Aug. 24, 1965

R. M. SHRADER

REFRIGERATION APPARATUS INCLUDING LIQUID INJECTION DESUPERHEATER

Filed Sept. 26, 1963

3,201,950

Fig. 1.

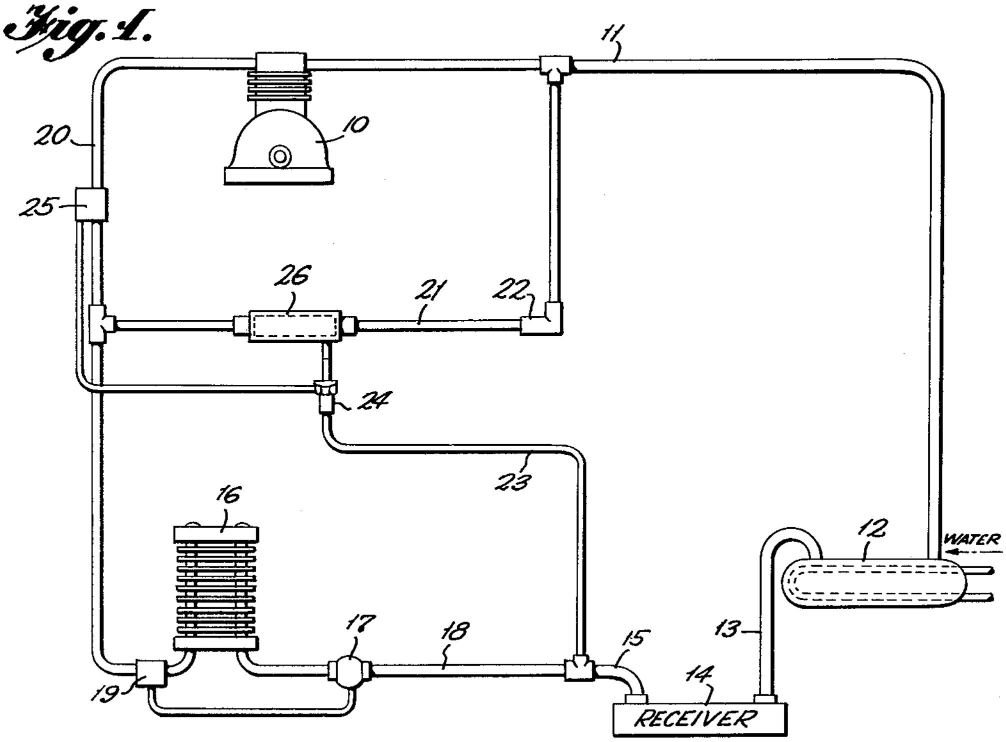


Fig. 2.

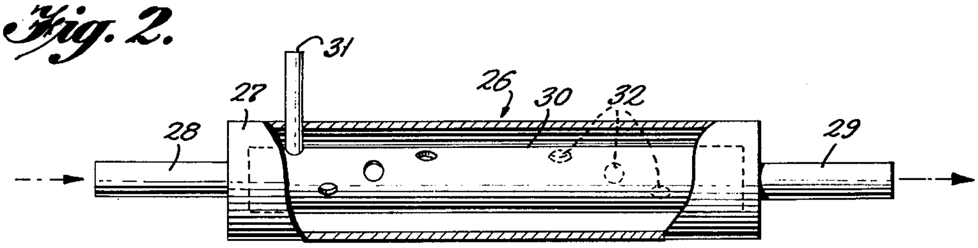
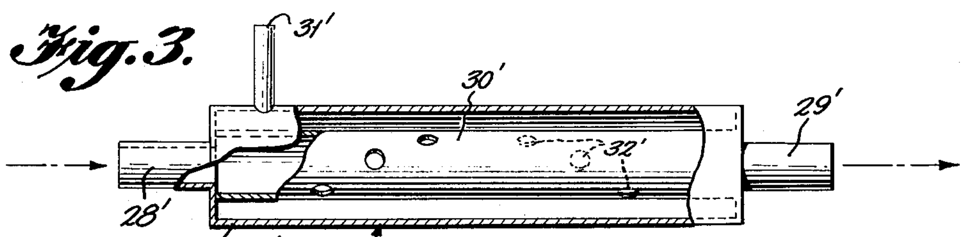


Fig. 3.



INVENTOR

Raymond M. Shrader

BY Mason, Fenwick & Lawrence

ATTORNEYS

United States Patent Office

3,201,950

Patented Aug. 24, 1965

3,201,950

REFRIGERATION APPARATUS INCLUDING LIQUID INJECTION DESUPERHEATER

Raymond M. Shrader, Decatur, Ga., assignor to Larkin Coils, Inc., Atlanta, Ga., a corporation of Georgia

Filed Sept. 26, 1963, Ser. No. 311,743
6 Claims. (Cl. 62—197)

This invention relates to refrigerating systems, and more particularly to improvements in the arrangements for automatic capacity control of such systems.

It is well known that automatic capacity control of a refrigeration system can be obtained by the expedient of by-passing a certain amount of the gaseous refrigerant discharged from the compressor around the condenser and evaporator and introducing the same directly into the compressor suction line. There is a limit to the amount of gaseous refrigerant which can be thus by-passed for the purpose of reducing system capacity, because of the superheating which may occur as the gaseous refrigerant again passes through the compressor. If the gaseous refrigerant is continuously by-passed to the compressor for long periods of time along such a short path wherein little heat is withdrawn, it is obvious that the temperature of the gaseous refrigerant will progressively rise due to superheating of the gas upon each cycle of passage through the compressor, accompanied by transmission of heat to the compressor. This condition will tend to damage the compressor over a period of operation. A popular method of preventing the by-passed gaseous refrigerant from attaining an excessively high temperature which would effect overheating of the compressor during periods when small evaporator load and by-passing of large amounts of gaseous refrigerant produce conditions exceeding the normal capacity reduction limit, has been to inject liquid refrigerant into the suction line vapor whereby the boiling refrigerant in heat exchange relation with the suction gas cools the suction gas before it enters the compressor.

By injecting liquid refrigerant into the suction gas in the suction line, a serious practical difficulty is encountered particularly in smaller horsepower systems. With fluctuations in loads and stopping and starting the compressor with the associated starting of the vapor flow, quite often the injected liquid refrigerant will not properly vaporize in the suction line gas and consequently the liquid passes into the compressor as a "slug" of liquid. It is easily seen that the non-vaporized slug of liquid, being incompressible, is apt to break the piston or other parts of the compressor.

An object of this invention is the provision of a novel refrigeration system having automatic capacity control of the type involving by-passing of gaseous refrigerant from the compressor discharge line to the suction line, wherein excessive heating of return gas to the compressor is avoided.

Another object of this invention is the provision in a refrigeration system of a novel arrangement for varying system capacity by by-passing gaseous refrigerant directly to the suction line and reducing the superheating of the by-passed gas by injecting liquid refrigerant into heat exchange relation with the by-passed gas to desuperheat the gas in order that the temperature of the compressor will be maintained below levels where damage may result.

Another object of this invention is the provision of a

liquid injector for injecting liquid refrigerant into the by-pass vapor line of a capacity control refrigeration system wherein complete vaporization of the injected refrigerant will be insured to thereby eliminate the possibility of damage to the compressor by preventing a slug of liquid from reaching the compressor.

Further aims, objects and advantages of this invention will appear from a consideration of the following description and the accompanying drawings showing for purely illustrative purposes the embodiments of this invention. It is to be understood, however, that the description is not to be taken in a limiting sense, the scope of the invention being defined in the appended claims.

In the drawings:

FIGURE 1 is a diagram of a refrigerative circuit utilizing the vaporizing chamber of the present invention.

FIGURE 2 is a view of a first embodiment of the vaporizing chamber partially in section and partially in elevation.

FIGURE 3 is a view of a second embodiment of the vaporizing chamber partially in section and partially in elevation.

Referring to the drawings, wherein like reference characters designate corresponding parts throughout the several figures, the refrigeration system of FIGURE 1 comprises a compressor 10, of any suitable size and design, which discharges the refrigerant through line 11 to a condenser 12, herein illustrated as a conventional water cooled condenser. The compressed vapor phase refrigerant entering the condenser condenses to liquid phase and is discharged through line 13 into a receiver 14 where the liquid refrigerant is stored. The liquid refrigerant is conveyed from the receiver 14 through conduit 15 to an evaporator 16.

The evaporator 16 may be of conventional construction, and is, of course, designed to have a selected cooling capacity for the normal heat loads expected to be encountered. Conventional means is provided for metering flow of liquid refrigerant from the receiver to the evaporator through liquid line 18 in accordance with the heat load on the evaporator, as for example a thermostatic expansion valve 17, regulated by the usual control bulb 19.

To provide for automatic capacity control of the refrigeration system as the means to reduce the cooling capacity of the evaporator for low heat loads, instead of cycling the compressor on and off, a part of the hot gaseous refrigerant discharged from the compressor is by-passed around the condenser-receiver-evaporator legs of the refrigerant circuit through by-pass conduit 21. This by-pass arrangement serves both to deprive the evaporator of some liquid refrigerant, thus reducing its cooling capacity, and further prevents attainment of harmful conditions which would otherwise occur if the compressor were operated continuously and the liquid refrigerant inflow to the evaporator were throttled down to an appropriate value for low heat loads. With minimum heat load conditions at the evaporator 16, continued operation of the compressor 10 would reduce the pressure in the suction line 20 to such a low value that problems of compressor shaft sealing, bearing lubrication and other problems with which those skilled in the art are familiar would be encountered. With a by-pass line 21 connected between the discharge line 11 and the suction line 20 around the condenser, receiver and evaporator when a low load condition is established at the evaporator **16** and the flow of vapor therefrom has been severely restricted, a controlled flow of gaseous refrigerant into the suction line **20** may be established by bleeding a portion of gaseous refrigerant from discharge line **11**.

The amount of vapor allowed to enter the by-pass line **21** is controlled by a conventional downstream pressure sensitive control valve **22** located in the by-pass line **21**. When the suction pressure in line **20** drops below a preselected value, this low pressure will activate the control valve **22**, allowing the valve to open and permitting a recirculation of gaseous refrigerant from the discharge line **11** back into the suction line **20** and thence to the intake of the compressor **10**. If the pressure in suction line **20** remains above the preselected pressure, then the control valve **22** will remain closed and thus allow operation of the system in the normal way with the cooling effect of the evaporator regulated by the control bulb **19** and expansion valve **17**.

With a restricted flow of liquid refrigerant to the evaporator **16** to meet a low load condition, and a resultant pressure decrease in suction line **20**, it will be evident that the control valve **22** will remain open and continue to recirculate the vapor through the by-pass line **21** and the compressor **10**. This continued recirculation of gaseous refrigerant through the compressor will produce a cumulative heating effect at the compressor as the progressively higher temperature gas is further superheated during compression, and if not offset, will produce a temperature within the compressor **10** that has a dangerously high value. To offset this heating effect, a second by-pass line **23** is connected from liquid refrigerant line **18** to by-pass line **21**, through which a portion of the liquid refrigerant in line **18** may be injected into the hot recirculating gaseous refrigerant in by-pass line **21** to effect cooling of the by-passing refrigerant. To control the amount of liquid refrigerant flowing through by-pass line **23** into by-pass line **21**, a conventional thermostatic-expansion valve **24** is interposed in by-pass line **23** with its associated control bulb **25** disposed adjacent the suction line **20**. The bulb **25** will sense the temperature of line **20** and will modulate valve **24** in such relation as to provide a rate of refrigerant injection into by-pass line **21** by way of a vaporizing chamber **26** such that the refrigerant will be completely vaporized before actual discharge into the by-pass line **21**, thereby preventing a slug of liquid from reaching the compressor.

The vaporizing chamber **26**, as shown in one preferred embodiment by FIGURE 2 comprises an outer elongated cylindrical tube **27** having a vapor inlet tube **28** on one end thereof and a vapor outlet tube **29** on the other end. Concentrically located within the outer tube **27** is an inner elongated cylindrical tube **30** coaxially arranged relative to the outer tube **27**. To provide access to inner tube **30** is an inlet pipe **31** which extends outwardly at right angles from one end of inner tube **30** through an aperture in outer tube **27** to allow the inlet pipe **31** to be connected to liquid injection line **23**. Inner tube **30** has located therein a plurality of sized orifices **32** that are spiralled around the tube **30** in an even distribution down its length which allow the liquid refrigerant coming in through pipe **31** to be injected in a swirling manner into the hot gaseous refrigerant which flows through tube **27** and surrounds inner tube **30**. It will thus be seen that heat exchange between the injected liquid refrigerant admitted through valve **24** into tube **30** and the by-passing gaseous refrigerant in tube **27**, produces boiling of the liquid refrigerant in the inner tube **30**. Because of the pressure differential between the relatively low pressure in the suction line **20** and the relatively high pressure of the liquid line **23**, the boiling refrigerant within tube **30** is discharged through orifices **32** in a spray of fine mist-like particles of liquid refrigerant which are entrained with the gaseous refrigerant and present a combined surface area sufficiently large to allow rapid absorption of heat from the gaseous refrigerant with a consequent change of state of the resulting mixture to all vapor while still within the confines of tube **27**.

Representative sizes of the vaporizing chamber **26** that have been found to operate in a practical manner with various refrigeration system capacities are as follows:

System Capacity, Tons	Number of 1/64″ Dia. Orifice Holes 32	Diameter of Inner Tube 30 (in.)	Length of Inner Tube 30 (in.)	Diameter of Outer Tube 27 (in.)	Length of Outer Tube 27 (in.)
½	4	½	3	⅞	5
1	8	½	5	⅞	8
1½	10	½	7	⅞	10
2	10	⅝	7	1⅛	10
3	16	⅝	10	1⅛	13
5	24	⅞	13	1⅝	18
10	36	⅞	20	1⅞	24

In describing the operation of the present refrigeration system, and in particular the vaporizing chamber, it will be assumed that the system is initially operating under a condition of maximum load. When the evaporator **16** is operating under a maximum load, the liquid refrigerant is fed through valve **17** to the evaporator at a maximum rate and is completely vaporized and returned to the compressor through the suction line. Thus, upon leaving the evaporator the now vaporized refrigerant produces a certain temperature at the location of the bulb **19** reflecting this load condition on the evaporator.

Under high load the compressor normally experiences no problems due to low pressure or excessive superheat as the temperature does not exceed that for which the system is designed when under full load. But when the evaporator is subjected to a small load, or no load conditions, a lesser temperature is sensed by the thermo-sensitive bulb **19** and activates the valve **17** to restrict the flow of liquid refrigerant from the condenser **12** to the evaporator **16**. With less vapor being discharged from the evaporator **16**, the compressor **10**, which is operating continuously, begins to reduce the pressure in the suction line **20**. This reduction in suction line pressure will be reflected through by-pass line **21** to the automatic pressure responsive control valve **22** which will then open to permit a recirculation of gaseous refrigerants from the discharge line **11** into the suction line **20** to reduce the liquid refrigerant supply to the condenser and evaporator and increase the suction line pressure at the intake of the compressor up to a normal value.

As has been noted above, continued recirculation of the discharge gaseous refrigerant through the compressor will permit a dangerously high temperature to be imparted to the gaseous refrigerant. Once this temperature reaches a predetermined value, the thermo-sensitive bulb **25** responds and allows the thermo-expansion valve **24**, located in liquid by-pass line **23**, to open and admit liquid refrigerant to the vaporizing chamber **26**. When this condition occurs the liquid refrigerant flows into the inner tube **30** by pipe **31** where it boils due to the heat exchange with the gas flowing within the outer tube **27**. As stated above the boiling refrigerant is discharged through orifice holes **32** in fine mist-like particles which absorb heat from the gaseous refrigerant flowing through outer tube **27** so that a complete vaporization occurs within the confines of outer tube **27**, and in the manner contemplated by the invention the gas leaving tube **27** by way of vapor outlet tube **29** contains no slugs of liquid that could possibly be transmitted to the compressor **10**.

A second embodiment of this invention as shown in FIGURE 3, comprises an elongated cylindrical outer tube **27′** having located concentrically therein an elongated cylindrical tube **30′** with orifice holes **32′**. The construction of this embodiment is just the opposite as that shown in FIGURE 2, that is, the liquid refrigerant is admitted through line **31′** into the outer tube **27′** and the liquid then boils by heat exchange with the hot gaseous refrigerant flowing through the inner tube **30′** with the result that the boiling liquid will then be injected in a fine spray into the inner tube **30'** through orifices **32'**. In all other respects this embodiment operates in the same manner as that shown in FIGURE 2.

In the refrigerant system of the present invention a high degree of modulation is achieved upon the temperature of the vapor entering the compressor **10**, because thermo-sensitive bulbs **19** and **25** work in conjunction with one another. While the bulb **19** senses only the temperature of the discharged gas from evaporator **16** and controls it accordingly, bulb **25** senses the temperature of the return vapor at a point in the return line after the thermal effects of the gas from by-pass line **21** are introduced and is able to control the temperature conditions at the compressor by opening and closing valve **24** to admit into the vaporizing chamber **26** a flow of liquid refrigerant just sufficient in quantity to offset the undesirable heating effects of the by-passed refrigerant.

Those skilled in the art will recognize that the various structural elements of the system including the compressor, condenser, evaporator, connecting lines and control valves may be of any conventional nature and may be varied according to good engineering practice.

Various modifications may be made in the invention without departing from the spirit and scope thereof, and it is desired, therefore, that only such limitations shall be placed thereon as are imposed by the prior art and set forth by the appended claims.

I claim:

1. In a refrigeration system having automatic capacity control means for varying the capacity thereof including a compressor, condenser, receiver and evaporator having the usual hot gas line from the outlet side of the compressor to the condenser, a suction line from the inlet side of the compressor to the evaporator and a liquid line from the receiver to the evaporator, a hot gas by-pass conduit directly connecting the outlet and inlet sides of said compressor, a liquid by-pass conduit directly connecting said receiver and said gas by-pass conduit, and means for regulating the flow of gaseous refrigerant through said gas by-pass conduit responsive to conditions in the system indicative of the load on the evaporator and pressure in the suction line; the improvement comprising liquid injection means in said gas by-pass conduit at the junction of said liquid by-pass conduit comprising a plurality of concentric tubular members, one of said tubular members having fixed sized orifices in heat exchange relation with the hot gas in said gas by-pass conduit wherein said orifices are so calibrated as to bring the liquid to a boil before said liquid is injected into said gas by-pass conduit whereby the injected liquid absorbs heat from the hot gas to effect complete vaporization of said injected liquid to prevent a slug of liquid from reaching said compressor.

2. In a refrigeration system having automatic capacity control means for varying the capacity thereof including a compressor, condenser, receiver and evaporator having the usual hot gas line from the outlet side of the compressor to the condenser, a suction line from the inlet side of the compressor to the evaporator and a liquid line from the receiver to the evaporator, a hot gas by-pass conduit directly connecting the outlet and inlet sides of said compressor, a liquid by-pass conduit directly connecting said receiver and said gas by-pass conduit, and means for regulating the flow of gaseous refrigerant through said gas by-pass conduit responsive to conditions in the system indicative of the load on the evaporator and pressure in the suction line; the improvement comprising liquid injection means in said gas by-pass conduit at the junction of said liquid by-pass conduit comprising a pair of concentric tubular members, one of said tubular members mounted in said gas by-pass conduit to permit the hot gas to pass therethrough, the other of said tubular members having means to admit

liquid from said liquid by-pass conduit, fixed sized orifices in the inner of said concentric tubular members spiralled therearound in heat exchange relation with the hot gas in said gas by-pass conduit wherein said orifices are so calibrated as to bring the liquid to a boil before said liquid is injected into said gas by-pass conduit whereby the injected liquid absorbs heat from the hot gas to effect complete vaporization of said injected liquid to prevent a slug of liquid from reaching said compressor.

3. In a refrigeration system having automatic capacity control means for varying the capacity thereof including a compressor, condenser, receiver and evaporator having the usual hot gas line from the outlet side of the compressor to the condenser, a suction line from the inlet side of the compressor to the evaporator and a liquid line from the receiver to the evaporator, a hot gas by-pass conduit directly connecting the outlet and inlet sides of said compressor, a pressure sensitive valve in said conduit adapted to be actuated in response to a preselected pressure value in said suction line to admit hot gaseous refrigerant to said gas by-pass conduit, a liquid by-pass conduit directly connecting said receiver and said gas by-pass conduit, a temperature sensitive valve in said liquid by-pass conduit adapted to be actuated in response to a predetermined temperature of the gas in said suction line to modulate the rate of liquid flow to said gas by-pass conduit, the improvement comprising liquid injection means in said gas by-pass conduit at the junction of said liquid by-pass conduit comprising a pair of concentric tubular members, one of said tubular members mounted in said hot gas by-pass conduit to permit the hot gas to pass therethrough, the other of said tubular members having means to admit liquid from said liquid by-pass conduit, fixed sized orifices in the inner of said concentric tubular members spiralled therearound in heat exchange relation with the hot gas in said gas by-pass conduit wherein said orifices are so calibrated as to bring the liquid to a boil before said liquid is spray injected into said gas by-pass conduit whereby the spray injected liquid absorbs heat from the hot gas to effect complete vaporization of said spray injected liquid to prevent a slug of liquid from reaching said compressor.

4. In a refrigeration system having automatic capacity control means for varying the capacity thereof including a compressor, condenser, receiver and evaporator having the usual hot gas line from the outlet side of the compressor to the condenser, a suction line from the inlet side of the compressor to the evaporator and a liquid line from the receiver to the evaporator, a hot gas by-pass conduit directly connecting the outlet and inlet sides of said compressor, a liquid by-pass conduit directly connecting said receiver and said gas by-pass conduit, and means for regulating the flow of gaseous refrigerant through said gas by-pass conduit responsive to conditions in the system indicative of the load on the evaporator and pressure in the suction line; the improvement comprising liquid injection means in said by-pass conduit at the junction of said liquid by-pass conduit comprising an outer elongated cylindrical tube having a gas inlet tube on one end thereof and a gas outlet tube on the other end, an inner elongated cylindrical tube coaxially arranged relative to said outer tube, means projecting through said outer tube providing liquid access to said inner tube and fixed sized orifices in said inner tube spiralled therearound in heat exchange relation with the hot gas in said gas by-pass conduit wherein said orifices are so calibrated as to bring the liquid to a boil before said liquid is spray injected into said gas by-pass conduit whereby the spray injected liquid absorbs heat from the hot gas to effect complete vaporization of said injected liquid to prevent a slug of liquid from reaching the compressor.

5. In a refrigeration system having automatic capacity control means for varying the capacity thereof including a compressor, condenser, receiver and evaporator having the usual hot gas line from the outlet side of the compressor to the condenser, a suction line from the inlet side of the compressor to the evaporator and a liquid line from the receiver to the evaporator, a hot gas by-pass conduit directly connecting the outlet and inlet sides of said compressor, a liquid by-pass conduit directly connecting said receiver and said gas by-pass conduit, and means for regulating the flow of gaseous refrigerant through said gas by-pass conduit responsive to conditions in the system indicative of the load on the evaporator and pressure in the suction line; the improvement comprising liquid injection means in said gas by-pass conduit at the junction of said liquid by-pass conduit comprising an outer elongated cylindrical tube having a liquid access aperture therein, an inner elongated cylindrical tube coaxially arranged relative to said outer tube having a gas inlet tube on one end thereof and a gas outlet tube on the other end and fixed sized orifices in said inner tube spiralled therearound in heat exchange relation with the hot gas in said gas by-pass conduit wherein said orifices are so calibrated as to bring the liquid to a boil before said liquid is spray injected into said gas by-pass conduit whereby the spray injected liquid absorbs heat from the hot gas to effect complete vaporization of said spray injected liquid to prevent a slug of liquid from reaching said compressor.

6. In a refrigeration system having automatic capacity control means for varying the capacity thereof including a compressor, condenser, and receiver and evaporator having the usual hot gas line fom the outlet side of the compressor to the condenser, a suction line from the inlet side of the compressor to the evaporator and a liquid

line from the receiver to the evaporator, a hot gas by-pass conduit directly connecting the outlet and inlet sides of said compressor, and means for regulatng the flow of gaseous refrigerant through said hot gas by-pass conduit responsive to pressure conditions in said suction line; the improvement comprising means for automatically injecting spray droplets of liquid refrigerant in a spiral pattern into direct heat exchange contact with the hot gaseous refrigerant flowing through said hot gas by-pass conduit quantities of liquid refrigerant extracted from a location between said condenser and said evaporator including means for regulating the quantity of the introduced liquid refrigerant responsive to thermal conditions of the suction line gas returned to said compressor to substantially that quantity required to maintain the return gas below compressor damaging temperature and effect complete vaporization of the introduced liquid refrigerant, said means for automatically injecting spray droplets of liquid refrigerant comprising means forming a chamber of concentric members, one of said members having sized orifices spiralled therearound.

References Cited by the Examiner

UNITED STATES PATENTS

2,363,273 11/44 Waterfill -------------- 62—196

OTHER REFERENCES

German printed application No. 1,055,561, printed April 23, 1959.

MEYER PERLIN, *Primary Examiner.*

ROBERT A. O'LEARY, *Examiner.*