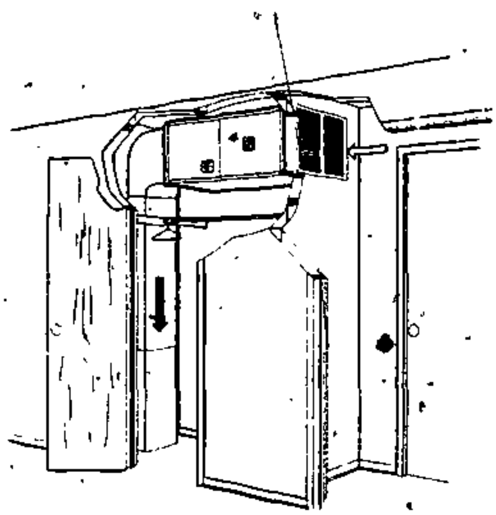
Closet Installation
With Cooling Coil
and Electronic
Air Cleaner

(Courtesy of Lennox Industries Inc., Dallas, Texas)

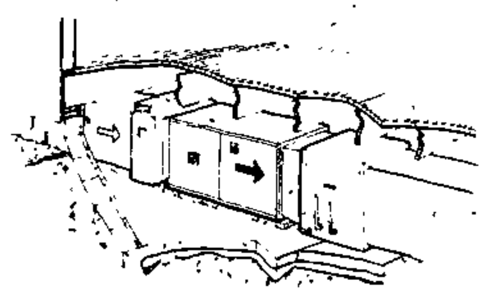
Horizontal Electric Furnace



Typical Applications



Horizontal Installation in Closet



Horizontal Installation
with Cooling Coil
and Electronic Air Cleaner

(Courtesy of Lennox Industries Inc., Dallas, Texas)

ELECTRICAL HEATING SYSTEMS
UNIT II

JOB SHEET #1--INSTALL, START, AND CHECK AN ELECTRICAL HEATING UNIT

I. Tools and equipment

A. Service technician's tool pouch

B. Ammeter-voltmeter

C. Hammer

D. Aviation snips

E. Electric drill and drill bits

II. Procedure

A. Remove electrical heating unit from crating

B. Place unit in designated location

C. Adapt and attach unit to duct system

D. Connect low voltage wiring to low voltage connections

E. Install thermostat

F. Connect power supply to load side of safety switch

G. Connect power supply wiring to supply power terminals on unit

H. Open thermostat

I. Close safety switch to energize system

J. Start unit by setting thermostat to "calling"

K. Use ammeter to check load on fan motor for tolerance

L. Use ammeter to check current load of heating elements

M. Check blower section for proper air delivery

N. Clean area and put tools away

ELECTRICAL HEATING SYSTEMS UNIT II

JOB SHEET #2--DISASSEMBLE, INSPECT, AND REASSEMBLE AN ELECTRIC FURNACE

I. Tools and equipment

A. Service technician's tool pouch

B. Ammeter-voltmeter

II. Procedure

A. Disconnect power source

B. Remove front panel

C. Remove blower and motor holding screws

D. Remove heater unit screws and slide the unit out

E. Inspect for element damage

F. Replace damaged parts

G. Clean and oil blower and motor assembly if needed

H. Reassemble unit by repeating steps D through B in reverse

I. Energize unit and check for proper operation

J. Clean area and put tools away

ELECTRICAL HEATING SYSTEMS
UNIT II

JOB SHEET #3--TROUBLESHOOT AN ELECTRIC FURNACE

I. Tools

A. Screwdrivers

B. Ohmmeter, voltmeter

II. Procedure

A. Disconnect furnace power source

B. Remove furnace panels

C. Remove cover of control box

D. Check for voltage at power lugs

E. Check for continuity and grounded heating elements

1. Set volt-ohmmeter to measure resistance

2. Remove power wires from elements

3. Measure resistance of heating elements and record

4. #1______ohms #2________ohms #3________ohms

5. Reconnect power wires to elements

6. Question: What would elements read if open? What would elements read if shorted?

7. Are any elements grounded?

G. Check contactor and sequencers for continuity

1. Set volt-ohmmeter to measure resistance

2. Disconnect low voltage wires from contactor and/or sequencer #1

3. Measure resistance of contactor coil and record

4. Measure resistance of sequencer heater and record

5. Measure resistance of any other sequencer heaters and record #2______ohms #3_______ohms

6. Reconnect low voltage wires to contactor and sequencer

JOB SHEET #3

7. Question: What would be the resistance of
   a. An open coil circuit? _______ ohms
   b. A burned out coil? _______ ohms
8. Question: What would be the resistance of
   a. An open heater circuit in a sequencer? _______ ohms
   b. A shorted heater circuit? _______ ohms

H. Check continuity and grounding of blower power circuit

I. Check continuity of fan relay coil circuit

1. Set volt-ohmmeter to measure resistance
2. Disconnect control wires from fan relay
3. Measure resistance of fan relay coil and record _______ ohms
4. Reconnect control wires to fan relay

J. Check resistance of primary and secondary windings of low voltage transformer

1. Set volt-ohmmeter to measure resistance
2. Disconnect secondary leads from transformer
3. Measure resistance of secondary windings of transformer and record _______ ohms
4. Disconnect primary leads from transformer
5. Measure resistance of primary windings of transformer and record _______ ohms
6. Measure resistance from each leg of primary winding to ground and record L_1 to ground _______ ohms
   L_2 to ground _______ ohms
7. Reconnect secondary and primary leads of transformer
8. Question: Is secondary winding of the transformer shorted? _______ Open? _______

   Is primary winding of the transformer shorted? _______ Open? _______ Grounded? _______

   Question: Have all the circuits in this electric furnace been checked? _______

   Is this furnace safe to energize? _______

JOB SHEET #3

K. Replace control box cover and furnace panels

L. Reconnect power source

M. Clean area and put tools away

ELECTRICAL HEATING SYSTEMS
UNIT II

JOB SHEET #4--PERFORM MAINTENANCE ON AN ELECTRIC FURNACE

I. Tools

A. Service technician's tool pouch

B. Thermometer and scratch awl

C. Shop rag

D. Ammeter-voltmeter

II. Procedure

A. Open furnace power switch

B. Service blower section

C. Energize furnace and record fan motor amperage draw and record

D. De-energize furnace and snap ammeter over wire to power lug to main furnace power

E. Set thermostat to "heat" and adjust setting to higher than room temperature

F. Re-energize furnace and record amp draw of heaters as sequencers close heater circuits and record

Blower motor and heater #1

__________ amps

#2__________

#3__________

#4__________

G. Compare full load amps with furnace nameplate rating

H. Check to see if all of the heaters pulling the proper amperage

I. Drive scratch awl into return air plenum, insert thermometer and record return air temperature ______°

J. Select a place in the supply trunk which is out of the "line of sight" of the electric heater elements and drive scratch awl into supply trunk. Record supply air temperature ______°

JOB SHEET #4

K. Record temperature rise through furnace ______°

L. Remove thermometer and plug holes

M. De-energize furnace at disconnect

N. Replace control box cover and panel

O. Re-energize furnace

P. Reset thermostat to proper setting

Q. Clean area and put tools away

ELECTRICAL HEATING SYSTEMS
UNIT II

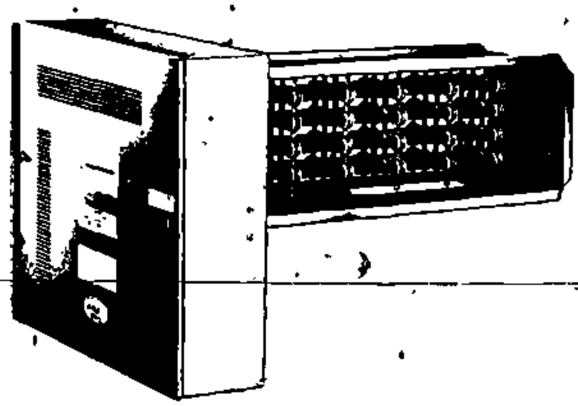
NAME ________________________________

TEST

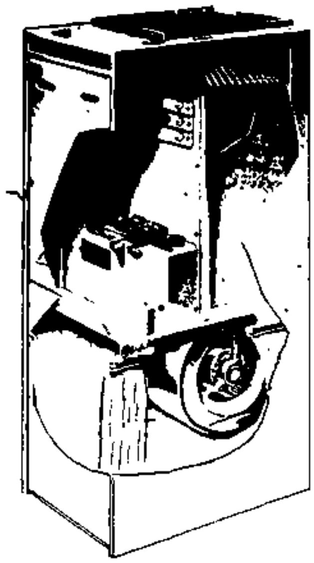
1. Match the terms on the right with their correct definitions.

_____a. An alloy used extensively as a heat source for electric heat as in electric ovens and toasters		1. Line voltage
_____b. A relay capable of opening and closing power circuits of high amperage		2. High limit switch
_____c. Voltage used in residential electric heating		3. Power lugs
_____d. A time delay device		4. Fusible link
_____e. A relay which operates a furnace blower, frequently incorporated as the first stage of a sequencer in an electric furnace		5. Nichrome
_____f. Heavy duty fittings for connecting power wires to a high amperage appliance such as an electric furnace		6. Contactor
_____g. A backup safety device designed to melt and open the circuit on an electric furnace at a temperature higher than the limit		7. Fan relay
_____h. A safety device which opens the circuit when there is excessive temperature rise		8. Sequencer

2. Identify the types of electrical heating systems shown below.



a. ________________________________



b. ______________________

3. Differentiate between duct heaters and electric furnaces by placing a "D" next to items that pertain to duct heaters and an "E" next to items that pertain to electric furnaces.

_____a. Placed in a heating duct with remote blower

_____b. Consists of self-contained complete system with blower assembly, electric heating elements, and line voltage and low voltage controls that vary with manufacturer

_____c. Installed four feet downstream from cooling coil unless approved for use as intregral part of equipment

4. Complete a list of components of electric heating equipment.

a. Blower assembly

b. Heater element assembly

1) ______________________

2) ______________________

3) ______________________

c. Electric heat circuits and controls

1) Low voltage fan circuit

a) ______________________

b) ______________________

c) ______________________

2) Line voltage fan circuit

a) ______________________

b) ______________________

c) ______________________

3) Low voltage heater circuits

a) ______________________

b) ______________________

c) ______________________

d) ______________________

4) Line voltage heater circuit

a) ______________________

b) ______________________

c) ______________________

d) ______________________

5. Select true statements concerning causes of common failures of electric heating equipment components by placing an "X" in the appropriate blanks.

(NOTE: For a statement to be true, all parts of the statement must be true.)

_____ a. Heating element circuit open

1) Melted fusible link

2) Nichrome wire burned in two because of:

a) Dirty filters

b) Undersized ductwork

c) Dirty cooling coil

d) Broken insulator

_____ b. Burned out sequencer

_____ c. Stuck limit switch

_____ d. Burned out transformer

_____ e. Loose connections

6. Demonstrate the ability to:

   a. Install, start, and check an electrical heating unit.

   b. Disassemble, inspect, and reassemble an electric furnace.

   c. Troubleshoot an electric furnace.

   d. Perform maintenance on an electric furnace.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

ELECTRICAL HEATING SYSTEMS
UNIT II

ANSWERS TO TEST

1. a. 5 e. 7
   b. 6 f. 3
   c. 1 g. 4
   d. 8 h. 2

2. a. Duct heater
   b. Electric furnace

3. a. D
   b. E
   c. D

4. b. 1) Nichrome wire coils installed through insulators in path of air stream
   2) Fusible link in line voltage circuit of heater coil exposed to radiant heat of heater element
   3) High temperature limit controls vary with manufacturer

   c. 1) a) Transformer
   b) Thermostat
   c) Fan relay coil or sequencer heater

   2) a) Blower motor
   b) Fan relay contacts or sequencer contacts
   c) Fuse, 15 amp

   3) a) Transformer
   b) Thermostat
   c) Contactor or sequencer coil
   d) High limit switch

   4) a) Heater element
   b) Fusible link
   c) Contactor contacts or sequencer contacts
   d) Fuse

5. a, b, c, d, e

6. Performance skills evaluated to the satisfaction of the instructor

RESIDENTIAL COOLING SYSTEMS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the mechanical and electrical components of a residential cooling system and discuss the processes in a cooling cycle. The student should also be able to relate component failures to their causes, troubleshoot a cooling system, and use a charging table correctly. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to residential cooling systems with their correct definitions.
2. Complete a list of mechanical components of an air conditioner.
3. Complete a list of electrical components of an air conditioner.
4. Select true statements concerning the processes in the cooling cycle.
5. State how the cooling cycle is completed.
6. Select true statements concerning what happens with fan on continuous operation.
7. Match compressor motor failures with ways they can be detected.
8. Match compressor failures with ways they can be detected.
9. Match failures in condensing sections with their possible causes.
10. Select true statements concerning functions of low side section components in an air conditioner.
11. Match component problems of low side sections with their possible causes.
12. Arrange in order the steps in using a charging table.
13. Select true statements concerning the rule of thumb procedure for working without a charging table.
14. Demonstrate the ability to:
    a. Troubleshoot an air conditioner condenser section on a "no cooling" complaint.
    b. Perform maintenance on an air conditioner.
    c. Use a charging table to check the charge in a capillary cooling system.

RESIDENTIAL COOLING SYSTEMS
UNIT III

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparency.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Discuss and demonstrate the procedures outlined in the job sheets.

VII. Invite a local or area service technician to talk to the class about troubleshooting cooling systems.

VIII. Invite an air conditioning contractor to talk to the class about component failures, the importance of the proper identification of problems, and cost factors related to replacement components.

IX. Invite a factory representative to talk to the class about innovations in cooling system design and the concept of energy efficiency ratings.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency Master 1--Typical Charging Table

D. Job sheets

1. Job Sheet #1--Troubleshoot an Air Conditioner Condenser Section on a "No-Cooling" Complaint

2. Job Sheet #2--Perform Maintenance on an Air Conditioner

3. Job Sheet #3--Use a Charging Table to Check the Charge in a Capillary Cooling System

E. Test

F. Answers to test

II. References

A. Althouse, Andrew D., and Carl H. Turnquist and Alfred F. Bracciano. *Modern Refrigeration and Air Conditioning.* South Holland, IL: The Goodheart-Willcox Company, Inc., 1975.

B. Lang, Paul V. *Principles of Air Conditioning.* Albany, NY 12205: Delmar Publishers, 1972.

RESIDENTIAL COOLING SYSTEMS
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Shrader valve--A gauge port made like an automobile tire valve

B. Crankcase heater--A low wattage wrap around device that boils refrigerant out of the compressor oil

C. Lockout relay--A normally closed relay used to open a protective circuit while the relay is energized

D. Hard start kit--A starting capacitor and starting relay added to a compressor circuit

E. Suction line accumulator--A tank used to hold liquid refrigerant which would normally flood back to a compressor during cold weather

F. Halo effect--Electrical discharge around terminals while under a vacuum, causing carbon tracks to deposit on the inside of a compressor and short circuit the compressor motor windings

G. Low side--The low pressure part of air conditioning equipment, namely the evaporator coil and suction line

H. Charging tables--Graphs or tables which list proper suction and head pressures at various outdoor temperatures

(NOTE: Always use table and method recommended by manufacturer.)

II. Mechanical components of an air conditioner

A. Evaporator

B. Metering device

C. Liquid line

D. Suction line

E. Compressor

F. Condenser

G. Liquid line dryer (optional)

H. Service valves

INFORMATION SHEET

III. Electrical components of an air conditioner

A. Thermostat

B. Subbase

C. Condenser fan

D. Transformer

E. Contactor

F. High pressure switch (optional)

G. Low pressure switch (optional)

H. Crankcase heater (optional)

I. Hard start kit (optional)

J. Run capacitor

K. Overload protector

L. Lockout relay (optional)

IV. Processes in the cooling cycle

A. System thermostat calls for "Cooling"

B. Fan switch set on automatic

C. TC 1 contacts made in thermostat

D. Fan relay coil is energized and the normally open set of contacts is closed and completes circuit to indoor fan motor on high speed

E. The contactor coil is energized closing the normally open contacts and completes the circuit to the compressor and condensing unit

V. How the cooling cycle is completed

A. Thermostat opens

B. Operating circuits de-energize

VI. What happens with fan on continuous operation

A. Fan selector switch reads "On"

B. Fan relay coil on indoor fan relay is energized

C. Circuit is completed through normally open set of contacts which are now closed and indoor fan is now in high speed

INFORMATION SHEET

VII. Compressor motor failures and ways they can be detected

A. Open windings--Can be detected by connecting an ohmmeter to the compressor motor terminals and reading infinite resistance of the motor windings

(NOTE: A hot compressor must be allowed to cool down to permit the internal overload switch to close.)

B. Shorted windings--Can be detected by connecting an ohmmeter to the compressor motor terminals and reading zero resistance of the motor windings

(NOTE: The large size of motor windings requires that anyone checking for a short be able to distinguish between the extremely low resistance of a good winding and the zero resistance in a shorted winding.)

C. Grounded windings--Can be detected by connecting an ohmmeter to ground and to each of the motor terminals and reading a resistance of zero

(NOTE: Grounded windings which are also shorted to each other may be caused either by lightning or by halo effect due to compressor operation with insufficient refrigerant charge.)

VIII. Compressor failures and ways they can be detected

A. Tight compressor--Can be detected by snapping an ammeter over a power wire to the compressor and reading locked rotor amperage while compressor fails to start

(NOTE: A new compressor that is tight can usually be started with a hard start kit.)

B. Broken motor shaft--Can be detected by attaching compound gauges to the gauge ports and reading the same pressure on both gauges while the motor is running

C. Leaking valves--Can be detected by attaching compound gauges to the gauge port and reading less than normal difference between head pressure and suction pressure

(NOTE: Leaking valves can sometimes be determined by feeling the temperature of the suction line immediately after stopping the compressor; a hot or cold suction line usually means leaking valves.)

D. Locked compressor--Can be determined if the compressor still won't start after all efforts to start it have failed

INFORMATION SHEET

IX. Failures in condensing sections and their possible causes

A. Refrigerant leaks

1. Loose refrigerant line fittings

2. Improperly made sweat joints or flares

3. Nail holes in refrigerant lines

B. Condenser fan motor failure

1. Seized bearings due to lack of lubrication

2. Burned motor windings

3. Capacitor failure

(NOTE: Capacitor failure is seldom a cause of condensor fan motor failure.)

C. Start capacitor or start relay

1. Capacitor terminal burned off

2. Capacitor boiled over

(NOTE: Replace the start relay when replacing a start capacitor.)

D. Run capacitor

1. Open circuit

2. Changed capacitance

3. Shorted from leveling or distortion

E. Contactor

1. Burned points making poor contact

2. Sticking carriage

F. Crankcase heater

1. Broken

2. Burned

INFORMATION SHEET

X. Functions of low side section components in an air conditioner

A. Blower section

1. Moves air from occupied space and forces it through the filter and cooling coil

2. Returns conditioned air to occupied space

B. Cooling coil

1. Removes heat and moisture from the air passing through it

2. When installed in an upflow or counterflow furnace the cooling coil must be shaped to allow condensed moisture to drip downward parallel to the air flow through the coil

(NOTE: This is called an "A" coil.)

3. When installed in the horizontal furnace the cooling coil is shaped to allow condensed moisture to drip downward perpendicular to the air flow through the coil

(NOTE: This is called a horizontal or slab coil.)

C. Condensate pan--Catches condensed water which drips off the cooling coil

D. Condensate drain fitting--A factory installed short tube soldered into the condensate pan, usually 3/4" I.D. copper for the purpose of connecting the drain pan to a field installed drain line

E. Metering devices

1. Capillary tubes

a. Meters refrigerant to the cooling coil by restricting its flow due to its length and small diameter

b. Permits manufacture of lower cost cooling equipment due to its lower cost and simplicity

2. Thermostatic expansion valve

a. Meters refrigerant to the cooling coil by restricting its flow by a continuous throttling action which is controlled by the super heat setting of the valve

b. Permits reliable operation of the cooling coil over a wider temperature range than is practical with other common types of metering devices

INFORMATION SHEET

F. Refrigerant lines--Connect cooling coil to condensing units to circulate refrigerant in an enclosed system

(NOTE: Refrigerant lines may be either flexible or hard copper, connected by sweating or with compression type fittings or quick connect devices, and may be either precharged with refrigerant or dehydrated and filled with dry nitrogen.)

G. Room thermostat--Regulates the operation of cooling equipment to maintain a desired temperature in a conditioned space

(NOTE: Room thermostats are remotely installed and field wired. They are usually manufactured to control both heating and cooling with the same thermostat, but require a heat/cool subbase.)

H. Transformer--Converts line voltage to 24 volts

(NOTE: Due to the presence of larger electrical control loads in an air conditioner, the transformer must be of larger capacity than in "heating only" transformers. This requires a minimum of 40 VA transformer capacity, which must be added to a "heating only" furnace; a fan relay must be added also.)

XI. Component problems of low side sections and their possible causes

A. Frozen coil

1. Insufficient air flow

a. Dirty filter

b. Dirty coil

c. Undersized ductwork

2. Low refrigerant charge

B. Refrigerant leaks at refrigerant line fittings

1. Galled threads

2. Compression ferrule on backwards

3. Incomplete make up of connection

(NOTE: A few drops of compressor oil on a refrigerant line fitting will assure a complete run up of the fitting nut.)

C. Leak in evaporator coil or return bends

1. Vibration

2. Corrosion

INFORMATION SHEET

D. Expansion valve

1. Out of adjustment or tolerance

2. Ruptured

(NOTE: Residential air conditioners and heat pumps have generally stopped using expansion valves in favor of simpler, less expensive capillary tubes. There are still many old air conditioners in service with expansion valves.)

E. Coil flooded with oil

1. Untrapped refrigerant lines

2. Result of too many compressor changes

XII. Steps in using a charging table (Transparency 1)

A. Attach a refrigeration thermometer to the system's suction line where it enters the condensing unit

B. Attach a suction gauge to the suction line port at the condensing unit

C. Record suction line pressure, ambient temperature, and suction line temperature

D. Suction line temperature reading should be within 3° F of table reading

Example: At 90°F outdoor temperature and 68 PSIG suction pressure, the system will be correctly charged if the recorded suction line temperature is between 54° and 60°F; a reading above 60°F would indicate an undercharge and a reading below 54°F would indicate an overcharge

XIII. Rule of thumb procedure for working without a charging table

A. Charge to a liquid line pressure equivalent to 30°F above ambient temperature

B. Suction line pressure should be equivalent to a temperature above freezing

Typical Charging Table

OUTDOOR AMBIENT (°F)	SUCTION PRESSURE AT OUTDOOR SECTION (PSIG)																								
	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98
	SUCTION LINE TEMPERATURE (±3°F.)																								
65	37	42	47	53	59	64	69	71	75	79	82	85													
70	32	37	43	48	53	59	64	69	71	75	79	82	85												
75		33	38	43	49	54	59	65	69	72	76	79	83	85											
80			32	39	43	48	54	59	64	69	72	75	79	81	85										
85				32	38	41	48	53	58	64	69	71	75	78	81	84									
90						35	40	47	52	57	62	65	68	72	75	78	81	85							
95								40	44	49	54	59	62	66	70	73	76	79	82	85					
100										44	48	53	58	63	65	69	72	75	78	81	85				
105											42	47	50	55	60	66	69	71	75	78	80	83	86		
110													45	50	55	60	65	68	70	73	76	79	82		
115															51	55	60	63	66	69	72	75	78	81	84

RESIDENTIAL COOLING SYSTEMS
UNIT III

JOB SHEET #1--TROUBLESHOOT AN AIR CONDITIONER CONDENSER SECTION ON A "NO COOLING" COMPLAINT

I. Tools and equipment

A. Screwdrivers

B. Nut drivers

C. Voltmeter-ammeter-ohmmeter

D. Gauge manifold

E. Gloves

II. Procedure

A. Set thermostat switch to "on"; if blower fails to start

B. Check fuse to furnace; if fuse is OK

C. Check output of transformer for 24 volts; if transformer is OK

D. Check line voltage at blower motor; if voltage is not present, fan relay is bad; if voltage is present, blower motor is bad

(NOTE: To troubleshoot an air conditioner, the indoor blower coil section must be operating normally with a clean coil and clean filter.)

E. Make sure indoor section is operating normally

F. Check condenser fan operation; if it is not operating

G. Remove panel and control box cover and note position of contactor carriage; if contactor points are closed

(NOTE: Some contactor carriages are covered with a plastic plate which must be removed. Others are mounted in such a way that inspection will not indicate whether points are closed or open.)

H. Press the carriage momentarily into a closed position with an insulated screwdriver

I. Note fan and compressor response; if fan and compressor start

J. Check for a broken wire in the low voltage 2-wire cable leading to the contactor

(NOTE: Dogs will sometimes chew this cable in two; lawn trimmers also cause damage.)

JOB SHEET #1

K. Check to see if contactor is closed and fan and compressor will not run; if so

L. Check line voltage to contactor terminals; if there is no voltage

(NOTE: If contactor operation cannot be determined by inspection, then disconnecting or cutting a low voltage control wire to the contactor will result in a loud click as the connection is made and broken by hand.)

M. Check fuse to condenser circuit if line voltage is present

N. Check for a tripped safety device, usually a high pressure cut out

O. Reset safety device and note compressor and fan operation; if no safety device is present

P. Feel the compressor temperature

(NOTE: Resetting a tripped high pressure cut out usually completes the low voltage circuit to the contactor, and some sophisticated systems require considerably more steps in troubleshooting; do not confuse a hot compressor with the effect of a normally operating crankcase heater; a compressor may be considered hot when it is too hot to hold a hand on for a few seconds.)

Q. Check for hot compressor that will not run; this indicates compressor is knocked out on internal overload

(NOTE: This does not necessarily affect the condenser fan.)

R. Check to see if contactor is closed; if fan does not run

S. Check for a bad condenser fan motor; if it is OK and high pressure cut out has been tripped or compressor is out on internal overload

(NOTE: A condenser fan motor does not always go bad all at once; sometimes it will run for an hour or more before it will heat up and quit; by the time a service technician arrives, it has cooled off and may run beautifully when energized.)

T. Check for cause of high pressure head

(NOTE: Leaves, grass clippings, drier lint, etc., can stop up a condenser coil and cause high head pressure, or it could be caused by a newspaper or other debris obstructing air flow; whatever the cause, the condenser coil must be cleaned.)

U. Determine that there is no apparent reason for high head pressure and that the high pressure cut out is tripped and the fan and compressor both run when reset, then

JOB SHEET #1

V. Follow procedure for checking the cut out point of the high pressure cut out; if compressor fails to run when line voltage is aplied to compressor terminals

(NOTE: Install gauge manifold, start equipment, and note pressure; block air flow through condenser coil with newspaper until cut out trips and note cut out pressure; this should be approximately 400 psi.)

W. Follow procedures for checking out hard start kit, capacitor, and compressor windings

X. Replace control box cover and panel and all screws

Y. Clean up area and put tools away

RESIDENTIAL COOLING SYSTEMS
UNIT III

JOB SHEET #2--PERFORM MAINTENANCE ON AN AIR CONDITIONER

I. Tools and equipment

A. Screwdrivers

B. Nut drivers

C. Ammeter-voltmeter-ohmmeter

D. Gauge manifold

E. Gloves

II. Procedure

A. Follow procedure for periodic maintenance call on indoor section

B. Remove panel and control box cover from condensing unit

C. Measure amperage of condenser fan and compare with fan motor specifications on nameplate

D. Measure amperage of compressor and compare with compressor motor specifications on nameplate

E. Kill power to unit, gain access to motor, and oil according to manufacturer's instructions; if condenser fan is mounted horizontally check to see if it can be oiled

(NOTE: Many condenser fan motors are mounted vertically and cannot be lubricated; even many horizontal ones cannot be lubricated.)

F. Touch crankcase heater to determine condition

G. Inspect condenser coil and clean with coil cleaner if dirty

H. Inspect terminals on capacitors, contactor, and compressor for corrosion and burning

I. Check cut out pressure of high pressure cut out if present

J. Check operation of lock out relay if present

K. Connect gauge manifold and determine operating pressures; if suction pressure corresponds to below freezing evaporator temperature, add refrigerant

(NOTE: Most systems use R-22 refrigerant; nevertheless, there are several manufacturers which use other refrigerants; be positive which refrigerant is used before adding any; refrigerant data is usually on the nameplate.)

JOB SHEET #2

L. Check head pressure

(NOTE: With suction pressure at proper level, the head pressure should be approximately 30° above ambient temperature. New high efficiency units have head pressures 20° above ambient; however, variable speed and multispeed condenser fans will confuse these readings unless the fan control is bypassed and set on high speed during the maintenance call.)

M. Shut down condensing unit and note speed at which suction pressure and head pressure equalize while feeling temperature of suction line

(NOTE: Too slow equalization of suction pressure indicates insufficient size or kinks in liquid line.)

N. Replace control box cover, panel, and all screws

O. Clean up tools and area and put tools away

RESIDENTIAL COOLING SYSTEMS
UNIT III

JOB SHEET #3--USE A CHARGING TABLE TO CHECK THE CHARGE IN A CAPILLARY COOLING SYSTEM

I. Tools and equipment

A. Service technician's tool pouch

B. Shop rags

C. Refrigeration thermometer or thermometer feeler bulb

D. Suction or compound gauge

E. Pencil and paper

F. Cooling system as selected by instructor

II. Procedure

A. Attach a refrigeration thermometer or thermometer feeler bulb securely to the system's suction line where it enters the condensing unit

B. Insulate around the connection with shop rags to insure an accurate reading

C. Attach a suction or compound gauge to the suction line port at the condensing unit

D. Allow suction line pressure to stabilize for 10 to 15 minutes

E. Read and record

1. Suction line pressure ______________________

2. Ambient temperature ______________________

3. Suction line temperature ______________________

F. Compare figures in the charging table with suction line pressure and ambient temperature (Figure 1)

(NOTE: The unit suction line temperature should be within 3°F of the chart reading for the unit to indicate a proper charge.)

G. Compare system readings wth chart readings; if unit suction line temperature is higher that 3°F over the value given, the system is undercharged

H. Compare system readings with chart readings; if unit suction line temperature is lower than 3°F below the value given, the system is overcharged

JOB SHEET #3

I Establish a condition of undercharge or overcharge and continue

J Check for low indoor unit airflow

K Check for restrictions in refrigerant line

L Check your findings with your instructor

M Clean up area and return tools

FIGURE 1

OUTDOOR AMBIENT (°F)	SUCTION PRESSURE AT OUTDOOR SECTION (PSIG)																								
	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98
	SUCTION LINE TEMPERATURE (±3°F)																								
65	37	42	47	53	59	64	69	71	75	79	82	85													
70	32	37	43	48	53	59	64	69	71	75	79	82	85												
75		33	38	43	49	54	59	65	69	72	76	79	83	85											
80			32	[illegible]	[illegible]	48	54	59	64	69	72	75	79	81	85										
85				32	38	41	48	53	58	64	69	71	75	78	81	84									
90						35	40	47	52	57	62	65	68	72	75	78	81	85							
95								40	44	49	54	59	62	66	70	73	76	79	82	85					
100										44	48	53	58	63	65	69	72	75	78	81	85				
105											42	47	50	55	60	66	69	71	75	78	80	83	86		
110													45	50	55	60	65	68	70	73	76	79	82		
115															51	55	60	63	66	69	72	75	78	81	84

RESIDENTIAL COOLING SYSTEMS
UNIT III

NAME________________________________

TEST

1. Match the terms on the right with their correct definitions.

_____a.	A gauge port made like an automobile tire valve	1.	Suction line accumulator
_____b.	A low wattage wrap around device that boils refrigerant out of the compressor oil	2.	Charging tables
		3.	Shrader valve
_____c.	A normally closed relay used to open a protective circuit while the relay is energized	4.	Halo effect
		5.	Crankcase heater
_____d.	A starting capacitor and starting relay added to a compressor circuit	6.	Lowside
		7.	Lockout relay
_____e.	A tank used to hold liquid refrigerant which would normally flood back to a compressor during cold weather	8.	Hard start kit
_____f.	Electrical discharge around terminals while under a vacuum, causing carbon tracks to deposit on the inside of a compressor and short circuit the compressor motor windings		
_____g.	The low pressure part of air conditioning equipment, namely the evaporator coil and suction line		
_____h.	Graphs or tables which list proper suction and head pressures at various outdoor temperatures		

2. Complete a list of mechanical components of an air conditioner.

a.

b.

c.

d.

e. Compressor

f. Condenser

g. Liquid line dryer

h. Service valves

3. Complete a list of electrical components of an air conditioner.

a.

b.

c.

d.

e.

f. High pressure switch

g. Low pressure switch

h. Crankcase heater

i. Hard start kit

j. Run capacitor

k. Overload protector

l. Lockout relay

4. Select true statements concerning processes in the cooling cycle by placing an "X" in the appropriate blanks.

_____a. System thermostat calls for "Cooling"

_____b. Fan switch set on manual

_____c. TC 1 contacts made in thermostat

_____d. Fan relay coil is energized and the normally open set of contacts is closed and completes circuit to indoor fan motor on high speed

_____e. The contactor coil is energized closing the normally open contacts and completes the circuit to the compressor and condensing unit

5. State how the cooling cycle is completed.

a.

b.

6. Select true statements concerning what happens with fan on continuous operation by placing an "X" in the appropriate blanks.

_____ a. Fan selector switch reads "On"

_____ b. Fan relay coil on indoor fan relay is energized

_____ c. Circuit is completed through normally open set of contacts which are now closed and indoor fan is now in high speed

7. Match compressor motor failures with ways they can be detected.

_____ a. Can be detected by connecting an ohmmeter to the compressor motor terminals and reading infinite resistance of the motor windings

_____ b. Can be detected by connecting an ohmmeter to the compressor motor terminals and reading zero resistance of the motor windings

_____ c. Can be detected by connecting an ohmmeter to ground and to each of the motor terminals and reading a resistance of zero

1. Shorted windings
2. Grounded windings
3. Open windings

8. Match compressor failures with ways they can be detected.

_____ a. Can be detected by snapping an ammeter over a power wire to the compressor and reading locked rotor amperage while compressor fails to start

_____ b. Can be detected by attaching compound gauges to the gauge ports and reading the same pressure on both gauges while the motor is running

_____ c. Can be detected by attaching compound gauges to the gauge port and reading less than normal difference between head pressure and suction pressure

_____ d. Can be determined if the compressor still won't start after all efforts to start it have failed

1. Broken motor shaft
2. Leaking valves
3. Locked compressor
4. Tight compressor

9. Match failures in condensing sections with their possible causes.

_____a.	1) Loose refrigerant line fittings 2) Improperly made sweat joints or flares 3) Nail holes in refrigerant lines	1.	Condenser fan motor failure
_____b.	1) Seized bearings due to lack of lubrication 2) Burned motor windings 3) Capacitor failure	2.	Refrigerant leaks
_____c.	1) Capacitor terminal burned off 2) Capacitor boiled over	3.	Run capacitor
_____d.	1) Open circuit 2) Changed capacitance 3) Shorted from leveling or distortion	4.	Start capacitor or start relay
_____e.	1) Burned points making poor contact 2) Sticking carriage	5.	Crankcase heater
_____f.	1) Broken 2) Burned	6.	Contactor

10. Select true statements concerning functions of low side section components in an air conditioner by placing an "X" in the appropriate blanks.

(NOTE: For a statement to be true, all parts of the statement must be true.)

_____a. Blower section

1) Moves air from occupied space and forces it through the filter and cooling coil

2) Returns conditioned air to occupied space

_____b. Cooling coil

1) Removes heat and moisture from the air passing through it

2) When installed in an upflow or counterflow furnace the cooling coil must be shaped to allow condensed moisture to drip downward parallel to the air flow through the coil.

3) When installed in the horizontal furnace the cooling coil is shaped to allow condensed moisture to drip downward perpendicular to the air flow through the coil

_____ c. Condensate pan--Catches condensed water which drips off the cooling coil

_____ d. Condensate drain fitting--A factory installed short tube soldered into the condensate pan, usually 3/4" I.D. copper for the purpose of connecting the drain pan to a field installed drain line

_____ e. Metering devices

1) Capillary tubes

a) Meters refrigerant to the cooling coil by restricting its flow with a miniature valve

b) Is expensive to manufacture

2) Thermostatic expansion valve

a) Meters refrigerant to the cooling coil by restricting its flow by a continuous throttling action which is controlled by the super heat setting of the valve

b) Permits reliable operation of the cooling coil over a wider temperature range than is practical with other common types of metering devices

_____ f. Refrigerant lines--Connect cooling coil to condensing units to circulate refrigerant in an enclosed system

_____ g. Room thermostat--Regulates the operation of cooling equipment to maintain a desired temperature in a conditioned space

_____ h. Transformer--Converts line voltage to 12 volts

11. Match component problems of low side sections with their probable causes.

_____ a. 1) Insufficient air flow

a) Dirty filter

b) Dirty coil

c) Undersized ductwork

2) Low refrigerant charge

_____ b. 1) Galled threads

2) Compression ferrule on backwards

3) Incomplete make up of connection

1. Frozen coil
2. Leak in evaporator coil or return bends
3. Coil flooded with oil
4. Expansion valve
5. Refrigerant leaks at refrigerant line fittings

_____ c. 1) Vibration

2) Corrosion

_____ d. 1) Out of adjustment or tolerance

2) Ruptured

_____ e. 1) Untrapped refrigerant lines

2) Result of too many compressor changes

12. Arrange in order the steps in using a charging table by placing the correct sequence number in the appropriate blank.

_____ a. Record suction line pressure, ambient temperature, and suction line temperature

_____ b. Suction line temperature reading should be within 3°F of table reading

_____ c. Attach a refrigeration thermometer to the system's suction line where it enters the condensing unit

_____ d. Attach a suction gauge to the suction line port at the condensing unit

13. Select true statements concerning the rule of thumb procedure for working without a charging table by placing an "X" in the appropriate blanks.

_____ a. Charge to a liquid line pressure equivalent to 30°F above ambient temperature

_____ b. Suction line pressure should be equivalent to a temperature above freezing

14. Demonstrate the ability to:

a. Troubleshoot an air conditioner condenser section on a "no cooling" complaint.

b. Perform maintenance on an air conditioner.

c. Use a charging table to check the charge in a capillary cooling system.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

RESIDENTIAL COOLING SYSTEMS
UNIT III

ANSWERS TO TEST

1. a. 3 e. 1
   b. 5 f. 4
   c. 7 g. 6
   d. 8 h. 2

2. a. Evaporator
   b. Metering device
   c. Liquid line
   d. Suction line

3. a. Thermostat
   b. Subbase
   c. Condenser fan
   d. Transformer
   e. Contactor

4. a, c, d, e

5. a. Thermostat opens
   b. Operating circuits de-energize

6. a, b, c

7. a. 3
   b. 1
   c. 2

8. a. 4
   b. 1
   c. 2
   d. 3

9. a. 2 d. 3
   b. 1 e. 6
   c. 4 f. 5

10. a, b, c, d, f, g

11. a. 1 d. 4
    b. 5 e. 3
    c. 2

12. a. 3
    b. 4
    c. 1
    d. 2

13. a, b

14. Performance skills evaluated to the satisfaction of the instructor

HEAT PUMP SYSTEMS
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify heat pumps in the heating, cooling, and defrost modes and describe the operation of a reversing valve. The student should also be able to trace operational circuits for heat pumps and troubleshoot heat pumps with heating or cooling problems. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to heat pump systems with their correct definitions.
2. Identify the components of a heat pump.
3. Identify the components of a 4-way reversing valve.
4. Differentiate between the operation of a 4-way reversing valve in the heating mode and cooling mode.
5. Select true statements concerning the operation of a heat pump in the defrost mode.
6. Identify the components of a heat pump indoor section.
7. Complete a chart showing the characteristics, advantages, and disadvantages of heat pump systems.
8. Complete a chart showing the differences between components of indoor sections of heat pumps and low side sections of air conditioners.
9. Complete a list showing common component failures of heat pumps in the cooling mode.
10. Complete a sketch showing the proper installation of an electric strip heater.
11. Complete a list of special precautions for replacing reversing valves.
12. State two major rules for good heat pump operation.
13. Trace operational circuits for a heat pump in the cooling mode.
14. Trace operational circuits for first stage heating in a heat pump.
15. Trace operational circuits for a heat pump in the defrost mode.

16 Trace operational circuits for second stage supplementary heat in a heat pump.

17. Demonstrate the ability to:

a Wire a control system for a heat pump.

b Troubleshoot a heat pump indoor section in the cooling mode.

c Perform maintenance on an indoor section of a heat pump in the cooling mode.

d. Troubleshoot a heat pump on a "no cooling" complaint.

e Troubleshoot a heat pump outdoor section on an "insufficient cooling" complaint.

f. Perform maintenance on an outdoor section of a heat pump in the cooling mode.

g Troubleshoot supplemental heat on a heat pump.

h Perform maintenance on heat pump supplemental heating.

i. Troubleshoot a heat pump on a "no heat" complaint when compressor will not run.

j. Troubleshoot a heat pump on a "no heat" complaint when compressor runs but cycles on compressor overload.

k. Troubleshoot a heat pump on an "insufficient heat" complaint when compressor will run.

HEAT PUMP SYSTEMS
UNIT IV

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Discuss and demonstrate the procedures outlined in the job sheets.

VII. Invite a homeowner with a heat pump system to talk to the class concerning initial costs, operational costs, and benefits or problems experienced with the system.

VIII. Demonstrate to the class how a heat pump system can be used to preheat domestic hot water.

IX. Invite a local or area contractor who installs solar devices to talk to the class concerning supplementary solar applications for heat pumps.

X. Invite a manufacturer's representative to talk to the class concerning improvements in heat pump design and performance in the past few years.

XI. Discuss and demonstrate to the class the various methods used to accomplish the defrost cycle in a heat pump, and prepare a wiring diagram to show typical defrost cycle circuit.

XII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Components of a Heat Pump
2. TM 2--Components of a 4-Way Reversing Valve
3. TM 3--Operation of a 4-Way Reversing Valve

4. TM 4--Heat Pump in Defrost Mode

5. TM 5--Components of a Heat Pump Indoor Section

6. TM 6--Supplemental Electric Heater and Typical Installation

D. Assignment sheets

1. Assignment Sheet #1--Trace Operational Circuits for a Heat Pump in the Cooling Mode

2. Assignment Sheet #2--Trace Operational Circuits for First Stage Heating in a Heat Pump

3. Assignment Sheet #3--Trace Operational Circuits for a Heat Pump in the Defrost Mode

4. Assignment Sheet #4--Trace Operational Circuits for Second Stage Supplementary Heat in a Heat Pump

E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1--Wire a Control System for a Heat Pump

2. Job Sheet #2--Troubleshoot a Heat Pump Indoor Section in the Cooling Mode

3. Job Sheet #3--Perform Maintenance on an Indoor Section of a Heat Pump in the Cooling Mode

4. Job Sheet #4--Troubleshoot a Heat Pump on a "No Cooling" Complaint

5. Job Sheet #5--Troubleshoot a Heat Pump Outdoor Section on an "Insufficient Cooling" Complaint

6. Job Sheet #6--Perform Maintenance on an Outdoor Section of a Heat Pump in the Cooling Mode

7. Job Sheet #7--Troubleshoot Supplemental Heat on a Heat Pump

8. Job Sheet #8--Perform Maintenance on Heat Pump Supplemental Heating

9. Job Sheet #9--Troubleshoot a Heat Pump on a "No Heat" Complaint When Compressor Will Not Run

10. Job Sheet #10--Troubleshoot a Heat Pump on a "No Heat" Complaint When Compressor Runs but Cycles on Compressor Overload

11. Job Sheet #11--Troubleshoot a Heat Pump on an "Insufficient Heat" Complaint When Compressor Will Run

G. Test

H. Answers to test

II. References:

A. *Heat Pump Design, Service, and Application.* Dallas, TX 75240: Education Department, Lennox Industries, Inc., 1979.

B. Harris, Norman C., and Conde, David F. *Modern Air Conditioning Practice, Second Edition.* New York: McGraw-Hill Book Company, 1974.

C. Althouse, Andrew D., and Carl H. Turnquist and Alfred F. Bracciano. *Modern Refrigeration and Air Conditioning.* South Holland, IL: The Goodheart-Willcox Company, Inc., 1975.

HEAT PUMP SYSTEMS
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Heat pump--Basically a refrigerated air conditioning system with two refrigerant coils and a valve to reverse the flow of refrigerant

B. Reversing valve--A heat pump control valve used to switch from heating mode to cooling mode by reversing the compressor connections to the inside and outside coils

C. Suction line--Refrigerant line that directs low pressure vapor from the evaporator coil to the compressor

D. Heat exchanger--A device used to transfer heat

E. Heat sink--A relatively cool substance that can readily absorb heat

F. Ground coil--A heat exchanger which is buried in the ground and functions as either a condenser or evaporator

G. Geothermal well--A heat exchanger which utilizes well, pond, or lake water as either a condenser or evaporator

II. Components of a heat pump (Transparency 1)

A. Indoor and outdoor refrigerant coils

B. Compressor

C. Indoor and outdoor metering devices

D. Indoor and outdoor check valves

E. 4-way reversing valve

F. Piston

G. Piston bleed ports

H. Crankcase heater

I. Accumulator

J. Indoor and outdoor blowers

K. Solenoid

INFORMATION SHEET

III. Components of a 4-way reversing valve (Transparency 2)

A. Connection to discharge line of compressor

B. Connection to suction line of compressor

C. Connection to outside coil

D. Connection to inside coil

E. Piston

F. Solenoid and activating device

G. Piston bleed ports

IV. Operation of a 4-way reversing valve (Transparency 3)

A. Heating mode

1. Solenoid is energized

2. Piston moves into heating position

3. Suction line of the compressor is connected to the outside coil making it an evaporator

4. Discharge line of compressor is connected to the inside coil making it a condenser

B. Cooling mode

1. Solenoid is de-energized

2. Piston returns to cooling position

3. Suction line of the compressor is connected to the inside coil making it an evaporator

4. Discharge line of the compressor is connected to the outside coil making it a condenser

V. Operation of a heat pump in the defrost mode (Transparency 4)

A. The defrost cycle is initiated by preset time controls, preset temperature controls, or preset controls to measure pressure drop across the outside coil

(NOTE: Methods of initiating the defrost cycle vary with manufacturer, and some systems may use combinations of time, temperature, and pressure.)

INFORMATION SHEET

B. The reversing valve reverses the heat pump from the heating to the cooling cycle on a preset schedule

C. Hot gas from the compressor discharge line is directed to the outside coil

D. Frost accumulation on the outside coil is removed

E. The outside blower is shut off to reduce cold air flow and assist the melting process

F. Supplementary heat systems are energized

G. After frost has been removed from the outside coil, the cycle is reversed

H. The defrost cycle is terminated by preset time controls, preset temperature controls, or preset controls to measure pressure rise across the outside coil

(NOTE: Methods of terminating the defrost cycle vary with manufecturer, and some systems may use combinations of time, temperature, and presure.)

VI. Components of a heat pump indoor section (Transparency 5)

A. Cabinet

B. Filter and cold air inlet

C. Heating elements of nichrome wire or tubular cased wire

D. Blower assembly

E. Blower and limit control switches

F. Heat exchange chamber and warm air outlet

G. Indoor coil

H. Supplementary heat controls and sequencing relays

INFORMATION SHEET

VII. Characteristics, advantages, and disadvantages of heat pump systems

Type of System	Air to Air	Air to Water
Characteristics	Uses atmosphere to cool condenser or to absorb heat from evaporator Requires a blower to provide air movement across outdoor coil	Uses the ground or a body of water to provide cooling or heat absorption Can use a geothermal well Requires no blower for outdoor coil
Advantages	Efficient in milder climates	High efficiency because ground or water acts as a heat exchanger Can use recirculated water for cooling and solar collectors for additional heat Can be used to preheat hot water
Disadvantages	Capacity and performance lowers as temperature drops Less efficient in cold climates Requires supplemental heating	Requires supplemental heating

VIII. Differences between components of indoor sections of heat pumps and low side sections of air conditioners

Component	Heat Pump	Air Conditioner
Blower Section	Driven by a 230-V motor	Driven by a 115-V motor
Metering Device	Always has a check-valve and a bypass arrangement	Has no check valve or bypass
Thermostat	Controls one stage of cooling and two stages of heating, and may contain a manually operated emergency heat switch	Controls one stage of cooling and one stage of heating
Transformer	Located in outdoor section instead of in air handler and is 230 volts	Located in the furnace and is 115 volts

INFORMATION SHEET

IX. Common component failures of heat pumps in the cooling mode

(NOTE: All common failures of air conditioners also apply to heat pumps.)

A. Transformer

1. Blown fuse

2. Burned out windings

B. Reversing valve

1. Leaking valves

2. Stuck piston

(NOTE: A stuck piston can be detected by feeling the temperature of the tubing stubs and pilot valve tubes.)

3. Burned out solenoid

X. General rules for installation of supplemental heating strips (Transparency 6)

A. Heating strip should never be installed from the bottom or top of the duct

B. Heating strips should always be installed on the discharge side of any air handling equipment

C. Controls for strip heaters must be readily accessable

XI. Special precautions for replacing reversing valves

A. Never expose a reversing valve to excessive heat

(NOTE: Wrapping a valve with a wet cloth can help moderate heat when brazing lines in the system.)

B. Keep the inside tubes of the valve and the system free of all foreign material

(NOTE: Flux, dirt, or even moisture can impair operation of a reversing valve and contribute to premature failure.)

C. Never strike a reversing valve with a hammer or any tool that could dent or bend any part of the valve

D. Install a reversing valve in a location on the refrigerant line that will help keep vibration from the compressor at a minimum

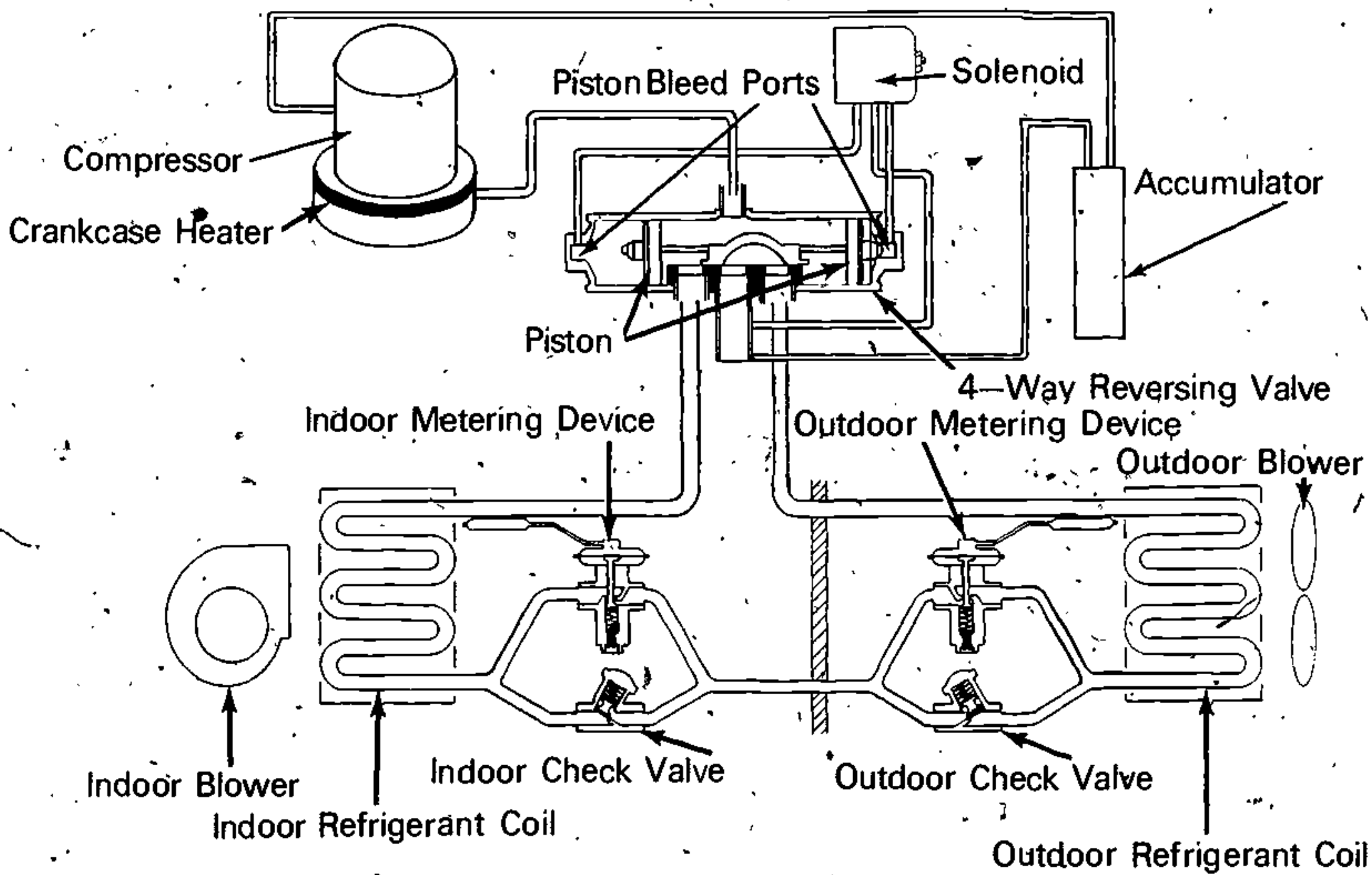
INFORMATION SHEET

XII. Two major rules for good heat pump operation

A. Filters, grilles, and coils must be kept clean to assure adequate air circulation

B. The refrigerant charge for the system should always be at the proper pressures

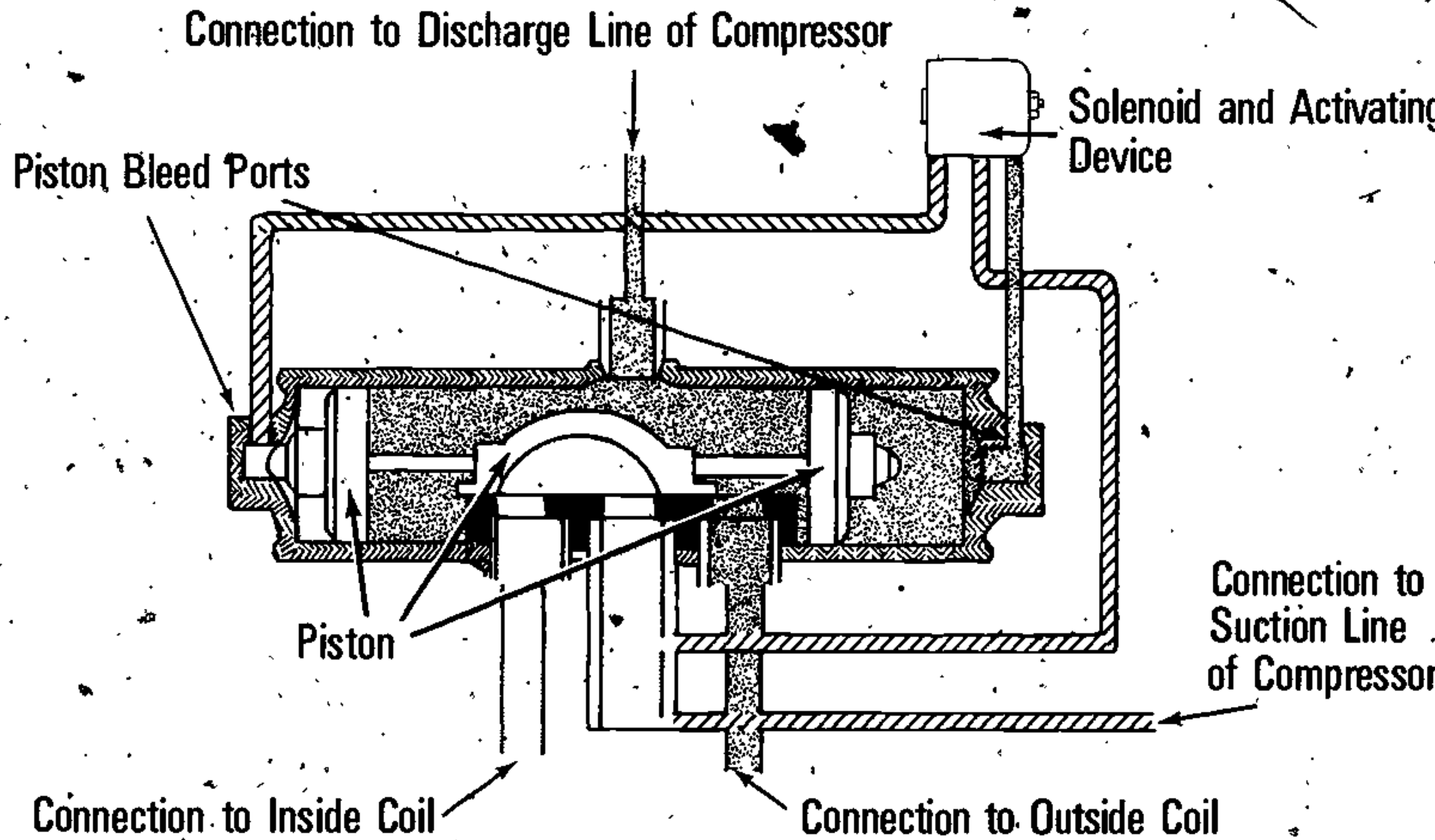
Components of a Heat Pump



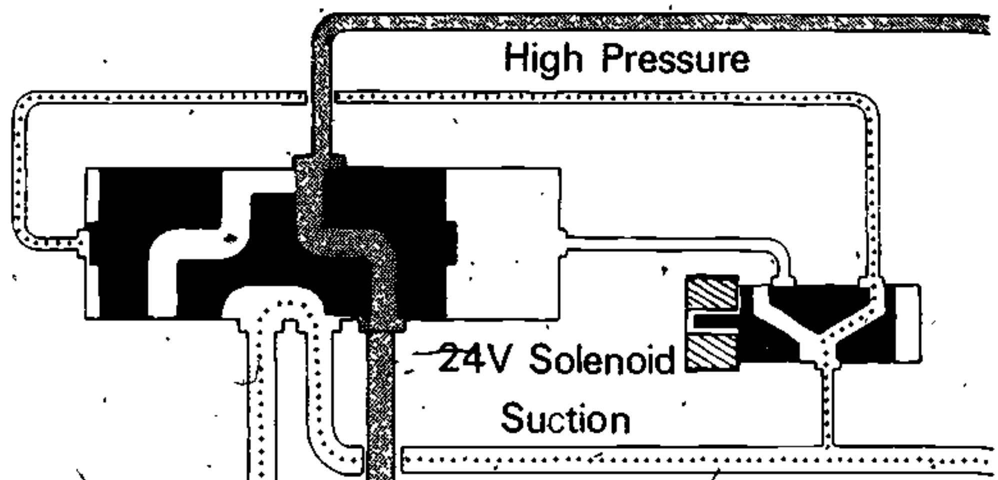
ACR IV - 155

TM.1

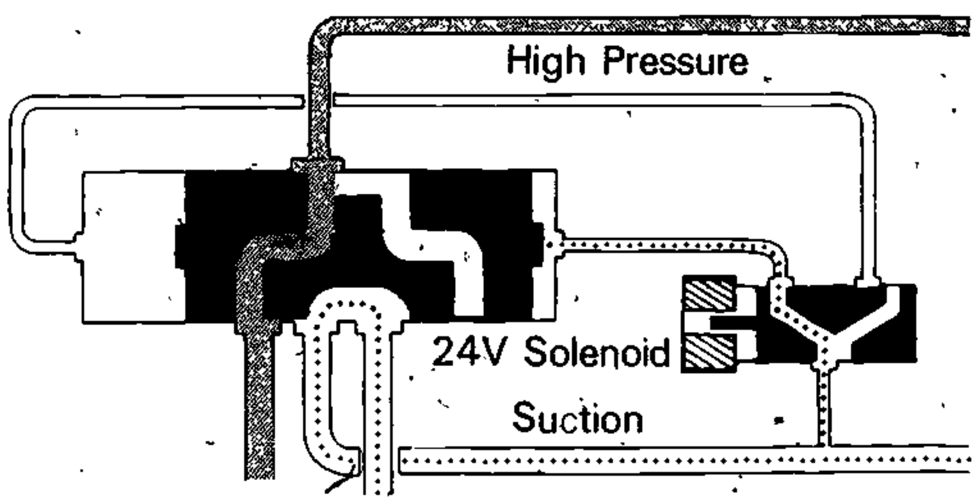
Components of a 4-Way Reversing Valve



Operation of a 4-Way Reversing Valve



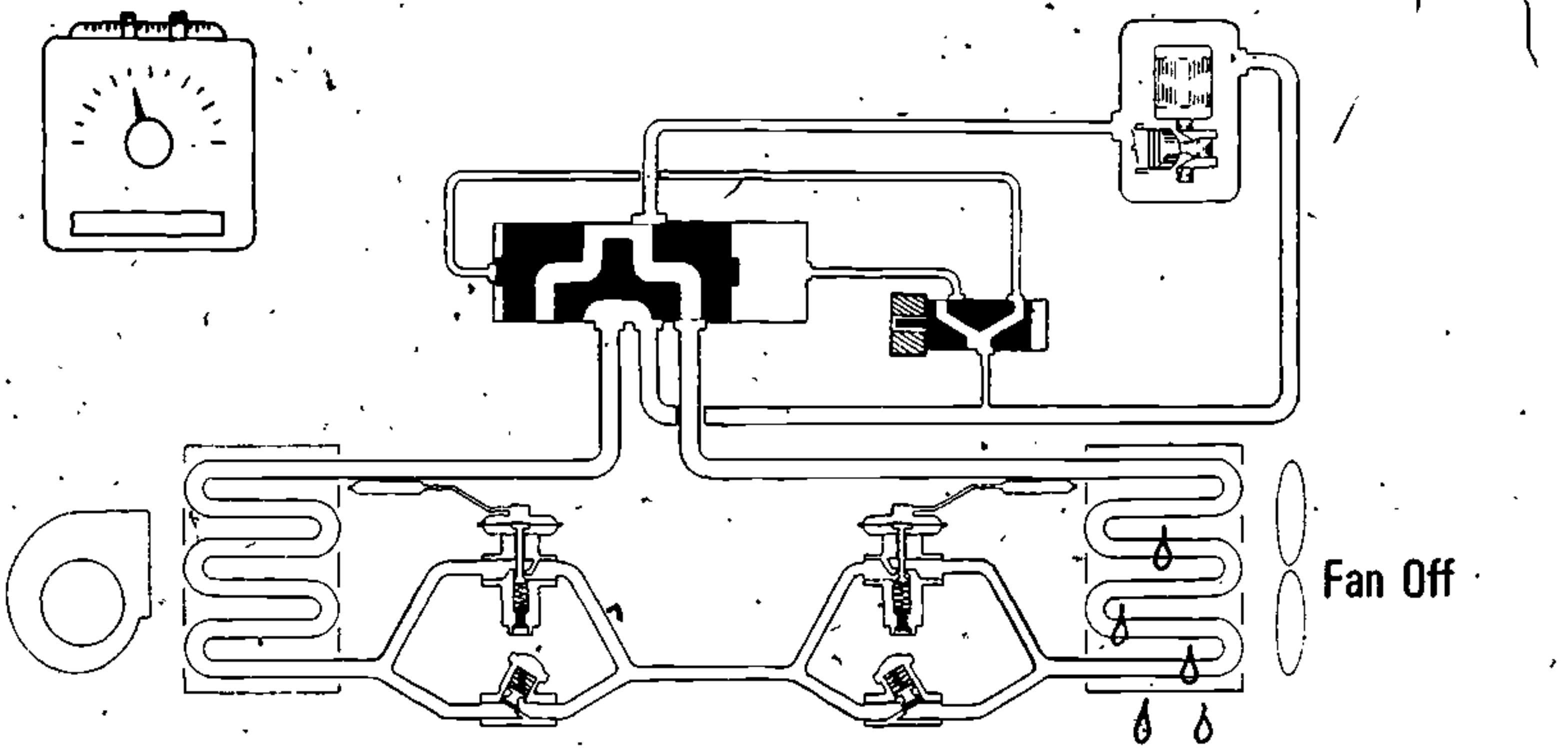
Cooling Mode



Heating Mode

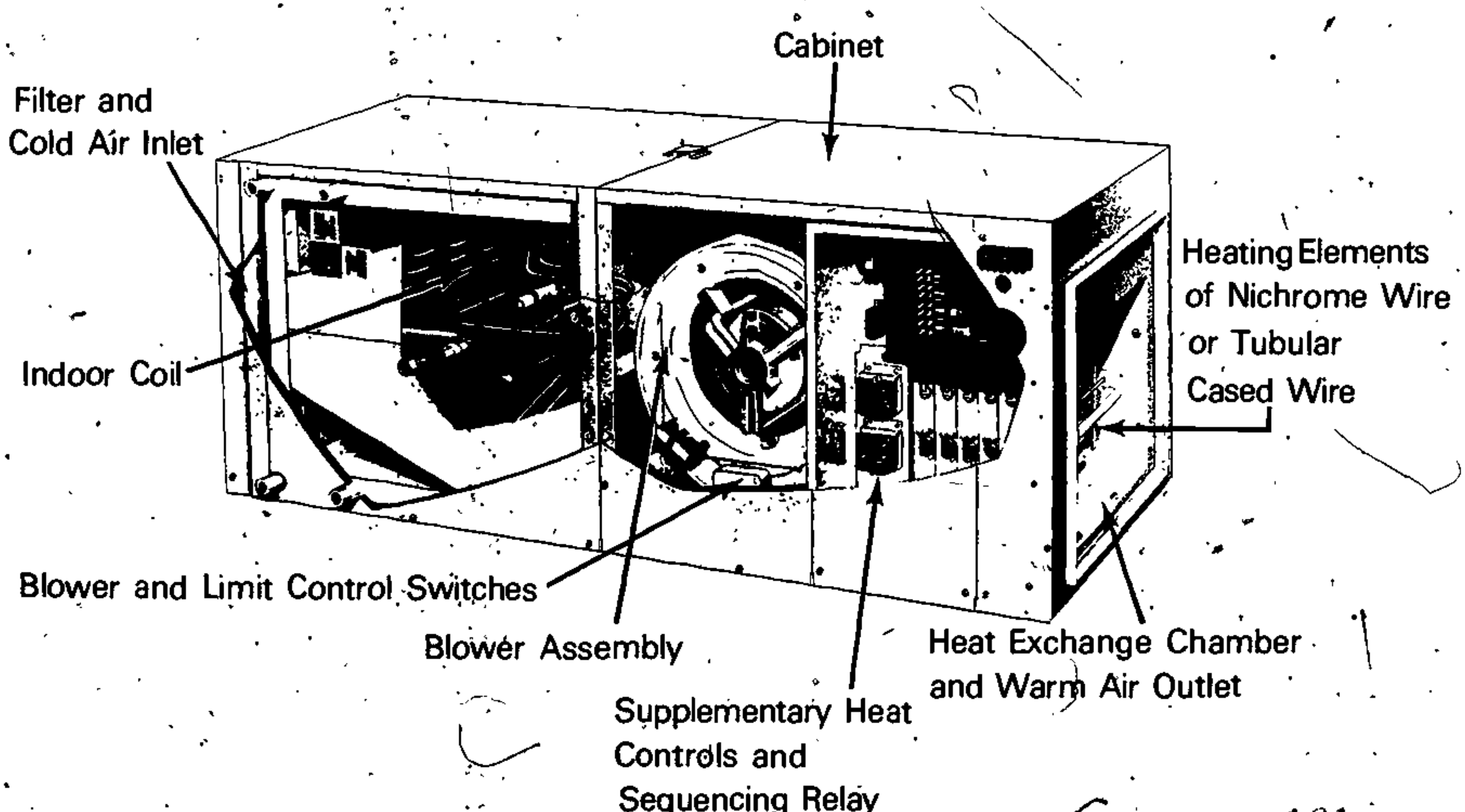
(Courtesy of Lennox Industries Inc., Dallas, Texas)

Heat Pump in Defrost Mode



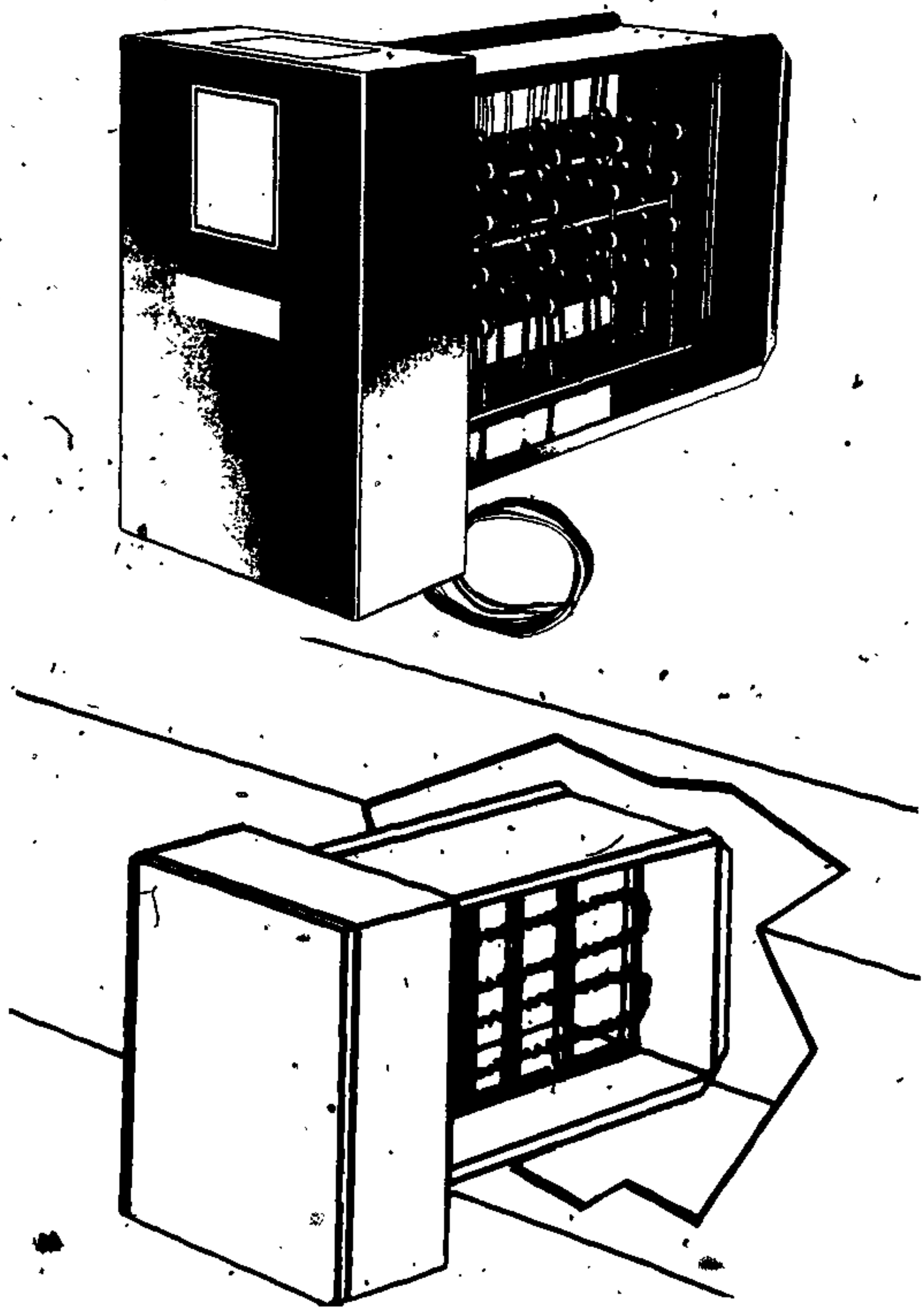
(Courtesy of Lennox Industries Inc., Dallas, Texas)

Components of a Heat Pump Indoor Section



(Courtesy of Lennox Industries Inc., Dallas, Texas)

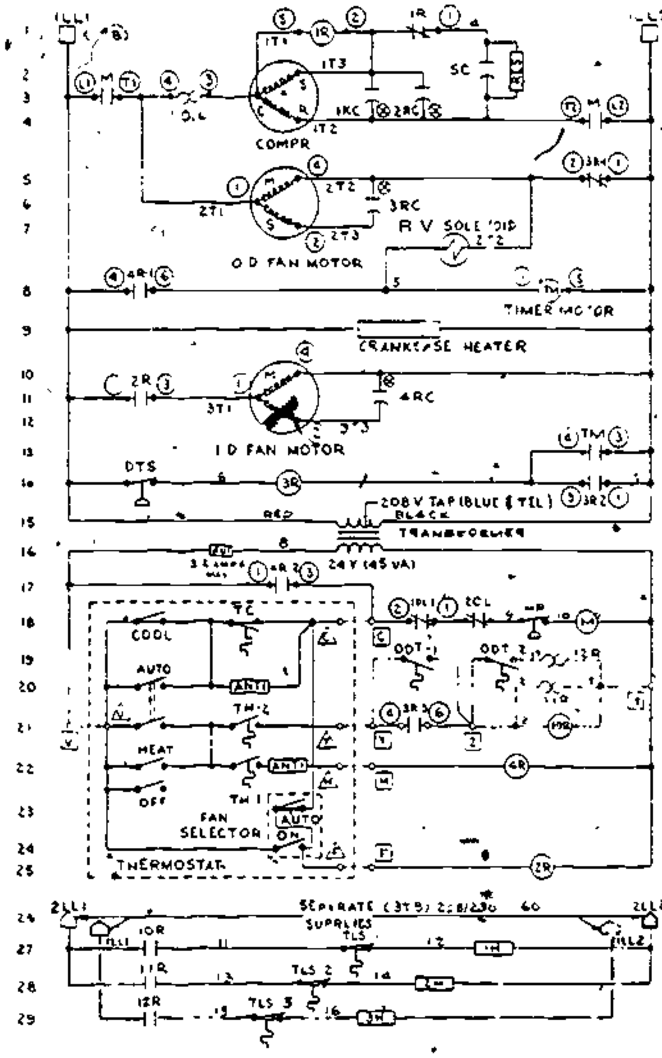
Supplemental Electric Heater and Typical Installation



(Courtesy of Lennox Industries Inc., Dallas, Texas)

HEAT PUMP SYSTEMS
UNIT IV

ASSIGNMENT SHEET #1--TRACE OPERATIONAL CIRCUITS FOR A HEAT PUMP IN THE COOLING MODE



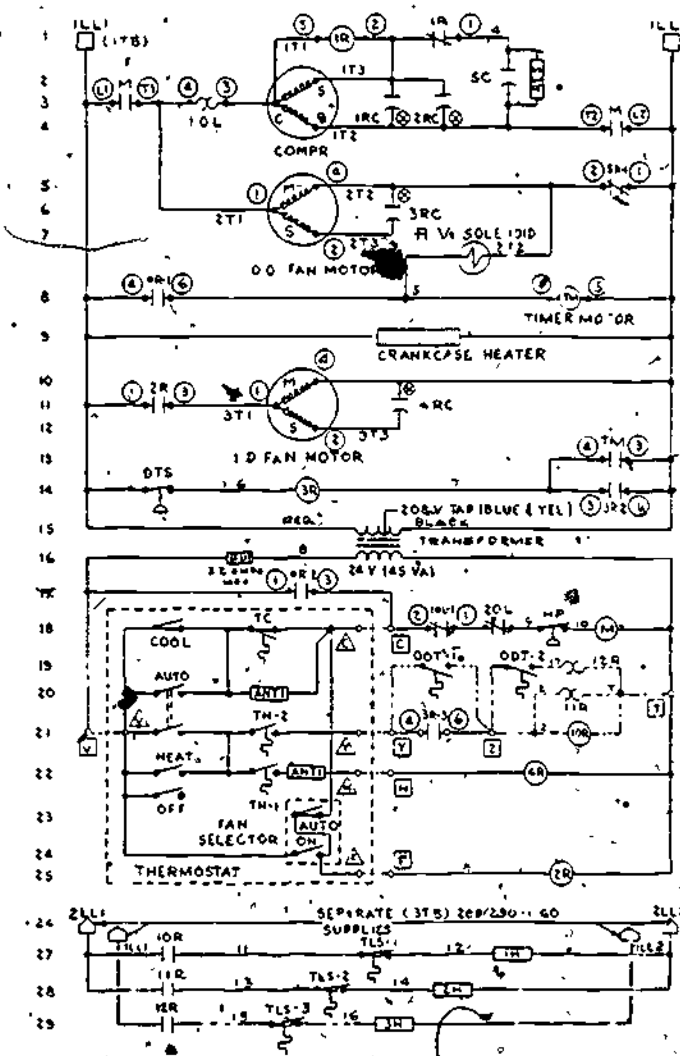
ELECTRIC HEAT ACCESSORY WIRING COMPLIES WITH NATIONAL ELECTRIC CODE

LEGEND

CONTR	M	2PNO Compr & O D Fan Motor	RES	Resistor	HP	High Pressure Cutout
RELAY	1R	SPNO Compr Motor Starter	T	Transformer	TLS	Thermal Limit Switch
RELAY	2R	SPNO I D Fan Motor	RC	Running Capacitor	DTS	Defrost Termination
RELAY	3R 1	SPNO Defrost Initiation	SC	Starting Compr	△	Terminal Block—Room Therm.
RELAY	3R 2	SPNO Defrost Holding	H	Heater (4KW)	▭	Terminal Block—Unit
RELAY	3R 3	SPNO Defrost—Indoor Aux Heat	FU	Fuse	⌂	Terminal Block—Duct Heater
RELAY	4R 1	SPNO 1st Stage Heat—R V Sol	TC	Thermostat—Cooling	⊗	Identified Terminal on Running Capacitor
RELAY	4R 2	SPNO 1st Stage Heat—Compr	TH	Thermostat—Heating		
RELAY	10R	SPNO 2nd Stage Heat	TB	Terminal Block		
RELAY	11R	SPNO 3rd Stage Heat (Time Delay)	ODT	Thermostat—Outdoor		
RELAY	12R	SPNO 4th Stage Heat (Time Delay)	R V	RV Reversing Valve Solenoid		

HEAT PUMP SYSTEMS
UNIT IV

ASSIGNMENT SHEET #2--TRACE OPERATIONAL CIRCUITS FOR FIRST STAGE HEATING IN A HEAT PUMP



ELECTRIC HEAT ACCESSORY WIRING COMPLIES WITH NATIONAL ELECTRIC CODE

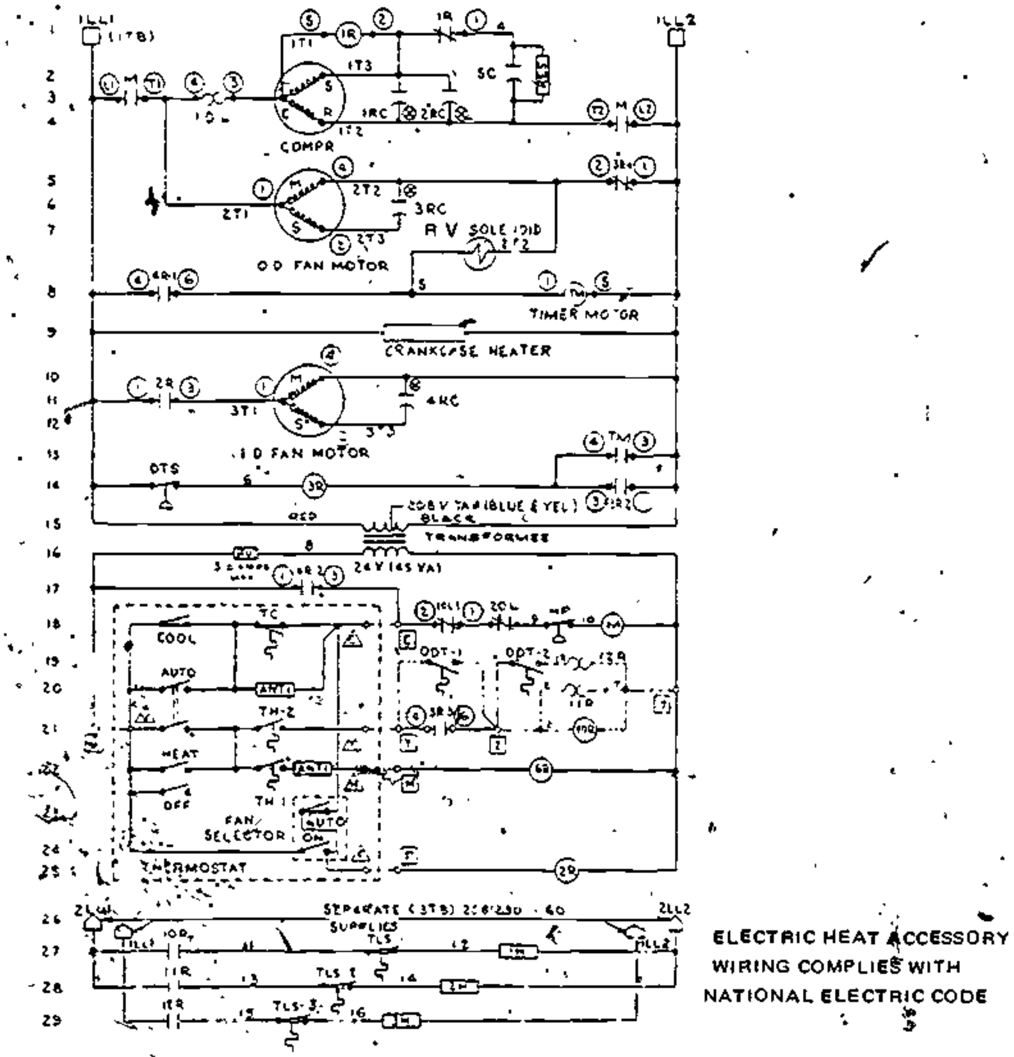
LEGEND

CONTR	M	2PNO Compr & O D Fan Motor	RES	Resistor	HP	High Pressure Cutout
RELAY	1R	SPNO Compr Motor Starter	T	Transformer	TLS	Thermal Limit Switch
RELAY	2R	SPNO I D Fan Motor	RC	Running Capacitor	OTS	Defrost Termination
RELAY	3R 1	SPNO Defrost Initiation	SC	Starting Compr	△	Terminal Block–Room Therm.
RELAY	3R 2	SPNO Defrost Holding	H	Heater (4KW)	⊡	Terminal Block–Unit
RELAY	3R-3	SPNO Defrost–Indoor Aux Heat	FU	Fuse.	⌂	Terminal Block–Duct Heater
RELAY	4R-1	SPNO 1st Stage Heat–R C Sol	TC	Thermostat–Cooling	⊗	Identified Terminal on Running Capacitor
RELAY	4R 2	SPNO 1st Stage Heat–Compr	TH	Thermostat–Heating		
RELAY	10R	SPNO 2nd Stage Heat	TB	Terminal Block		
RELAY	11R	SPNO 3rd Stage Heat (Time Delay)	ODT	Thermostat–Outdoor		
RELAY	12R	SPNO 4th Stage Heat (Time Delay)	R.V	Reversing Valve Solenoid		

HEAT PUMP SYSTEMS
UNIT IV

ASSIGNMENT SHEET #3--TRACE OPERATIONAL CIRCUITS FOR A HEAT PUMP IN THE DEFROST MODE

(NOTE: Be sure to consider what happens with the outdoor fan and reversing valve.)

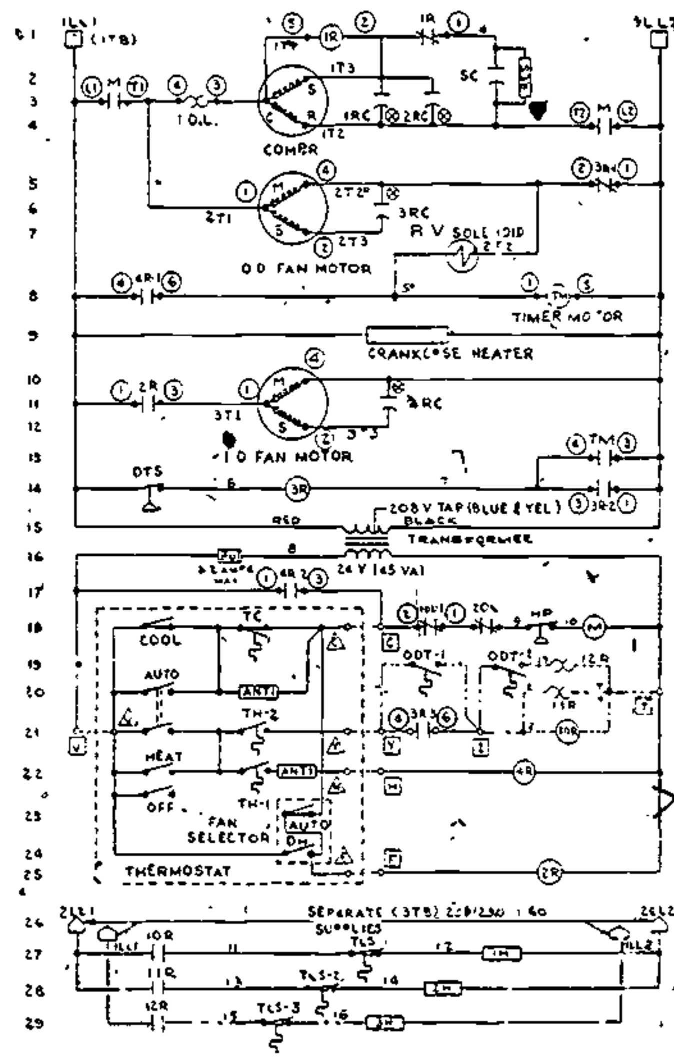


LEGEND

CONTR M	2PNO Compr & O-D Fan Motor	RES	Resistor	HP	High Pressure Cutout
RELAY 1R	SPNO Compr Motor Starter	T	Transformer	TLS	Thermal Limit Switch
RELAY 2R	SPNO I D Fan Motor	RC	Running Capacitor	OTS	Defrost Termination
RELAY 3R 1	SPNO Defrost Initiation	SC	Starting Compr	△	Terminal Block – Room Therm.
RELAY 3R 2	SPNO Defrost Holding	H	Heater (4KW)	▢	Terminal Block – Unit
RELAY 3R 3	SPNO Defrost – Indoor Aux Heat	FU	Fuse	⌂	Terminal Block – Duct Heater
RELAY 4R 1	SPNO 1st Stage Heat – R C Sol	TC	Thermostat – Cooling	⊗	Identified Terminal on Running Capacitor
RELAY 4R 2	SPNO 1st Stage Heat – Compr	TH	Thermostat – Heating		
RELAY 10R	SPNO 2nd Stage Heat	TB	Terminal Block		
RELAY 11R	SPNO 3rd Stage Heat (Time Delay)	ODT	Thermostat – Outdoor		
RELAY 12R	SPNO 4th Stage Heat (Time Delay)	RV	Reversing Valve Solon Solenoid		

HEAT PUMP SYSTEMS
UNIT IV

ASSIGNMENT SHEET #4--TRACE OPERATIONAL CIRCUTS FOR SECOND STAGE SUPPLEMENTARY HEAT IN A HEAT PUMP



ELECTRIC HEAT ACCESSORY WIRING COMPLIES WITH NATIONAL ELECTRIC CODE

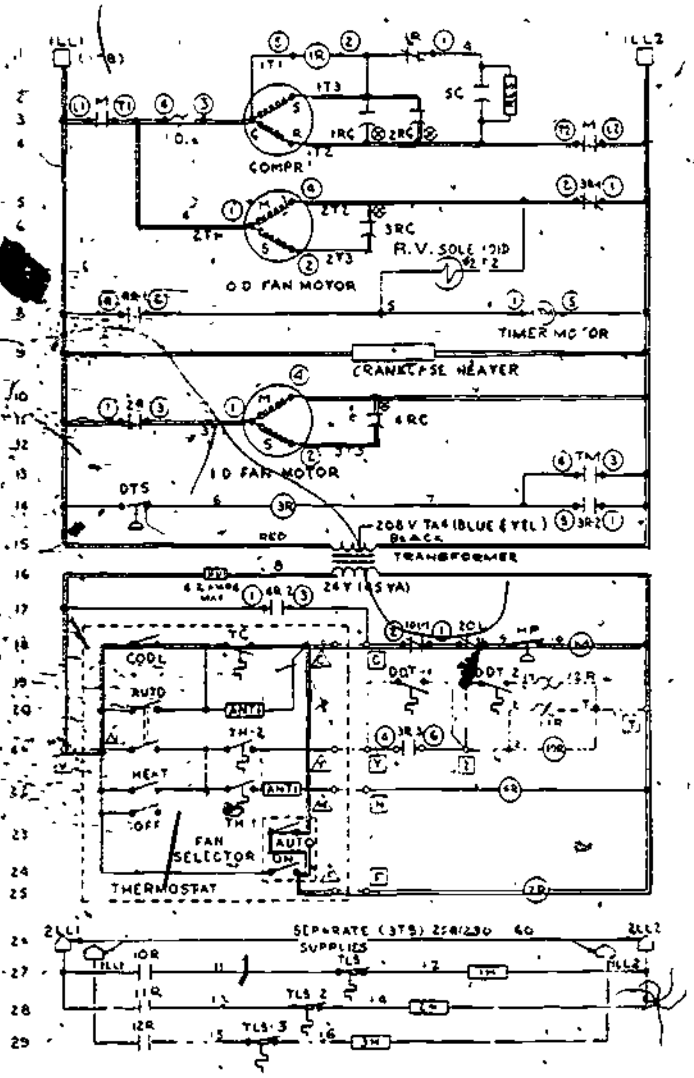
LEGEND

CONTR	M	2PNO Compr & O D Fan Motor	RES	Resistor	HP	High Pressure Cutout
RELAY	1R	SPNO Compr Motor Starter	T	Transformer	TLS	Thermal Limit Switch
RELAY	2R	SPNO I O Fan Motor	RC	Running Capacitor	DTS	Defrost Termination
RELAY	3R 1	SPNO Defrost Initiation	SC	Starting Compr	△	Terminal Block–Room Therm.
RELAY	3R-2	SPNO Defrost Holding	H	Heater (4KW)	□	Terminal Block–Unit
RELAY	3R-3	SPNO Defrost–Indoor Aux Heat	FU	Fuse	⌂	Terminal Block–Duct Heater
RELAY	4R 1	SPNO 1st Stage Heat–R C Sol	TC	Thermostat–Cooling	⊗	Identified Terminal on Running Capacitor
RELAY	4R 2	SPNO 1st Stage Heat–Compr	TH	Thermostat–Heating		
RELAY	10R	SPNO 2nd Stage Heat	TB	Terminal Block		
RELAY	11R	SPNO 3rd Stage Heat (Time Delay)	ODT	Thermostat–Outdoor		
RELAY	12R	SPNO 4th Stage Heat (Time Delay)	R V.	Reversing Valve Solenoid		

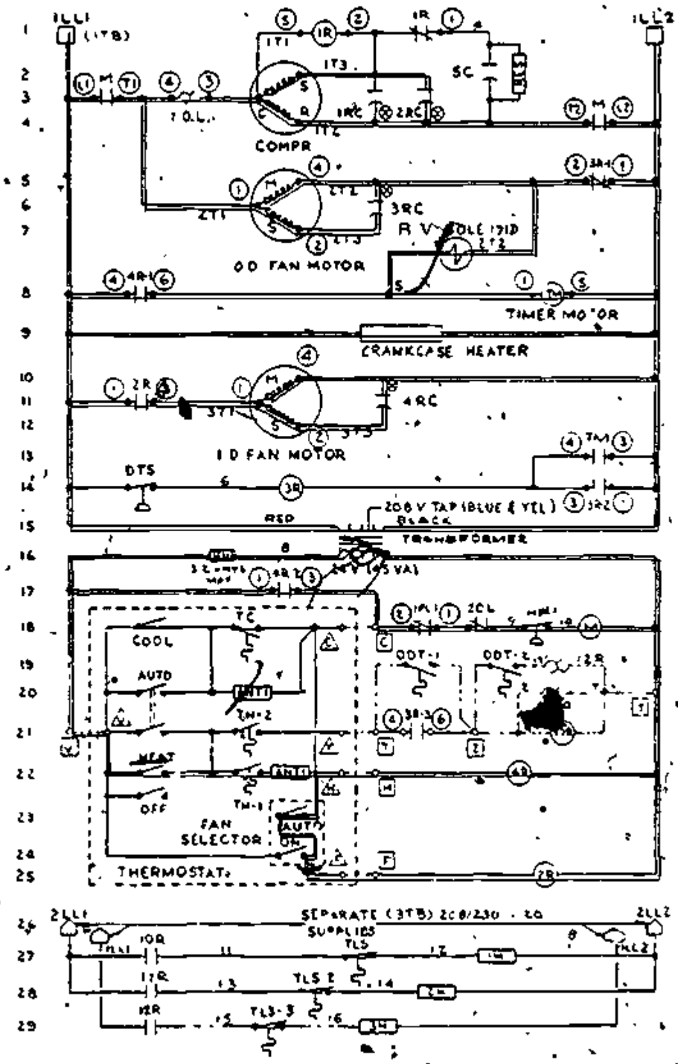
HEAT PUMP SYSTEMS
UNIT IV

ANSWERS TO ASSIGNMENT SHEETS

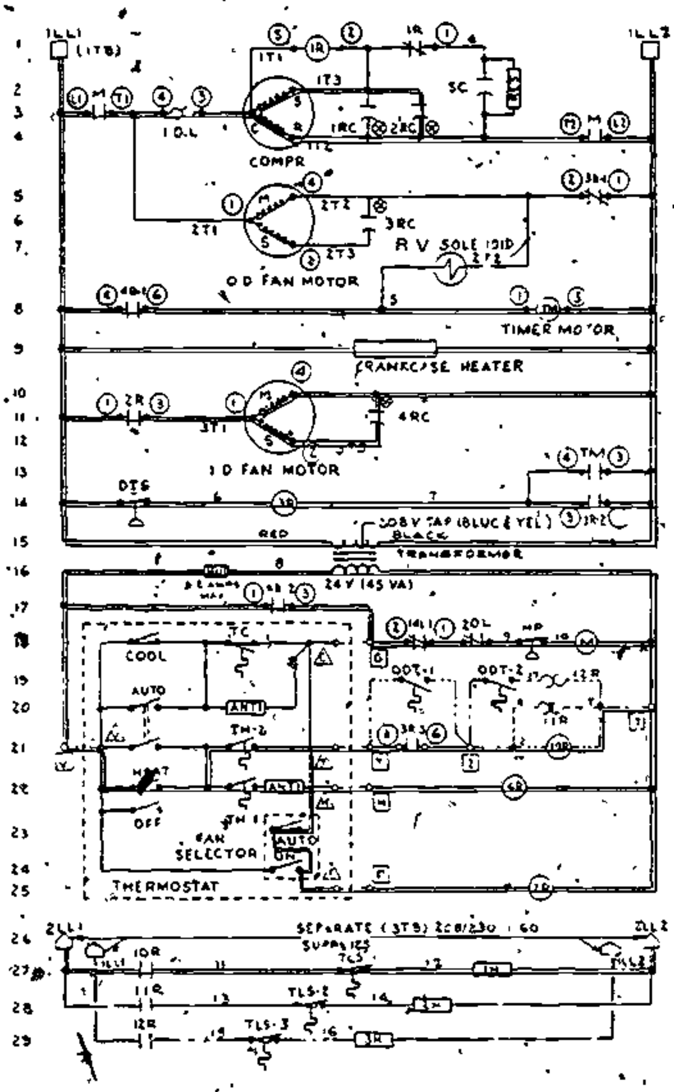
Assignment Sheet #1



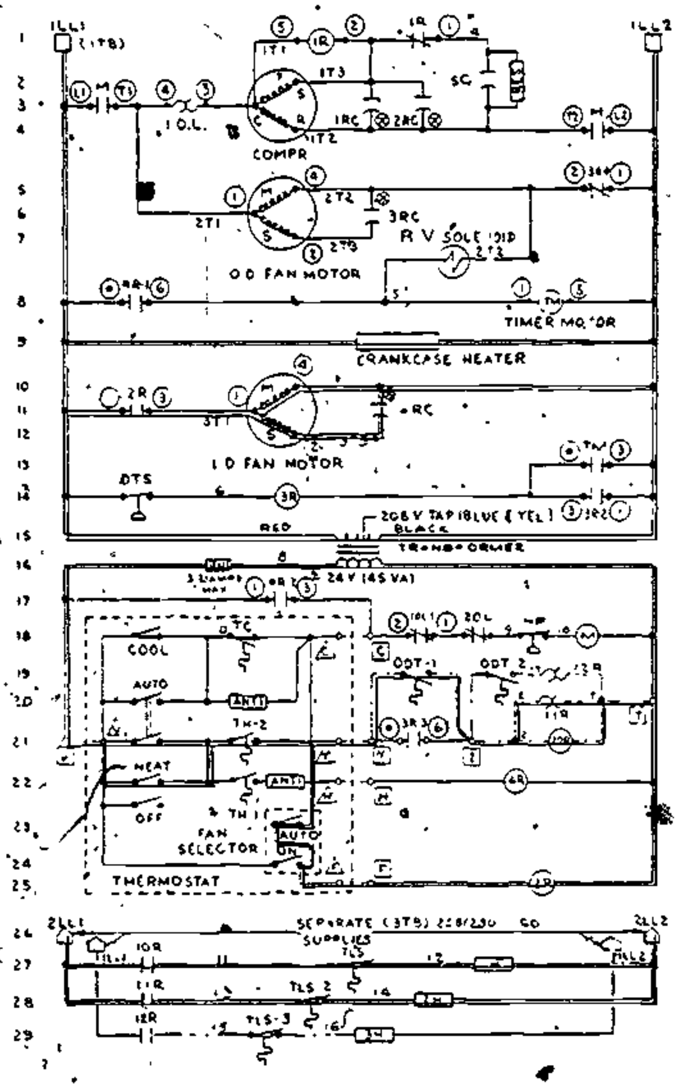
Assignment Sheet #2



Assignment Sheet #3



Assignment Sheet #4



HEAT PUMP SYSTEMS
UNIT IV

JOB SHEET #1--WIRE A CONTROL SYSTEM FOR A HEAT PUMP

I. Tools and equipment

A. Service technician's tool pouch

B. Voltmeter-ohmmeter

C. Heat pump trainer or system selected by instructor

(NOTE: System should have wiring diagram recommended by manufacturer; diagram in Figure 1 is included for general reference.)

II. Procedure

A. Check power source

B. Apply power to system

C. Turn power off

D. Wire necessary circuits to energize indoor fan motor

E. Turn power on

F. Operate indoor fan motor

G. Have instructor verify operation

H. Turn power off

I. Wire necessary circuits to operate cooling

J. Turn power on

K. Operate system for cooling

L. Have instructor verify operation

M. Turn power off

N. Wire necessary circuits for first stage heat (reverse cycle heating)

O. Turn power on

P. Operate system for first stage heating

Q. Have instructor verify operation

JOB SHEET #1

R. Turn power off

S. Wire necessary circuits for second stage supplemental heat

T. Turn power on

U. Operate system for second stage supplemental heat

V. Have instructor verify operation

W. Turn power off

X. Wire necessary circuits for defrost

Y. Turn power on

Z. Operate system for defrost

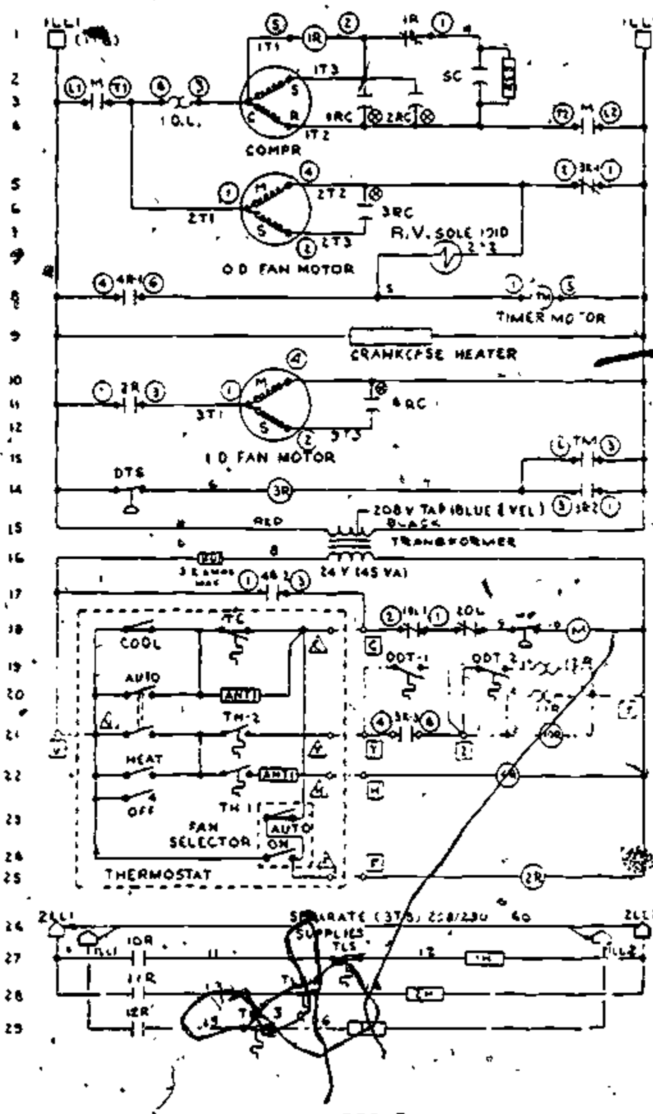
AA. Have instructor verify operation

BB. Turn power off

CC. Clean area and return tools

JOB SHEET #1

FIGURE 1



ELECTRIC HEAT ACCESSORY WIRING COMPLIES WITH NATIONAL ELECTRIC CODE

LEGEND

CONTR M	2PNO Compr & O O Fan Motor	RES	Resistor	HP	High Pressure Cutout
RELAY 1R	SPNO Compr Motor Starter	T	Transformer	TLS	Thermal Limit Switch
RELAY 2R	SPNO I D Fan Motor	RC	Running Capacitor	DTS	Defrost Termination
RELAY 3R 1	SPNO Defrost Initiation	SC	Starting Compr	△	Terminal Block – Room Therm
RELAY 3R 2	SPNO Defrost Holding	H	Heater (4KW)	□	Terminal Block – Unit
RELAY 3R 3	SPNO Defrost – Indoor Aux Heat	FU	Fuse	⬭	Terminal Block – Duct Heater
RELAY 4R 1	SPNO 1st Stage Heat – R.V. Sol	TC	Thermostat – Cooling	⊗	Identified Terminal on Running Capacitor
RELAY 4R 2	SPNO 1st Stage Heat – Compr	TH	Thermostat – Heating		
RELAY 10R	SPNO 2nd Stage Heat	TB	Terminal Block		
RELAY 11R	SPND 3rd Stage Heat (Time Delay)	DDT	Thermostat – Outdoor		
RELAY 12R	SPNO 4th Stage Heat (Time Delay)	R.V	RV Reversing Valve Solenoid		

HEAT PUMP SYSTEMS
UNIT IV

JOB SHEET #2--TROUBLESHOOT A HEAT PUMP INDOOR SECTION IN THE COOLING MODE

I. Tools and equipment

A. Screwdrivers

B. Nut drivers

C. Volt-ohmmeter

D. Scratch awl

E. Thermometer

F. Pencil and note pad

G. Duct tape

II. Procedure

A. Disconnect power from air handler and check with voltmeter

B. Follow procedure for troubleshooting blower section

C. Disconnect fan relay

D. Measure resistance of fan relay coil and record whether OK ____________ Open______________Shorted______________

E. Disconnect secondary leads of transformer

F. Measure resistance of secondary windings of transformer and record whether OK ______________Open______________Shorted______________

G. Disconnect primary windings of transformer

H. Measure resistance of primary windings of transformer and record whether OK ______________Open______________Shorted______________

I. Measure resistance of each leg of transformer to ground and record whether OK ______________Grounded______________

1. Question: Have all electrical components of the air handler fan circuit been tested?______________

2. Has coil surface been checked and cleaned if needed?__________

3. Is this equipment safe to energize?______________

J. Reconnect fan relay and transformer

JOB SHEET #2

K. Energize air handler power circuit

L. Energize fan circuit at thermostat subbase and note blower operation OK ______________

M. Set thermostat to "cool" and adjust to colder setting than room temperature

N. Drive scratch awl into return plenum and measure return air temperature and record ______________°

O. Drive scratch awl into supply plenum and measure supply temperature and record ______________°

P. Calculate temperature amp across cooling coil and record ______________°; a temperature drop of 12° - 16° is regarded as OK after 15 minutes operation

(CAUTION: Be certain that scratch awl is not driven into cooling coil or electric heat strip section; inexperienced service people frequently do this.)

Q. Cover plenum holes with duct tape

R. Check findings with instructor

HEAT PUMP SYSTEMS
UNIT IV

JOB SHEET #3--PERFORM MAINTENANCE ON AN INDOOR SECTION OF A HEAT PUMP IN THE COOLING MODE

I. Tools and equipment

A. Screwdrivers

B. Nutdrivers

C. Gloves and shop rag

D. Scratch awl

E. Thermometer

F. Pencil and note pad

II. Procedure

A. Follow procedure for maintenance call on blower sections

B. Set indoor thermostat to "cool" and adjust setting to cooler than room temperature

C. Allow condensing unit to stabilize refrigerant pressures, then disconnect condensate drain and blow out slime with pressure through old charging hose wrapped in a shop rag

D. Reconnect condensate drain

(NOTE: Installers usually cement all joints in a new condensate drain line. The serviceman usually cuts the line with a hacksaw and after servicing reconnects the line with a coupling and friction tape.)

E. Feel suction line leaving evaporator

(NOTE: Suction line should be cold but not freezing.)

F. Wait for 15 minutes of continuous compressor operation then take temperature drop across under coil and record ______________°

G. Note any conditions which might affect air conditioner performance inside the structure

1. Abnormal indoor temperature
2. Furniture placement and draperies over supplies and returns
3. Improper design of supply registers
4. Thermostat over lamp or other heat source

JOB SHEET #3

H. Reset thermostat to room temperature and note temperature difference between switching temperature and room temperature __________ °

(NOTE: Thermostats with mercury switches are sensitive to vibration; they must be checked, leveled, and secured.)

I. Check findings with instructor

HEAT PUMP SYSTEMS
UNIT IV

JOB SHEET #4--TROUBLESHOOT A HEAT PUMP ON A "NO COOLING" COMPLAINT

I. Tools and equipment

A. Screwdrivers

B. Nut drivers

C. Ammeter-voltmeter-ohmmeter

D. Gauge manifold

E. Gloves

II. Procedure

A. Set thermostat-fan switch to "on"

B. Note blower response; if it fails to start, continue

C. Check fuse to furnace; if it is OK, continue

D. Check output of transformer for 24 volts; if it is OK, continue

E. Check for line voltage at blower motor

(NOTE: If voltage is not present, then the fan relay is bad; if voltage is present, the blower motor is bad.)

F. Check indoor blower section to make sure coil and filter are clean so the section will operate normally

G. Energize blower section for normal operation

H. Check condenser fan; if it is not operating, continue

I. Remove control box cover

J. Note position of contactor carriage

(NOTE: Some contactor carriages are covered with a plastic plate which must be removed; others are mounted in such a way that inspection will not reveal whether points are open or closed.)

K. Close contactor points if they are not closed; do this by momentarily pressing the carriage into a closed position with an insulated screwdriver

JOB SHEET #4

L. Note fan and compressor response; if fan and compressor start, continue

M. Look for a broken wire in the low voltage 2-wire cable leading to the contactor

(NOTE: Dogs will sometimes chew this cable in two; lawn trimmers can also cut it.)

N. Determine if fan and compressor will not run when contactor is closed; if they don't run, continue

O. Check for line voltage and contactor terminals; if there is no line voltage, continue

(NOTE: If contactor operation can't be determined by inspection, disconnect or cut a low voltage control wire to the contactor; when the connection is made and broken by hand, it will cause a loud click.)

P. Check fuse to condenser circuit; if line voltage is present, continue

Q. Look for a tripped safety device (usually a high pressure cut out)

R. Reset safety device

S. Note compressor and fan operation; if no safety device is present, continue

T. Feel the compressor; if it is hot and not running, this indicates a compressor internal overload

(NOTE: Do not confuse a hot compressor with the heat of a normally operating crankcase heater; when a compresser is too hot to hold a hand on it for a few seconds, it is hot.)

U. Check condenser fan, it it does not run while contactor is closed, continue

V. Check condenser fan motor; if it is OK, continue

(NOTE: Sometimes condenser fan motors will run a long time before they heat up and quit. A bad condenser fan motor that has had time to cool off may fool a service technician by running beautifully when it is first energized.)

W. Look for cause of high head pressure once it has been established that compressor is out on internal overload and high pressure cutout has been tripped

(NOTE: Leaves, grass clippings, clothes dryer lint, etc., can stop a condenser coil and cause high head pressure; a newspaper or other obstruction to air flow can also cause it.)

JOB SHEET #4

X. Establish that there is no apparent reason for high head pressure, high pressure cut out has been tripped, and fan and compressor both run when reset, and continue

Y. Follow procedure for checking the cut out point of the high pressure cut out, and continue

(NOTE: Install gauge manifold, start equipment, and note pressures; block air flow through condenser coil with newspaper until cut out trips and note cut out pressure, this should be approximately 400 psi; some cut outs are adjustable, but many are not.)

Z. Follow procedure for check out of hard start kit, capacitor, and motor windings if compressor fails to run when line voltage is applied

AA. Replace control box cover and panel and all screws

BB. Clean up tools and area and put tools away

HEAT PUMP SYSTEMS
UNIT IV

JOB-SHEET #5--TROUBLESHOOT A HEAT PUMP OUTDOOR SECTION ON AN "INSUFFICIENT COOLING" COMPLAINT

I. Tools and equipment

A. Screwdrivers

B. Nut drivers

C. Ammeter-voltmeter-ohmmeter

D. Gauge manifold

E. Gloves

II. Procedure

A. Follow procedures for checking an air conditioner condenser section

B. Operate indoor section normally, and with outdoor fan and compressor running, install gauge manifold

(CAUTION: Damage to the compound gauge can result if it is installed on the vapor line of a heat pump. Suction pressure is measured at a gauge port on the suction line near the compressor inside the outdoor cabinet.)

C. Use manufacturer's charging table to check operating pressures, if it is available

(NOTE: There is an unfortunate lack of information from many manufacturer's regarding their heat pumps. Many heat pumps have been installed which have no charging tables available. Heat pumps which have no suction line accumulator usually specify blowing the entire refrigerant charge and measuring in a new charge based on laboratory conditions which seldom exist in the field. In the absence of charging tables, use a rule of thumb. Charge to a liquid line pressure equivalent to 30° above ambient temperature, and a suction pressure equivalent to a temperature above freezing.)

D. Follow procedures for checking leaking valves in reversing valve and check valve in liquid line if pressures will not conform to charging tables or rules of thumb

(NOTE. One of the greatest problems with heat pumps has been liquid flood back to the compressor with resulting compressor motor burn-out or destroyed valves. Bad compressor valves cannot be accurately determined unless the reversing valve is disconnected from the compressor. The touch test on the reversing valve does not indicate the condition of the compressor valves.)

JOB SHEET #5

E. Replace compressor if compressor valves are leaking

(NOTE: The home owner will frequently declare that the heat pump heated satisfactorily all winter and express displeasure at the cost of replacing the compressor. Many home owners are unaware that the strip heat supplied most, if not all, of the heat during the winter after the compressor failed.)

F. Clean up tools and area and put tools away

HEAT PUMP SYSTEMS
UNIT IV

JOB SHEET #6--PERFORM MAINTENANCE ON AN OUTDOOR SECTION OF A HEAT PUMP IN THE COOLING MODE

I. Tools and equipment

A. Screwdrivers

B. Nut drivers

C. Ammeter-voltmeter-ohmmeter

D. Gauge manifolds

E. Gloves

II. Procedure

A. Follow procedure for periodic maintenance call on indoor section

B. Remove panel and control box cover from condensing unit

C. Measure amperage of condenser fan and compare with fan motor specifications on nameplate

D. Measure amperage of compressor and compare with compressor motor specifications on nameplate

E. Kill power to unit, gain access to motor, and oil according to manufacturer's instructions; if condenser fan is mounted horizontally check to see if it can be oiled

(NOTE: Many condenser fan motors are mounted vertically and cannot be lubricated; even many horizontal ones cannot be lubricated.)

F. Touch crankcase heater to determine condition

G. Inspect condenser coil and clean with coil cleaner if dirty

H. Inspect terminals on capacitors, contactor, and compressor for corrosion and burning

I. Check cut out pressure of high pressure cut out if present

J. Check operation of lock out relay if present

K. Connect gauge manifold and determine operating pressures. If suction pressure corresponds to below freezing evaporator temperature, add refrigerant

(NOTE: Heat pumps use R-22 refrigerant. Nevertheless, there are several manufacturers which use other refrigerants. Be positive which refrigerant is used before adding any. Refrigerant data is usually on the nameplate.)

JOB SHEET #6

L. Check head pressure

(NOTE: With suction pressure at proper level, the head pressure should be approximately 30° above ambient temperature. New high efficiency units have head pressures 20° above ambient; however, variable speed and multispeed condenser fans will confuse these readings unless the fan control is bypassed and set on high speed during the maintenance call.)

M. Shut down condensing unit and note speed at which suction pressure and head pressure equalize while feeling temperature of suction line

(NOTE: A warm suction line immediately after shut down indicates leaking valves. Too slow equalization of suction pressure indicates insufficient size or kinks in liquid line.)

N. Make touch test of reversing valve and note results

O. Replace control box cover, panel, and all screws

P. Clean up tools and area and put tools away

HEAT PUMP SYSTEMS
UNIT IV

JOB SHEET #7--TROUBLESHOOT SUPPLEMENTAL HEAT ON A HEAT PUMP

I. Tools and equipment

A. Service technician's tool pouch

B. Ohmmeter, voltmeter

II. Procedure

A. Disconnect power source

B. Remove cover of control box

C. Check for voltage at power lugs

D. Check for continuity and grounded heating elements

1. Set volt-ohmmeter to measure resistance

2. Remove power wires from elements

3. Measure resistance of heating elements and record

4. #1 ______ ohms #2 ______ ohms #3 ______ ohms

5. Reconnect power wires to elements

6. Question: What would elements read if open? What would elements read if shorted?

7. Are any elements grounded?

E. Check contactor and sequencers for continuity

1. Set volt-ohmmeter to measure resistance

2. Disconnect low voltage wires from contactor and/or sequencer #1

3. Measure resistance of contactor coil and record

4. Measure resistance of sequencer heater and record

5. Measure resistance of any other sequencer heaters and record #2 ______ ohms #3 ______ ohms

6. Reconnect low voltage wires to contactor and sequencer

JOB SHEET #7

7. Question: What would be the resistance of

   a. An open coil circuit? ______ohms

   b. A burned out coil? ______ohms

8. Question: What would be the resistance of

   a. An open heater circuit in a sequencer? ______ohms

   b. A shorted heater circuit? ______ohms

F. Check continuity and grounding of blower power circuit

G. Check continuity of fan relay coil circuit

1. Set volt-ohmmeter to measure resistance
2. Disconnect control wires from fan relay
3. Measure resistance of fan relay coil and record ______ohms
4. Reconnect control wires to fan relay

H. Check resistance of primary and secondary windings of low voltage transformer

1. Set volt-ohmmeter to measure resistance
2. Disconnect secondary leads from transformer
3. Measure resistance of secondary windings of transformer and record ______ohms
4. Disconnect primary leads from transformer
5. Measure resistance of primary windings of transformer and record ______ohms
6. Measure resistance from each leg of primary winding to ground and record L_1 to ground______ohms; L_2 to ground______ohms
7. Reconnect secondary and primary leads of transformer
8. Question: Is secondary winding of the transformer shorted?__________ Open?__________
9. Question: Have all the circuit in the heating elements been checked?______
10. Are the heating elements safe to energize?______

JOB SHEET #7

I. Replace control box cover

J. Reconnect power source

K. Clean area and put tools away

HEAT PUMP SYSTEMS
UNIT IV

JOB SHEET #8--PERFORM MAINTENANCE ON HEAT PUMP SUPPLEMENTAL HEATING

I. Tools and equipment

A. Service technician's tool pouch

B. Thermometer and scratch awl

C. Shop rag

D. Ammeter-voltmeter

II. Procedure

A. Open main power switch

B. Remove control box cover

C. Service blower section

D. Energize heater strips and record fan motor amperage draw

E. De-energize strips and snap ammeter over wire power lug to main power source

F. Set thermostat to "heat" and energize second-stage thermostat

G. Energize outdoor thermostats

H. Re-energize strips and record amp draw of heaters as sequencers close heater circuits

Blower motor and heater #1

__________ amps

#2__________

#3__________

#4__________

I. Compare full load amps with strip heater nameplate rating

J. Determine if all of the elements are pulling the proper amperage

K. Drive scratch awl into return air plenum, insert thermometer, and record return air temperature______°

JOB SHEET #8

L. Select a place in the supply trunk which is out of the "line of sight" of the electric heater elements and drive scratch awl into supply trunk. Record supply air temperature______°

M. Record temperature rise through furnace______°

N. Remove thermometer and plug holes

O. De-energize outdoor thermostats

P. De-energize supplemental heat at disconnect

Q. Replace control box cover

R. Re-energize supplemental heat

S. Reset thermostat to proper setting

T. Clean area and put tools away

HEAT PUMP SYSTEMS
UNIT IV

JOB SHEET #9 TROUBLESHOOT A HEAT PUMP ON A "NO HEAT" COMPLAINT WHEN COMPRESSOR WILL NOT RUN

I. Tools and equipment

A. Service technician's tool pouch

B. Volt-ohm-ammeter

II. Procedure

A. Disconnect power supply

B. Set volt-ohmmeter to measure resistance

C. Check contactor; if it is open, continue

1. Check for malfunction at low voltage transformer

2. Check for malfunction in remote control center

3. Check to see if contactor coil is open or shorted

4. Check time delay devices for malfunction

5. Check for an open pressure switch in the liquid line

6. Check control circuit to see if it is open

7. Check charge in system, and record high pressure reading__________ and low pressure reading__________

D. Reconnect power supply and energize system

E. Check contactor; if it is closed, continue

1. Check for open power supply to compressor

2. Measure and record amp reading to see if compressor is stuck________

F. Disconnect power supply

G. Check for loose leads at the compressor

H. Check compressor windings to make sure they are not open, shorted, or grounded

I. Check to see if compressor overload is open

J. Obtain instructor's OK before reconnecting power supply

K. Clean area and put tools away

HEAT PUMP SYSTEMS
UNIT IV

JOB SHEET #10--TROUBLESHOOT A HEAT PUMP ON A "NO HEAT" COMPLAINT WHEN COMPRESSOR RUNS BUT CYCLES ON COMPRESSOR OVERLOAD

I. Tools and equipment

A. Service technician's tool pouch

B. Volt-ohm-ammeter

II. Procedure

A. Check for dirty filters

B. Check indoor coil to make sure it is free of dirt and debris

C. Check indoor fan; if it is cycling on overload, continue

1. Check for damage or malfuncton of reversing valve

(NOTE: Make sure reversing valve is not stuck in mid-position.)

2. Check for restriction in discharge line

3. Check system for overcharge and record high pressure ____________

4. Check system for undercharge and record low pressure ____________

5. Check for high or low line voltage and record high voltage __________ and low voltage __________

6. Check for malfunction in run capacitor

7. Check high load condition

8. Check high superheat control

E. Have instructor check your findings

F. Clean up area and put tools away

HEAT PUMP SYSTEMS
UNIT IV

JOB SHEET #11--TROUBLESHOOT A HEAT PUMP ON AN "INSUFFICIENT HEAT" COMPLAINT WHEN COMPRESSOR WILL RUN

I. Tools and equipment

A. Service technician's tool pouch

B. Volt-ohm-ammeter

II. Procedure

A. Check for low suction and low head; if both are present, continue

B. Check outdoor fan; if it is stopped; continue

1. Check for loose leads at fan motor
2. Check to see if internal fan motor overload is open
3. Check to see if fan motor is shorted, grounded, or open
4. Check to see if defrost relay contacts are open

C. Check outdoor fan, if it is running, continue

1. Check for stuck reversing valve
2. Check for restrictions in liquid line
3. Check for malfunction in outdoor metering device
4. Check for undercharged system and record high pressure ______ and low pressure ______
5. Check for dirty outdoor coil
6. Check strainer and make sure it isn't clogged

D. Check outdoor coil; if it is heavily frosted, continue

1. Check for malfunction in defrost control
2. Check to see if defrost thermostat is in poor physical contact with line
3. Check for malfunction in defrost relay or defrost timer
4. Check complete defrost circuit for any bad electrical connections

JOB SHEET #11

E. Check strip heaters; if they are not operating, continue

1. Set thermostat to energize second stage heating

2. Check for malfunction in outdoor thermostat

3. Determine if outdoor thermostat is set too low

4. Check for pinched capillary tube or bulb not sensing true outdoor temperature

F. Check for malfunction in strip heater relay or contactor

G. Check power circuit to heater elements and record high voltage___________ and low voltage_____________; if circuit to heater elements is open, continue

1. Check for blown fuse link

2. Check for a broken heater element

H. Check for an open in the over-temperature thermostat

I. Check for defective second stage room thermostat

J. Have instructor check your findings

K. Clean up area and return tools

HEAT PUMP SYSTEMS
UNIT IV

NAME ______________________

TEST

1. Match terms related to heat pump systems with their correct definitions.

_____a. Basically a refrigerated air conditioning system with two refrigerant coils and a valve to reverse the flow of refrigerant

_____b. A heat pump control valve used to switch from heating mode to cooling mode by reversing the compressor connections to the inside and outside coils

_____c. Refrigerant line that directs low pressure vapor from the evaporator coil to the compressor

_____d. A device used to transfer heat

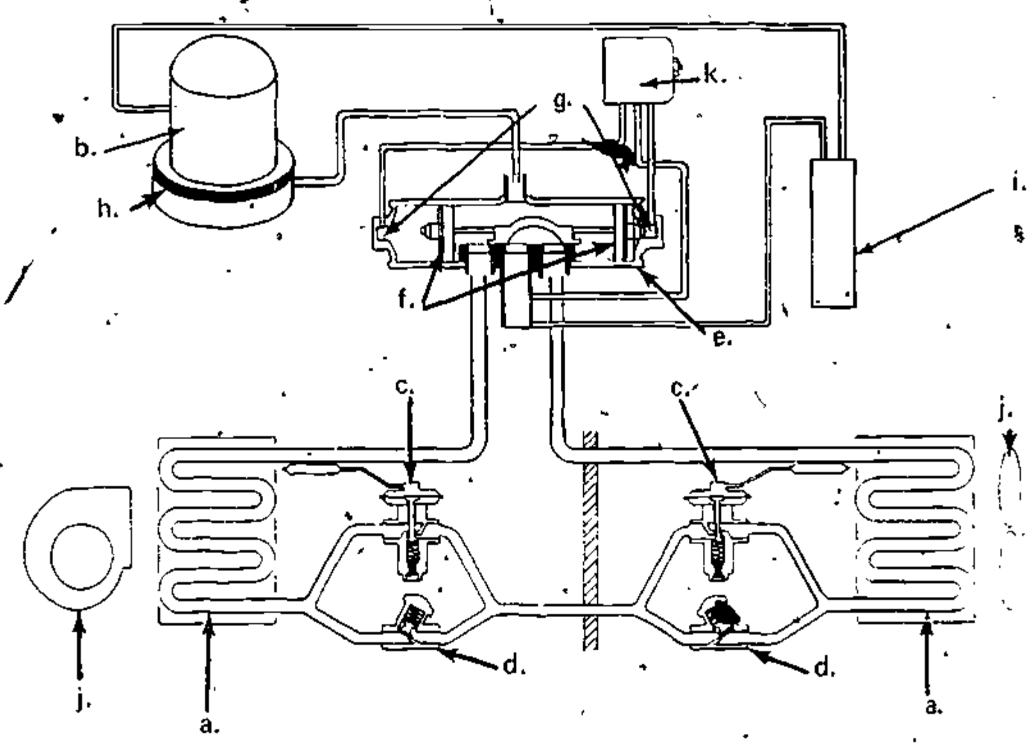
_____e. A relatively cool substance that can readily absorb heat

_____f. A heat exchanger which is buried in the ground and functions as either a condenser or evaporator

_____g. A heat exchanger which utilizes well, pond, or lake water as either a condenser or evaporator

1. Heat exchanger
2. Geothermal well
3. Heat pump
4. Heat sink
5. Suction line
6. Reversing valve
7. Ground coil

2. Identify the components of a heat pump.



a. ______________________

b. ______________________

c. ______________________

d. ______________________

e. ______________________

f. ______________________

g. ______________________

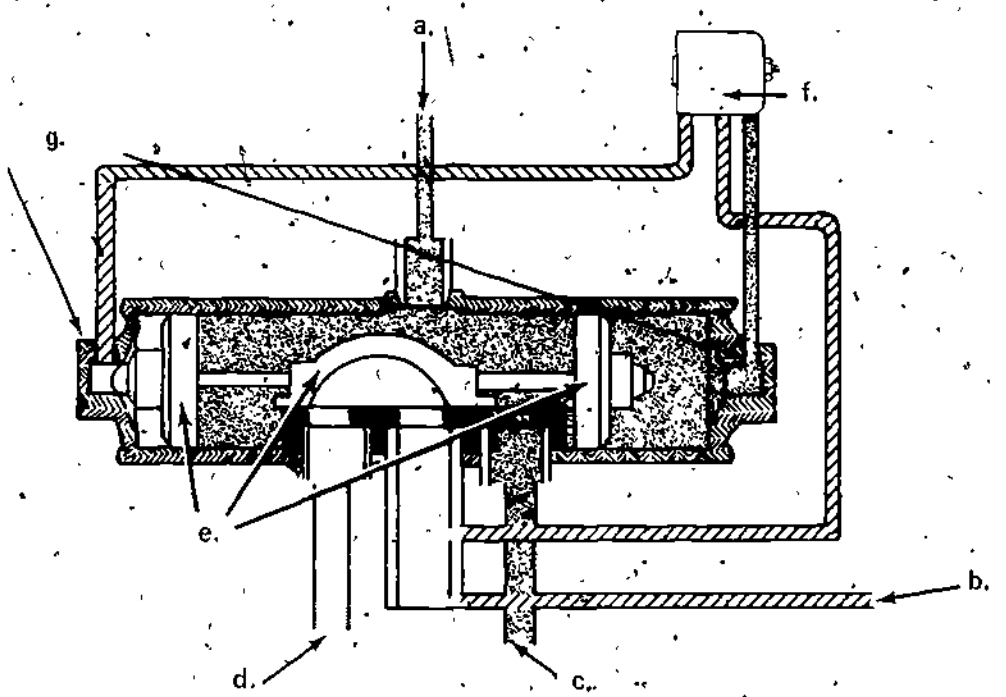
h. ______________________

i. ______________________

j. ______________________

k. ______________________

3. Identify the components of a 4-way reversing valve.



a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

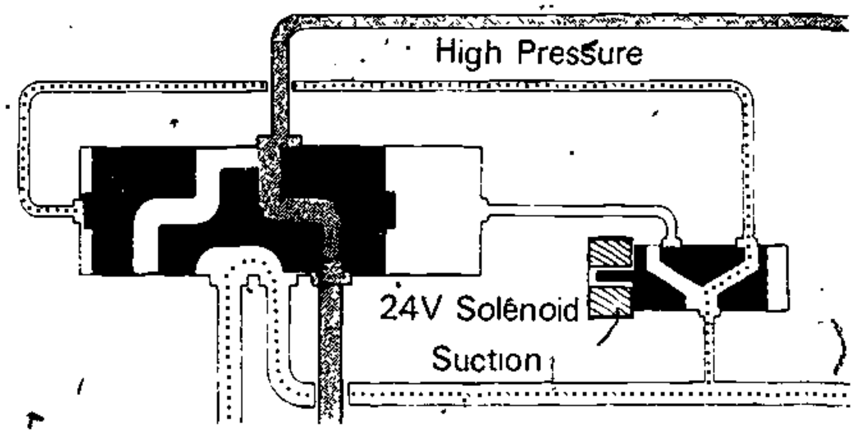
e. ______________________________

f. ______________________________

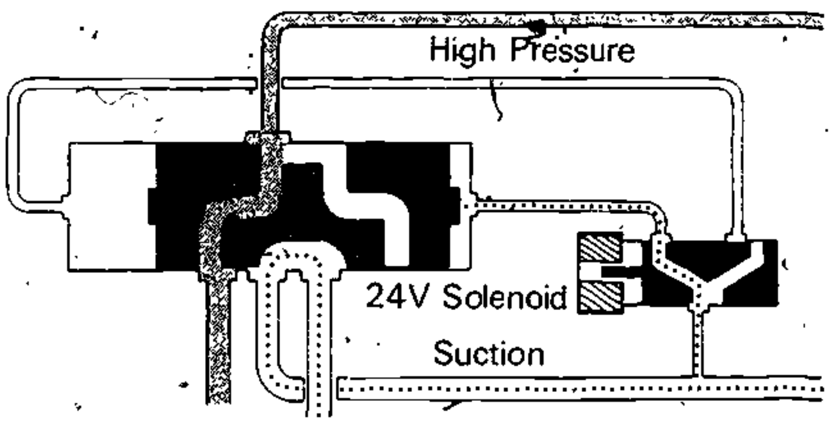
g. ______________________________

4. Differentiate between the operation of a 4-way reversing valve in the heating mode and cooling mode by placing an "X" beside the illustration of a 4-way reversing valve in the cooling mode.

_____ a.



_____ b.



5. Select true statements concerning the operation of a heat pump in the defrost mode by placing an "X" in the appropriate blanks.

_____a. The defrost cycle is initiated by preset time controls, preset temperature controls, or preset controls to measure pressure drop across the outside coil

_____b. The reversing valve reverses the heat pump from the heating to the cooling cycle on a preset schedule

_____c. Hot gas from the compressor discharge line is directed to the outside coil

_____d. Frost accumulation on the outside coil is removed

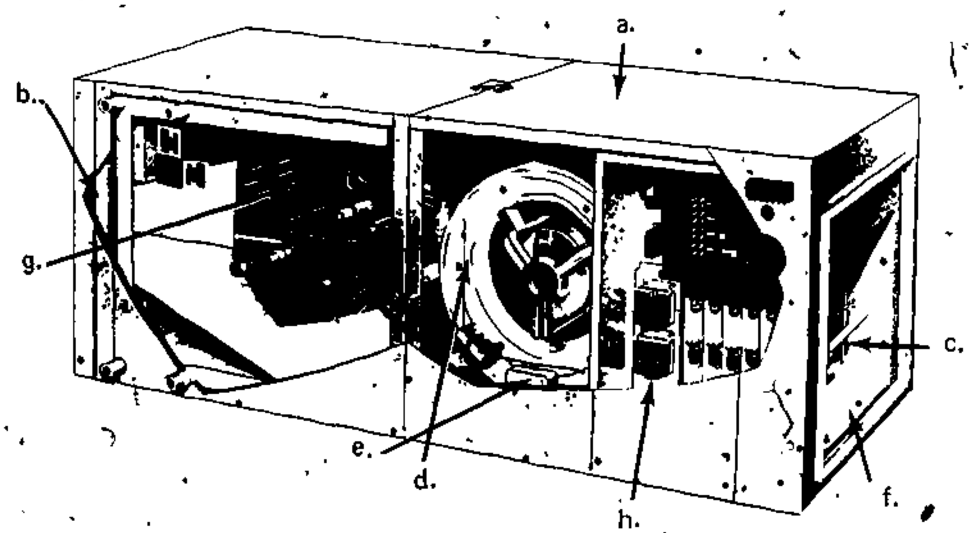
_____e. The outside blower is energized to speed frost removal

_____f. Supplementary heat systems are energized

_____g. After frost has been removed from the outside coil, the cycle is reversed

_____h. The defrost cycle is terminated by preset time controls, preset, temperature controls, or preset controls to measure pressure rise across the outside coil

6. Identify the components of a heat pump indoor section.



a. ____________________ e. ____________________

b. ____________________ f. ____________________

c. ____________________ g. ____________________

d. ____________________ h. ____________________

7. Complete the following chart to show the characteristics, advantages, and disadvantages of heat pump systems.

Type of System	Air to Air	Air to Water
Characteristics	Uses atmosphere to cool condenser or to absorb heat from evaporator	Uses the ground or a body of water to provide cooling or heat absorption
	Requires a blower to provide air movement across outdoor coil	Can use a geothermal well Requires no blower for outdoor coil
Advantages	______ ______	High efficiency because ground or water acts as a heat exchanger Can use recirculated water for cooling and solar collectors for additional heat Can be used to preheat hot water
Disadvantages	______ ______ ______ ______ ______ ______ ______ ______	Requires supplemental heating

8. Complete the following chart to show the differences between components of indoor sections of heat pumps and low side sections of air conditioners.

Component	Heat Pump	Air Conditioner
Blower Section	Driven by a 230-V motor	______
Metering Device	Always has a check valve and a bypass arrangement	______ ______
Thermostat	Controls one stage of cooling and two stages of heating, and may contain a manually operated emergency heat switch	______ ______ ______
Transformer	Located in outdoor section instead of in air handler and is 230 volts	______ ______

9. Complete a list showing common component failures of heat pumps in the cooling mode.

   a. Transformer

      1) ______________________________

      2) ______________________________

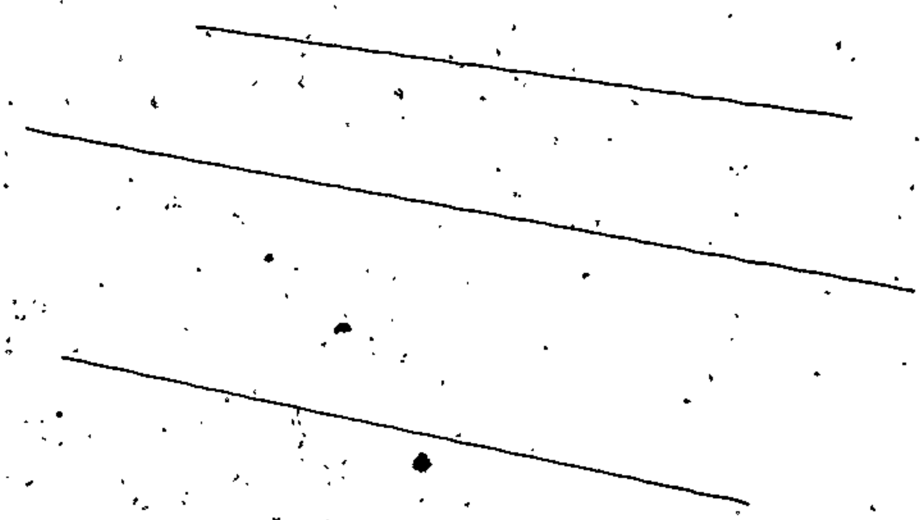
   b. Reversing valve

      1) ______________________________

      2) ______________________________

      3) ______________________________

10. Complete the following sketch of a duct section to show the proper installation of an electric strip heater.



11. Complete a list of special precautions for replacing reversing valves.

   a.

   b.

   c.

   d. Install a reversing valve in a location on the refrigerant line that will help keep vibration from the compressor at a minimum.

12. State two major rules for good heat pump operation.

    a.

    b.

13. Trace operational circuits for a heat pump in the cooling mode.

14. Trace operational circuits for first stage heating in a heat pump.

15. Trace operational circuits for a heat pump in the defrost mode.

16. Trace operational circuits for second stage supplementary heat in a heat pump

17. Demonstrate the ability to:

    a. Wire a control system for a heat pump.

    b. Troubleshoot a heat pump indoor section in the cooling mode.

    c. Perform maintenance on an indoor section of a heat pump in the cooling mode.

    d. Troubleshoot a heat pump on a "no cooling" complaint.

    e. Troubleshoot a heat pump outdoor section on an "insufficient cooling" complaint.

    f. Perform maintenance on an outdoor section of a heat pump in the cooling mode.

    g. Troubleshoot supplemental heat on a heat pump.

    h. Perform maintenance on heat pump supplemental heating.

    i. Troubleshoot a heat pump on a "no heat" complaint when compressor will not run.

    j. Troubleshoot a heat pump on a "no heat" complaint when compressor runs but cycles on compressor overload.

    k. Troubleshoot a heat pump on an "insufficient heat" complaint when compressor will run.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

HEAT PUMP SYSTEMS
UNIT IV

ANSWERS TO TEST

1. a. 3 e. 4
   b. 6 f. 7
   c. 5 g. 2
   d. 1

2. a. Indoor and outdoor refrigerant coils
   b. Compressor
   c. Indoor and outdoor metering devices
   d. Indoor and outdoor check valves
   e. 4-way reversing valve
   f. Piston
   g. Piston bleed ports
   h. Crankcase heater
   i. Accumulator
   j. Indoor and outdoor blowers
   k. Solenoid

3. a. Connection to discharge line of compressor
   b. Connection to suction line of compressor
   c. Connection to outside coil
   d. Connection to inside coil
   e. Piston
   f. Solenoid and activating device
   g. Piston bleed ports

4. a

5. a, b, c, d, f, g, h

6. a. Cabinet
   b. Filter and cold air inlet
   c. Heating elements of nichrome wire or tubular cased wire
   d. Blower assembly
   e. Blower and limit control switches
   f. Heat exchange chamber and warm air outlet
   g. Indoor coil
   h. Supplementary heat controls and sequencing relays

7.

Type of System	Air to Air	Air to Water
Characteristics	Uses atmosphere to cool condenser or to absorb heat from evaporator Requires a blower to provide air movement across outdoor coil	Uses the ground or a body of water to provide cooling or heat absorption Can use a geothermal well Requires no blower for outdoor coil
Advantages	Efficient in milder climates	High efficiency because ground or water acts as a heat exchanger Can use recirculated water for cooling and solar collectors for additional heat Can be used to preheat hot water
Disadvantages	Capacity and performance lowers as temperature drops Less efficient in cold climates Requires supplemental heating	Requires supplemental heating

8.

Component	Heat Pump	Air Conditioner
Blower Section	Driven by a 230-V motor	Driven by a 115-V motor
Metering Device	Always has a check valve and a bypass arrangement	Has no check valve or bypass
Thermostat	Controls one stage of cooling and two stages of heating, and may contain a manually operated emergency heat switch	Controls one stage of cooling and one stage of heating
Transformer	Located in outdoor section instead of in air-handler and is 230 volts	Located in the furnace and is 115 volts

9. a. 1) Blown fuse

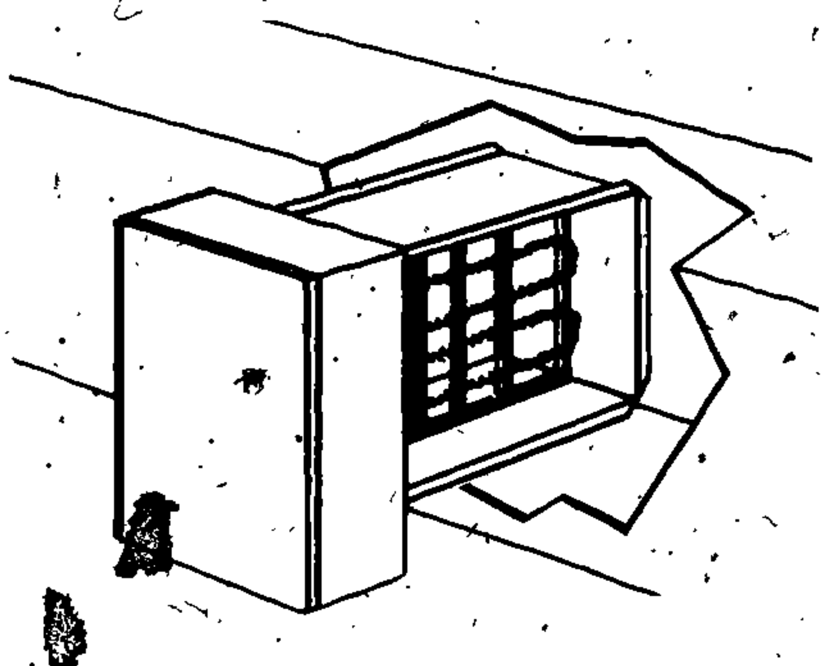
2) Burned out windings

b. 1) Leaking valves

2) Stuck piston

3) Burned out solenoid

10.



11. a. Never expose a reversing valve to excessive heat

    b. Keep the inside tubes of the valve and the system free of all foreign material

    c. Never strike a reversing valve with a hammer or any tool that could dent or bend any part of the valve

12. a. Filters, grilles, and coils must be kept clean to assure adequate air circulation

    b. The refrigerant charge for the system should always be at the proper pressures

13. Evaluated to the satisfaction of the instructor

14. Evaluated to the satisfaction of the instructor

15. Evaluated to the satisfaction of the instructor

16. Evaluated to the satisfaction of the instructor

17. Performance skills evaluated to the satisfaction of the instructor

BALANCE POINTS
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to determine the coefficient of performance of a heat pump and relate balance points to typical stages in heating continuity. The student should also be able to plot a heat pump performance curve, a heat loss line, and plot balance points for given design conditions. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to balance points with their correct definitions.
2. Distinguish between the COP of a direct electrical heating element and the COP of a heat pump.
3. Determine the COP of a heat pump at a given design temperature.
4. Select true statements concerning balance points and their relation to COP.
5. Match balance points with typical stages in heating continuity.
6. Complete a list of factors needed to plot balance points.
7. Plot a heat pump performance curve from manufacturer's specifications.
8. Plot balance point #1 from given design conditions.
9. Plot additional balance points from given design conditions.
10. Select true statements concerning the procedure for sizing a heat pump on the cooling load.
11. List two advantages of controlled heating stages.
12. Select true statements concerning installation considerations related to heat pump performance.
13. Size a heat pump on the cooling load.
14. Plot balance points for a heat pump at given design conditions.
15. Locate equipment to obtain maximum COP from a heat pump.

BALANCE POINTS
UNIT V

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparency.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Invite an electric utility representative to talk to the class concerning heat pump installations and a comparison of operatings costs for heat pumps and other systems.

VII. Invite the city (or an area) electrical inspector to talk to the class concerning codes that affect heat pump installations.

VIII. Invite a local or area contractor who makes heat pump installations to discuss typical systems and balance points that are used in the area, and especially any variations in heat staging continuity.

IX. Invite a manufacturer's representative to demonstrate to the class how indoor and outdoor sections of heat pumps are matched, and how outdoor design conditions affect equipment selection, particularly supplementary heating.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency Master 1--Typical Balance Points

D. Assignment sheets

1. Assignment Sheet #1--Size a Heat Pump on the Cooling Load

2. Assignment Sheet #2--Plot Balance Points for a Heat Pump at Given Design Conditions

3. Assignment Sheet #3--Locate Equipment to Obtain Maximum COP From a Heat Pump

E. Answers to assignment sheets

F. Test

G. Answers to test

II. References:

A. Harris, Norman C., and David F. Conde. *Modern Air Conditioning Practice, Second Edition*. New York: McGraw-Hill Book Company, 1974.

B. *Heat Pump Design, Service and Application*. Dallas, TX 75240: Lennox Industries Inc., Education Department, 1979.

BALANCE POINTS
UNIT V

INFORMATION SHEET

I. Terms and definitions

A. Balance point--The point, expressed in °F, where the heat pump capacity is equal to or balanced with the heat loss of the structure

B. Additional balance points--Points beyond the initial balance point which indicate the most advantageous temperatures for energizing supplementary heating

C. Balance point number--A system of identifying the initial balance point as balance point #1, and additional balance points as balance point #2, balance point #3, etc.

D. Supplementary heating--Electrical heating strips programmed to energize in stages to compensate for reduced heat pump capacity as temperature drops

E. Critical unbalance--The point at any °F where heat pump output will not equal or balance with the heat loss of the structure

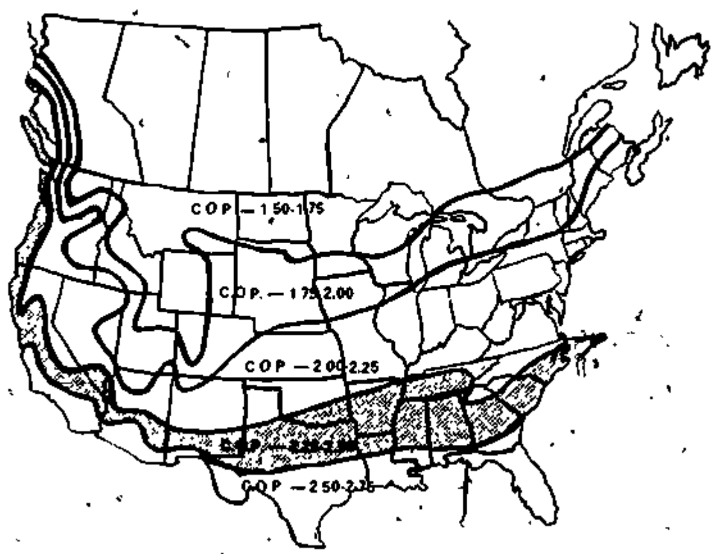
F. COP--Coefficient of performance, the ratio of heat output to heat input

II. Comparison of direct electrical heating elements and heat pumps

A. Ordinary direct heating elements have a COP of 1.0

B. The COP of a heat pump is always greater than 1.0 (Figure 1)

FIGURE 1



(Courtesy of Lennox Industries Inc., Dallas, Texas)

INFORMATION SHEET

III. How to determine the COP of a heat pump

A. COP = Btuh output divided by Btuh input

Example: $COP = \frac{\text{Btuh output (useable heat)}}{\text{Btuh input (heat paid for)}}$

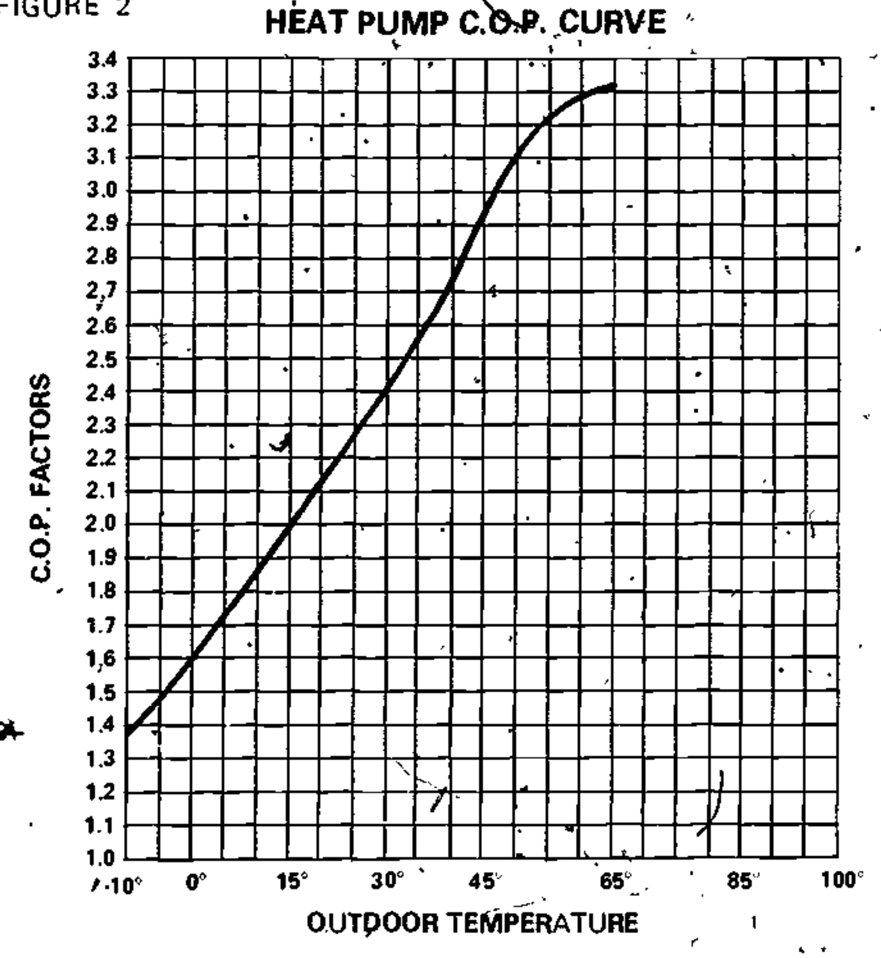
B. When unit input is given in watts, the conversion factor of 3.413 should be used to convert watts to Btuh

Example: $COP = \frac{\text{Btuh output}}{\text{Unit wattage} \times 3.413}$

Using the formula, a unit with a 4,380 watt input and a 39,000 Btuh output would have a COP of 2.6 because 4,380 x 3.413 = 14,948 Btuh, or rounded off, 14,950 Btuh, and 39,000 divided by 14,950 = 2.6

C. COP has a direct relation to outdoor temperature, and COP will decline as outdoor temperature drops (Figure 2)

FIGURE 2



(Courtesy of Lennox Industries Inc., Dallas, Texas)

INFORMATION SHEET

IV. Balance points and their relation to COP

A. When the COP of a heat pump drops, balance points maintain economical heating continuity in a conditioned space

B. Balance points postpone the point of critical unbalance and promote maximum COP

(NOTE: At the point of critical unbalance, the compressor shuts down and all heat comes from supplemental units; for a heat pump to be practical, critical unbalance should be no more than 5 to 10 percent of the total operating hours for the heat pump.)

C. Balance points determine equipment sizing and the amount of supplemental heat required

V. Balance points and typical stages in heating continuity (Transparency 1)

A. Balance point #1--When outdoor temperature falls below this point, an indoor thermostat calls for second-stage heat and the first two heating elements will energize

B. Balance point #2--When outdoor temperature continues to fall, an outdoor thermostat calls for third-stage heat and a third heating element is energized

C. Balance point #3--When outdoor temperature continues to fall even more, a second outdoor thermostat calls for fourth-stage heat and a fourth heating element is energized

(NOTE: This staging process is typical of balance points and heating continuity, but there are many variations depending on equipment, outdoor design temperature, and manufacturer's specifications.)

VI. Factors needed to plot balance points

A. Performance curve based on Btuh of the heat pump

B. Heat loss calculation for the structure

C. Outside design temperature

D. Inside design temperature

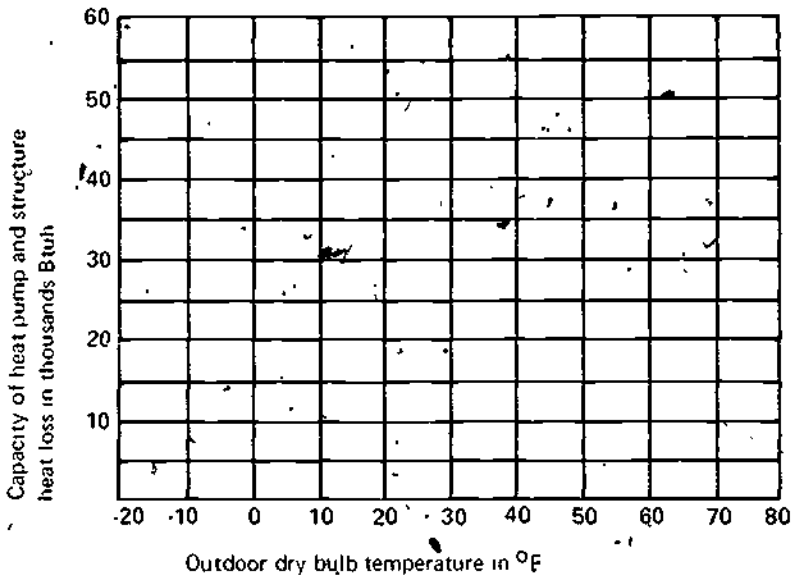
VII. Steps in plotting a heat pump performance curve

A. Prepare a graph with capacity of heat pump and structure heat loss shown in thousands Btuh on the vertical axis; work with units of 5,000 Btuh starting with zero at the bottom

INFORMATION SHEET

B. Complete the graph with outdoor dry bulb temperature ranging from -20°F to 80°F shown in units of 10 on the horizontal axis from left to right

Example:

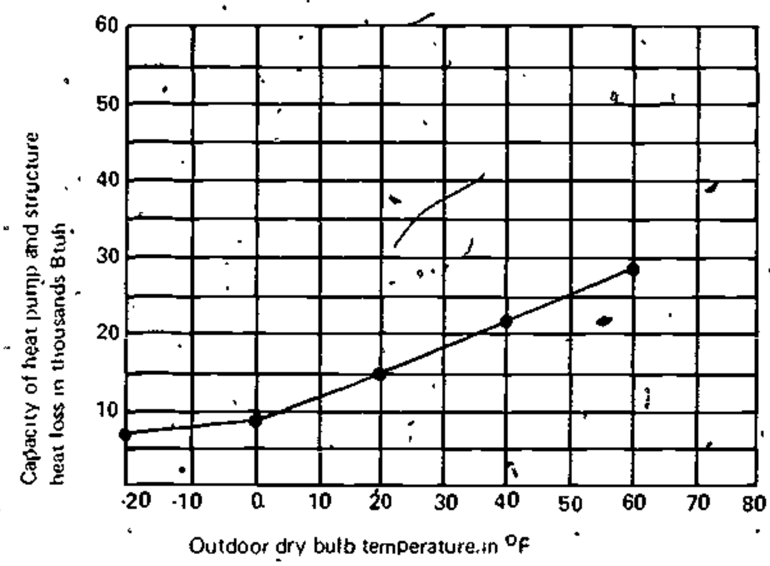


C. From available manufacturer's specifications, transfer total Btuh output to the proper points on the chart and connect the points to show the performance curve

Example:

Outdoor Temperature (Degree F)	Compressor Motor Watts Input	Total Output (Btuh)
65	2730	32,200
60	2540	29,900
55	2345	27,900
50	2180	25,700
45	2000	23,500
40	1900	21,200
35	1790	19,600
30	1705	18,300
25	1635	16,500
20	1555	15,000
15	1500	13,600
10	1430	11,900
5	1375	10,500
0	1310	9,100
-5	1250	7,800
-10	1195	6,700
-15	1130	6,100
-20	1060	5,700

INFORMATION SHEET



VIII. Steps in plotting balance point #1

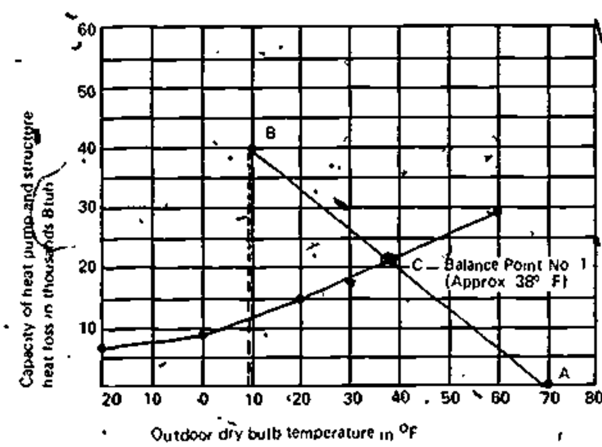
A. On a graph showing the heat pump performance curve, locate the indoor design temperature of 70° on the horizontal axis and mark it point A

B. Assume an outdoor design temperature of 10°F and a structure heat loss of 40,000 Btuh; sketch a vertical dotted line up from the 10°F point until it intersects the 40,000 Btuh line and mark it point B

C. Draw a solid diagonal line connecting points A and B

D. Balance point #1 is located at the point where the performance line and the heat loss line intersect; mark it point C

Example:



INFORMATION SHEET

IX. Steps in plotting additional balance points

A. Assume the indoor thermostat at balance point #1 energizes two 2-kw strip heaters

B. Draw a dotted vertical line up from the 38°F point until it goes to a point that represents 13,600 Btuh, and mark this as point D

(NOTE: Remember the conversion factor, 1 kw = approximately 3,400 Btuh, so 4 kw = 13,600 Btuh.)

C. Draw a straight line from point D so that it runs parallel to the heat pump performance line and intersects the heat loss line, and mark this point E

D. Point E gives the temperature where balance point #2 should be

E. Assume the outdoor thermostat at balance point #2 energized another 2-kw strip heater

F. Draw a dotted vertical line up from the 27°F point until it goes to a point that represents 6,800 Btuh, and mark this point F

G. Draw a straight line from point F so that it runs parallel to the heat pump performance line and intersects the heat loss line, and mark this point G

H. Point G gives the temperature where balance point #3 should be

I. Assume the outdoor thermostat at balance point #3 energizes another 2-kw strip heater

J. Draw a dotted vertical line up from the 21°F point until it goes to a point that represents 6,800 Btuh, and mark this point H

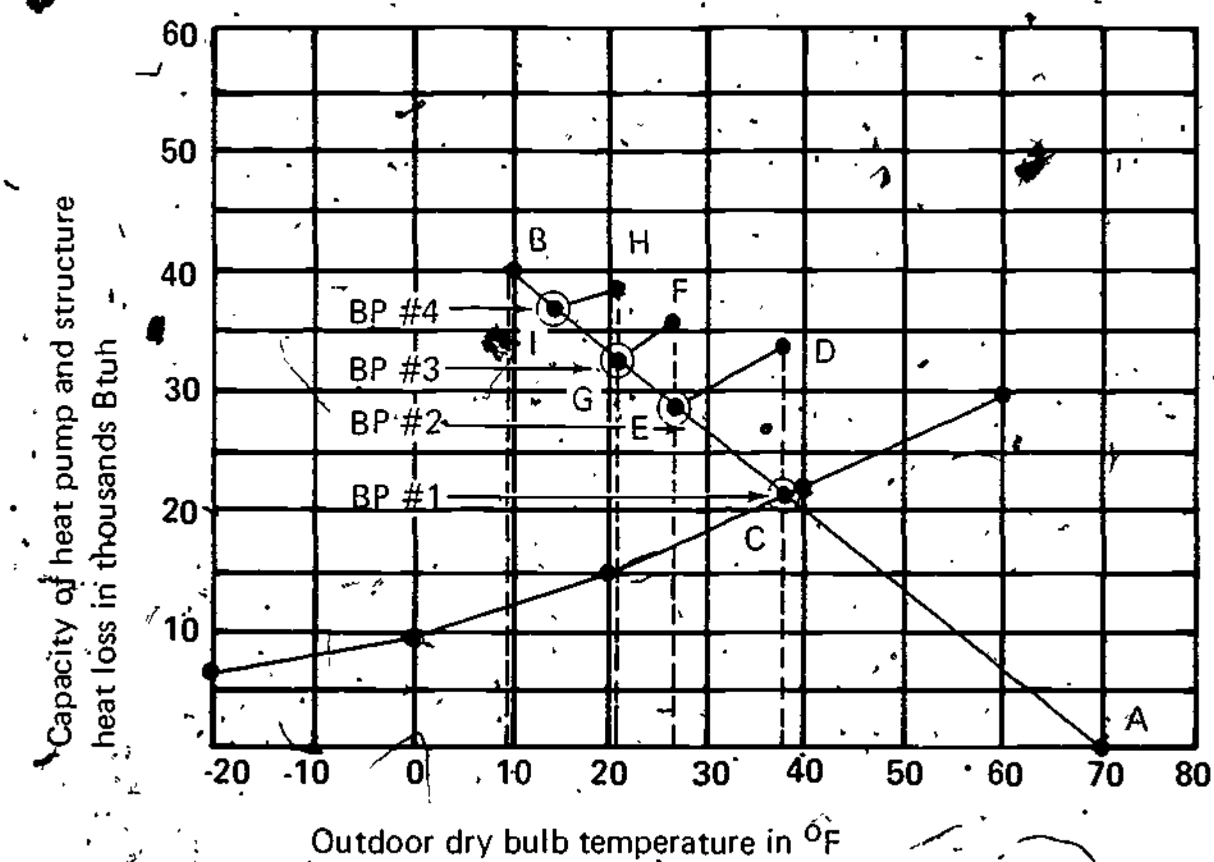
K. Draw a straight line from point H so that it runs parallel to the heat pump performance line and intersects the heat loss line, and mark this point I

L. Point I gives the temperature where balance point #4 should be

(NOTE: By following this procedure, additional balance points can be plotted as design conditions require.)

INFORMATION SHEET

Example:



X. Procedure for sizing a heat pump on the cooling load

A. Determine heat gain and calculate cooling load

(NOTE: In design conditions where the COP average of the heat pump is 2.25 or higher, the unit can usually be sized on the cooling load and provide a compatible match with the heat load.)

B. Select a system that has a Btuh cooling capacity equal to or slightly beyond the cooling load, but never select a system with a Btuh cooling capacity below the estimated cooling load

INFORMATION SHEET

C. Use the nominal cfm rating of the unit as the air quantity for duct sizing

Example: If the cooling load is 33,800 Btuh, select a 3-ton unit 12,000 Btuh per ton or 36,000 total Btuh; with a summer outdoor design temperature of 95°F and an entering wet bulb temperature of 67°F, 35,000 Btuh will easily handle the 33,800 Btuh cooling load requirement and provide the required 450 cfm/ton air quantity requirement for the 3-ton unit which would be a total of 1,350 cfm

TYPICAL 3-TON SPLIT SYSTEM

TEMP (F) AIR ENT OUTDOOR Unit	AIR ENT INDOOR UNIT CFM								
	1200			1350			1500		
	INDOOR UNIT ENT AIR TEMP Ewb (F)								
	72	67	62	72	67	62	72	67	62
85	36	33	30	41	37	34	43	39	35
95	34	31	29	38	35	32	39	36	33
100	33	30	29	37	34	31	38	35	32

D. Plot heat pump performance curve on a graph

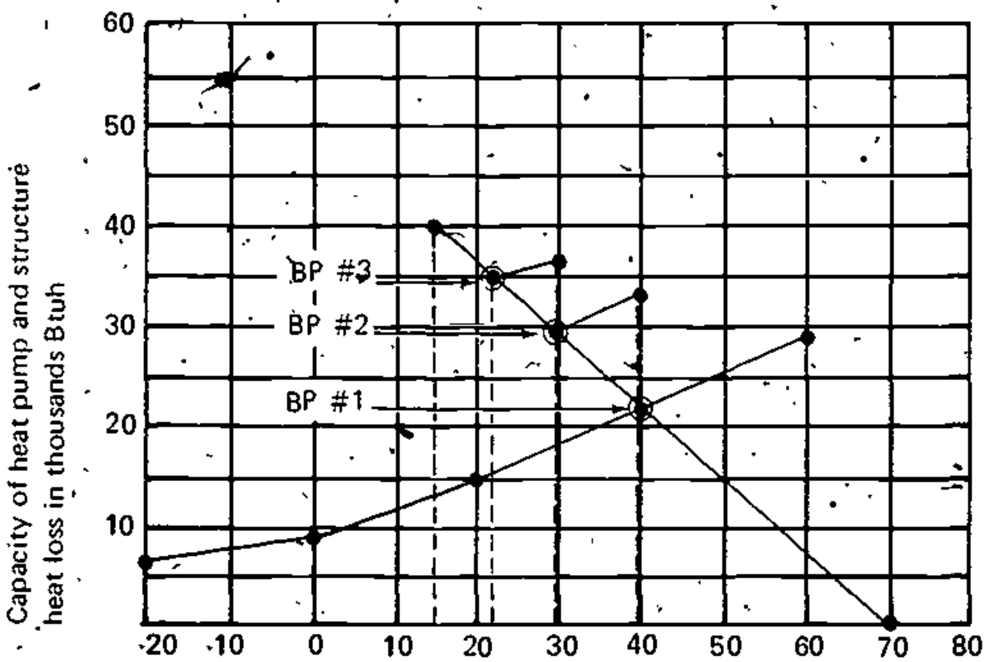
E. Determine structure heat loss and plot it on the graph in relation to design conditions

F. Establish balance point #1

G. Establish additional balance points as required

Example: Assume an inside design temperature of 70°F, an outside temperature of 15°F, and a structure heat loss of 40,000 Btuh; supplemental heating requirements can be determined by following the procedure outlined in Objective IX

INFORMATION SHEET



Plotting balance points indicates a need for 8-kw of supplementary heat; 4-kw would be energized in the first two heating stages by the indoor thermostat at BP #1, 2-kw would be energized by the first outdoor thermostat at BP #2, and the final 2-kw would be energized by the second outdoor thermostat at BP #3, and the unit is well balanced for both heating and cooling

XI. Important advantages of controlled heating stages

A. They meet most power company specifications that require large, instantaneous load increases to be minimized

B. They eliminate shorter fan cycles and stratification

C. They provide the homeowner with a built-in warning system in the event of compressor failure

(NOTE: In mild weather the outdoor thermostats prevent staged heating from coming on, so a compressor failure would cause the house to get cold, but if all supplemental heat is on and the compressor fails, a homeowner might not realize that all heat is coming from heating units unless there is a warning circuit to warn of compressor failure.)

INFORMATION SHEET

XII. Installation considerations related to heat pump performance

A. When prevailing winds are from the west or north, the outside unit should be placed on the south or east side of the home

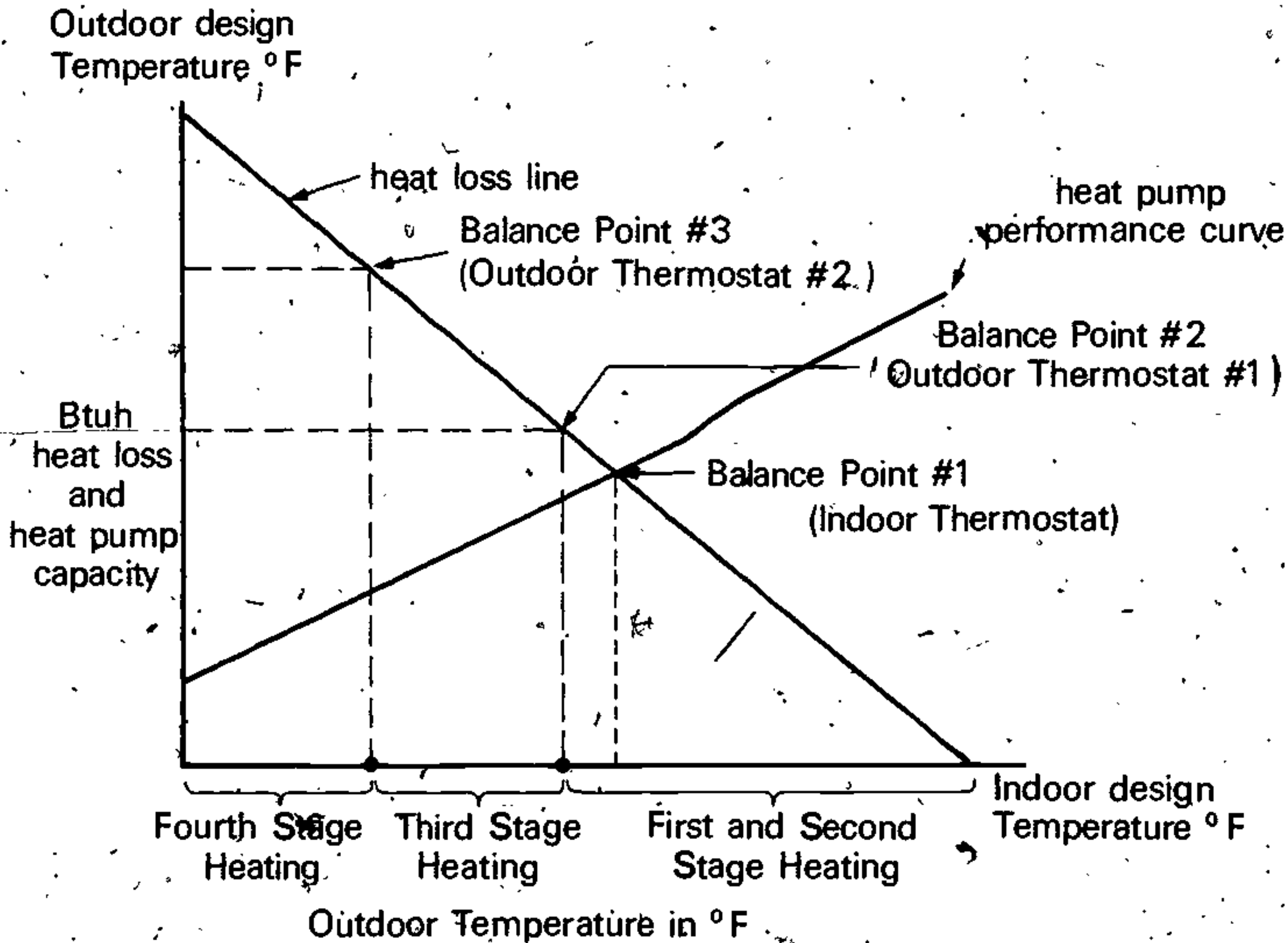
(NOTE: This minimizes wind through the unit during the defrost cycle and helps reduce ice buildup on the slab beneath the coil.)

B. When equipment is placed on a roof, a windshield should be placed so that it will help keep air from blowing directly on the outdoor coil

C. Both indoor and outdoor units should be located so there is ample room for service, and all sides of the outdoor unit should be accessible

D. Operating voltage should not be less than 10% of nameplate rating

Typical Balance Points



BALANCE POINTS
UNIT V

ASSIGNMENT SHEET #1--SIZE A HEAT PUMP ON THE COOLING LOAD

Directions. Assume that the cooling load for a residence has been calculated at 32,500 Btuh with a summer outdoor design temperature of 95°F and an entering wet bulb temperature of 62°F. Assume also that the air quantity requirements are 450 cfm/ton. Using the table in Figure 1, answer the following questions:

A. What size unit should be selected? ______________________

B. What is the Btuh rating of the unit? ______________________

C. From what factor can the air quantity for duct sizing be determined?

____

FIGURE 1

TEMP (F) AIR ENT OUTDOOR Unit	AIR ENT INDOOR UNIT CFM								
	1200			1350			1500		
	INDOOR UNIT ENT AIR TEMP-Ewb (F)								
	72	67	62	72	67	62	72	67	62
85	36	33	30	41	37	34	43	39	35
95	34	31	29	38	35	32	39	36	33
100	33	30	29	37	34	31	38	35	32

BALANCE POINTS
UNIT V

ASSIGNMENT SHEET #2--PLOT BALANCE POINTS FOR A HEAT PUMP AT GIVEN DESIGN CONDITIONS

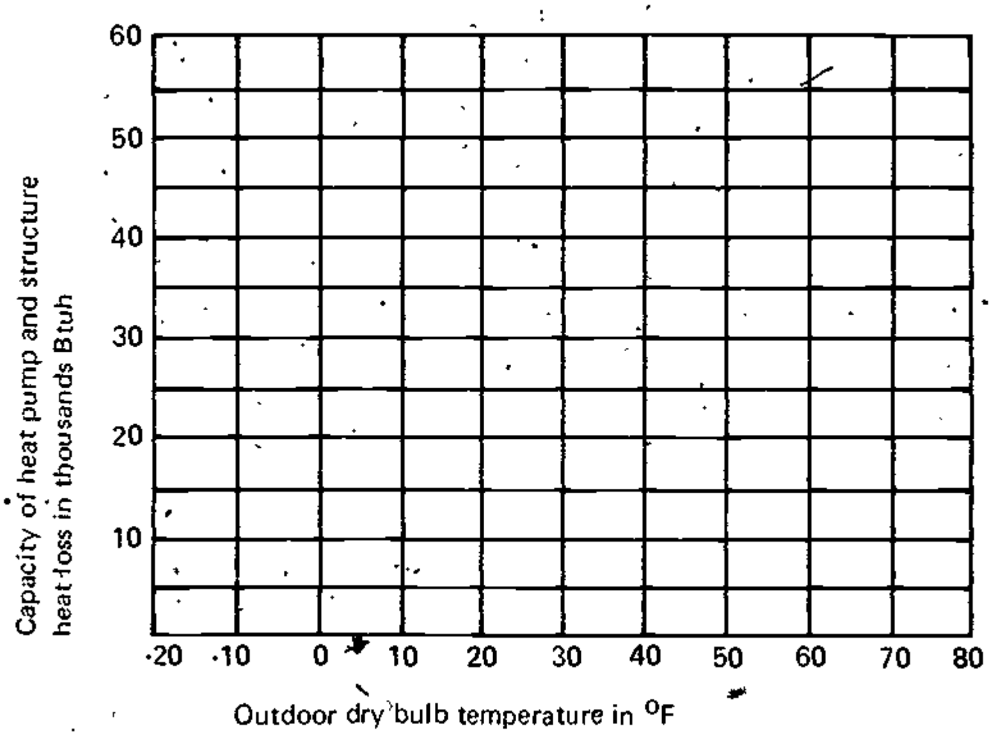
Directions: Using the graph below, plot a heat pump performance curve, heat loss line, and all balance points for the following design conditions: Structure heat loss, 35,000 Btuh; indoor design temperature, 70°F; outdoor design temperature, 15°F. Use the manufacturer's specifications in the example in item C, Objective VII to plot the heat pump performance curve. Assume the indoor thermostat energizes two 2-kw strip heaters and that all outdoor thermostats energize single 2-kw strip heaters. After balance points are plotted, answer the following questions:

A. What is the approximate °F at balance point #1? ____________

B. What is the approximate °F at balance point #2? ____________

C. What is the approximate °F at balance point #3? ____________

D. Will there be a need for a balance point #4? ____________



BALANCE POINTS
UNIT V

ASSIGNMENT SHEET #3--LOCATE EQUIPMENT TO OBTAIN MAXIMUM COP FROM A HEAT PUMP

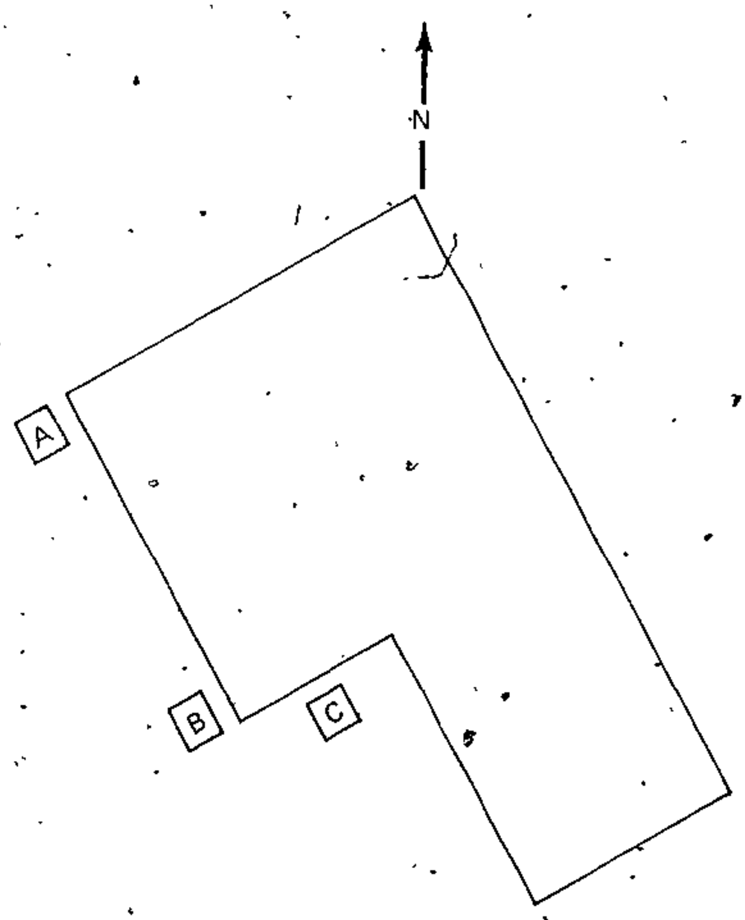
Directions: Assume the residence in the following plot-plan is in an area where the prevailing winds are from the northwest. Answer the following questions:

A. Of the points A, B, and C, which is the best place to locate the outdoor unit of the heat pump to obtain maximum COP from the unit?

____

B. If the outdoor unit had to be installed on the roof, what should be done to help obtain maximum COP from the outdoor unit?

____



BALANCE POINTS
UNIT V

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

a. 3-ton

b. 36,000 Btuh

c. The cfm rating of the air quantity for the unit

Assignment Sheet #2
(Answers to a, b, and c should be within 2°F of those shown)

a. 38°F

b. 26°F

c. 19°F

d. No

Assignment Sheet #3

a. C

b. A windshield should be placed so that it will help keep air from blowing directly on the outdoor coil

BALANCE POINTS
UNIT V

NAME ____________________

TEST

1. Match the terms on the right with their correct definitions.

____ a. The point, expressed in °F, where the heat pump capacity is equal to or balanced with the heat loss of the structure

____ b. Points beyond the initial balance point which indicate the most advantageous temperatures for energizing supplementary heating

____ c. A system of identifying the initial balance point as balance point #1, and additional balance points as balance point #2, balance point #3, etc.

____ d. Electrical heating strips programmed to energize in stages to compensate for reduced heat pump capacity as temperature drops

____ e. The point at any °F where heat pump output will not equal or balance with the heat loss of the structure

____ f. Coefficient of performance, the ratio of heat output to heat input

1. Balance point number
2. COP
3. Critical unbalance
4. Balance point
5. Supplementary heating
6. Additional balance points

2. Distinguish between the COP of a direct electrical heating element and the COP of a heat pump by placing an "X" in the blank that indicates the COP of a heat pump.

____ a. These heating devices have a COP of 1.0

____ b. These heating devices have a COP that is always greater than 1.0

3. Determine the COP of a heat pump that has a 4,400 watt input and a 40,000 Btuh output.

COP = ____________

4. Select true statements concerning balance points and their relation to COP by placing an "X" in the appropriate blanks.

_____ a. When the COP of a heat pump drops, balance points maintain economical heating continuity in a conditioned spece

_____ b. Balance points postpone the point of critical unbalance and promote maximum COP

_____ c. Balance points do not affect equipment sizing and the amount of supplemental heat required

5. Match balance points with typical stages in heating continuity.

_____ a. When outdoor temperature falls below this point, an indoor thermostat calls for second-stage heat and the first two heating elements will energize

_____ b. When outdoor temperature continues to fall, an outdoor thermostat calls for third-stage heat and a third heating element is energized

_____ c. When outdoor temperature continues to fall even more, a second outdoor thermostat calls for fourth-stage heat and a fourth heating element is energized

1. Balance point #2
2. Balance point #3
3. Balance point #1

6. Complete a list of factors needed to plot balance points.

a.

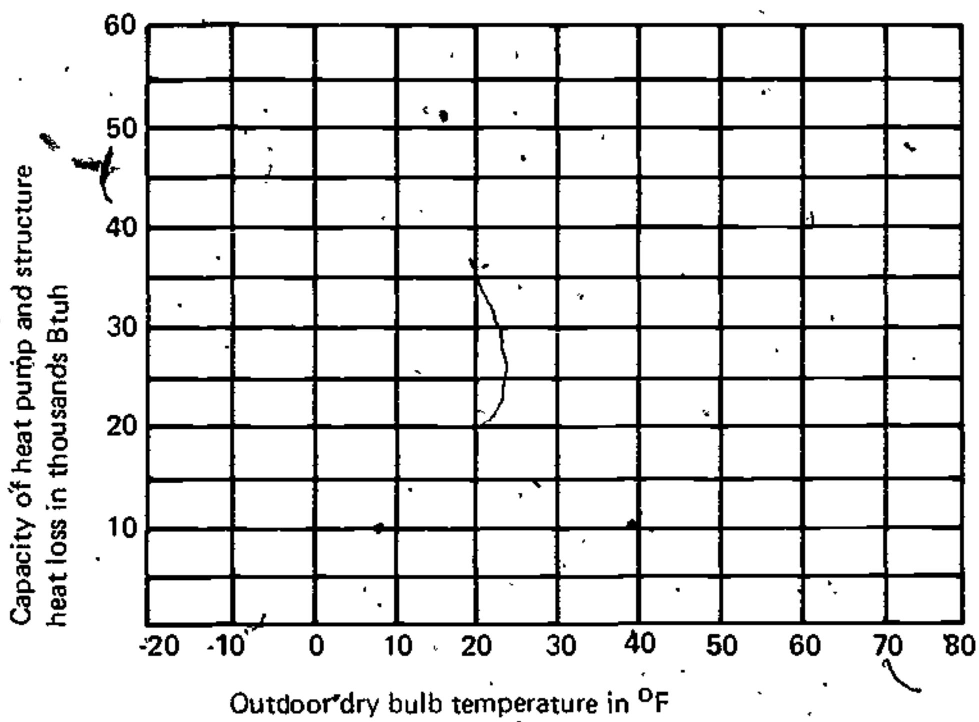
b. Heat loss calculation of the structure

c.

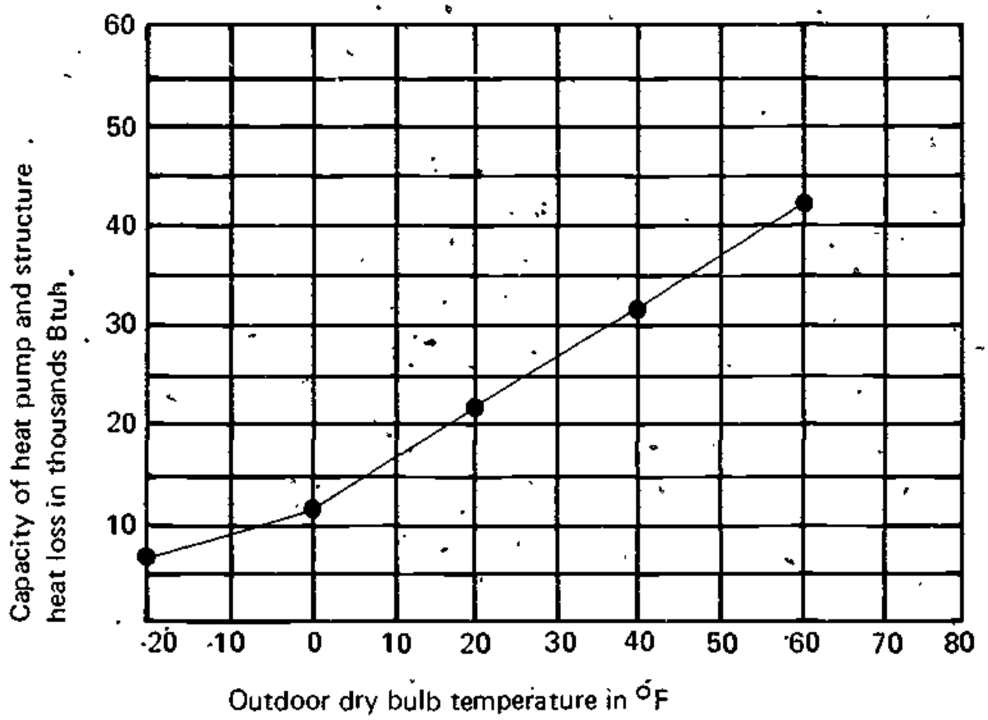
d. Inside design temperature

7. Plot a heat pump performance curve on the graph below using the following manufacturer's specifications.

Outdoor Temperature (Degree F)	Total Output (Btuh)
65	44,600
60	42,000
55	39,100
50	36,500
45	33,900
40	31,600
35	29,100
30	26,700
25	24,100
20	21,500
15	19,500
10	16,900
5	14,900
0	12,300
-5	10,300
-10	8800
-15	7500
-20	6200



8. Plot balance point #1 using the heat pump performance curve shown below and an indoor design temperature of 70°F; outside design temperature of 10°F; and a structure heat loss of 45,000 Btuh.



9. Plot additional balance points for the design conditions given in question 8, assuming that the indoor thermostat at balance point #1 energizes 4-kw of supplemental heating and all outside thermostats energize 2-kw strip heaters.

(NOTE: Use the graph in question 8 to complete this test item, use broken lines to indicate your plotting, and circle and label all balance points.)

10. Select true statements concerning the procedure for sizing a heat pump on the cooling load by placing an "X" in the appropriate blanks.

_____a. Determine heat gain and calculate cooling load

_____b. Select a system that has a Btuh cooling capacity equal to or slightly below the cooling load, but never select a system with a Btuh cooling capacity above the estimated cooling load

_____c. Using the nominal cfm rating of the unit as the air quantity for duct sizing

_____d. Plot heat pump performance curve on a graph

_____e. Determine structure heat loss and plot it on the graph in relation to design conditions

_____f. Establish balance point #1

_____g. Establish additional balance points as required

11. List two advantages of controlled heating stages.

a.

b.

12. Select true statements concerning installation considerations related to heat pump performance by placing an "X" in the appropriate blanks.

_____a. When prevailing winds are from the west or north, the outside unit should be placed on the south or east side of the home

_____b. When equipment is placed on a roof, a windshield should be placed so that it will help keep air from blowing directly on the outdoor coil

_____c. Both indoor and outdoor units should be located so there is ample room for service, and all sides of the outdoor unit should be accessible

_____d. Operating voltage should not be less than 10% of nameplate rating

13. Size a heat pump on the cooling load.

14. Plot balance points for a heat pump at given design conditions.

15. Locate equipment to obtain maximum COP from a heat pump.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

BALANCE POINTS
UNIT V

ANSWERS TO TEST

1. a. 4 d. 5
   b. 6 e. 3
   c. 1 f. 2

2. b

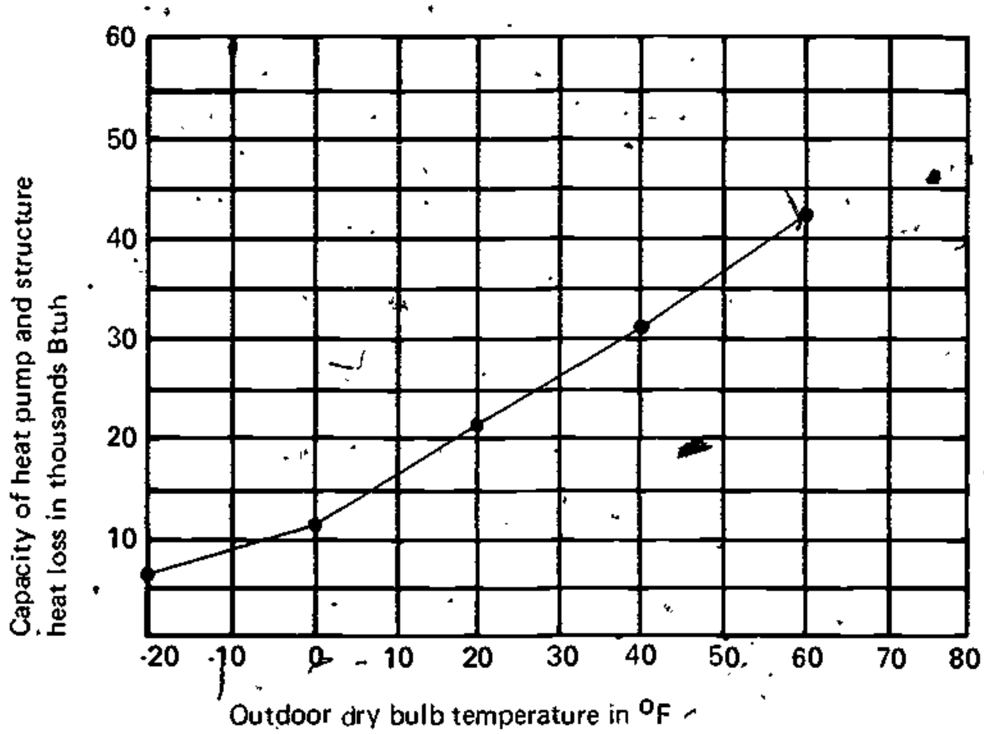
3. 3.1

4. a, b

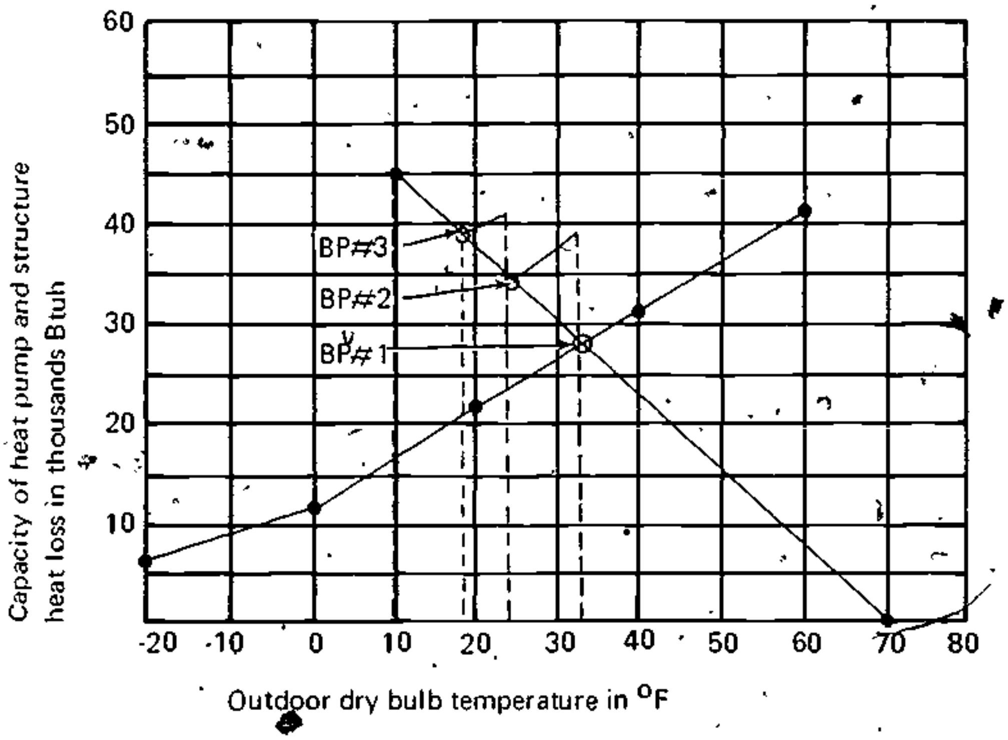
5. a. 3
   b. 1
   c. 2

6. a. Performance curve based on Btuh of the heat pump
   c. Outside design temperature

7.



8.



9. Answers are incorporated in the graph in answer 8

10. a, c, d, e, f, g

11. Any two of the following:

   a. They meet most power company specifications that require large, instantaneous load increases to be minimized

   b. They eliminate shorter fan cycles and stratification

   c. They provide the homeowner with a built-in warning system in the event of compressor failure

12. a, b, c, d

13. Evaluated to the satisfaction of the instructor

14. Evaluated to the satisfaction of the instructor

15. Evaluated to the satisfaction of the instructor

HYDRONICS
UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to classify hydronic systems in relation to design water temperature and design water flow rates. The student should also be able to select boilers, expansion tanks, and pumps suitable to specific systems, and lay out a series loop single circuit hydronic system. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to hydronics with their correct definitions.
2. Distinguish between basic types of hydronic systems.
3. Match classifications of hydronic systems with their water temperature - pressure characteristics.
4. Identify types of common hydronic system designs.
5. Match common hydronic system designs with their advantages and disadvantages.
6. Select true statements about design water temperature.
7. Match terminal units with their design water temperature drop.
8. Solve a problem involving design water flow rates through circuits.
9. Match minimum flow rates through terminal units with their tubing sizes.
10. Select true statements concerning placement of terminal units.
11. Match terminal units with their characteristics and uses.
12. Complete a list of steps in the selection and sizing of terminal units.
13. Select true statements concerning fuels, ratings, and selection of boilers.
14. Distinguish between advantages and disadvantages of types of residential expansion tanks.
15. Select true statements concerning steps in the selection of residential expansion tanks.
16. Select true statements concerning the types, designs, and sizing of residential pumps.

17. Complete a list of factors in the selection of residential pumps.
18. Arrange in order the steps in selection of residential pumps.
19. Complete a list of factors affecting pipe sizing.
20. Select true statements concerning the procedure for selection of pipe sizes.
21. Match types of hydronic specialties with their characteristics and uses.
22. Select true statements concerning steps in designing a hydronic system.
23. Lay out a series loop single circuit hydronic system with boiler located under floor of dining room.
24. Select boiler and expansion tank.
25. Make a trial selection of pump and select pipe size for series loop system.

HYDRONICS
UNIT VI

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Review all assignment sheets and modify as needed to reflect available systems and local practices; Assignment Sheet #2 requires materials to be supplied by the instructor, and materials for the other assignment sheets may be supplied as needed to benefit the intent of the assignment.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Common Types of Hydronic System Design
2. TM 2--Common Types of Hydronic System Design (Continued)
3. TM 3--Common Types of Hydronic System Design (Continued)
4. TM 4--Common Types of Hydronic System Design (Continued)
5. TM 5--Types of Cast Iron Radiators and Heat Emission Rates
6. TM 6--Ratings of Small Tube Radiators-Square Feet
7. TM 7--Basic Classes of "Residential" Baseboard Terminal Units
8. TM 8--Compression Tank Capacity
9. TM 9--Water Content of Hot Water System
10. TM 10--Cutaway View of Diaphragm Air Cushion Tank
11. TM 11--Pipe Sizing-Head Pressure Table

D. Assignment sheets

1. Assignment Sheet #1--Lay Out a Series Loop Single Circuit Hydronic System with Boiler Located Under Floor of Dining Room

2. Assignment Sheet #2--Select Boiler and Expansion Tank

3. Assignment Sheet #3--Make a Trial Selection of Pump and Select Pipe Size for Series Loop System

E. Answers to assignment sheets

F. Test

G. Answers to test

II. References:

A. Harris, W. S. *Modern Hydronic Heating.* NHAW Home Study Institute.

B. *Pump and System Curve Data for Centrifugal Pump Selection and Application, Bulletin No. TEH 375.* Bell & Gossett Division, ITT.

C. *Parallel and Series Pump Application. Bulletin No. TEH 1065.* Bell & Gossett Division, ITT.

D. *One Primary Systems Flow Rate and Water Temperature Determination, Bulletin No. TEH-1066.* Bell & Gossett Division, ITT.

E. *Basic System Control and Valve Sizing Procedures, Bulletin No. 1165.* Bell & Gossett Division, ITT.

F. *Fundamentals ASHRAE Handbook and Product Directory*, 1977.

HYDRONICS
UNIT VI

INFORMATION SHEET

I. Terms and definitions

A. Hot water or steam coils--Transfer heat from the water to the air which is blown through the coil; similar in construction to automobile radiators and located in air ducts

B. Head--The pressure exerted by a column of water measured in the height of the water column

C. Forced circulation system--System which requires pump pressure for circulation

D. Tankless water heater--A device immersed in a boiler which transfers heat from the boiler to the domestic hot water supply of a structure

E. Psi--Pounds per square inch of pressure

F. Chilled water--Water which has been cooled before circulating through coils for cooling purposes

G. Radiant heat--The heat delivered from a hot or warm surface to a cooler surface by radiation of infrared rays

H. MBH--Heat expressed in thousands of Btu's per hour

I. Btuh--British thermal units per hour

J. Gpm--Flow rate in gallons per minute

K. IBR--Institute of Boiler and Radiator Manufacturers

L. SBI--Steel Boiler Institute

(NOTE: The Steel Boiler Institute is now known as IBR)

M. Centrifugal pump--A type of pump in which fluid is "thrown" by an impellor rather than "pushed" by a piston

N. Hydronics--The science of heating with water

O. Design water temperature drop--The difference in temperature between supply and return water temperature at the boiler at design output

P. Terminal units--Equipment which releases heat from a hydronic system to a conditioned space

INFORMATION SHEET.

II. Basic types of hydronic systems

A. Hydronic gravity system

(NOTE: Hydronic gravity systems are seldom used in the United States.)

1. Operates on the principle that hot water is lighter than cold water

   (NOTE: The difference between the weight of hot water and the weight of cold water is expressed in millinches (.001 in.) per foot of height.)

2. Head seldom exceeds 3 to 4 inches in gravity system

3. Requires much larger pipe systems

   (NOTE: The gravity system often requires up to 2 1/2" pipe.)

B. Forced circulation system

(NOTE: Because of their advantages, forced circulation systems have replaced gravity systems in the United States.)

1. Operates on pump pressure rather than gravity

2. Head may be 8-15 feet

3. Frequently uses pipe size 3/4" to 1/2"

4. When tankless water heater is present, provision must be made to prevent gravity effect during off cycle

III. Classifications of hydronic systems by water temperature - pressure characteristics

A. Low temperature water system (LTW)

1. Maximum temperature--250 degrees

2. Maximum pressure--160 psi

3. Usual upper limit--30 psi

B. Medium temperature water system (MTW)

1. Maximum temperature--350 degrees

2. Maximum pressure--150 psi

3. Usual design temperature--250 to 325 degrees

4. Usual design pressure--150 psi

INFORMATION SHEET

C. High temperature water system (HTW)

1. Minimum temperature--Over 350 degrees
2. Maximum temperature--400 to 450 degrees
3. Usual pressure--300 psi

D. Chilled water (CW)

1. Usual temperature--40 to 50 degrees
2. Operating pressure--125 psi

(NOTE: For process applications below 40 degrees, water is replaced with anti-freeze solution or brine. Well water may be used in chilled water application at temperatures below 60 degrees.)

E. Dual-temperature system (DTW)

1. Hot and chilled water
2. Usual temperatures of 100 to 150 degrees, winter
3. Usual temperatures of 40 to 55 degrees, summer

IV. Common hydronic system designs

A. Series loop (Transparency 1)

(NOTE: The series loop hydronic system makes one continuous loop around the perimeter of the structure. It is most common in small residences and small buildings.)

B. One pipe system (Transparency 1)

(NOTE: Individual terminal units are connected to one pipe loop by smaller pipes and hydronic fittings.)

C. Two pipe reverse return system (Transparency 2)

(NOTE: The two pipe reverse return system has a common supply loop to all terminal units in the circuit. It has a separate circuit of return water from the terminal units in reverse order from the supply.)

D. Two pipe direct return system (Transparency 3)

(NOTE: In the two pipe direct return system the supply pipe ends at the farthest terminal unit and the return pipe starts at the farthest terminal unit.)

E. Panel system (Transparency 3)

(NOTE: Panel systems are built into the floor or the ceiling and use radiant heat.)

INFORMATION SHEET

F. Multiple circuit systems (Transparency 4)

(NOTE: Multiple circuit systems can be used on any other type of system.)

V. Common hydronic system designs and their advantages and disadvantages

A. Series loop

1. Advantage--Low installation cost

2. Disadvantages

a. Water temperature is progressively reduced around circuit requiring allowance for colder water for heating purposes

b. Water temperature and rate of flow to any terminal unit within a circuit cannot be regulated without affecting all other terminal units in the circuit

c. Tube size in terminal unit limits flow of water and capacity of system

B. One pipe system

1. Advantage--Possible to control flow and heat from individual terminal units

2. Disadvantages

a. Higher in cost than the series loop system

b. Shows progressive drop in temperature around the water circuit

C. Two pipe reverse return system

1. Advantages

a. Equalizes distance water flows through each terminal unit and equalizes temperature drop

b. Eliminates allowance for temperature drop between terminal units

c. Individual control of terminal units does not affect other terminal units

2. Disadvantage--Additional pipe increases cost

INFORMATION SHEET

D. Two pipe direct return system

1. Advantages

   a. Valuable in split system (dual temperature)

   b. Lower in cost than reverse return system

2. Disadvantages

   a. Creates balancing problems due to different temperature drops across terminal units with low resistance to flow

   b. Limited applications unless the terminal units have high resistance to flow

E. Panel system

1. Advantage--Does not interfere with placement of furniture

2. Disadvantage--Leaks are expensive to repair

F. Multiple circuit system

1. Advantages

   a. Reduces the total length of circuits

   b. Reduces number of terminal units in a circuit

   c. Reduces pipe size of main trunk pipe

   d. Simplifies pipe design in certain types of buildings

2. Disadvantage--Could unnecessarily complicate an installation where a simple circuit would be satisfactory

VI. Design water temperature

A. Design water temperature is not used when compensating for temperature drop through series loop circuits

B. High temperature requires less radiation equipment

C. Determines basis for selection of terminal units

D. Does not have any effect on selection of boiler size

E. Each circuit of a multiple circuit system may have a different design water temperature

INFORMATION SHEET

VII. Terminal units and their design water temperature drop

A. Cast iron radiator--30°

B. Convectors--10°-30°

C. Unit heaters--Up to 50°

D. Baseboard--Up to 50°

(NOTE: Temperature drop does not affect selection of boiler size.)

VIII. Steps in determining design water flow rates through circuits

A. Add heat loss of each area on circuit

B. Divide by 500

C. Divide again by design temperature drop

(NOTE: 1 gpm equals 500 Btuh for each degree of temperature drop.)

Example: At 20 degree temperature drop

Area #1	23000 Btuh
Area #2	32000 Btuh
Area #3	25000 Btuh
TOTAL CIRCUIT "A"	80000 Btuh

80000/500 = 160

160/20 = 8 gpm, Circuit "A"

IX. Tubing sizes of minimum flow rates through terminal units

(NOTE: Flow rates are determined by the manufacturer of the terminal unit. See the manufacturer's catalog for specific data.)

A. 1/2" tube size--0.3 minimum design gpm

B. 3/4" tube size--0.5 minimum design gpm

C. 1" tube size--0.9 minimum design gpm

D. 1 1/4" tube size--1.6 minimum design gpm

X. Placement of terminal units

A. Terminal units should be placed under glass areas to counteract cold air falling from contact with cold glass

B. Terminal units should be placed along outside walls not containing glass

INFORMATION SHEET

C. When outside walls are used to fullest extent, balance of required terminal unit length may be placed along inside walls

D. Long, thin units along walls under windows produce more comfort economically than high, thin units

E. A unit on the stair landing will temper or stop the flow of cool air falling down stairs

F. Terminal units should distribute heat over the full length of long rooms to prevent spot heat

G. Forced air heaters should be installed so that heaters and registers do not create objectionable blasts of hot air

H. Combination heating and cooling units require special installation; follow manufacturers' recommendations

XI. Terminal units and their characteristics and uses

A. Cast iron radiators (Transparency 5)

(NOTE: Cast iron radiators are widely used in low water temperature systems.)

1. Column and large tube radiators are no longer manufactured but ratings are based on their performance

2. Slim tube and wall type radiators are suitable for homes and small office buildings

3. May be hung on walls or ceilings where floor space is not available

4. Modern radiators are rated in Btuh per square foot of Equivalent Direct Radiation (EDR) (Transparency 6)

B. Convectors

(NOTE: Used extensively in kitchen and baths where wall space is limited.)

1. Room air enters at bottom and passes between hot fins to reenter room through outlet at top of convector

2. Delivers more heat for its size than radiators due to chimney effect of the cabinet

INFORMATION SHEET

C. Baseboards (Transparency 7)

(NOTE: Baseboards replace portions of conventional wood baseboard moldings.)

1. Made from hollow cast iron sections

2. Made from 3/4" to 1/2" copper tubing with aluminum fins surrounded by sheet metal enclosure with openings at top and bottom

D. Finned tube–Larger diameter, higher capacity commercial equivalents of residential baseboard terminals

E. Air heating coils

1. Used to temper, reheat or boost heating of ducted air

2. Finned tube construction similar to air conditioning coils or automobile radiators

3. Must be protected from freezing

4. Ratings are not uniform due to varying air velocities, varying water velocities, varying air and water temperatures; use manufacturers' literature for ratings and coil selection

XII. Steps in the selection and sizing of terminal units

A. Determine room heat loss and MBH

B. Determine design water temperature

C. Determine design temperature drop

D. Select adequate size terminal from manufacturer's literature

XIII. Fuels, ratings, and selection of boilers

A. Fuels used for boilers

1. Gas

2. Electricity

3. Coal

4. Oil

(NOTE: Boilers may be substituted by solar collectors. Solar heating will not be discussed in this unit.)

INFORMATION SHEET

B. Ratings are either in gross IBR or SBI output or net IBR or SBI output

1. Gross IBR or SBI output is not used for selecting boilers for residential application

2. Net IBR or SBI output is rated in Btuh for water boilers and in square feet of radiator area for steam boilers

C. In new construction, select boiler with net rating of 100% of connected load

D. In replacement boilers, recalculate the heat loss of the structure and select boiler in accordance with new calculations

(NOTE: Old boilers are usually grossly oversized.)

XIV. Advantages and disadvantages of types of residential expansion tanks (Transparencies 8 and 9)

A. Open expansion tank

1. Advantages

a. Permits the expansion of water when heated

b. Lower initial installation cost

2. Disadvantages

a. Allows the evaporation of boiler water which must be replaced

b. Produces boiler scale and loss of efficiency due to the addition of make-up water

B. Air cushion expansion tank

1. Advantages--Maintains system pressure below safety pressure relief valve setting

(NOTE: The setting of the safety pressure relief valve is commonly 30 psi.)

2. Disadvantages

a. If sized too small, it will exceed the setting of the pressure relief

b. If sized too large, it can result in noisy operation due to boiling in areas of less pressure

c. Water can absorb the air and waterlog the expansion tank over a period of time

INFORMATION SHEET

C. Air-cushion expansion tank with diaphragm (Transparency 10)

1. Advantages

a. Permits smaller tank size due to prepressurization above the diaphragm

b. Water cannot absorb the air that is trapped above the diaphragm

2. Disadvantage -- More costly tank over a period of time

XV. Steps in the selection of residential expansion tanks

(NOTE: The selection of expansion tanks is subject to many variables such as height of water column, temperature of fill water, expansion of water, expansion of pipes, boiling temperature of water under pressure, etc. In large structures the calculation of expansion tank sizes and location of the tanks require an elaborate procedure which is beyond the scope of this unit of instruction.)

A. Allow 1 gallon of tank capacity for each 5000 Btuh of total heat loss if conventional tank is used

B. Allow 1 gallon of tank capacity for each 7000 Btuh of total heat loss if prepressurized diaphragm tank is used, and prepressurized to at least 6 psig

C. If calculated tank size is not available, select next size larger tank

XVI. Types, designs, and sizing of residential pumps

A. Residential pumps are usually centrifugal

B. For a given motor horsepower, a pump can be designed to deliver either high volume at low pump head or high pump head at low volume

C. Residential pumps are sized from 5 to 150 gallons per minute with head pressures of 4 to 14 feet of head

XVII. Factors in the selection of residential pumps

A. For a given size of piping, pressure drop will increase as rate of flow increases

B. For a given rate of flow, pressure drop will decrease as size of pipe increases

C. There will always be more than one combination of pipe size and pump head which will produce required water flow rate

INFORMATION SHEET

XVIII. Steps in the selection of residential pumps

A. Determine design rate of flow in gpm

B. Refer to manufacturer's literature for pump performance curves

C. Make trial selection of several pumps with various available pump heads at design rate of flow

D. Make selections including consideration of cost of pump

E. Solve for piping size and select proper pump for most economical total cost of piping and pump

XIX. Factors affecting pipe sizing (Transparency 11)

A. Rate of flow in gallons per minute

B. Length of pipe circuit in feet of pipe

C. Available pump head pressure

D. Cost of pipe and fittings

XX. Procedure for selection of pipe sizes

A. Refer to pipe sizing table in manufacturer's literature

B. Refer to pump manufacturer's pump performance charts

C. Plot pipe size curves on pump performance curves for various acceptable sizes of pipe

D. Select most economical combination of pipe size and pump size

E. If total system cost is not acceptable, select new system design

1. Increase or decrease number of circuits

2. Increase or decrease number of pumps

3. Increase or decrease sophistication of specialty fittings and controls

4. Increase or decrease design water temperature

5. Increase or decrease design temperature drop

XXI. Types of hydronic specialities and their characteristics and uses

A. Air elimination devices

1. Eliminates air absorbed by water

2. Usually located at the boiler

INFORMATION SHEET

B. Air vents

1. Eliminates air trapped in system
2. Usually installed in high points in system at terminal units
3. May be either manually operated or automatic

C. Fill valve

1. Common globe valve in old manually operated systems
2. In modern automatic systems, the fill valve is a combination pressure reducing valve set at 12 psi combined with a check valve
    a. Adds water to boiler when pressure drops below set point of fill valve
    b. Prevents boiler water from backing into municipal water system

D. Balancing valves

1. Used in multiple circuit systems
2. Regulates flow rate of water in separate circuits
3. Usually inexpensive square head cock valves
4. Usually located in return legs of branch circuits at manifold near boiler

E. Flow control valve

1. Used to prevent gravity effect of rising hot water during off cycle
2. Usually a type of weighted check valve with enough resistance to prevent hot water from rising by gravity but will open easily under pump pressure

F. Pressure relief valve

1. Used as a safety valve
2. Usually comes as part of boiler
3. Must be capable of discharging full Btuh rating of boiler in form of steam at a pressure setting 3 psig above rated working pressure of boiler
4. Discharge rate is indicated on nameplate of valve

INFORMATION SHEET

G. One-pipe fitting

1. Used in one pipe systems

2. Operates as a choke on supply loop to divert water to terminal unit

H. Zone valve

1. Used to open or shut off flow of hot water to a zone

2. Thermostatically controlled

3. Either motorized or solenoid operated

XXII. Steps in designing a hydronic system

A. Make trial selection of system design

B. Make a layout of piping system

C. Calculate heat loss

D. Determine Btuh requirements for each circuit or zone of piping system

E. Select design system temperature and design system temperature drop

F. Determine water flow rate required

G. Select terminal units

H. Select boiler

I. Select expansion tank

J. Determine length of circuits

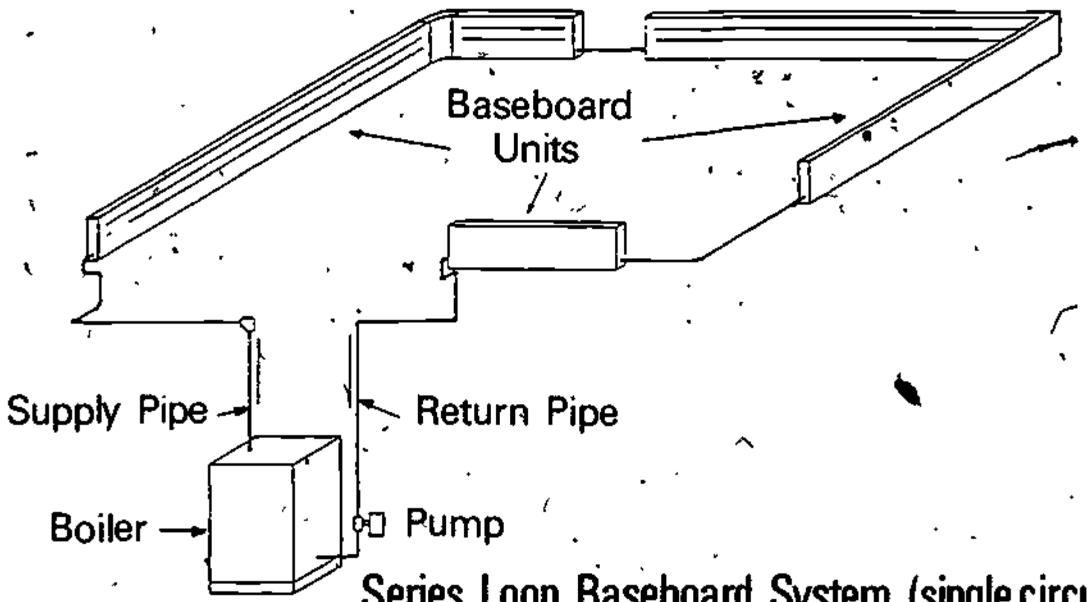
K. Make trial selection of pump

L. Determine pipe sizes for each trial pump selection

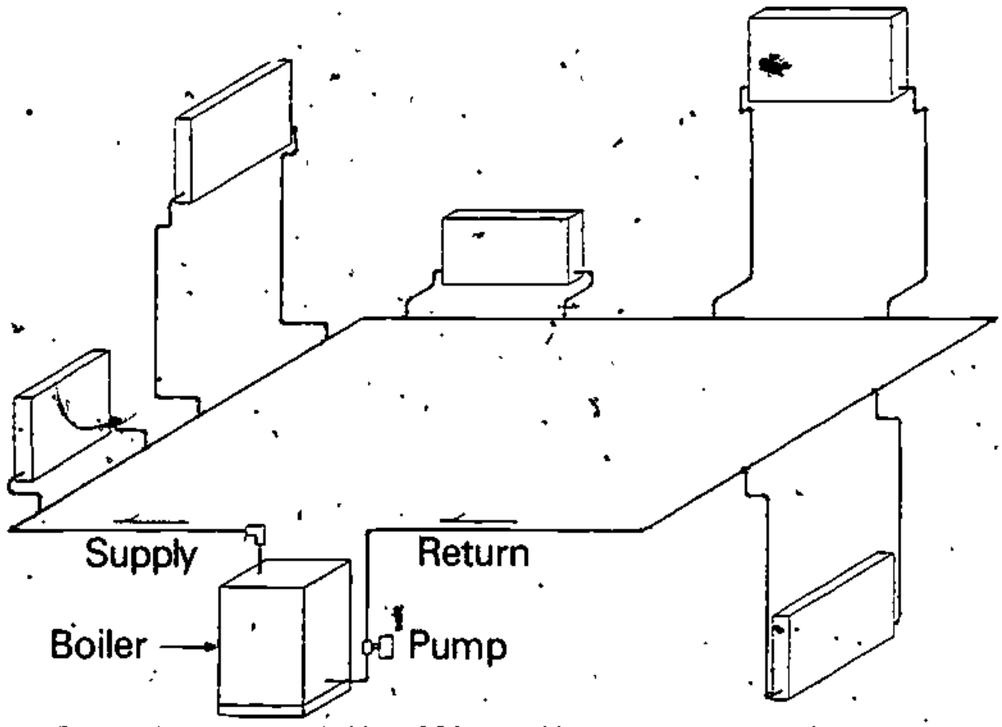
M. Make final selection of pump and pipe size and system design

N. Make selection of hydronic specialties

Common Types of Hydronic System Design



Series Loop Baseboard System (single circuit)



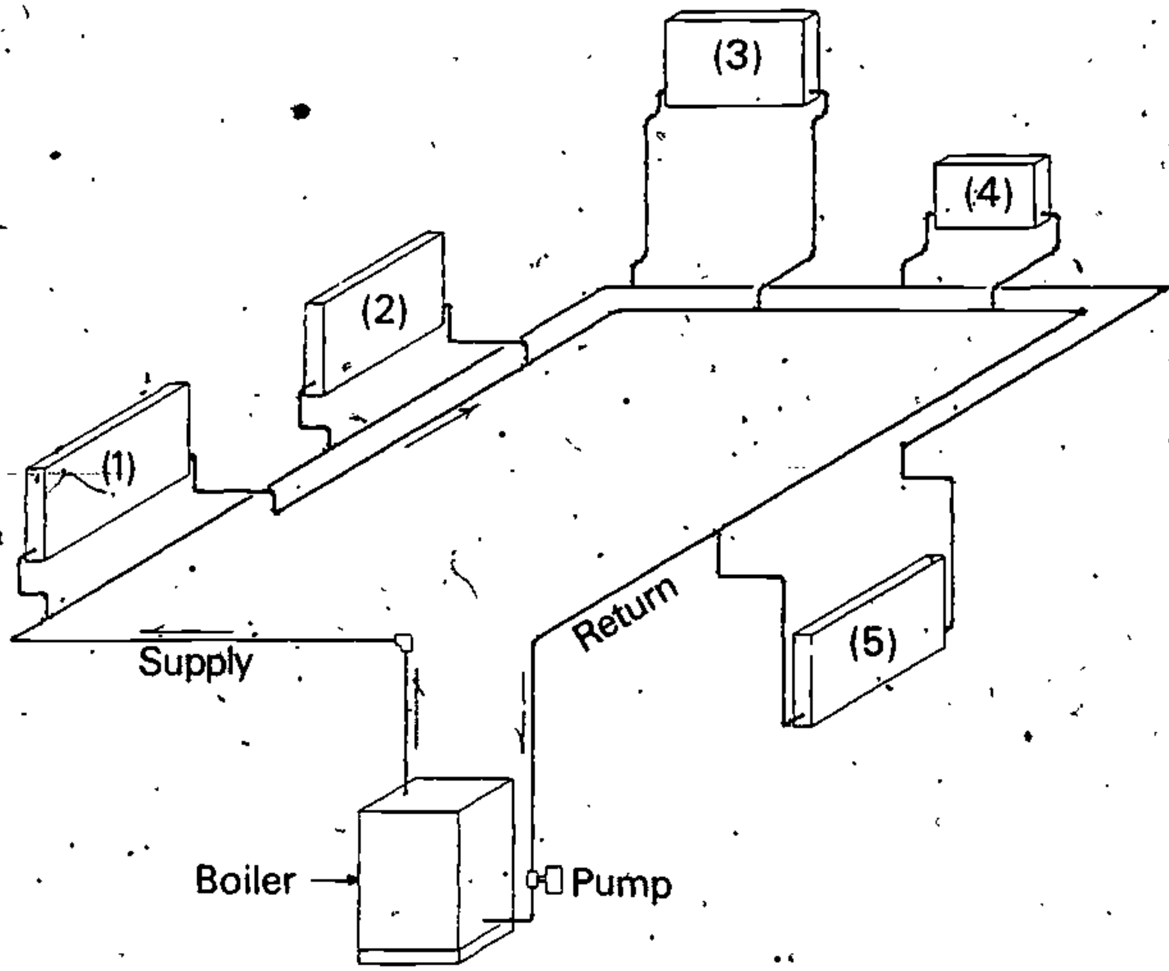
One Pipe Forced Hot Water Heating System (single circuit)

(Courtesy NHAW Home Study Institute)

TM 1

Common Types of Hydronic System Design

(Continued)

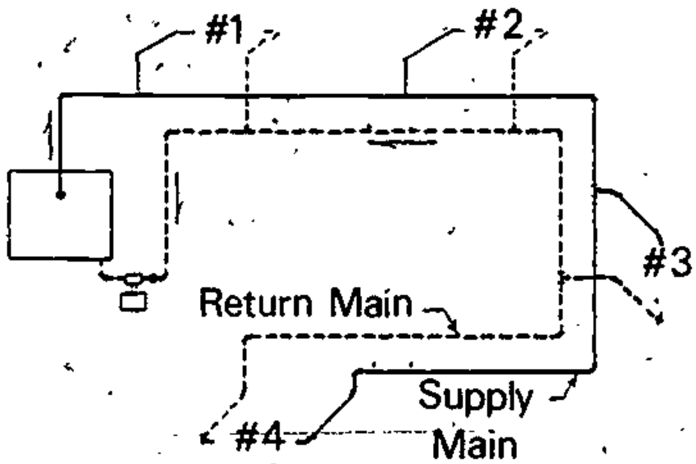


Two Pipe Reverse Return Forced Hot Water Heating System

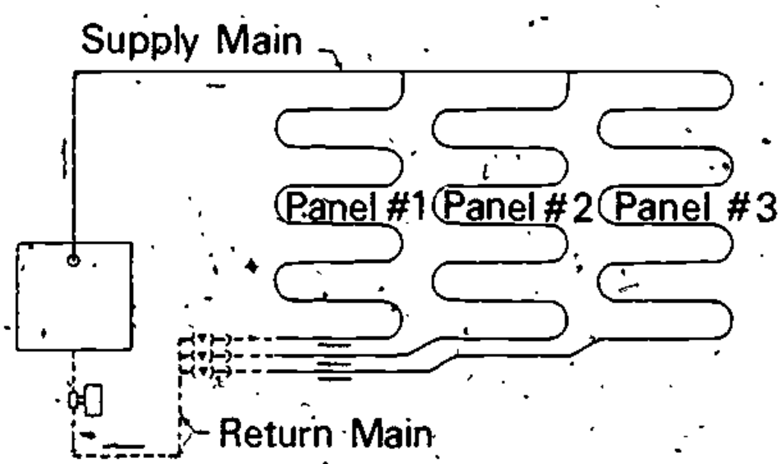
(Courtesy NHAW Home Study Institute)

Common Types of Hydronic System Design

(Continued)



Two Pipe Direct Return Forced Hot Water Heating System

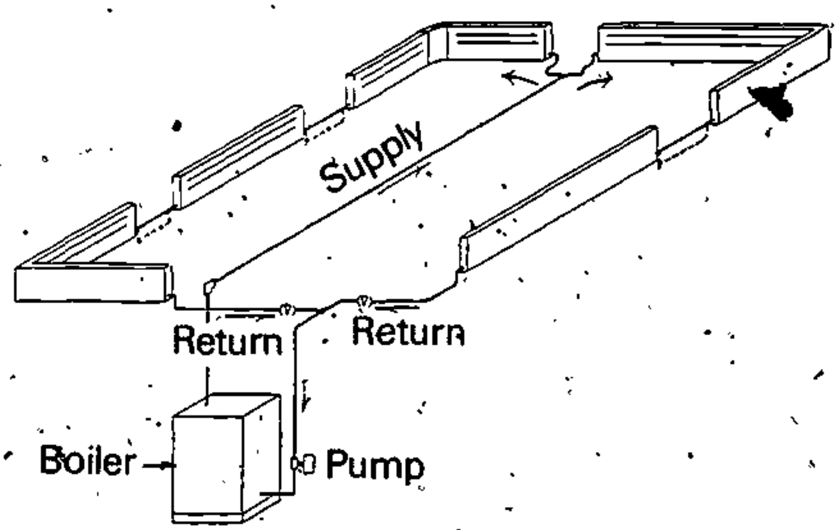


Forced Circulation Hot Water Panel Heating System

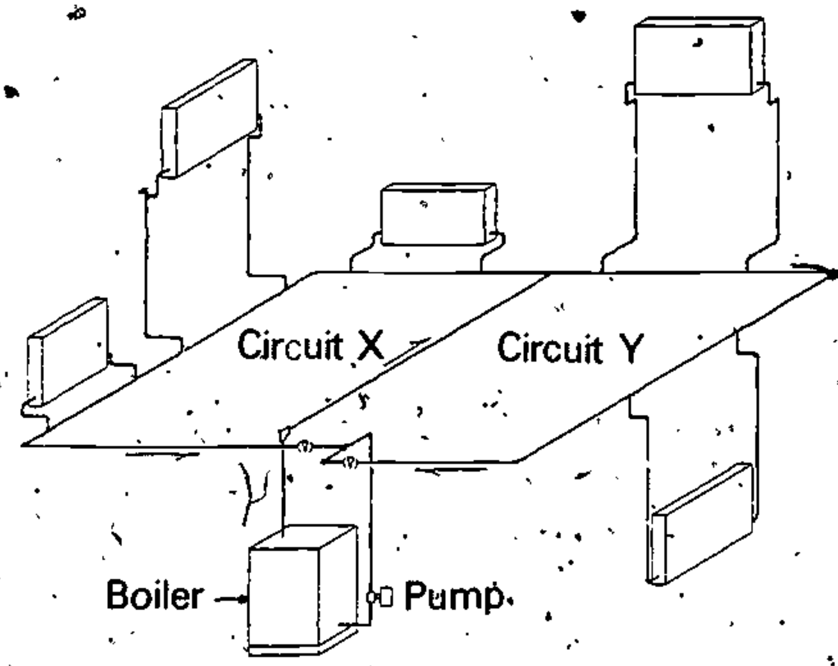
(Courtesy NHAW Home Study Institute)

Common Types of Hydronic System Design

(Continued)



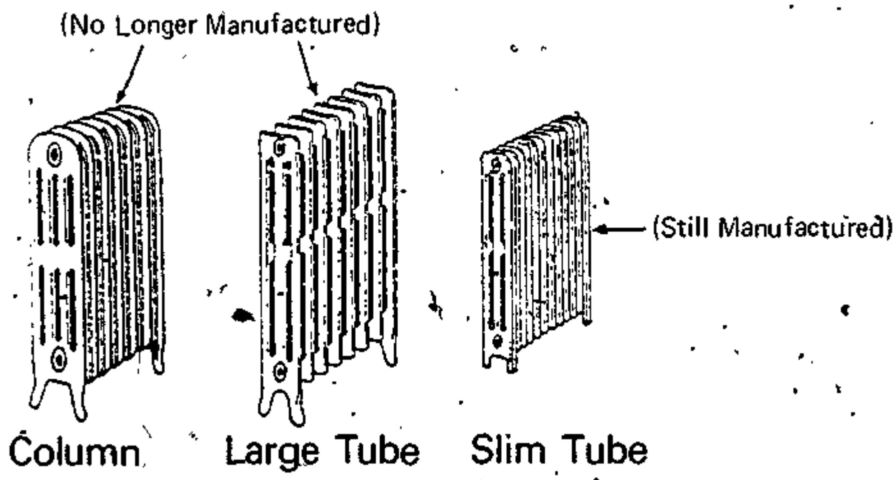
Series Loop Baseboard System – Multiple Circuit



One Pipe Forced Hot Water Heating System – Multiple Circuit

(Courtesy NHAW Home Study Institute)

Types of Cast Iron Radiators and Heat Emission Rates



Heat Emission Rates for Cast Iron Radiators

Design or Average Water Temperature	Heat Emission Rates Btu/Hr. per sq. ft.
170	150
175	160
180	170
185	180
190	190
195	200
200	210
205	220
210	230
215	240

(Courtesy NHAW Home Study Institute)

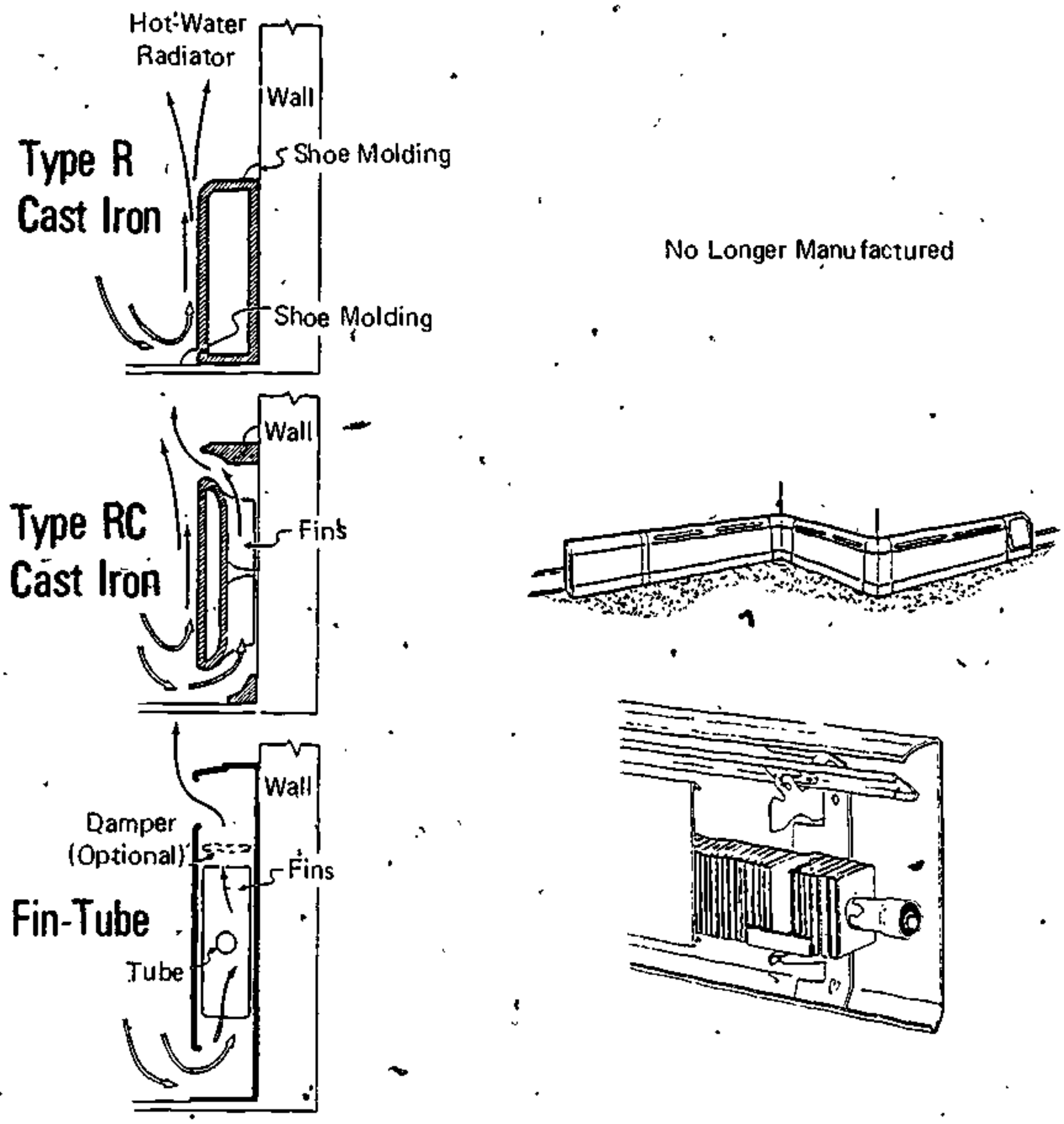
Ratings of Small Tube Radiators - Square Feet

Number of Sections	Length 1¾ Inches per Section	3 TUBE	4 TUBE			5 TUBE		6 TUBE		
		25" Height	19" Height	22" Height	25" Height	22" Height	25" Height	19" Height	25" Height	32" Height
2	3½	3.2	3.2	3.6	4	4.2	4.8	4.6	6	7.4
4	7	6.4	6.4	7.2	8	8.4	9.6	9.2	12	14.8
6	10½	9.6★	9.6★	10.8★	12★	12.6★	14.4★	13.8	18★	22.2★
8	14	12.8	12.8	14.4	16	16.8	19.2	18.4	24	29.6
10	17½	16.0★	16.0★	18.0★	20★	21.0★	24.0★	23.0★	30★	37.0★
12	21	19.2	19.2	21.6	24	25.2	28.8	27.6	36	44.4
14	24½	22.4★	22.4★	25.2★	28★	29.4★	33.6★	32.2★	42★	51.8★
16	28	25.6	25.6	28.8	32	33.6	38.4	36.8	48	59.2
18	31½	28.8★	28.8★	32.4★	36★	37.8★	43.2★	41.4★	54★	66.6★
20	35	32.0	32.0	36.0	40	42.0	48.0	46.0	60	74.0
22	38½	35.2★	35.2★	39.6★	44★	46.2★	52.8★	50.6★	66★	81.4★
24	42	38.4	38.4	43.2	48	50.4	57.6	55.2	72	88.8
26	45½	41.6★	41.6★	46.8★	52★	54.6★	62.4★	59.8★	78★	96.2★
28	49	44.8	44.8	50.4	56	58.8	67.2	64.4	84	103.6
30	52½	48.0★	48.0★	54.0★	60★	63.0★	72.0★	69.0★	90★	111.0
32	56	51.2	51.2	57.6	64	67.2	76.8	73.6	96	118.4
34	59½	54.4	54.4	61.2	68	71.4	81.6	78.2	102	125.8
36	63	57.6	57.6	64.8	72	75.6	86.4	82.8	108	133.2
38	66½	60.8★	60.8★	68.4★	76★	79.8★	91.2★	87.4★	114	140.6
40	70	64.0	64.0	72.0	80	84.0	96.0	92.0	120	148.0
42	73½	67.2	67.2	75.6	84	88.2	100.8	96.6	126	155.4
44	77	70.4	70.4	79.2	88	92.4	105.6	101.2	132	162.8
46	80½	73.6	73.6	82.8	92	96.6	110.4	105.8	138	170.2
48	84	76.8	76.8	86.4	96	100.8	115.2	110.4	144	177.6
50	87½	80.0	80.0	90.0	100	105.0	120.0	115.0	150	185.0
52	91	83.2	83.2	93.6	104	109.2	124.8	119.6	156	192.4
54	94½	86.4	86.4	97.2	108	113.4	129.6	124.2	162	199.8
56	98	89.6	89.6	100.8	112	117.6	134.4	128.8	168	207.2

(Note: The Assemblies with a ★ are Considered Stock Assemblies. These Ratings and Stock Assemblies are Based on Simplified Practice Recommendation R-174-47, issued by the U.S. Department of Commerce.)

(Courtesy NHAW Home Study Institute)

Basic Classes of 'Residential' Baseboard Terminal Units



Basic Classes of 'residential' type baseboard terminal units.

(Courtesy NHAW Home Study Institute)

Compression Tank Capacity

Initial or fill pressure psig	Altitude	Max. height of system above gage ft	Air cushion tank capacity in gallons per gallon of water in system	Diaphragm tank pre-pressurized to 6 psig
4	9	0	0.10	
6	14	5	0.12	
8	18	9	0.15	0.11
10	23	14	0.19	0.14
12	28	19	0.22	0.17
14	32	23	0.26	0.20
16	37	28	0.32	0.24
18	41	32	0.39	0.29
20	46	37	0.48	0.36
22	51	42	0.63	0.47
24	55	46	0.85	0.64

This table is based on a final pressure of 30 psig at the boiler, or low point in the system and an initial fill temperature of 60°F.

(Courtesy NHAW Home Study Institute)

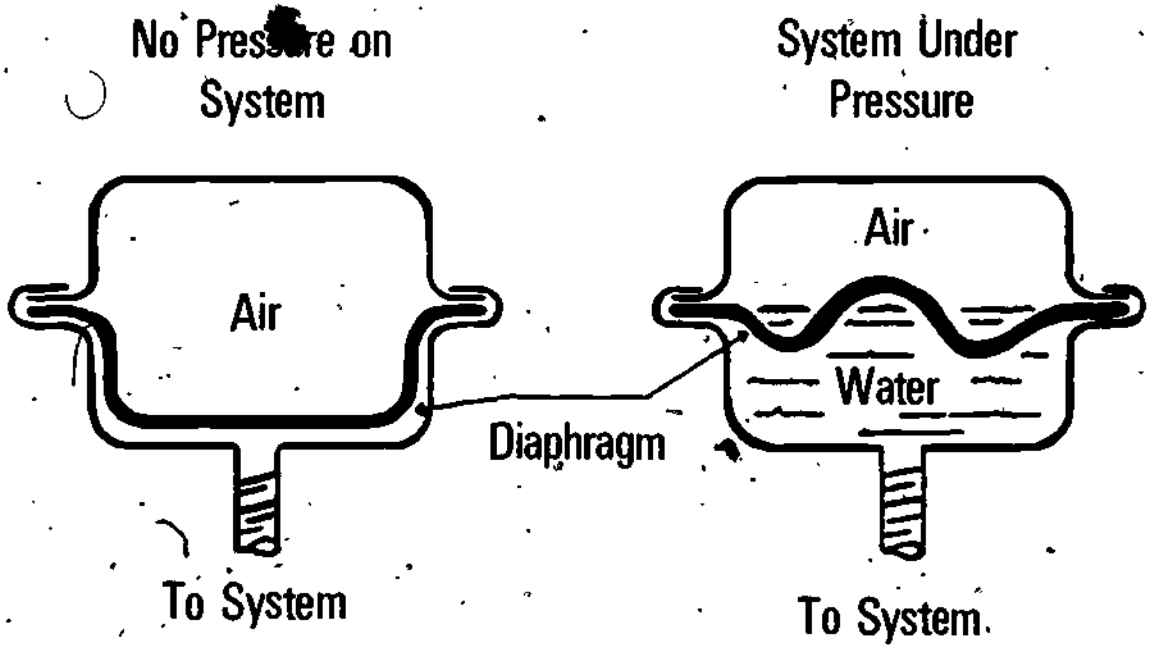
Water Content Of Hot Water Systems

Design Load Mbh	Boilers Conventional	Boilers Flash	Radiators large tube	Radiators small tube	Terminal Units Convectors	Terminal Units Baseboard	Radiant Panels	Series Loop	Piping Systems 1-Pipe	Piping Systems 2-Pipe
50	12	5	28	16	7	3	11	5	8	10
60	15	6	34	17	8	4	14	5	9	13
70	17	7	40	20	9	5	16	6	10	15
80	20	8	46	22	10	6	19	7	12	17
90	22	9	51	25	11	7	21	8	13	18
100	25	10	57	28	12	8	24	9	14	21
125	30	11	71	39	18	9	30	11	18	27
150	36	13	86	48	21	10	37	13	22	34
175	42	15	99	55	25	11	44	16	26	40
200	48	16	114	64	29	13	50		30	47
250	60		142	80	36	16	65		39	62
300	70		171	96	43	20	70		49	78
350	84		199	111	50	23			58	94
400	95		228	127	57	26			70	110
450	107		256	143	64	29			80	130
500	120		285	157	71	33			90	150
600	140		342	191	86	39			115	190
700	160		399	223	99	46			140	225
800	190		456	251	114	52			165	260
900	210		513	287	128	59			195	310
1000	235		570	319	142	65			225	360

Table is adapted from Table 1, D271TT Bell & Gossett "B&G School of Living Comfort"

(Courtesy NHAW Home Study Institute)

Cutaway View of Diaphragm Air Cushion Tank



(Courtesy NHAW Home Study Institute)

Pipe Sizing-Head Pressure Table

AVAILABLE HEAD ft. of water	TOTAL LENGTH OF CIRCUIT (AS MEASURED ON PIPING LAYOUT)																	
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r
4	35	45	50	60	65	70	75	80	90	100	110	130	150	180	220	290	400	620
5	45	60	65	70	80	90	100	100	120	130	140	160	190	230	290	360	510	790
6	55	70	80	90	100	110	120	130	140	160	180	200	240	290	350	450	620	950
7	65	90	100	110	120	130	140	150	170	190	210	240	290	340	420	540	730	1120
8	75	100	110	130	140	150	160	180	200	220	250	290	330	400	490	620	850	
9	85	110	130	150	160	170	190	200	230	250	290	330	380	450	560	710	950	
10	100	130	140	170	180	190	210	230	260	290	320	370	430	510	620	790	1080	
11	110	140	160	190	200	220	240	260	290	320	360	410	480	570	690	880	1170	
12	120	160	180	200	220	240	260	290	320	350	400	450	530	620	760	960		
14	150	190	210	250	260	290	310	340	380	420	470	540	620	730	900	1120		
16	170	220	250	290	310	330	360	400	440	490	550	620	720	850	1020			
18	190	250	290	330	350	380	420	450	500	560	620	710	830	950	1150			
20	220	290	320	370	400	430	470	510	560	620	700	790	910	1060				
PIPE SIZE	GALLON PER MINUTE CAPACITIES																	
3/8"*	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.2
1/2"	2.3	2.0	1.9	1.8	1.7	1.7	1.6	1.5	1.5	1.4	1.3	1.2	1.2	1.1	0.9	0.8	0.7	0.6
3/4"	5.0	4.3	4.1	3.8	3.7	3.6	3.4	3.2	3.1	2.9	2.8	2.6	2.4	2.2	2.0	1.8	1.6	1.3
1"	9.6	8.3	7.7	7.3	7.0	6.8	6.5	6.3	5.9	5.7	5.5	5.0	4.6	4.3	3.8	3.4	2.9	2.3
1 1/4"	—	18	17	16	15.5	15	14.5	14.0	13.0	12.0	11.5	11.0	9.7	9.0	8.3	7.3	6.3	4.8
1 1/2"	—	27	25	24	23	22	21	20	19	18	17	16	15	13	12	11	9.3	7.5
2"	—	—	—	—	—	42	40	39	38	36	34	32	29	27	24	21	18	14
2 1/2"	—	—	—	—	—	—	—	—	60	57	54	52	47	44	38	32	29	24

* 3/8" Copper Tubing only

NOTE: Do not go beyond the maximum or below the minimum figures shown in the table.

HOW TO USE THIS TABLE FOR FINAL PIPE SIZE SELECTION

a) Single Pump

Enter the upper portion of the Table at the head pressure of the pump selected. Read across to the figure closest to the total length of circuit. Read down to the lower portion of the Table to the gpm figure equal to or greater than the gpm required for the circuit. Read to the left-hand column to determine the pipe size required. Repeat for each circuit. Staying in the same column established by the circuit with the longest total length, repeat the last step for the gpm requirements of the trunk and distribution piping.

b) Multiple Pumps

Enter the upper portion of the Table at the head pressure of the pump selected. Read across to the figure closest to the total length of the longest circuit served by the pump. Read down to the lower portion of the Table to the gpm figure equal to or greater than the gpm required for the circuit. Read to the left-hand column to determine the pipe size required. For a two-pipe circuit, size all piping in the circuit from the same column in the Table established above.

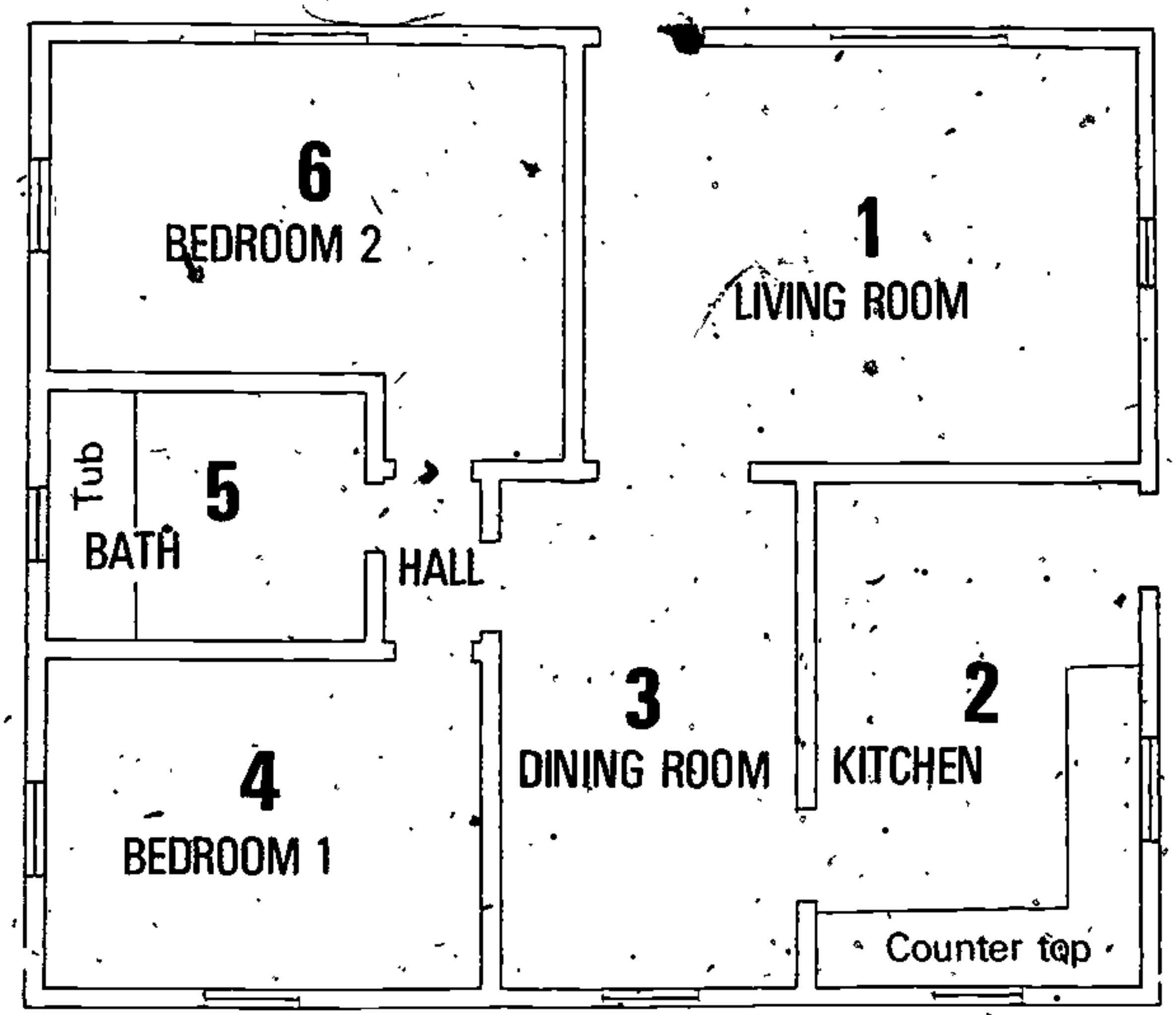
Size the trunk and any distribution piping using the total gpm of the system, the lowest head pressure of the pumps selected, and the longest total length of circuit.

(Courtesy NHAW Home Study Institute)

HYDRONICS
UNIT VI

ASSIGNMENT SHEET #1--LAY OUT A SERIES LOOP SINGLE CIRCUIT HYDRONIC SYSTEM WITH BOILER LOCATED UNDER FLOOR OF DINING ROOM

Directions: Use the floor plan below to sketch in the series loop piping, the location of baseboard terminal units, and the kitchen convector; your instructor has the option of modifying this assignment sheet to reflect available systems and local installation practices.



(Courtesy NHAW Home Study Institute)

ASSIGNMENT SHEET #1

Specifications:

Room #1	Living Room	15630 Btuh
Room #2	Kitchen	7540 Btuh
Room #3	Dining Room	8530 Btuh
Room #4	Bedroom #1	7330 Btuh
Room #5	Bath	3250 Btuh
Room #6	Bedroom #2	7220 Btuh
Total Heat Loss		49500 Btuh

Equipment to be located in basement

Design System Temperature 200 degrees

Design Temperature Drop 20 degrees

1. Calculate gpm: ______________________________

2. Select baseboard terminal units from manufacturer's catalog:

   Baseboard Model # ____________ (See Figure 1)

3. Select convector for Kitchen from manufacturer's literature:

   a. Kitchen percent of total heat loss: ____________ percent

   b. Kitchen temperature drop: ____________ degrees

   c. Kitchen convector

      1) Model # ______ (See Figure 2)

      2) Height ______

      3) Depth ______

      4) Length ______

   d. Room #1 baseboard length: _____ ft

   e. Room #3 baseboard length: _____ ft

   f. Room #4 baseboard length: _____ ft

   g. Room #5 baseboard length: _____ ft

   h. Room #6 baseboard length: _____ ft

4. Sketch in on the floor plan the series loop piping and the location of baseboard radiation units and the kitchen convector.

ASSIGNMENT SHEET #1

FIGURE 1

DESCRIPTION OF BASEBOARD	I=B=R RATINGS per linear feet — WATER: Average Water Temperature °F	Btuh at lb/hr flow rate of 500	2000	WATER: Average Water Temperature °F	Btuh at lb/hr flow rate of 500	2000
No 7A	150	270	290			
	160	320	340			
Front Outlet	170	370	390			
	180	420	440			
Cast Iron RC	190	470	500			
Height, 7"	195	490	520			
	220	520	550			
	210	570	600			
	220	420	660			
	230	660	700			
No 9A	150	390	410			
	160	450	480			
Front outlet	170	520	550			
Cast Iron RC*	180	590	620			
	190	450	690			
Height 9⅝"	195	680	720			
	200	710	750			
	210	770	810			
	220	830	880			
	230	890	940			
88A	150	390	410	200	720	760
	155	430	450	205	750	790
Inclined Outlet	160	460	490	210	790	840
	165	490	520	215	820	870
¾" Copper Tubing	170	530	560	220	850	900
	175	560	590	225	890	940
Fins Aluminum, 2" x 2½" x .010"	180	590	620	230	920	970
51 fins per foot	185	620	660	235	950	1000
Height 8 5/16"	190	660	700	240	980	1040
	195	690	730			
	170	470	500	210	710	750
	175	500	530	215	740	780
Inclined outlet	180	530	560	220	770	810
	185	560	590	225	800	850
¾" Copper Tubing	190	590	620	230	830	880
Fins, Aluminum 2¼"x2¼"x .008"	195	620	660	235	860	910
54.2 fins per foot	200	450	690	240	890	940
Height, 8½"	205	480	720			

*These ratings contain an effective heat allowance of 15 percent

FIGURE 2

Entering Air Temperature = 65F Front Outlet Cabinets - Model CF

Temp. Drop	Height	Heating Effect Factor	Depth	Water Temperature - Degrees F: 180				200				220			
				Length Inches											
				20	24	28	32	20	24	28	32	20	24	28	32
F	In	%	In	Rated Output MBh (1000 Btuh)											
10	20	14.4	4	1.7	2.1	2.5	3.0	2.1	2.6	3.2	3.8	2.5	3.7	3.9	4.5
			6	2.4	3.0	3.7	4.3	3.0	3.8	4.6	5.4	3.7	4.6	5.4	6.6
			8	3.0	3.8	4.6	5.4	3.8	4.8	5.8	6.8	4.6	5.8	7.0	8.3
			10	3.5	4.4	5.3	6.3	4.4	5.6	6.7	7.9	5.3	6.7	8.1	9.5
	24	10.4	4	1.9	2.4	2.9	3.4	2.4	3.0	3.6	4.3	2.9	3.4	4.4	5.2
			6	2.8	3.6	4.3	5.1	3.6	4.5	5.4	6.4	4.3	5.4	6.6	7.7
			8	3.4	4.2	5.1	6.0	4.2	5.3	6.4	7.5	5.1	6.4	7.8	9.1
			10	3.8	4.8	5.8	6.8	4.8	6.1	7.3	8.6	5.8	7.3	8.9	10.4
	26	8.4	4	1.9	2.5	3.0	3.5	2.4	3.1	3.7	4.4	2.9	3.7	4.5	5.3
			6	2.9	3.7	4.5	5.2	3.7	4.4	5.6	6.6	4.4	5.6	6.8	7.9
			8	3.4	4.4	5.3	6.2	4.3	5.5	6.6	7.8	5.2	6.6	8.0	9.4
			10	3.9	5.0	6.0	7.0	4.9	6.2	7.5	8.8	6.0	7.5	9.1	10.7
20	20	14.4	4	1.5	1.8	2.2	2.6	1.8	2.3	2.8	3.3	2.2	2.8	3.4	4.0
			6	2.3	2.7	3.2	3.8	2.7	3.4	4.1	4.8	3.2	4.0	4.9	5.8
			8	2.7	3.4	4.1	4.8	3.3	4.2	5.1	6.0	4.0	5.1	6.2	7.2
			10	3.1	3.9	4.7	5.5	3.9	4.9	5.9	6.9	4.7	5.8	7.1	8.4
	24	10.4	4	1.7	2.1	2.6	3.0	2.1	2.7	3.2	3.8	2.5	3.2	3.9	4.5
			6	2.5	3.2	3.8	4.5	3.1	4.0	4.8	5.6	3.8	4.8	5.8	6.7
			8	3.0	3.7	4.5	5.3	3.7	4.7	5.7	6.4	4.5	5.6	6.8	8.0
			10	3.4	4.3	5.1	6.0	4.2	5.3	6.5	7.2	5.1	6.4	7.8	9.1
	26	8.4	4	1.7	2.2	2.4	3.1	2.1	2.7	3.3	3.9	2.6	3.3	3.9	4.6
			6	2.6	3.3	3.9	4.6	3.2	4.1	4.9	5.8	3.9	4.9	5.9	6.9
			8	3.0	3.8	4.4	5.4	3.8	4.8	5.8	6.8	4.6	5.8	7.0	8.2
			10	3.5	4.4	5.2	4.2	4.4	5.5	6.6	7.8	5.2	6.6	8.0	9.4

ASSIGNMENT SHEET #1

FIGURE 3

APPROVED I=B=R water ratings

model R-500-A Heatrim-capacities Btu/hr per lineal foot

number of lineal feet	water flow rate 500 lbs/hr average water temperature °F 170°	180°	190°	200°	210°	220°	water flow rate 2000 lbs/hr average water temperature °F 170°	180°	190°	200°	210°	220°
1	510	570	630	690	750	810	540	600	670	730	790	860
2	1020	1140	1260	1380	1500	1620	1080	1200	1340	1460	1580	1720
3	1530	1710	1890	2070	2250	2430	1620	1800	2010	2190	2370	2580
4	2040	2280	2520	2760	3000	3240	2160	2400	2680	2920	3160	3440
5	2550	2850	3150	3450	3750	4050	2700	3000	3350	3650	3950	4300
6	3060	3420	[illegible]	4140	4500	4860	3240	3600	4020	4380	4740	5160
7	3570	3990	[illegible]	4830	5250	5670	3780	4200	4690	5110	5530	6020
8	4080	4560	[illegible]	[illegible]	6000	6480	4320	4800	5360	5840	6320	6880
9	4590	5130	5670	6210	6750	7290	4860	5400	6030	6570	7110	7740
10	5100	[illegible]	6300	6900	7500	8100	5400	6000	6700	7300	7900	8600
11	5610	6270	6930	7590	8250	8910	5940	6600	7370	8030	8690	9460
12	6120	6840	7560	8280	9000	9720	6480	7200	8040	8760	9480	10320
13	6630	7410	8190	8970	9750	10530	7020	7800	8710	9490	10270	11180
14	7140	7980	8820	9660	10500	11340	7560	8400	9380	10220	11060	12040
15	7650	8550	9450	10350	11250	12150	8100	9000	10050	10950	11850	12900
16	8160	9120	10080	11040	12000	12960	8540	9600	10720	11680	12640	13760
17	8670	9690	10710	11730	12750	13770	9180	10200	11390	12410	13430	14620
18	9180	10260	11340	12420	13500	14580	9720	10800	12060	13140	14220	15480
19	9690	10830	11970	[illegible]	14250	15390	10260	11400	12730	13870	15010	16340
20	10200	11400	12600	13800	15000	16200	10800	12000	13400	14600	15800	17200
21	10710	11970	13230	14490	15750	17010	11340	12600	14070	15330	16590	18060
22	11220	12540	13860	15180	16500	17820	11880	13200	14740	16060	17380	18920
23	11730	13110	14490	15870	17250	18630	12420	13800	15410	16790	18170	19780
24	12240	13680	15120	[illegible]	18000	19440	12960	14400	16080	17520	16960	20640
25	12750	14250	15750	[illegible]	18750	20250	13500	15000	16750	18250	19750	21500
26	13260	14820	16380	17940	19500	21060	14040	[illegible]	17420	18980	20540	22360
27	13770	15390	17010	18630	20250	21870	14580	16200	18090	19710	21330	23220
28	14280	15960	17640	19320	21000	22680	15120	16800	18760	20440	22120	24080
29	14790	16530	18270	20010	21750	23490	15660	17400	19430	21170	22910	24940
30	15300	17100	18900	[illegible]	22500	24300	16200	18000	20100	21900	23700	25800

(NOTE Approved I=B=R water ratings shown above for American-Standard Heatrim Panels (with Model E-500 element) are based on a water flow of 500 pounds per hour with a pressure drop of 0 260 inches of water per lineal foot and a water flow rate of 2000 pounds per hour with a pressure drop of 2,900 inches of water per lineal foot. As allowed by the Institute of Boiler and Radiator Manufacturers (I=B=R) Testing and Rating Code for Baseboard Type of Radiation, 15% is added to water heat capacity The use of I=B=R ratings at water flow rates 2000 pounds per hour is limited to installation where the water flow rate through the baseboard unit is equal to or greater than 2000 pounds per hour. Where the water flow rate through the baseboard is not known, the I=B=R rating at the standard water flow of 500 pounds per hour must be used. These ratings are based on active (finned) Heatrim lengths Difference between active length and total length of the standard Heatrim heating elements is 2 15/22 inches. Elements are unpainted Non-ferrous fins on Model E-500 elements measure 2 1/8 x 2 1/8 x 0 008 inches. spaced 52 fins per foot)

HYDRONICS
UNIT VI

ASSIGNMENT SHEET #2--SELECT BOILER AND EXPANSION TANK

Directions: Using a manufacturer's catalog provided by your instructor, select an appropriate boiler and two expansion tanks using the following specifications.

Specifications:

Total Heat Loss:	125,000 Btuh
Design System Temperature:	200 degrees
Design Temperature Drop:	20 degrees
Type of equipment selected:	LTW Boiler
Initial fill pressure:	12 psig
Type of terminal units:	Baseboard
System selected:	Series loop

1. Select boiler from manufacturer's catalog:

   Boiler Model No. ____________

2. Select conventional air cushion expansion tank.

   Minimum tank size: ____________ Gal.

3. Select diaphragm tank size.

   Minimum Diaphragm tank size: ____________ Gal.

HYDRONICS
UNIT VI

ASSIGNMENT SHEET #3--MAKE A TRIAL SELECTION OF PUMP AND SELECT PIPE SIZE FOR SERIES LOOP SYSTEM

Specifications:

Total heat loss	49500 Btuh
Design System Temperature:	200 degrees
Design temperature drop	unknown
Total length of system piping design	100 feet

1. Calculate System flow rate in gpm

   A. @ 10 degrees drop:________gpm

   B. @ 20 degrees drop:________gpm

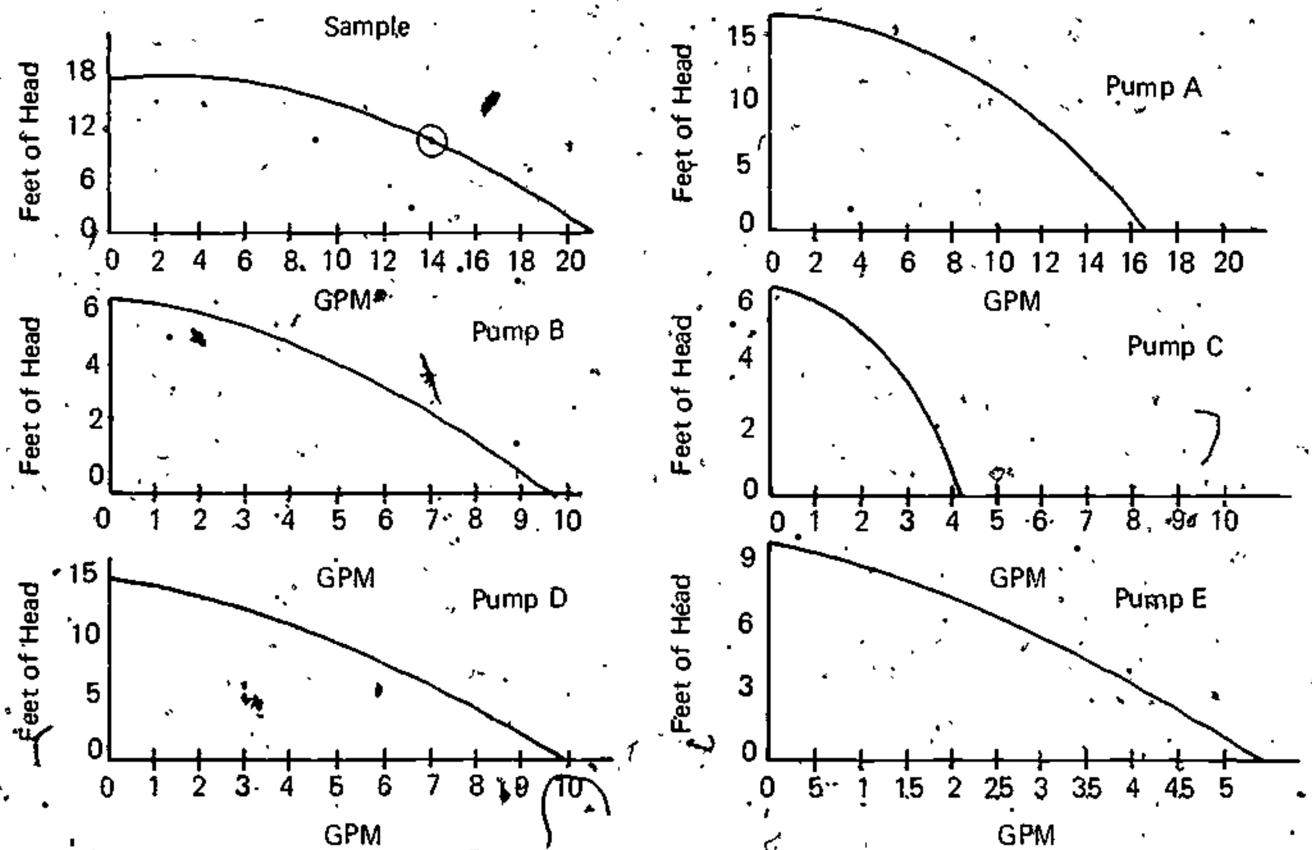
   C. @ 30 degrees drop:________gpm

   D. @ 40 degrees drop:________gpm

   E. @ 50 degrees drop:________gpm

2. Plot gpm on each of the following pump performance curves:

   (Example: Plot 14 gpm on sample curve:)



ASSIGNMENT SHEET #3

3. List available head pressure of each pump selected:

   (Example: Sample pump has 12 ft of head pressure at 14 gpm)

   Pump A:____, Pump B:____, Pump C:____, Pump D:____, Pump E:____

4. From Table indicate minimum tubing size for each pump: Refer to Transparency 11).

   Pump A:____", Pump B:____", Pump C:____", Pump D:____", Pump E:____"

5. Assume prices of pumps and tubing to be as follows:

   Pump A: $125, Pump B: $220, Pump C: $200, Pump D: $150, Pump E: $200

   1/2" copper tubing: $ 40.00 per 100 ft.
   3/4" copper tubing: $ 60.00 per 100 ft.
   1" copper tubing: $110.00 per 100 ft.

   Indicate least expensive combination of pump and tubing which will provide adequate flow of hot water:

   Pump: _____ Tubing size: _____ Temperature drop: _____degrees

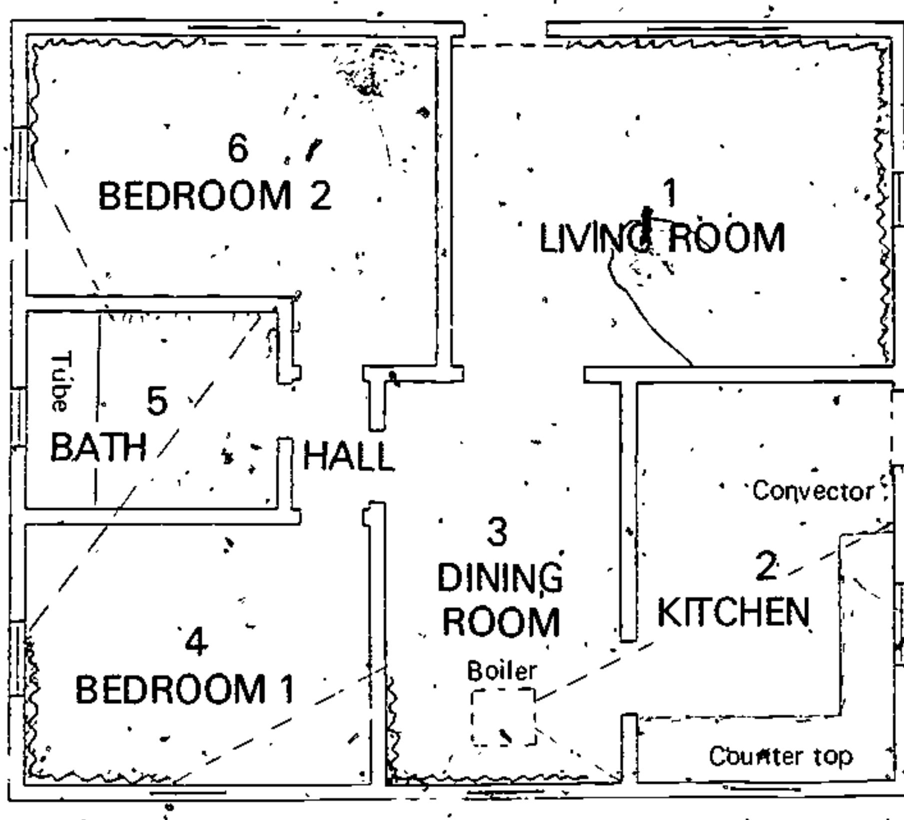
HYDRONICS
UNIT VI

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. 5 gpm
2. Answers will vary
3. a. 15.2%
   b. 3 degrees
   c. 1) Answers will vary
      2) 20, 24, 26
      3) 10, 8, 10
      4) 32, 32, 28

   (NOTE: 24-8-32 is preferred due to thinner configuration.)

   d. 21 ft.
   e. 12 ft.
   f. 10 ft.
   g. 5 ft.
   h. 10 ft.
4. 

Assignment Sheet #2

Answers should be determined by materials provided by instructor

Assignment Sheet #3

1. a. 10 gpm or 9.9 gpm

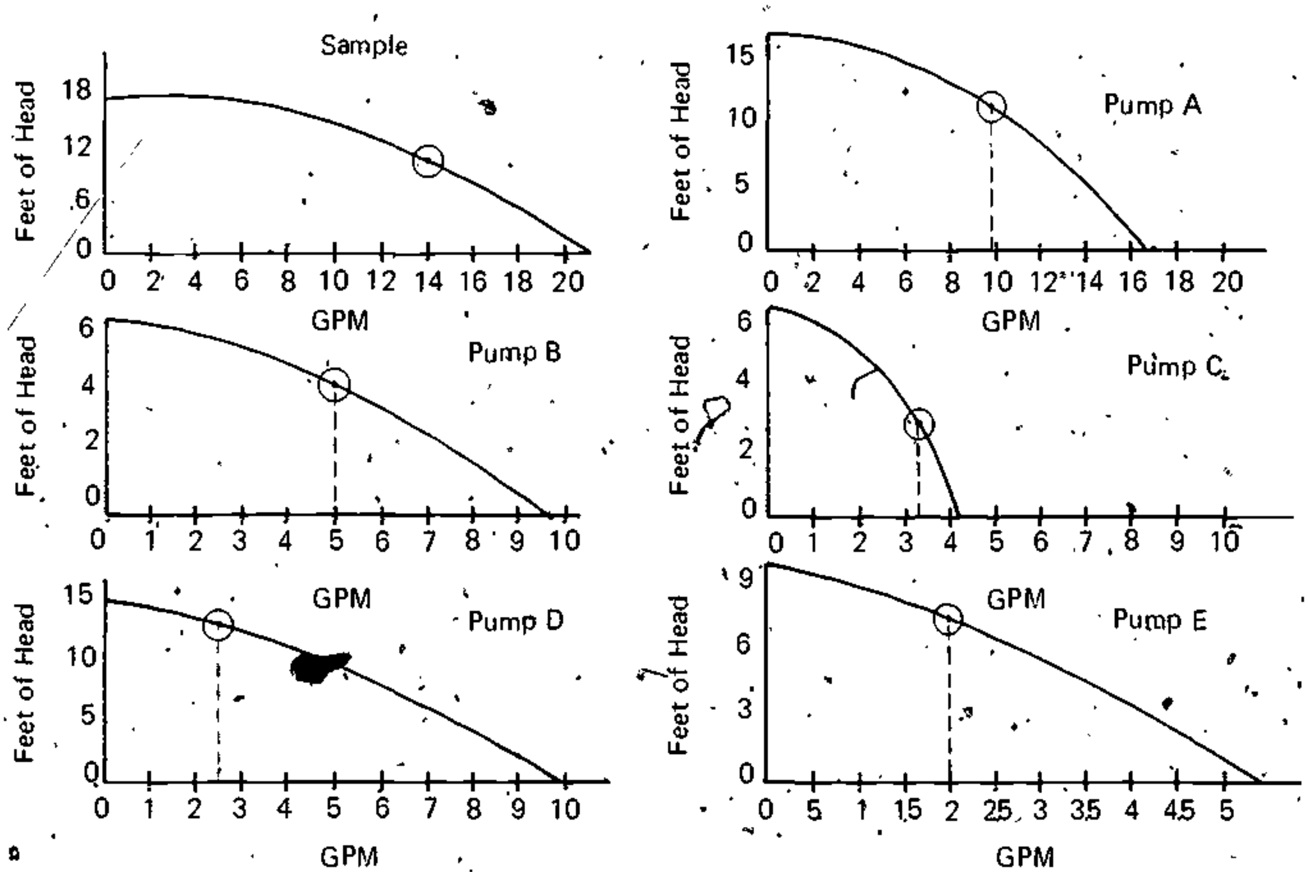
   b. 5 gpm

   c. 3.3 gpm

   d. 2.5 gpm

   e. 2.0 gpm

2.



Assignment Sheet #3

3. a. 10

   b. 4

   c. 3

   d. 5

   e. 2

4. a. 1"

   b. 3/4"

   c. 3/4"

   d. 3/4"

   e. 1/2"

5. Pump D, tubing size 3/4" Temperature drop 20 degrees

HYDRONICS
UNIT VI

NAME ______________________

TEST

1. Match the terms on the right with their correct definitions.

_____a. Transfer heat from the water to the air which is blown through the coil; similar in construction to automobile radiators and located in air ducts

_____b. The pressure exerted by a column of water measured in the height of the water column

_____c. System which requires pump pressure for circulation

_____d. A device immersed in a boiler which transfers heat from the boiler to the domestic hot water supply of a structure

_____e. Pounds per square inch of pressure

_____f. Water which has been cooled before circulating through coils for cooling purposes

_____g. The heat delivered from a hot or warm surface to a cooler surface by radiation of infrared rays

_____h. Heat expressed in thousands of Btu's per hour

_____i. British thermal units per hour

_____j. Flow rate in gallons per minute

_____k. Institute of Boiler and Radiator Manufacturers

_____l. Steel Boiler Institute

_____m. A type of pump design whereby fluid is "thrown" by an impellor rather than pushed by a piston

1. SBI
2. Design water temperature drop
3. MBH
4. Hot water or steam coils
5. Psi
6. Gpm
7. Terminal units
8. Chilled water
9. Hydronics
10. Head
11. Radiant heat
12. IBR
13. Btuh
14. Tankless water heater
15. Centrifugal pump
16. Forced circulation system

_____n. The science of heating with water

_____o. The difference in temperature between supply and return water temperatures at the boiler at design output

_____p. Equipment which releases heat from a hydronic system to a conditioned space

2. Distinguish between a hydronic gravity system and a forced circulation system by placing an "X" next to the descriptions of a forced circulation system.

_____a. Head seldom exceeds 3 to 4 inches in this system

_____b. When tankless water heater is present, provision must be made to prevent gravity effect during off cycle

_____c. Head may be 8-15 feet

_____d. Requires much larger pipe systems

_____e. Operates on the principle that hot water is lighter than cold water

_____f. Operates on pump pressure rather than gravity

_____g. Frequently uses pipe size 3/4" to 1/2"

3. Match the classifications of hydronic systems with their temperature-pressure characteristics.

_____a. 1) Maximum temperature--250 degrees
2) Maximum pressure--160 psi
3) Usual upper limit--30 psi

_____b. 1) Maximum temperature--350 degrees
2) Maximum pressure--150 psi
3) Usual design temperature--250 to 325 degrees
4) Usual design pressure--150 psi

_____c. 1) Minimum temperature--Over 350 degrees
2) Maximum temperature--400 to 450 degrees
3) Usual pressure--300 psi

1. Dual temperature system
2. Low temperature water system
3. Chilled water
4. Medium temperature water system
5. High temperature water system

_____ d. 1) Usual temperature--40 to 50 degrees

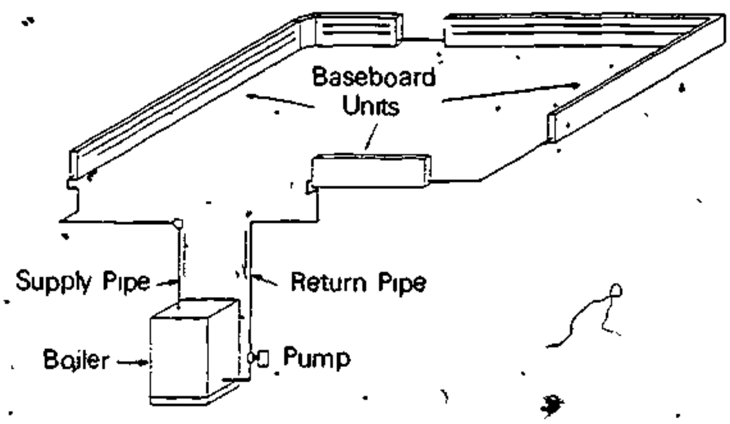
2) Operating pressure--125 psi

_____ e. 1) Hot and chilled water

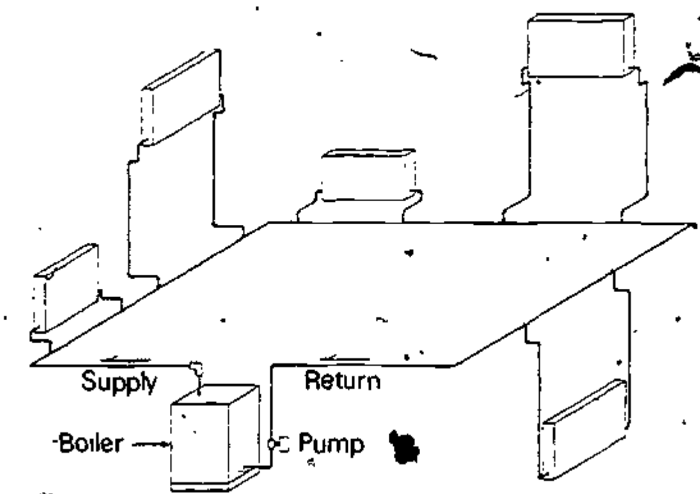
2) Usual temperatures of 100 to 150 degrees, winter

3) Usual temperatures of 40 to 55 degrees, summer

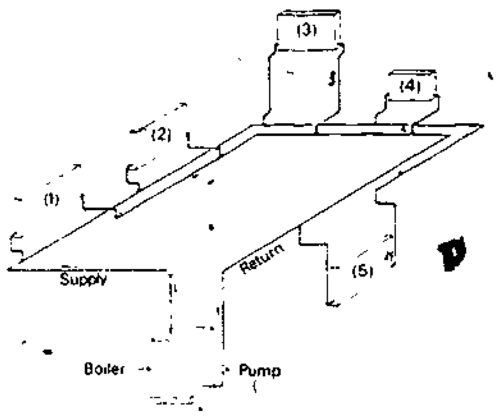
4. Identify the types of common hydronic system designs.



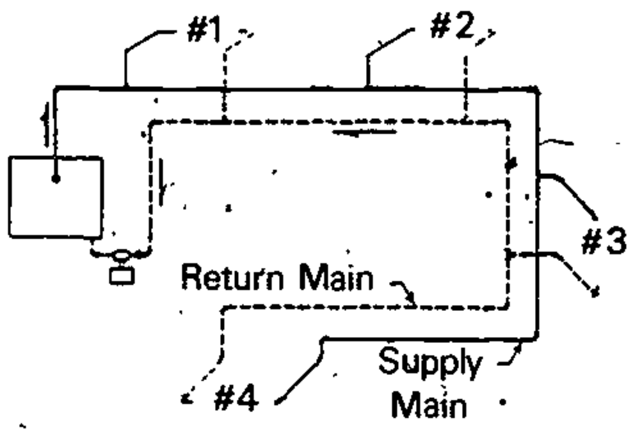
a. ________________________________



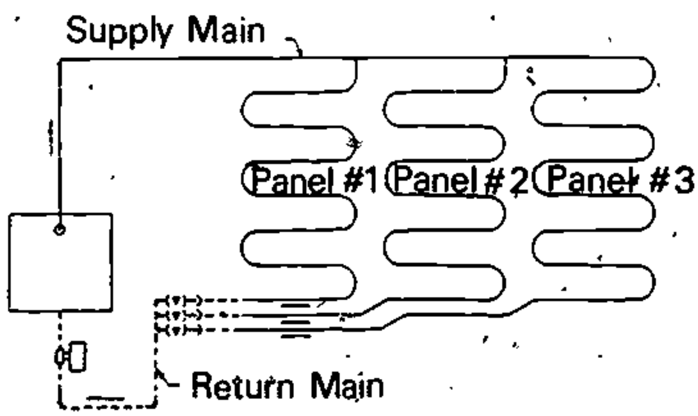
b. ________________________________


(3)
(4)
(2)
(1)
Supply
Return
(5)
Boiler
Pump

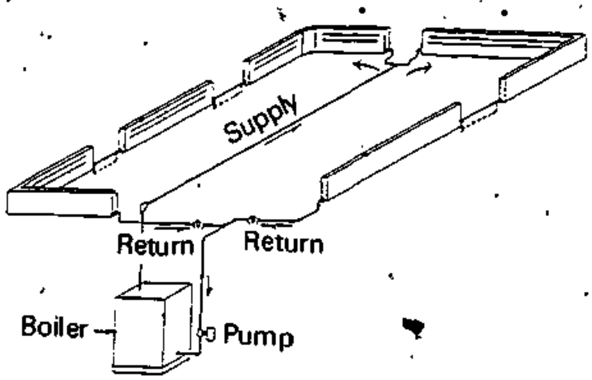
c. ______________________

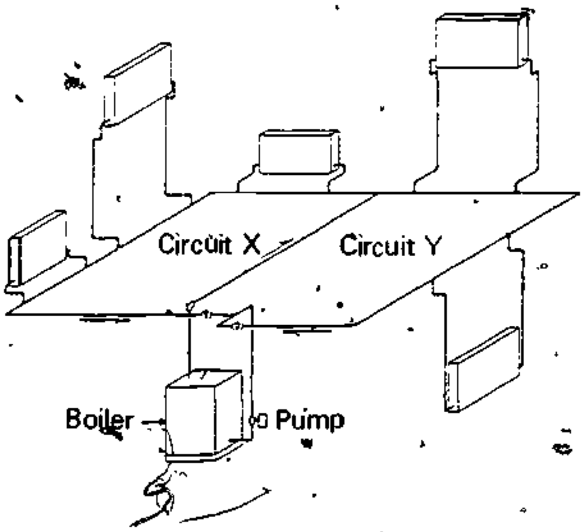

#1
#2
#3
Return Main
#4
Supply
Main

d. ______________________


Supply Main
Panel #1
Panel #2
Panel #3
Return Main

e. ______________________





f. ____________

5. Match common hydronic system designs with their advantages and disadvantages.

____ a. 1) Advantage--Low installation cost

2) Disadvantages

a) Water temperature is progressively reduced around circuit requiring allowance for colder water for heating purposes

b) Water temperature and rate of flow to any terminal unit within a circuit cannot be regulated without affecting all other terminal units in the circuit

c) Tube size in terminal units limits flow of water and capacity of system

1. Multiple circuit systems
2. Series loop
3. Panel system
4. One pipe system
5. Two pipe direct return system
6. Two pipe reverse return system

_____ b. 1) Advantage--Possible to control flow and heat from individual terminal units

2) Disadvantages

a) Higher in cost than the series loop system

b) Shows progressive drop in temperature around the water circuit

_____ c. 1) Advantages

a) Equalizes distance water flows through each terminal unit and equalizes temperature drop

b) Eliminates allowance for temperature drop between terminal units

c) Individual control of terminal units does not affect other terminal units

2) Disadvantage–Additional pipe increases cost

_____ d. 1) Advantages

a) Valuable in split system (dual temperature)

b) Lower in cost than reverse return system

2) Disadvantages

a) Creates balancing problems due to different temperature drops across terminal units with low resistance to flow

b) Limited applications unless the terminal units have high resistance to flow

_____ e. 1) Advantage--Does not interfere with placement of furniture

2) Disadvantage--Leaks are expensive to repair

_____ f. 1) Advantages

a) Reduces the total length of circuits

b) Reduces number of terminal units in a circuit

c) Reduces pipe size of main trunk pipe

d) Simplifies pipe design in certain types of buildings

2) Disadvantage--Could unnecessarily complicate an installation where a simple circuit would be satisfactory

6. Select true statements about design water temperature by placing an "X" in the appropriate blanks.

_____ a. Design water temperature is used when compensating for temperature drop through series loop circuits

_____ b. High temperature requires less radiation equipment

_____ c. Determines basis for selection of terminal units

_____ d. Does have an effect on selection of boiler size

_____ e. Each circuit of a multiple circuit system may have a different design water temperature

7. Match the design water temperature drop on the right to the correct terminal unit.

_____ a.	Unit heater	1.	Up to 50°
_____ b.	Convectors	2.	30°
_____ c.	Cast iron radiator	3.	10°-30°
_____ d.	Baseboard		

8. Solve the following problem involving design water flow rates through a circuit.

Specifications:

30° temperature drop

Area 1--36,000 BTU's heat loss

Area 2--22,000 BTU's heat loss

Area 3--25,000 BTU's heat loss

What is the design water flow rate through each circuit?

9. Match the minimum design flow rate on the right with the correct tubing size.

_____a. 1/2" tube size	1. 0.9 minimum design gpm
_____b. 3/4" tube size	2. 0.3 minimum design gpm
_____c. 1" tube size	3. 1.6 minimum design gpm
_____d. 1 1/4" tube size	4. 0.5 minimum design gpm

10. Select true statements about the placement of terminal units by placing an "X" in the appropriate blanks.

_____a. Terminal units should be placed under wood areas to counteract cold air falling from contact with cold wood

_____b. Terminal units should be placed along outside walls not containing glass

_____c. When outside walls are used to the fullest extent, balance of required terminal unit length may be placed along inside walls

_____d. Long, thin units along walls under windows produce more comfort economically than high, thin units

_____e. A unit on the stair landing will temper or stop the flow of hot air falling down stairs

_____f. Terminal units should distribute heat over the full length of long rooms to prevent spot heat

_____g. Forced air heaters should be installed so that heaters and registers create objectionable blasts of hot air

_____h. Combination heating and cooling units require special installation; follow manufacturer's recommendations

11. Match terminal units with their characteristics and uses.

_____a. 1) Column and large tube radiators are no longer manufactured but ratings are based on their performance

2) Slim tube and wall type radiators are suitable for homes and small office buildings

3) May be hung on walls or ceilings where floor space is not available

4) Modern radiators are rated in Btuh per square foot of Equivalent Direct Radiation (EDR)

______b.	1) Room air enters at bottom and passes between hot fins to reenter room through outlet at top of device	1. Baseboards
	2) Delivers more heat for its size than radiators due to chimney effect of the cabinet	2. Air heating coils
______c.	1) Made from hollow cast iron sections	3. Convectors
	2) Made from 3/4" to 1/2" copper tubing with aluminum fins surrounded by sheet metal enclosure with openings at top and bottom	4. Cast iron radiators
______d.	Larger diameter, higher capacity commercial equivalents of residential baseboard terminals	5. Finned tube
______e.	1) Used to temper, reheat or boost heating of ducted air	
	2) Finned tube construction similar to air conditioning coils or automobile radiators	
	3) Must be protected from freezing	
	4) Ratings are not uniform due to varying air velocities, varying water velocities, varying air and water temperatures; use manufacturers' literature for ratings and coil selection	

12. Complete a list of steps in the selection and sizing of terminal units.

a.

b. Determine design water temperature

c.

d. Select adequate size terminal from manufacturer's literature

13. Select true statements concerning fuels, ratings, and selection of boilers by placing an "X" in the appropriate blanks.

______a. Fuels used for boilers

1) Gas

2) Electricity

3) Coal

4) Oil

_____ b. Ratings are either in gross IBR or SBI output or net IBR or SBI output

1) Gross IBR or SBI output is not used for selecting boilers for residential application

2) Net IBR or SBI output is rated in Btuh for water boilers and in square feet of radiator area for steam boilers

_____ c. In new construction, select boiler with net rating of 100% of connected load

_____ d. In replacement boilers, select a boiler about the size of the old boiler

14. Distinguish between advantages and disadvantages of types of residential expansion tanks by placing an "X" in all blanks that indicate advantages.

a. Open expansion tank

_____ 1) Permits the expansion of water when heated

_____ 2) Lower initial installation cost

_____ 3) Allows the evaporation of boiler water which must be replaced

_____ 4) Produces boiler scale and loss of efficiency due to the addition of make-up water

b. Air cusion expansion tank

_____ 1) Maintains system pressure below safety pressure relief valve setting

_____ 2) If sized too small it will exceed the setting of the pressure relief

_____ 3) If sized too large, it can result in noisy operation due to boiling in areas of less pressure

_____ 4) Water can absorb the air and waterlog the expansion tank over a period of time

c. Air-cushion expansion tank with diaphragm

_____ 1) Permits smaller tank size due to prepressurization above the diaphragm

_____ 2) Water cannot absorb the air that is trapped above the diaphragm

_____ 3) More costly tank over a period of time

15. Select true statements concerning steps in the selection of residential expansion tanks by placing an "X" in the appropriate blanks.

_____a. Allow 1 gallon of tank capacity for each 5000 Btuh of total heat loss if conventional tank is used

_____b. Allow 1 gallon of tank capacity for each 7000 Btuh of total heat loss if pressurized diaphragm tank is used, and prepressurized to at least 6 psig

_____c. If calculated tank size is not available, select next size smaller tank

16. Select true statements about the type, designs, and sizing of residential pumps by placing an "X" in the appropriate blanks.

_____a. Residential pumps are usually piston driven

_____b. For a given motor horsepower a pump can be designed to deliver either high volume at low pump head or high pump head at low volume

_____c. Residential pumps are sized from 5 to 150 gallons per minute with head pressures of 4 to 14 feet of head

17. Complete a list of factors in the selection of residential pumps.

a. For a given size of piping, pressure drop will increase as rate of flow increases

b.

c.

18. Arrange in order the steps in selection of residential pumps by placing the correct sequence number in the appropriate blank.

_____a. Make selections including consideration of cost of pumps

_____b. Refer to manufacturer's literature for pump performance curves

_____c. Determine design rate of flow in gpm

_____d. Make trial selection of several pumps with various available pump heads at design rate of flow

_____e. Solve for piping size and select proper pump for most economical total cost of piping and pump

19. Complete a list of factors affecting pipe sizing.

a.

b.

c. Available pump head pressure

d. Cost of pipe and fittings

20. Select true statements concerning the procedure for selection of pipe sizes by placing an "X" in the appropriate blanks.

(NOTE: For a statement to be true, all parts of it must be true.)

_____a. Refer to pipe sizing table in manufacturer's literature

_____b. Refer to pump manufacturer's pump performance charts

_____c. Plot pipe size curves on pump performance curves for various acceptable sizes of pipe

_____d. Select most economical combination of pipe size and pump size

_____e. If total system cost is not acceptable, select new system design

1) Increase or decrease number of circuits

2) Increase or decrease number of pumps

3) Increase or decrease sophistication of specialty fittings and controls

4) Increase or decrease design water temperature

5) Increase or decrease design temperature drop

21. Match types of hydronic specialities with their characteristics and uses.

_____a. 1) Eliminates air absorbed by water

2) Usually located at the boiler

_____b. 1) Eliminates air trapped in system

2) Usually installed in high points in system at terminal units

3) May be either manually operated or automatic

_____c. 1) Common globe valve in old manually operated systems

2) In modern automatic systems the fill valve is a combination pressure reducing valve set at 12 psi combined with a check valve

a) Adds water to boiler when pressure drops below set point of fill valve

b) Prevents boiler water from backing into municipal water system

1. Balancing valves
2. Zone valve
3. Air elimination devices
4. Pressure relief valve
5. Fill valve
6. One-pipe fitting
7. Air vents
8. Flow control valve

_____ d. 1) Used in multiple circuit systems

2) Regulates flow rate of water in separate circuits

3) Usually inexpensive square head cock valves

4) Usually located in return legs of branch circuits at manifold near boiler

_____ e. 1) Used to prevent gravity effect of rising hot water during off cycle

2) Usually a type of weighted check valve with enough resistance to prevent hot water from rising by gravity but will open easily under pump pressure

_____ f. 1) Used as a safety valve

2) Usually comes as part of boiler

3) Must be capable of discharging full Btuh rating of boiler in form of steam at a pressure setting 3 psig above rated working pressure of boiler

4) Discharge rate is indicated on nameplate of valve

_____ g. 1) Used in one pipe systems

2) Operates as a choke on supply loop to divert water to terminal unit

_____ h. 1) Used to open or shut off flow of hot water to a zone

2) Thermostatically controlled

3) Either motorized or solenoid operated

22. Select true statements concerning steps in designing a hydronic system by placing an "X" in the appropriate blanks.

_____ a. Make trial selection of system design

_____ b. Make a layout of piping system

_____ c. Calculate heat loss

_____d. Determine Btuh requirements for each circuit or zone of piping system

_____e. Select design system temperature and design system temperature drop

_____f. Determine water flow rate required

_____g. Select terminal units

_____h. Select boiler

_____i. Select expansion tank

_____j. Determine length of circuits

_____k. Make trial selection of pump

_____l. Determine pipe sizes for each trial pump selection

_____m. Make final selection of pump and pipe size and system design

_____n. Make selection of hydronic specialities

23. Lay out a series loop single circuit hydronic system with boiler located under floor of dining room.

24. Select a boiler and expansion tank.

25. Make a trial selection of a pump and select pipe size for series loop system.

(NOTE. If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

HYDRONICS
UNIT VI

ANSWERS TO TEST

1.

a.	4	g.	11	m.	15
b.	10	h.	3	n.	9
c.	16	i.	13	o.	2
d.	14	j.	6	p.	7
e.	5	k.	12		
f.	8	l.	1		

2. b, c, f, g

3. a. 2
   b. 4
   c. 5
   d. 3
   e. 1

4. a. Series loop
   b. One pipe system
   c. Two pipe reverse return system
   d. Two pipe direct return system
   e. Panel system
   f. Multiple circuit systems

5. a. 2
   b. 4
   c. 6
   d. 5
   e. 3
   f. 1

6. b, c, e

7. a. 1
   b. 3
   c. 2
   d. 1

8. 5 5 gpm

9. a. 2
   b. 4
   c. 1
   d. 3

10. b, c, d, f, h

11 a. 4
b. 3
c. 1
d. 5
e. 2

12. a. Determine room heat loss and MBH
c. Determine design temperature drop

13. a, b, c

14 a. 1, 2 b. 1 c. 1, 2.

15. a, b

16. b, c

17 b. For a given rate of flow, pressure drop will decrease as size of pipe increases

c. There will always be more than one combination of pipe size and pump head which will produce required water flow rate

18. a. 4
b. 2
c. 1
d. 3
e. 5

19. a. Rate of flow in gallons per minute
b. Length of pipe circuit in feet of pipe

20. a, b, c, ~~d~~, e

21. a. 3 e. 8
b. 7 f. 4
c. 5 g. 6
d. 1 h. 2

22. a, b, c, d, e, f, g, h, i, j, k, l, m, n

23. Evaluated to the satisfaction of the instructor

24. Evaluated to the satisfaction of the instructor

25. Evaluated to the satisfaction of the instructor