GROUND SOURCE HEAT PUMP
WITH A NEW COMPACT COLLECTOR

Johnny Wärnelöf, General Manager, IVT Industrier AB, Box 1012, 573 28 Tranås Sweden
Urban Kronström, Technical Manager, IVT Industrier AB, Box 1012, 573 28 Tranås Sweden.

ABSTRACT

A fundamental point, strongly effecting the development of a heat pump market, is economy. Installation of a Ground source heat pump (GSHP) is normally more expensive than a gas/oil boiler. In this paper we present a way to reduce the cost of installation.

The total cost for a Swedish heat pump installation is USD 14000 to 20000. The cost is divided into three parts:

- Heat source, normally vertical or horizontal ground loops, 35-40%
- Heat pump, 40 %
- Installation, 20-25%

A short pay-back time (total investment divided by first year savings) is one reason why the Swedish market for Ground source heat pumps was near 39000 units year 2004 (SEV/SVEP market statistics 2004). The normal pay-back time in a Swedish installation is 5-7 years. For the rest of Europe the pay-back time is longer due to higher investment and smaller savings. The high investment is mainly due to higher cost for the heat source. Horizontal collectors are not suitable because of small garden areas and vertical collectors, boreholes, are sometimes very expensive due to variable rock quality. The vertical collector only, can cost up to USD 10000-14000 in certain areas. This high level of investment is a large barrier and therefore the number of installed Ground source heat pumps is comparably small in central Europe.

Our idea is to increase the heat pump market by reducing the main barrier, cost of installation, and specially reduce the cost of the heat source.
To do this, we have developed a new highly efficient compact collector. The collector requires only a small garden area and it can be installed in less than a day. The compact collector is always combined with heat recovery from exhaust air. By using this combination the compact collector is recharged continuously. The system is also securing a good indoor climate, thanks to the continuous ventilation.

Key words: ***ground source heat pumps, compact collector system, heat recovery, exhaust air, recharging, ventilation***

1 INTRODUCTION

Ground source heat pumps in well designed systems can significantly reduce the CO_2-emmissions by reducing the electric power consumption for heating. A seasonal performance factor of more than 4 is possible in a under floor heating system. To increase the number of installed Ground source heat pumps in Europe we have addressed the main barrier for increased sales, the cost of installation and specially the cost of the heat source. In this paper we describe a new type of compact collector for Ground source heat pumps. Figure 1 shows the possible reduction in electric input after installation of an efficient Ground source heat pump.

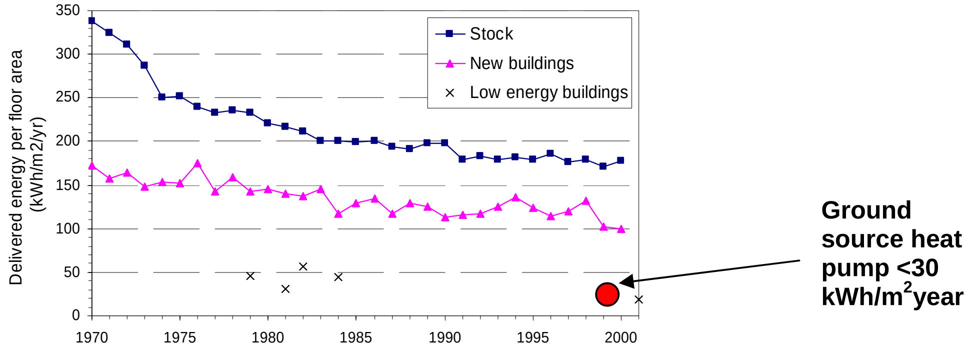

Fig. 1. Heating demand for Swedish houses (Holmberg 2004)

2 REQUIREMENTS

A development project was started 2002 with the following requirements:

- Ground source collector with a compact design
- Cost effective
- Simple installation
- Designed for industrial production

The project was run together with suppliers and inventors. Theoretical calculations have been made by Göran Hellström, University of Lund. Several different prototypes were built and tested.

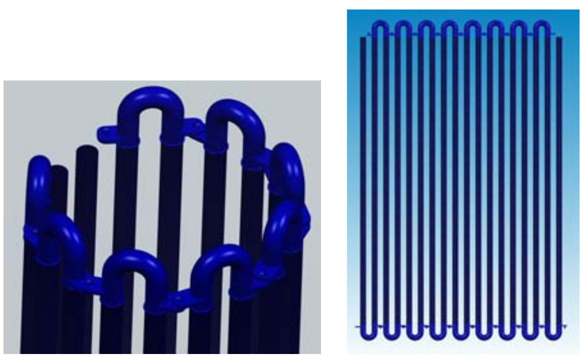

Fig. 2. First prototype drawings

3 DESCRIPTION OF THE SYSTEM

The compact collector system is a concept consisting of three different components:

- A ground source heat pump
- A heat recovery unit for exhaust air
- A number of compact collector modules

3.1 Ground Source Heat Pump

The heat pumps used are Ground source heat pumps designed to cover 100% of the capacity needed for space heating and domestic hot water. Normal size of heat pumps is 4-11 kW. This corresponds to new built houses with a building area of 100- 300 m^2.

Two models are used, a normal Ground source heat pump and a Hybrid heat pump with dual heat sources, ground and exhaust air.
In the Hybrid heat pump the ground collector acts like an accumulator. The recovered heat from ventilation is used in the heat pump when the heat pump is running. When the heat pump is standing still the recovered heat is stored in the ground. The products are shown in Figure 3 and 4 below.

Fig. 3. Ground-source heat pump with and without boiler tank for hot water

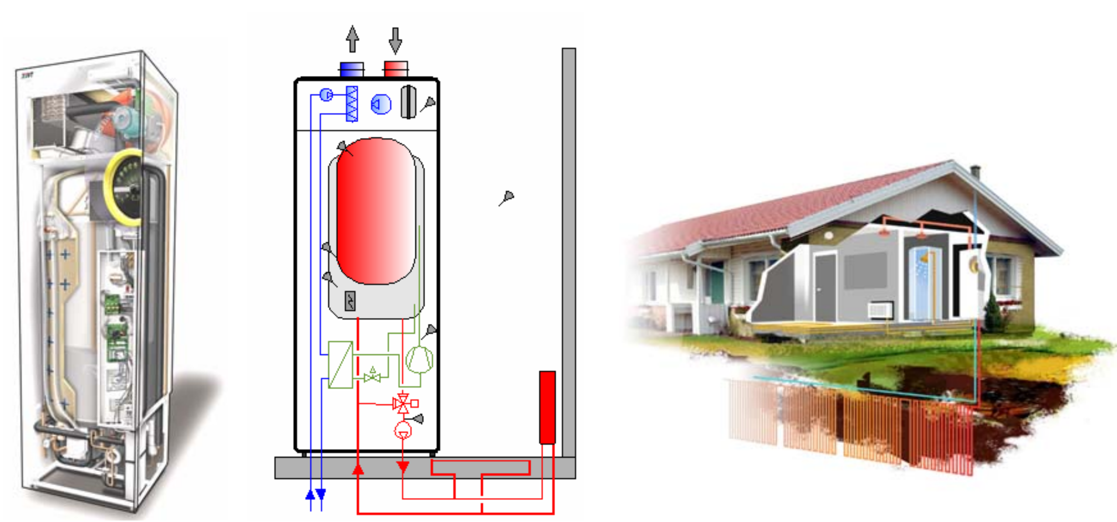

Fig. 4. Hybrid heat pump, Ground source heat pump with built in exhaust air unit

3.2 Heat Recovery Unit for Exhaust Air

The heat recovery unit consists of a fan and a brine/water coil for heat recovery. The unit is connected to the duct system for exhaust ventilation where used air is drawn from bathrooms, toilettes and kitchen. The unit is designed for air flow of 100-400 m^3/h or 30-120 l/s. The heat recovery coil is connected to the brine circuit of the heat pump. In this way continuous heat recovery and recharging is possible.

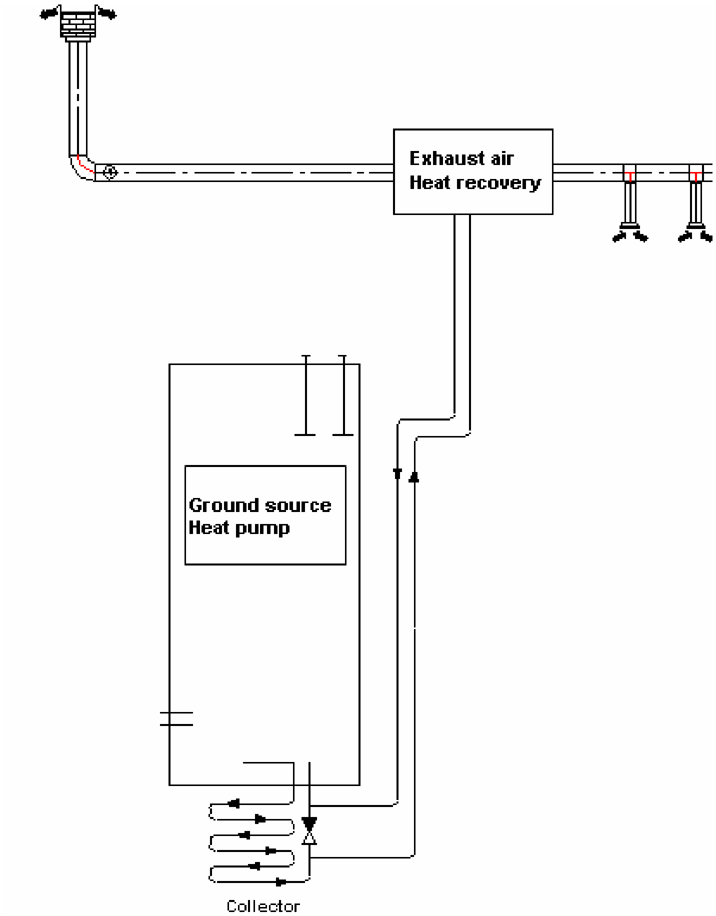

Fig. 5. Heat recovery unit for exhaust air and integration with the Ground source heat pump

3.3 Compact Collector

The compact collector is a modular ground heat exchanger built in PEM, Poly Ethene. The collector consists of a number of 40 mm pipes connected with U-bends at the top and at the bottom. Each module has the dimension 1500 x 2000 mm (width x height). Due to the large pipe diameter, up to 10 modules can be connected in series. Modules are easily connected with weld connections or screw connections. Each top connection has a de-airing device to speed up the filling process.
To size the system we have developed design software, the theoretical model is developed by Göran Hellström, University of Lund (Hellström 2004).

Fig. 6. Compact collector module and a top U-bend

4 PRODUCTION OF COMPACT COLLECTORS

To cover large demand for collector modules a semi automatic welding machine was developed. Pipes and U-bends are fed to the machine and the automatic welding process finishes the collector module in a short time.

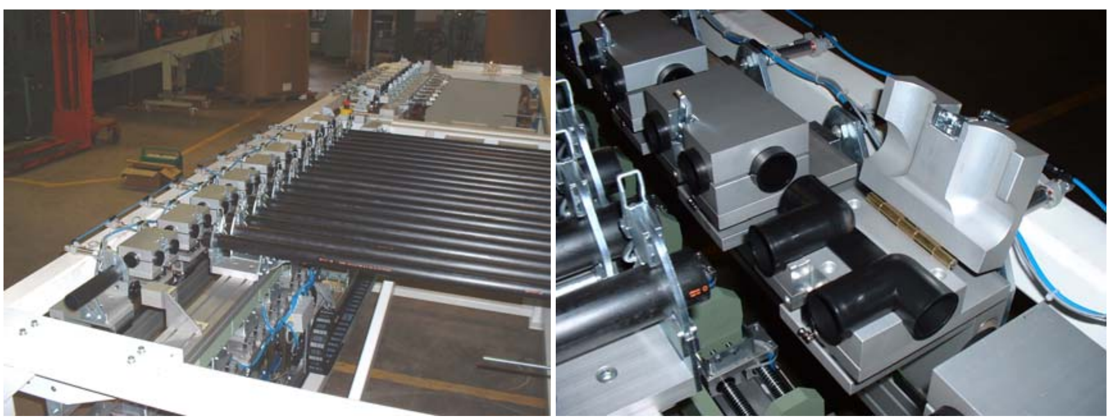

Fig. 7. Mirror welding machine for compact collectors

5 INSTALLATION METHODS

The compact collector can be installed in two ways

- Vertical installation
- Horizontal installation

The vertical installation is preferred and it is also the most compact way. The required numbers of collector modules are put in a 3 meter deep trench with a length of less than 2 m per module and a width of about 1 m. The modules are connected with weld or screw connections. A normal installation requires 8-12 collector modules corresponding to a 20 m long trench.

If ground conditions are difficult, risk of sliding or very wet conditions, horizontal installation is recommended. The collector modules are then put on 1.5-2.0 m depth with the connections slightly higher than the bottom of the module. The length of the trench is similar to the vertical installation. The outdoor installation is normally finished in less than a day.

Fig. 8. Vertical and horizontal installation

6 TEST INSTALLATION

To verify the theoretical design model we have made several test installations during the winters 2002/3 and 2003/4. In these houses we have measured ground temperatures and electric power consumption. One house is described below:

House type:	Low energy, single family, single floor, built 1990
Heated area:	150 m^2
Garden area:	Less than 200 m^2
Heating system:	Exhaust air heat pump and electric heater, radiators
Max temp for heating:	55-60 degree C
Old electric power cons.	11000 kWh/year for heating and domestic hot water
Old heating demand:	18000 kWh/year for heating and domestic hot water
	(The difference is recovered heat from ventilation, 7000 kWh/year)
New heat pump:	IVT Greenline HT C6, Ground source heat pump 6 kW heating capacity
Recharging:	Exhaust air unit for heat recovery and recharging
Compact collector:	9 modules in series
Garden area used:	Less then 50 m^2

Fig. 9. Test installation

7 RESULTS

The installation has run for almost two winter seasons and we have reached a stable ground temperature even during the coldest periods when the heat pump runs continuously. The temperature entering the heat pump has never gone below +1°C, which is higher than in a traditional system with horizontal or vertical ground loops in Sweden. Normal minimum temperature for horizontal ground loop is -2°C and for vertical 0°C to -2°C depending on geographical area.

The higher temperature compared to traditional systems gives a better COP for the heat pump system. Normally 1K increase in temperature corresponds to 2.5-3.0% increase in COP.
The test is showing that there is a good balance between heat demand for the house and heat stored in the ground together with heat recovered from exhaust air. Already in spring, April/May, the ground temperature is higher than undisturbed ground temperature. This is proving that the recharging capacity is sufficient.

In addition we have reached a substantial decrease in electric power consumption in the test house above. The new power consumption for heating and domestic hot water is 5500 kWh/year, half the old figure with the exhaust air heat pump. Seasonal performance factor or annual COP is 3.3. In an under floor heating system the corresponding figure would have been 4.0-4.5 and the electric power consumption even lower.

The reason for the low electric power consumption is that the new Ground source heat pump has a higher heating capacity than the old exhaust air heat pump. This is possible because of the dual heat sources, the heat pump extracts heat from both ventilation and ground. With the new compact collector this is possible even in a small garden.
Figure 10 below shows the outdoor temperature and the entering cold carrier temperature during the winter period 2003/2004.

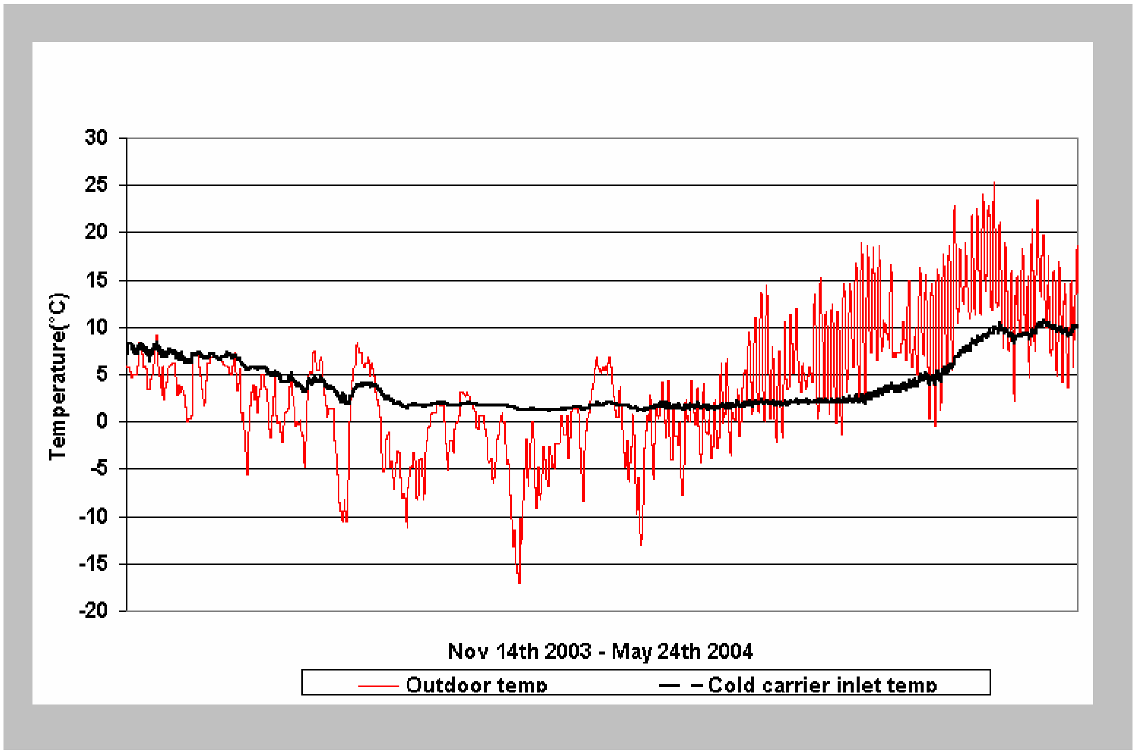

Fig. 10.Temperature measurement during winter 2003/2004

8 CONCLUSION

Recharging the heat source for a Ground source heat pump with exhaust air opens up the possibility to use a compact collector. With the compact collector system described in this paper Ground source heat pumps, covering the full demand for heating and domestic hot water in low energy houses, can be installed even if the garden area is very small. The compact collector with recharging is giving a stable and relatively high inlet temperature to the heat pump and the COP is 3.3 even in a normal heating system. With under floor heating the COP would be higher than 4.0.

Tests have shown that the heat recovered from the exhaust air well balances the heat rejection from the ground, giving even a slightly higher ground temperature the second year. In areas where vertical collectors are too expensive the Compact collector system is a way to lower the cost for Ground source heat pump installations.

REFERENCES

Hellström Göran, University of Lund, calculations on IVT compact collector system.

Holmberg John, Ph.D. Chalmers University of Technology, Physical resource theory, Heating demand statistics 1970 to 2000.

SEV/SVEP market statistics for 2004, Ground source heat pumps for the Swedish market.