and 3 to 5 times practically, as the work introduced[1]. There are a number of limitations, however, the most serious of which is the lack of ready availability of a practical source of heat.

1. Well water is the most desirable since its temperature is higher than other sources even in the winter, and thus a large amount of heat may be removed in relation to the weight of water handled.

2. Air may be used but its specific heat is low and its temperature uncertain. When the most heat is needed, the temperature of the air is lowest, thus resulting in the least favorable temperature combination.

3. It has been proposed to obtain heat by freezing water but this is still in the experimental stage.

Some of the other factors which act as limitations are: the large temperature spread when using air as a source of heat and when attempting to cool with even moderately low outside temperatures, the frequent disparity between the size of the cooling load and heating load requiring

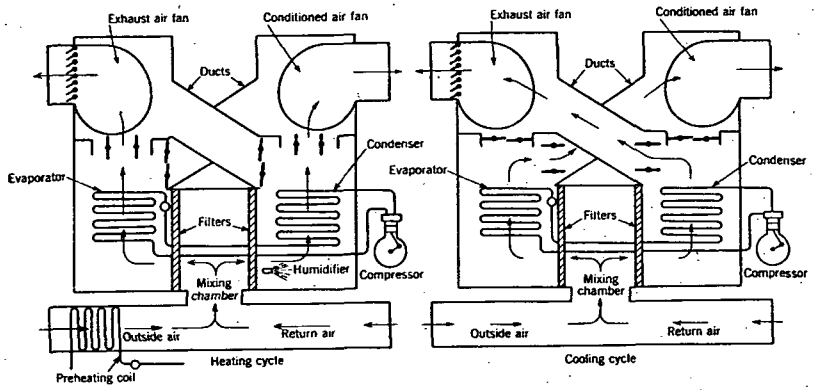

FIG. 11. SCHEMATIC OPERATION OF REVERSED CYCLE CONDITIONING SYSTEM

extra equipment for a complete heating load, and the relatively high initial cost of equipment as compared to that at present available for heating by conventional means.

Because of these limitations, the present application of the system is largely limited to temperate climates, such as Florida and Southern

[1]Cooling Homes, A Field for Refrigeration, by A. R. Stevenson, presented at the symposium of the Refrigeration with Gas Committee of the *American Gas Association*, April 20, 1926.

The Heat Pump, An Economical Method of Producing Low-grade Heat from Electricity, by T. G. N. Haldane (*Electric Review*, Vol. 105, p. 1161-1162, December 27, 1929, and *I. E. E. Journal*, Vol. 68, p. 666-675, June, 1930).

Edison Building Heated and Cooled by Electricity, by H. L. Doolittle (*Power*, Vol. 74, p. 384, September 8, 1931).

House Heating by Pump with 5 to 1 Pick-up Ratio, by Gilbert Wilkes and R. E. Marbury (*Electrical World*, Vol. 100, p. 828, December 17, 1932).

An All Electric Heating, Cooling and Air Conditioning System, by Philip Sporn and D. W. McLenegan (A.S.H.V.E. TRANSACTIONS, Vol. 41, 1935, p. 307).

Using the Reversed Cycle Refrigerating Principle for a Self-Contained Heating and Cooling Unit, by Henry L. Galson (A.S.H.V.E. JOURNAL SECTION, *Heating, Piping and Air Conditioning*, October, 1935, p. 497).

Heating by Reversed Refrigeration, by A. J. Lawless (*Heating, Piping and Air Conditioning*, August, p. 473, September, p. 519, 1940).

California, or to heating only for intermediate seasons, or to other localities which have peculiar advantages as, for instance, the ready availability of well water. In these locations it is frequently possible to do all of the heating necessary with the refrigeration equipment so that the extra cost is only that of reversing the functions of the condenser and evaporator.

There are a number of reversed systems now in operation, particularly among utility companies, using well water as the source of heat. These systems range in size up to 320 hp. In the case of the largest system in operation at present, the cost of the electrical energy would have to be approximately 0.7 cents per kilowatthour in order to compete with oil at 6 cents per gallon.

A typical arrangement of a reversed cycle conditioning system where air is used as a source of heat is shown in Fig. 11. If the air seldom drops below freezing, heat is often required in the morning and cooling during the afternoon in order to maintain comfortable conditions in such a system. The arrangement as shown lends itself to automatically changing over as required.

Example 1. Electrically driven dichlorodifluoromethane condensing units are to be used in an air conditioning system, requiring 20 tons refrigerating capacity for conditions of maximum load. An overall analysis of the seasons operating conditions shows an average load factor of 62.5 per cent, and allowing for variable time intervals of operation of refrigeration units installed, three-quarters of the operating season, or 750 hr, would require operation of the equipment at one-half load, and one-quarter of the operating season or 250 hr full load capacity of the refrigeration equipment would be required.

The increased first cost of 2-10 hp, 10 ton condensing units over 1-20 hp, 20 ton condensing unit is, $830.00 installed price, to the customer.

The increased first cost of a 2-speed compressor motor of 20 hp size over a constant speed of 20 hp size motor including increased starter cost is $210.00. The efficiency of the 2-speed motor above is 83 per cent at full load speed, and 79 per cent for full load at ½ speed. At ½ speed, full load is ½ total bhp of full load speed.

Discuss the consideration involved in making a decision as to whether a single unit with a 20 hp motor of the 2 speed type would be used in preference to 2-10 hp constant speed units.

Solution. The cost of 2-10 hp 10 ton units in excess of 1-20 hp, 20 ton unit with 2-speed motor, is $830.00 − $210.00 or $620.00, increased first cost. At 15 per cent fixed charges, this represents an increased annual cost of $93.00 for 2 compressors over one compressor. The advantage of 2 compressors instead of one compressor on an installation of this type, is in the breakdown service provided in the event one compressor is shut down for repairs the system could be operated at one-half capacity utilizing the duplicate machine. The motor efficiency of the constant speed unit would be higher at full load than would be the efficiency of the 2-speed motor at low speed. Offsetting this latter advantage however, is the fact that the condenser on the condensing unit would provide a lower refrigerant condensing temperature for ½ load operation with the same final condensing water temperature than would be the case with duplicate units each furnished with its own compressor and condenser. Operation at a lower condensing temperature would provide for a power saving compensating for the lower efficiency of the 2-speed motor when operated at slow speeds. It is, in a case of this kind, purely a question as to whether or not the purchaser would deem an investment of $620.00 more and an increased fixed charge of $93.00 a year, advisable to get breakdown service through the installation of duplicate units. In most cases, this increased first cost would not be warranted because of the fact that satisfactory indoor conditions could not be obtained at full load if only one-half the refrigeration capacity were available.

Example 2. For condensing purposes, an air conditioning system uses city water which has an average 70 F supply temperature. The following table lists the number