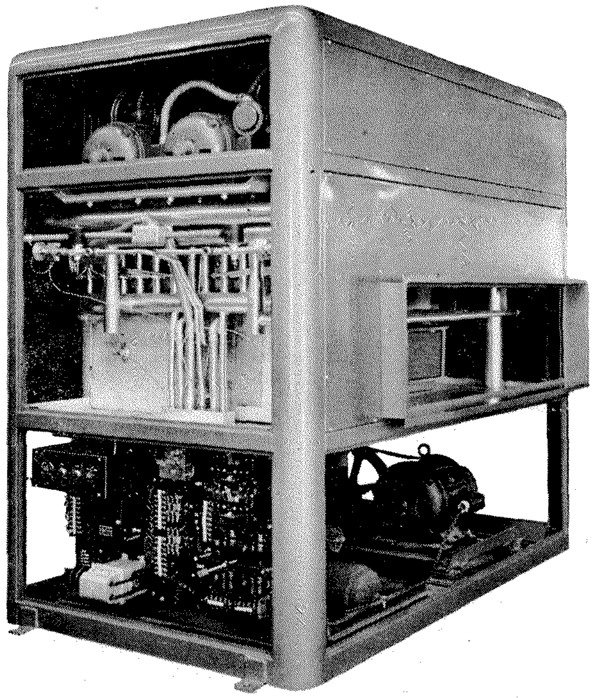


Typical air-actuated heat pump — Drayer-Hanson's 5 hp "Airtopia". Panels have been removed to show refrigerant headers, blower motors, electrical panel and motor compressor assembly. The large opening at right, center, is outside air inlet.

THE HEAT PUMP

What it is, what it does, and what it may do someday

by BILL HOLLADAY

SINCE DECEMBER 1852, when Lord Kelvin presented before the Glasgow Philosophical Society a modest little paper, "On the Economy of the Heating or Cooling of Buildings by Means of Currents of Air," the Heat Pump has been a prime target for technical writers. In fact, for most of the 96 years since Kelvin's article, there have been more papers on the subject than there were heat pumps in operation. (A bibliography listing 160 references was published by the Southern Research Institute in 1946.) Recently, however, a number of experimenters and manufacturers have made efforts to equalize the disparity. In California, for instance, there are over 100 heat pumps now in use.

First, what is the heat pump? Briefly, any refrigerating machine is simply a device for moving heat from one point to another. It can be used not only to cool food or people or freeze water; it can also be used for heating things with the very heat which is disposed of when the machine is used "normally." We all know, if we have not forgotten, that a mechanical refrigerating unit does its job by means of a motor-driven compressor, which sucks "refrigerant" vapor out of a vessel called an evaporator, where the resulting pressure reduction causes a violent boiling of the remaining liquid refrigerant. This boiling, or evaporation, is accompanied by absorption of heat, just as boiling water on the stove absorbs heat from a burner.

The compressor then squeezes together a charge of refrigerant from the evaporator, a process accompanied by a rise of temperature and super-heating of the vapor. In order to reuse the vapor, it must be liquefied. This is done by cooling it under pressure, and when something more than the equivalent of the latent heat of evaporation has been given up, the vapor will liquefy and may be fed into the evaporator by means of a pressure-reducing valve. The circuit is shown on the following page.

This cycle has been used for quite a number of years for cooling or water-freezing in a great variety of sizes—commercially from one-tenth to hundreds or thousands of horsepower. The condenser heat on sizes up to about three hp is frequently discharged into the atmosphere; on larger sizes, the unwanted heat is sometimes disposed of by heating a water stream going into a sewer—though not in Pasadena, New York, or an increasing number of other municipalities, where disposal capacities could not keep pace with water use for this purpose. Cooling towers, spray ponds, or evaporative condensers are also used for heat disposal.

With the increasing use of these machines for cooling air in summer, inventors and engineers have turned more and more to the possibilities of using the refrigerating principle for heating as well as cooling. It's an appealing idea, and it looks easy. If we can dispose of heat, we should be able to pick it up again—maybe even the same heat—when we need it.

One source of such heat is the atmosphere—billions of tons of it, always at hand. One needs merely to put an evaporator outside the structure to be heated, cool off some outdoor air, pull the heat thus acquired into our machine, and subsequently raise the temperature of the air in the house. Unfortunately, we are licked by the freezing point of water, which occurs at a point well above average winter temperatures in most inhabited areas. As soon as the surface temperature of our evaporator reaches 32°F. moisture from the air condenses and then begins to freeze, covering the surface with an insulating blanket which prevents the flow of air and the pick-up of heat.

Further, there is a thermodynamic reason why air actuation is limited in application. Carnot showed in 1824 that the maximum possible theoretical coefficient of performance of a reversible heat engine could be expressed by a simple temperature relationship:

$$\text{c. o. p.} = \frac{T_1}{T_1 - T_2}, \text{ where}$$

T_1 = condensing temperature, degrees absolute
T_2 = evaporating temperature, degrees absolute

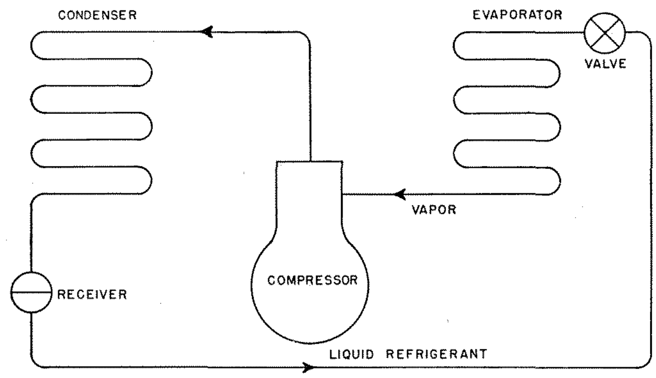
It will be seen that as the evaporating temperature decreases, the efficiency of our system is sharply lowered, and we are faced with a problem of a machine reducing its capacity in the face of an increasing load. The only answer to such a situation is a larger machine, one that has sufficient capacity at a low design temperature to take care of the increased load at that point. Such a solution is costly and cumbersome.

A second source of heat is water, and again we have some practical limitations; cost, temperature, disposal problems. Comparatively few structures are located beside rivers, lakes, or springs where the water supply is limitless and free except for pumping cost. Water temperature, in some areas around 50°F. or below in winter, sharply limits the potential heat. As an example, water can safely be cooled with most equipment to 35°F. If 70-degree water is available, about three gallons per minute will be required for a five hp unit. But if the initial water temperature is 40°F. one must pump over 20 gpm to obtain the same amount of heat.

A third source is the earth. Much research on this idea is going on at present, but no firm statements about practicability should be made. For maintenance reasons it does not seem advisable to bury refrigerant coils, although some successful projects have been operated for periods up to several years in this manner. The best way to remove earth heat now seems to be through the use of a water coil, and the transfer of heat from water to refrigerant through an exchange of conventional design. The bottleneck in heat transfer is from earth to water pipe, and a number of ingenious schemes have been planned or tried for improving conductivity at that point. No matter how we do it, one or both of these limitations face us:

The conductivity of earth varies between wide limits, depending on the structure and moisture content of the soil; hence quantitative engineering design is difficult if not impossible.

To use earth heat, a hole must be dug, and the cost, while not always predictable, will surely be high: maybe from 25 to 50 per cent of the entire project.



Basis for the heat pump is the standard refrigerant cycle.

This is the gloomy side of the picture, of course. There are some areas, usually having hot summers, where the temperature rarely if ever goes below freezing in winter, and where air can be used at a heat source. Other areas may have colder winters, but the dew point is so low that frost formation is not burdensome. Defrosting methods are available and have been used successfully. Supplementary electric heat can be applied in some cases, though the rates for standby service of this kind are not usually attractive.

There are some structures located on streams, or in country where water is close to the surface, and sometimes water can be pumped out of one well and disposed of into another, if the two are not too close together. There are many successful projects employing the heat sources discussed, or combinations of them.

Each of these so-called "sources" of heat should be used as the sink for getting rid of heat in the summer, for it is not yet commercially practical to use a refrigeration machine purely as a heat source, though experimental household water heating units have been built and operated. The first cost of the equipment is sufficiently high that, to justify the investment, we must think in terms of a year-round conditioning unit which can, either automatically or manually, be used for heating or cooling as needed.

The refrigerant flow diagrams for a year-round system don't bear much resemblance to the simple picture shown above. Some plants use the right and left hand heat exchangers alternately as condenser and evaporator, so that the conditioned air stream, always following the same path, may be heated or cooled as required. The transfer valves for this method are usually manually operated, since it is necessary to change the fluid flow through four pipes. Dual-purpose coils are not very efficient heat exchangers, since a good condenser does not necessarily make a good evaporator.

In other systems, single-purpose coils are employed, with air streams shifting from side to side. This involves extra duct work and dampers, and is somewhat cumbersome and expensive.

Still another plan has two condensers and two evaporators, one of each in each air stream. When the conditioned air evaporator is in use for cooling, the outside air condenser is employed. While this arrangement is also expensive, it is quite efficient and it is possible to handle the transfer automatically with but two solenoid valves; the comparative freedom from trouble of the simple valve mechanism may overbalance some additional cost.

In California there are probably 125 to 150 heat pumps operating today—a few of them for periods up to ten years. Most of these are products of Drayer-Hanson, Inc., a Los Angeles manufacturer which has promoted the heat pump idea aggressively.

In operation, coefficients of performance usually run between 3 and 4. As an example, a 5-hp unit, taking about 5 kw, will produce about 55,000 Btus per hour. Since the heat equivalent of 5 kw is 17,000 Btus per hour (the amount of heat which would be obtained if the 5 kw were used to actuate resistance heaters), the apparent coefficient of performance is 3.22. Of the 55,000 Btus per hour listed as the output of the unit, 14,000 is the input to the compressor (the 17,100 motor input less motor losses) and the balance of 41,000 must be picked up from air, water or earth. Therefore, if one wishes to use electricity for heat, it costs only 1/3 to 1/4 as much to do so through a heat pump as through resistance heating.

Some conclusions from field experiences with the heat pump may be summarized here.

The best field for commercial exploitation is a commercial establishment where the winter heating load and the summer cooling load approximately equalize. This obtains in offices, restaurants, stores, where people constitute a large source of heat and where the level of interior lighting is fairly high.

Buildings should be well-insulated, since good insulation reduces external load both in summer and winter, and tends to reduce also the difference between the two. Buildings should be shaded as much as possible, and windows should be shaded, particularly on south and west sides.

Prices are comparatively high, although a good case can be made out for the advantages of year-round temperature control (which can be obtained from other systems, though not so easily).

Operating costs of heating are probably higher than for efficient gas-fired furnaces. (When one includes summer cooling, the comparison naturally looks better.) Present utility rates are around 2 to 2½ cents per kwh for this service, and on a theoretical basis the cost equalizes with gas at about 1 cent per kwh. Utility spokesmen state that the minimum profitable rate is probably about 1.75 cents per kwh. On the other hand, few genuine mechanical improvements in living have been sold because they cost less. Usually they cost more.

The application problems are subtantially those of any air conditioning system, which means that a heat pump installation ought to take good layout engineering and careful erection. More operating failures have been due to poor application and bad air distribution than to manufacturing and design errors. In other words, the pump isn't a piece of package goods like a radio or refrigerator, but an engineering project.

The field of special applications of the heat pump principle is wide, and new possibilities continue to be investigated. Any building requiring heating and cooling may investigate whether the heat pump can be installed to advantage or profit, and in a large ratio of cases, it will be found to compare favorably with other methods of air conditioning.

Bill Holladay has been a part of the refrigerating and air conditioning industry for 21 of his 24 years since graduation — first with the General Electric Company, for which he pioneered the original "Monitor Top" refrigerator in Texas and Oklahoma; then for 14 years as service manager for the George Belsey Company in Los Angeles. He was also Purchasing Agent for the General Air Conditioning Company of Oakland, and Manager of Field Engineering for Drayer-Hanson, Inc., Los Angeles. He is now Vice President of Hieatt Engineering Company, a firm specializing in ultra-low temperatures and other unusual applications of what he would like to call "thermal engineering," if he were sure of being understood.

He is a member of A.I.E.E. and A.S.R.E., an associate of A.S.H.V.E., teaches refrigeration and air conditioning at the University of Southern California on the side, and is an ardent Scouter and photographer. He is married, has three children, and lives in Altadena.

FIRST HIXON SYMPOSIUM ON "CEREBRAL MECHANISMS AND BEHAVIOR"

THE OVERLAP of psychology into the field of biology and vice versa, were examined and discussed this month at Caltech when the biology division sponsored the first Hixon Symposium on "Cerebral Mechanisms in Behavior."

To discuss this relatively new field of psychobiology twelve outstanding scientists in the fields of psychology, neuropsychology, psychiatry, zoology and mathematical physics met daily at Caltech from September 20 through 25. Host to the group was Dr. George W. Beadle, Caltech biology division head, and Dr. Lloyd A. Jeffress, visiting professor of psychobiology.

Seven papers, with titles ranging from "Functional Differences between the Occipital and Temporal Lobes" to "Why the Mind is in the Head" were presented and discussed. The final day of the symposium was devoted entirely to discussions on the general subject of psychobiology.

Speakers were Professor Ward C. Halstead, University of Chicago; Professor Heinrich Kluver, University of Chicago; Professor Wolfgang Kohler, Swarthmore College; Professor K. S. Lashley, Harvard University; Dr. R. Lorente de No, Rockefeller Institute for Medical Research; Professor Warren S. McCulloch, University of Illinois; and Dr. John von Neumann, Institute for Advanced Study.

Discussion panel members, in addition to the above and Dr. Jeffress, included Professor R. W. Gerard and Professor Paul Weiss, University of Chicago; Professor H. S. Liddell, Cornell University; Professor Donald B. Lindsley, Northwestern University, and Dr. J. M. Nielsen, Los Angeles psychiatrist.