AMMONIA-WATER REFRIGERATION SYSTEM

PROJECT REPORT

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RATIONALE

There appears to be ever increasing demand for refrigeration in developing countries for the preservation of perishable commodities, particularly food stuffs. At present, food is more important than ever before in man's history. Considerable amount of food is lost each year due to improper preservation techniques soon after harvest, during transit and subsequent storage until they are finally consumed.

At present, the most widely used refrigeration system is the one based on vapor compression cycle which requires electricity. Unfortunately, in most developing countries electricity is either becoming increasingly expensive or not available in rural areas. For this reason use of conventional refrigeration is not common in food preservation in developing countries.

OBJECTIVE

The objective of this investigation was to contrubute to the technical development of a simple refrigerator that meets certain criteria common in developing countries.

METHODOLOGY

The above objective would be achieved through the following procedure:

- Initial test of a previously built unit at TAET laboratory.
- Identify deficiencies of the above system
- Re-design the unit with the introduction of appropriate changes and evaluate the performance of the modified design

Specifically, this study was to focus on trying to eliminate the need for "manual agitation" of the existing design during the cooling cycle.

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ABSORPTION REFRIGERATION

Continuous Cycle:

This system of refrigeration is based on an absorbtion cycle of water-ammonia solution. The system requires little or no electricity to operate; hence can be used in situations described above. Power input to these units is in the form of low grade heat, which can be easily obtained from any one of the following sources: hot water from a solar collector; waste heat from engine exhaust; burning of agricultural wastes; etc. Although the unit is known to have a lower coefficient of performance (C.O.P.), around 0.65 compared to a vapour compression system which has about 2.5, it has the advantage of converting low grade thermal energy to a much more valuable cooling effect.

In a typical ammonia-water absorption refrigerator, ammonia is absorbed by water which has a high affinity for the ammonia vapour. This mixture is then transferred to a generator where it is heated. At this high temperature, the solubility of the refrigerant being low, part of it evaporates. This vapour is made to condense at a condenser which is maintained at a lower temperature than the generator. The liquid refrigerant is then expanded through an expansion valve into the evaporator, where the refrigerant evaporates while absorbing latent heat. Refrigerant vapour is then absorbed by the liquid in the absorber from where it is pumped to a generator where the cycle is repeated. Both absorber and condensing processes generate heat which must be removed by circulating water around the tanks. Main components of this cycle are shown in Figure I.

Generator and condenser pressure, which is the same, is determined by the condenser temperature where the liquid refrigerant is in equilibrium with its vapour. Regrigerant concentration in the generator is a function of its pressure and temperature and can be read from Figure 2. Similarly the evaporator and the absorber are at the saturation pressure of the refrigerant at the evaporation temperature. The concentration of refrigerant in the absorber liquid is, again, a function of its temperature and pressure.

The coefficient of performance (C.O.P.) of the system is defined as the ratio of refrigeration effect at the evaporator to the heat input at the generator. A better indication of the system efficiency is given by the energy efficiency ratio (E.E.R.) which is defined as the ratio of the refrigeration effect to the total power consumed by the system which is the sumation of power input to generator, coolent pump, fans, refrigeratant pumps, controls and so on.

Intermittent System

Essentially, the system built at TAET was an intermittent one. The continicus cycle discussed above was simplified by replacing absorber and generator with a single vessel, and condenser and evaporator by another. Such a system is known as intermittent as the vessels have to change their functions from one phase to another. During the generation phase of the operation the vessel containing the mixture of refrigerant (NH_3) and absorbent (H_2O) is heated, causing a portion of refrigerant to evaporate. The refrigerant vapour is then condensed in the second vessel which is maintained at a lower temperature. When the pressure and temperature of the two vessels stabilize, the generation phase of the cycle is assumed completed. Valves V_1, V_2, and V_3 are closed, there by separating the two vessels. Figure 3.

During the second phase of the cycle, the liquid refrigerant tank, now acting as evaporator, is placed in the environment where refrigeration or cooling is needed. The mixture vessel is maintained at a temperature as close as possible to ambient temperature either by air or water cooling.

At this temperature of the mixture tank, now lower than that of the generation process, the absorber liquid is capable of absorbing great amounts of NH_3 vapour. Hence by opening valve V_1 and V_2, ammonia liquid evaporate producing cooling effect at the evaporator tank.

TEST OBSERVATIONS

Upon conducting a test run on the TAET existing system, the following empirical observations were made:

1. This intermittent system has a lower capital input as it does not require liquid pumps and has only two tanks in contrast to the four vessels in the continuous cycle system
2. This system is combersome or could cost more to operate due to extra operation effort needed in swithing from one phase of the cycle to another.

3. Frequent "manual agitation" of the absorber, during the cooling phase, was necessary for ammonia vapour to combine easily with water in the absorber. This was viewed as a major drawback to the existing TAET design.

4. The refrigeration chamber was poorly insulated, hence considerably reducing the system's overall efficiency.

5. Proper expansion valve of capillary tube is required to correctly monitor NH_3 vapour to absorber.

IMPROVEMENTS ON TAET DESIGN

Due to limitation of time available to the researchers, major focus was on solving the "manual agitation" problem of the existing TAET design. This called for re-designing the system so that a continuous absorption of ammonia vapour by water solution in absorber would take place during the cooling phase; thereby eliminating completely the need for manual shaking. To accomplish this objective, a "diffuser" tube was incorporated in the system. The tube would conduct NH_3 vapour to the bottom of water solution tank causing the vapour to bubble through the solution. Figure 3.

OPERATION OF THE MODIFIED NH_3H_2O REFRIGERATOR

From Figure 3, it is apparent that the design and construction of the new version of the NH_3H_2O was basically the same as the previous TAET one. The difference being that a diffuser was added in order to achieve the objective described above. Safety procedures in the construction and operation were observed in accordance with ASHRAE regulations.

Actual operation conditions were as follows:

Generation Phase:

As stated above, the main purpose of this experiment was to investigate a means of eradicating the need for manual agitation of the absorber during the cooling phase, hence less emphasis was made in analysing the generation phase of the system. However, generation condition was as follows:

- NH_3H_2O solution 1:6 ratio
- Generator heating water 175°F
- H_2ONH_3 solution maximum temperature 169°F inside generator
- System pressure at end of generation process was 160 psi corresponding to saturated ammonia vapour at the condensing temperature of 85°F
- Valve V_1 and V_2 open
  V_3 and V_4 closed

Cooling Phase:

After the initial 45 minutes of generation phase, V_1 and V_2 were closed followed by removal of generator heating water. Sufficient time was allowed for the generator to cool down to ambient temperature (86°F). The cooling phase was then started by slightly opening V_3, and V_2 while V_1 remained shut. Evaporator, absorber, and cooling load (1 litre of water inside refrigerator) temperatures are represented on Figure 4.

OBSERVATIONS

- From Figure 4 we noticed that the cooling process took approximatele 2 hours and 20 minutes
- Within the initial 20 minutes of cooling, absorber temperature rose sharply by ~12°F
- Although the evaporator temperature fell sharply during the initial half hour from 61°→ 42°F, only 2.5°F temperature fall was recorded during the following hour

- The above condition continued until the absorber was sprayed by cold water to about ambient temperature. At this point the evaporator temperature continued to fall to about 26.5°F.

RECOMMENDATIONS

During the start of the cooling cycle valve V_2 should only be cracked open to allow minimum amount of NH_3 vapour to flow through it. It was observed that if valve V_2 is fully opened larger amounts of ammonia vapour is absorbed and the sudden combination release heat which in terms raises the absorber temperature rapidly. This effect considerably reduces the C.O.P. of the cycle.

1. Further investigation for determining the correct orifice size of valve V_2 should be made to establish optimum duration of cooling cycle.

2. This system proved too expensive by utilizing such expensive materials such as stainless steel piping and fittings. Use of locally available materials should be encouraged.

3. Although it is observed that the refrigeration effect increases with the use of additional cooling as provided by spraying cold water on the condenser and absorber, it is recommended that the system be operated without the use of these or any other artifical conditions.

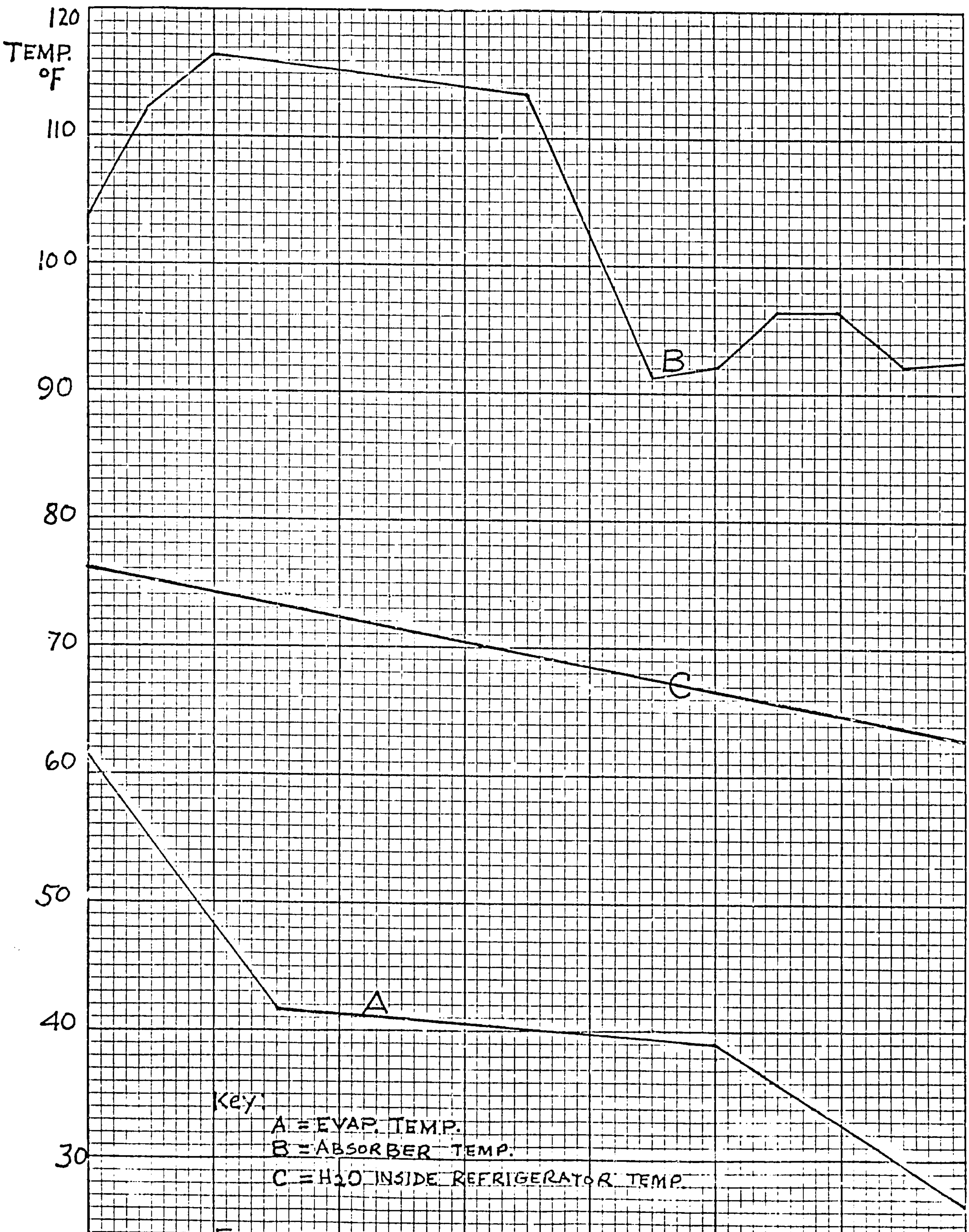


FIG. 4 COOLING PHASE

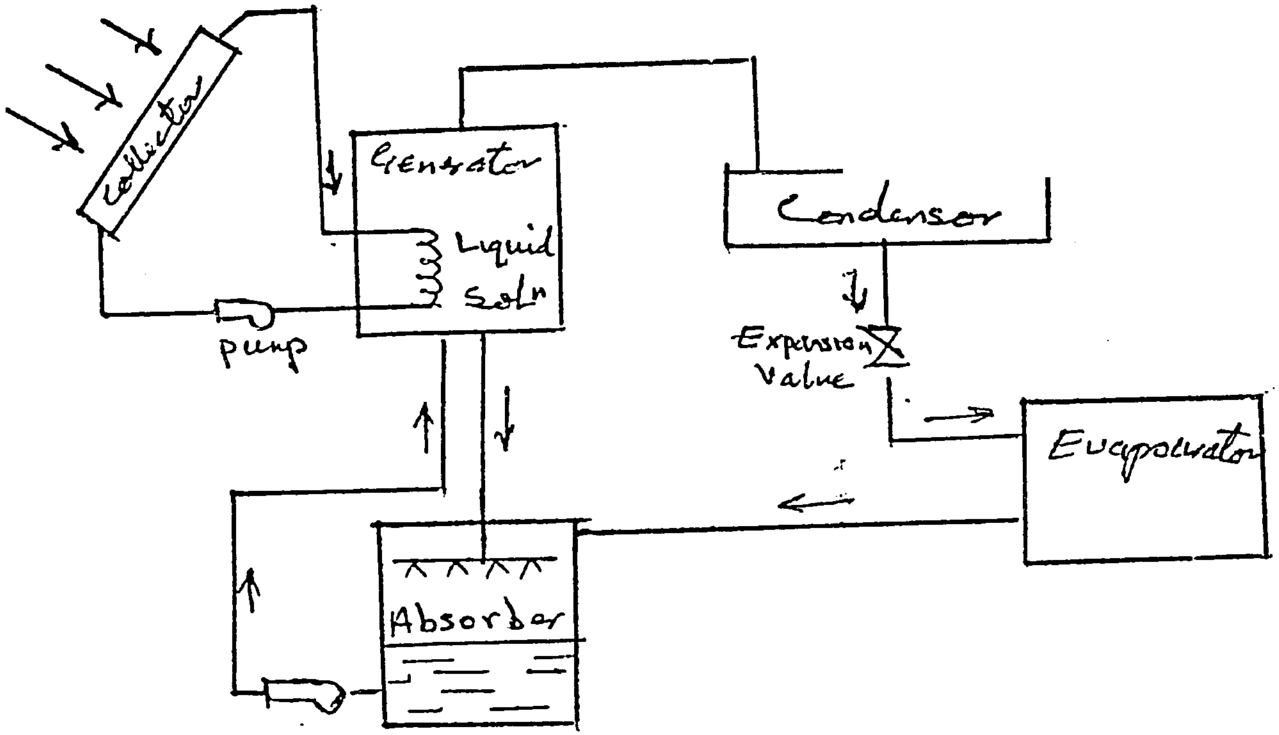
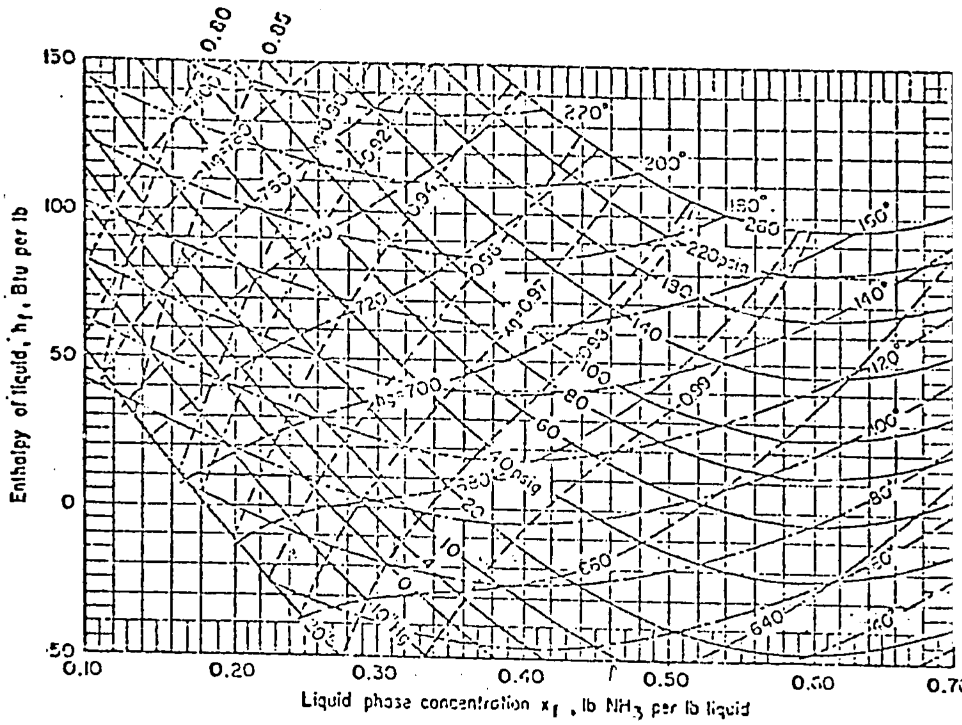
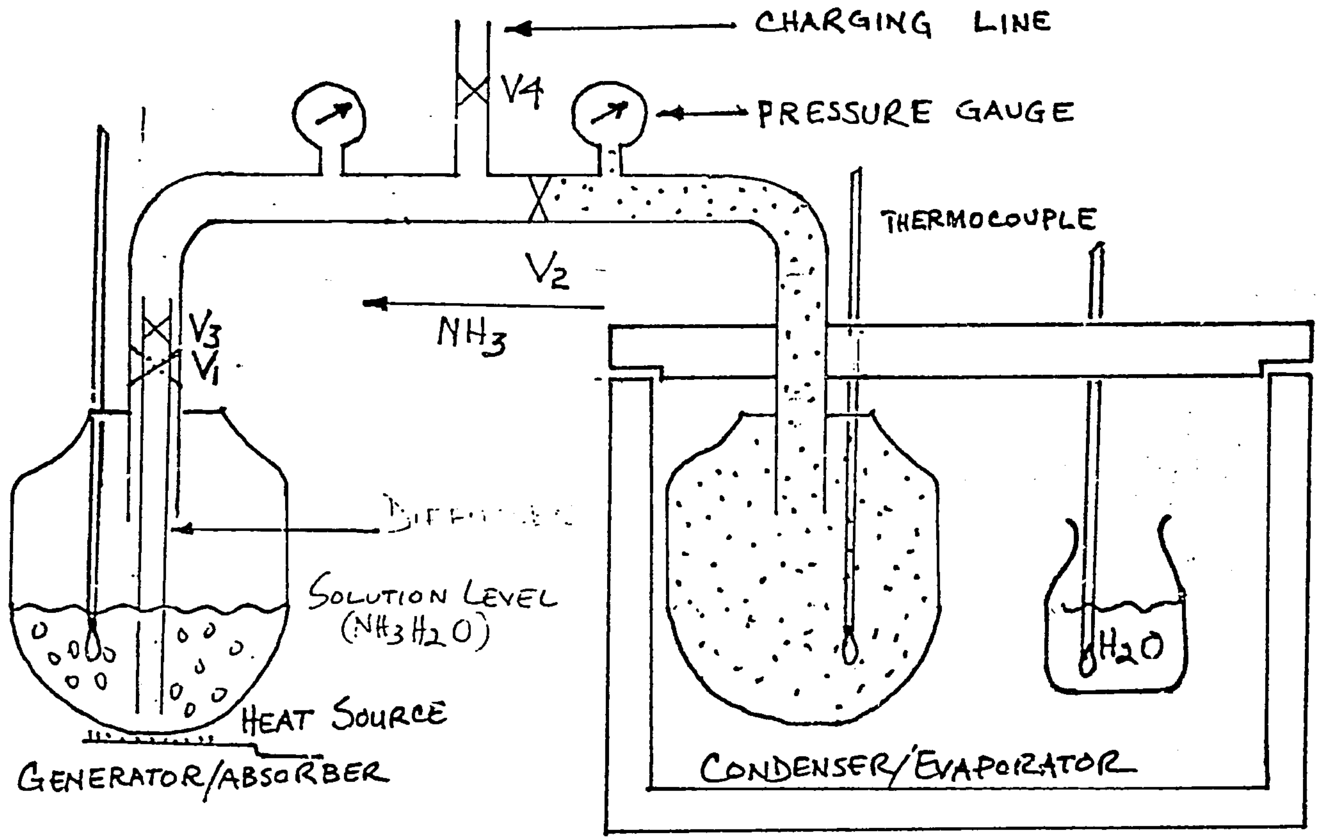

Collector
Generator
Liquid
soln
pump
Condenser
Expansion
Value
Evaporator
Absorber

FIGURE 1



Enthalpy of liquid, h_f, Btu per lb
150
100
50
0
-50
0.10
0.20
0.30
0.40
0.50
0.70
Liquid phase concentration x_f, lb NH_3 per lb liquid
0.80
0.85
270°
200°
180°
160°
140°
120°
100°
80°
220 psia
700
720
660
640

FIGURE 2



MODIFIED AMMONIA-WATER REFRIGERATOR

FIGURE 3