The Economics of the Heat Pump for Residential Heating

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THE USE of the heat pump for space heating, especially for the heating of homes, has attracted such widespread attention in recent years that the popular demand for such a method of heating has almost entirely preceded the necessary research and compilation of data for the proper design and installation of such units. Because of the present dearth of such information each heat pump installation must, if properly installed, be carefully studied and engineered, and thus becomes rather expensive in first cost. Fortunately, a few brave souls are wagering their judgment, backed by the necessary cash, that such a heating system will prove economical, and careful studies of the efforts of these pioneers may supply much of the necessary information. Once such design and installation data have been established and become common knowledge, the competition in supplying such installations will probably bring the costs within the range of other methods of heating, while the fuel costs will be much less.

SAVING IN FUEL COST STUDIED

WITH SUCH CONSIDERATIONS in mind, the University of Washington has planned a rather extensive study of some of the factors involved. The first problem studied, and now completed, was a survey of the possible saving in fuel cost over other types of heating. This report briefly summarizes the results of that portion of the work.

The calculations involved in such a study must be based upon definite assumptions, or sets of conditions, which should correspond as nearly as possible to the average practical conditions. At the time this study was started, no authentic data could be obtained upon the first cost or installation cost of heat pump equipment. Thus the first cost of the heating installation could not be utilized as a factor. A comparison of the fuel energy costs appears to be the most logical means of conducting the study. With this difference established, the home owner could consider the amount saved in energy costs during the useful life of the equipment might be safely invested in the greater original cost plus the interest. Twenty years might be considered the useful life for equipment of any heating method considered. The usual rate of depreciation would reduce the first cost to zero in that time, and the equipment would probably be obsolete as well. However, with proper maintenance such equipment should still be serviceable.

In calculating the data for the heat pump two sources of information were used. First, the power required for the given heat load was computed by using the pressure-enthalpy thermodynamic cycle which corresponds as nearly as possible to the practical case, and applying reasonable factors for all known losses. Second, the power required for these same heat loads was calculated by using actual test data obtained from the companies dealing in refrigeration equipment. Results obtained from data supplied by the various companies checked within about 1 per cent. The results from the theoretical computations were in general lower, with a maximum difference of about 9 per cent.

HEAT LOSS DETERMINES SIZE OF EQUIPMENT

THE SIZE OF THE EQUIPMENT necessary for any house is in general determined by the heat losses of the house on the coldest day of the season. The energy necessary over the heating season depends largely upon the degree days for that year, as well as the size and type of house, and the inside temperature maintained. The following equation is the one usually used in computing the yearly consumption.

$$\text{Kw-h. per year} = \frac{(24 \text{ hr./day})\ (\text{deg. days/year})\ (\text{heat load Btu./hr.})}{(\text{temp. difference inside to outside})\ (3414 \text{ Btu./Kw-h.})}$$

The heat loss for a given house should be determined by calculating the heat passing through the walls, ceilings, windows, etc. Some contractors use the cubical contents, or the floor area, of the heated portion of the house together with the proper empirical factor to calculate the heat loss. Such methods often prove sufficiently accurate if properly applied.

While studying the various factors involved, and performing the multitude of calculations necessary, the set of related curves shown in Figure 1 were obtained, and found to be convenient for heating-energy relationships.

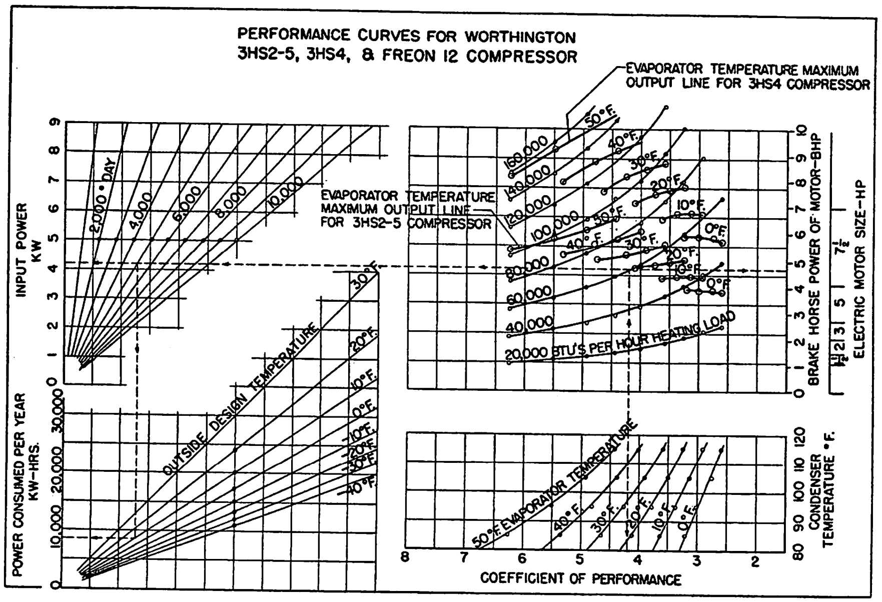

Figure 1

Thus by starting with a known evaporator temperature of, e.g., 40° F. and a condenser temperature of 110° F., the coefficient of performance (C.O.P.) of the compressor unit is given as 4.2. By following the dash line vertically to the known heating curve above of, let us say, 60,000 Btu. per hour, the driving motor size shown to the right should be about 7 1/2 hp. Following this horizontal dash line to the left until it intersects the degree day curve for the locality, say 5000, and from this point vertically down to the curve of minimum outside temperature of the locality, the yearly kw-h. consumption for heating to an inside temperature of 70° F. is given on the left hand scale.

In the original report corresponding sets of curves were calculated for other makes and types of existing refrigerating equipment, as well as for the theoretical calculations.

Attention might be directed to the curves of minimum outside temperature on the lower left hand side of the figure. These curves appear to be in reverse order, but by referring to the formula for calculating the kw-h. per year, the factor for the temperature difference between inside and outside temperature appears in the denominator, which indicates that the kw-h. is inversely related to the outside temperature. A lower outside temperature would, of course, increase either the heating losses for the house or the degree days for the year, or both.

The curves in Figure 1 can also be used to find the kw-h. per year required for straight electric heating with unit type of heaters. Thus by starting from some assumed point on the proper heating load curve for heat losses of the house considered, the C.O.P. for the point chosen is found directly below. From the point on the heating load curve chosen, follow horizontally to the proper degree day curve, thence directly downward to the outside design temperature curve, and again to the left find the kw-h. necessary at the C.O.P. indicated. The product of the kw-h. value and the chosen C.O.P. factor will give the proper kw-h. for straight electric heating. In general, heating by the use of electric energy is not attempted unless the house is well insulated to keep the losses low.

The maximum load curves in the heating load section indicate the maximum loads the specified type of machine will carry with the evaporator temperature indicated. A study of the various curves clearly indicates that to obtain the greatest possible delivered heat from a given unit, the evaporator temperature must be as high as possible, and to obtain a good C.O.P. the difference between the evaporator and condenser temperatures must be as small as possible.

Fuel Energy Costs Compared

The economic study was greatly aided by the use of the curves of Figure 1. For this study a number of assumed cases were used, and the fuel energy costs by means of the different heating methods were calculated for comparison. The data compiled in Table 1 and shown in curve form in Figure 2, gives the energy cost per year for the various heating loads. The last two columns give the saving in fuel energy costs over twenty years time for two types of heat pump as compared to the electric furnace method of heating.

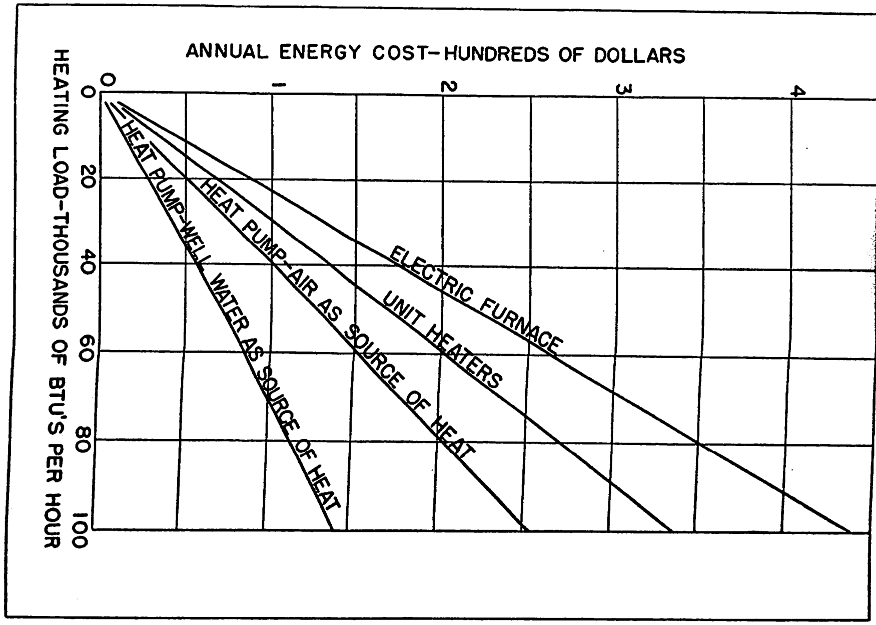

Figure 2

Heating by means of unit heaters in each room was assumed to give 100 per cent efficiency of fuel, while to carry the same heating load by means of the central electric furnace was assumed to require 30 per cent more electrical energy in accordance with rather extensive tests conducted by the Portland General Electric Company of Portland, Oregon. In making the calculations for the heat pump data, the power requirements for all of the necessary auxiliary equipment such as fans, pumps, etc., were included in the overall coefficient of performance. The C.O.P. thus derived is a little lower than a well designed unit would give since no salvaging of motor heating losses, except that of the compressor motor, was assumed. Usually such losses can be recovered in the heating system.

Other constants and conditions for the calculations were as follows: condenser temperature, 110° F.; evaporator temperature, 40° F.; C.O.P. of heat pump only 4.15 using well water as heat source; C.O.P. overall of system 2.56 using well water as heat source; C.O.P. of heat pump only 2.40 using

air as the heat source; C.O.P. overall of system 1.73 using air as the heat source; electrical energy cost 7.5 mills per kw-h.; degree days per year 5000; inside temperature maintained 70° F.; lowest outside temperature 10° F.; air used as heat source, 1900 cu. ft. per minute; static head of air 1/2 in. water; water used as heat source, 11.5 gal. per minute; water pumped against 100 ft. head.

Table 1

Heat load 1000 Btu./hr.	Energy cost per year				Savings in 20 years over furnace	
	Electric furnace	Elec. unit heaters	Heat pump using water	Heat pump using air	Heat pump using water	Heat pump using air
	(dollars)	*(dollars)*	*(dollars)*	*(dollars)*	*(dollars)*	*(dollars)*
20	88	67.50	28	50.75	1200	745
40	176	135.00	56	101.75	2400	1490
60	264	202.50	84	152.50	3600	2235
80	352	270.00	112	203.50	4800	2980
100	440	337.50	140	254.25	6000	3725

Since compiled data on electrically heated houses in and near Portland, Oregon, were available such data over a period of three years, on 39 houses, were utilized for further comparisons. The energy consumed per year for the average house was 10,776 kw-h. The average degree days per year for the three years was 5105. By using the heating formula previously stated, this gives the average heating load per house as 18,000 Btu. per hour for the unit heater type of installation, or 23,400 Btu. per hour for a central furnace type of installation. The central furnace compares more favorably with the heat pump in the heating comfort it affords. Using the method of calculating and the constants assumed for calculating data in Table 1, the total power consumed, per year, by this average house was 4,933 kw-h. when using the heat pump with ground water as its source of heat as compared to 14,000 kw-h. when using an electric furnace. This results in a total savings in twenty years of $1360.00, at 7.5 mills per kw-h.

Another comparison was carried out in Table 2 by selecting twelve of the most representative houses in the list from lowest to highest in energy cost as well as a similar variation in cubic foot volume. The first five columns in Table 2 were taken from the original report; the remaining data were calculated.

In order to compare the relative costs of heating by coal and oil to those for the heat pump and resistance type of electrical heating, Figure 3 gives

Table 2.—A study of the use of the heat pump as compared to unit heaters for heating twelve selected homes

No. of Rooms	Vol.	Energy using unit heaters		Kw-h. energy cost	Savings over 20-year period assuming elec. furnace heating		
		Kw-h. per yr.	Cost per yr.		Unit heater	Heat pump using water	Heat pump using air
	(*cu. ft.*)		(*dollars*)	(*mills*)	(*dollars*)	(*dollars*)	(*dollars*)
6	9800	5377	31.62	5.9	190	532	362
3	4032	6106	36.68	6.1	220	618	421
5	9160	8006	46.82	5.8	281	790	537
5	6900	8187	54.15	6.6	327	912	620
6	7200	9533	65.46	6.9	393	1100	750
7	8832	10662	75.00	7.0	450	1260	860
6	9672	12049	83.13	6.9	500	1400	963
7	11880	13599	96.34	7.1	578	1620	1110
6	9980	15458	108.53	7.0	652	1830	1240
7	13000	14853	112.84	7.6	675	1900	1300
6	10500	18172	125.57	6.9	755	2120	1440
4	7168	19565	143.95	7.3	865	2420	1650
Ave. 6	8332	10776	72.00	6.7	432	1215	825

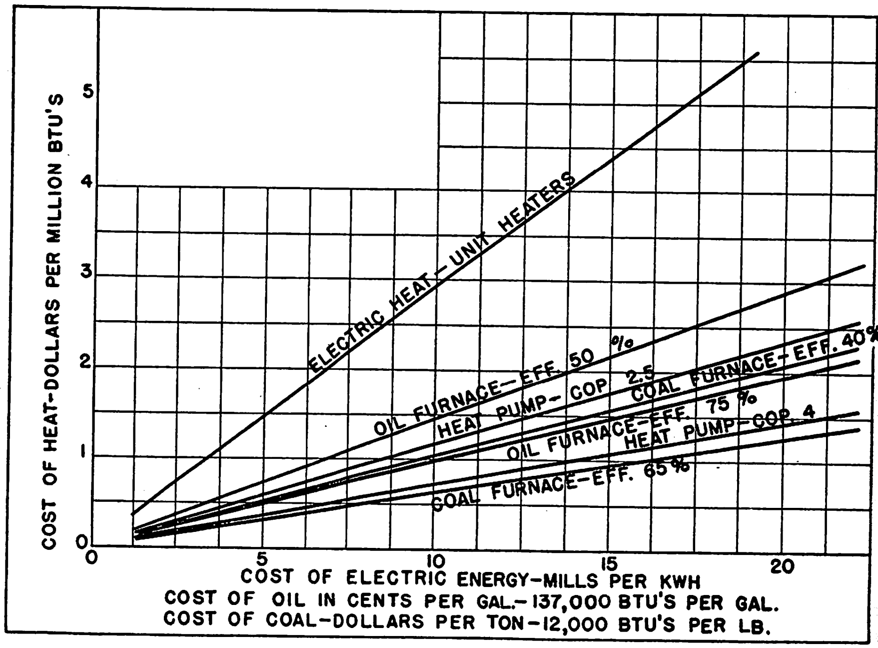

Fig. 3.—Comparative heating costs

the cost in dollars per million Btu. of heat for each of the fuels or fuel energy considered over a rather wide range of cost prices. Since the furnace efficiency in using oil or coal is always a very debatable value, curves for high and low extremes are given for each.

From this economic study of the heat pump as well as from studies and data obtained since, there is every evidence that heat pump installations with overall C.O.P. of three to four or better are very possible especially where ground water at 50° F. or above can be used. With a C.O.P. of three or above, the fuel cost is far below electric heating and also compares well with coal and oil even when these are utilized at exceptionally good furnace efficiencies. Reports on the use of a gasoline engine instead of an electric motor to operate the heat pump indicate a still further reduction in fuel costs.

Original Cost High

The first cost of the installation at present is rather high. One company has set a price, using radiant panels, at $1.50 per square foot of heated area. An air heated house, now under study in Seattle, using a well as the source of heat, ran near this value in first cost.

The heating data presented in Table 2, when compared with the usual calculated heating costs on similar homes, require some interpretation. Even in Table 2 the larger houses are not on the average the most expensive ones to heat. Again the yearly cost for heating in this list is not far from the cost for heating with oil or even coal as experienced by most home owners. Probably the following items may partly explain the inconsistencies. First, there is every evidence in all the compiled data on electrically heated houses that a large majority of the occupants are more careful in using heat when using electrical energy than is the average occupant of an oil or coal heated house. This can be so easily accomplished with unit heaters, and is one of the causes of the central electric furnace showing a 30 per cent increase in fuel cost over a similar house heated with unit heaters. Second, the houses listed were all, more or less, well heat insulated. There is a strong inclination to compare such well insulated electrically heated houses with houses having little heat insulation now heated with coal or oil.

While the use of the heat pump for heating homes is still very new, demand for it is rapidly increasing and since the energy cost is so low the demand will probably grow as the cost of other fuels increases. The heat pump has most of the desirable features of electric heating and has a great advantage in energy costs. The greatest disadvantage at present is its first cost, and with a better understanding of its proper design and installation the first cost will probably be greatly reduced.

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The original report, which includes several sets of curves and other data not presented in this paper, is available at the University of Washington as an Engineering Experiment Station Bulletin.

Meteorological Aspects of the Columbia River Basin Flood of 1948

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THE FLOOD OF THE COLUMBIA during May and June 1948 was the most disastrous in the history of this river. The toll: about 50 lives, nearly 50,000 people made homeless, about 10,000 homes destroyed or requiring much repair, close to 5000 acres of land lost from erosion, with an additional 19,000 acres badly damaged, and about 1000 miles of roads damaged. Property loss was conservatively estimated at $100,000,000. No estimate has been made of the man-hours used to combat the flood during its rampage or of the man-hours lost because of the damage.

Flood waters at The Dalles reached the third greatest discharge rate since stream flow records began there in 1857; the floods of 1894 and probably of 1876 had somewhat higher water. Between 1894 and 1948 the maximum discharge of the Columbia did not exceed 800,000 second feet at The Dalles until 1948, when it reached 1,010,000 second feet on May 31. This was somewhat less than the 1894 flood, which had a peak discharge of 1,240,000 second feet. For more than 50 years there had been no floods of disastrous proportions; the general trend of peak discharge, again at The Dalles, was downward. What events led to the enormous discharge of 1948? How did they differ from other years? Will events of 1948 repeat themselves and bring other floods?

It is not necessary to point out that the area drained by the Columbia River receives more of its precipitation in the colder half year than in the warmer half. It is largely in the form of snow; the amount on the ground increases more rapidly than melting and evaporation can decrease it, until diminishing precipitation and temperature, mounting above freezing in spring, bring about the removal.

By April 1 usually there is a maximum amount of suspended water, as snow, at altitudes above about 3000 feet in the Cascades and at a somewhat higher altitude in the Bitterroots. Further, there is little snow left below 3000 feet and