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HEAT PUMPS FOR GEOTHERMAL APPLICATIONS: AVAILABILITY AND PERFORMANCE

Quarterly Technical Progress Report

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Gordon M. Reistad
Department of Mechanical Engineering
Oregon State University
Corvallis, OR 97331

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DISCLAIMER

INTRODUCTION

Oregon State University is under contract with the U.S. Department of Energy to carry out a survey of the performance and availability of water source heat pumps. The primary purpose for this work is to obtain information so the role of water source heat pumps in geothermal energy utilization can be evaluated and/or to identify the research needed to accomplish this. The project is of eight months duration.

This report is the first quarterly report, covering activities during the period June through August, 1979. During this period, Dr. Gordon M. Reistad, the project director, spent 0.6 man months on the project and Mr. Paul Means, a Graduate Research Assistant, spent 1.5 man months on the project. During this period, the primary efforts have been directed at (i) surveying the literature, (ii) identifying manufacturers, (iii) obtaining performance data, and (iv) contacting the major manufacturers.

LITERATURE

The literature reveals that interest and activity in the heat pump area has increased sharply in the mid and late 1970's. The activity covers the full range from public interest, increased sales, research and development (both government and industry sponsored), and substantially increased published literature. The primary reasons for this activity stem from (i) an increased awareness of our limited available energy and the heat pump's potential to use this energy more effectively in certain applications, and (ii) the shift towards using electrical power for residential heating as oil and natural gas supplies become increasingly scarce and less reliable*

*Two-thirds of the electrical power generated in the U.S. is from more abundant sources such as coal, nuclear, and hydro power (Comly, et al., 1975).

(Pietsch, 1977 and Comly, et al., 1975).

The emphasis of this report is on water source heat pumps and to a large degree, unitary units. The basic type of heat pump considered here is shown in Figure 1. The major components are 1) a reciprocating compressor unit, typically hermetically sealed, 2) an air side heat exchanger with fan, 3) either a thermostatically controlled expansion valve or more commonly, a capillary tube, 4) a tube in tube water to refrigerant heat exchanger, and 5) a four-way reversing valve. Refrigerant 22 is used almost universally as the working fluid in these heat pump applications. A unitary heat pump is one which has all of these components and associated controls enclosed in one or two factory assemblies. Typical size ranges are from 1.5 to 20 tons.

Heat pump development, as indicated by the published literature, is being advanced in three primary and interrelated areas. These areas are: (i) new and expanding applications, (ii) performance improvement of the existing type units, and (iii) development and evaluation of alternate system designs.

The most widespread application of water source heat pumps for space heating is in the use of groundwater as an energy source for heating single family residences. Such units are also typically used for cooling during the summer months, with the well water then being used as the energy sink. These applications are common in many areas of the country, and efforts to allow heat pumps to use lower temperature water (approaching 40°F) are directed at expanding the areas where these units are viable.

Solar heated water is also being used, on a limited scale, as an energy

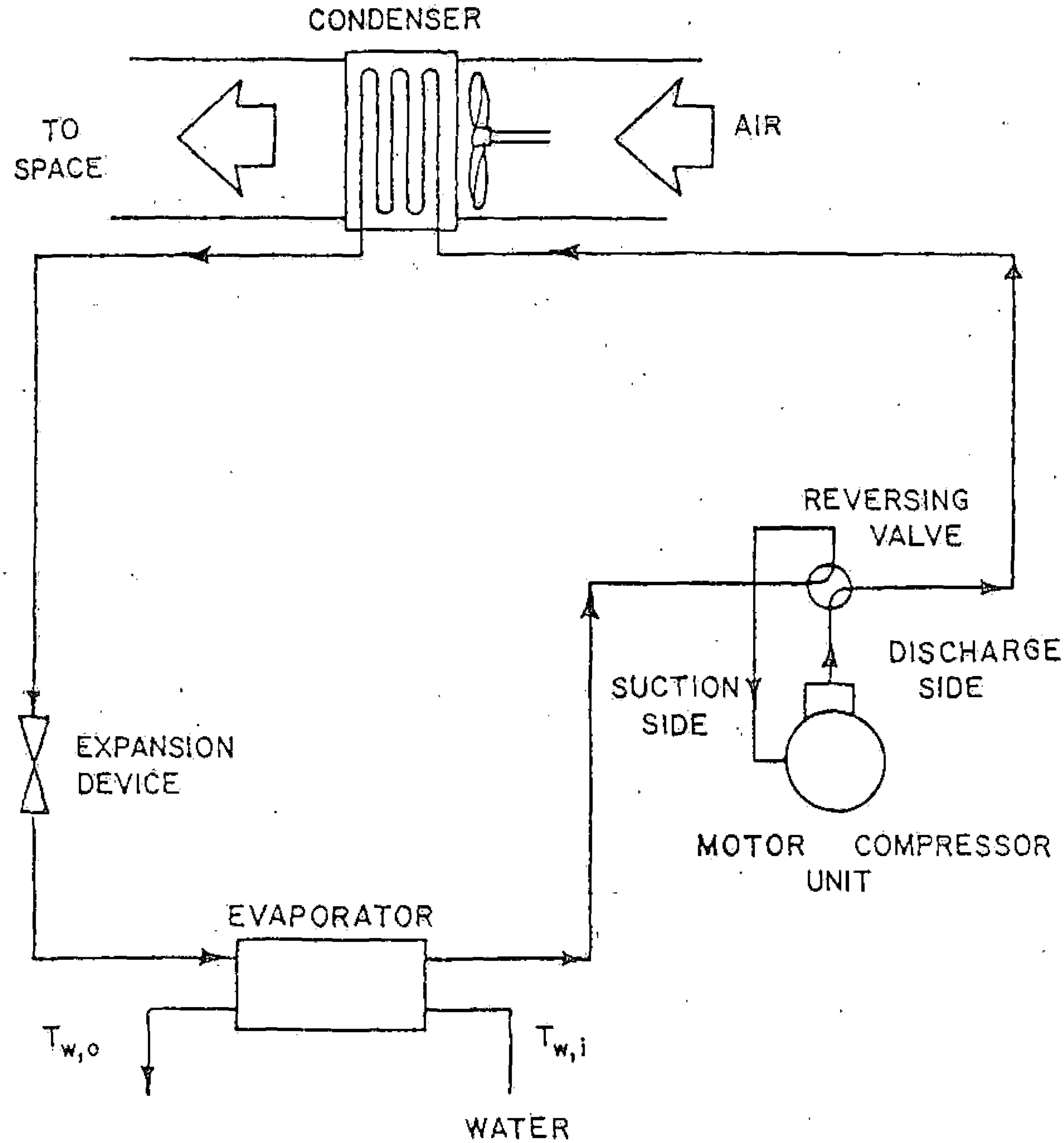

Figure 1. Water source heat pump operating in the heating mode.

source for residential heat pumps. A few of the smaller heat pump manufacturers/suppliers have limited product lines directed at this market. The most activity in this area is in the evaluation of such systems. There is an extensive amount of published literature on this topic, some of which is contradictory as to the real benefit of such a solar-heat pump series system (Andrews, et al., 1978). It has been stressed by some authors that a heat pump with good high temperature performance is essential to obtain the most advantage of such a system (Kush, 1979).

Commerical and industrial water source heat pumps are also common. Commercial installations are usually in the form of distributed systems consisting of a one or two pipe water distribution system with terminal heat pumps. Such units are typically designed to operate in both cooling and heating modes and with water in a restricted temperature range. Industrial applications usually have custom engineered systems.

The published literature on actual water source heat pump performance, specifically Coefficient of Performance in Heating (COPH) as a function of source water temperature, is limited and rather general. The COPH values increase slightly with increasing source temperature up to 60 or 70°F, however, at higher temperatures there is essentially no improvement in COPH. This is in contrast to the theoretical COPH which increases monotonically with increasing source temperature. There are several reports which detail very well the reasons why the actual heat pump performance is so much less than the theoretical (for example, Comly, et al., 1975 and Ambrose, 1974). Although, these reports are directed towards air to air heat pumps much of the discussion is also appropriate for the water source units.

A much larger portion of the heat pump literature deals with performance improvement techniques. These include compressor capacity control, larger heat exchangers, more controllable expansion devices, and heat only heat pumps to name a few. Analytical methods are often used to show the value of such performance improvement techniques (Gordian Assoc., 1978, Kirshbaum, et al., 1977, and Blundell, 1977).

Many alternative designs have been proposed (usually much more complex than existing units). These include multipressure systems, parallel compression, series compression, and alternative compressor motor power concepts. A limited number of these systems have been tested. More often the performance is based on numerical analysis from which economic evaluations are made (Comly, et al., 1975 and Gordian Assoc., 1978).

MANUFACTURERS

Table 1 shows a list of water to air heat pump manufacturers. A majority of these have been contacted by phone or mail or both and the remainder have been recently mailed a written questionnaire. The table was compiled from information obtained from (i) the Air Conditioning and Refrigeration Institute (ARI), (ii) the ASHRAE Handbook and Product Directory, and (iii) the National Water Well Association. ARI claims that its directory covers 90% of all water source heat pumps manufactured although only about one-third of the companies in Table 1 were found in the directory. This implies that primarily the major manufacturers are certified by ARI and that some of the smaller manufacturers, especially those oriented towards solar assisted heat pumps, are relatively new in the water source heat pump business and/or have limited production. Although 33 companies are listed, they do not necessarily represent 32 different product lines. Some of the companies simply market

Table 1. Water Source Heat Pump Manufacturers

Name and City	Source
Air Conditioning Corporation Greensboro, NC	3
American Air Filter Co., Inc. Louisville, KY	1,2,3
American Solar King Corp. Waco, TX	1
Barkow Manufacturing Co., Inc. Milwaukee, WI	2
Budco Bloomfield, CT	2
Carrier Corporation, Air Conditioning Group Syracuse, NY	1,2,3
Climate Master Products, Inc., Div. Weil McClain Co. Ft. Lauderdale, FL	2
Command Aire Waco, TX	1,2,3
Elm Brook Refrigeration, Inc. Brookfield, WI	2
Florida Heat Pump Corp. (Div. Leigh Products Co.) Pampano Beach, FL	1,2,3
Friedrich Air Conditioning and Refrigeration Co. San Antonio, TX	1,2,3
Heat Controller, Inc. (Div. Addison Products)* Jackson, MI	2,3
Heat Exchangers, Inc., Koldwave Division Skokie, IL	1,2,3
International Environmental Corp. Oklahoma City, OK	1,2
Lear Siegler, Inc., Mammoth Division Holland, MI	1,2,3
Northrup, Inc. Hutchins, TX	1,2,3
Ramada Energy Systems, Inc. Tempe, AZ	2
Singer Co., Climate Control Division Auburn, NY	1,2,3
Solar Energy Research Corp. Longmont, CO	2
Solar Energy Resources Corp.** Miami, FL	1,3
Solar Kinetics Mechanicsburg, OH	2
Spectrum Solar Systems Corp. Pickerington, OH	3

Table 1. Continued

Name and City	Source
Tempmaster International Energy Conservation Systems, Inc. Orlando, FL	2,3
Thermal Energy Transfer Co. Westerville, OH	3
Vanguard Energy Systems San Diego, CA	2,3
Vilter Manufacturing Corp. Milwaukee, WI	2,3
Weatherking (Div. Addison Products) Orlando, FL	2,3
WESCORP, Inc. (Subsidiary of Vaughn Corp.) Andover, MA	3
Westinghouse Electric Corp. Commercial-Industrial Air Conditioning Division Staunton, VA	2
Whalen Co. Baltimore, MD	2,3
Wilcox Manufacturing Corp. Pinellas Park, FL	3
Wormser Scientific Corp. Stamford, CT	2
York Division Borg Warner Corp. York, PA	2,3

Sources

1 - Air Conditioning and Refrigeration Institute, June 1 - November 30, 1979, Directory of Certified Applied Air-Conditioning Products.

2 - 1979 ASHRAE Handbook and Product Directory.

3 - National Water Well Association Listing.

Footnotes

* - Heat Controller, Inc., and Weatherking, Inc., are both divisions of Addison Products Co., Inc., and market identical water source heat pumps.

** - Also identified as "Solar Oriented" Environmental Systems, Inc.

heat pumps manufactured by others under a different name. A few companies that were included in the three sources mentioned, when contacted, said they no longer manufacture water source heat pumps. These companies therefore are not listed in Table 1.

PERFORMANCE

Performance data for water source heat pumps has been obtained from most of the major manufacturers listed in Table 1. The performance values have not been completely compiled at this time, but the data have been examined in several ways.

Water source heat pump performance, in terms of COPH was plotted versus nominal heating capacity for ARI certified units. This data set, shown in Figure 2, is based on rating conditions per ARI Standard 320-76. The plot, which is very similar to that done by Briggs and Shaffer, 1977 shows a wide range of performance between units at any one capacity. There is a slight trend for increased performance with increasing capacity, however this is only a general trend and may not be true for all manufacturers. Comparison of this current data with that presented by Briggs and Shaffer in 1977 shows an average increase in COPH of around 0.2 over the last two years. This increase may not be entirely due to product improvement, however, since the 1979 rating condition is based on a 70°F water source temperature and the 1977 ratings are based on a 60°F water source temperature and, based on manufacturers' data, a majority of the units have slightly better performance with 70°F than 60°F entering water temperature. Also, there is no allowance for the water pumping power in the 1979 ratings while there was some allowance in the 1977 ratings. Examination of certain units does

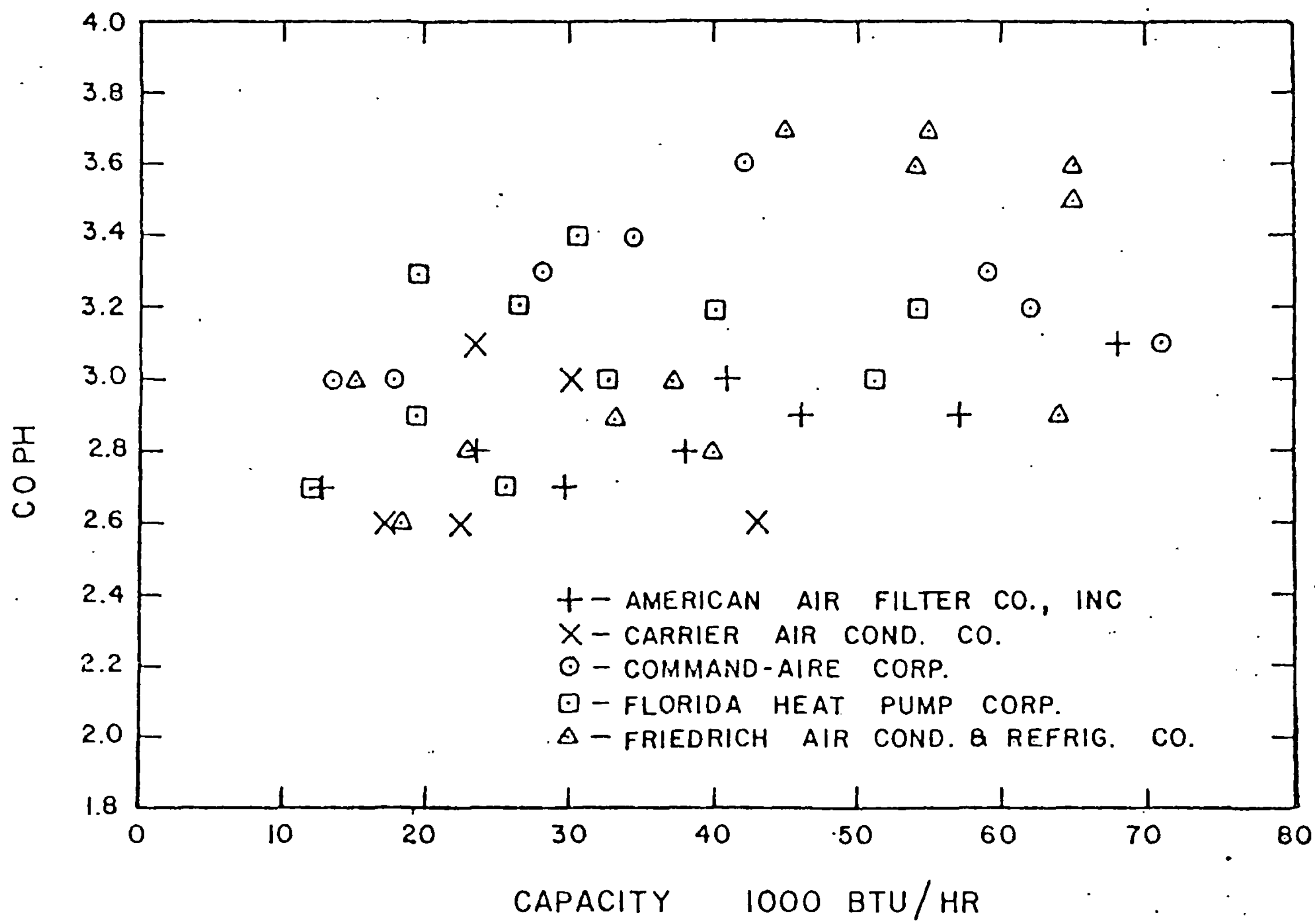

Figure 2a. COPH vs. Capacity for single package water source heat pumps. Data per ARI Standard Ratings, June 1 - Nov. 30, 1979 Directory.

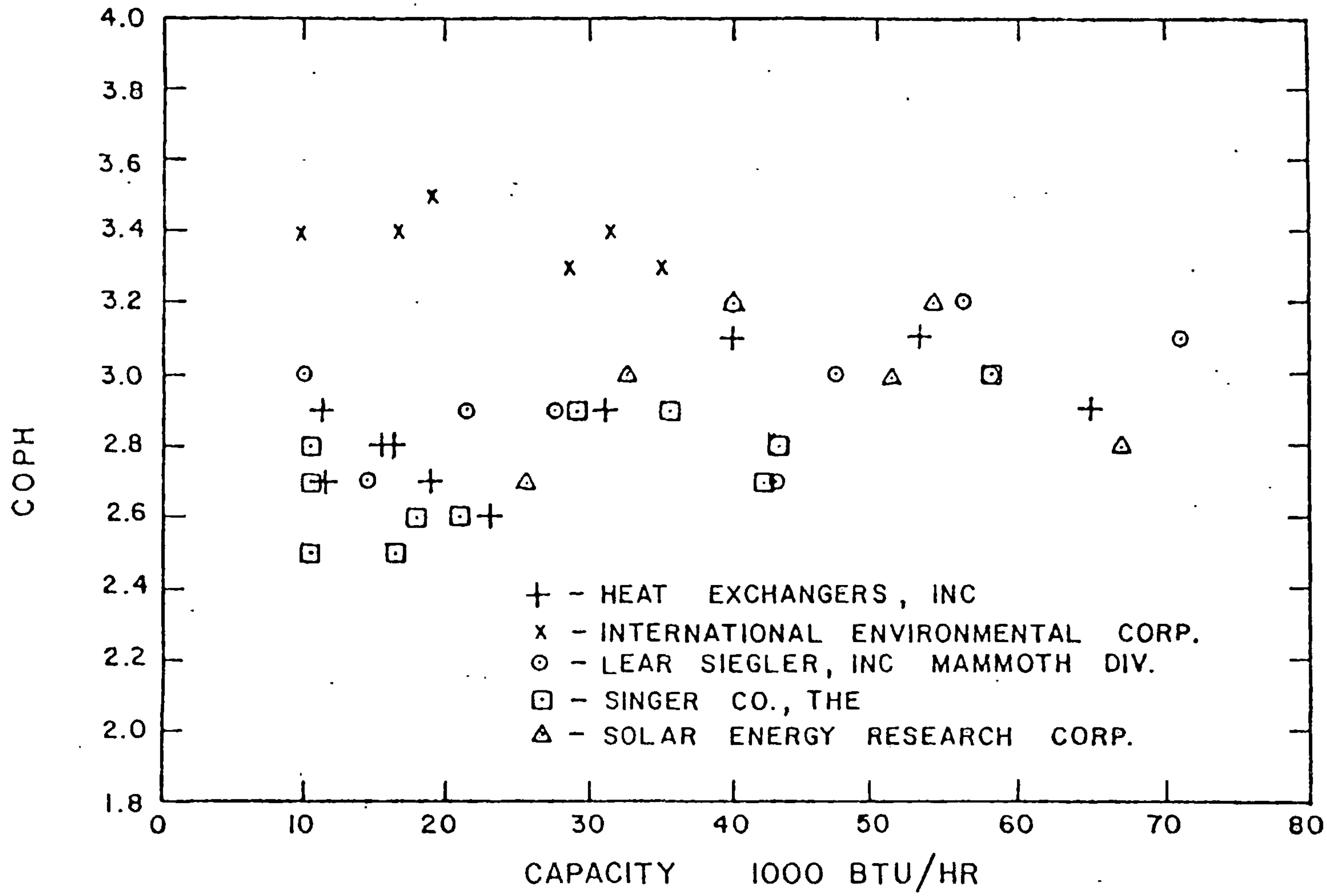

Figure 2b. COPH vs. Capacity for single package water source heat pumps. Data per ARI Standard Ratings, June 1 - Nov. 30, 1979 Directory.

however show substantial improvement since 1977.

A major concern is the water source heat pump performance as a function of water source temperature. Figure 3 shows how the COPH varies with water outlet temperature for five typical mid-sized heat pumps based on manufacturers' data. In Figure 3, the leaving water temperature rather than the entering water temperature was used as the independent variable, because better correlation should result. It is planned to examine several ways of presenting the data for the best utility. Not much variation is evident between the different models at lower outlet water temperatures, however at higher outlet temperatures the difference is pronounced. This is not easily explained without more detailed evaluation of the different units. (A possible explanation is that some manufacturers have calculated performance at higher source temperatures rather than conducting extensive testing. This has been observed in some of the data examined to date.)

CONTACT WITH MANUFACTURERS

Many of the water source heat pump manufacturers listed in Table 1 have been contacted to determine several aspects of their present activity and attitude in regard to water source heat pumps. Those companies which have large scale production of unitary water-source heat pumps and which manufacture their own units were the main ones contacted. Additional companies, both custom water source heat pump manufacturers and traditionally air-to-air heat pump manufacturers that are in the research stage on water-source units, were also contacted. Although the manufacturers in general would not discuss the specifics of their planned developments, they appeared to be willing to discuss the trends of developments and the

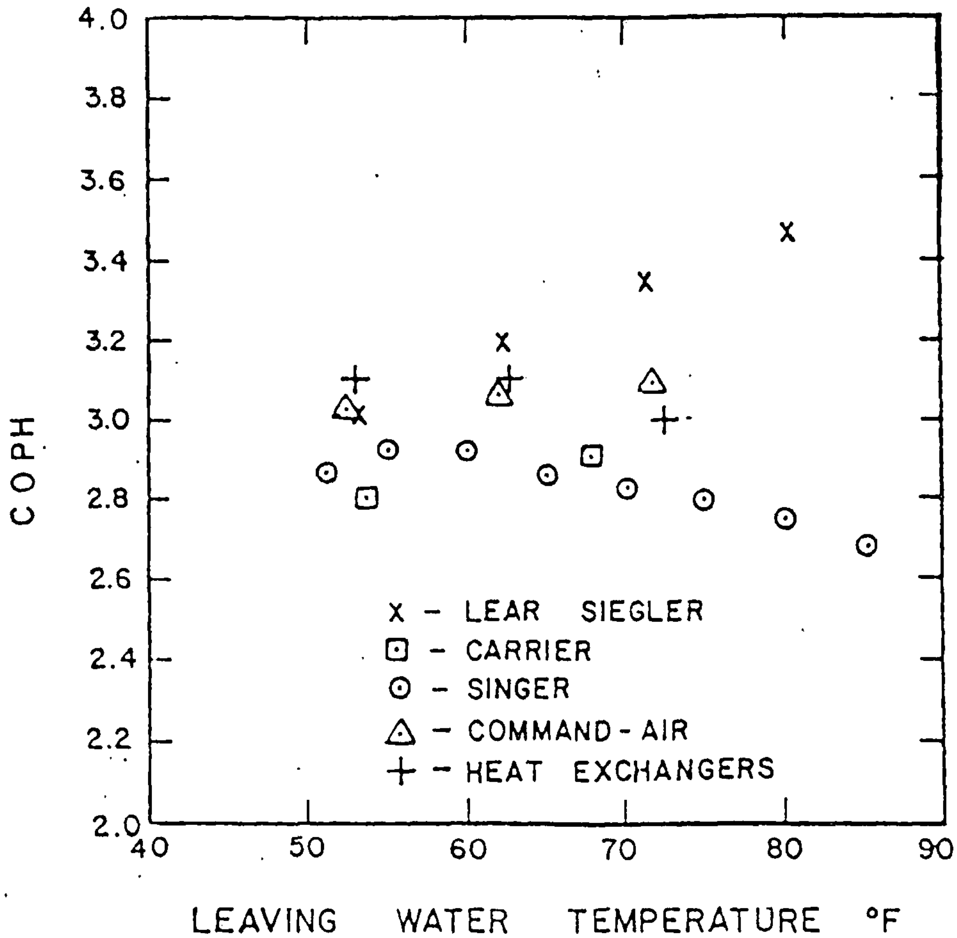

Figure 3. COPH vs. Evaporator exiting water temperature for typical 35000 to 42000 Btu/hr capacity heat pumps.

present position of the company on many aspects that impact present and near-term future products.

The conclusions reached from these discussions are:

- The COPH at ARI rating conditions can be expected to increase slightly over the next few years, at the rate of about 0.1 per year. Most of the companies have a moderate program directed at COPH performance improvement of the water source units. Several companies have quite strong programs in these areas and the performance improvements of their units in the last few years indicate this. Most companies, however, emphasize the cooling performance rather than the heating performance in their system design.
- The entering source water temperature should be less than about 95°F for most of the water source heat pump units primarily because they will shut off on high head pressure as the capacity increases with increasing source water temperature. Some units may be purchased with a special package that regulates the water flow and permits inlet temperatures as high as about 110°F.
- Most of the manufacturers showed little interest in developing a product line directed specifically toward geothermal applications. The primary reasons were (i) they viewed the market as quite limited and (ii) they already have many production lines and they are presently very much bogged down with getting their present units tested under the new DOE guidelines. There are several manufacturers that are very much committed to vigorous programs in water-source heat pump development, and if shown

the need for a product line in the geothermal area would be interested in that application.

- All of the companies contacted indicated that they were not interested in developing a "heating only" water source heat pump. One company said that a decision is near in regard to whether they will or will not start producing a "heating only" air source unit.
- All unitary water-source heat pumps for space heating are presently single stage compression and no change is expected.
- More complex heat pump systems such as hybrid water and air source/sink units are not being seriously considered at this time because great advantage is seen in simplicity and also each different operating mode requires a whole series of additional certification testing. Less significant modifications such as dual compressors are being considered more, but probably will not be commercial for several years.

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