Convective Heat Transfer in a Geothermal Heat Pump

1. Introduction

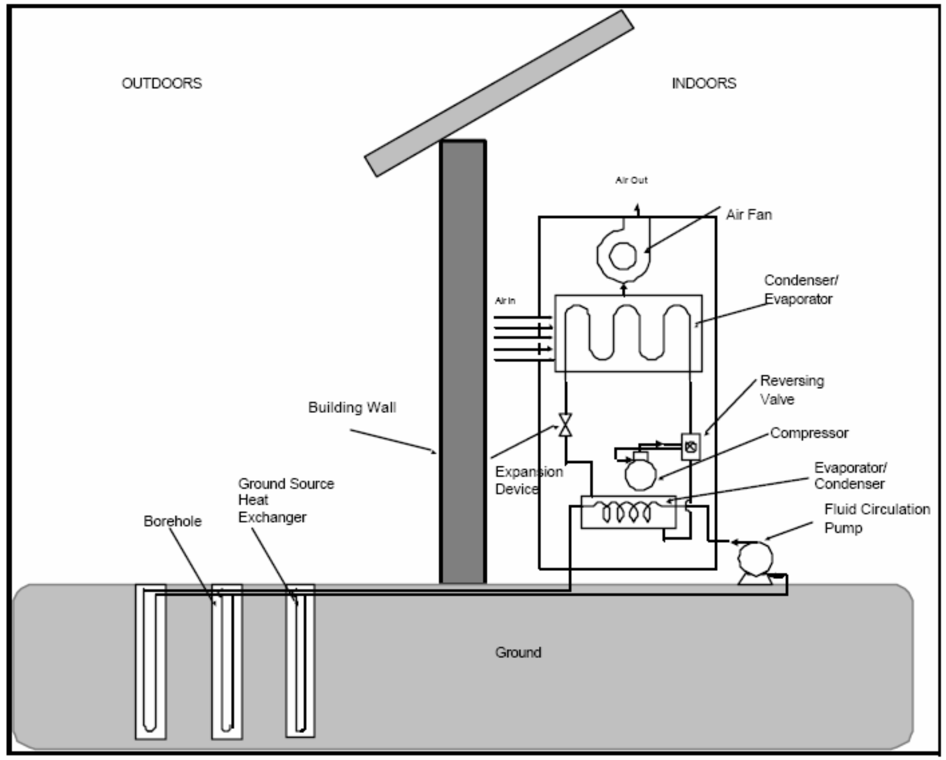

Figure 1.1. *Schematic of a Typical Vertical Closed-Loop, Ground-Coupled Heat Pump*

Geothermal heat pumps, also called Ground source heat pumps, offer an attractive option for heating and cooling residential and commercial buildings.

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2. Governing Equations

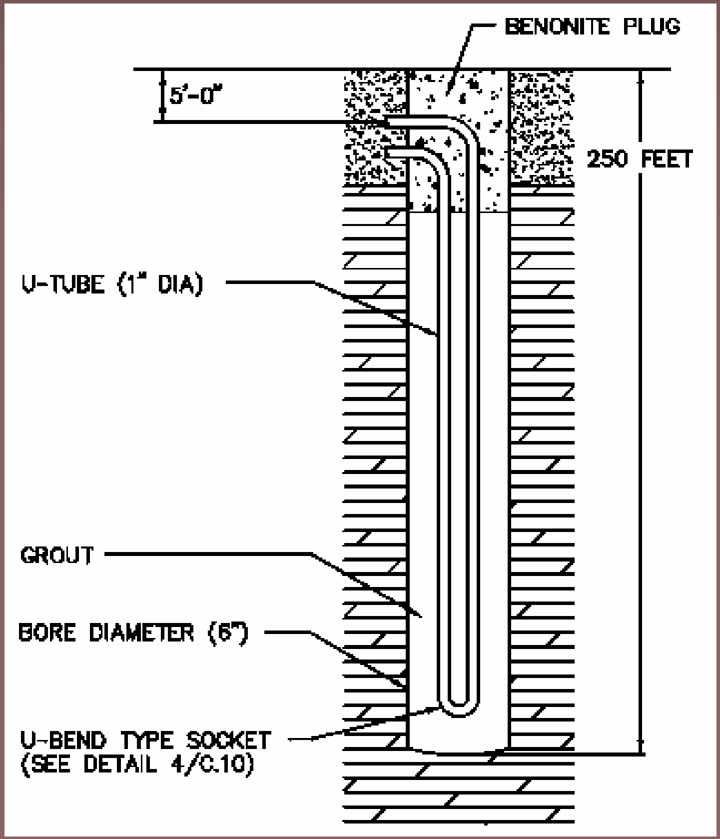


Figure 2-1: Sketch of geothermal heat exchanger.

1 →
$$-\nabla\cdot\eta(\nabla\mathbf{u}+(\nabla\mathbf{u})^T)+\rho(\mathbf{u}\cdot\nabla)\mathbf{u}+\nabla p=0$$
$$\nabla\cdot\mathbf{u}=0$$

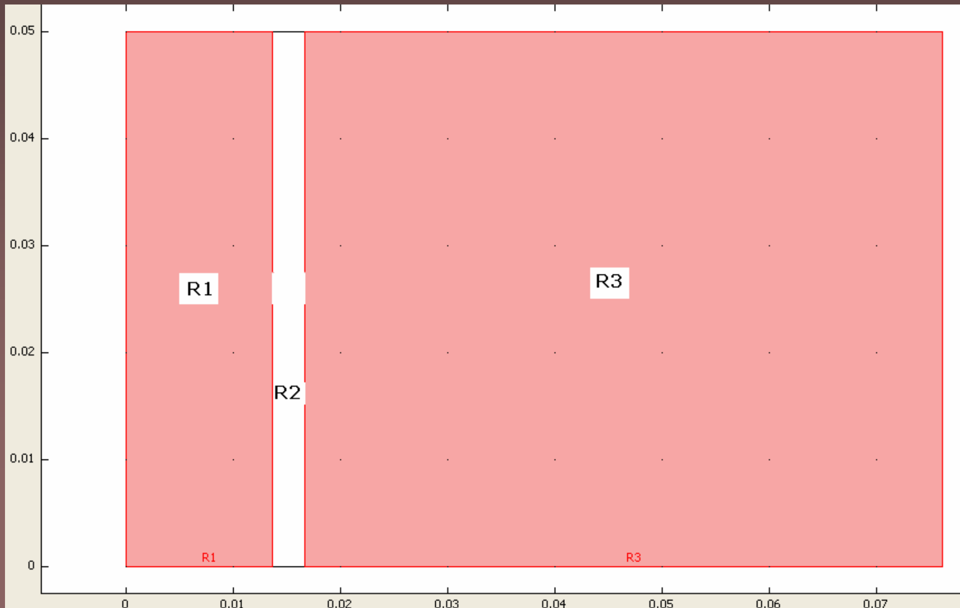
2 →
$$\nabla\cdot(-k\nabla T+\rho C_p T\mathbf{u}) = 0$$

3 →
$$\mathbf{u}\cdot\mathbf{n}=u_0$$
$$T=T_0$$

4 →
$$\mathbf{q}\cdot\mathbf{n} = \rho C_p T\mathbf{u}\cdot\mathbf{n}$$

5 →
$$\mathbf{u}=\bar{0}$$
$$T=T_1$$

3. Formulation



Thermal Properties: **Water**

eta	1.00E-03	Dynamic Viscocity	(kg m-1 s-1)
rho	1.00E+03	Density	(kg-3)
Cp	4.20E+03	Heat Capacity	(J kg-1 K-1)
k	0.6	Thermal Conductivity	(J s-1 m- K-1)
Tin	301.8	Temperature entering	(K)
Tw	284.3	Temperature wall	(K)

Thermal Properties: **PVC**

eta	1.00E+00	Dynamic Viscocity	(kg m-1 s-1)
rho	1.76E+03	Density	(kg-3)
Cp	3.20E+02	Heat Capacity	(J kg-1 K-1)
k	0.1	Thermal Conductivity	(J s-1 m- K-1)

Thermal Properties: **Concrete**

eta	1.00E+00	Dynamic Viscocity	(kg m-1 s-1)
rho	2.30E+03	Density	(kg-3)
Cp	1.28E+03	Heat Capacity	(J kg-1 K-1)
k	1.8	Thermal Conductivity	(J s-1 m- K-1)

Incompressible Navier-Stokes

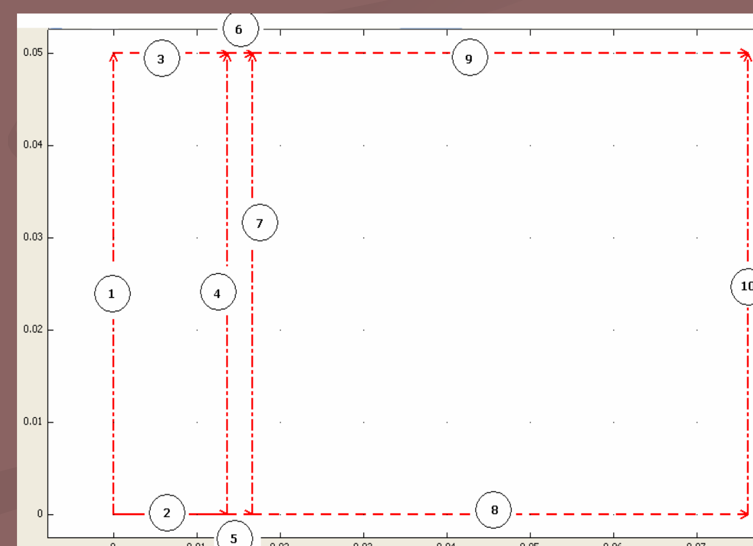
Boundary	1	2	3	4	5	6	7	8	9	10
Type	S/S	I/O	Nf/P	/	NS	Nf/P	/	NS	Nf/P	S/S
u		0								
v		v0								
p			0							

Notes:
- S/S: Slip/Symmetry
- I/O: Inflow/Outflow Velocity
- Nf/P: Normal flow/Pressure
- NS: No-Slip

Convection and Conduction

Boundary	1	2	3	4	5	6	7	8	9	10
Type	TI	T	CF	/	TI	TI	/	TI	TI	T
T		Tin								Tw

Notes:
- TI: Thermal Insulation
- T: Temperature
- HF: Heat Flux
- CF: Convective Flux



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4. Solution

.0005 →

(m/s)

.0025 →

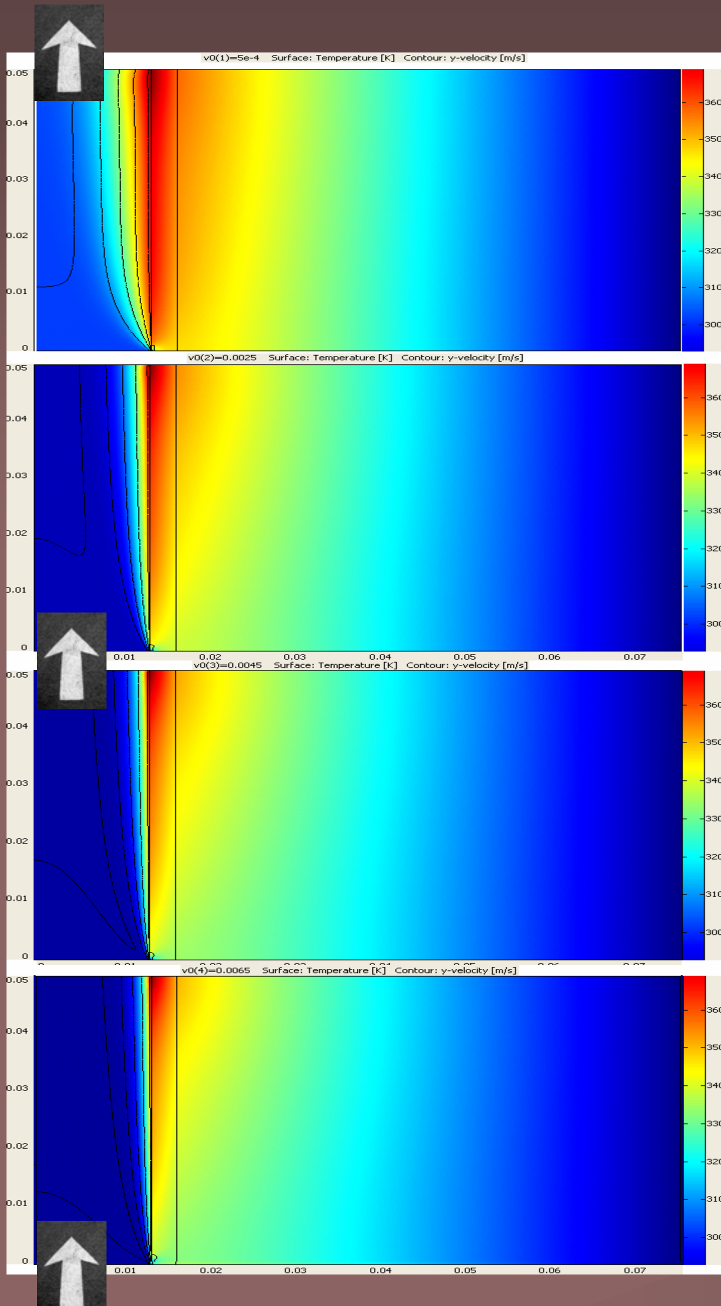
(m/s)

.0045 →

(m/s)

.0065 →

(m/s)



From top to bottom:

Convection decreases as velocity incerease.

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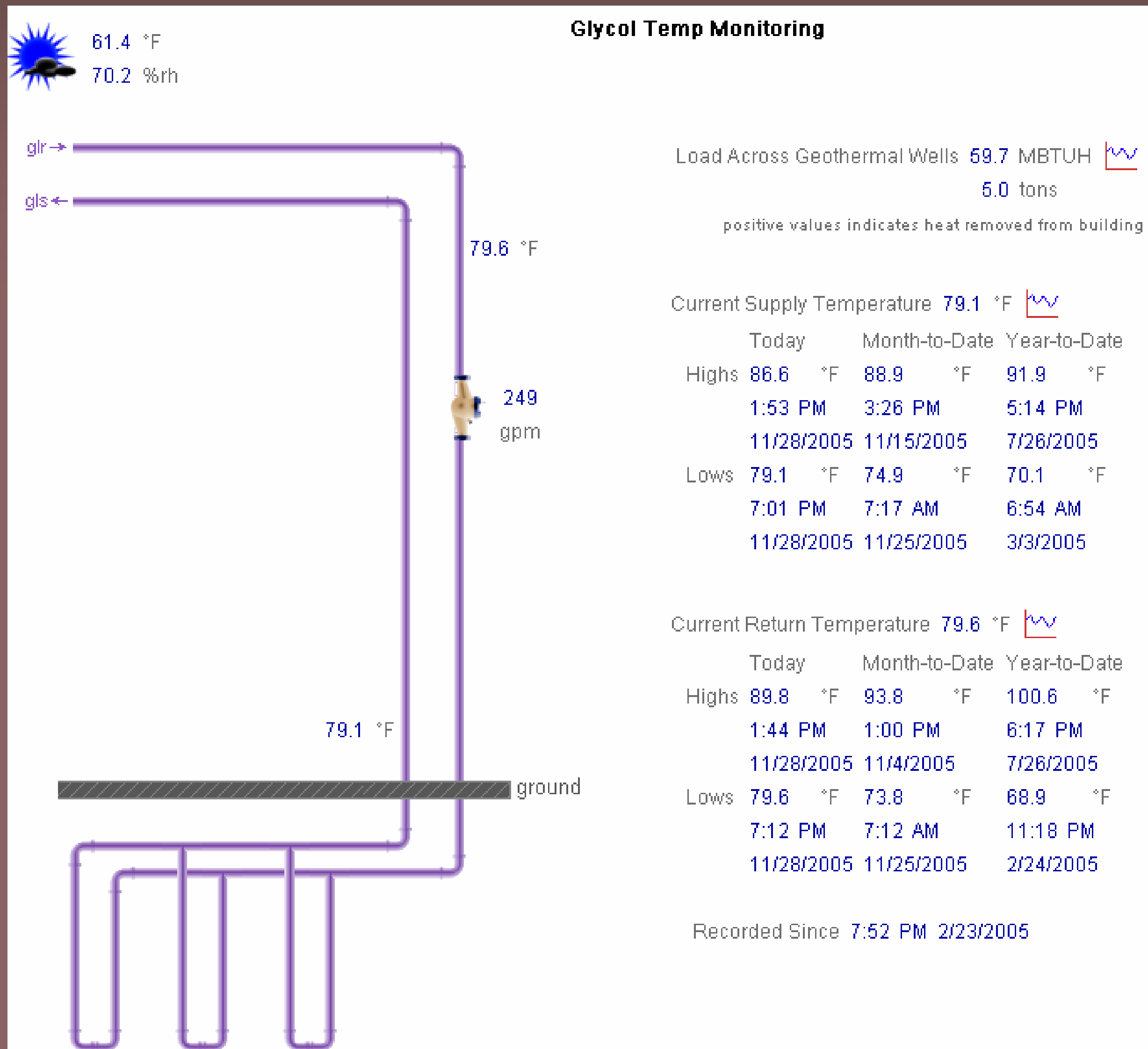
5. Validation



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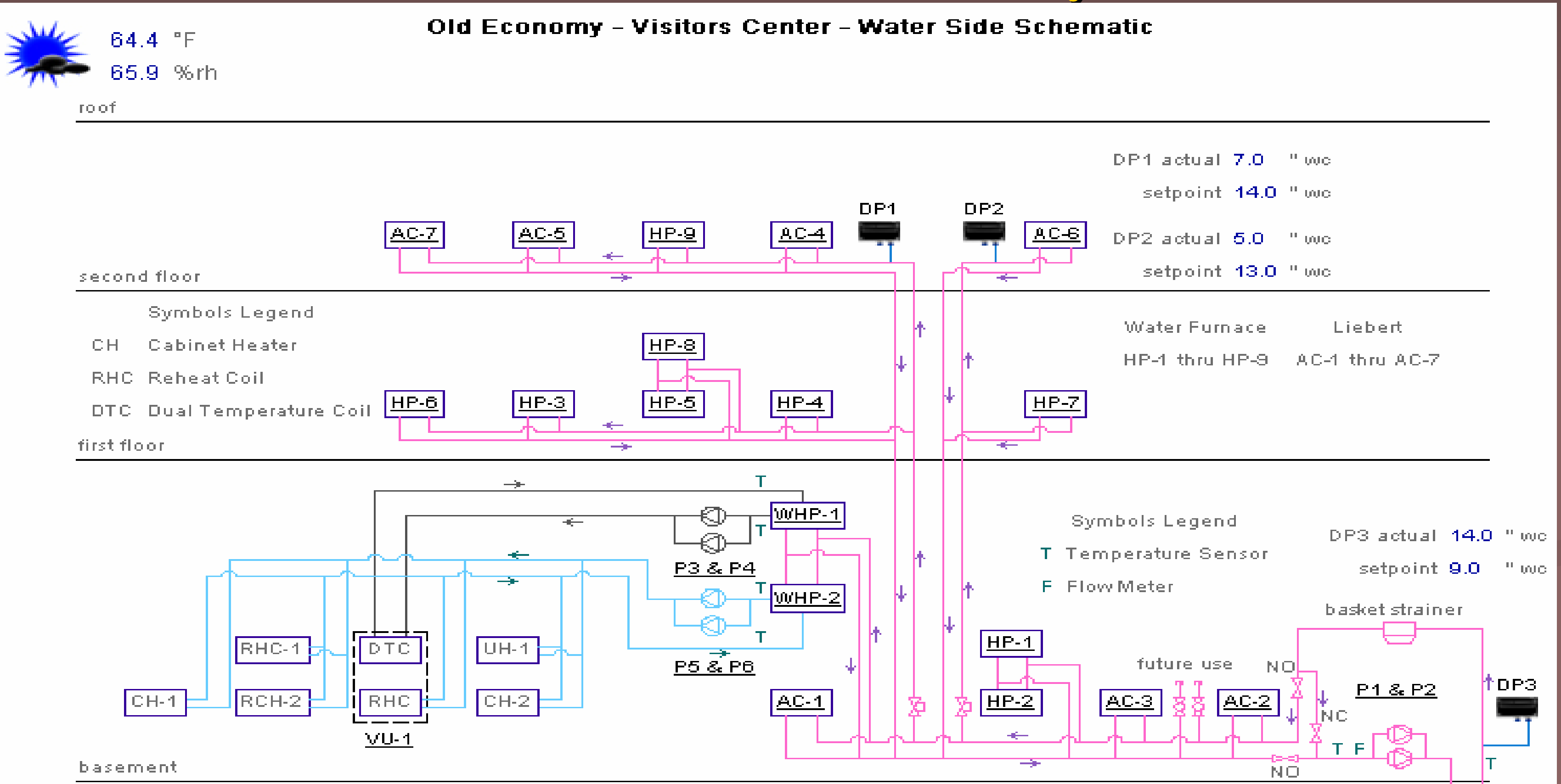
6. Parametric Study



Temperature Monitoring Points

Unit Name	Supply Temp	ST Setpoint	Return Temp
WHP-1	71.0	100.0	71.1
WHP-2	80.2	100.0	79.9
glycol	79.8	NA	80.6

Pump 1 & 2 Summary

Lead Pump	2	
Pump 1 s/s	Disabled	
Pump 1 status	Off	
Pump 2 s/s	Disabled	
Pump 2 status	Off	
VFD	0	%speed
Glycol Flow Rate	244	gpm

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7. Conclusions

1. Varying flow has more impact in ground source heat transfer systems than varying temperature (Tin)

2. Flow is varied in real systems using variable speed drives coupled to the building load profile through building automation control systems.

3. Ability to visualize remote or hidden processes lead to better understanding of systems.