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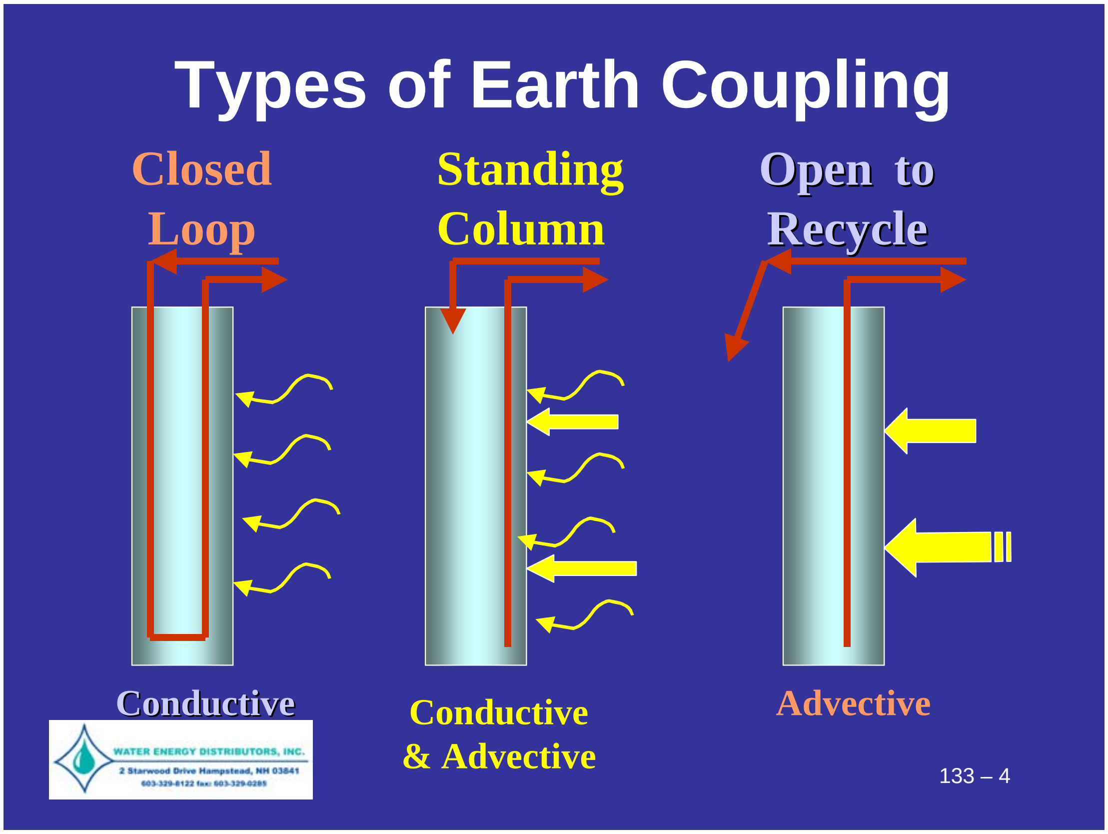
Geothermal Earth Coupling
Technical Bulletin 2007-33

NOTES

Three popular earth coupling methods are most commonly employed throughout the geothermal industry.

All three options take advantage of the virtually limitless renewable energy that the earth provides. Each of these three methods has advantages and disadvantages, they are discussed below. To best understand these options first consider the general approach to taking energy <u>from</u> OR returning energy <u>to</u> the earth. During the winter months we extract stored solar energy that resides in the earth. Approximately 50% of the solar energy that strikes the earth is stored in the waters of the earth. In the summer the relatively cool earth serves as a convenient sink for the excess energy from our homes and buildings.



Closed Loops, either horizontal or vertical (as shown) depend upon an antifreeze solution being returned to the earth to exchange energy. The average New England earth temperature is 50°F – in winter, a cold 30°F return antifreeze solution will make the earth energy flow *towards* the well bore *(CONDUCTIVE FLOW)*, warming the solution. The opposite energy flow occurs in the summer.

Standing Columns, likewise, take advantage of the conductive heat transfer but also augment their energy transfer capability by simply moving small amounts of stable earth temperature (50°F) water, “ADVECTIVE” flow. This stable temperature water is typically located only 40-50 feet away from the bore.

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Open to Re-circulation earth coupling methods simply take advantage of the stable ground water temperatures, within rock fractures or in porous earth and depend solely upon an ADVECTIVE flow into the borehole. High yield wells and a responsible method of returning the water to the earth is required. This method is also known as a “doublet” earth coupling.

As geothermal heat pump application grows each of these generalized methods have developed variants. This technical bulletin reviews the industry validated methods evaluated by third party agencies. These methods are available through the established Heating Ventilating & Air Conditioning (HVAC) infrastructure in the USA and internationally. The International Standards Organization (ISO) has taken responsibility to evaluate geothermal heat pumps in its “standard ISO 13256”. Previously, the Air-Conditioning & Refrigeration Institute (ARI), in the USA, had that responsibility. Today, ISO and ARI are overlapping with ISO taking the lead.

METHODS of GEOTHERMAL EARTH COUPLING

Estimated costs for complete earth coupling systems are typical and fluctuate relatively as material prices and location change. Note these typical costs relate to “tons”– a ” ton” is a nominal 12,000 BTU/Hr The average 1,800–2,500 square foot home is typically in the three (3) to five (5) ton range.

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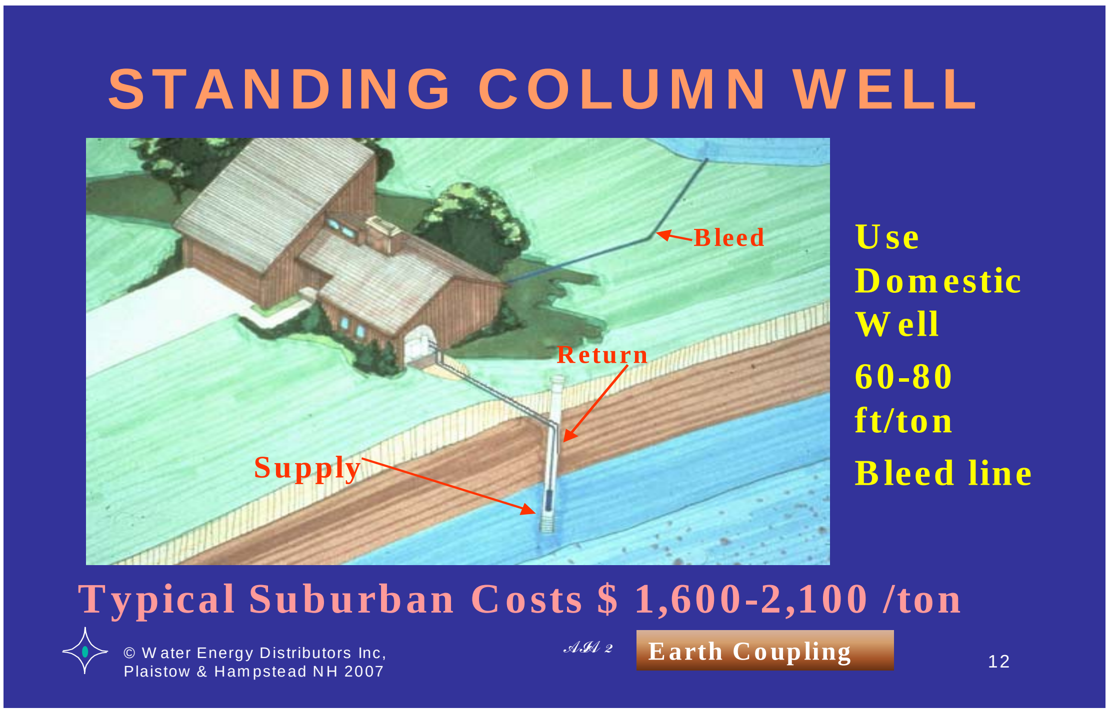
The **open to recycle** system shown above responsibly returns the water to the environment via surface water that is owned by the user. If a responsible surface water return to the earth is not available, a diffusion or reinjection well is drilled to return the water back into the earth. Wells are typically 6 inches in diameter. These wells are often also used for domestic and/or irrigation water and are built to domestic water well standards. Southeastern Massachusetts and Long Island, New York typically employ diffusion wells for responsible return of the well water as the geology in these locations typically allows for this low cost, high efficiency method.



Standing Column Wells (SCW) are the most common in areas with near-surface bedrock and are employed in approximately 80% of the geothermal wells in the Northeast.
Often these geothermal wells are also employed for domestic and/or irrigation purposes. Domestic Standing Column wells are typically 6 inch rock bores with 8 inch casing pocketed into the bedrock to assure segregation of surface water from pure ground water. Well bore depths provide the design heat transfer required to satisfy the buildings dominant heating or cooling load.

A “bleed” system provides the advective insurance that miscalculations in rock thermal characteristics, building insulation values not being achieved, weather extremes beyond Federal standards and the like can be mitigated. Small amounts of advective water drawn from the earth surrounding the borehole stabilize the well bore temperatures by drawing in constant temperature bedrock water from 40-50 feet away. Should additional bore temperature stabilization be required, an automatic “bleed” overflow of typically 5%-10% ensures fresh and temperature constant water is drawn into the water column. Advective bleed periods are typically 30-60 minutes favorably changing the well bore temperature by 4-5 °F.

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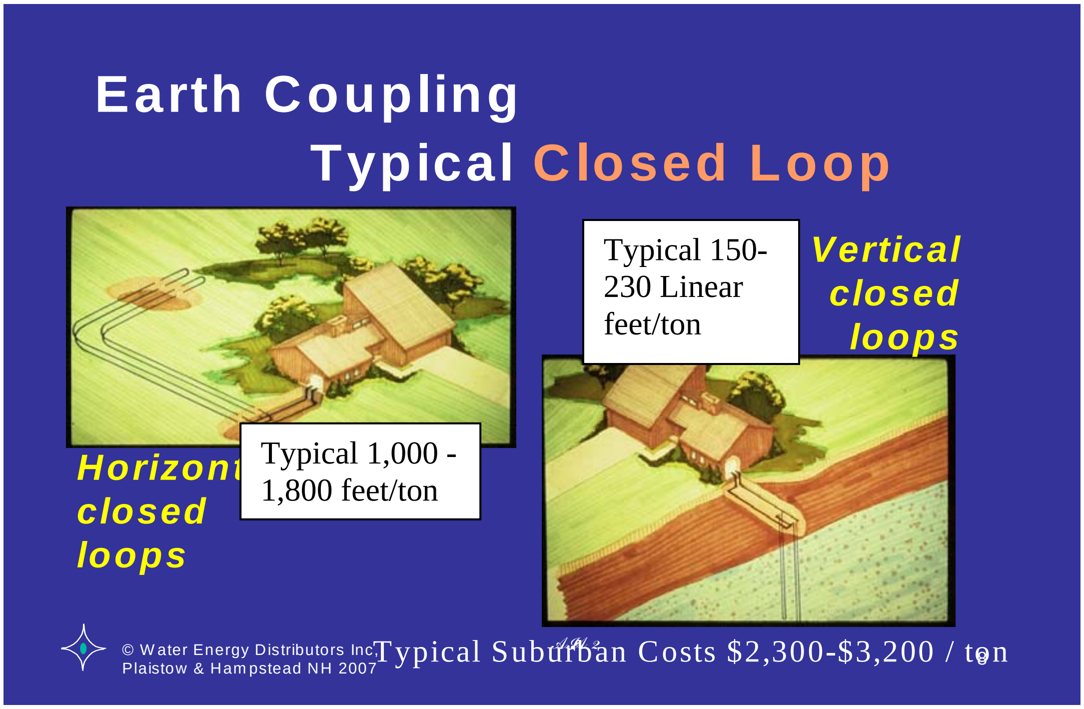
A No-bleed Standing Column Well can be designed. The resultant no-bleed SCW will be 1.5 to 2.0 times deeper to achieve more heat transfer surface area.Commercial Standing Column Wells may utilize larger diameter casings and bores.



Closed Loops utilize high-density polyethylene pipe buried horizontally or vertically. The non-biodegradable buried pipe is filled with an antifreeze solution, allowing lower solution temperatures to reach the heat pump. Temperatures can be well below freezing generating the need for an antifreeze solution rather than pure water to prevent freezing in the heat pump, heat exchangers or piping. As the plastic piping creates another heat transfer barrier, earth water solution temperatures must be lower in the winter and higher in the summer.

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COMPARISON of METHODS

GEOTHERMAL HEAT PUMPS
Earth Coupling Options

EACH METHOD MUST BE EVALUATED FOR THE APPLICATION & LOCATION

	Closed	Standing Column	Open/Recycle
Efficiency	3	2	1
First Cost	3	2	1
Geology	2	2	3
Maintenance	2	2	2
Regulatory	3	2-3	2
Thermal Stability	2	2	1

1 = highest/best

101 – 10

EFFICIENCY

The **Open/Recycling** system takes constant temperature water (typically 50°F in New England) from the earth, reducing the return water temperature typically by 8°F in winter and typically increasing by 10°F in summer. As the source/sink water temperature remains unchanged throughout the year, this provides the highest efficiency of the three methods.

The **Standing Column** winter temperature is designed around a minimum of 45°F entering water temperature (EWT) in winter and 60°F in summer (residential).

Closed loops are designed around 32°F, EWT in winter (with antifreeze solution) and 77°F in summer. We only condone food-grade propylene-glycol as the antifreeze solution of choice.

Third party efficiency evaluations have been performed by the Air-Conditioning and Refrigeration Institute (ARI 325 & 330) and more recently by the International Standards Organization (ISO). ISO 13256 standards are somewhat more conservative than the more dated ARI standards.

FIRST COST

Most often, the **Open/Recycle** method is realized in areas where there is abundant near-surface water. Wells are not deep and pumping is achieved with modest pumping costs. If employed, return wells are generally similar to supply wells with shallow depths but slightly larger, and also at relatively low costs when compared to other well types. Open wells are often in "unconsolidated" aquifers, loose gravel and sand, and require steel or plastic casing to maintain bore hole integrity. Casing is typically required in "overburden" and terminal moraine (where the glacier stopped) – SW Massachusetts, Cape cod, Long Island and Brooklyn are examples of deep moraine.

Standing Column Wells are employed when there is near-surface bedrock and require depths of 50-100 feet of water column per ton (12,000 btu/hr) of heating or cooling requirement. (The typical home maybe in the 3 to 5 ton range). Well depths are deeper, consequent costs are higher. However, the cost of a return or diffusion well is not required as the return water to the earth is returned back to the same borehole. Typically, domestic water needs are met by the same well. This can positively effect "first cost" as the well can provide for both needs.

Closed loops are the most costly as bore depths are typically 150-200 linear feet of bore per ton for a heating dominated geothermal application (vertical application). For a cooling dominated, typical of a very large home or commercial, bore depths are in the 220-280 linear feet of bore per ton. Horizontal loops, including slinky, straight horizontal, and pond applications typically require 1,000ft or more of pipe per ton.

GEOLOGY

An **Open to Earth** recycling system requires large amount of water and a responsible return of the water to the earth where its energy is renewed by solar contribution. (Every 55 days, the waters of the earth absorb as much solar energy as all of the known oil and gas reserves in the world). Wells in the Northeast are not often able to provide the high flow rates required to utilize this beneficial method – and often a return or diffusion well is not practical. Under local or State environmental controls, return has been allowed to surface waters owned by the user. The geology south of Plymouth MA and Long Island NY can lend itself to this advantageous method.

A **Standing Column Well** system depends upon near-surface bedrock, this is defined as bedrock being within 150-200 feet of the surface. The bedrock provides enhanced heat transfer and requirement for costly steel/plastic casing to keep the borehole open in the "overburden" above the stable bedrock. Approximately 65% of the U.S. meets this criteria and approximately 80% of the Northeast qualifies. The geothermal designer must know the rock types and densities and heat transfer characteristics of the rock.

For Closed Loops, in a likewise manner, the designer must know the earth or rock types, moisture content and thermal characteristics of each to design an effective earth coupling method. Non-biodegradable plastic piping and earth coupling grouts are utilized in this earth coupling method. Non-toxic antifreezes and antifreeze additives must be employed in the plastic loops to prevent heat pump heat exchanger or loop freezing during winter operation.

MAINTENANCE

Each of the three methods should check their "liquids" every 1½ to 2 years.

The **Open Systems** and **Standing Column Well** systems are often employed in conjunction with domestic water systems and should be maintained in a sterile state at all times. Any open well system, whether used for a heat pump or only domestic, should be free of harmful bacteria (e.g. fecal coliform) and should be checked periodically. Iron bacterial (e.g. gallionella) is not harmful to humans and is often man-induced. The iron bacterium causes "red-brown" deposits in toilet bowls and in pipes. If the deposits are not controlled, pipes can eventually become occluded. Geothermal heat pump heat exchangers are not effected, as they are copper-nickel alloy and are heated well above bacterial killing temperatures (>130°F) during air conditioning periods.

Closed Loop systems can develop oxygen entrainment and can react with the antifreeze solutions and their additives to develop and acid concentration. These are easily checked with litmus or other pH evaluation methods. Some closed loop systems have automatic make-up water devices in the event the loop should develop a leak. These systems must be periodically verified for proper antifreeze concentration and pH (Acid activity).

REGULATORY

Open to recycle to geothermal earth systems have been in the Northeast for over 60 years and as a result have been the most regulated. Our oldest knowledge is a geothermal well water system in New Haven CT, installed in 1938. For **Open to recycle** and **Standing Column Well** systems, Federal and related State regulations involve permitting of water withdrawal and responsible return of the water to the earth. Other regulations may apply to excessive withdrawal, return to navigable streams or rivers, and other activities that may impact the water supply or quality.

Closed Loop systems designs are more recent, only being listed and evaluated by the Air Conditioning and Refrigeration Institute (ARI), since 1988 (ARI 330). Most states are now starting to develop regulations on these systems with some states still having no regulations relating to these earth coupling methods. Typical regulatory requirements include certification of loop installers, abandonment plan filings, listing of antifreeze solution compounds including additives, and mapping of loop fields.

THERMAL STABILITY

Open to recycle systems are by definition thermally stable over a multiple year period. As the ground water at a constant temperature is employed and "new" thermally consistent water is employed there is no thermal change in the subsurface geology.

Standing Column Well systems change the earth temperature in a cylinder about the well column on an annual basis. The thermal effect is typically depleted 40-50 feet from the borehole column. Ten plus years of field tests have shown no annual change in the mean earth temperature in properly designed and implemented **Standing Column Well** systems. Should a Standing Column Well manifest a trend away from the mean earth temperature a small advective "bleed" or over flow (5%-10%) results in the rapid re-stabilization of the bore temperature, i.e. increased in winter and decreased in summer.

Proper design must recognize geologic thermal characteristics, relative heating and cooling loads and adequate spacing of multiple **Standing Column Wells.** A standing column well can be up to 1,500 feet deep and develop 30-43 tons of capacity. A 350-foot deep domestic use Standing Column Well can develop approximately 5 tons of heat transfer.

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Typical spacing is 50-75 feet for multiple Standing Column Wells. Closer spacing can reduce bore hole heat transfer due to thermal interference between bores. Design compensation is necessary when faced with closer spacings.

Close Loop Systems do not have the ability to "bleed" or otherwise introduce fresh water into the loop bores to re-stabilize the earth temperature surrounding the plastic loops. As such, the closed loops are then most sensitive to annual thermal effects. Absolute annual earth moisture minimums must be considered and will impact responsible closed loop designs. Field test have shown long term earth temperature increases in commercial installations.

Typical spacing of closed vertical loops are 15-20 feet apart with 6-inch bores with, 300-450 foot depths, providing 1½ to 2½ tons per bore hole. Closed loop bores are often grouted with bacteria free Bentonite clay or other type grouts to enhance heat transfer to the earth.