Progress Report – Air Conditioning (Aug 22)

The summer of 2009 has been notably undemanding for air conditioning systems. The temperatures were consistently cool until August, and while much of August has been much warmer the average temperature for that month will probably still be below average.

The cooling performance has been excellent. The cooling system cools the house rapidly even on extremely hot days, and has sufficient capacity left over to chill the house well below the desired temperature. The room air heat exchanger temperature was in the range 7 to 10 degrees C with an output differential of about 2 to 4 degrees, depending on the load.

There in no flow meter on the ground lines that feed the outer four tubes. The maximum flow rating for the pump is 2 litres per second, and since the flow resistance is small with the eight lines in parallel the flow rate should be in excess of the median performance of about 1 litre per second. That permits us to calculate the approximate amount of power being transferred into the ground.

The power measurements were made under three conditions:

(1) shortly after startup on the first day on which the AC system was used, which was a relatively cool day. The temperature difference across the ground heat exchanger lines was 3 degrees C, indicating that the power transfer was between 12.5 and 25 kW. The exit temperature from the heat pump was 30 degrees, or about 7 degrees above the room temperature, indicating that the COP would have been very high, although it could not be measured because the duty factor was relatively low (because of the cooler weather) and that factor is also not monitored.

(2) The other extreme was encountered on Aug 17, a very hot day (30 degrees) that followed a previous hot day when the AC was not in use, thus presenting an extremely high load. On that occasion the water temperature difference at mid afternoon was 14 degrees, indicating a power dissipation of from 58.5 kW to 117 kW. In that case the compressor duty factor would have been high, so assuming the maximum electric power load of 4.8 kW the COP appears to have been in excess of 13.6. In spite of the high power load the exit temperature from the ground was still only 28 degrees, showing that the ground heat exchanger was functioning very efficiently.

(3) The third set of measurements was made after a protracted period of hot weather. The exit temperature had risen to 34 degrees, but that is still well within the heat pump limitation of 80 degrees (the factory setting is 50 degrees, however). The water temperature differential was 3 degrees, corresponding to 12.5 to 25 kW., but again the COP could not be determined because the duty factor was unknown. The COP would have been lower than case (1) in this case because the heat pump lift was 9 degrees greater.

During the hot periods the grout temperature of the outer boreholes was about 7 degrees higher than the water temperature of the central boreholes. That implies that if the six holes were connected together, as is done at mid-winter, then the relatively hot (up to 42 degree) AC heat could be injected into the central heat store that is at half of that temperature. That would increase the amount of heat being stored, boost the already high COP, and provide a lot of insurance against running out of cooling capacity in the case of an exceptionally hot summer.

That will be a useful benefit in the event of an extremely hot summer but since our objective with an AE system is to have a zero net ground heat flow (in urban applications) the AC contributes to that goal in any case, so the 6-hole connection has not been implemented.

Because of the cool summer the contribution of the AC to the ground heat will be relatively small, very roughly estimated at 1000 kWh. The total annual heat demand for the house is estimated to be 13,600 kWh, which will be made up of :

injected heat 6400 kWh
heat pump power 3200 kWh
AC heat 1000 kWh
natural ground heat 3000 kWh (as planned)
Total = 13,600 kWh

We can optionally inject 3000 kWh of heat extracted from the air in the late winter to achieve a net zero ground heat exchange if we choose. The injection of heat during the winter may be counter intuitive but actually it is very efficient because what matters is the temperature difference between the air and the ground, and at that time of the cycle the ground is very cold. In the summer the factor that limits the heat injection is the warming of the grout during the day, but that effect is much smaller in the winter because heat is still being withdrawn to heat the house, the four outer holes serve as heat storage facilities, and there are 6 boreholes in use, not two.

One implication of the excellent performance of the AE system for cooling is that the provincial objective of reducing the summer power demand peak can be met even if the heat pump is used for air conditioning.