OFFSHORE WATERSOURCE HEAT PUMP APPLICATIONS

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ABSTRACT

The heat pump is an efficient air conditioning device that is a popular unit for space conditioning of commercial and industrial buildings. A more efficient version of this device is the Ground Source Heat Pump (GSHP) which uses the ground as its heat source or sink, instead of the atmosphere. A wide range of unit capacities and configurations are available to suit any design situation. These GHSP's are dependable, easy to maintain, long lasting and priced competitively. A body of water can be used as a heat source or sink instead of the ground. Such applications are even more efficient because loop piping immersed in water provides a better heat transfer coupling than piping buried in the ground. This paper discusses applications of the Water Source Heat Pump (WSHP) technology for offshore drilling or production operations to result in a substantial savings in space conditioning and domestic hot water production. An even more cost competitive application of the WSHP is the once thorough design which circulates cool water from deep in the ocean straight through the unit, then discharges it to the ocean surface. A modification of this open loop technique circulates the fluid within an abandoned well bore casing. The advantage of this system is that natural convection of warm water from deep in the well upward, as the unit returns cool water at or near the surface, will greatly enhance the thermal advantage of the system. This will enable direct use in the heating season and perhaps be sufficient to operate an absorption chiller in the cooling season. The initial cost of either of these systems is equivalent to a packaged ac system, making the WSHP an ideal energy conservation measure.

THE OPERATING PRINCIPLES

The ground source heat pump (GSHP) is designed to reject heat to the ground instead of the air in the cooling mode. This is a more efficient method for two reasons: (1) the ground is typically cooler than the air in the summer, and (2) the fluid to fluid heat exchange process in the GSHP is more efficient than the fluid to air that is the basis for cooling towers and condensing units.

The GSHP also has advantages over other systems when operating in the heating season. First, the ground is typically warmer than the air in the winter. Second, the fluid to fluid heat exchange process, in which the refrigerant accepts heat from the water in the ground loop, is more efficient than absorbing heat form the ambient air.

THE EQUIPMENT

A diverse selection of GSHP air handling units is available from a number of reputable manufacturers. The equipment comes in a wide range of tonnages, fan sizes and supply and return air duct configurations. The air handling units (AHUs) are available in vertical, horizontal, rooftop and console arrangements. The fans and compressors used are the same devices used on the conventional packaged systems. As a result these aspects of the units have been tried and proven from many years of refinement by the industry. The only new aspect of the GSHP units is the refrigerant to water heat exchanger. This device is a simple and dependable one, proven effective in many rigorous applications.

Several manufacturers provide GSHP units with optional energy saving features such as two speed fan motors and two speed compressors. All come with factory controls to regulate the water flow, protect against overloading and wintertime freezing of the circulating fluid. The pump is controlled by the AHU, typically receiving its electrical power from a control panel integral to the air handler.

The pumps used by the GSHPs are compact, dependable units provided by manufacturers who have been building industrial circulators for decades. The pumps can be wall, floor or rack mounted and are available in a variety of sizes to suit a wide range of flow rates and static pressures.

The pump itself is mounted adjacent to the AHU and is connected via flex hose to the unit coil on one side and the ground loop piping on the other. (See Figure 1) Some manufacturers offer a pump kit that includes the pump, flex hose and valves needed for a complete installation.

The ground loop piping is made of a sturdy polyethylene plastic that is heat fusion welded and pressure tested before installation. It is fire retardant and satisfies the National Fire Protection Association requirements for indoor installation. The best designs will call for the loop to be grouted in the drill well using a bentonite slurry. This maximizes the pipe to ground thermal bridging. Other designs specify the use of cuttings from the drilling operation to backfill the hole. The latter is a less dependable method that can limit the capacity of the AHU by reducing the effective heat transfer area of the ground loop piping.

The drilling of wells for the ground loop is refined to suit a variety of soil and geologic conditions. The two major means are air drilling and mud drilling, the latter done when the cutting size is too large to be circulated out of the drill well using air or when their is ground water. Most systems use straight wells (see Figure 2), although the technology and expertise exist to drill directional and horizontal wells for the ground loop. This is helpful when the available land area is limited, such as in densely populated areas.

SYSTEM DESIGN

Design guidelines have been developed by the industry to provide direction in determining minimum well depth, well spacing and number of wells needed per ton of cooling capacity. These manuals help the designer determine the static pressure of the ductwork - needed to properly size the blower fan - and to analyze the necessary heating and cooling needs of the facility. This aspect of the design process, however, is the same as the design approach used for any other HVAC system.

The most common applications to date are residential systems. Incentives and rebates from utility companies have given impetus to this trend, as utilities strive to limit the need for additional power generating capacity by encouraging customers to install the most efficient systems available.

Increasingly, the efficiency of the GSHP system is attracting commercial customers. School districts have so far been the main industrial users. They have a large land area available and escalating costs have driven them to install the most efficient systems when retrofitting or in new construction projects.

The major drawback to the ground source systems is the high initial cost. However, the higher system efficiency usually provides a payback (that is, cost per savings) of five years or less. The advantage of a water source system is that the expense of drilling the wells and installing all the ground loop piping is avoided. As a result the cost is equal to, or less than, conventional installations.

WATER SOURCE SYSTEMS

In the most common water source system the ground loop is installed in a body of water such as a lake or river. Other installations will not have this closed loop arrangement, but will pump the water directly from the source through the unit heat exchanger. One manufacturer is studying such a once through system that a homeowner can tie directly to the city water mains. Either of these methods avoids the piping and drilling and trenching installation costs that make the ground source system so costly. Applications that employ the once through technique are even more economical since they completely eliminate the expense of thousands of feet of piping and the energy expended in pumping the working fluid against a high static pressure through this piping. This arrangement will, in fact, be less costly than a conventional system because it does not require a condensing unit.

A typical heat pump application on a drill ship or a drilling platform will circulate water through the heat exchanger during the cooling season, or through a secondary loop if the water source is the ocean. During the heating season the most promising and available heat source is the mud pits. The loop heat exchanger could be located there, sized to suit the heating needs of the installation.

A more sophisticated application takes advantage of an abandoned, cased well on a drilling or production platform offshore. The wellbore is isolated from the ocean waters and from the drilled strata, and this fluid is circulated through the GSHP unit. This is effectively a closed secondary loop since it is isolated from any possible sources of contamination. This permits quality control over the circulating fluid and prevents corruption of the heat exchanger surface. It also provides advantages of an open loop arrangement.

THE WELLBORE LOOP

The target heat sink in the cooling season is the ocean. At this time it is advantageous to isolate that portion of the well located in the ground since it will be warmer. This can be accomplished by locating a baffle (see Figure 3) at the ocean grade to minimize fluid flow and thermal convection from the lower portion of the well. This baffle can be lowered at the end of the pipe, or inserted mechanically by a modified blow-out preventer at the ocean floor.

In this cooling arrangement, the pump suction line is situated near the ocean floor (within the well casing), drawing the coldest water up to the air handling unit through insulated piping. The water is discharged from the unit at the surface of the column.

The setup for the heating season (see Figure 4) will isolate the piping loop and the circulating fluid through that portion of the cased well below the ocean floor. This is accomplished by draining the well fluid down to the ocean floor level and pressurizing the column to keep the well fluid down to below the ocean floor level. The loop piping, held in the middle of the casing with centralizers, will be insulated from the cold ocean by the air column.

In this modified arrangement the suction end of the pump loop piping will be at the top of the column (e.g. just below the ocean floor), the discharge much deeper. The reason for this is to take advantage of thermal currents that will cause warmer fluid to migrate upward. The general flow of this fluid up through the cased well may also enhance another affect: the well presumably extends far deeper than the extent of the actual loop piping, penetrating formations that are quite hot. These strata will warm the fluid within the casing and it will move upward naturally to the actively circulating portion of the fluid column, thus enhancing the heating capacity of the system.

HIGH CAPACITY SYSTEMS

Several modifications of this basic design will be needed to increase the capacity for larger loads. The piping arrangement will remain at the surface. Several units can be operated from the same loop (see Figure 5), but the heat transfer capacity of the cased part of the well bore must be enhanced.

In the cooling mode fins on the outside of the casing will increase the capacity to reject heat. Centralizers or other internal projections inside the casing - especially if lower in the casing, which abuts colder ocean waters - will cause turbulent flow, thus increasing the heat transfer rate while, because of the metal to casing contact, providing additional thermal bridging to the casing itself.

In the heating mode the discharge can be located below the intake. This will target hotter strata and, in the smaller sized casing, there will be turbulent flow around the annulus that will cause a higher rate of heat transfer.

PRACTICAL CONSIDERATIONS

There are several environmental conditions to consider in evaluating this WSHP system application. First, the ground will not remain at a constant temperature during the cooling season around the vertical bore hole. The average ground temperature, as measured by field testing of many installations at the Austin (Texas) Independent School District - which has over 6,000 tons of installed ground loops - increases from the ambient 70°F to 100°F or more during the course of the cooling season.

The consequences of this increase in ground temperature are (1) a reduction in the efficiency of the system; (2) a loss of capacity of the system, as exemplified by catalog specs on a Trane unit:

Entering Water Temp	Sensible MBH
45	49.21
70	48.14
85	46.49
105	42.13
120	38.79

and (3) a higher use of electricity because the unit compressor(s) will operate longer to accomplish the same amount of cooling. A WSHP operating off a heat sink at a constant temperature will not experience this loss in efficiency, which can be as much as 22%.

This same affect has been seen to occur during the course of a single day as well. The ground heats up slowly, until the unit is turned off and the ground is able to dissipate the stored thermal energy over night. Thus the system has a loss in capacity late in the summer afternoons, at the very time that total capacity is needed.

There is a third affect, in addition to the daily and seasonal ground temperature increases. The ground also will increase in average temperature by 10°F or more if the heat rejected to the ground during the cooling season is disproportionately larger than the heat extracted from the ground in the winter. Several software programs approved by the International Ground Source Heat Pump Association show this affect clearly, as has practical experience. These three affects can combine to seriously reduce the system capacity.

The system operation in the winter follows similar principles, whereby the low thermal momentum of the earth causes the ground temperature to drop. The variation in capacity of a common system for heating is:

Entering Water Temp.	Sensible MBH
45	50.59
70	66.00
85	73.23

which is a 30% reduction in heating capacity for a forty degree difference in entering water temperature to the WSHP unit.

The use of an open loop system in a large-bore cased well takes advantage of two things. First there is the natural increase in temperature with depth, that follows the function for the Gulf Coast region.

$$T = D(.008) + 80F$$

For a 5,000 foot well the temperature at the bottom is 120°F. If the water temperature that is returned to the unit is increased by only half this amount (e.g. [80 + 120]/2) then the unit will have 100°F water, instead of 45°F water - with a 40% boost in capacity and efficiency.

The second principle that benefits the open wellbore concept is that the water has more flexibility than solid earth. Whereas the ground can dissipate the energy only by virtue of conduction, the water allows convection to happen as well because of the gravity flow of a higher heat exchange rate because the water-to-earth temperature difference at any given point is greater.

CONCLUSION

The ground source heat pump technology is tested and proven. It is a simple, effective and efficient system that has the confidence of utilities and the public. This paper has discussed an application of this technology to reduce space conditioning expenses on an offshore drilling or production platform.

The proposed system uses dependable equipment that can be easily installed and integrated into existing HVAC systems. It will save on utility bills and has the potential of optimizing the drilling or production operation by utilizing waste heat. This has the benefit of possibly reducing the required size of the mud pits and of reducing the energy spent in rejecting process heat by artificial mechanical means.

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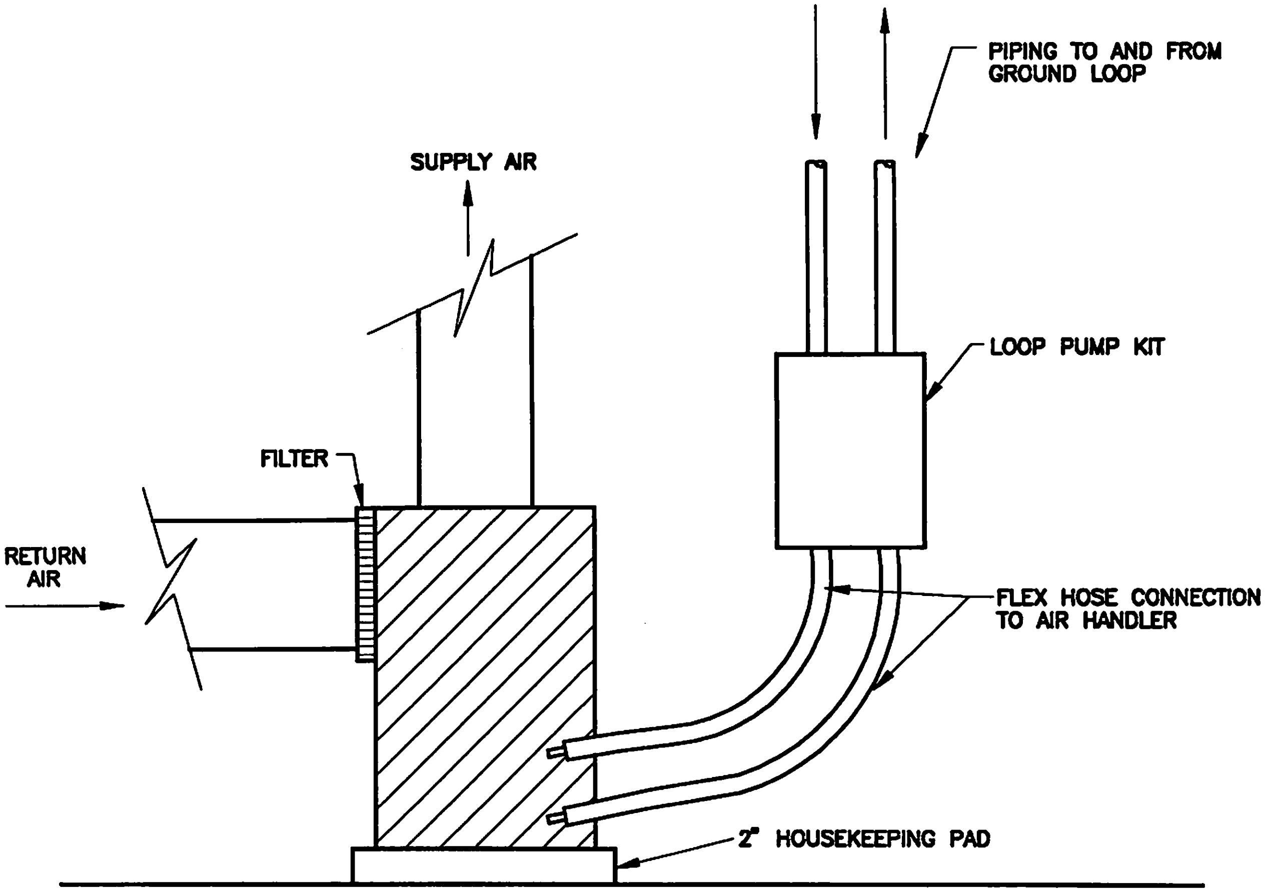
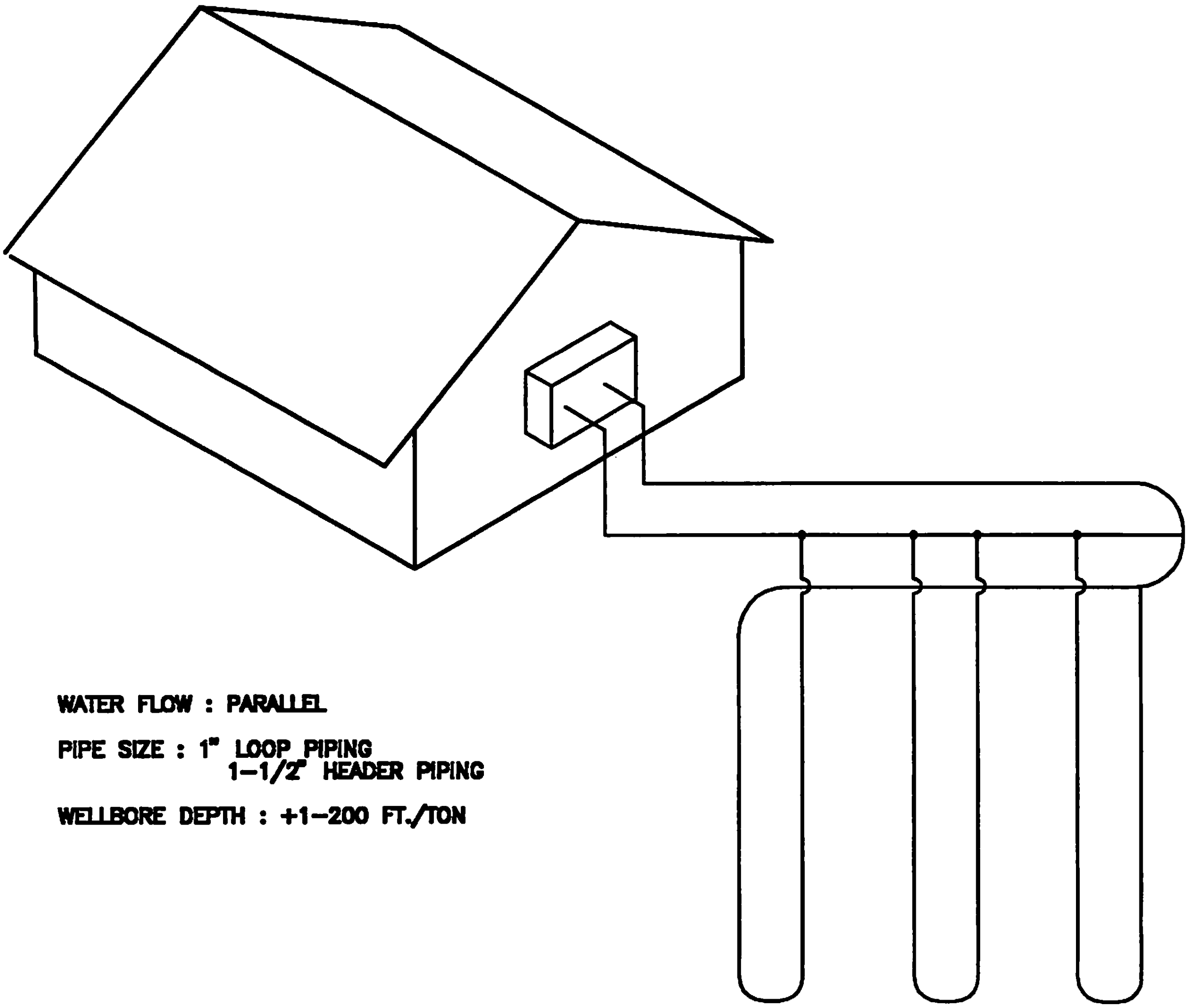


① WATER SOURCE HEAT PUMP INSTALLATION

SCALE: NONE



WATER FLOW : PARALLEL

PIPE SIZE : 1" LOOP PIPING
1-1/2" HEADER PIPING

WELLBORE DEPTH : +1-200 FT./TON

2 GROUND LOOP PIPING

SCALE: NONE