PART 12

Water And DX Systems

CONTENTS PART 12 WATER AND DX SYSTEMS

SYSTEM DESIGN MANUAL

SUMMARY OF PART 12

This part of the System Design Manual presents data and engineering procedures to guide the engineer in the practical designing of water and DX systems.

The text of this Manual is offered as a general guide for the use of industry and of consulting engineers in designing systems. Judgment is required for application to specific installation, and Carrier is not responsible for any uses made of this text.

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CHAPTER 1. FAN-COIL UNIT SYSTEM

The all-water fan-coil unit system is well suited for many applications. It is particularly applicable to a multi-room building where ductwork costs may be prohibitive. Where the climate permits, it is equally applicable to the relatively low temperature hot water characteristics of central heat pump systems, using an interior zone load as a heat source. A fan-coil unit system is not recommended for applications having high latent heat loads.

The system is used in many applications such as hotels, motels, hospitals, apartments, office buildings, professional buildings and clinics. Units may be located under the window, over closets, in dropped ceilings or furred down spaces.

This chapter discusses the fan-coil unit system covering the System Description, System Features, Engineering Procedure and a control arrangement.

TYPE OF SYSTEMS

All-water fan-coil systems may be classified in two major groups:

1. Single (2-pipe) piping system in which a single supply of water (cold or hot depending on the reason) is available at each fan-coil unit and a single return piping system is utilized.
2. Multi- piping system in which a double supply of water (cold or hot) is available at each fan-coil unit and a single (3-pipe) or double (4-pipe) return piping system is utilized.

SINGLE PIPING SYSTEM

SYSTEM DESCRIPTION

This system (*Fig.1*) consists of central water heating and cooling equipment, fan-coil units, controls, interconnecting piping and wiring as required.

The fan-coil units system is designed to provide individual space temperature control without utilizing central station air handling equipment or ductwork. *Figure 2* illustrates the basic elements of the unit which include the air inlet, filter, fan and cooling and heating coil. The unit may be under-the-window or ceiling mounted.

Either a mixture of outdoor and return air or return air alone is supplied to the unit. Filters clean the air. The coil cools and dehumidifies during the summer and heats during the winter.

In *Fig.1* the outdoor air for the under-the-window unit is shown delivered directly to the unit by low pressure ductwork. Such a method is preferable to ventilation air introduced thru a wall opening (*Fig.2*). The use of a wall opening to introduce outdoor air to the fan-coil unit is not generally recommended for multi-story building. Stack and wind effects may affect adversely the performance of the units. In some instances air obtained by infiltration may be sufficient for ventilation, or air obtained from an interior zone system may be utilized for ventilation. Other methods of introducing outside air are discussed in *Part 11, Primary Air Fan-Coil System.*

Temperature control is maintained in two ways:

1. Fan speed adjustment or on-off fan control.
2. Water flow modulation or on-off water flow.

Electric reheat is sometimes installed at each unit to improve the operation of the fan-coil unit systems during the intermediate season. Motels particularly are a good application for electric reheat.

Chilled water from a central refrigeration plant is circulated thru the unit coils to remove excess moisture and cool the air during the summer. Hot water from a water heater is supplied to the same unit coils during the winter.

SYSTEM FEATURES

Features of the fan-coil unit system are:

1. *Individual Room Temperature Control* – The system is adaptable to such a control because each unit has an integral cooling and heating coil designed for chilled and hot water.
2. *Confined Room Air Circulation* – Each unit recirculates only room air. Therefore, recirculation of air between rooms is minimized.
3. *Economy of Operation* – Outdoor air is available during marginal weather for free cooling. An outdoor-room air proportioning damper at the unit provides control.

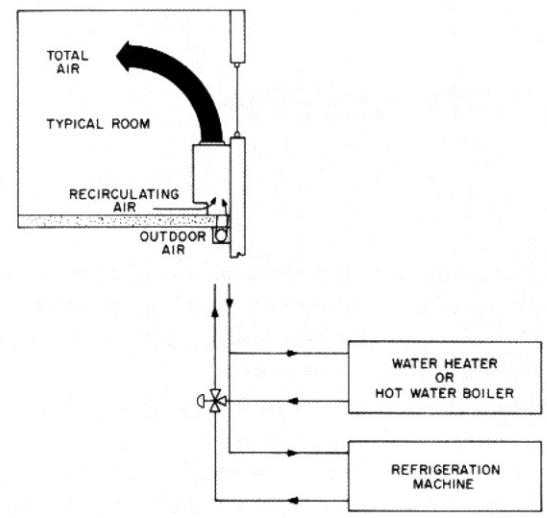


Fig. 1 – Two-Pipe Fan-Coil Unit System

4. *Minimum Ductwork, Cutting and Patching* - Design costs of ductwork are minimized since supply and return air ductwork are not normally required. Cutting and patching in old buildings is normally confined to requirements for water piping and ventilation.
5. *Under-the-Window Air Distribution* - Under-the-window upward air distribution is superior to other methods for small rooms, particularly those having a heating or year-round load.

ENGINEERING PROCEDURE

The following is a design procedure for a fan-coil unit air conditioning system. As in all design work a survey and preliminary layout *(Part 1)* are required. Room loads and minimum ventilation air quantities are determined by methods outlined in *Part 1*.

Room Cooling Load

Calculate the load for all typical spaces on east, west, north and south exposures and for any space that has an unusual load. It may be necessary to provide flexibility in these calculations to allow for future partition changes, depending on the type of application. Eight to sixteen room load calculations may be required for most multi-room applications. The computations should include both sensible and latent load requirements.

To determine the total sensible and cooling capacity required of the unit, ventilation air and room loads must be combined.

Room Heating Load

Calculate the room heating load in the normal manner. The computations should include the heating requirements to offset transmission and infiltration and sufficient heat to temper the outdoor air from the temperature at which it enters the unit to the room design temperature (depending on the type of system).

Unit Selection

Select the room units to satisfy the following requirements:

1. Maximum room and ventilation air cooling load, both sensible and total.
2. Maximum room and ventilation air heating load.
3. External resistance imposed upon the unit by additional required ductwork. The external resistance should be considered relative to its effect on the air volume and the cooling and heating capacity of the unit.

The unit is normally adequate for zone depths of approximately 20 feet. Vertical air distribution of the perimeter unit spreads out in blanketing the exterior wall and travels along the ceiling for a distance of 15 to 20 feet before falling toward the floor in return air circulation.

Select the fan-coil units so that the smallest units are used coincident with the highest water temperature. Water temperatures are usually selected between 45 F and 50 F. A few trial unit selections give an indication if the water temperature is acceptable.

The same water flow rate is used for heating as is used for cooling. System heating capacity is obtained by an adjustment of entering water temperature.

Convector heating during overnight, weekend or holiday periods is impractical; only one room heating load calculation with the unit fan operating is required.

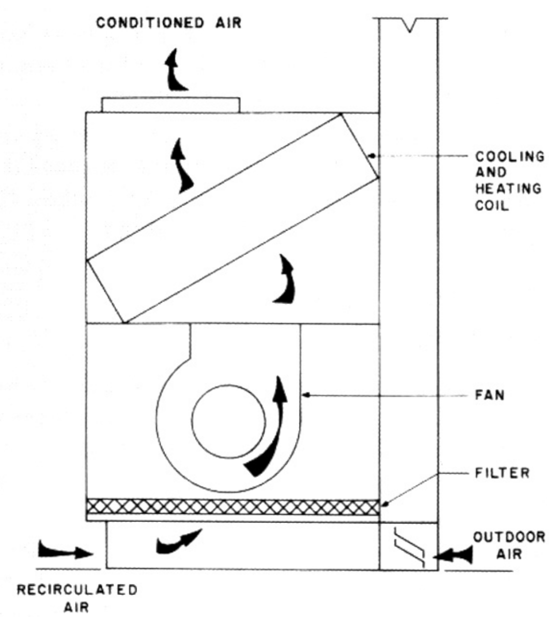


Fig. 2 – Typical Fan-Coil Unit

Piping Design

Design the piping system in the normal manner. A single piping system is used to circulate chilled or hot water to the unit coil. Good design practice should be followed in system layout *(Part 3)*. A reverse return system *(Fig. 3)* is recommended and should be used whenever it is adaptable to the building layout; this provides an inherently balanced system. Otherwise a direct return system may be used.

In buildings with units on more than one exposure a diversity factor should be applied as outlined in *Part 3*. In addition to resulting in smaller piping, headers and circulating pumps, diversity aids in minimizing sound problems when the system is operating at low water quantities. Diversity is not applied to the risers.

If more than one zone of water piping is desired, secondary circuits can be arranged accordingly. However, a three- or four-pipe system should be considered before designing a zoned single piping system.

The design water flow rate selected for the units can influence the total system cost. The lower the flow rate, the lower the first cost of the system piping and pump. However a check should be made to assure turbulent flow in the unit coil. The minimum flow per coil circuit to maintain turbulent flow conditions for a 3/8, 1/2, or 5/8 inch OD tube is approximately 0.5, 0.7 or 0.9 gpm respectively.

The secondary water pump is operated continuously and should be selected for an extremely flat head characteristic (Curve A, *Fig. 4*). Do not select a pump that has a steep head characteristic (Curve B, *Fig. 4*).

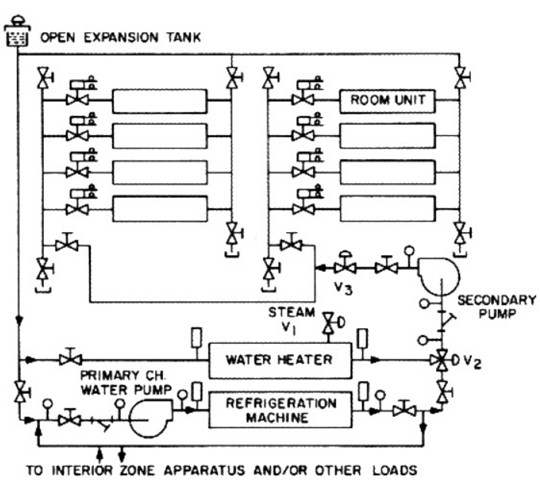


Fig. 3 – Schematic Water Piping, Two-Pipe Fan-Coils Unit System

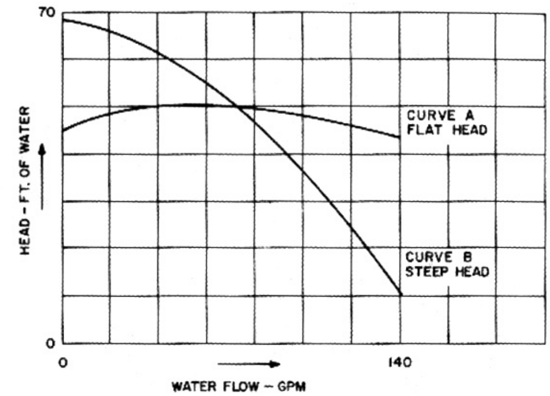


Fig. 4 – Pump Head Characteristics

Before the final secondary water pump selection is made, a check should be made to determine if head pressure control is required. When the water control valve (a three-way solenoid valve) in the closed position permits full water flow bypass around the coil, head pressure control is not required. If the water velocity in the runout is less than 10 fps, head pressure control is not required. Head pressure control requirements are determined by plotting the head curve of a trial pump selection (Curve A, *Fig. 5*). The system pressure drop curve is added at its various flow rates (Curve B, *Fig. 5*). The intersection of Curve A and B is the operating point of the pump at full load.

The sum of the pressure drops of the unit runout, fittings, control devices and unit coil are plotted in curve from (Curve C, *Fig. 6*). This is the pressure drop of the system at various water flow rates from the supply riser thru the unit and back to the return riser. The velocity of

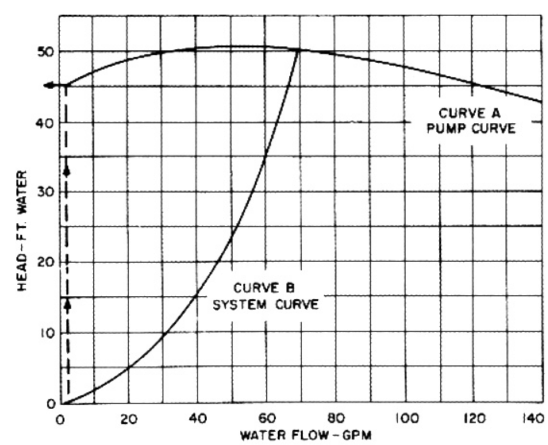


Fig. 5 – Pump Selection

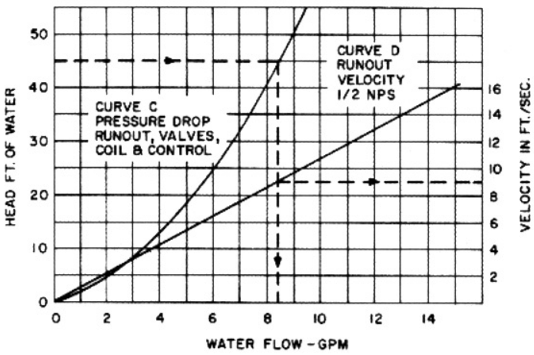


Fig. 6 – Runout Characteristics

the water flowing in the runout is also plotted for various flow rates (Curve D, *Fig. 6*). *Example 1* illustrates the use of *Fig. 5 and 6* in determining the water velocity in the runout when one unit is operating.

Example 1 – Runout Water Velocity

Given:

Figure 5 and 6

Unit design water quantity – 1 gpm

Find:

Water velocity in runout

Solution:

Enter *Fig. 5* at water flow gpm = 1.
Read head from Curve A = 45 ft water.
Enter *Fig. 6* at 45 ft water.
Read water flow from Curve C = 8.4 gpm thru the unit.
Enter *Fig. 6* at water flow = 8.4 gpm.
Read velocity from Curve D = 9.0 ft/sec in runout.

If the water velocity is above 10 fps, two courses of action are open:

1. Add head pressure control at the pump, or
2. Redesign the piping for a lower pressure drop so that the pump with a lower head at shutoff can be selected.

Optimum design of drain piping considers the type of ventilation air supply provided. When the fan-coil unit system handles the entire dehumidification of outdoor and recirculated air, there is a substantial amount of condensate from the units. However if the system draws ventilation air from an interior zone (conditioned by a separate system), very little condensate collects. The amount of condensate is, therefore, a consideration when sizing drain piping.

Vaporproof insulation is required for water piping and runouts.

Refrigeration Load

The refrigeration load is established by the peak building load (or block estimate) of the areas served by the system. Such an estimate includes all the applicable items to be found on an Air Conditioning Load Estimate from shown in *Part 1*. Provide 5% allowance for overcooling in the block load estimate.

CONTROLS

A typical control arrangement for the fan-coil unit and secondary water coil circuit is shown in *Fig. 7and 8* respectively. *Figure 7* is a schematic of a control package consisting of a solenoid valve operated from a room thermostat in conjunction with a manual multi-speed fan switch.

Unit Control

Sensible and latent cooling capacity when the performed by a single element cannot be adjusted to the wide range of coil sensible heat ratios which occur in comfort cooling. Maintenance within acceptable limits of

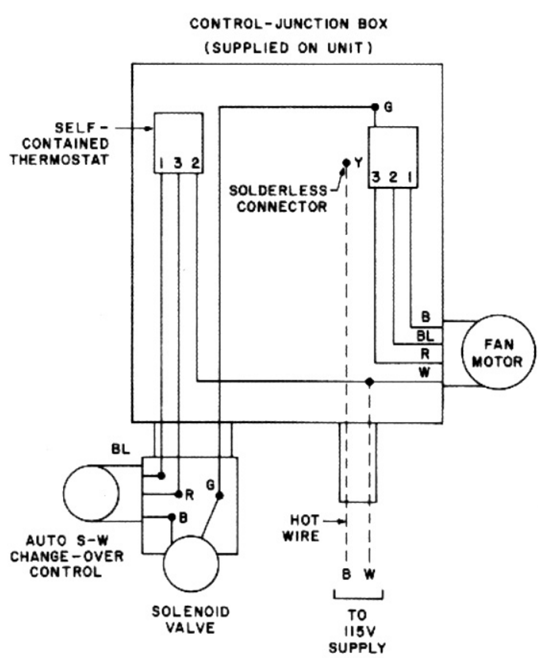


Fig. 7 – Control Package, Manual Three-Speed Fan Control with Automatic On-Off Water Flow

room relative humidity is specified in order to provide desired dry-bulb temperature. Room conditions may be controlled by fan speed adjustment for cooling or by on-off fan control for heating. It may also be controlled by a combination of fan speed adjustment and on-off water flow to the heat transfer coil within the unit (or water flow modulation).

Basic control at the unit is accomplished by a multi-speed fan switch. Control of the water flow thru the unit coil may be manual, electric or pneumatic.

Continuous design flow of chilled water thru the cooling coil provides better maintenance of room humidity levels. However even with multi-speed fan control for loads below that equivalent to the minimum fan speed, the room temperature cannot be maintained and the fan must be shut down. Typical room temperature and humidity conditions for a fan-coil unit with manual, three-speed fan control are illustrated in *Fig. 9*.

When unit fans are shut down, the chilled water to the coils should be shut off, preferably automatically, to prevent damage from condensation. If the chilled water is permitted to flow, the entire unit may approach the temperature of the chilled water, including the condensate pan and drain line. This can lead to condensation problems, such as water spotting and mildew.

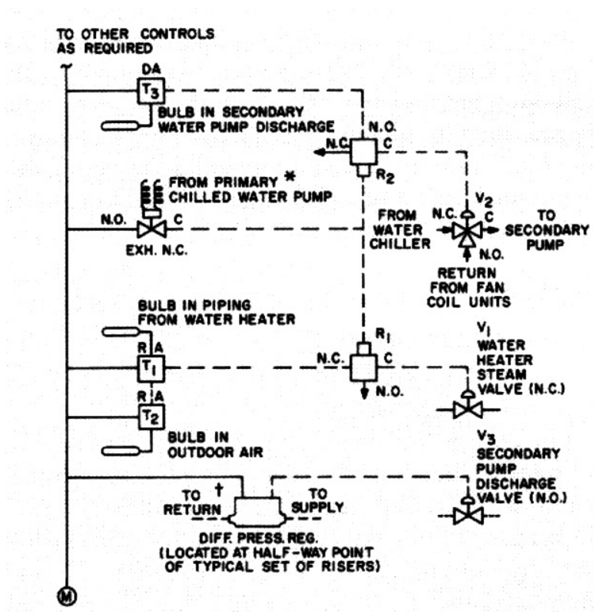


Fig. 8 – Control Diagram, Pneumatic, Two-Pipe Fan-Coil Unit System

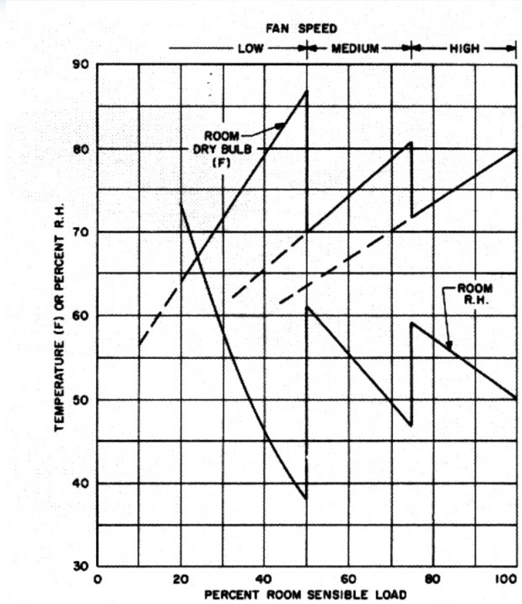


Fig. 9 – Room Temperature and Humidity Conditions, Manual Three-Speed Fan Control

Modulated control of chilled water thru the cooling coil allows the room humidity level to rise as the room sensible load falls. Typical room temperature and humidity conditions for such a control are shown in *Fig. 10*.

Typical room temperature and humidity conditions for manual, on-off fan control are illustrated in *Fig.11*.

When selecting a control system, it is recommended that:

1. The room thermostat should be located on the room wall and not at the unit when outdoor air is admitted directly to the unit.
2. Means should be available to shut off the flow of outdoor air to the unit to prevent coil freeze-up in winter when the unit is shut down. This provision should be made when ventilation air is admitted to the unit thru a wall opening.

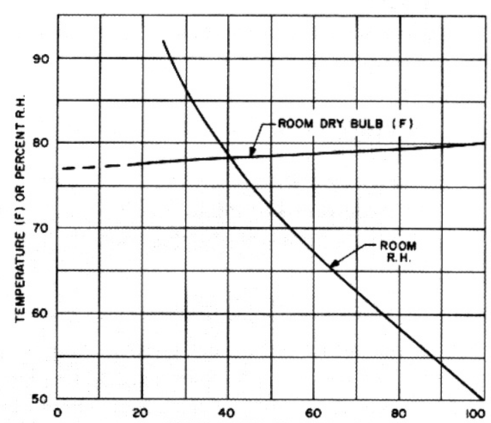


Fig. 10 – Room Temperature and Humidity Conditions, Automatic Modulated Water Control

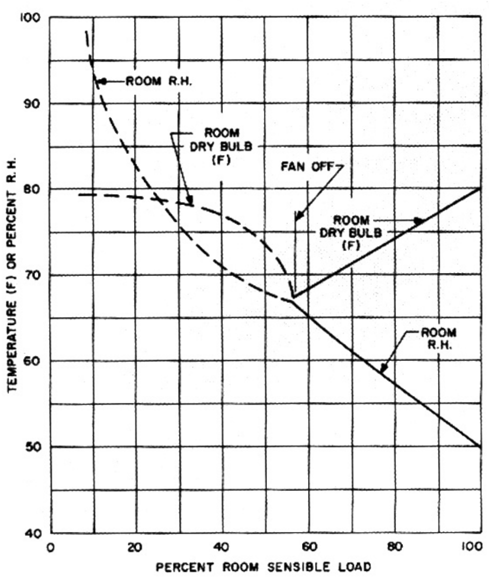


Fig. 11 – Room Temperature and Humidity Conditions, Manual On-Off Fan Control

Secondary Water Coil Circuit Controls

Either electric or pneumatic controls may be used for control of the water temperature to the fan-coil units. The sequence of operation is the same regardless of which is used.

Summer Operation

Outdoor air damper control may be either manual or automatic when ventilation is obtained thru an outside wall opening at the unit. If automatic control is used, the damper may be operated from the unit fan motor control to open when the fan is started. If outdoor air is supplied by a separate fan system thru low pressure ductwork, the fan may be started manually. With the primary chilled water pump running, the secondary water thermostat at the secondary water pump discharge controls a three-way mixing valve *(Fig. 8)*. It maintains a constant secondary water temperature to the fan-coil units.

The room or unit thermostat *(Fig. 7)*controls the solenoid valve in the water line to the unit coil. A manual multi-speed fan switch is adjusted by the room occupant as required.

Winter Operation

The outdoor air damper operates as in summer. With no need for chilled water the primary chilled water pump is shut down. The three-way mixing valve is positioned to channel the secondary water from the fan-coil units thru the water heater, to the secondary water pump, and then to the units. The water heater stream valve is controlled by a thermostat at the leaving side of the water heater. The thermostat is reset by a master outdoor air thermostat to maintain a scheduled hot water temperature relative to the outdoors.

Automatic summer-winner change-over control *(Fig. 7)* senses the hot water temperature at the unit and reverses the action of the room or unit thermostat for winter operation. The thermostat opens or closes the solenoid valve in the water line to the unit coil. The manual multi-speed fan switch is adjusted by the occupant as desired.

MULTI-PIPING SYSTEM

SYSTEM DESCRIPTION

Figure 12 is a sketch of a 3-pipe system and *Figure 13* shows a 4-pipe system.

The ability of a single piping system to satisfy the constantly changing heating and cooling requirements of individual perimeter spaces increases with the number of zones provided. A multi-piping system provides hot and chilled water at each fan-coil unit the year round. In effect each unit then is a separate zone and functions independently. Its control valve selects either hot or chilled water for the unit coil depending on whether the module it serves requires heating or cooling. Simple, nonreversing thermostats may be utilized and change-over controls are not required. Design water quantities for the heating load may be minimized.

Certain aspects of the three-pipe system should be investigated before deciding on a system design since three-pipe systems are covered by one or more patents. Although the system permits substantial first cost savings by using a common return, the operating costs are somewhat higher than those of a four-pipe system because of the mixing in the common return of water from the units operating on heating with water from the units operating on cooling.

The four-pipe system provides isolation of the hot and cold water circuits to minimize hydraulic problems. A single or split coil may be used at the unit. A split coil simplifies unit piping

Two methods of operation are commonly used for multi-piping systems. The first method gives complete year-round temperature control in the room. Hot and cold water are necessaryat the room until at all times of the year. If the room temperature is too cold, hot water flows thru the fan-coil unit. If the room temperature is too warm, cold water flows thru the fan-coil unit. The second method of operation has hot and cold water available at the room unit only during the intermediate seasons. It is used when economy of operation is paramount and adequate room temperature control is desired. The sequence of equipment operation is shown in *Chart 1*. The temperatures at which the cooling and heating equipment is started and stopped vary from building to building.

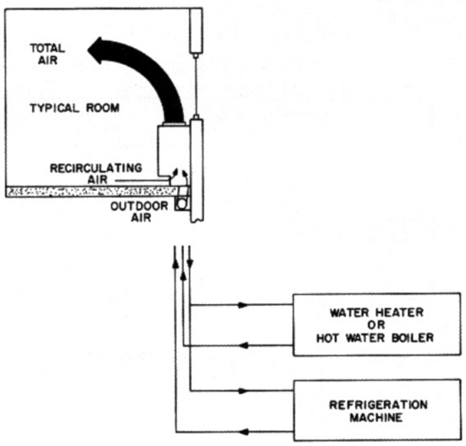


Fig. 12 – Three-Pipe Fan-Coil Unit System

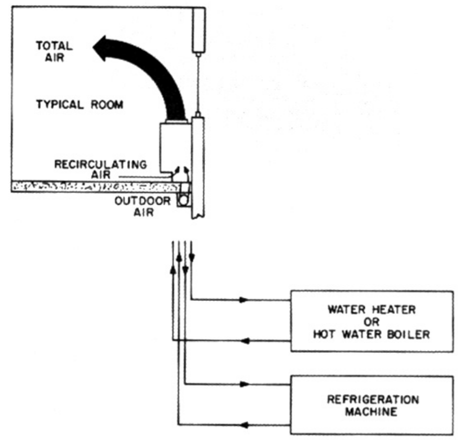


Fig. 13 – Four-Pipe Fan-Coil Unit System

SYSTEM FEATURES

In addition to the features of the fan-coil unit system as itemized under Single Piping System, additional features of the multi-piping system are:

1. *Quick Response to Thermostat Settings* – A change in thermostat setting is immediately apparent because hot and cold water are available at each unit. Quick response is psychologically advantageous
2. *Elimination of Zoning by Exposure* – Multiple pumps, zoned piping and allied controls are eliminated because each space is a zone in itself as compared to the single piping system.
3. *Elimination of Operational Difficulties of Change-over* – When the system is properly designed, change-over is not required and operation is simplified.
4. *Year-round Room Temperature Control* – Tenant complaints during the intermediate season are eliminated because of the availability of both heating and cooling.

CHART 1 – OPERATING SCHEDULE

OPERATING SCHEDULE		
OUTDOOR TEMPERATURE	REFRIGERATION EQUIPMENT	BOILER
95 – 70	ON	OFF
70 – 50	ON	ON
50 – 0	OFF	ON

ENGINEERING PROCEDURE

The design procedure for a multi-piping system is similar to the design of a single piping system. The few differences in design procedure are created by the piping system and involve piping design, controls and hot water quantities.

Unit Selection

Water quantities for the design heating load should be selected to give as high a rise as possible while matching the required heating load coincident with turbulent flow.

Piping Design

A multi-piping system is used to circulate chilled and hot water to the fan-coil unit.

The cold water supply and the common return line on a three-pipe system are sized first. Both headers are designed using a diversity factor. Several pumping arrangements can be used with this system. With a separate hot water pump *(Fig. 14)*, the hot water piping is designed in accordance with normal practice.

A four-pipe system completely isolates the cold and hot water systems *(Fig. 15)* so that the piping for each system may be designed independently using a diversity factor on the chilled water supply and return headers.

The secondary and hot water pumps are selected for an extremely flat head characteristic *(Fig. 4)*. Head pressure control requirements, if any, should be determined as in *Example 1*.

Heating Load

The heating load is established from a summation of the room heating loads plus 20% for quick warm-up.

Heating equipment can be either a stream

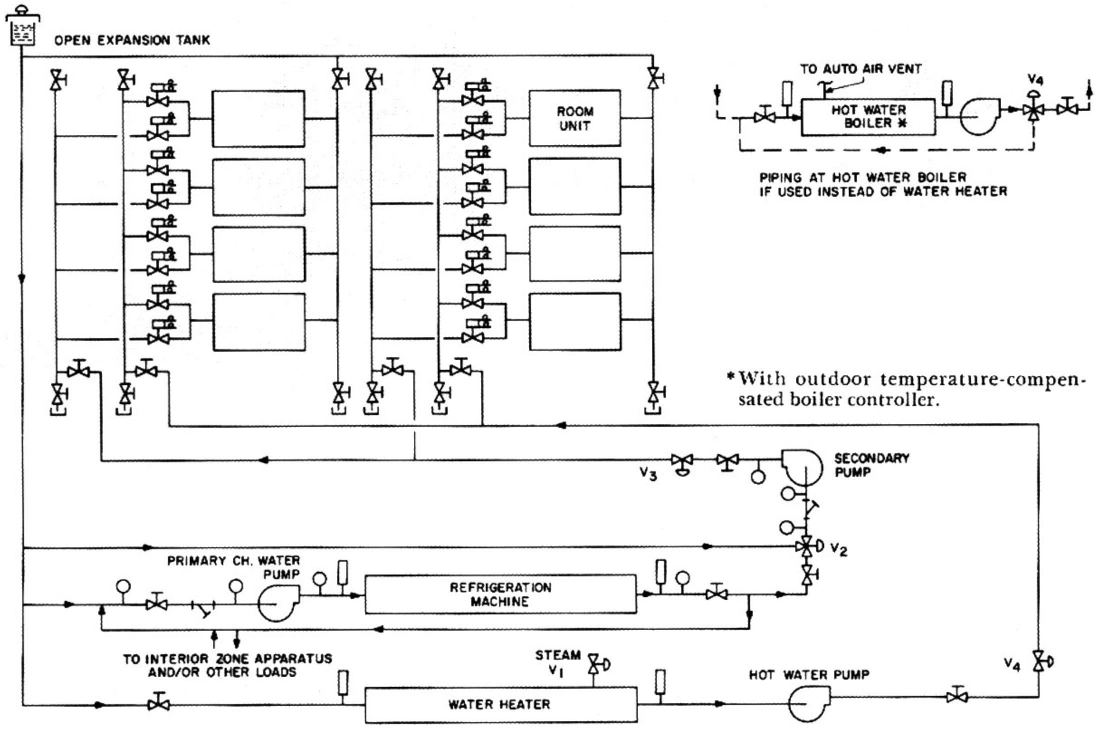


Fig. 14 – Schematic Water Piping, Three-Pipe Fan-Coil Unit System

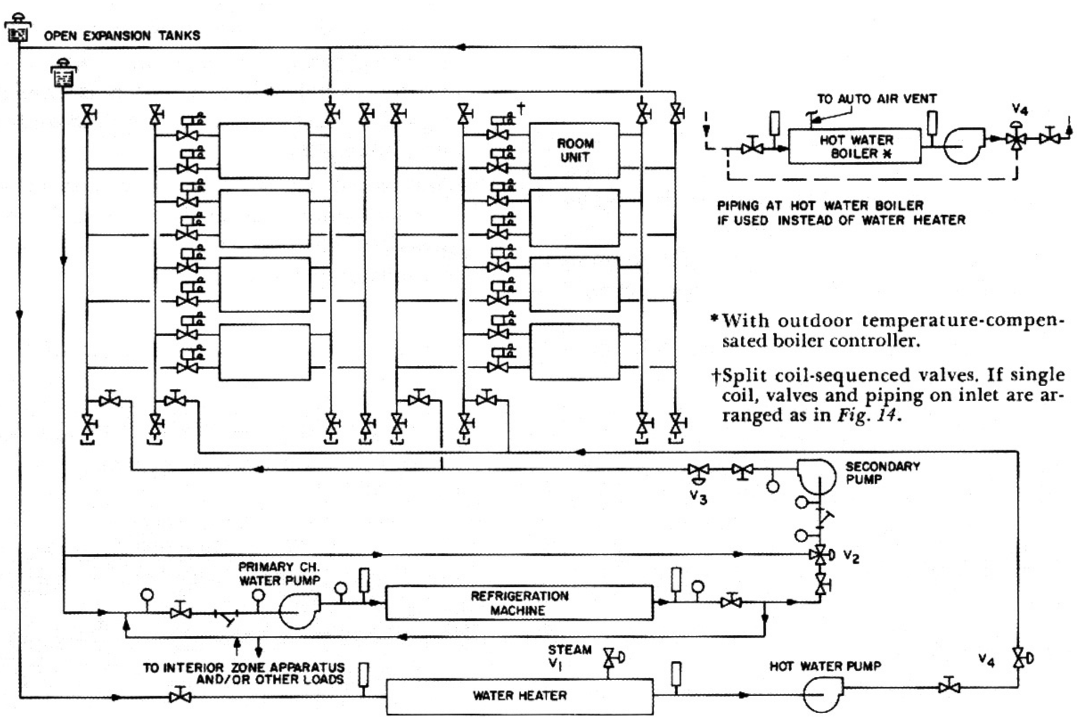
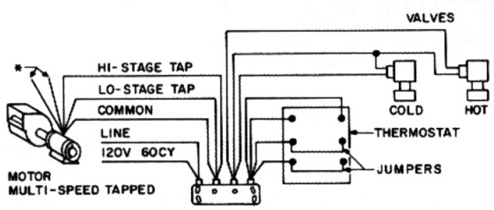


Fig. 15 – Schematic Water Piping, Four-Pipe Fan-Coil Unit System



* Choose taps to give desired Hi and Lo stage speeds.

Fig. 16 – Wiring Diagram, Three-Pipe and Four-Pipe Fan-Coil Unit System Using Multi-speed Motor

converter or a hot water boiler. The design water temperature is that which is determined from the unit selection. The water quantity is that determined from the sum of the individual room requirements.

CONTROLS

Control arrangements are many and varied. Pneumatic, electric or manual are used. Unit controls are often electric and may be automatic or partially automatic.

Typical control arrangements for the fan-coil unit and secondary chilled and hot water coil circuits are illustrated in *Fig. 16, 17 and 18* respectively. The control is fully automatic at the unit.

Unit Control

On a three- or four-pipe system two control valve actions are required, one to control hot water and a second to control cold water. In addition, fan speed adjustment and/or on-off air flow may be accomplished. The control valve action may be modulating or two-position. Manual control valves should not be used with any multi-piping system.

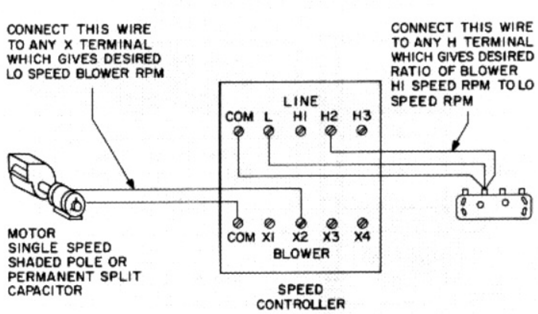
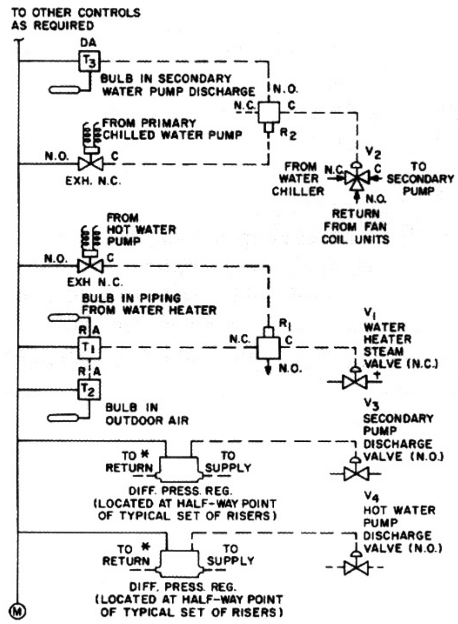


Fig. 17 – Wiring Diagram, Single Speed Motor



*Head pressure control required only if water velocity in unit runout exceeds 10 ft/sec.

†When using hot water boiler, use outdoor temperature-compensated boiler controller.

Fig. 18 – Control Diagram, Pneumatic, Three-Pipe Or Four-Pipe Fan-Coil Unit System

The sequence of operation for fully automatic control is shown graphically in *Fig. 19*.

Secondary Chilled Water and Hot Water controls

Either electric or pneumatic controls may be used for control of the water temperature to the fan-coil units. The sequence of operation is the same regardless of which is used.

With the primary chilled water pump running, the chilled water thermostat at the secondary chilled water pump discharge controls a three-way mixing valve *(Fig. 18)*. It maintains a constant chilled water temperature to the fan-coil units. With the hot water pump running, the hot water thermostat at the leaving side of the water heater controls the water heater stream valve. The thermostat is adjusted by a master outdoor air thermostat to maintain a scheduled hot water temperature relative to the outdoors.

Referring to *Fig. 19*, on a rise in room temperature the unit fan is started on low speed and the cold water solenoid valve is opened. On a further rise in room temperature, the fan is automatically changed to high speed. As the room temperature approaches the

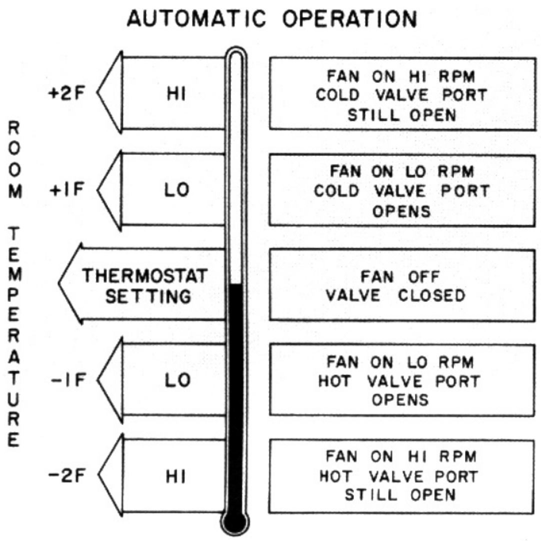


Fig. 19 – Unit Control Operation

thermostat setting, the fan returns to the low speed setting; when the thermostat is satisfied, the fan and cold water solenoid are shut off. On a drop in temperature the fan is started on low speed and the hot water solenoid valve is opened. On a further drop in room temperature the fan is automatically changed to high speed.

This control arrangement offers the advantage of longer operation at minimum sound level with close temperature regulation. For a few hours of peak load the fan is automatically changed to high rpm to give maximum heating or cooling capacity.

CHAPTER 2. DX SYSTEMS

DX systems are confined to the smaller and intermediate tonnage air conditioning and refrigeration applications. Packaged centrifugal and absorption machine liquid chillers are used for the higher tonnages.

DX systems for air conditioning or liquid chilling are those employing field-fabricated refrigerant piping. Condensing units and remote condenser (reciprocating) liquid chilling packages may be utilized in such systems. The piping interconnects reciprocating compressors, condensers and cooling coils or liquid chillers.

Refrigerant piping becomes economically less attractive as the amount of piping and distance between compressor, evaporator and condenser increases. The use of a cooling tower and/or reciprocating liquid chiller may then be more economical.

This chapter includes System Description, System Features and Engineering Procedure.

SYSTEM DESCRIPTION

Field-fabricated refrigerant piping is required for an air conditioning system using direct expansion coils and for a liquid chiller with a remote condenser. It is also required between the coils, the reciprocating compressor and the condenser when using direct expansion coils in either a built-up apparatus, fan-coil equipment or both. The minimum piping required for a liquid chiller (unless close-coupled) is that needed to connect the compressor and the condenser.

DIRECT EXPANSION AIR COOLING

Figure 20 is an isometric of a typical basic refrigeration system serving fan-coil equipment and utilizing direct expansion coils. Two compressors in parallel using an evaporative condenser and a sub-cooling coil provide refrigeration for direct expansion coils in each of three fan-coil units. A liquid suction interchanger in the liquid line from the sub-cooling coil increases the refrigerant cycle efficiency.

Capacity control at the compressors maintains a relatively stable suction pressure at the direct expansion coils. Solenoid valves in the liquid line to each coil are de-energized to shut off the flow of liquid refrigerant when its respective fan-coil unit is shut down.

LIQUID CHILLING

Figure 21 is an isometric of a typical DX system for water chilling. A packaged water chiller utilizes an evaporative condenser for condensing. The water chiller illustrated is a dry expansion cooler and is dual circuited. Chilled water temperature is controlled by compressor capacity and cooler circuit control.

Although dry expansion coolers are used on most applications, flooded coolers are available *(Fig.22)*. Dry expansion coolers are desirable because of:

1. Low first cost
2. Smaller space requirements
3. Minimum refrigerant requirements
4. Minimum freeze-up possibilities
5. Minimum oil return problems

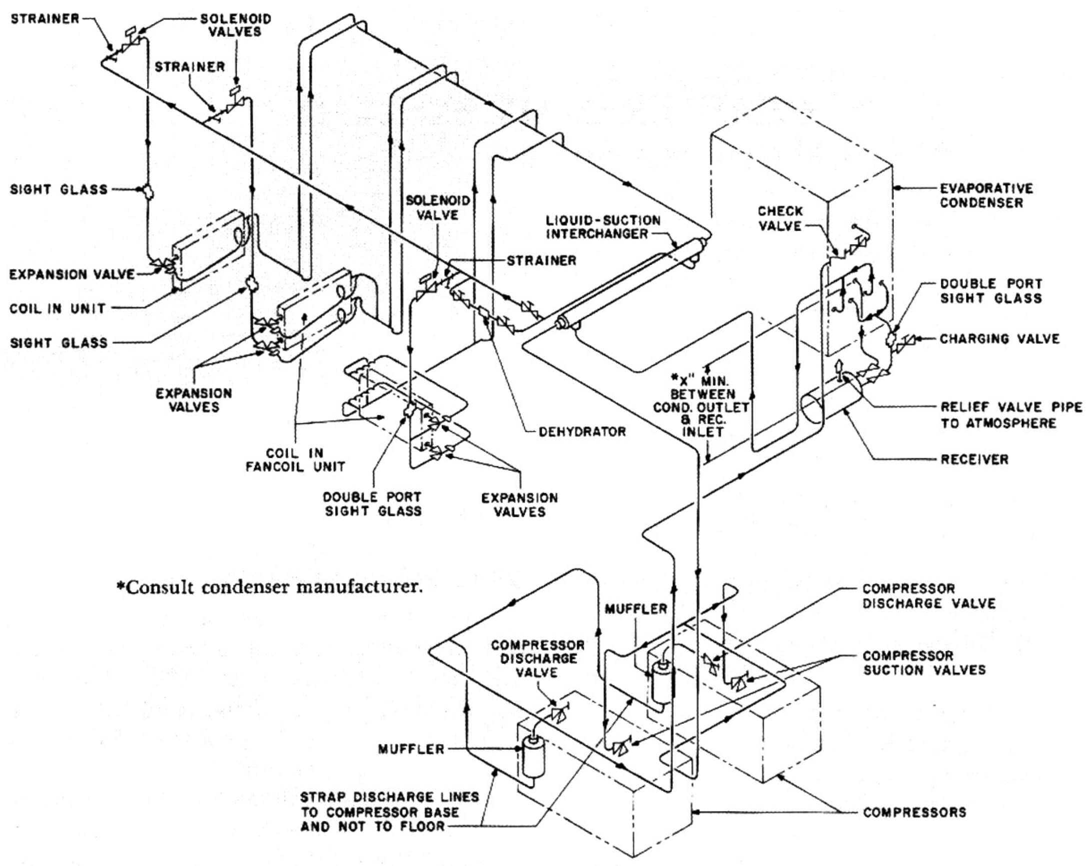


Fig. 20 – Refrigeration System Supplying Direct Expansion Coils

SYSTEM FEATURES

Features of the DX system are:

1. *Flexibility* – Physical layout and matching of equipment is more flexible.
2. *Low First Cost* – Reciprocating machines provide the lowest capital expenditure for refrigeration applications below approximately 100 tons.
3. *Suitability* – The trend towards air-cooled condensers makes the system suitable for many refrigeration applications. In addition the system can be used with an existing air handling apparatus which includes direct expansion cooling coils.

ENGINEERING PROCEDURE

The following procedure is offered to assure a practical basic refrigeration system. As in all design work a survey and preliminary layout are required as covered in *Part 1*. Refrigeration load is determined by using the method applicable to the particular type of air conditioning system *(Part 1)*.

The utilization of a single compressor and condenser is desirable when designing a DX system because of lower first cost, smaller space requirements and minimized hydraulic problems.

However multiple compressors and condensers are commonly used. Factory packages consisting of liquid chiller, multiple compressors and condensers are satisfactory because of low mass production costs and single controlled design.

When a single compressor or condenser of adequate size is unavailable to match load requirements, it may be advisable to design several systems each having its own evaporator, compressor and condenser. This is done with the understanding that the load may be readily divided into smaller portions which can be physically and more conveniently located apart.

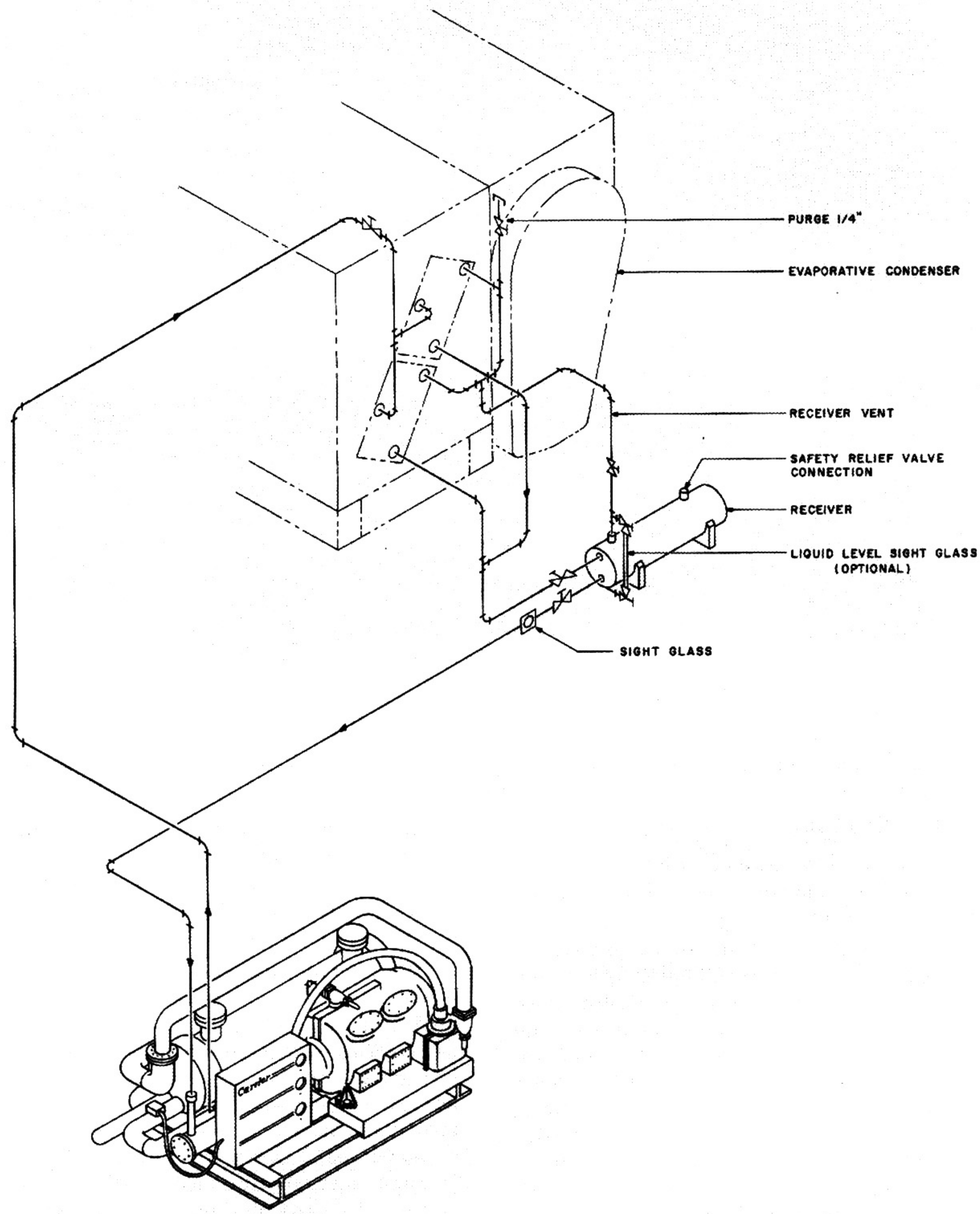


Fig. 21 – Dry Expansion Reciprocating Liquid Chilling Package with Evaporative Condenser

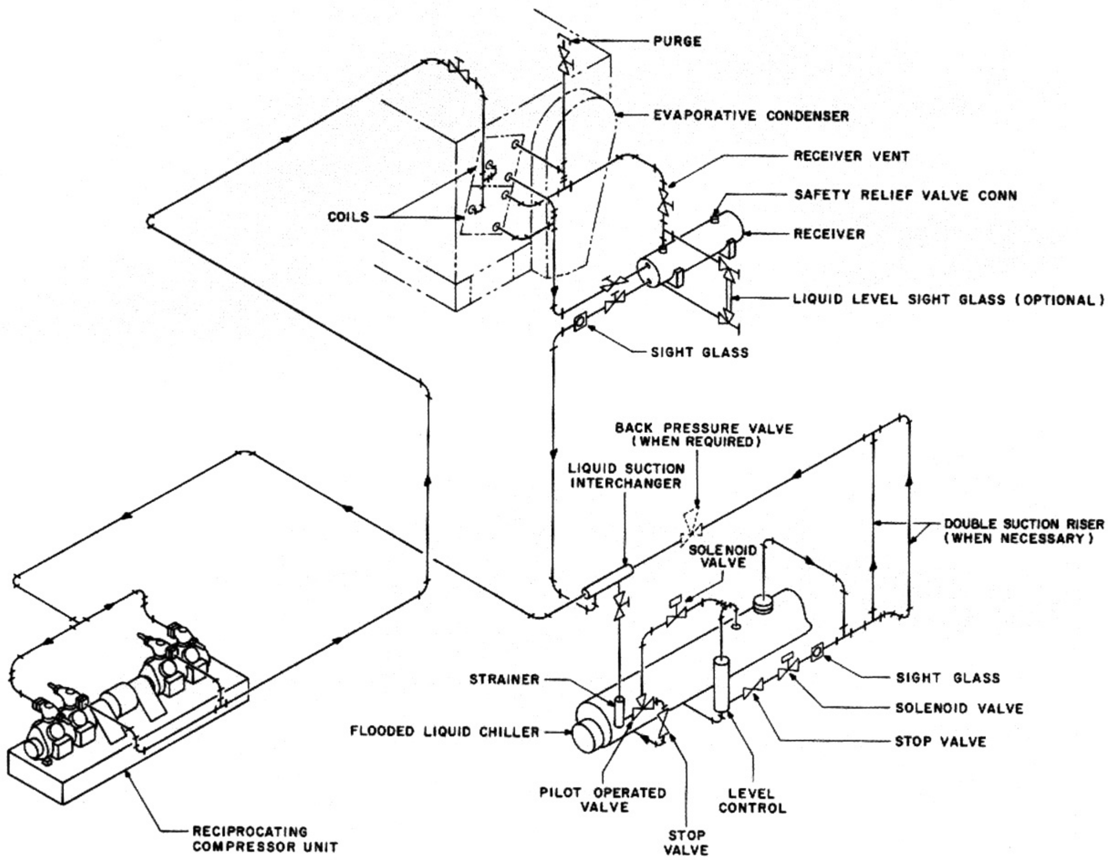


Fig. 22 – Flooded Liquid Chiller and Reciprocating Compressors with Evaporative Condenser

EQUIPMENT SELECTION

When selecting equipment, primary considerations involve the evaporator, condensing media and component balancing.

Evaporator selection is logically the first step in the selection of equipment for a basic refrigeration system, whether direct expansion or chilled water. In order to satisfy the established conditions of air quantity and entering and leaving wet- and dry-bulb temperatures, a specific coils surface is required. Direct expansion air cooling coils may therefore be selected without having to consider the refrigeration machine or condenser. The selection of the refrigeration machine requires the determination of the refrigerant temperature from the cooling coil selection. This invariably proves more economical than the completely arbitrary choice of an initial refrigerant temperature.

Chilled water quantity and temperature are pre-determined for air conditioning or process work. The chiller of a liquid chilling plant should therefore be selected prior to the compressor. An adjustment of chiller size may prove desirable when balancing the components.

The selection of a condensing media is an economic consideration. In some cases it is a matter of preference. Air cooling, water cooling and evaporative cooling methods of condensing are available. The greater the distance between refrigeration and heat rejection equipment, the more economically favorable is the cooling tower (water cooling method of condensing). In other circumstances, despite higher power costs an air-cooled condenser is selected because of scarcity of water, less maintenance, nonicing features and simplicity.

Some components of the system such as the evaporator can be selected individually based on operating requirements and without particular regard to other components in the system. However most components should be selected so that when operated

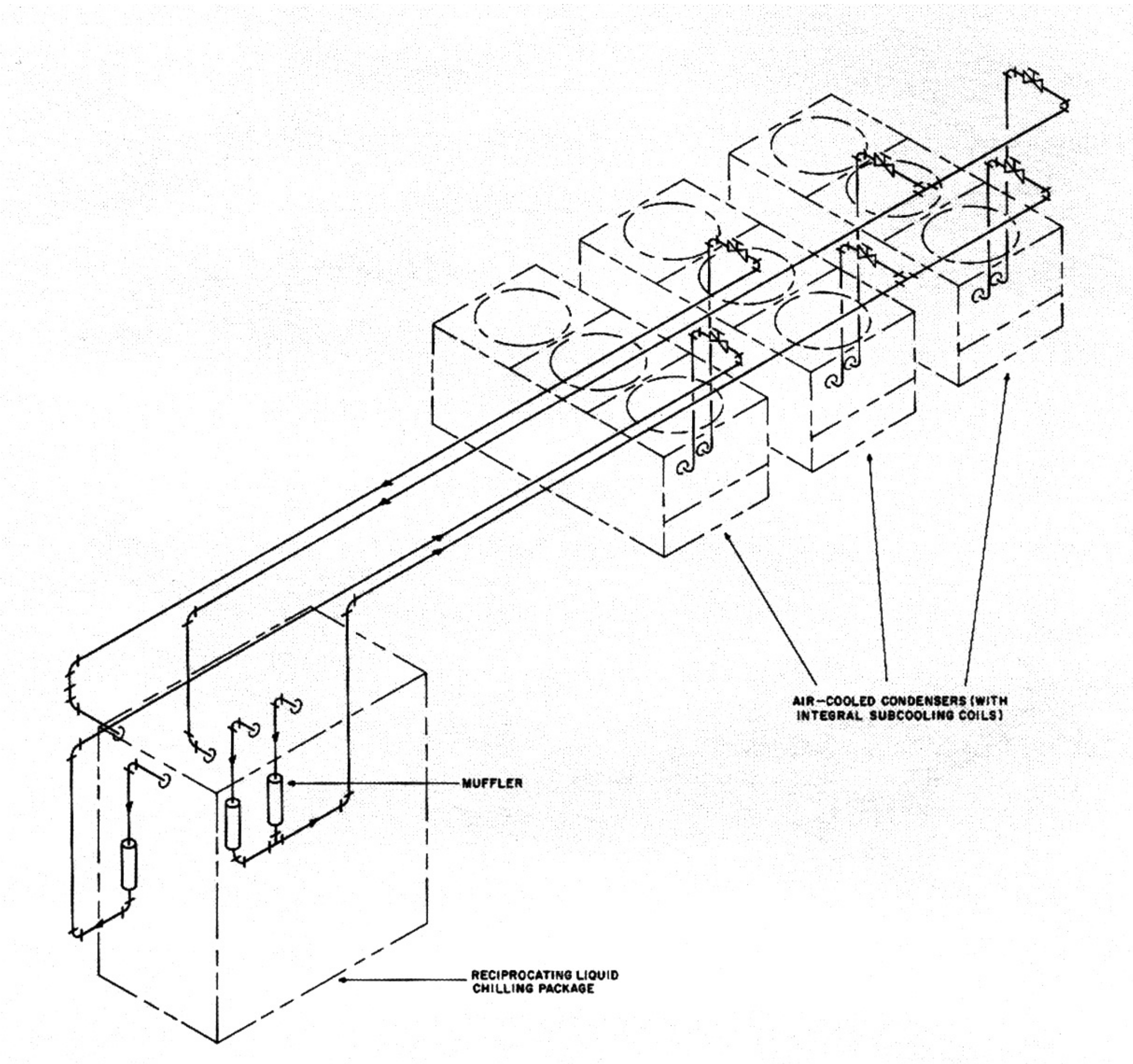


Fig. 23 – Reciprocating Liquid Chilling Package with Air-Cooled Condensers, Three Compressors

together as a system, performance requirements are satisfied.

Balancing of the components of a basic refrigeration system is covered in *Part 7*. In general more than one combination of components meets the performance required of the system. Examination of several such combinations should be made to determine the optimum design.

The selection and balancing of system components influences the initial operating cost of the system. If optimum first cost is desired, compressor design, suction and head pressures are secondary; if optimum operating cost is desired, pressures are of primary importance.

Accessories such as liquid subcooling equipment and liquid suction interchangers should be considered when balancing components of the systems. These accessories are covered in *Parts 3, 4 and 7*.

Utilization of liquid subcooling increases the capacity of both the compressor and the condenser by the same amount. The evaporator is not affected.

The use of liquid subcooling:

1. Provides an increase in system capacity.
2. Subcools the liquid to offset the effect of moderate lifts.

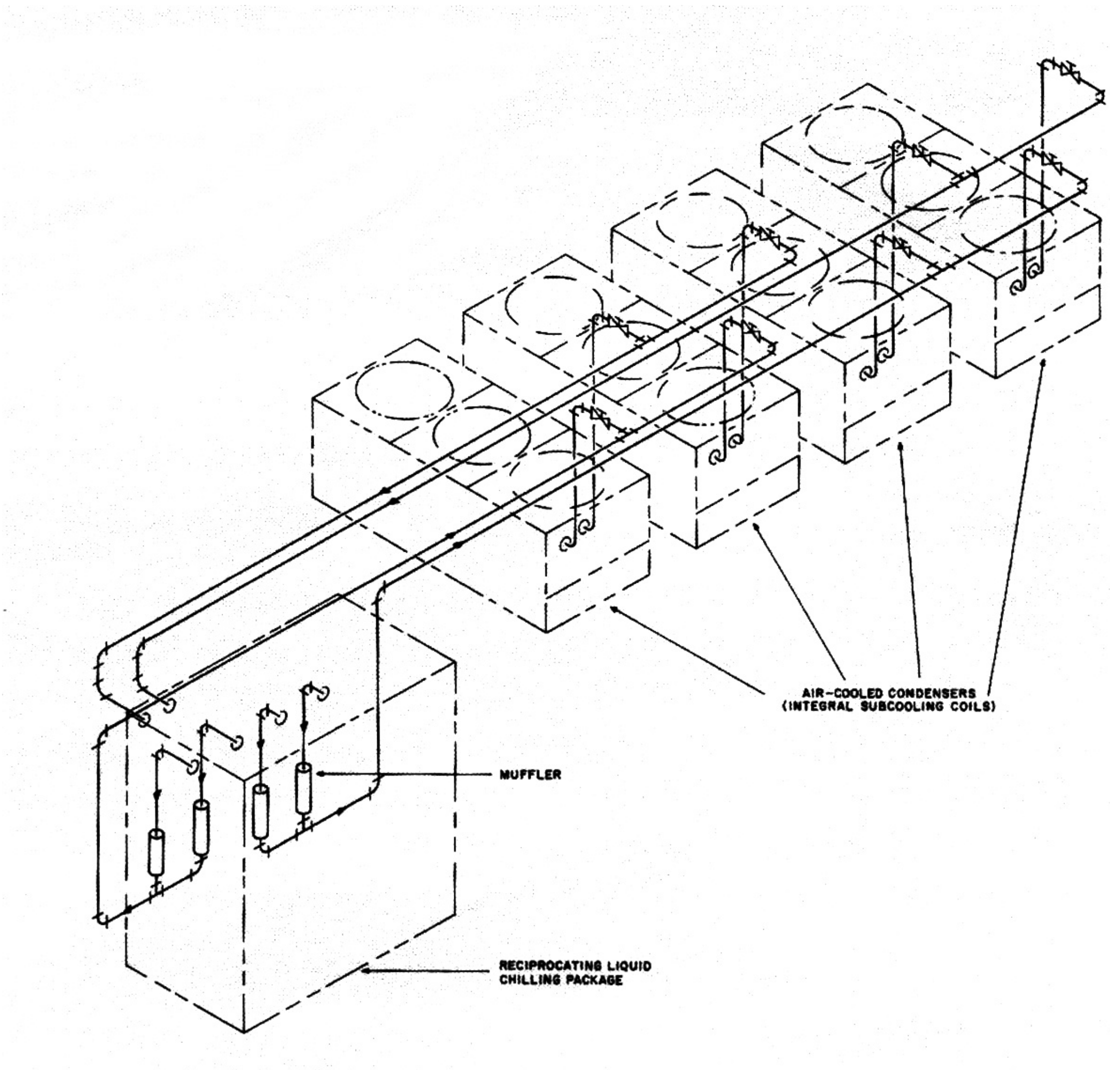


Fig. 24 – Reciprocating Liquid Chilling Package with Air-Cooled Condensers, Four ,Compressors

3. Reduces horsepower per ton of refrigeration.

When the balanced capacity of a combination of compressor and evaporative condenser is slightly undersize, it is normally more economical to add a subcooling coil than to select the next larger combination. The capacity of the condenser and compressor is increased by the same amount because with subcooled liquid each pound of refrigerant evaporated does more work. While increasing the capacity of the system, subcooling does not require any additional horsepower. Therefore the horsepower per ton of refrigeration is reduced.

Compressor ratings for Refrigerants 12 and 500 are generally based on 65 F actual suction gas temperatures. When this suction gas temperature is not obtained at the compressor, its rating must be lowered by an appropriate multiplier. To develop the full rating the required superheat over and above that available at the evaporator outlet may be obtained by means of a liquid suction interchanger. The effect of a liquid suction interchanger on the refrigeration cycle is discussed in *Part 4*.

PIPING DESIGN

Piping design *(Part 3)* should be followed when

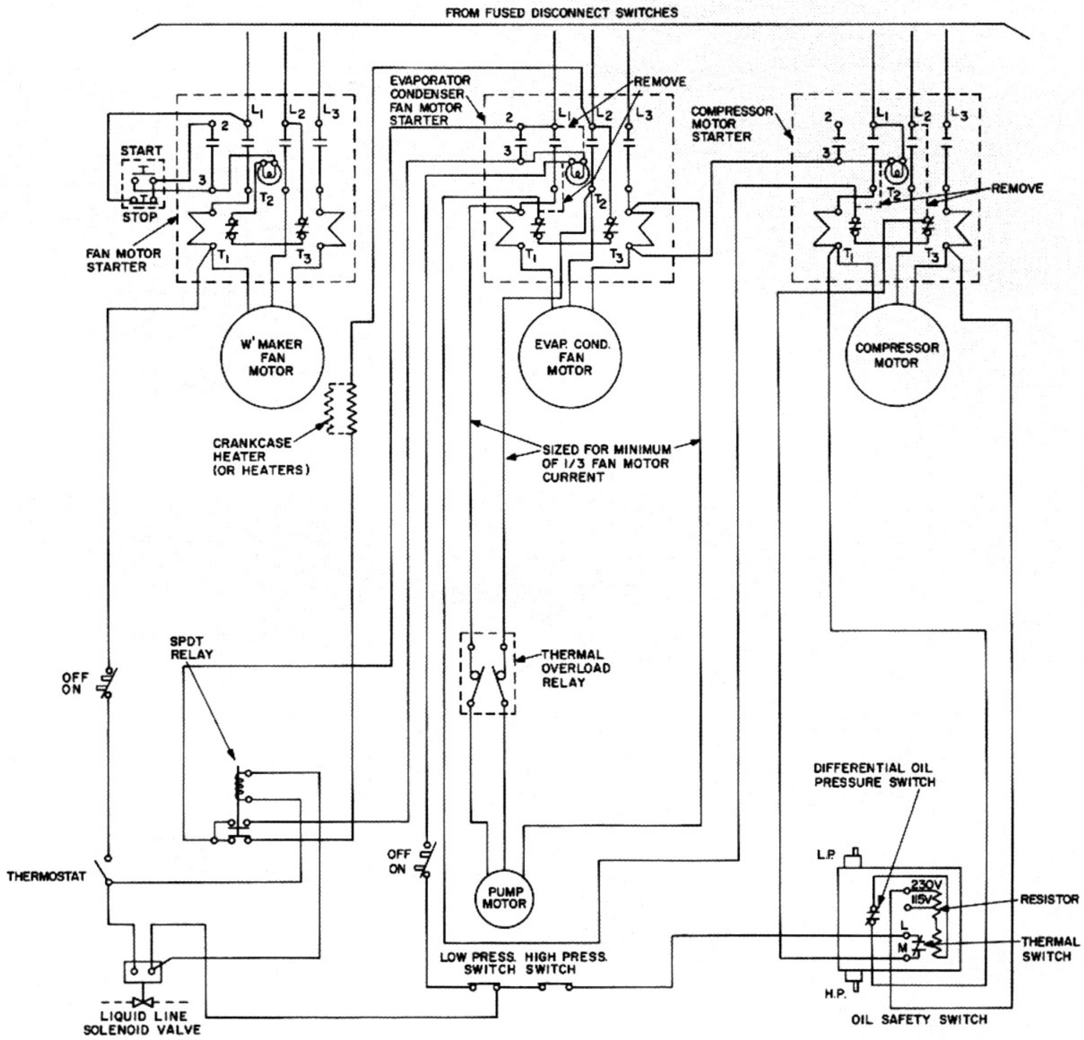


Fig. 25 – Typical Wiring Diagram for Evaporative Condenser Installation, 208-220 Volts, with Single Pumpout Compressor Control and Crankcase Heater

multiple or single compressors, condensers and evaporators are selected for a system.

Remote condenser type reciprocating liquid chiller packages require field-fabricated refrigerant piping between the compressors and condensers. Piping design and condenser selection should be made as recommended in *Part 3*.

Figures 23 and 24 illustrate a layout for a reciprocating water chiller package utilizing air-cooled condensers. In *Fig. 23* the water chiller package consists of three compressors and a dual circuited cooler. Two compressors, two condensers and one cooler circuit are joined while the remaining compressor, condenser and cooler circuit are similarly connected. The condensers utilized in this instance are air-cooled with integral subcooling coils. Receivers are not used with this type of condenser because of the liquid seal maintained and the

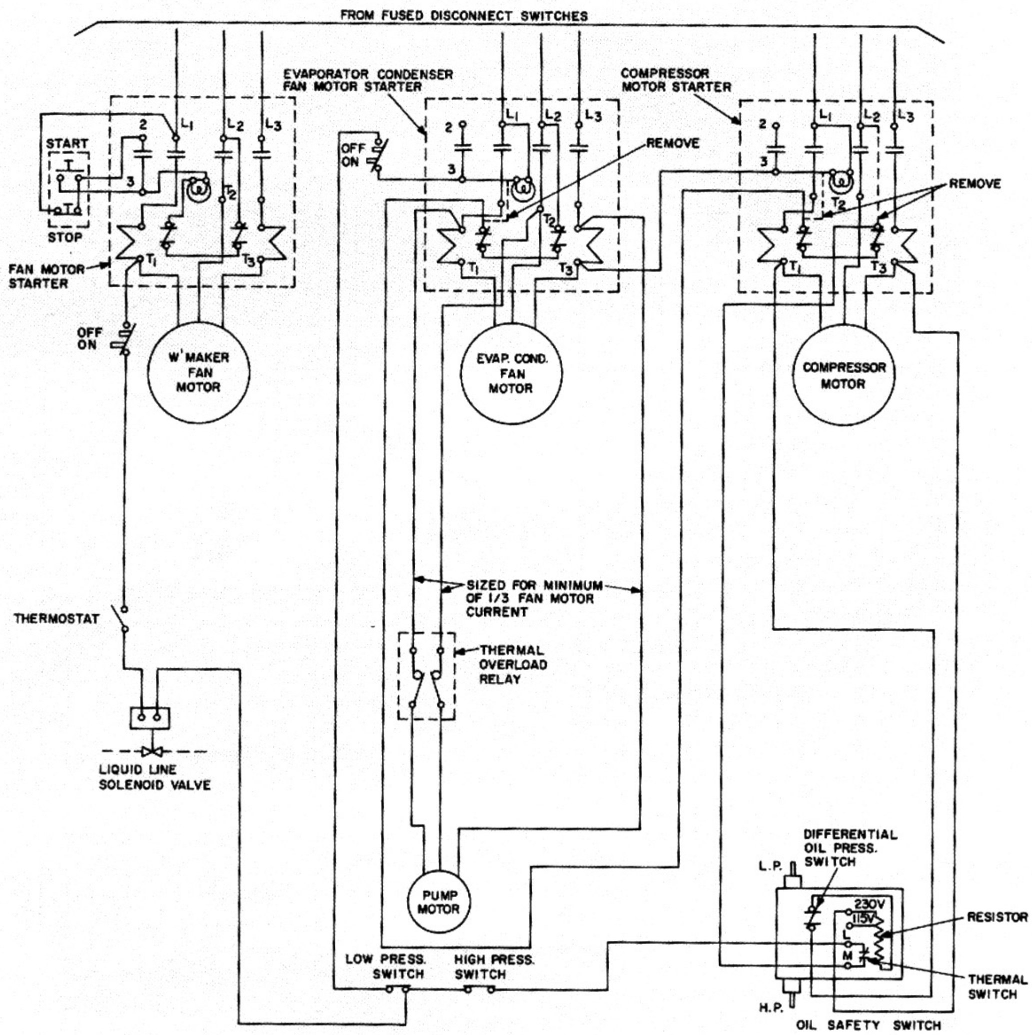


Fig. 26 – Typical Wiring Diagram for Evaporative Condenser Installation, 208-220 Volts, with Pumpdown Compressor Control

storage capacity afforded by the subcooling coil. The liquid refrigerant is piped directly from the liquid connection at the condenser to the chiller.

In *Fig. 24* the water chiller package consists of four compressors, four condensers and a dual circuited cooler. Two compressors, two condensers and one cooler circuit are connected while the remaining compressors, condensers and cooler circuit are similarity joined.

CONTROLS

A basic electric control arrangement is shown in *Fig. 25 and 26*. An electric control is particularly suited to this type of application because of the number of interconnections required between the controls and motor starters.

Single pumpout compressor control with crankcase heater is shown. It minimizes the accumulation of liquid refrigerant in the compressor crankcase during system shutdown. Single pumpout and automatic pumpdown control is covered in *Part 3 and 7*.

The liquid line solenoid valve and crankcase heaters are interconnected with the fan starter and room thermostat. When the fan is running and the thermostat demands cooling, the liquid line solenoid valve opens, the compressor crankcase heaters are deenergized, and the single-pole double throw (SPDT) relay starts the evaporative condenser fan and pump motors. The compressor starts and continues to run if within a short period of time the oil pressure has built up sufficiently. Oil pressure is sensed at the differential oil pressure switch. The low and high pressure switches can shut down the compressor and evaporative condenser.

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FIGURE PART 12 WATER AND DX SYSTEMS

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Fig. 3 - Schematic Water Piping, Two-Pipe Fan-Coil Unit System

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Fig. 5 - Pump Selection

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Fig. 9 - Room Temperature and Humidity Conditions, Manual Three-Speed Fan Control

Fig.10 - Room Temperature and Humidity Conditions, Automatic Modulated Water Control

Fig.11 -Room Temperature and Humidity Conditions, Manual On-Off Fan Control

Fig.12 - Three-Pipe Fan- Coil Unit System

Fig.13 - Four-Pipe Fan-Coil Unit System

Fig.14 -Schematic Water Piping, Three-Pipe Fan-Coil Unit System (12-8)

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Fig. 22 - Flooded Liquid Chiller and Reciprocating Compressors with Evaporative Condenser

Fig. 23 - Reciprocating Liquid Chilling Package With Air Cooled Condensers, The Compressors

Fig. 24 - Reciprocating Liquid Chilling Package With Air Cooled Condensers, Four Compressors

Fig. 25 -Typical Wiring Diagram for Evaporative Condenser Installation, 208-220 Volts, with Single PumpoutCompressor Control and Crankcase Heater

Fig. 26 –Typical Wiring Diagram for Evaporative Condenser Installation, 208-220 Volts, withPumpout Compressor Control