GROUND SOURCE HEAT PUMPS FOR SCHOOLS

BY
WILLIAM H. CLARK II, P.E.

The Austin Independent School District has installed over six thousand tons of ground source heat pump systems in the last ten years. The utility bills have dropped an estimated 15% at every installation. (Refer to the attached bar charts). The systems are still operating with few problems. In fact, the first compressor problems have happened only recently.

The following report describes the different applications used for the schools. The installations use the full range of equipment available on the market. Installation tips, control principles and operational limitations of each type system are described in detail. General design guidelines are provided in the report . These recommendations are based upon extensive experience the school district has had with ground source heat pumps.

INTRODUCTION

The Austin School District made a thorough study of the HVAC systems district-wide in the early 1980's. The alternatives considered were:

1. Central Chiller / Boiler Systems
2. Packaged Direct Expansion Systems
3. Ground Source Heat Pumps (GSHP)

Of these systems, the packaged systems was the least expensive and the ground source systems had the highest installation cost. The efficiency of the GSHP systems was in contrast to their cost, as the ground source heat pump installations were projected to be the most effective. Ground Source Heat Pump Systems were projected to pay off in approximately seven years because the lower operating and maintenance costs offset the high initial cost.

The cost benefits of a ground source heat pump have been realized as projected, also the low maintenance cost has enhanced this fiscal advantage. Of the perhaps two thousand compressors in use throughout the District, only two have failed to date. Some have been in operation for ten years or more. This is a great benefit to a large school district with campuses spread throughout a sprawling urban area, and it is an important factor in the District's contained use of ground source systems in their HVAC retrofits.

GENERAL DESIGN CRITERIA

The first ground source heat pump was installed by the Austin Independent School District in 1984. Since that time over 6000 tons of ground source capacity has been installed at over one hundred schools in the Austin Metropolitan area, half in new schools, half as retrofits. Some general design parameters have been devised relative to the prevailing climate, geology and building use:

1. One well per ton of installed capacity.
2. 260' well depth
3. Average 3 GPM fluid flow through well.
4. Twelve foot spacing of wells.
5. 1" diameter well piping (vertical portion)
6. 1" header piping if unit is less than 80' from unit, 1 1/2" otherwise (for a typical 3 ton unit.
7. Reverse-return piping of wells in header loop.

These criteria are time tested, except recently the advent of longer operating hours on some campuses has impelled modifications to these criteria. Some of the things that have been done to allow for an increase of operating hours of the systems are:

1. Deeper well completions, up to 300'.
2. Wider spacing, 15' or greater.
3. More wells per ton (e.g. four wells for a 3 ton unit)
4. Grouting (bentonite based) pumped to the bottom and up.

A number of safety features and controls are also standard to the Austin Independent School District systems.

1. Random start relay.
2. Winter morning warm-up cycle.
3. Cold weather override.
4. Over-ride timer.

These are typically factory designed and installed.

CLASSROOM UNITS

The most common installation for the Austin Independent School District is a stand alone 3 ton console unit. As illustrated in Figure 1, three wells are piped to the unit from a location near the classroom. The loop piping and condensate drain line are routed out the bottom of the unit, then into a trench drain/trench out to the well location(s). The condensate drain line is terminated in a 10 ft. perforated section of PVC pipe, sitting in a pea grave bed and wrapped with a fine plastic mesh screen to keep the perforations clear.

The headers and piping are not insulated at any point, since the fluid temperature is between 60°F and 105°F. Also, freeze protection is provided by a systems freeze stat that turns all the equipment on when the temperature drops below setpoint.

A potential design problem of most console units is that only one size pump is available. As a result, if the wells are more than 80' from the unit, the header must be oversized to minimize the pump head pressure. Also, in multi-story buildings, the wells for the upper floors should be located nearest the building, to minimize piping runs and pump pressure head,

Two types of arrangements are used to introduce 15-20 cfm of outside air per student to each classroom. A ducted supply from the back of the console can be used to bring fresh air to the console unit if it is located on an exterior wall. This requires creating the opening and installing a brick vent with a short piece of duct to the unit. Another alternative is to temper outside air and to introduce it to each space by a separate duct system. The outside air unit brings the air temperature down to a near typical return air temperature, and the classroom unit conditions it thereafter.

MULTI-ZONE UNIT REPLACEMENT

Recent projects by the Austin Independent School District have retrofit multi-zone air handlers with several vertical ground source heat pumps, one per zone. The original supply branches are used, re-routing each branch to an individual vertical unit. The return air ductwork is also re-used. If a common return is used, a backdraft damper must be installed at the return plenum of each unit. This will prevent air from being drawn backwards through the unit when it is off while others are running. This can cause the fan blade to rotate backwards, and if the unit starts up in this condition the fan will continue to rotate backwards.

The stock fans of most vertical units have a relatively low static pressure capacity Consequently, if there is a long supply and return duct runs, then an over-sized motor and fan is necessary. The static pressure at any given unit should be calculated assuming every unit is running at the same time so they can supply sufficient air to the conditioned space at all times.

Outside air is introduced to this system in much the same way as in the original multi-zone arrangement, i.e., if the return air system is used relatively unchanged. The only limitation to the ground source heat pump arrangement is that outside air is introduced to the return air steam far enough upstream of the first unit in line so that thorough mixing can occur.

The most challenging aspect of a multi-zone retrofit to GSHP's is arranging all the units, equipment, and pumps for easy access and maintenance. The filters must be easily replaced, pumps serviced, and there must be good access to the heat pump to service the compressor and fan. Typically there is enough room to accomplish these in the footprint area of the multi-zone unit being replaced, using all floor-mounted vertical units. If space is short, then one or two horizontal units can be used to allow extra floor space for the veritcal units.

LARGE ASSEMBLY AREAS

A particular challenge of GSHP systems is the conditioning of gymnasiums and cafeterias, where the load is high but short-lived. Two or more units were used, in lieu of one large one, for redundancy. Since both were typically served by independent ground loops, the units can be staged to alternate the lead air handler. This keeps one unit from constantly running at near peak capacity, and exhausting the capacity of the ground loop.

The thermal mass/momentum of the ground is a crucial issue in GSHP design. As an example, one pair of school cafeteria units was isolated from the time clock circuit by a malfunctioning relay. It ran continuously day and night for several weeks. The diagnosis was that the units would have to remain completely off for sixty days in order for the ground temperature to fall to an acceptance temperature to recover.

The controls for a multi-unit system serving a single zone use one multi-stage thermostat. The unit fans are interlocked so they run whenever there is a call for heating/cooling. This maintains good air circulation. The first stage of cooling brings one unit on line, with both fans on; then the second stage activates the second unit.

Other precautions for large areas, which often have an extended occupancy schedule because of community and other meetings on the premises after hours, include deeper wells, greater well spacing, and installing the system with an extra well, e.g. more than one per ton of cooling capacity.

LIMITATIONS

The systems as described in this paper apply to fairly rigid conditions: 9-5 daily operation, Monday through Friday use, with relatively constant use during these times. In Summer the schools are closed and equipment does not operate. Even within these conditions, however, there have been problem areas that necessitate extra installed ground loop capacity, e.g. computer labs, administration areas and hallways (which should be conditioned by a dedicated unit.) Since the predominant load is cooling, there is plenty of capacity for heating from the ground loop.

The most economical remedy, historically, has been to install a cooling tower to handle the peak load for the building. However, since the ground loop systems were not typically installed in a common loop, but were individually piped to the units, this is often not possible. Other options are to install a central system to duct outside air to each space, relieving that load from the classroom units, or adding wells to the loops. A final option is to install a common header among all the individual ground loops, with a properly sized cooling tower to boost the total system cooling capacity.

CONCLUSION

The water source heat pump assemblies on the market offer a diverse selection of equipment for many applications. The systems that have been installed to date realize an estimated savings of 15-25% over conventional systems. Unfortunately, few records have been kept to pinpoint the utility savings, so this is not a firm number. This is a major impediment to justifying additional ground source systems.

Careful record keeping is not difficult, even for systems that are not completely retrofit to ground source equipment. As long as the tonnage of the total ground source heat pump systems is known, then a load simulation program can determine, with good accuracy, that portion of the utility bill attributable to the conventional system.

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Brentwood Elementary

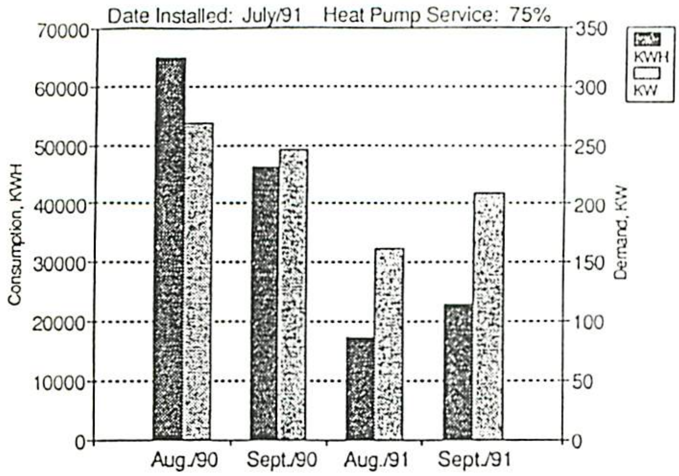


Figure 3. Peak month electricity use and demand comparison.

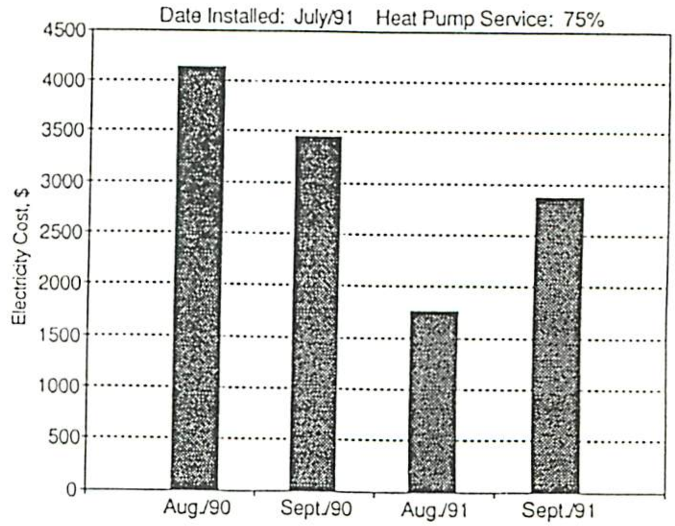


Figure 4. Peak month energy cost comparison.

F. R. Rice Elementary

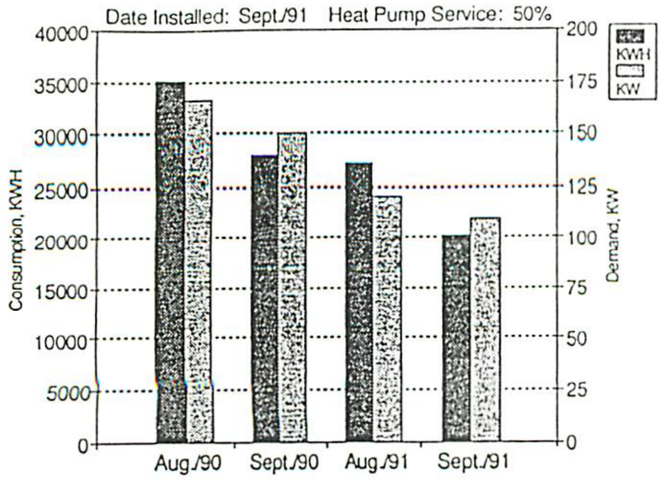


Figure 5. Peak month electricity use and demand comparison.

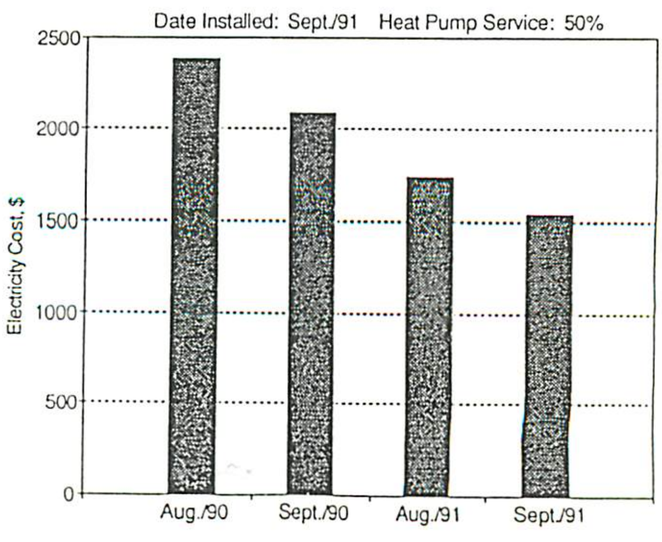


Figure 6. Peak month energy cost comparison.

Walnut Creek Elementary

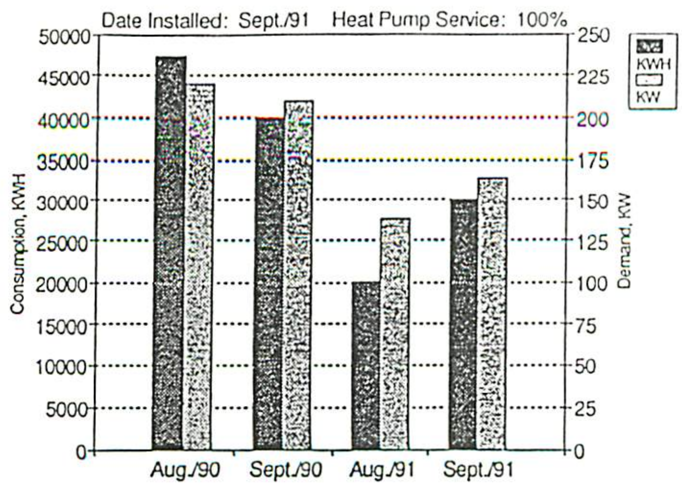


Figure 11. Peak month electricity use and demand comparison.

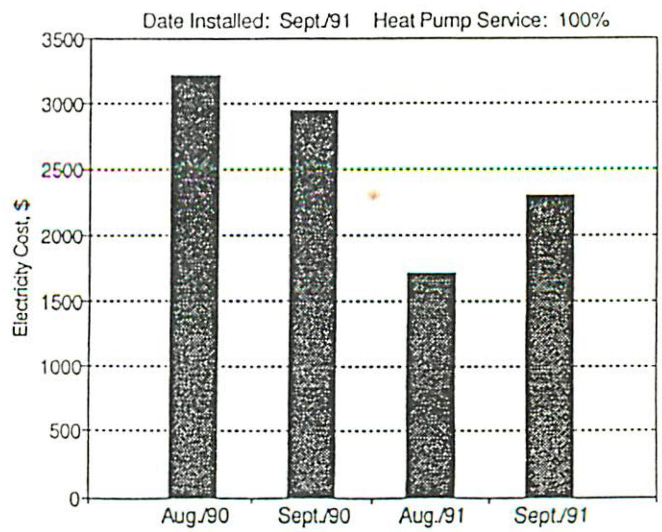


Figure 12. Peak month energy cost comparison.

Joslin Elementary

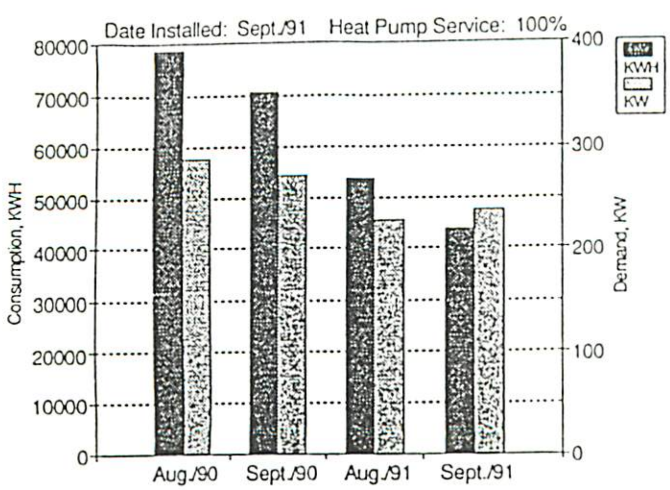


Figure 1. Peak month electricity use and demand comparison.

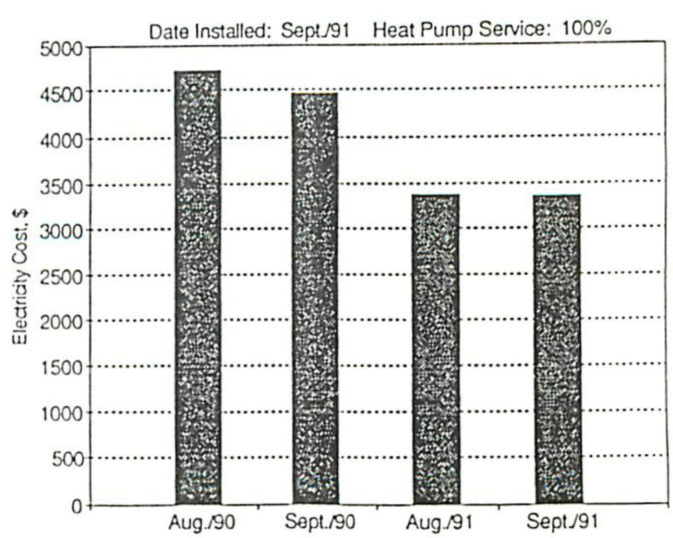
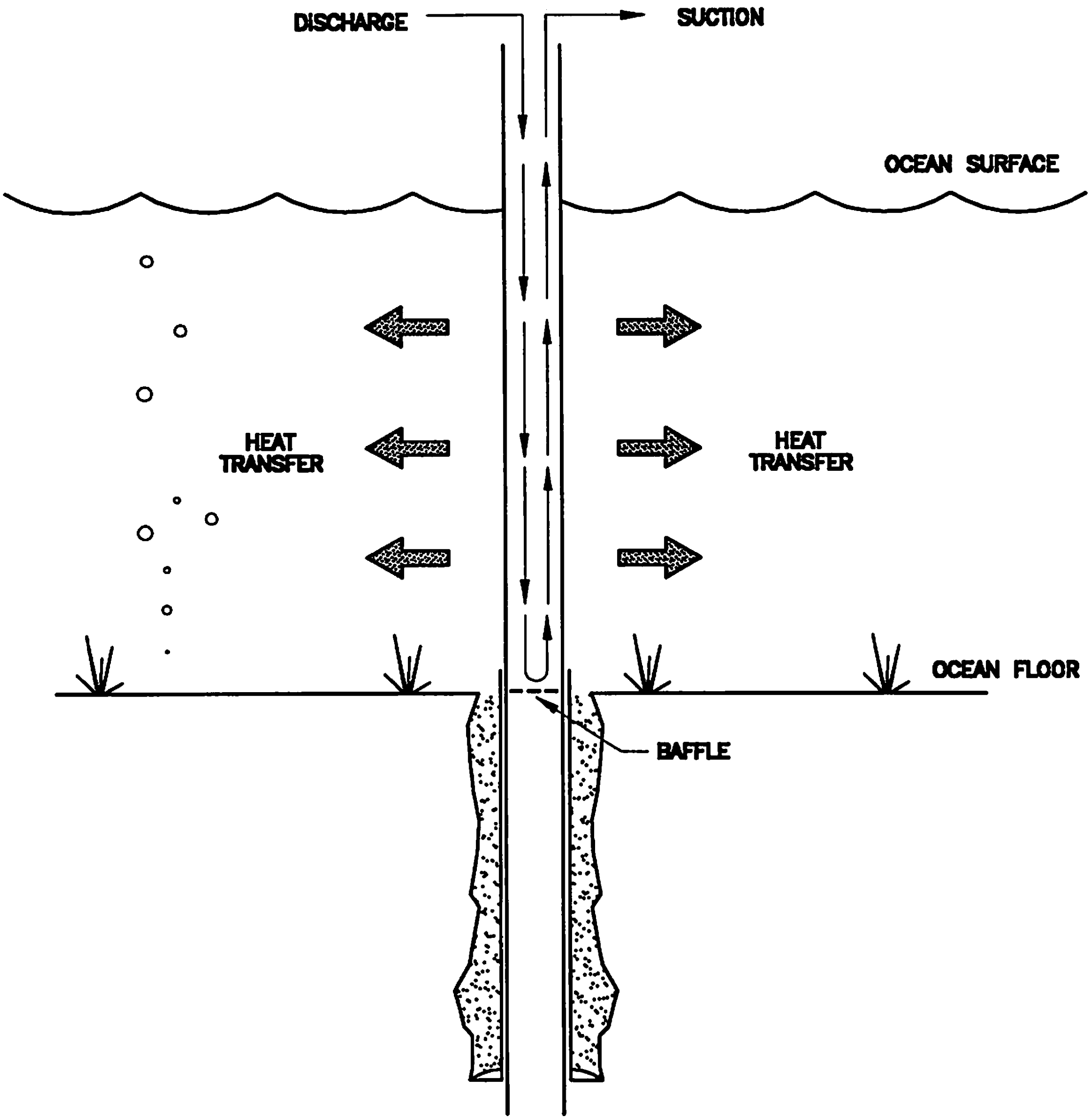
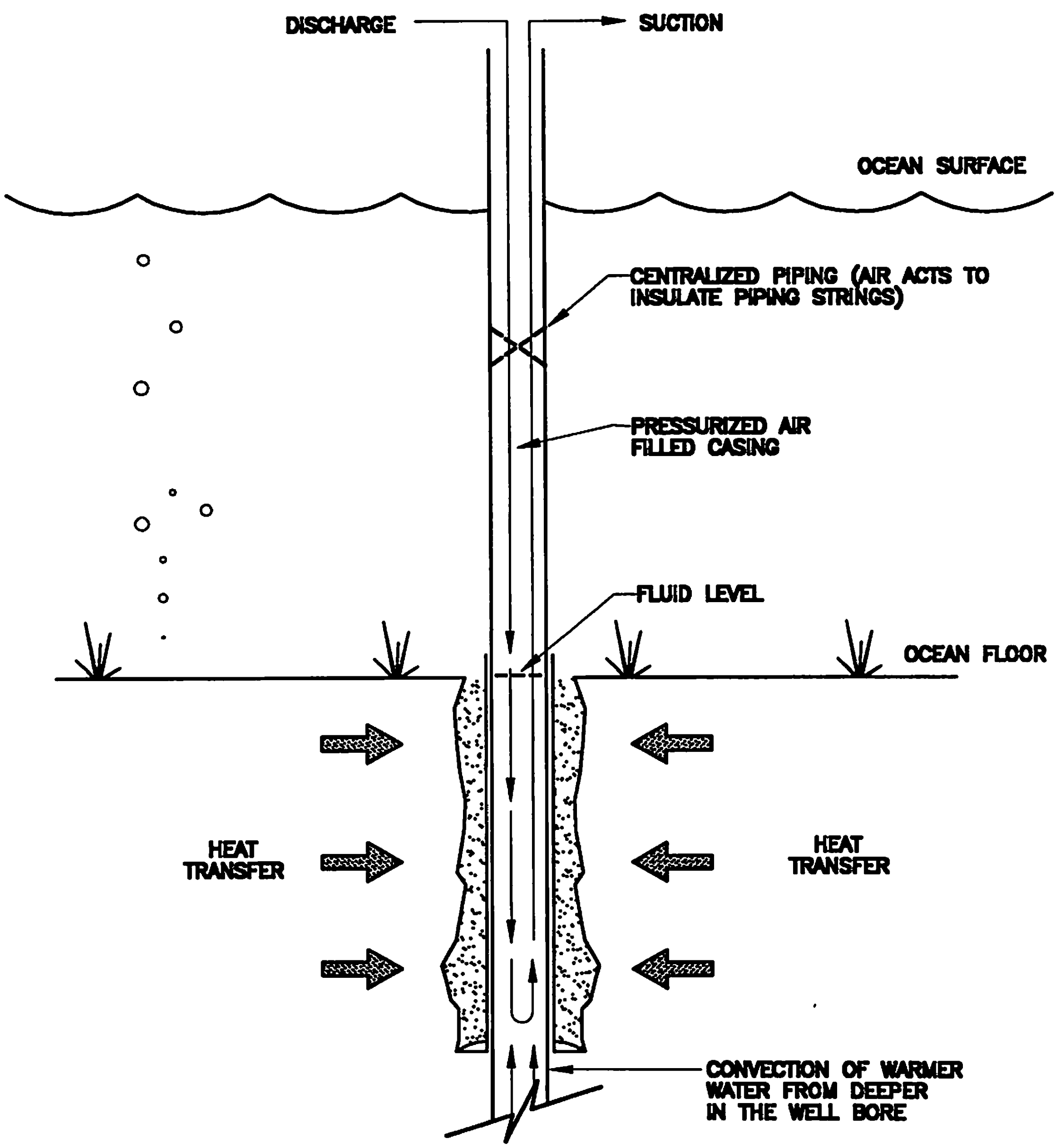


Figure 2. Peak month energy cost comparison.



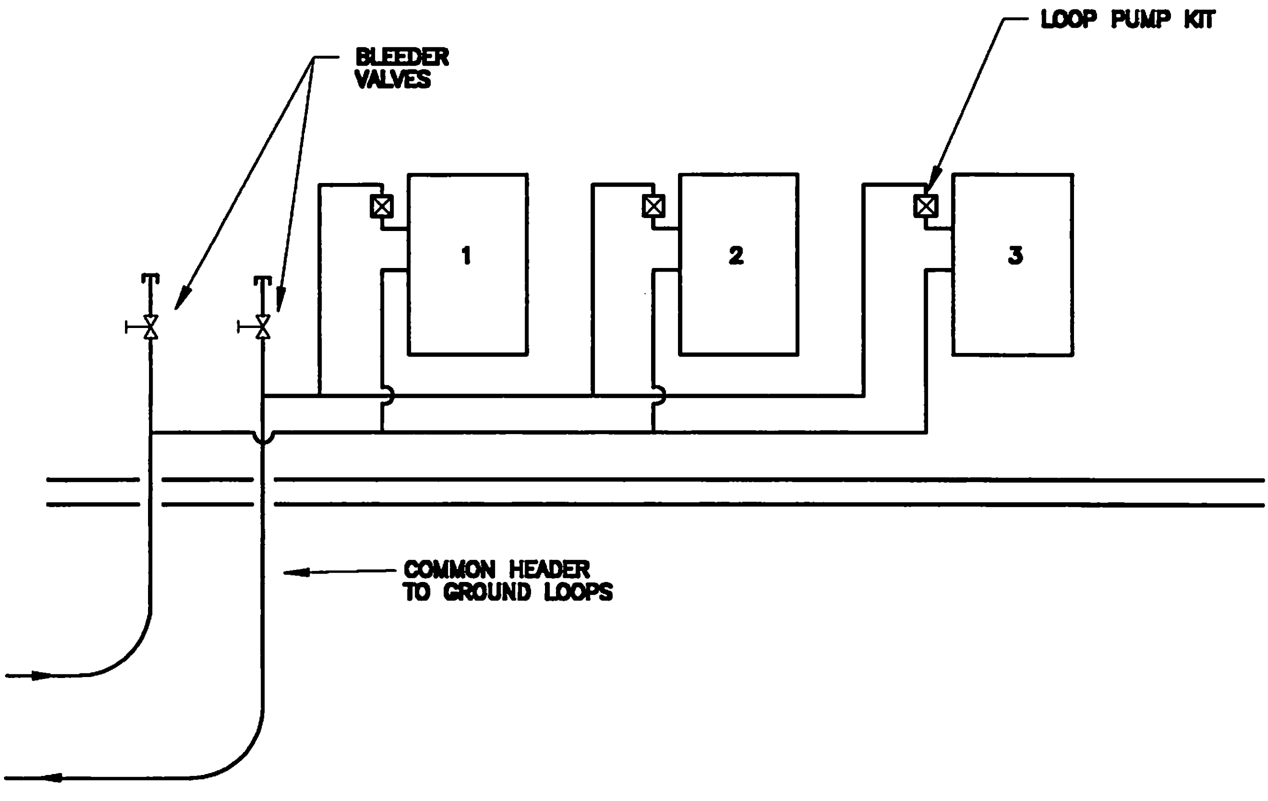
3 OPEN LOOP COOLING MODE

SCALE: NONE



4 OPEN LOOP HEATING MODE

SCALE: NONE



5 MULTIPLE UNIT INSTALLATION

SCALE: NONE