May 2, 1967 R. F. LAUER 3,316,730

AIR CONDITIONING SYSTEM INCLUDING REHEAT COILS

Filed Jan. 11, 1966 2 Sheets-Sheet 1

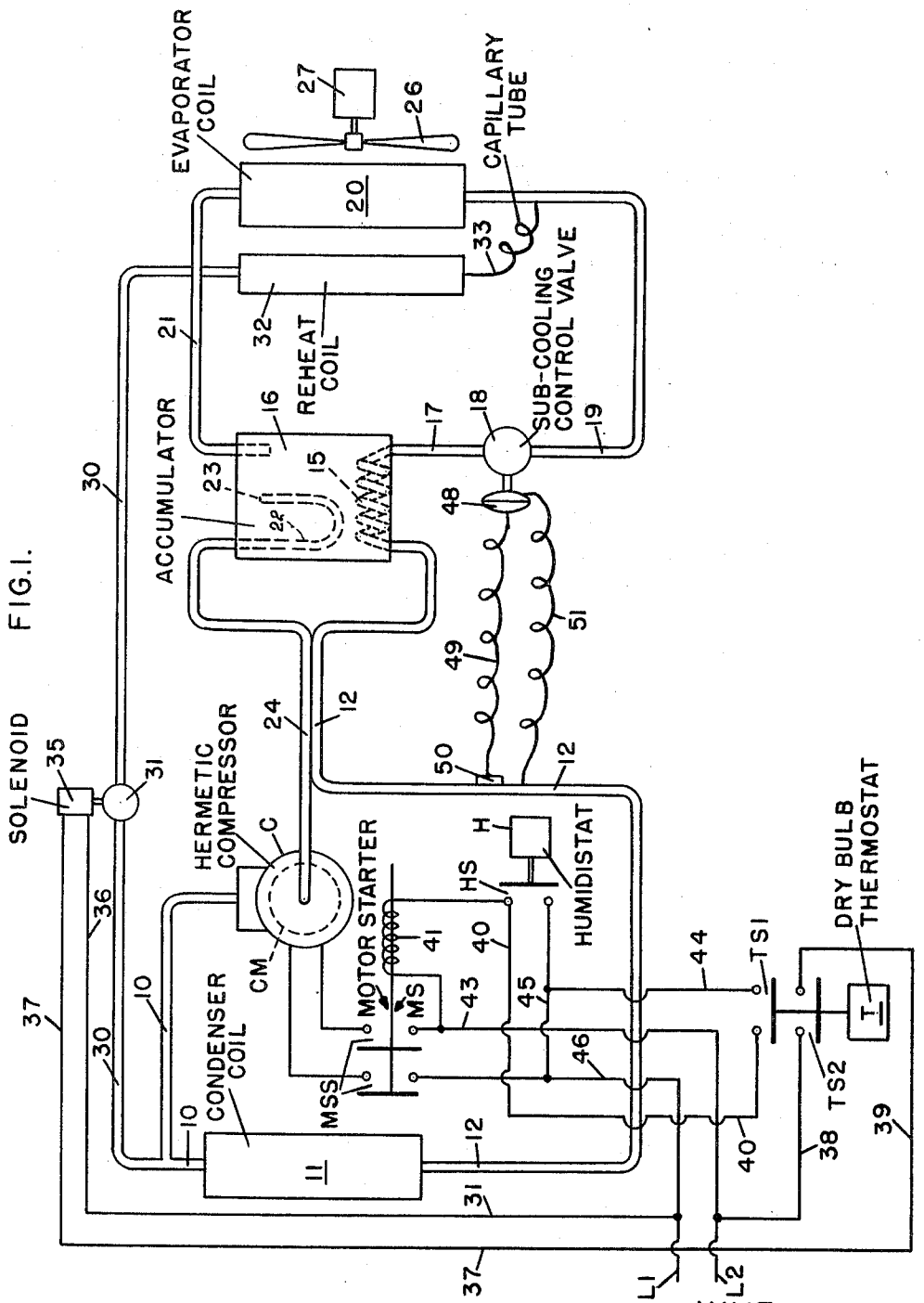



FIG. 1.

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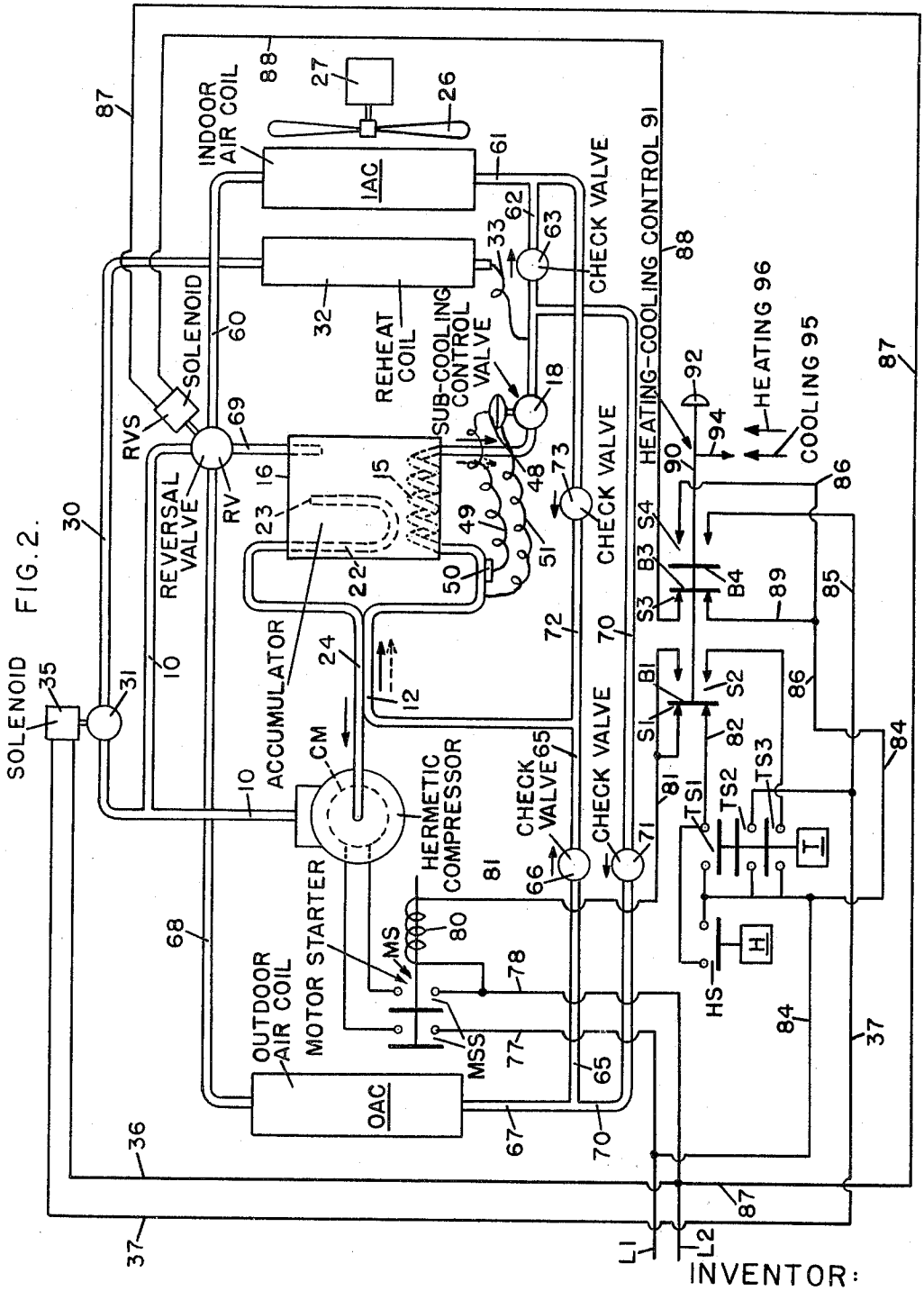



FIG. 2.

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3,316,730

# AIR CONDITIONING SYSTEM INCLUDING REHEAT COILS

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6 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 air is frequently so high that where the utmost in comfort is desired, it is necessary to operate an air cooling system to chill the air to be cooled below its dew point temperature, and then to reheat the air to a comfortable 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 for condensers of refrigeration systems. This invention improves the latter systems.

In one embodiment of this invention using a non-reversible refrigeration system, an expansion valve, preferably a sub-cooling control valve, meters refrigerant liquid to an associated evaporator coil at the rate at which refrigerant is condensed in an associated condenser coil. This results in over feeding the evaporator coil, and to prevent refrigerant liquid from flowing into the associated compressor, the gas and unevaporated refrigerant from the evaporator is flowed into an accumulator in which gas is separated from the liquid and supplied to the suction side of the compressor. The liquid from the condenser coil flows through a heat exchange coil within the accumulator before it is supplied to the sub-cooling control valve, the heat from the high pressure liquid flowing through such coil evaporating the excess refrigerant liquid flowing from the evaporator coil into the accumulator. A reheat coil is connected through a solenoid-controlled valve to the discharge side of the compressor, and when reheat is required, the solenoid-controlled valve is opened to supply discharge gas into the reheat coil to operate it as an auxiliary condenser coil. The reheat coil is connected to the evaporator coil through a fixed restrictor which may be a capillary tube. Thus, when reheat is required, the reheat coil and its restrictor are connected in parallel with the condenser coil and its sub-cooling control valve.

In a heat pump embodying this invention, the operation is that described in the foregoing during cooling operation. During heating operation, the reheat coil operates continuously as a condenser coil, aiding in heating the indoor air.

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 using a non-reversible refrigeration system, embodying this invention, and

FIG. 2 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**, heat exchange coil **15** within the lower portion of accumulator **16**, tube **17**, sub-cooling control valve **18** and tube **19** to one end of evaporator coil **20**. The other end of the coil **20** is connected by tube **21** to the upper portion 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. Portions of the tubes **12** and **24** are in heat exchange contact.

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

The discharge gas tube **10** is also connected through tube **30** and valve **31** to one end of reheat coil **32**, the other end of which is connected through a restrictor **33** shown as a capillary tube, to the tube **19**. The restrictor **33** could be a high pressure float or a steam trap. The reheat coil **32** is adjacent to and downstream with respect to air flow, of the evaporator coil **20**.

The valve **31** is adjusted by a solenoid **35** which is connected by wire **36** to electric supply line **L1**, and by wire **37** to switch **TS2** of dry bulb thermostat T. The switch **TS2** is connected by wire **38** to electric supply line **L2**. Switch **TS1** of the thermostat T is connected by wire **40** to switch HS or humidistat H, and to one end of winding **41** of compressor motor starter MS, the other end of which is connected by wire **43** to the line **L2**. The switch **TS1** is connected by wire **44** to the switch HS, and by wires **45** and **46** to the line **L1**. The switch **TS1** of the thermostat T, and the switch HS of the humidistat H are connected in parallel with each other, and in series with the motor starter winding **41** to the lines **L1** and **L2** so that either switch, when closed, can energize the starter MS. The starter MS has switches MSS which connect, when closed, through the wires **46** and **43**, the compressor motor CM to the lines **L1** and **L2**.

The sub-cooling control valve **18** has a diaphragm chamber **48**, the outer portion of which is connected by capillary tube **49** to thermal bulb **50** in heat exchange contact with the tube **12**, and the inner portion of which is connected by capillary tube **51** to the interior of the tube **12**. The valve **18**, the details of which are disclosed in the U.S. Patent No. 3,171,262 of J. R. Harnish which issued on March 2, 1965, responds to the temperature and pressure of the high pressure refrigerant within the tube **12**, and meters refrigerant to the evaporator coil **20** at the rate at which the refrigerant is condensed within the condenser coil **11**, while maintaining a predetermined amount of sub-cooling in the condensed refrigerant.

*Operation of FIG. 1*

The motor starter MS is energized by the closing of the humidistat switch HS when the relative humidity of the indoor air is above, for example, 50%, or by the closing of the thermostat switch **TS1** when the indoor temperature increases above, for example 80° F., and closes its switches MSS, starting the compressor motor CM. Discharge gas is supplied from the compressor C through the tube **10** into the condenser coil **11**. Liquid flows from the coil **11** through the tube **12**, the coil **15** within the accumulator **16**, the sub-cooling control valve **18** and the tube **19** into the evaporator coil **20**. The valve **18** operates to supply to the coil **20** all of the refrigerant condensed within the condenser coil **11** while maintaining, for example, 10° F. sub-cooling of the liquid flowing from the coil **11** at a condensing temperature of 100° F., and is preferred for this reason. However, a conventional expansion valve controlled by a high pressure pilot float meters refrigerant at the rate at which it is condensed, and may be used, without the sub-cooling advantage. The evaporator coil **20** is overfed by the valve **18** so that gas and unevaporated refrigerant liquid flow from the evaporator coil into the accumulator where the excess refrigerant liquid is evaporated by heat from the high pressure liquid flowing through the coil **15**, the liquid being further subcooled by

this action. Gas separated from the liquid within the accumulator flows through the suction gas tube **24** to the suction side of the compressor C. Any liquid which may enter the tube **24** is evaporated by the heat exchange between the contacting portions of the tubes **12** and **24**, the liquid flowing through the tube **12** being further subcooled by this action.

When the humidistat H is in control of the compressor C, the indoor air may be chilled to such a low temperature that reheat is required. When this happens, the switch TS2 closes at, for example, 78° F., and energizes the solenoid **35** which opens the valve **31** to supply discharge gas from the compressor C through the tube **30** into the reheat coil **32** to operate the latter as an auxiliary condenser for heating the indoor air chilled by the evaporator coil **20**. The refrigerant condensed within the reheat coil **32** is expanded through the restrictor **33**, and is supplied into the evaporator **20**. The heat from the coil within the accumulator **16** evaporates the excess refrigerant liquid fed from both the reheat coil **32** and the condenser coil **11**. Advantages of overfeeding the evaporator are that its internal surfaces are thoroughly wetted, and distribution is not critical. Therefore, its efficiency is increased. There is no energy loss in evaporating the excess refrigerant liquid by heat from the high pressure liquid flowing through the coil **15** within the accumulator **16** since such high pressure liquid is subcooled by this action.

*Description of FIG. 2*

Those components of FIG. 2 which correspond to components of FIG. 1 are given the same reference characters.

Compressor motor CM drives compressor C. The latter is connected by tube **10** to a conventional reversal valve RV, adjustable by a solenoid RVS. The valve RV is connected by tube **60** to one end of indoor air coil IAC, the other end of which is connected by tube **61**, tube **62** containing a check-valve **63**, and sub-cooling control valve **18** to the outlet of coil **15** within accumulator **16**. The valve **18** has a diaphragm chamber **48**, the upper portion of which is connected by a capillary tube **49** to thermal bulb **50** in contact with tube **12**, and the lower portion of which is connected by capillary tube **51** to the interior of the tube **12**. The inlet of the coil **15** is connected by tube **12**, tube **65** containing a check-valve **66**, and tube **67** to one end of outdoor air coil OAC, the other end of which is connected by tube **68** to the valve RV. The valve RV is connected by tube **69** to the upper portion of the accumulator **16**. The accumulator **16** contains a U-shaped tube **22** having an open upper end **23**, with its other end connected by suction gas tube **24** to the suction side of the compressor C. Portions of the tubes **12** and **24** are in heat exchange contact. A tube **30** containing a valve **31** adjustable by a solenoid **35** is connected to the tube **10** and to one end of reheat coil **32**, the other end of which is connected by restrictor **33** to the tube **62** between the valve **18** and the check-valve **63**. The tube **67** is connected by tube **70** containing a check-valve **71** to the tube **62** between the valve **18** and the check-valve **63**. The tube **65** is connected by tube **72** containing a check-valve **73**, to the tube **61**. The reheat coil is located adjacent to and downstream of the indoor air coil IAC. A fan **26** driven by an electric motor **27**, moves indoor air over the coils IAC and **32**. A fan, which is not shown, could be used to move outdoor air over the outdoor air coil OAC.

The compressor motor CM is connected by wires **77** and **78**, and switches MSS of starter MS to electric supply lines L1 and L2 respectively. The starter MS has an energizing winding **80** connected by the wire **78** to the line L2, and connected by wire **81** to switches S1 and S2. The switch S1 is also connected by wire **82** to switch TS1 of indoor thermostat T which is connected across switch HS of indoor humidistat H. The switches TS1



and HS are connected in parallel with each other and in series with the switch S1 and the winding **80** of the motor starter MS to the supply lines L1 and L2. The solenoid **35** is connected by wire **36** to the line L2, and by wire **37** to switch TS2 of the thermostat T, which switch is connected by wire **84** to the line L1. Switch S4 is connected by wire **85** to the wire **37**, and by wire **86** and the wire **84** to the line L1. The reversal valve solenoid RVS is connected by wire **87** to the line L2, and by wire **88** to switch S3 which is connected by wire **89** and the wires **86** and **84** to the line L1. Switch TS3 of the thermostat T is connected to the wire **84** and to the switch S2.

The switch S1 is closed by switch blade B1 attached to insulator rod **90** of cooling-heating control **91**, when control knob **92** on the right end of the rod **90** is adjusted to place the control **91** in cooling position as shown by FIG. 2. The switch S2 is on the opposite side of the blade B1 from the switch S1, and is adapted to be closed by the blade B1 when the control knob **92** is moved to the right of the position shown by FIG. 2, to adjust the control **91** to heating position. The switch S3 is closed by switch blade B3 when the control **91** is in its cooling position as shown by FIG. 2. The switch S4 is adapted to be closed by switch blade B4 when the control **91** is in its heating position. The blades B3 and B4 are also attached to the rod **90**. An indicator arrow **94** on the rod **90** is opposite a fixed indicator arrow **95** when the control **91** is in cooling position as shown by FIG. 2, and is opposite a fixed indicator arrow **96** when the control **91** is in its heating position.

The reversal valve RV is of the type which, when its solenoid RVS is deenergized, is in its heating position, and when its solenoid is energized, is in its cooling position.

*Operation of FIG. 2*

When indoor air cooling is desired, the control **91** is placed in its cooling position as shown by FIG. 2. The switches S1 and S3 are closed, and the switches S2 and S4 are open. The switch S1 connects the thermostat switch TS1 and the humidstat switch HS to control the compressor motor starter MS. The switch S3 energizes the reverasal valve solenoid RVS which adjust the reversal valve RV to its cooling position. The starter MS is energized by the closing of the switch HS when the relative humidity of the indoor air is too high, or by the closing of the switch TS1 when the temperature of the indoor air is too high, and starts the compressor motor CM. Discharge gas from the compressor C flows through the tube **10**, the reversal valve RV and the tube **68** into the outdoor air coil OAC operating as a condenser coil. Condensed refrigerant flows from the coil OAC through the tube **67**, the tube **65**, the check-valve **66**, the tube **12**, the coil **15**, the subcooling control valve **18**, the tube **62**, the check-valve **63** and the tube **61** into the indoor air coil IAC operating as an evaporator coil. Gas and unevaporated refrigerant flow from the coil IAC 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 tube **22** and the suction gas tube **24** to the suction side of the compressor C. The subcooling control valve **18**, and the coil **15** operate as described in the foregoing in connection with the operation of FIG. 1.

When reheat is required, the thermostat switch TS2 closes and energizes the solenoid **35** which opens the valve **31**, supplying discharge gas from the tube **10** through the tube **30** into the reheat coil **32**, operating the latter as a condenser coil for heating the air blown by the fan **26** over the indoor air coil IAC. Refrigerant condensed in the reheat coil **32** is expanded through the restrictor **33** and flows through the tube **62** and check-valve **63** into the indoor air coil IAC which is operating as an evaporator. Gas and unevaporated refrigerant flow from the coil IAC into the accumulator **16** and from there the

gas separated from the liquid flows to the suction side of the compressor as described in the foregoing.

When indoor air heating is required, the control **91** is placed in its heating position by moving the control knob **92** to the right so that the indicator arrow **94** lines up with the indicator arrow **96**. The switches **S1** and **S3** are opened, and the switches **S2** and **S4** are closed. The now open switch **S1** disconnects the thermostat switch **TS1** and the humidistat switch **HS** from control of the motor starter MS. The open switch **S3** deenergizes the reversal valve solenoid which adjusts the reversal valve RV to its heating position. The closed switch **S2** connects the thermostat switch **TS3** to control the starter MS. The closed switch **S4** energizes the solenoid **35** which opens the valve **31** so that discharge gas is supplied into the reheat coil **32** to operate it as a condenser coil during all of the heating operation.

When the thermostate T calls for heat, the switch **TS3** closes and energizes the motor starter MS which closes its switches MSS, starting the compressor motor CM. Discharge gas flows from the compressor C through the tube **10**, the reversal valve RV and the tube **60** into the indoor air coil IAC operating as a condenser coil. Refrigerant condensed within the coil IAC flows through the tubes **61** and **72**, the check-valve **73**, the tube **12**, the coil **15** within the accumulator **16**, the tube **62**, the subcooling control valve **18**, the tube **70**, the check-valve **71** and the tube **67** into the outdoor air coil OAC operating as an evaporator coil. Discharge gas also flows from the tube **10** through the tube **30** and the valve **31** into the reheat coil **32** operating as a condenser coil. Refrigerant condensed in the reheat coil **32** is expanded in the restrictor **33**, and flows through the tube **70**, the check-valve **71** and the tube **67** into the outdoor air coil OAC operating as an evaporator coil. Gas and unevaporated refrigerant flow from the coil OAC through the tube **68**, the reversal valve RV and the tube **69** into the accumulator **16**. Gas separated from the liquid within the accumulator **16** flows through the tubes **22** and **24** to the suction side of the compressor C. The subcooling control valve **18**, and the coil **15** within the accumulator **16** operate as described in the foregoing in the description of FIG. 1.

The reheat coil **32** operating as a condenser coil, adds its heat to that provided by the indoor air coil IAC operating as a condenser coil, facilitating the heating of the indoor air.

What is claimed, is:

**1.** An air cooling system comprising a refrigerant compressor; a condenser coil; an evaporator coil; a discharge gas tube connecting said compressor to said condenser coil; accumulator means; a heat exchange coil arranged to heat liquid within said accumulator means; a suction gas tube connecting said accumulator means to said compressor; a liquid tube connecting said condenser coil to said heat exchange coil; an expansion valve; a fourth tube connecting said heat exchange coil to said valve; a fifth tube connecting said valve to said evaporator coil; a sixth tube connecting said evaporator coil to said accumulator means; means for moving air to be cooled over said evaporator coil; a reheat coil adjacent to and downstream with respect to air flow of said evaporator coil; a seventh tube connecting said discharge gas tube to said reheat coil; a normally closed valve in said seventh tube; expansion means connecting said reheat coil to said fifth tube; means for opening said normally closed valve when reheat is required and for reclosing said normally closed valve when no reheat is required; 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.

**2.** An air cooling system as claimed in claim **1** in which said expansion valve is a subcooling control valve, and in which said means for adjusting said expansion valve responds to the pressure and the temperature of the refrigerant in said liquid tube.



**3.** A heat pump for conditioning indoor air, comprising a refrigerant compressor; an outdoor coil; an indoor coil; accumulator means; a heat exchange coil arranged to heat liquid within said accumulator means; means for moving indoor air over said indoor coil; a reheat coil adjacent to and downstream with respect to air flow of said indoor coil; an expansive valve; expansion means; control means; means including said control means, when air cooling is required, for directing refrigerant from said compressor in a first circuit through said outdoor coil operating as a condenser, said heat exchange coil, said expansion valve, said indoor coil operating as an evaporator, and said accumulator means to said compressor; means including said control means when reheat is required while refrigerant is flowing in said first circuit, for directing refrigerant from said compressor through said reheat coil and said expansion means into said indoor coil; means including said control means when air heating is required, for directing refrigerant from said compressor in a second circuit through said indoor coil operating as a condenser, said heat exchange coil and said expansion valve into said outdoor coil operating as an evaporator, and from said compressor through said reheat coil and said expansion means into said outdoor coil, from said outdoor coil into said accumulator means, and from said accumulator means to said compressor; and means for adjusting said expansion valve to supply refrigerant to said indoor coil when it is operating as an evaporator and said outdoor coil is operating as a condenser, at the rate at which refrigerant is condensed in said outdoor coil, and to supply refrigerant to said outdoor coil when it is operating as an evaporator and said indoor coil is operating as a condenser, at the rate at which refrigerant is condensed in said indoor coil.

**4.** A heat pump as claimed in claim **3** in which said expansion valve is a subcooling control valve, and in which said means for adjusting said expansion valve responds to the pressure and the temperature of the refrigerant flowing into said heat exchange coil.

**5.** A heat pump for conditioning indoor air, comprising a refrigerant compressor; refrigerant reversal means; a discharge gas tube connecting said compressor to said reversal means; an outdoor coil; an indoor coil; accumulator means; a heat exchange coil arranged to heat liquid within said accumulator means; a suction gas tube connecting said accumulator means to said compressor; a third tube connecting said reversal means to said accumulator means; a fourth tube connecting said reversal means to said outdoor coil; a fifth tube containing first check-valve means connecting said outdoor coil to said heat exchange coil; an expansion valve; a sixth tube connecting said heat exchange coil to said expansion valve; a seventh tube containing second check-valve means connecting said expansion valve to said indoor coil; an eighth tube connecting said indoor coil to said reversal means; means for moving air over said indoor coil; a reheat coil adjacent to and downstream with respect to air flow of said indoor coil; a ninth tube containing a normally closed valve connecting said discharge gas tube to said reheat coil; means including expansion means connecting said reheat coil to said seventh tube between said expansion valve and said second check-valve means; a tenth tube containing third check-valve means connecting said seventh tube between said expansion valve and said second check-valve means to said fifth tube between said first check-valve means and said outdoor coil; an eleventh tube containing fourth check-valve means connecting said seventh tube between said second check-valve means and said indoor coil to said fifth tube between said first check-valve means and said heat exchange coil; means for adjusting said reversal means to cooling position for routing discharge gas from said discharge gas tube through said fourth tube into said outdoor coil to operate the latter as a condenser; means for opening said normally closed valve when reheat is required while said reversal means

is in cooling position, for routing discharge gas from said discharge gas tube through said ninth tube into said reheat coil to operate the latter as a condenser, and for reclosing said normally closed valve when no reheat is required; means for concurrently opening said normally closed valve and adjusting said reversal means to heating position for routing discharge gas from said discharge gas tube through said eighth tube into said indoor coil and through said ninth tube into said reheat coil for operating said indoor and reheat coils as condensers; and means for adjusting said expansion valve to supply refrigerant to said indoor coil while said outdoor coil is operating as a condenser at the rate at which refrigerant is condensed in said outdoor coil, and to supply refrigerant to said outdoor coil while said indoor coil is operating as a condenser at the rate at which refrigerant is condensed in said indoor coil.



6. A heat pump as claimed in claim 5 in which said expansion valve is a subcooling control valve, and in which said means for adjusting said expansion valve responds to the pressure and the temperature of the refrigerant flowing into said heat exchange coil.

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