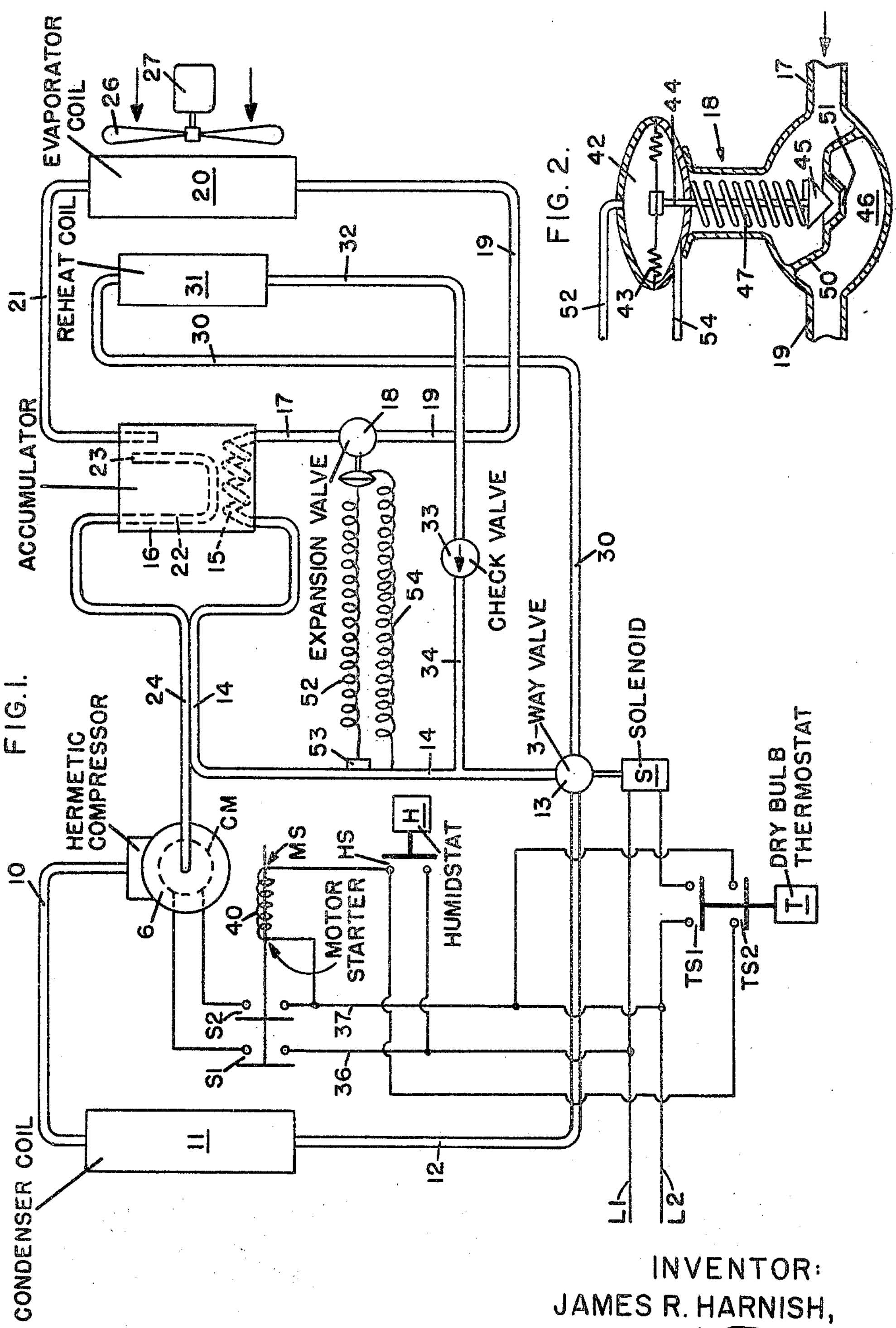
Aug. 9, 1966 J. R. HARNISH 3,264,840

AIR CONDITIONING SYSTEMS WITH REHEAT COILS

Filed May 3, 1965 2 Sheets-Sheet 1



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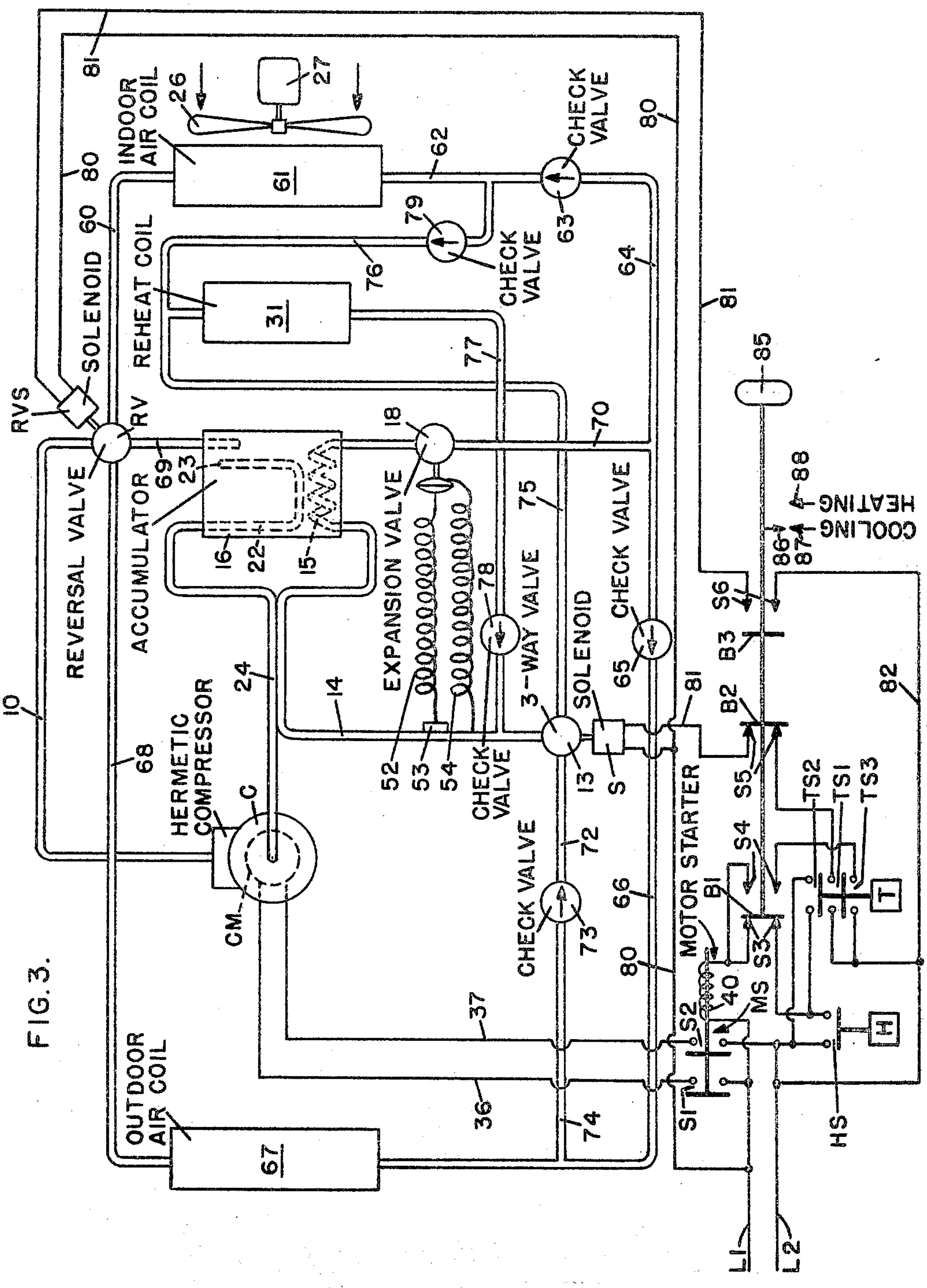

FIG. 3.

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United States Patent Office 3,264,840

Patented August 9, 1966

3,264,840
AIR CONDITIONING SYSTEMS WITH REHEAT COILS

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Filed May 3, 1965, Ser. No. 452,480
8 Claims. (Cl. 62—173)

This invention relates to air conditioning systems in which reheat is used for increasing the sensible heat of air which has been chilled, for dehumidification, to a temperature which is too low for comfort, and has as an object to improve such systems.

In many locations, the wet bulb temperature of the outdoor is frequently so high that where the utmost in comfort is desired, it is necessary to chill the air to be conditioned below its dewpoint temperature, and then to reheat the air to increase its dry bulb temperature. This has been accomplished in many ways, including using the heat in recirculated air in so-called "by-pass systems," and using the heat from condensers of refrigeration systems.

This invention uses a reheat coil which is connected in series with a condenser coil to operate as an auxiliary condenser coil when reheat is required. An expansion valve is used which supplies refrigerant liquid to the associated evaporator coil at the rate at which refrigerant is condensed in the condenser coil when no reheat is required, and at the rate at which refrigerant is condensed in the condenser and reheat coils when reheat is required, so that the condenser and reheat coils are adequately drained for good heat transfer. This results in the evaporator coil being supplied with more refrigerant liquid than it can evaporate. The unevaporated liquid is supplied into a suction line accumulator where it is evaporated by heat from the high pressure liquid supplied to the expansion valve. A valve controlled by a thermostat connects the reheat coil in series with the condenser coil when reheat is required. In a heat pump, the reheat coil is used as an axiliary condenser coil during air heating operation.

This invention will now be described with reference to the annexed drawings, of which:

FIG. 1 is a diagrammatic view of an air conditioning system embodying this invention;

FIG. 2 is a sectional view of the expansion valve used in the system of FIG. 1, and

FIG. 3 is a diagrammatic view of a heat pump embodying this invention.

Description of FIG. 1

The discharge side of a hermetic refrigerant compressor C driven by an enclosed electric motor CM, is connected by discharge gas tube **10** to one end of condenser coil **11**, the other end of which is connected by tube **12**, three-way valve **13**, tube **14**, heat exchange coil **15** within accumulator **16**, tube **17**, expansion valve **18**, and tube **19** to one end of air cooling evaporator coil **20**. The other end of the coil **20** is connected by tube **21** to the upper portion of the interior of the accumulator **16**. U-shaped tube **22** within the accumulator **16** has an open end **23**, and its other end is connected by suction gas tube **24** to the suction side of the compressor C. Portions of the tubes **14** and **24** are in heat exchange contact.

A fan **26** driven by an electric motor **27** moves indoor air to be chilled over the coil **20**. A fan which is not shown, could be used to move outdoor air over the condenser coil **11** when the latter is air cooled.

The three-way valve **13** is also connected by tube **30** to one end of reheat coil **31**, the other end of which is connected by tube **32**, check-valve **33** and tube **34** to the tube **14**. The coil **31** is adjacent to and downstream with respect to air flow of the evaporator coil **20**. The valve **13** is adjusted by a solenoid S which is connected in series with switch TS1 of dry bulb thermostat T to electric supply lines L1 and L2.

The compressor motor CM is connected by switches S1 and S2, and wires **36** and **37** respectively, to the supply lines L1 and L2 respectively. The switches S1 and S2 are switches of motor starter MS which has an energizing coil **40** which is connected in series with switch HS of humidistat H to the lines L1 and L2. Switch TS2 of the thermostat T is connected across the switch HS.

The expansion valve **18**, shown in detail by FIG. 2, has a diaphragm chamber **42**, the outer portion of which is connected by capillary tube **52** to thermal bulb **53** in heat exchange contact with the tube **14**. The inner portion of the diaphragm chamber **42** is connected by capillary tube **54** to the interior of the tube **14**. The bulb **53** contains the same refrigerant that is used in the system of FIG. 1.

The system of FIG. 1 contains a refrigerant charge that is larger than is necessary to satisfy the requirements of the system so that there is always a quantity of refrigerant liquid within the accumulator **16**.

Description of FIG. 2

The valve **18** is a subcooling control valve such as is disclosed in my Patent No. 3,171,263. Its diaphragm chamber **42** has a diaphragm **43** extending across its center, and which is connected at its center to the upper end of rod **44**, the lower end of which is connected to valve piston **45** within valve chamber **46**. A coiled spring **47** having its upper end in contact with the bottom wall of the diaphragm chamber **42**, and its lower end in contact with the top of the piston **45** extends around the rod **44**. The valve chamber **46** has an inlet connected to the tube **17**, and an outlet connected to the tube **19**. A partition **50** extends across the chamber **46** between its inlet and outlet, and has a valve opening **51** below the piston **45**. The spring **41** biases the piston **45** towards closed position.

Operation of FIGS. 1 and 2

The starter MS is energized by the closing of the humidistat switch TS when the relative humidity of the indoor air increases, for example, above 50%, or by the closing of the thermostat switch TS2 when the indoor temperature increases, for example above 80° F., and closes its switches S1 and S2, starting the compressor motor CM. Discharge gas from the compressor C is supplied through the tube **10** into the condenser coil **11**. Refrigerant liquid from the coil **11** flows through the tube **12**, and if no reheat is required, through the three-way valve **13**, the tube **14**, the coil **15** within the accumulator **16**, the tube **17**, the expansion valve **18** and the tube **19** into the evaporator coil **20**. The expansion valve **18** operates to supply to the evaporator coil **20** all of the condensed refrigerant. An increase in the temperature of the liquid within the tube **14** tends to close the valve **18** so as to back up more liquid within the condenser coil **11** for increasing the subcooling of the liquid. Increased liquid pressure within the tube **14** tends to open the valve **18**. For an increase in the rate at which refrigerant is condensed, if the valve **18** is not open sufficiently, liquid will back up in the condenser coil until the pressure is increased sufficiently or the temperature is reduced sufficiently, to cause the valve **18** to open further. When the condensing rate changes, the valve **18** readjusts accordingly as do all modulating expansion valves, and meters refrigerant liquid to the evaporator coil at the rate at which the liquid is condensed as does an expansion valve controlled by a high pressure float.

In the system of FIG. 1, the valve **18** maintains, for example, 10° F. subcooling of the liquid flowing from the condenser coil, at a condensing temperature of 100° F., and is preferred for this reason. However, a conventional expansion valve controlled by a high pressure float, could be used without the subcooling advantage.

Since the evaporator coil **20** receives more refrigerant liquid than it can evaporate, its interior surface is thoroughly wetted for increased heat transfer. The unevaporated liquid passes with the gas from the evaporated liquid, through the tube **21** into the accumulator **16**. Heat from the high pressure liquid flowing through the coil **15** evaporates the excess liquid at the rate at which it is supplied into the accumulator. The liquid flowing through the coil **15** is further subcooled by this action. Gas is separated from the liquid within the accumulator **16**, and passes through the tube **24** to the suction side of the compressor C. Any refrigerant liquid entering the tube **24** is evaporated by heat from the liquid flowing through the tube **14** with which the tube **24** is in contact, the liquid flowing through the tube **14** being further subcooled by this action.

When the humidistat H is in control of the compressor, the indoor air may be chilled to such a low temperature that reheat is required. When this happens, the switch TS1 of the thermostat T closes at, for example, 78° F., and energizes the solenoid S which adjusts the three-way valve **13** to discontinue supplying liquid from the condenser coil **11** directly into the tube **14**, and to supply the refrigerant leaving the condenser coil **11**, through the tube **30**, the reheat coil **31** operating as an auxiliary condenser coil, the tube **32** and the check-valve **33** into the tube **14**. From this point on, the system operates as described in the foregoing except that heat from the reheat coil **31** raises the dry bulb temperature of the air leaving the evaporator coil **20** to a comfortable temperature.

Since the expansion valve **18** acts to maintain the coils **11** and **31** adequately drained, their efficiency is increased, and the coil **31** effectively reheats the chilled air.

Description of FIG. 3

Those components of FIG. 3 which correspond to components of FIG. 1 are given the same reference characters.

Compressor C, driven by enclosed electric motor CM, is connected by discharge gas tube **10** to a conventional four-way reversal valve RV, adjustable by a solenoid RVS and by tube **60** to one end of indoor air coil **61**, the other end of which is connected by tube **62**, check-valve **63**, tube **64**, check-valve **65** and tube **66** to one end of outdoor coil **67**. The other end of the coil **67** is connected by tube **68** to the reversal valve RV. The reversal valve RV is also connected by tube **69** to the top of the accumulator **16**. U-shaped tube **22** within the accumulator **16** has an open upper end **23**, and its other end is connected by suction gas tube **24** to the suction side of the compressor C. The tube **64** is connected by tube **70**, expansion valve **18**, heat exchange coil **15** within the accumulator **16**, tube **14**, three-way valve **13** adjustable by solenoid S, tube **72**, check-valve **73** and tube **74** to the tube **66**. The valve **13** is also connected by tube **75** to one end of reheat coil **31**, which end is also connected through tube **76** and check-valve **79** to the tube **62**. The other end of the coil **31** is connected by tube **77** and check-valve **78** to the tube **14**.

The expansion valve **18** is a subcooling control valve as described in the foregoing, and has a diaphragm chamber **42**, the outer portion of which is connected by capillary tube **52** to thermal bulb **53** in heat exchange contact with the tube **14**. The inner portion of the diaphragm chamber **42** is connected by capillary tube **54** to the interior of the tube **14**. The bulb **53** contains the same refrigerant that is used in the heat pump of FIG. 3.

A fan **26** driven by an electric motor **27**, moves indoor air over the coils **61** and **31**. A fan which is not shown, could be used to move outdoor air over the coil **67** if the latter is an air contacting coil.

The compressor motor CM is connected by wires **36** and **37**, switches S1 and S2 respectively, of motor starter MS to electric supply lines L1 and L2 respectively. Energizing coil **40** of the starter MS is connected at one end to the line L1, and at its other end through switch contacts S3, switch blade B1 normally in contact with the contacts S3, and switch HS of humidistat H to the line L2. Switch TS2 of dry bulb thermostat T is connected across the switch HS. The other end of the coil **40** is also connected through switch contacts S4 normally spaced from the blade B1, and the latter when the latter is moved against the contacts S4, to switch TS3 of the thermostat T, which switch TS3 is connected to the line L2. The solenoid S is connected to the line L1, and through switch contacts S5 normally in contact with switch blade B2, the blade B2 and switch TS1 of the thermostat T to the line L2. The solenoid RVS is connected by wire **80** to the line L1, and by wire **81**, switch contacts S6 and switch blade B3 when the latter is moved against the contacts S6, and by wire **82** to the line L2.

The switch blades B1, B2 and B3 are attached to a rod **84** of electric insulation which is movable lengthwise by a knob **85**. The rod **84** has an indicator arrow **86** shown opposite "Cooling" marker **87**, and movable with the rod opposite "Heating" marker **88**. FIG. 3 shows the switch blades and their associated switch contacts in positions for air cooling operation of the heat pump.

Air cooling operation of FIG. 3

The starter MS of the compressor motor CM is energized by the closing of the switch HS of the humidistat H when the relative humidity of the indoor air is too high, or by the closing of the switch TS2 of the thermostat T when the dry bulb temperature of the indoor air is too high, and closes its switches S1 and S2, starting the motor CM. Discharge gas from the compressor C flows through the tube **10**, the reversal valve RV, and the tube **68** into the outdoor coil **67** operating as a condenser. The valve RV is in its cooling position at this time due to the solenoid RVS being deenergized. Liquid from the coil **67** flows through the tube **74**, the check-valve **73**, and if no reheat is required, through the three-way valve **13**, the tube **14**, the coil **15**, the expansion valve **18**, the tubes **70** and **64**, the check-valve **63** and the tube **62** into the indoor coil **61** operating as an evaporator. The expansion valve **18** operates as described in the foregoing in connection with FIGS. 1 and 2. Gas and unevaporated liquid flow from the coil **61** through the tube **60**, the reversal valve RV and the tube **69** into the accumulator **16**. Gas separated from the liquid within the accumulator flows through the suction gas tube **24** to the suction side of the compressor C. Heat from the coil **15** evaporates the excess refrigerant liquid flowing into the accumulator at the rate at which it flows into the latter, the liquid flowing through the coil **15** being subcooled by this action. Heat from the liquid flowing through the tube **14** evaporates any liquid refrigerant which may enter the tube **24** through the heat exchange contact between the tubes **14** and **24**, the liquid flowing through the tube **14** being cubcooled by this action.

When reheat is required, the switch TS1 of the thermostat T closes, and connects through the switch contacts S5 and the switch blade B2, the solenoid S to the supply lines L1 and L2. The solenoid S is energized and adjusts the three-way valve **13** to prevent the flow of refrigerant from the tube **72** into the tube **14**, and to permit refrigerant to flow from the tube **72** into the tube **75** and from the latter through the reheat coil **31**, the tube **77** and the check-valve **78** into the tube **14**, and from the latter through the coil **15**, the expansion valve **18**, the tubes **70** and **64**, the check-valve **63** and the tube **62** into the indoor coil **61** operating as an evaporator. Expanded refrigerant from the tube **62** cannot flow through the check-valve **79** and the tube **76** into the coil **31** since the tube **75** supplies high pressure refrigerant at the junction of the tubes **75** and **76**.

Heat from the condensing refrigerant flowing through the coil **31** increases the sensibe heat in the air dehumified by the coil **61** to that required for comfort. The liquid flowing through the coil **31** is also subcooled by this action.

Air heating operation of FIG. 3

To convert to air heating operation, the control knob **85** should be moved to the right of the position shown by FIG. 3, to place its indicator arrow **86** opposite the "Heating" marker **88**. This would move the switch blade B3 against the switch contacts S6, energizing the solenoid RVS which would adjust the reversal valve RV to its air heating position. This would also move the switch blade B2 from contact with the switch contacts S5, deenergizing the solenoid S of the three-way valve **13**. This would also move the switch blade B1 from contact with the switch contacts S3, disconnecting the switch HS of the humidistat H, and the switch TS2 of the thermostat T from control of the motor starter MS, and would move the blade B1 in contact with the switch contacts S4, placing the switch TS3 of the thermostat T in control of the motor starter MS.

When the thermostat T calls for heat, its switch TS3 closes at, for example, 73° F. to energize the starter MS which closes its switches S1 and S2, starting the compressor motor CM. Discharge gas from the compressor C flows through the tube **10**, the reversal valve RV and the tube **60** into the indoor coil **61** operating as a condenser. Refrigerant from the coil **61** flows through the tube **62**, the check-valve **79** and the tube **76** into the reheat coil **31** operating as an auxiliary condenser. Liquid from the coil **31** flows through the tube **77**, the check-valve **78**, the tube **14**, the coil **15**, the expansion valve **18**, the tube **70**, the check-valve **65** and the tube **66** into the outdoor coil **67** operating as an evaporator. Gas and unevaporated liquid flowing from the coil **67** flow through the tube **68**, the reversal valve RV and the tube **69** into the accumulator **16**. Gas separated from the liquid within the accumulator flows through the suction gas tube **24** to the suction side of the compressor C.

During air cooling and air heating operation of the heat pump of FIG. 3, the expansion valve **18** operates to control subcooling of the condensed refrigerant, and to supply to the coil operating as an evaporator, refrigerant liquid at the rate at which it is condensed. The coil operating as an evaporator is supplied with more refrigerant liquid than it can evaporate, with the excess liquid flowing into the accumulator **16** where it is evaporated by heat from the coil **15** at the rate at which it is supplied into the accumulator as described in connection with FIG. 1, the liquid flowing through the coil **15** being subcooled by this action. The refrigerant which is condensed is that evaporated within the coil **61** or **67** plus that evaporated within the accumulator **16**. Any refrigerant liquid entering the suction gas tube **24** is evaporated by heat from the tube **14** with which it is in contact, the liquid flowing through the tube **14** being subcooled by this action.

The coil **67** may be in heat exchange with air, or may be part of a shell-and-tube heat exchanger through which water or another liquid is circulated for heat exchange.

What is claimed is:

1. An air conditioning system comprising a refrigerant compressor, a condenser coil connected at one end to the discharge side of said compressor, a suction line accumulator connected to the suction side of said compressor, a heat exchange coil arranged to heat liquid within said accumulator, an expansion valve connected to one end of said heat exchange coil, an evaporator coil connected at one end to said expansion valve and at its other end to said accumulator, means for moving air to be chilled over said evaporator coil, a reheat coil adjacent to and downstream with respect to air flow of said evaporator coil, means when no reheat is required, for routing refrigerant from the other end of said condenser coil into the other end of said heat exchange coil, and when reheat is required, for routing refrigerant from said other end of said condenser coil through said reheat coil into said other end of said heat exchange coil, and means for adjusting said expansion valve to supply refrigerant liquid from said heat exchange coil to said evaporator coil at the rate at which refrigerant is condensed in said condenser coil when no reheat is required, and at the rate at which refrigerant is condensed in said condenser coil and in said reheat coil when reheat is required.

2. An air conditioning system as claimed in claim **1** in which said means for adjusting said expansion valve responds to the temperature and pressure of the refrigerant flowing from said condenser coil into said heat exchange coil when no reheat is required, and responds to the temperature and pressure of the refrigerant flowing from said reheat coil into said heat exchange coil when reheat is required.

3. An air conditioning system comprising a refrigerant compressor, a condenser coil connected at one end to the discharge side of said compressor, a suction line accumulator connected to the suction side of said compressor, a heat exchange coil arranged to heat liquid within said accumulator, an expansion valve connected to one end of said heat exchange coil, an evaporator coil connected at one end to said expansion valve and at its other end to said accumulator, means for moving air to be chilled over said evaporator coil, a reheat coil adjacent to and downstream with respect to air flow of said evaporator coil, a three-way valve connected to the other end of said condenser coil, to the other end of said heat exchange coil, and to one end of said reheat coil, a check-valve connected to the other end of said reheat coil and to said other end of said heat exchange coil, means for adjusting said three-way valve when no reheat is required, to route refrigerant from said other end of said condenser coil to said other end of said heat exchange coil, and when reheat is required, to route refrigerant from said other end of said condenser coil through said reheat coil and said check-valve to said other end of said heat exchange coil, and means for adjusting said expansion valve to supply refrigerant from said heat exchange coil to said evaporator coil at the rate at which refrigerant is condensed in said condenser coil when no reheat is required, and at the rate at which refrigerant is condensed in said condenser coil and in said reheat coil when reheat is required.

4. An air conditioning system as claimed in claim **3** in which said means for adjusting said expansion valve responds to the temperature and the pressure of the refrigerant flowing from said condenser coil into said heat exchange coil when no reheat is required, and responds to the temperature and the pressure of the refrigerant flowing from said reheat coil into said heat exchange coil when reheat is required.

5. A heat pump comprising a refrigerant compressor; an outdoor coil; an indoor air coil; an expansion valve; a suction line accumulator connected to the suction side of said compressor; a heat exchange coil arranged to heat liquid within said accumulator; means for moving air to be conditioned over said indoor coil; a reheat coil adjacent to and downstream with respect to air flow of said indoor coil; control means; means including said control means when indoor air cooling without reheat is required, for routing discharge gas from said compressor to said outdoor coil operating as a condenser, for routing referigerant from said outdoor coil through said heat exchange coil and said expansion valve to said indoor coil operating as an evaporator, and for routing gas and unevaporated refrigerant from said indoor coil into said accumulator; means including said control means when indoor air cooling with reheat is required, for routing discharge gas from said compressor to said outdoor coil operating as a condenser, for routing refrigerant from said outdoor coil through said reheat coil, through said heat exchange coil and said expansion valve to said indoor coil operating as an evaporator, and for routing gas and unevaporated refrigerant from said indoor coil into said accumulator; means including said control means when indoor air heating is required, for routing discharge gas from said compressor to said indoor coil operating as a condenser, for routing refrigerant from said indoor coil through said reheat coil, through said heat exchange coil and said expansion valve to said outdoor coil operating as an evaporator, and routing gas and unevaporated refrigerant from said outdoor coil into said accumulator; and means for adjusting said expansion valve to supply refrigerant from said heat exchange coil to said indoor coil when indoor air cooling without reheat is required, at the rate at which refrigerant is condensed in said outdoor coil, to supply refrigerant from said heat exchange coil to said indoor coil when indoor air cooling with reheat is required, at the rate at which refrigerant is condensed within said outdoor coil and said reheat coil, and to supply refrigerant from said heat exchange coil when indoor air heating is required, to said outdoor coil at the rate at which refrigerant is condensed in said indoor coil and said reheat coil.

6. A heat pump as claimed in claim **5** in which said means for adjusting said expansion valve responds to the temperature and pressure of the refrigerant flowing from said outdoor coil to said heat exchange coil when indoor air cooling without reheat is required, and responds to the temperature and pressure of the refrigerant flowing from said reheat coil to said heat exchange coil when indoor air cooling with reheat is required, and when indoor air heating is required.

7. A heat pump comprising a refrigerant compressor; reversal valve means; a discharge tube connecting the discharge side of said compressor to said valve means; a suction line accumulator; a suction gas tube connecting said accumulator to the suction side of said compressor; a heat exchange coil arranged to heat liquid within said accumulator; an expansion valve connected to one end of said heat exchange coil; an outdoor coil; an indoor air coil; means for moving air to be conditioned over said indoor coil; a reheat coil adjacent to and downstream with respect to air flow of said indoor coil; a three-way valve; first; second; third; fourth and fifth check-valves; a third tube connecting one end of said outdoor coil to said reversal means; a fourth tube containing said first check-valve connecting the other end of said outdoor coil to said three-way valve; a fifth tube connecting said three-way valve to the other end of said heat exchange coil; a sixth tube connecting said three-way valve to one end of said reheat coil; a seventh tube containing said second check-valve connecting the other end of said reheat coil to said fifth tube; an eighth tube connecting one end of said indoor coil to said reversal means; a ninth tube containing said third and fourth check-valves in series connecting the other end of said indoor coil to said fourth tube; a tenth tube containing said fifth check-valve connecting said one end of said reheat coil to said ninth tube; an eleventh tube connecting said expansion valve between said third and fourth check-valves to said ninth tube; a twelfth tube connecting said reversal means to said accumulator; said reversal means in air cooling position connecting said discharge tube through said third tube to said outdoor coil operating as a condenser, and connecting said indoor coil operating as an evaporator through said eighth and twelfth tubes to said accumulator, said reversal means in air heating position connecting said discharge gas tube through said eighth tube to said indoor coil operating as a condenser, and connecting said outdoor coil operating as an evaporator through said third and twelfth tubes to said accumulator; means for adjusting said three-way valve to a first position when said reversal means is in cooling position and no reheat is required, to route refrigerant from said outdoor coil through said fourth tube, said first check-valve and said fifth tube into said heat exchange coil with refrigerant flowing from the latter through said expansion valve, said eleventh and ninth tubes and said third check-valve into said indoor coil; means for adjusting said three-way valve to a second position when said reversal means is in cooling position and reheat is required, to route refrigerant from said outdoor coil through said fourth tube, said first check-valve, said sixth tube, said reheat coil, said seventh tube, said second check-valve and said fifth tube into said heat exchange coil with refrigerant flowing from the latter through said expansion valve, said eleventh and ninth tubes and said third check-valve into said indoor coil; said three-way valve when air heating is required being in said first position with refrigerant from said indoor coil flowing through said tenth tube, said fifth check-valve, said reheat coil, said seventh tube, said second check-valve and said fifth tube into said heat exchange coil, with refrigerant flowing from the latter through said expansion valve, said eleventh, ninth and fourth tubes and said fourth check-valve into said outdoor coil; and means for adjusting said expansion valve to supply refrigerant from said heat exchange coil to said indoor coil when indoor air cooling without reheat is required, at the rate at which refrigerant is condensed in said outdoor coil, to supply refrigerant from said heat exchange coil when indoor air cooling with reheat is required, at the rate at which refrigerant is condensed in said outdoor and reheat coils, and to supply refrigerant from said heat exchange coil to said outdoor coil, when indoor air heating is required, at the rate at which refrigerant is condensed in said indoor and reheat coils.

8. A heat pump as claimed in claim **7** in which said means for adjusting said expansion valve responds to the temperature and pressure of the refrigerant flowing from said outdoor coil to said heat exchange coil when indoor air cooling without reheat is required, and responds to the temperature and pressure of the refrigerant flowing from said reheat coil to said heat exchange coil when indoor air cooling with reheat is required, and when indoor air heating is required.

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WILLIAM J. WYE, *Primary Examiner.*