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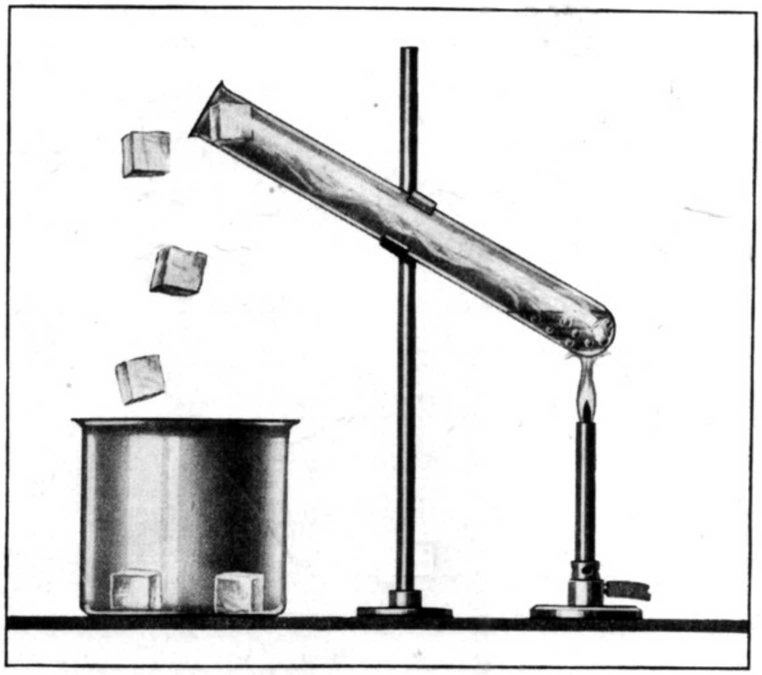
THE MIRACLE OF ICE FROM HEAT



THE SCIENTIFIC MARVEL OF

Gas Refrigeration

EXPLAINED SO EVERYONE CAN UNDERSTAND IT

FOREWORD

This Booklet has been prepared in response to many requests for an explanation of how a tiny gas flame can produce constant cold and cubes of ice—*without moving parts*.

You have probably heard about the remarkable *Gas* refrigerator that has no moving parts in its freezing system—the refrigerator that has inspired such unusual expressions as "The Flame that Freezes" and "The Refrigerator You Hear About But Never Hear."

Perhaps you have wondered about it, and imagined that so amazing an appliance must be difficult to understand. Happily, this is not so. It is actually *easy* for anyone to understand how and why a tiny gas flame can make ice and keep constant refrigerator temperature.

What seems to be an almost magical transformation is really an ingenious application of some simple laws of Nature which can be described in familiar language by reference to everyday knowledge. This little booklet gives the explanation in non-technical terms.

We believe you will find it interesting to know why "heat makes ice." And knowing this, you will be able more fully to appreciate the value of simplicity in this "no moving parts" freezing system.

For those who are scientifically-minded, a technical description follows the "popular" explanation.

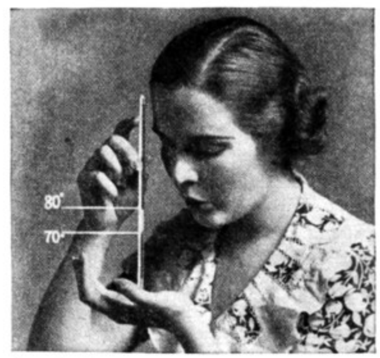
TRY THIS SIMPLE EXPERIMENT

(Some facts about cooling by evaporation of a liquid into a gas)

POUR some alcohol (rubbing alcohol or wood alcohol will do) on the back of your hand. Blow on the alcohol. This spot will feel real cool. Now blow on your other hand where there is no alcohol. It will not feel cool, but warm. What happened when you blew on the alcohol? Liquid alcohol was swept by a stream of warm air and the result was a temperature below the temperature of either the alcohol or the air. In reality this simple process produced refrigeration.

When alcohol is applied to the human body a cooling sensation is produced. This is because the alcohol evaporates into the air and the heat necessary for the evaporation is removed from the body.

As the air sweeps past the hand, the alcohol disappears. It evaporates into the air. Cold can be produced by evaporation of a liquid. You proved this by blowing on the hand that had alcohol on it. You could feel the cold.



As alcohol evaporates it forms a gas mixture of air and alcohol just above the liquid. If this gas mixture is blown away so that more alcohol can evaporate freely, considerable cooling can be produced.

You will be surprised how much cold can be produced in this way. Pour some alcohol in the hollow of your hand and place a thermometer bulb in the liquid. Then as you blow on the alcohol watch how quickly the mercury drops. If you could blow continuously and had a continuous supply of alcohol poured into your hand you would be producing continuous refrigeration.

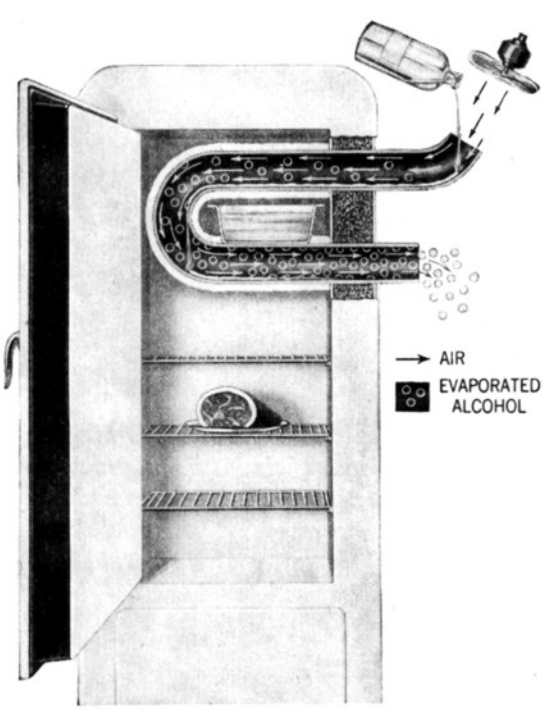
Evaporation is used by nature to cool the human body. The body has pores or moisture outlets. Normal body temperature is 98.6° F. If the atmosphere is appreciably cooler, the heat continuously generated by the body is readily dissipated. However, the body may produce heat faster than it is dissipated in normal manner. Nature then comes to our assistance by producing body moisture (perspiration) and evaporation of body moisture. The evaporation of the moisture (water) into the air takes heat from the body and the removal of heat is a cooling effect. *An intense chill may be felt if you perspire and stand in a breeze.*

A SIMPLE REFRIGERATOR

(The foregoing facts applied)

WE HAVE SEEN that evaporation can produce a cooling effect. How can we use this evaporative cooling effect in a refrigerator box? We need a supply of alcohol and a flow of air. Of course the alcohol should not evaporate directly into the air in the refrigerator. Flow suggests pipes. So let us run an ordinary metal pipe through the box and have the alcohol and air flow through the pipe. A metal pipe is a good conductor. Consequently the cold produced by evaporation in the pipe is directly used to refrigerate the contents of the box.

So we place a loop of pipe in the box and pass the ends through the insulation of the box. If we pour liquid alcohol into the pipe so that it flows down through the pipe, and if we pass a current of air through the pipe, we will have evaporation within the pipe and the box will be refrigerated. As the alcohol evaporates into the air, a gaseous mixture of alcohol vapor and air is formed in the same way as when you blew on the alcohol in your hand. We have made a simple refrigerator.



Evaporation can take place in a pipe by letting alcohol trickle down the pipe while a slow breeze of air passes over the liquid alcohol. Such a pipe is an "evaporator." If the evaporator is placed in an insulated enclosure we have a simple refrigerator.

If we place a tray containing water on the pipe, we can produce ice.

The evaporator is the part of the refrigerating "system" which is inside the refrigerator box. There are other parts to the system, but they are outside the insulated food space. They serve to make the process continuous, automatic, and economical.

The evaporator of the Gas refrigerator is made up of a number of loops of pipe arranged in the walls of a "chest" for ice drawers and also exposed to directly cool the food space.

RECLAIMING THE EVAPORATED LIQUID

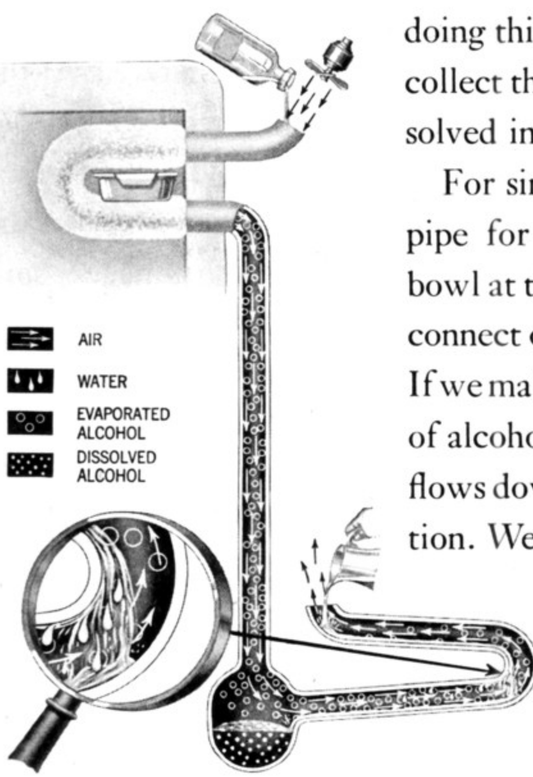
(We begin the addition of parts to make the system automatic)

A MIXTURE of alcohol vapor and air leaves our experimental evaporator. If we are to use the alcohol over again, we must first separate it from the air. This is easily done if we dissolve the alcohol in water. We know that water dissolves alcohol but does not dissolve air. A rain shower clears the air–actually washes it–but does not dissolve the air.

Rain "washes" the air.

So let us sprinkle water into the mixture of alcohol and air leaving the evaporator. The shower of water washes the alcohol out of the air and the alcohol becomes dissolved in the water. This is what is known as "absorption." Since we are doing this to save the alcohol, we will collect the water with the alcohol dissolved in it in a "bowl."

For simplicity, we can use another pipe for this "absorption," with the bowl at the lower end of the pipe. Of course, we must connect our new pipe and "bowl" to the evaporator. If we make the connection to our "bowl", the mixture of alcohol vapor and air will flow up; while the water flows down. This "counter-flow" gives good absorption. We have made an "absorber".



We "wash" the alcohol out of the air. The water absorbs the alcohol but not the air. The dissolved alcohol is collected at the bottom of the absorber.

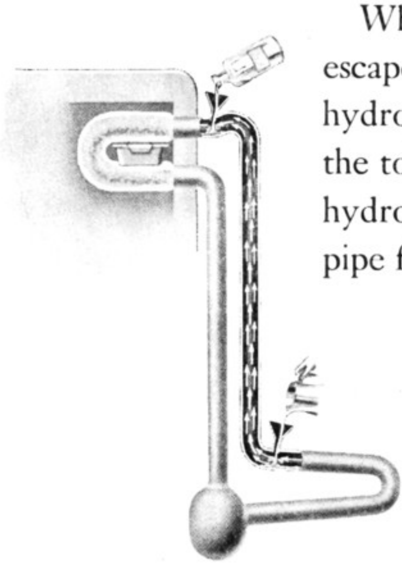
When the air reaches the top of the absorber, alcohol has been washed out of the air. When the water reaches the bottom of the absorber, it has absorbed alcohol. We have now segregated the alcohol from the air and have the alcohol in a readily usable form for reclamation.

THE EVAPORATOR-ABSORBER CIRCUIT

(In which a continuous flow is produced without moving parts)

SO FAR we have used air as the "gas" into which the alcohol evaporates. We could use other gases. The lighter the gas, the easier the alcohol evaporates into it. Hydrogen is the lightest gas and, at the same time, is not soluble in water and does not rust metal.* Let us change from air to hydrogen and blow hydrogen through the evaporator and into the absorber, just as we did with the air. The action will be the same.

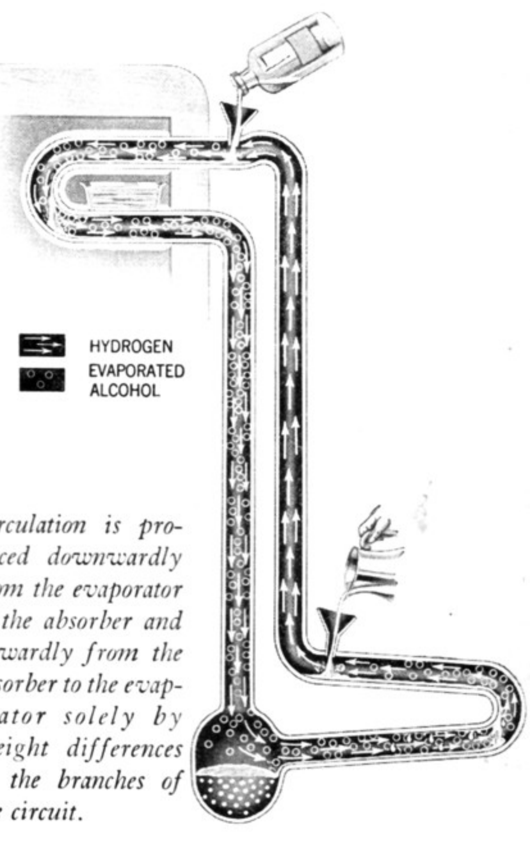
When we used air, which costs nothing, we could let it escape from the top of the absorber. But when we use hydrogen, we cannot afford to waste it. When it reaches the top of the absorber, alcohol has been removed and the hydrogen can therefore be used again. So let us connect a pipe from the top of the absorber to the top of the evaporator, so the hydrogen can pass back to the evaporator.



We connect a pipe between the top of the absorber and the evaporator to make a circuit for gas.

We have now made a circuit for the hydrogen through the evaporator, from the evaporator down to the absorber, up through the absorber and back to the evaporator.

When we used air it was easy to produce a "breeze." Even our lungs could provide the motive power. But, of course, when we change to hydrogen and close the circuit, we must supply some other force for producing a flow around the circuit.

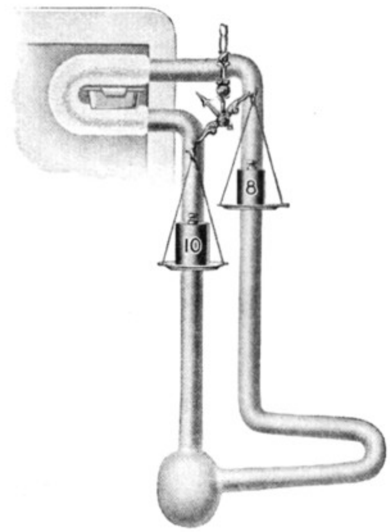


Circulation is produced downwardly from the evaporator to the absorber and upwardly from the absorber to the evaporator solely by weight differences in the branches of the circuit.

It might be thought that a fan could produce the breeze of hydrogen. But we can apply a natural circulating force and eliminate moving parts because we have different gas conditions in different parts of

**When the reader has read all of pages 4 and 5, it will be understood that another important reason for using hydrogen is its marked difference of weight (specific weight) relative to the evaporated fluid, which is important in the production of circulation without moving parts.*

the circuit. A mixture of alcohol vapor and hydrogen is heavier than hydrogen alone. As we have arranged the circuit, there are two vertical branches or columns: the heavier gas is in the down-flow pipe from the evaporator to the absorber and the lighter gas is in the up-flow pipe from the absorber to the evaporator. The heavier gas mixture produced in the evaporator therefore flows down by gravity and the lighter gas (the freed hydrogen) resulting from the absorption of the alcohol in the absorber must go up; just as the heavy side of a balance goes down and the light side goes up.



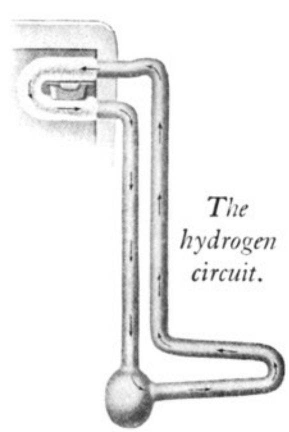
The circulating force is analogous to difference in weights on a balance scale. The preponderance of weight on one side makes the gas go down on that side and up on the other.

The hydrogen may be likened to a water wheel. It is weighted on one side by the relatively heavy alcohol vapor and the weight is released on the other side by absorption of the alcohol into water.

In effect, the heavy gas mixture flows by gravity from the evaporator through one pipe into the absorber and pushes the light hydrogen up in the absorber and back through the other pipe to the evaporator.

As long as we supply alcohol to the evaporator and water to the absorber, the heavy gas mixture is continuously formed in the evaporator and the lighter gas is continuously formed in the absorber. We therefore have continuous circulation, like a water wheel constantly supplied with water flowing down on one side and weighing that side down and flowing away at the bottom so that the other side is lighter.

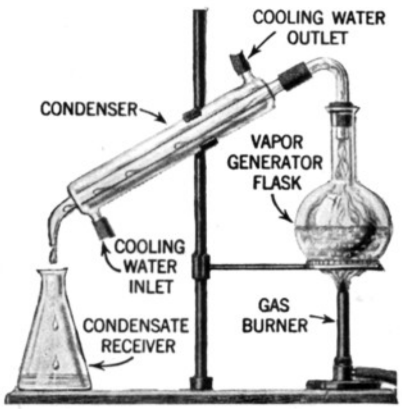
In our case, the hydrogen gas is the wheel which goes round and round. The alcohol evaporating into the hydrogen weighs down the hydrogen to make one side of the circuit heavy. The other side is lighter because the alcohol is taken away at the bottom (in the absorber). We now have a closed evaporator-absorber circuit continuously producing cold—without the use of a fan, pump, or other machinery.



The hydrogen circuit.

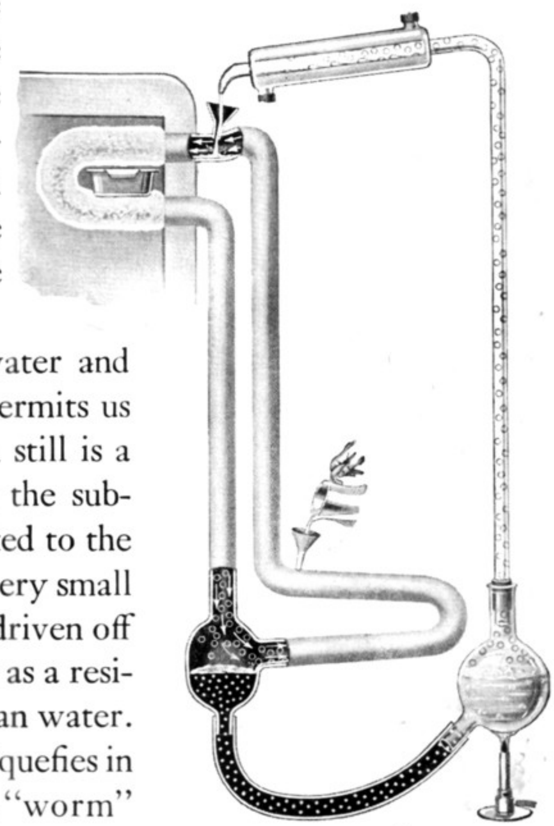
WE COMPLETE AND CLOSE THE SYSTEM

(In which a number of circulations are accomplished without moving parts)



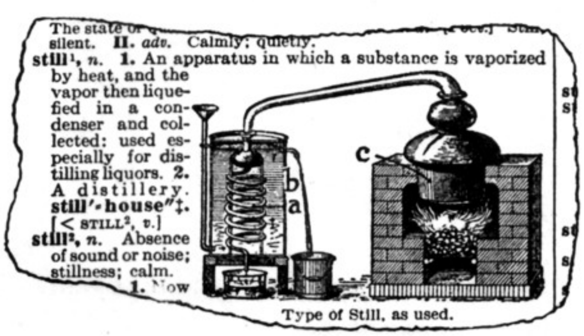
A laboratory still. Vapor is driven off and condenses in the condenser.

IN THE SYSTEM so far built up, we have an outside supply of alcohol to the evaporator; we also have an outside supply of water to the absorber; and we are collecting alcohol dissolved in water at the bottom of the absorber. To make the system complete, we must separate the alcohol from the water; also we must lift the separated alcohol and return it to the evaporator as a liquid; and we must lift the water and return it to the absorber.

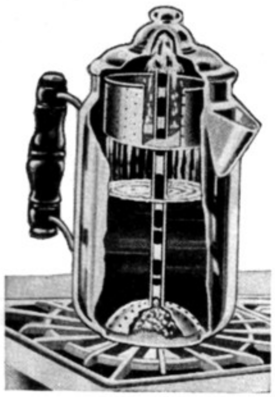


The alcohol is distilled from the solution and is liquefied in the condenser and flows into the evaporator.

An easy way to separate alcohol from water and liquefy the alcohol is to use a "still." This permits us to use heat alone and avoid moving parts. A still is a simple structure–a generator for vaporizing the substance to be distilled and a condenser connected to the generator to liquefy the vapor. We can use a very small still heated by a small burner. The alcohol is driven off as a vapor in the generator, leaving the water as a residue. Alcohol has a lower "boiling point" than water. The vapor, as we know, rises in the still and liquefies in the "worm" or condenser, and issues as a pure liquid. So, let us connect an ordinary still to the bottom of the absorber to receive the alcohol solution and connect the drip outlet of the still to the evaporator. We see that the evaporator becomes the receiver of the still.


The state of ... silent. **II.** *adv.* Calmly; quietly.
still[1], *n.* **1.** An apparatus in which a substance is vaporized by heat, and the vapor then liquefied in a condenser and collected: used especially for distilling liquors. **2.** A distillery. **still'-house"**‡. [< STILL[2], *v.*]
still[2], *n.* Absence of sound or noise; stillness; calm. **1.** Now

A dictionary definition of "still": (a) is the worm or condenser, (b) the cooler for the worm, (c) the generator.

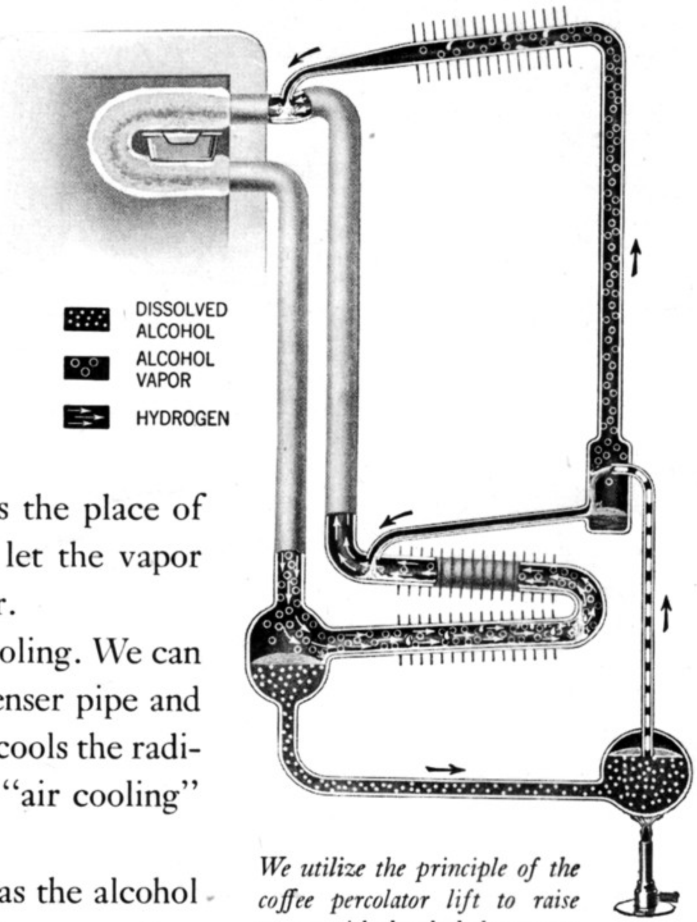


In a coffee percolator, steam raises water to the top of the percolator so that it can drip down through the coffee grounds.

We have now completed the system, except for one thing: We have not raised the water so it can flow back into the absorber.

How shall we lift the water? Of course, we could use a mechanical pump, but that would require moving parts. We do not want moving parts. What is there that lifts liquid without moving parts? We all know that a coffee percolator lifts liquid.

Let us place a percolator lifter in the still. Instead of a perforated pan at the top of the liquid lifter as in a coffee pot, which lets the water flow right back, we will catch the water at a level above the absorber so that it can flow into the absorber by gravity. The alcohol vapor takes the place of steam in the coffee pot. We simply let the vapor pass on to the "worm" or condenser.



We utilize the principle of the coffee percolator lift to raise water with the alcohol vapor so that the water can flow through the absorber without the use of moving parts.

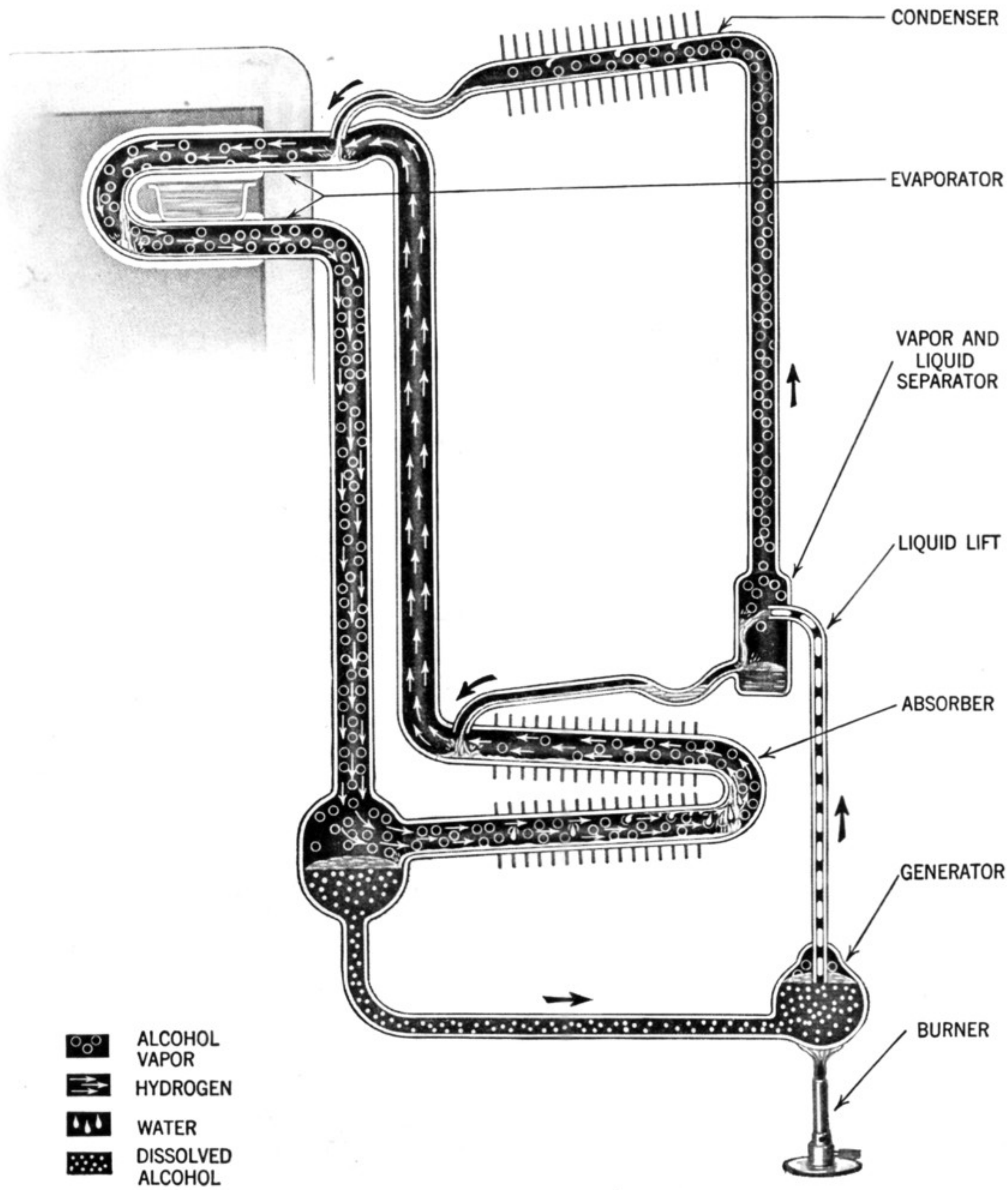
We actually do not need water cooling. We can simply put cooling fins on the condenser pipe and let the atmosphere cool it, as the air cools the radiator in our automobile. Due to the "air cooling" the alcohol vapor is liquefied.

The absorber will become warm as the alcohol dissolves, so we must cool the absorber as well as the condenser. This part we can also "air cool" in the same way as our condenser by simply putting cooling fins on the absorber pipe.

In order to confine the hydrogen to its circuit we can simply bend the pipes carrying liquid to this circuit so as to form liquid traps (see illustration on next page).

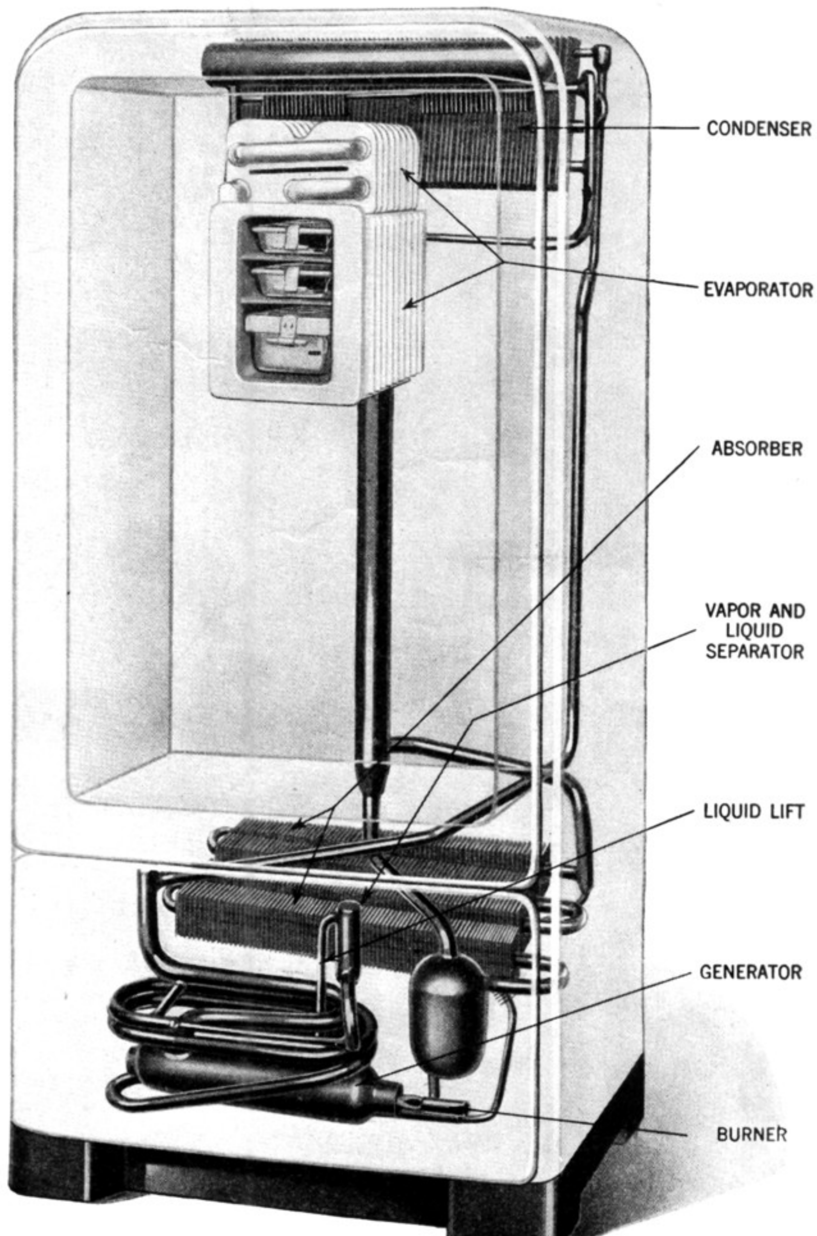
COLD FROM HEAT, IN PRINCIPLE

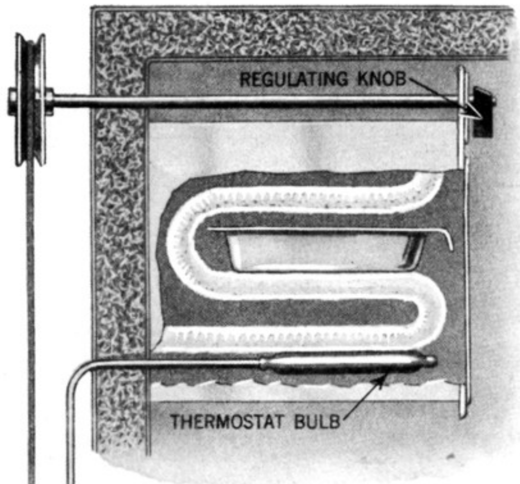
HERE we have the complete refrigerator which we have built up step by step. The parts are shown opened so that we can see the hydrogen flowing in its circuit between the evaporator and the absorber; the water flowing in its circuit between the absorber and the generator; and the evaporative fluid flowing in its circuit through the evaporator, absorber, generator, vapor and liquid separator, and condenser, and back to the evaporator.



PRINCIPLE APPLIED TO PRACTICE

HERE we have the refrigerating system as actually built for one model of the Servel Gas refrigerator. Note how the parts correspond. The actual refrigerator includes some additional refinements not included in the system we have built up. Additional refinements are described on later pages. However, the picture on page 8 shows clearly how cold is obtained from heat without moving parts.





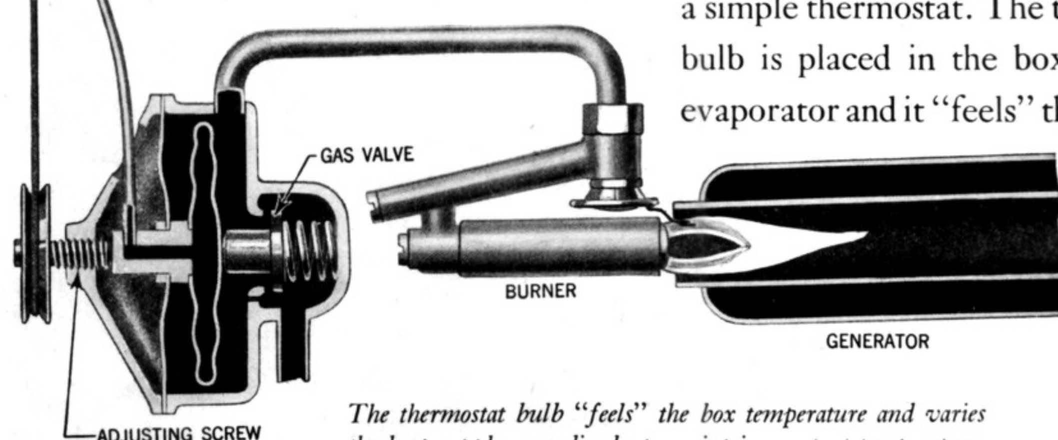
CONTROLLING OUR REFRIGERATOR

(Showing the ease of control and safety of a gas flame)

WE HAVE built a refrigerator in which we apply heat to one part and at the same time produce refrigeration at a remote part. How can we control the amount of refrigeration produced so that the refrigerator box will be neither too warm nor too cold? If we analyze the system we have built up we will find that this solves itself.

Suppose we increase the supply of heat. This will drive off more vapor in the generator and consequently more will condense in the condenser. This means that more liquid will flow into the evaporator to evaporate and more intense cold will be produced. Also, since evaporation is increased, the circulation between the evaporator and the absorber will be intensified, because one vertical branch of the hydrogen circuit gets heavier as the evaporation is intensified. We have seen that by increasing the alcohol quantity and "blowing" more on it we can produce more cold. So, by merely varying the heat supply, the whole system can be made to give more or less refrigeration.

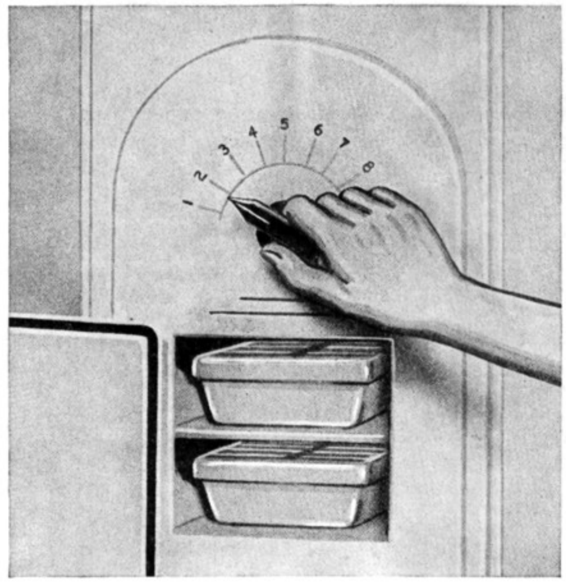
Since we are using a gaseous fuel, the regulation is easily accomplished by a simple thermostat. The thermostat bulb is placed in the box near the evaporator and it "feels" the temper-



The thermostat bulb "feels" the box temperature and varies the heat supply accordingly to maintain constant temperature.

ature. When it is too warm it causes expansion of a simple diaphragm to give a wider opening of a valve in the gas supply line. When it is too cold, it reduces the gas supply to the burner.

Also we can easily control the burner flame for safety. A shut-off valve in the gas line is connected to a simple foolproof disc which has a finger extending into the burner flame. If the burner flame should go out, the finger quickly cools and so does the disc, and when it cools, it closes the shut-off valve.

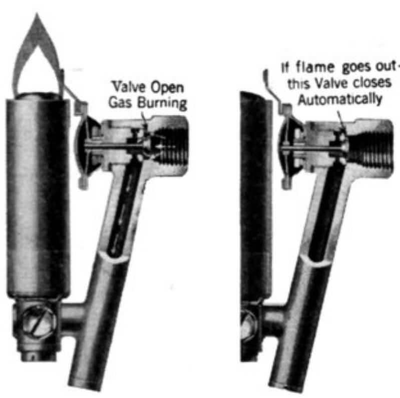


THE TEMPERATURE REGULATOR

A turn of the knob adjusts the thermostat so that a higher or lower evaporator temperature is automatically maintained.

Our system and its simple control also permits easy manual setting for faster freezing of ice cubes or desserts. We can place a knob on the evaporator and have it connected to adjust the thermostat to a higher or lower temperature. This is easily done by an adjusting screw connected to the knob by a simple pulley.

Gas has proved to be an ideal fuel for this refrigerating system, because of its economy, safety, availability, freedom from attention and ease of automatic control.



The heat of the flame buckles a disc to one side to hold a valve in the gas line open. If the flame goes out, the disc buckles to the other side, closing the valve.

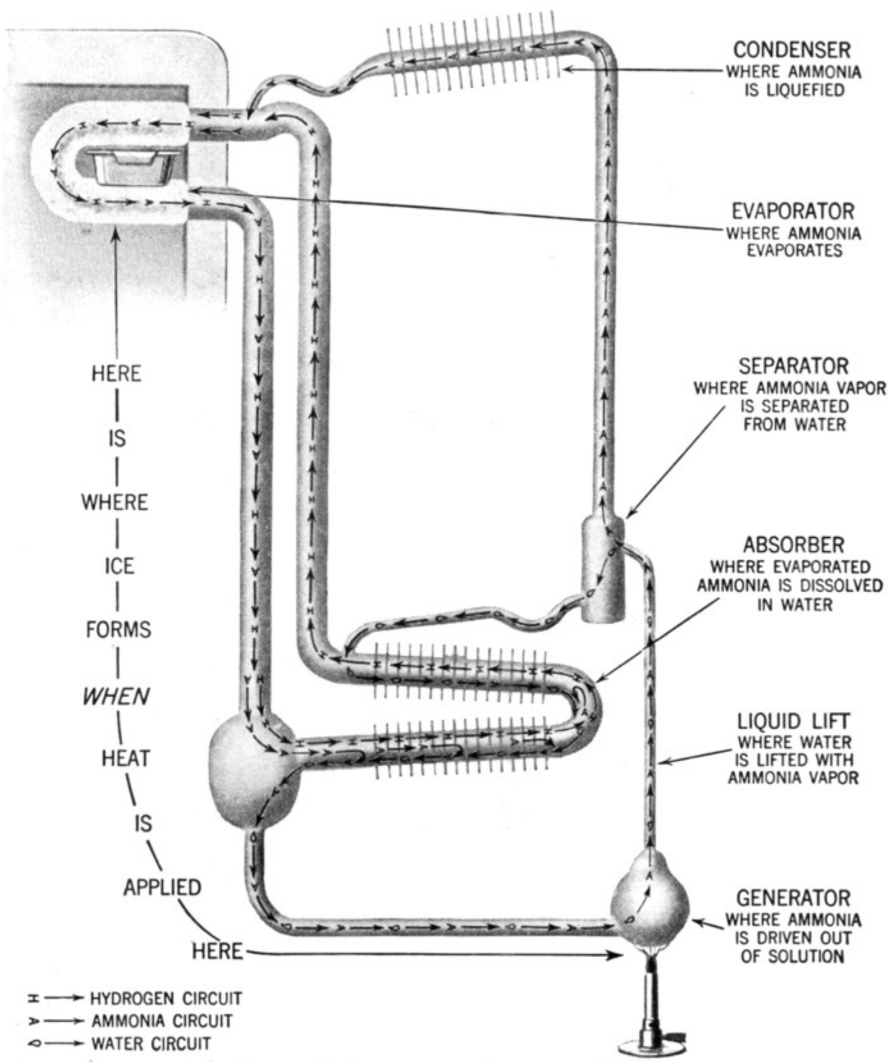
OTHER SOURCES OF HEAT

We have used gas as a convenient source of heat. It is most commonly used. In principle, however, we are not limited as to sources of heat. Another source of heat actually used for heating the refrigerator is kerosene. The reader will readily understand in principle how a kerosene burner can be substituted for the gas burner. The kerosene burner is also equipped with safety devices, though of different form. Still other sources of heat are "bottled" gas and "tank" gas. Even electricity is an available source of heat.

WHY AMMONIA?

When we first produced cold by blowing into our evaporator, we used alcohol as the evaporating fluid. Alcohol could be used, but ammonia is better. It requires less ammonia than alcohol to take up and transmit a certain amount of heat. Since we need to circulate less ammonia than alcohol to obtain the same amount of refrigeration, we are able to build a smaller unit if we use ammonia. Of course, compactness is very important in a household refrigerator.

The system will work the same way when using ammonia, but it requires a higher pressure to condense ammonia. This is accomplished by introducing the fluids into the unit under a suitable pressure before the unit is finally sealed in the factory.



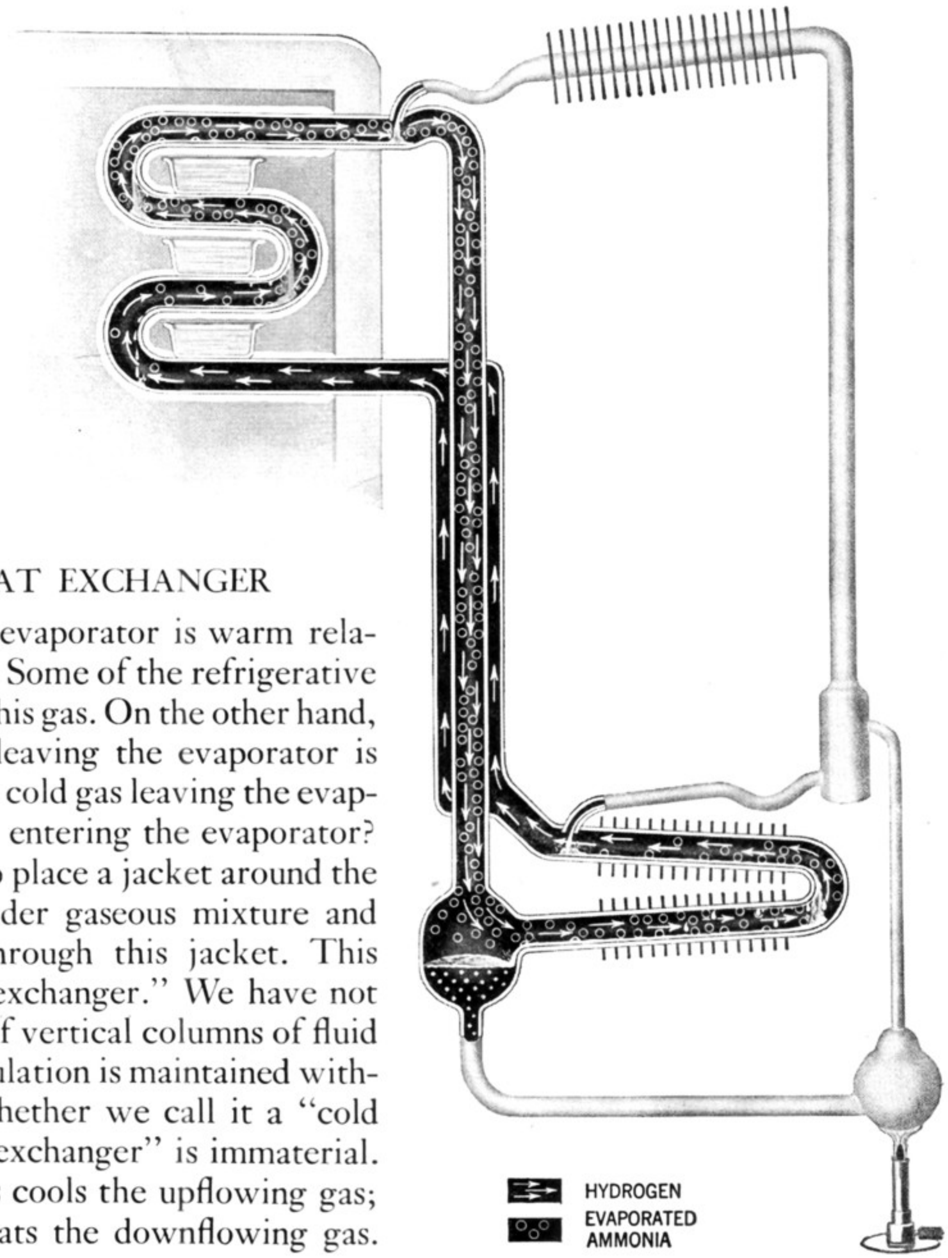
A picture of the system using ammonia looks just like the picture of the system using alcohol.

WE ADD SOME REFINEMENTS

(We revise the evaporator and add a heat exchanger for greater efficiency)

COUNTER-FLOW IN THE EVAPORATOR

AS WE first built the evaporator, both the evaporative liquid and the gas flowed downwards. When we built the absorber, we had the gas pass upwardly "counter-flow" to the liquid for more efficient contact. Likewise we will have better efficiency if we have the hydrogen gas pass upwardly in the evaporator. And we can simply reverse the connections to do this without disturbing the natural circulation between the absorber and the evaporator because the absorber is well below the evaporator so that a heavier gas column must form in the pipe now connecting the top of the evaporator with the bottom of the absorber.



THE GAS HEAT EXCHANGER

THE gas entering the evaporator is warm relative to the evaporator. Some of the refrigerative effect goes to cooling this gas. On the other hand, the gaseous mixture leaving the evaporator is cold. Why not use this cold gas leaving the evaporator to cool the gas entering the evaporator? All we need to do is to place a jacket around the pipe carrying the colder gaseous mixture and pass the hydrogen through this jacket. This makes the "gas heat exchanger." We have not changed the relation of vertical columns of fluid and therefore the circulation is maintained without moving parts. Whether we call it a "cold exchanger" or "heat exchanger" is immaterial. The downflowing gas cools the upflowing gas; the upflowing gas heats the downflowing gas.

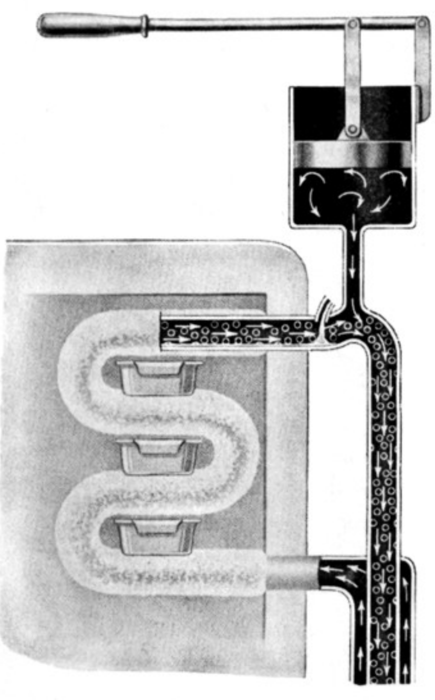
THE HYDROGEN RESERVE VESSEL

(A special feature for air cooling)

OUR system is "air cooled." It is air cooled by atmospheric air. The temperature of the atmosphere is high in summer and low in winter. Consequently we have a higher condenser temperature in the summer than in the winter.

In a condenser containing only ammonia, there is a relation between pressure and temperature. As the outside temperature varies, so the temperature inside the condenser varies and the pressure goes up and down with the temperature. There is a relation between pressure and temperature in a fluid changing from liquid to vapor (and vice versa). A familiar illustration of this is the decrease in temperature at which water boils as we go up a mountain because of the decrease of atmospheric pressure. If the pressure in the condenser is too low in relation to the temperature, the ammonia will not condense.

In our system as we have built it up so far, the pressure must be high enough so that we will have condensation of ammonia in the ammonia condenser at the highest air temperature of the summer time. We can easily charge the system to accomplish this by adding enough hydrogen. But in that case we would be operating at a higher pressure during most of the year when we could very well do with much less pressure. We would prefer to have a lower pressure as much of the time as possible because it is easier to drive the ammonia out of solution at lower pressure, and this in turn results in lower operating cost.



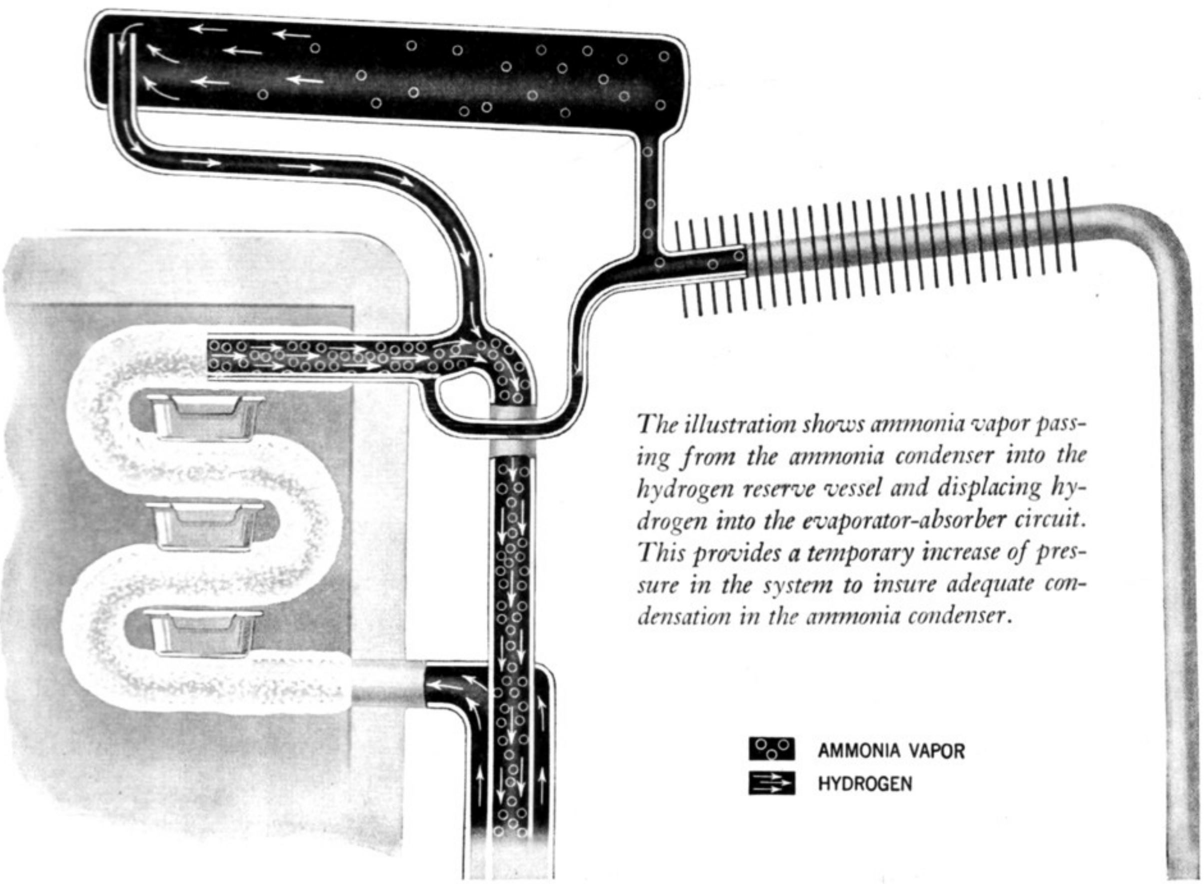
A reserve of hydrogen to be pushed into the circuit when outside temperature is high.

Can we build the system so that we ordinarily have a low pressure and only increase the pressure on the hottest days? We can do this if we can have a reserve of hydrogen which is pushed into the evaporator-absorber circuit only when the air temperature is abnormally high.

So we make a reserve vessel for hydrogen and connect it to the system. Normally the hydrogen stays in this reserve vessel and we can operate normally at lower pressure. If the air temperature rises so high that the pressure is inadequate for condensation in the ammonia condenser, we simply push more hydrogen into the active part of the system from our reserve vessel. To push this hydrogen into the circuit we could use a pump or a piston. But we would like to accomplish this also without moving parts and automatically. Fortunately we have factors in our system which can be applied to accomplish this. We can push the hydrogen into the active part of the system by the ammonia which does not condense.

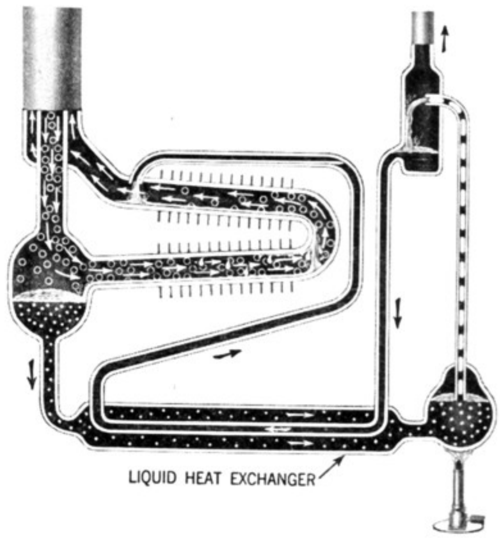
Therefore in place of using a pump or piston we simply connect our reserve vessel to the outlet of the ammonia condenser. If the ammonia vapor cannot condense, it must pass through our new pipe to the reserve vessel. This displaces the hydrogen out into the active part of the system. The ammonia vapor now in the reserve vessel corresponds to a quantity of ammonia (by weight) which was previously in solution and therefore occupied only a fraction of the space it now occupies in the reserve vessel. The hydrogen is still a gas. Due to the greater proportion of gaseous to liquid ammonia in the system the pressure is higher, which permits adequate condensation in the ammonia condenser.

When the outside temperature becomes normal again, the condenser action is intensified and the ammonia is drawn back into the active part of the system from the reserve vessel; and hydrogen is drawn back into the reserve vessel.



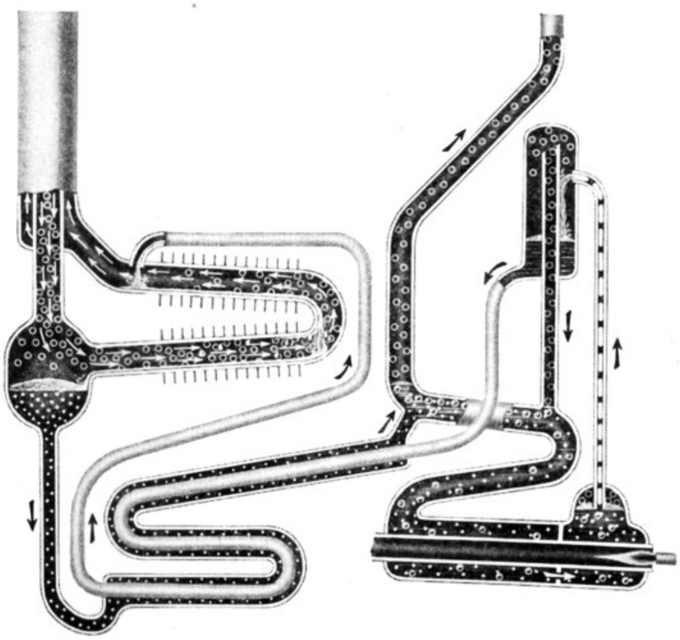
The illustration shows ammonia vapor passing from the ammonia condenser into the hydrogen reserve vessel and displacing hydrogen into the evaporator-absorber circuit. This provides a temporary increase of pressure in the system to insure adequate condensation in the ammonia condenser.

THE LIQUID HEAT EXCHANGER *(another economizer) and* THREE STAGE AMMONIA DISTILLATION



THE solution flowing to the generator is cool. The liquid flowing to the absorber is warm. We can save gas if we use the warm liquid to heat the cooler liquid. To do this, we simply run the water pipe downwardly from the "separator" and inside the pipe carrying the solution to the generator. Of course we then must run this pipe up again to connect with the upper part of the absorber. We have made a simple "liquid heat exchanger." The warm liquid "preheats" the colder solution flowing to the generator. The cool solution "precools" the liquid flowing to the absorber.

We can make a further saving if we distill off the ammonia in stages of increasing temperature. To do this, we first "bubble" the ammonia vapor through the solution flowing to the generator. This can be done by running the ammonia vapor pipe from the separator down to connect with the pipe in which the solution flows to the generator. This forms a "submersion analyzer" in which water vapor is removed from the ammonia flowing to the condenser. From the analyzer, the solution flows through a second generator chamber before it flows to the final and hottest generator chamber.



A TRIUMPH OF YOUTH

Baltzar von Platen and Carl G. Munters, inventors of the Electrolux refrigerator, in their student days.

THE Electrolux refrigerator originated as an invention of two Swedish students—by name, Carl Munters and Baltzar von Platen. They made their brilliant discovery while still undergraduates at the Royal Institute of Technology at Stockholm.

They took their invention to the Swedish Electrolux Company, which initiated a world-wide industrial development of this refrigerator. American rights were acquired by Servel, Inc. Servel was already established as a pioneer in the household refrigeration field. The original system has been developed and incorporates many additional inventions resulting from unceasing research in various laboratories including the large, modern laboratory of Servel at its 33 acre plant in Evansville, Indiana, where Servel Gas Refrigerators and Servel Kerosene Refrigerators are constantly being made and tested for shipment to the homes of America.

This remarkable refrigerator has been awarded prizes at numerous expositions both here and abroad. It has the endorsements of such well-known authorities on appliances as Good Housekeeping Institute and the Underwriters Laboratories.

Today, in the United States alone, over a million satisfied users testify to the value of simplicity, silence, permanence and efficiency of this refrigerator and to the merit of the extraordinary achievement of the student inventors.

QUESTIONS

Test your knowledge of the refrigerating system by answering these questions:

1. Give two examples of cooling by evaporation.
2. What part is inside the food space of the refrigerator cabinet?
3. What happens to the evaporated ammonia leaving the evaporator?
4. Name three circuits in the system in which circulation is accomplished without moving parts.
5. What causes circulation between the evaporator and absorber?
6. What word describes the driving out of ammonia from solution and its condensation?
7. What common kitchen utensil is illustrative of the mode of lifting liquid in the system?
8. Name more than three unique characteristics of the system.
9. Is there any danger from the gas burner failing and give your reason for the answer?
10. Name two heat exchangers and their locations.

Answers to the above questions are given on page 18.

ANSWERS

Here are the answers to the questions on page 17:

1. (*a*) Evaporation of alcohol on the body.
   (*b*) Evaporation of body moisture.
2. The evaporator.
3. It flows to the absorber and is dissolved in water.
4. (*a*) The circuit for hydrogen between the evaporator and the absorber;
   (*b*) The circuit for water between the absorber and the generator; and
   (*c*) The circuit for ammonia through the generator, condenser, evaporator and absorber.
5. Difference in weight of substances in different vertical branches of the circuit.
6. Distillation.
7. Coffee percolator having a liquid-vapor lift.
8. (*a*) Cold produced while heat is applied; (*b*) continuous action without moving parts; (*c*) uniformity of pressure; (*d*) continuous application of heat; (*e*) hydrogen circulation by difference of specific weights; (*f*) circulation of liquid by vapor in narrow pipe; (*g*) hydrogen reserve vessel—and others.
9. No—because of the safety cut-out.
10. (*a*) The gas heat exchanger between the evaporator and the absorber;
    (*b*) The liquid heat exchanger between the generator and the absorber.

A MORE TECHNICAL DESCRIPTION—STARTING AT THE GENERATOR

(Diagram on Inside Back Cover)

THE freezing system of the Servel Gas Refrigerator is made up of a number of steel vessels and pipes welded together to form a hermetically sealed system. All the spaces of the system are in open and unrestricted communication so that all parts are at the same total pressure.

The charge includes an aqua-ammonia solution of a strength of about 30% concentration (ammonia by weight) and hydrogen. For a unit of sufficient capacity for a 5 cu. ft. cabinet, the approximate charge is: 1.1 lbs. ammonia; 2.6 lbs. water; 0.03 lb. hydrogen. The liquid is charged into the unit as solution and then the hydrogen is added.

The elements of the system include a *generator* (1) (sometimes called *boiler* or *still*), a *condenser* (2), an *evaporator* (3), an *absorber* (4), and a *hydrogen reserve vessel* (5). There are three distinct fluid circuits in the system: An ammonia circuit including the generator, condenser, evaporator, and absorber; a hydrogen circuit including the evaporator and absorber; and a solution circuit including the generator and absorber.

Starting with the generator, heat is applied by a gas burner or other source of heat to expel ammonia from solution. The ammonia vapor thus generated flows to the condenser. In the path of flow of ammonia from the generator to the condenser are interposed an *analyzer* (6) and a *rectifier* (7). Some water vapor will be carried along with the ammonia vapor from the generator. The analyzer and rectifier serve to remove this water vapor from the ammonia vapor. In the analyzer, the ammonia passes through strong solution which is on its way from the absorber to the generator. This reduces the temperature of the generated vapor somewhat to condense water vapor and the resulting heating of the strong solution expels some ammonia vapor without additional heat input. The ammonia vapor then passes through the rectifier (7) where the residual small amount of water vapor is condensed by atmospheric cooling and drains to the generator (1) by way of the analyzer (6).

The ammonia vapor, which is still warm, passes on to the section (2a) of the condenser (2) where it is liquefied by air cooling. The condenser is provided with fins for this purpose. The ammonia thus liquefied flows into the evaporator (3) at an intermediate point. A liquid trap is interposed between the condenser section (2a) and the evaporator to prevent hydrogen from entering the condenser.

Ammonia vapor which does not condense in the condenser section (2a) passes to the section (2b) of the condenser and is liquefied and flows through another trap into the top of the evaporator.

The evaporator is made up of two sections (3a) and (3b). The upper section (3a) is provided with fins and directly cools the food space. The lower section (3b) is in direct contact with the ice freezing compartment.

Hydrogen gas enters the lower evaporator section (3b) and, after passing through a precooling pipe part, flows upwardly, in counter-flow to the downwardly flowing liquid ammonia. The effect of the placing of a hydrogen atmosphere above the liquid ammonia in the evaporator is to reduce the partial pressure of the ammonia vapor in accordance with Dalton's law of partial pressures. While the total or gage pressure in the evaporator and the pressure in the condenser are the same, there is substantially pure ammonia in the space where condensation is taking place and consequently the vapor pressure of the ammonia substantially equals the total pressure. Under Dalton's law, the total pressure of a gas mixture is equal to the sum of the partial pressures of the individual gases. Consequently in the evaporator the partial ammonia vapor pressure is less than the total pressure by the value of partial pressure of the hydrogen. The lesser ammonia vapor pressure results in evaporation of the ammonia with consequent absorption of heat from the surroundings of the evaporator and the cooling of the surroundings which are in a well-insulated enclosure.

The cool heavy gas mixture of hydrogen and ammonia vapor formed in the evaporator leaves the top of the evaporator and passes downwardly through the center of the *gas heat exchanger* (8) to the absorber (4). In the absorber, ammonia is absorbed by water, and the hydrogen, which is practically insoluble, passes upwardly from the top of the absorber through the external chamber of the gas heat exchanger (8) into the evaporator. Perfect separation of gases is of course not possible and some ammonia vapor passes with the hydrogen from the absorber to the evaporator. It is probably more accurate to call the gas flowing from the evaporator to the absorber *strong gas* (hydrogen strong in ammonia) and call the gas flowing from the absorber to the evaporator *weak gas* (hydrogen weak in ammonia).

Since the weight of a gas is proportional to its molecular weight and the molecular weight of ammonia is 17 and the molecular weight of hydrogen is 2, it follows that the specific weight of the strong gas is greater than that of the weak gas. This difference in specific weights is alone sufficient to initiate and maintain circulation between the evaporator and the absorber. Since the absorber is below the evaporator, it is possible to have upward gas flow in the evaporator. The long vertical column of strong gas in the central chamber of the gas heat exchanger is heavier than the vertical column in the absorber, external heat exchanger space and evaporator, despite the fact that the gas in the evaporator is heavy. Consequently the gas will flow as above stated due to the difference in specific weights of the gases in the different vertical branches of the circuit. The gas heat exchanger transfers heat from the weak gas to the strong gas. This saves some cooling in the evaporator by precooling the entering gas. A liquid drain at the bottom of the evaporator is connected to the downflow space of the gas heat exchanger.

Counter-current flow in the evaporator permits the location of the box cooling section of the evaporator in the most effective position, at the very top of the food space. Also, the gas leaving the lower temperature evaporator section (3b) can pick up more ammonia at the higher temperature prevailing in the box cooling evaporator section (3a), thereby increasing capacity and efficiency. There is still another advantage in that liquid ammonia flowing to the lower temperature evaporator section is precooled in the upper evaporator section.

The dual liquid connection between the condenser and the evaporator is advantageous in applying the unit to the cabinet. It permits extending the condenser below the top of the evaporator to provide more surface while having gravity flow of liquid ammonia to the evaporator.

The two-temperature evaporator partially segregates the ice freezing function from the box cooling function. This provides a better humidity condition in the food space because, due to the higher temperature of the box cooling section (though adequately low for proper preservation), and due to the reduced surface of the low temperature section permitted by the partial segregation of function, less moisture is extracted to form frost.

In the absorber, a flow of weak solution (water weak in ammonia) comes in direct contact with the strong gas. The liquid and gas flow in counter-current. The weak solution is thus enriched or strengthened while the strong gas is weakened.

From the absorber, the strong solution flows through the *liquid heat exchanger* (9) to the analyzer (6) and thence to the strong liquid chamber (1a) of the generator (1). Heat applied to this chamber causes vapor to pass upwardly through analyzer (6) and to the condenser. The solution passes through an aperture in the generator partition into the weak liquid chamber (1b). Heat applied to this chamber causes vapor and liquid to pass upwardly through the small diameter pipe (10), as in an "air lift," to the separation vessel (11). Liberated ammonia vapor passes through the analyzer (6) and thence to the condenser. The weak solution flows through the liquid heat exchanger (9) and to the absorber. The liquid heat exchanger precools the liquid entering the absorber and preheats the liquid entering the generator. Further precooling of the weak solution is obtained in the finned air cooled loop (12) between the liquid heat exchanger and the absorber.

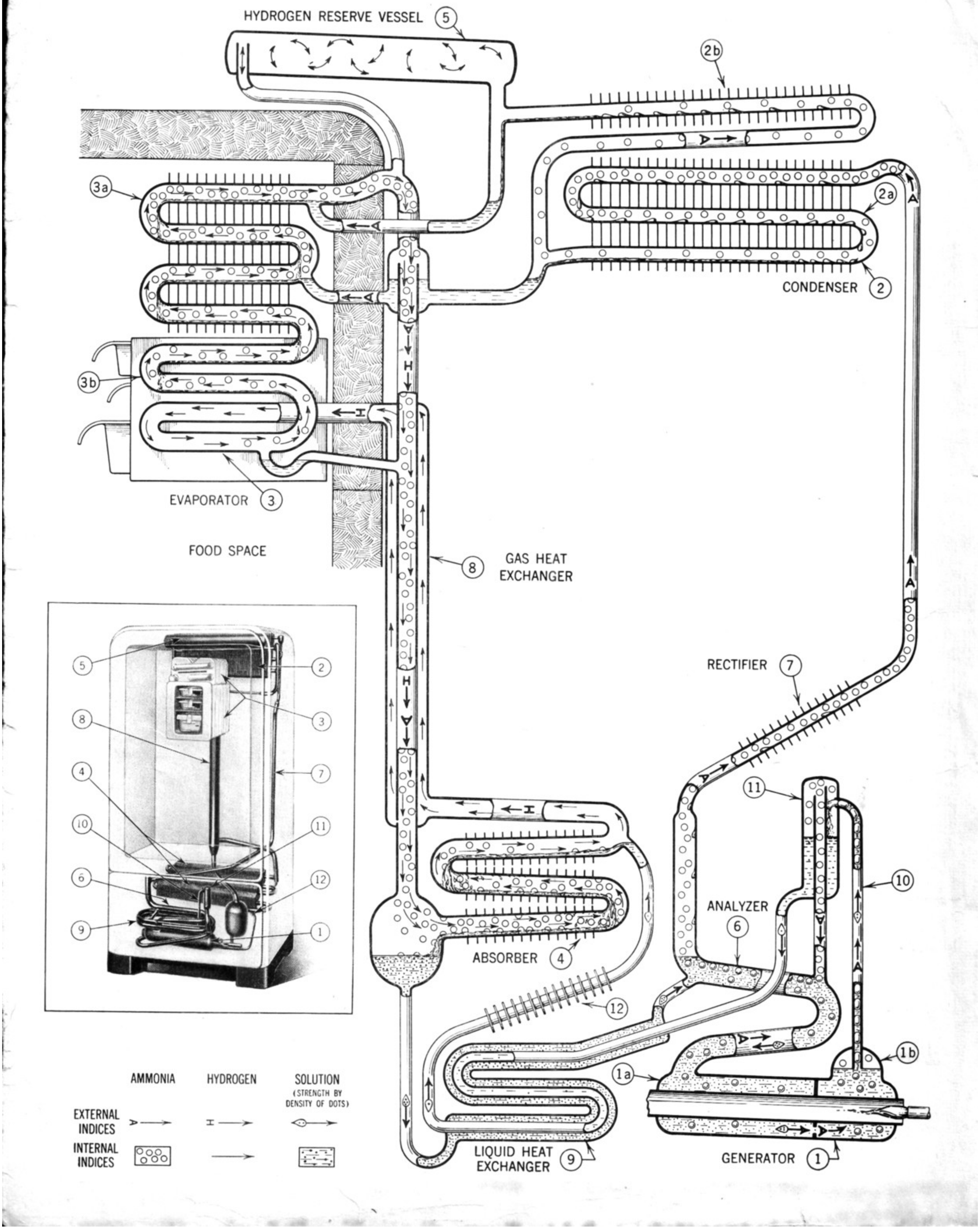
The heat which is liberated by absorption of ammonia in the absorber is carried away by air flowing in contact with the absorber fins.

The hydrogen reserve vessel (5) which is connected between the condenser outlet and the hydrogen circuit may be described as a reservoir for hydrogen gas while the refrigerator is operating under normal room temperature conditions. Under these conditions an appreciable part of the hydrogen in the system is stored in the reserve vessel. The remainder is located in the evaporator-absorber circuit and serves to balance the condenser pressure. This pressure must of course be adequate to liquefy the ammonia gas in the condenser. If the pressure is increased, the efficiency under normal conditions will be impaired, and yet it is necessary to have a higher pressure in the system to insure condensation of the ammonia under high room temperature conditions. The reserve vessel and its connection in the system is an automatic pressure variant to take care of the variable room temperature and loads and to permit lower operating pressure at lower room temperature, thereby resulting in better efficiency and higher operating pressure under extreme conditions to insure condensation of ammonia. It operates in the following manner:

Should the room temperature rise materially, ammonia vapor fails to condense in adequate quantity and some vapor flows to the hydrogen reserve vessel. Thus additional ammonia vapor is liberated by the generator and is pushed through the condenser and into the reserve vessel, displacing the hydrogen therein, which is in turn pushed into the active part of the system. This displacement of hydrogen by ammonia and the redistribution of hydrogen has a double effect. The pressure in the system is increased due to the additional ammonia gas present. This results in an adequate condensing pressure at the higher room temperature. At the same time the additional hydrogen in the evaporator serves to balance the increased condenser pressure without increasing the partial pressure of ammonia in the evaporator. Without this additional hydrogen it would be necessary to balance the increased pressure by raising the ammonia pressure in the evaporator which would result in an undesirable increase in evaporator temperature. When the room temperature decreases again, the more effective condensation in the condenser causes the ammonia gas to return from the reserve vessel to the ammonia condenser and hydrogen (weak gas) flows from the evaporator-absorber circuit into the reserve vessel.

As refrigeration load increases, a thermostat functions to increase the flow of gas to the burner which causes a greater amount of ammonia to be expelled, condensed, and evaporated per unit of time.

The actual construction includes additional refinements which increase efficiency.



HYDROGEN RESERVE VESSEL 5
2b
3a
2a
CONDENSER 2
3b
EVAPORATOR 3
FOOD SPACE
GAS HEAT EXCHANGER 8
RECTIFIER 7
11
10
ANALYZER 6
ABSORBER 4
12
1b
1a
LIQUID HEAT EXCHANGER 9
GENERATOR 1
AMMONIA
HYDROGEN
SOLUTION (STRENGTH BY DENSITY OF DOTS)
EXTERNAL INDICES
INTERNAL INDICES

PATENT NOTICE

The Servel Electrolux Refrigerator System is protected by many patents. The following is a partial list of United States patents owned by Servel, Inc. Servel, Inc. is also licensed under many patents.

1,609,334	1,780,272	1,882,026	1,996,094	2,055,856	2,079,608	2,133,266	2,161,852
1,620,843	1,781,541	1,884,939	2,001,797	2,056,081	2,080,195	2,134,149	2,161,875
1,629,733	1,785,700	1,887,651	2,008,343	2,057,408	2,083,454	2,134,888	2,163,815
1,645,706	1,789,346	1,900,650	2,009,479	2,057,429	2,085,867	2,136,395	2,164,045
1,651,007	1,793,873	1,901,458	2,013,469	2,058,042	2,085,868	2,136,600	2,164,730
1,651,410	1,799,081	1,905,727	2,027,057	2,059,841	2,086,632	2,136,790	2,165,138
1,664,471	1,799,201	1,905,918	2,027,7[illegible]1	2,059,876	2,087,641	2,136,791	2,165,831
1,666,760	1,805,293	1,910,853	2,027,779	2,059,877	2,088,609	2,138,132	2,167,663
1,669,269	1,805,656	1,912,644	2,034,149	2,059,878	2,091,595	2,139,244	2,167,697
1,670,632	1,808,723	1,914,222	2,034,153	2,063,276	2,091,607	2,140,947	2,169,201
1,671,949	1,818,433	1,914,861	2,037,782	2,063,292	2,092,935	2,141,609	2,169,214
1,672,265	1,822,224	1,915,584	2,039,588	2,063,353	2,093,552	2,141,882	2,169,284
1,673,931	1,822,250	1,920,612	2,040,174	2,064,233	2,096,828	2,145,063	2,169,295
1,674,830	1,823,456	1,924,770	2,040,399	2,064,396	2,098,850	2,145,678	2,169,820
1,678,277	1,823,497	1,936,039	2,041,585	2,066,042	2,099,041	2,146,076	2,170,656
1,679,439	1,830,203	1,946,467	2,041,946	2,066,660	2,104,759	2,146,077	2,171,745
1,679,440	1,830,632	1,949,637	2,042,355	2,068,549	2,105,562	2,146,078	2,171,815
1,685,764	1,830,894	1,949,651	2,042,373	2,069,062	2,109,502	2,147,066	2,172,442
1,687,957	1,836,719	1,950,703	2,042,507	2,069,808	2,109,607	2,147,867	2,172,458
1,693,970	1,841,136	1,958,573	2,043,058	2,069,839	2,111,774	2,148,983	2,172,467
1,702,754	1,841,293	1,960,809	2,043,059	2,069,840	2,112,261	2,148,991	2,172,958
1,709,588	1,846,006	1,960,821	2,044,597	2,069,852	2,112,537	2,149,603	2,173,150
1,711,553	1,848,815	1,961,324	2,044,609	2,069,857	2,114,316	2,149,807	2,177,072
1,723,453	1,848,918	1,962,512	2,044,811	2,069,863	2,114,602	2,149,820	2,177,380
1,728,644	1,849,685	1,964,391	2,044,951	2,069,865	2,116,998	2,149,821	2,177,503
1,729,355	1,867,181	1,966,003	2,045,134	2,072,144	2,116,999	2,150,411	2,177,880
1,729,625	1,869,853	1,973,127	2,045,204	2,072,987	2,122,293	2,151,001	2,178,807
1,738,678	1,873,435	1,974,728	2,045,205	2,073,091	2,122,361	2,151,451	2,178,815
1,738,720	1,875,626	1,976,202	2,045,491	2,073,092	2,122,625	2,152,663	2,179,734
1,750,335	1,878,111	1,986,304	2,051,318	2,073,651	2,123,920	2,154,258	2,180,177
1,757,254	1,879,352	1,992,842	2,051,723	2,075,437	2,123,921	2,155,188	2,181,221
1,757,578	1,880,525	1,993,764	2,051,760	2,076,058	2,127,212	2,158,274	2,181,276
1,758,099	1,880,533	1,994,080	2,052,580	2,076,770	2,129,982	2,158,282	2,181,376
1,758,215	1,881,978	1,994,475	2,055,851	2,079,419	2,130,503	2,159,601	2,181,493

Servel, Inc.—Evansville, Indiana.