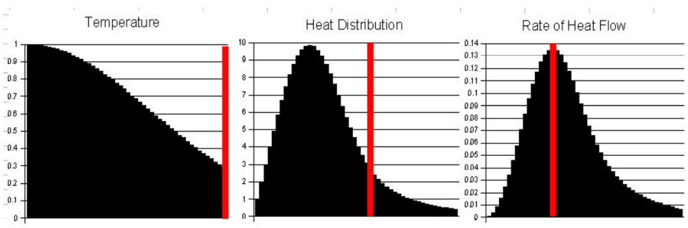
Trapping Heat

Seasonal storage of summer heat is commonly accomplished by using ground storage fields that are large enough to make their peripheral heat loss tolerable. An alternative is to utilize a design that traps the heat. Heat trapping systems can be made small enough to store the heat needed for a single house, and with no net loss of heat at all. Moreover, they are relatively inexpensive per home and offer the additional advantage of being able to store cold at a temperature that is low enough to obviate the need for using a heat pump for air conditioning.

Figure 1 shows the calculated heat distribution for heat that is injected at a central point (zero on the horizontal axis) as a function of the distance from the center (max 9.35m). The vertical axes are normalized so their peak values for T, heat distribution and rate of heat flow are 1.0. The extraction from the outer boreholes was not considered in these calculations, which show the values for the end of the heating season (assumed to be the beginning of April).



The outer boreholes for the demonstration system are located at an average distance of 4.5 metres from the center so the heat distribution curve indicates that very little heat will escape from the sides. About 5% of the heat will escape from the ends of this 20m deep store but for an AE-Street system, which will have much deeper boreholes, this loss will be much less than 1%.

In the simplest case we would like the maximum heat flow to occur during the period of maximum heating demand, which is normally January in most parts of Canada. The maximum heat flow will occur at the pincushion shaped interface between the hot and cold regions but it takes time for the heat to travel from that point to the extraction holes so it would be desirable to provide a month's lead time. The calculations based on the observed velocity of the heat wave front indicate that this interface will be reached at the end of January, so remedial measures are required for this example.

Another fundamental consideration is that we would like to inject only as much energy as will be used for heating purposes but the end of year graph indicates that about one third of the heat will remain in the central zone, and this also requires remedial measures.

Both needs for remedial actions can be accomplished by opening the valves for the central holes so that their heat is added to that from the four outer holes. This both adds a new source of heat and also increases the heat exchanger area by 50% so there is a large and immediate boost in the heat delivery capacity. A month later the heat flow peak will augment this surge so the boost will be sustained through the coldest part of the winter.

Opening the central valves will also strip away the extra heat from the left side of the heat distribution peak so that nearly all of the injected heat will be recovered. Since heat is also being extracted from the ground surrounding the system it is possible to balance the injection vs. the demand, or to deliberately recover extra heat from the surroundings where this does not interfere with the neighbours.

The choice of how much heat to leave in the central store depends on whether the system is also supplying hot water. In that case a surplus of central heat should be provided so that the hot water is heated throughout the summer via heat that was collected from the air. The feasibility of using the stored cold for air conditioning depends on the use of the system to provide hot water since the outer regions would otherwise become too warm.

A fundamental consideration is that the fluid temperature must never fall below the minimum for the operating range for the heat pump, which for the demo system is -3 degrees C. When the central valves are opened their heat is continuously transferred into the centers of the four outer holes and it is stored there in readiness for any subsequent peak demands, putting the heat where it is most needed and at the time it is most needed. These valves must be closed before starting heat injection in the spring.

At the design stage an AE-Street system should have the number of stores and a borehole depth that matches the annual heat demand. The borehole spacing can be increased if there is a need to store extra heat for DHW. The design capacity should be sufficient to handle any desired future capacity since the annual injection can always be lower to match the actual load. There should always be a surplus of air conditioning capacity because that is a natural byproduct of the heating capability.

After construction the controllable variables are the amount of heat injected, the timing of the central valve opening, and the use of the heat pumps for cooling for special needs, such as for IT buildings that have very high cooling requirements.