DESIGN AND CONSTRUCTION OF A GAS ABSORPTION REFRIGERATOR TO OPERATE WITHOUT THE USE OF COOLING WATER OR A PUMP.

by

Edward Lafayette Lyle.

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INTRODUCTION.

The purpose of this thesis is to determine if possible a means of getting refrigeration from a gas refrigerator without the use of cooling water or a pump.

It consists of the design and construction of a machine which is air cooled and uses no pump. A series of tests were made on this machine in the laboratory to find out to what extent the object was accomplished.

The refrigerator built is an absorption machine designed to have a capacity of 50# ice melting effect per 24 hours; to work without a pump, and reject the heat of condensation and absorption to the atmosphere. The absorber and generator work alternately, one absorbing while the other generates the refrigerating media.

This machine is unlike any other machine in use today in that it operates at a pressure of approximately 300# per square inch on the generator side and 44# per square inch in the cooler without the use of a pump. There has not been an absorption machine perfected that is air cooled. Probably this is because the area to radiate the heat of absorption and condensation in the large ice plants would be too great to make it practical.

No absorbant other than water has, so far as known, been found satisfactory where ammonia was used as the refrigerant. However, calcium chloride seemed to meet the conditions in this machine and was used in preferance to water.

RELATION OF THIS MACHINE TO THE MACHINES NOW IN USE.

There has been but little change in the absorption refrigerating principle since the art was discovered, and not until within the last year or two has the process been applied to home use. The absorption machine now in use is a very ingenious device; operates without any moving parts, whatever. It operates on unipressure throughout, the pressure gap being filled by an inert gas which is not absorbed by water. The strong liquor is returned by heating a coil, containing the liquor, below the generator, thereby creating a differential pressure which forces the liquor above the surface of the liquid in the generator. The weak liquor flows by gravity to the absorber. A rectifier is used to take the water vapor out of the ammonia gases. The method of getting rid of the heat of condensation and absorption is by circulating cooling water around the condenser coils and the absorber.

One big objection to this machine is the amount of cooling water required to cool the condenser and absorber. It is designed to have a pressure in the condenser of 186# absolute. This would give a temperature of 91.4 Farenheit. Then the cooling water would have to leave at temperature of approximately 87 Farenheit. The range of the temperatures in the cooling water is very low, since the average of water that could be obtained in the homes is approximately 80 Farenheit.

The cost of the water equals approximately the cost of the fuel on which the machine operates.

DESIGN OF MACHINE.

The reasons for selecting the present design are the following: It is simple and fairly easy to construct. There is no pump to be used in the system, neither is there an exchanger.

Calcium chloride used as an absorbant seems to have favorable properties for working under high temperatures. It does not break down upon heating. One molecule of calcium chloride absorbs eight molecules of NH_3 forming a compound $CACL_2 \cdot 8NH_3$.

No information could be found regarding the temperature at which it would give up ammonia, and the heat required to drive the gases off. Neither could any information be found concerning the heat given off when it absorbed ammonia.

It was assumed that a pretty high temperature, from 300 Farenheit to 400 Farenheit, would be required in the generator, so the heating coils in both generator and absorber were made to work under 150# per square inch (gage) steam pressure.

Referring to diagram (Figure 1), the generator A and absorber B were made of extra heavy steam pipe 18" long and 5" in diameter. Extra heavy caps were fitted on both ends of the pipes. It was rather difficult to get the steam coils and the calcium chloride in place in the condenser and absorber so they could be sealed up and work under a pressure of approximately 300# per square inch (absolute). However, this was done by welding the pipes to the caps after the caps were screwed on tight.

All the piping in the machine that came in contact with the ammonia was made of steel (3/8" pipe). A smaller pipe could have been used, but the friction would probably have been too great.

One great difficulty in handling ammonia at high pressures is getting the valves and joints where they will not leak. All of the joints in this machine were sealed with a paste made of litharge and glycerin; this being spread upon the threads before the joints were made.

No information could be found on the change of volume, if there is any, when calcium chloride absorbs ammonia. However, a suitable allowance was made for this; only ten pounds of calcium chloride were used in each of the containers used as absorber and generator. This was finely pulverized so that it would present a greater surface to the ammonia gases.

For fear that the absorbing action might not take place satisfactorily with the ammonia gas pipes G and G', (Figure 1), leading from cooler or receiver F and terminating in the bottom cap of absorber and generator at X and X', the pipes O and O' were extended some 6" or 8" up in generator A and absorber B so that the molecules of gas might be better distributed throughout the calcium chloride, and no liquid, if any was formed, would collect in the gas pipes.

The steam coils S and S' were wound around a 3" steel shaft. This was made so as to get approximately 3/4" clearance between the coil and the walls of the 5" pipes, A and B, used as generator and absorber.

The condenser coil C was wound on a drum 15" in diameter. Eighty feet of piping was used in this coil which furnished approximately one and one half times the area required to radiate the latent heat of condensation of ammonia making 50# of ice per 24 hours. The assumed value of K, or factor of radiation, is 1.5.

A factor of safety of from four to six was used in the construction of the machine in order to prevent an accident.

A high pressure ammonia gage was placed between the generator and condenser coil so that the pressure in the condensing coils might be obtained.

It was thought that before the machine was ready to operate the water of crystalization in the calcium chloride would have to be driven off. However, the highest temperature that could be reached with the steam coils would not drive the water off. A steam pressure of 140# gage was applied, giving a temperature of 361.1 Farenheit. This pressure was held on the coils for 1½ hours. Finding that the water could be driven off only at some higher temperature, no further action was taken to remove it.

EXPLANATION OF THE CYCLE.

The ammonia is driven off as a gas from generator A (Figure 1). It passes through valve p' into condenser coil C. The pressure in this coil being 300# per square inch absolute with a temperature of 122 Farenheit. The difference between this temperature and room temperature is sufficient to radiate the latent heat of condensation, so the vapor is liquified and passes on to receiver E through valve H. The receiver acts as both

receiver and cooler. The ammonia is vaporized in the cooler and then passes through valve I to absorber B. When all of the ammonia has been driven out of A and B, has absorbed all it will, close steam valves L and J' and ammonia valves M and d', then open steam valves J and L' and ammonia valves M' and d. Now B is acting as generator and A as absorber.

EXPERIMENTS.

In running some tests on the machine the receiver was charged with approximately 4# of ammonia. Tests were made when at the beginning the absorber was at room temperature. Other tests were made when the calcium chloride in the absorber was heated to approximately 200 Farenheit. It was found in these latter tests that the ammonia was absorbed very rapidly at first but as soon as the heat of absorption ran the temperature up still higher the action almost ceased. The gage pressure ran up to 90# per square inch at first, then pretty quickly came down to 30# per square inch. The pressure, however, built up to 60# gage and seemed to be in equilibrium at this point as long as the supply from the receiver was on.

After all the gas that the calcium chloride would take at that temperature, 200 Farenheit, had been absorbed the steam was turned on the coil in the absorber to try to drive the ammonia off. Gas was being given off when the steam pressure had reached 130# gage in the heating coil. The steam pressure was raised to 140# gage and the ammonia gases given off accumulated a pressure of 30# gage in the condenser coil. It seemed to reach an equilibrium at this point.

In the test made, beginning with the absorber at room temperature or approximately 80 Farenheit, different results were obtained from those in the test just described. The receiver was charged with two pounds of ammonia, and then the liquid was vaporized; and the gas allowed to enter the absorber. The absorption was fast enough to keep the pressure on the ammonia gage down to 30# (gage) throughout the test. When all the liquid had been vaporized and absorbed the process was reversed and steam pressure of 140# (gage) was applied to the steam coils. After five or six minutes the ammonia gases started coming off. The steam pressure was held on the heating coils for about 3/4 of an hour. At the end of this time the pressure in the condenser coils had risen to 40# (gage). It seemed to reach an equilibrium at this point, since a further application of heat would not cause the pressure to increase.

In these tests that were made no information as to the amount heat given off by the absorption of ammonia gases with calcium chloride were obtained. Neither was the amount of heat supplied by the steam determined. The refrigerating effect could have been determined approximately, but on account of some leaks through brass globe valves in the system there would have been some error in the calculation. However, working under the difficulties that were presented with this crude machine, there was an absorption of the gases fast enough to cause a frost to form on the receiver. In the test made when absorber was at a high temperature, both absorber and generator were run in series in order to keep the pressure low enough for

frost to form on receiver.

Had the particles of calcium chloride been ground into powder the absorption would have taken place faster. It would also have been a better conductor of heat.

No conclusions as to the future possibilities of this machine can be drawn with the results obtained.

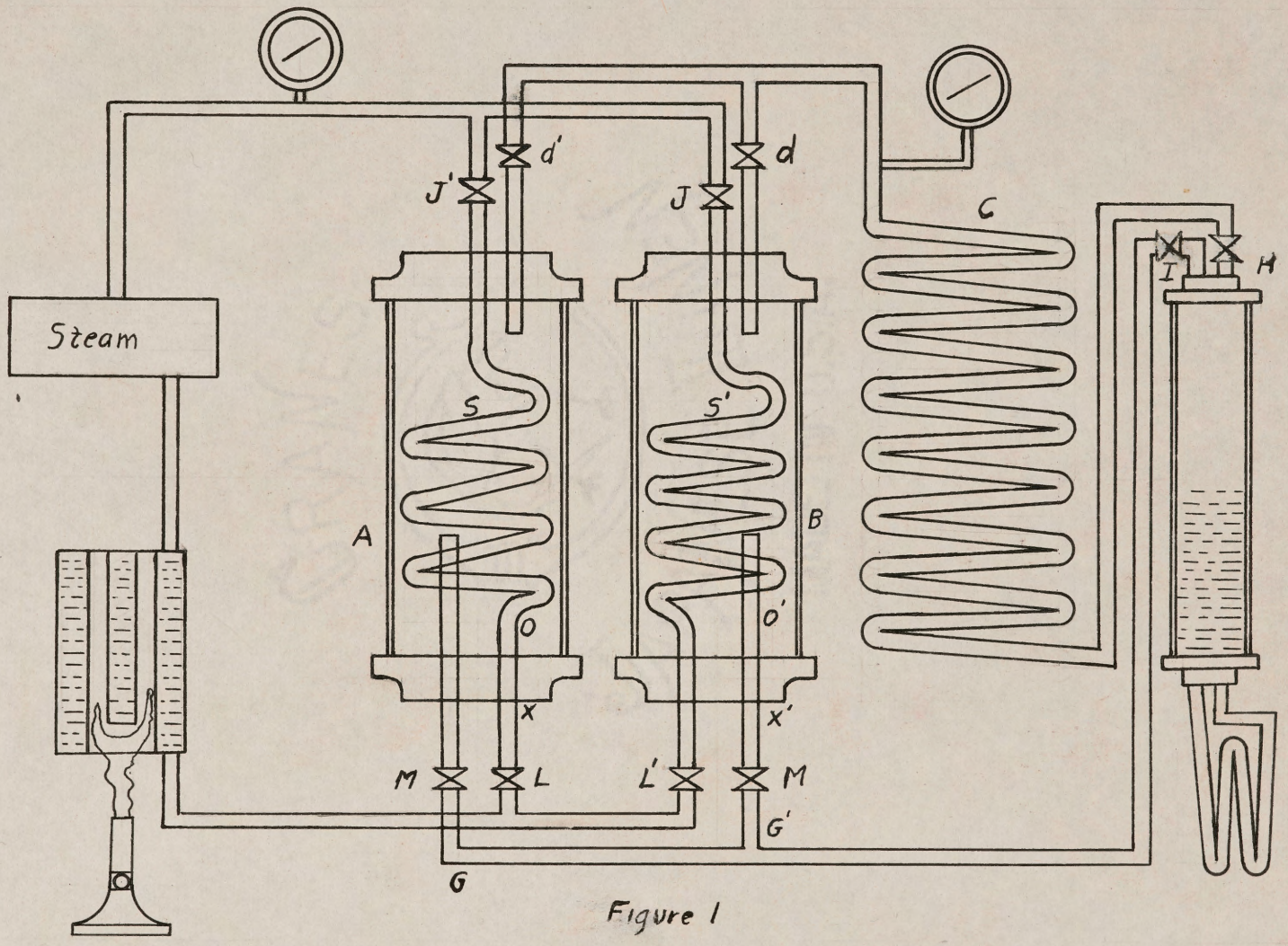

Figure 1

APPROVAL.

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

Name W. R. Woolrich

Title Prof. Mech. Eng.