DIRECT HEAT ACTIVATED COOLING ADAPTED TO GEOTHERMAL ENERGY

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ABSTRACT

Development in recent years of direct low temperature heat operated cooling equipment has the potential of improving geothermal economics by enabling more uniform seasonal load distribution and capital amortization. Source temperatures below 200°F and improved auxiliary power consumption are the primary advantages over previously available equipment. Of the various types of equipment on which development was undertaken, only absorption is beyond the developmental stage, being in current volume production.

Availability of these advanced absorption machines in small tonnage capacities (as low as 3 tons) facilitates the undertaking of demonstration projects at greatly reduced costs, freeing R & D monies for instrumentation, analysis and reporting expenses.

INTRODUCTION

Increasing concern over the cost and availability of energy has initiated investigation into alternate sources of, and more efficient methods of, utilizing energy. Coincident concern over ecological considerations and use of non-renewable resources has encouraged development of naturally occuring sources of energy. Of particular interest are solar and geothermal. The former because of technology development for solar application. The second because much of the solar technology is directly applicable and may, in some instances, prove to be a more economical application.

Both solar and geothermal immediately suggest the availability of heat for direct use in space, hot water and process heating applications. Higher source temperatures suggest electrical power generation application. Recent interest has also focussed on direct heat operated cooling equipment with the intent of amortizing the heat source development capital over the cooling season as well as the heating season.

Historically, absorption machines have been the most commonly used apparatus in direct heat operated cooling applications, and initial attention was directed to this equipment.

Initial solar cooling installations using low temperature heat employed modified versions of commercially available fuel-operated absorption air conditioners in residential application. In commercial structures, standard equipment (most derated to lower capacities to operate at the lower temperatures) was employed.

DEVELOPMENT REQUIRED

The operating experiences gained from these early installations indicated the requirement for a new generation of equipment designed specifically to operate within the parameters imposed by the new applications. Design objectives established were:

1) Full design capacity of the machine to be obtained at lower than traditional (230 - 270°F) source temperatures. Source temperatures below 212°F would be desireable.

2) Temperature Flexibility: A broader temperature range must be acceptable to the machine.

3) Parasitic power (power for such auxiliaries as pumps) to be reduced to absolute minimum. The capacity to parasitic ratio determines the advantage, if any, the heat operated system will have over a conventional electrically driven system.

4) Maintenance requirements must be minimized The possibility of over-concentrating the absorption machine must be reduced.

RESULTING EQUIPMENT

To meet these objectives and bring the resulting equipment to the marketplace, machine development received federal funding in the absorption, Rankine and Brayton cycles. The latter two are in development with field testing of experimental units scheduled this year.

In early 1977 the first two machines designed to the new objectives rolled off the production line at Arkla Industries. The Model WF-36 was directed at the residential market and has a nominal design capacity of 3 tons. The Model WFB-300 was developed for the light and medium commercial market and has a nominal design capacity of 25 tons. The capacity rating of both machines is taken with a source temperature of 195°F. Capacity varies with the source temperature. Specifically, the relationship to the design objectives are detailed as follows and in the accompanying tables:

1) Full design capacity obtained with source temperature of 195°F, 17°F below the 212°F target. This makes it possible to avoid the use of pressure code vessels, reducing the system costs.

2) Temperature Flexibility: A source temperature range of 35° - 40°F with capacities as indicated in the accompanying tables, in addition to a relatively high turn-down.

3) Parasitic Power at Full Capacity:

25 Ton: Absorption cycle electric - 300 watts.
Auxiliary Pumping: 9.6 GPM/ton

3 Ton: Absorption cycle electric - 250 watts.
Auxiliary Pumping: 10 GPM/ton

Development timing necessitated the use of an off-the-shelf solution pump on the 3 ton machine not allowing optimization of the pump for power consumption. A new pump is currently completing development.

4) Maintenance: Use of relatively dilute solution eliminates dilution cycle requirements and over-concentrating resulting from unintentional shut-downs and under-firing conditions. Use of inherently self-cleaning dripper fluid distribution instead of spray nozzles eliminates clogging problems and reduces solution pump horsepower. Use of air-tight construction normally associated with low-maintenance requirements of residential type construction eliminates periodic solution sampling and avoids motor driven purging mechanisms.

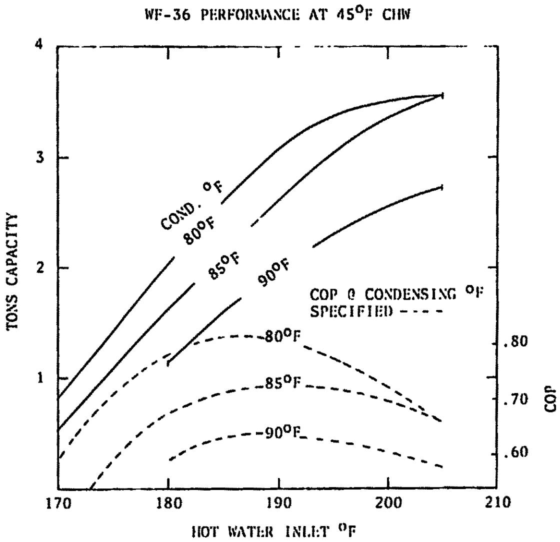


FIGURE 1: CAPACITY & COP TABLE FOR 3-TON MACHINE.

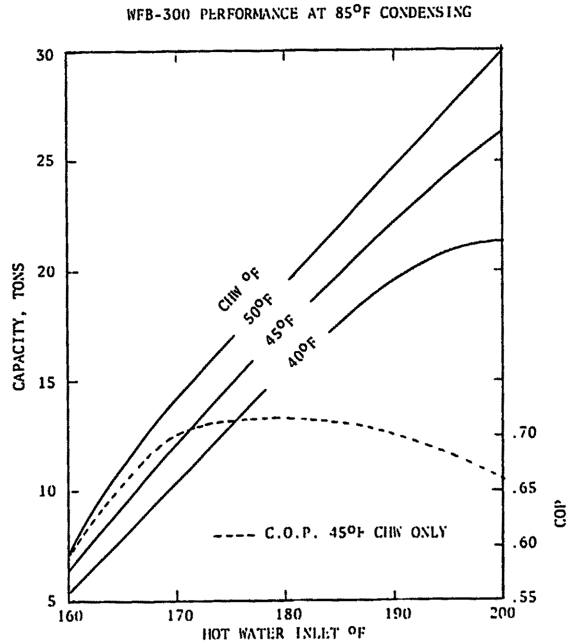
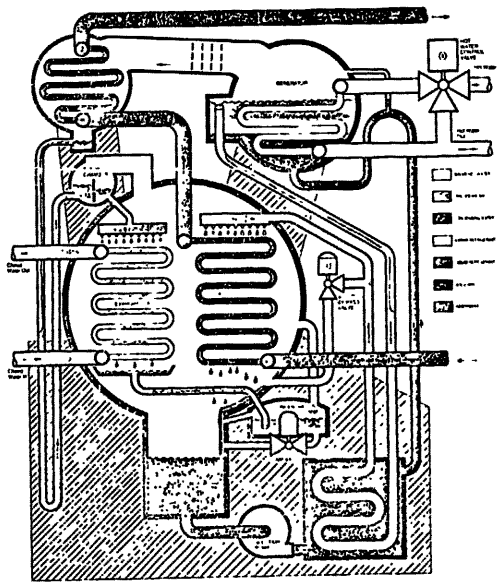


FIGURE 2: CAPACITY & COP TABLE FOR 25-TON MACHINE

FIGURE 3: WFB-300 CYCLE.



The Arkla SOLAIRE 300 Water Chiller operates on the absorption principle. Solar heated water is the energy source, circulating in a closed loop between the unit's generator and the solar collectors. In a second closed loop, the refrigeration tonnage is delivered by chilled water which circulates between the unit's evaporator coil and a refrigeration load. In a third water circuit, condensing water flows through the unit's absorber and condenser coils, carrying away the waste heat.

To begin the cycle, solar heated water enters the generator tubes. Its heat vaporizes part of the water refrigerant in solution, separating it from the lithium bromide absorbent.

The vaporized refrigerant passes to the condenser where it gives up its latent heat to the condensing water and is liquefied. It then flows through a "U" tube and through the flash chamber into the evaporator, wetting the outer surfaces of the evaporator coil tubes. There it is again vaporized as it absorbs the heat of the refrigeration load from the chilled water. The vapor then flows to the absorber where it is again liquefied as it combines with the absorbent in the process that gives the cycle its name.

The hot absorbent passes from the generator to the liquid heat exchanger where it gives up some of its heat. The pre-cooled absorbent then enters the absorber where it wets the outer surface of the absorber coil tubes and combines with the vapor refrigerant. It then gives up the remainder of its heat to the condensing water flowing inside the absorber coil tubes.

After the absorption process, the reunited refrigerant-absorbent solution drains into the solution sump. From there, it flows to the solution pump which moves it through the liquid heat exchanger where it is pre-heated before continuing on to the generator to repeat the cycle.

Refinements, in addition to the liquid heat exchanger, include:

1) The Concentration Chamber and Dump Valve. The chamber, by collecting and storing a portion of the liquid refrigerant, provides the optimum solution concentration for best unit performance when entering condensing water temperatures are in the normal range of from 75°F to 90°F. If condensing water temperature drops below 75°F, the dump valve opens and empties any stored refrigerant into the solution sump, diluting the solution. This dilution allows stable and continuous unit operation at the lower condensing water temperatures.

2) The Solution By-Pass Valve. This valve is opened for a timed interval during the initial minutes of any start, by-passing solution around the absorber coil directly back to the solution sump. This allows time for the evaporator to be fully wetted with liquid refrigerant before the absorber becomes active.

3) The Hot Water Control Valve. This valve, in addition to acting as an on-off device, modulates the flow of hot water (input energy) to the generator according to the entering and leaving chilled water temperatures. If either or both temperatures drop below preselected points, the valve reduces hot water flow through the generator by diverting some hot water into its by-pass. Thus, input energy is adjusted to match the refrigeration load.

SYSTEM APPLICATIONS

Five different methods of applying these machines have been proposed in various private and federally funded projects. The basic types of systems are briefly outlined as:

1) Conventional Central Station: The conditioned structure has its own heat source and central HVAC plant which provides all conditioning and DHW (domestic and service hot water). This is the most common application.

2) District Heating & Cooling - 4 Pipe: A central heat source plant simultaneously providing hot and chilled water in separate circuits to numerous, physically independent structures. Each structure retains independent control over its requirements.

3) District Heating & Cooling - 2 Pipe: As in number 2), but hot water only is circulated during the heating season and chilled water only is circulated during the cooling season. DHW is available from the central plant only during the heating season. This system also places restraints on the individual structure's ability to determine heating or cooling requirements during intermediate seasons (Spring and Fall) when frequent changeover may be required.

4) District Hot Source - 2 Pipe: The central heat source provides only heat to the individual structures during all seasons. Each structure has its own central HVAC and DHW system. Each structure independently determines its own requirements. Provides the economy of a 2-pipe system over a 4-pipe system while providing operating mode selection for the individual user. The latter might increase the probability of successful marketing of this concept.

5) Cogeneration: Efficient electrical generation requires relatively high temperature sources. To increase overall system efficiency the heat rejected from the generation cycle may be used directly to activate the absorption cycle, assuming the heat engine's condensing temperature is within range of the absorber's generator temperature. Such a system has been in use at Sandia Labs employing a derated Arkla 100-ton machine (no longer produced). Additionally, NASA is using the cooling water from a diesel generator set to operate a WFB-300 which provides cooling for a tracking station. Such systems, already demonstrated are directly applicable to geothermal applications which have sufficiently high temperatures.

The significance of these applications is their potential, however limited, of providing energy-intensive work utilizing a virtually untapped ecologically favorable resource. In some areas, it may be possible that the economics are favorable with currently available technology and hardware. The following table was prepared as a "glance" in that direction, but a more detailed analysis with hard number should be examined for a proper determination.

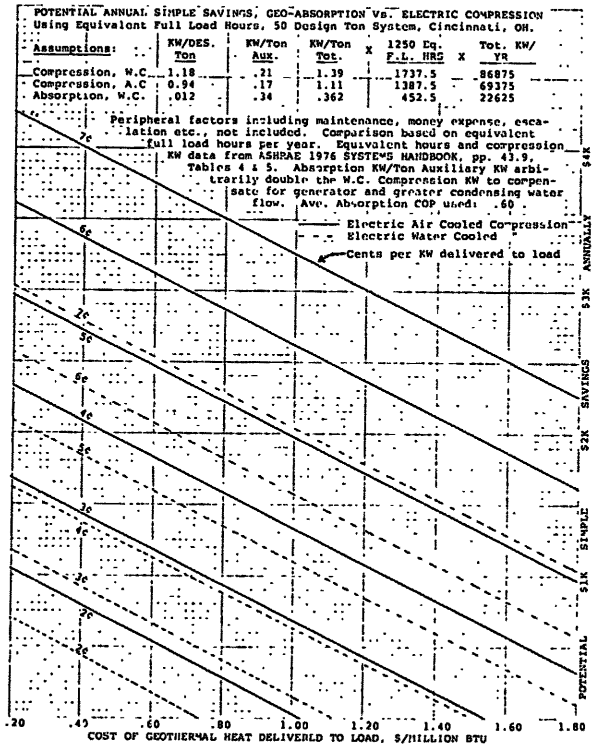


FIGURE 4

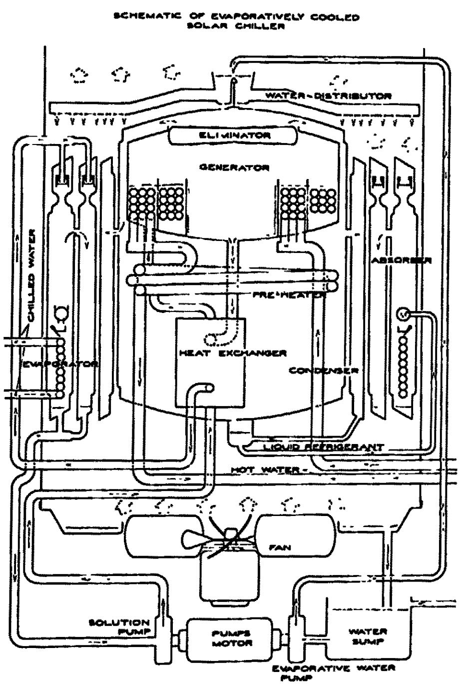


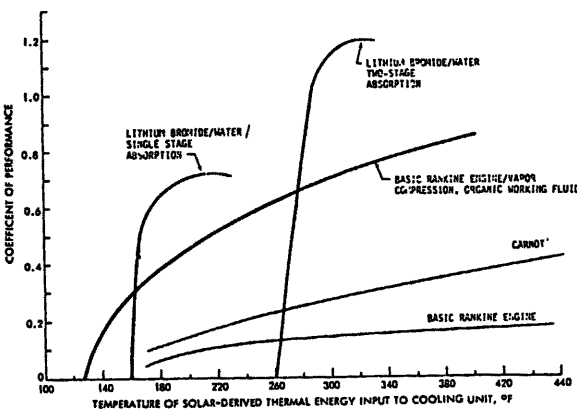
FIGURE 5: DIAGRAM OF 3RD GENERATION MACHINE.

CURRENT DEVELOPMENT

Although equipment currently in development may be years from the marketplace, it is interesting to see what's "down the road". Arkla is currently in development of the "3rd" generation of residential cooling equipment for a direct low temperature application. It is a novel departure from traditional concepts in that it has been "turned inside out", using the external shell surfaces for heat rejection. Distributing the cooling (condensing) water directly over the machine eliminates the cost of a separate cooling tower, reduces pumping energy and decreases scaling by reducing heat flux. Prototypes have achieved design goals. The previous schematic of this evaporatively cooled chiller shows its basic configuration. Please note that it is a "cut-away" of concentric shells. The heat exchange tubing is circularly wound.

Beyond the 3rd generation machine it is difficult to predict events. If sufficiently high temperatures are made available, it may be practical to develop double-effect absorption machines for the lower tonnage market. They are currently available above 500 tons. The double effect machine requires 300°F internal operating temperatures, but offers higher efficiencies than single effect machines. Arkla currently has double effect experience in-house. A 15-ton machine designed by an engineer on the Arkla development staff achieved its design COP of 1.20. This is contrasted to the single effect machines which typically attain COP's in the range of .66 to .72. (Note that the WF-36 achieves .80 in off-design conditions of 185°F source, 80°F condensing, 45°F CHW).

For general information, the following table has been abstracted from DOE information and is intended to demonstrate design objectives of the various R & D programs. The absorption curves, however, represent developed technology and have been overlaid on the DOE data.



Coefficient of Performance Comparison for Water-Cooled Rankine Engine/Vapor Compression Cooling Units and Absorption Cooling Units

FIGURE 6

CONCLUSION

Current efforts in new energy technology represent an investment in the future. It would appear that Geoheat represents a relatively untapped resource which is available for near-term utilization in some areas. If so, increased development effort in this area represents a sound investment.

This dictates the requirement for geothermal demonstration programs for problem solving, technology development and feasibility determination. Where cooling is required, absorption technology should be applied and evaluated. Finally, the economics should be evaluated from the initial cost and savings potential to determine ROI.

As is occuring with solar, the increased level of activity has a significant impact on legislative action and may provide a degree of "self-help" in this area.

Arkla is well-situated to provide technical assistance in applying absorption cooling to this area and welcomes inquiries from individuals preparing demonstration projects.

REFERENCES

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Development of Unitary Solar Heating/Cooling Packages, Merrick, Richard H., Arkla Industries, Evansville, Indiana (DOE Contract No. EG-77-C-02-4593). Reported in: Proceedings For The Third Work Shop On The Use Of Solar Energy For The Cooling Of Buildings, 1978, University of Colorado Conf 780249.

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