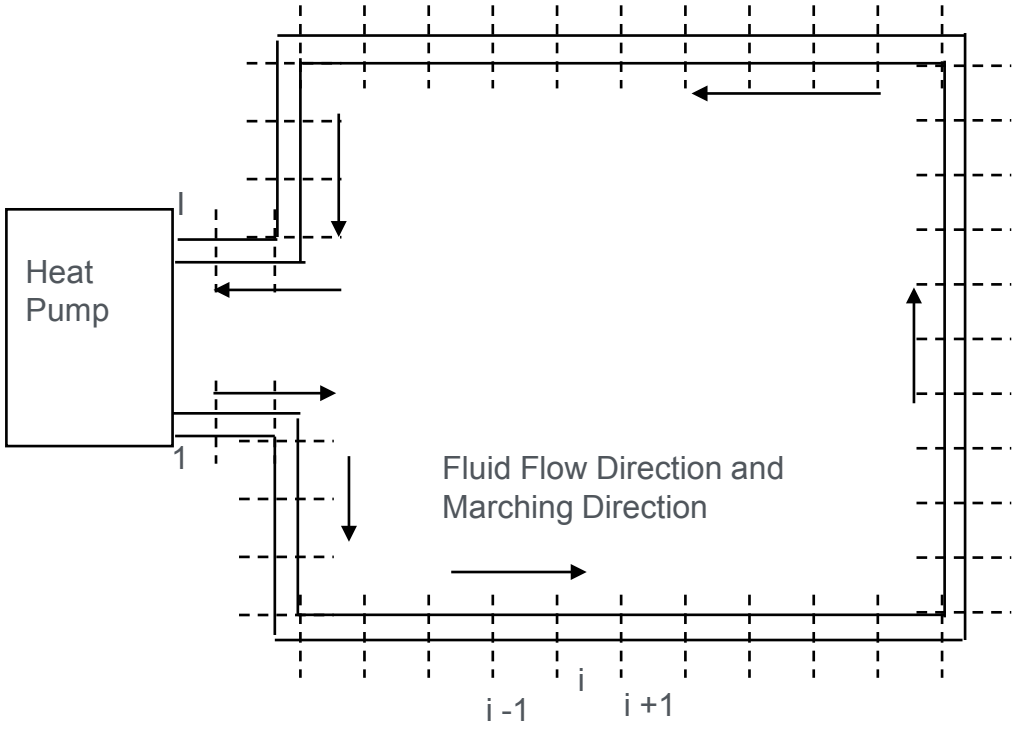
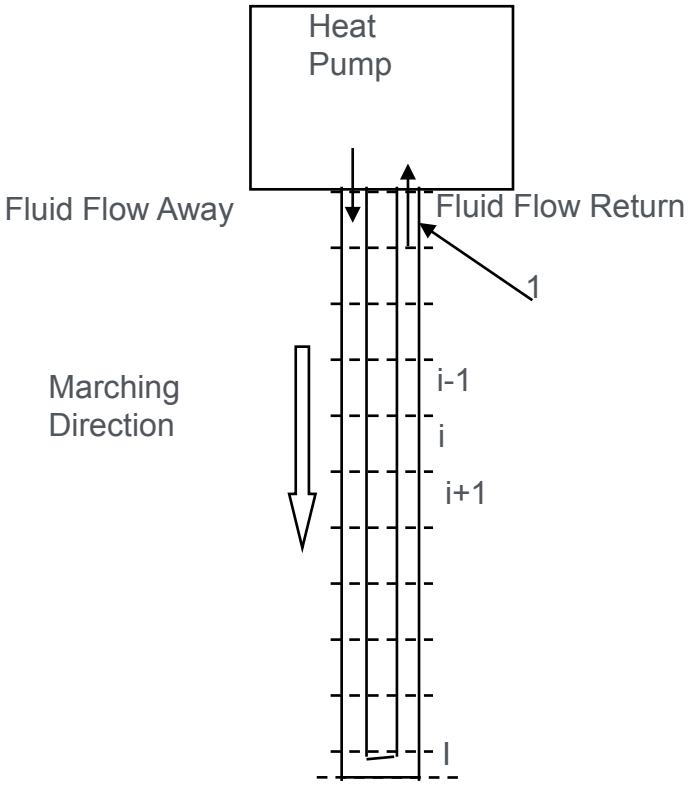




Finite Volume Based Computer Program for Ground Source Heat Pump Systems

May18, 2010

Principal Investigator: Jim Menart
Presenter Name: Jim Menart
Organization: Wright State University

Track Name: GSHP Demonstration Projects

Mandatory Overview Slide

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Timeline
  - Project start date: April 1, 2010 (January 29, 2010)
  - Project end date: March 31, 2011 (February 28, 2011)
  - Percent complete: 10%
- Budget
  - Total project funding: $290,749
  - DOE share: $232,596
  - Awardee share: $58,153
  - Funding received in FY09: $0
  - Funding received for FY10: $0 (nothing has been billed yet)

Mandatory Overview Slide

- Barriers
  - The only barrier that can be seen is computational time
    - Computer computational times for long simulated geothermal loop operation times can be long
    - This will not interfere with running shorter geothermal loop operation times quickly
    - This will make the program less desirable commercially
- Partners
  - Wright State is the only Institution involved on project
  - A number of local companies/organizations have shown interest in this work
    - Emerson Climate Technologies
    - Heapy Engineering
    - Weibull Energy Systems – works with TRANE
    - Haley & Aldrich
    - Melink Coorporation
    - KLH Engineers
    - City of Dayton

Overall Objective

Create a new modeling “decision” tool that will enable ground source heat pump (GSHP) designers and customers to make better design and purchasing decisions.

Specific Objectives

- Develop a user friendly computational tool for sizing geothermal ground loop geothermal systems
  - Horizontal loops
  - Veritical loops
  - Open loops
- Use a more detailed analysis than is currently used in commercial codes
  - Do not use g-factor approach
- Provide length and spacing information for the ground loop
  - Present commercial codes do not provide spacing information
  - Spacing is critical for optimal system performance
- Provide plots of temperature profiles in the ground as a function of time and position

Specific Objectives Continued

- Provide costing information on
  - Designed geothermal system
  - Gas heating with vapor-compression air-conditioning system
  - Oil heating with vapor-compression air-conditioning system
  - Propane heating with vapor-compression air-conditioning system
  - Air-to-air heat pump system
- Provide payback period of geothermal system compared to other four systems

Desired Long Term Impact of this Research

- More efficient geothermal systems
- More economical geothermal systems
- Increased use of geothermal systems
- While this is a design tool, it is hoped that this program will be used in a research mode to find other ways to do ground loops

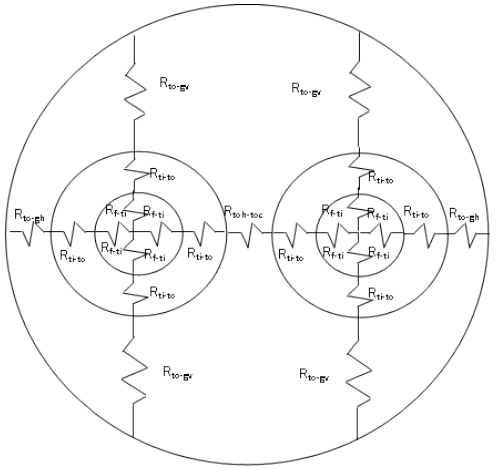
Scientific/Technical Approach

- Use finite volume method to model unsteady heat transfer in the earth

$$\frac{T_{f,i}^{p}-T_{1,i}^{p+1}}{R_{tot,f-go}}+k_s 2\pi r_{j+1/2}\Delta x_i\frac{T_{j+1,i}^{p+1}-T_{j,i}^{p+1}}{r_{j+1}-r_j}=\rho_s C_s\pi\left(r_{j+1/2}^2-r_{j-1/2}^2\right)\Delta x_i\frac{T_{j,i}^{p+1}-T_{j,i}^{p}}{\Delta t^{p+1/2}}$$

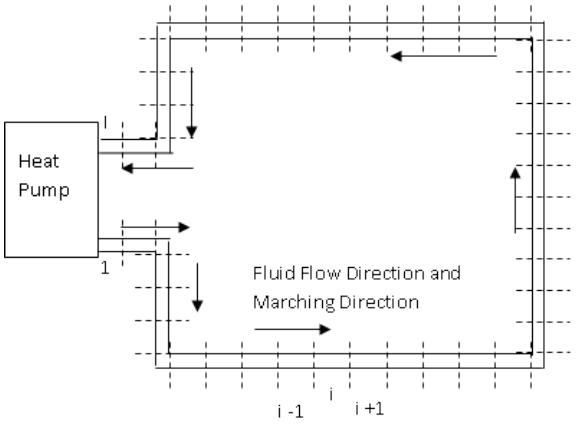
$$k_s 2\pi r_{j+1/2}\Delta x_i\frac{T_{j+1,i}^{p+1}-T_{j,i}^{p+1}}{r_{j+1}-r_j}-k_s 2\pi r_{j-1/2}\Delta x_i\frac{T_{j,i}^{p+1}-T_{j-1,i}^{p+1}}{r_j-r_{j-1}}=\rho_s C_s\pi\left(r_{j+1/2}^2-r_{j-1/2}^2\right)\Delta x_i\frac{T_{j,i}^{p+1}-T_{j,i}^{p}}{\Delta t^{p+1/2}}$$

$$T_{J,i}^{p+1}=T_{s,\infty}$$



Thermal Resistive Technique

- Use thermal resistive technique to model heat transfer in liquid, tubes, and any grouting used
- Use axial marching solution to model changes in the flow direction
- Use heat pump performance curves to model effect of heat pump on system
  - Coupled with ground loop analysis



Spatial Marching Technique

Scientific/Technical Approach

- Estimate costs of gas, oil, and propane systems coupled to vapor compression refrigeration system
  - Initial costs of equipment
  - Operating costs
  - Costing will be based on present day prices with option to enter other prices
- Estimate costs of air-to-air heat pump system
  - Initial costs of equipment
  - Operating costs
  - Costing will be based on present day prices with option to input other prices
- Do payback period calculation
  - Account for time value of money
- Milestones will be presented with timeline graph
  - (see slide 13)

Scientific/Technical Approach

- Program results will be tested against published experimental results
- Program results will be tested against other model results
- Perform some survey results to judge whether program is working correctly
- Different parts of program will be tested as they are developed to see that they are performing properly
- Will have a GUI interface on the program to make it user friendly

Accomplishments, Expected Outcomes and Progress

- I have a research professor and graduate student on board
  - Programming work has begun
- We are working on the finite difference portion of computer code
  - Expect to have this done by end of June
  - This is the heart of the computer model
- No data to report as of this time
- PI (Dr. Menart) and Research Scientist (Dr. Shiva Prasad) have over 40 years of computer programming experience in CFD and heat transfer
  - Dr. Menart has developed a number of large scale computational programs

Project Management/Coordination

- Dr. Menart is leading a group of a Research Scientist and a graduate student
  - A second graduate student will be on board this summer
  - The research scientist is helping guide the work with the graduate student
  - A number of industries have shown interest in the project as mentioned earlier
- Resources for this project are essentially used for salaries
- Next slide shows the time line for the project

Project Management/Coordination

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

	Month											
Project Task	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
PHASE I – COMPUTER PROGRAM DEVELOPMENT												
Task 1.0 – Program Inner Region Loop Model												
Task 2.0 - Program Outer Region Loop Model												
Task 3.0 - Program Axial Marching Solution												
Task 4.0 - Program Time Marching Solution												
Task 5.0 - Program Heat Pump Model												
Task 6.0 - Program Costs												
Task 7.0 - Program GUI												
PHASE II - COMPUTER PROGRAM TESTING												
Task 8.0 – Test Computer Program to Verify Accuracy												
PHASE III – PARAMETER SURVEY												
Task 9.0 – Perform Survey Runs												
Task 10.0 Project Management and Reporting												
Recruit Graduate Students												
Attend conferences to present results												
Develop web site												
Write final technical report												

Future Directions

- When finished this program will be made available on the web as free software for a period of three years
- After three years the software will be available for a cost
- This project is scheduled to be done in one year
- After this project we would like to write a scientific version of this program that models the geothermal system in full 3-D finite volume form
  - Will not worry about computational time in this version

Mandatory Summary Slide

- Better commercial computer codes are required in the geothermal ground loop industry.
- Present commercial models seem to focus on the length of the ground loop and not the spacing
  - Our program will give the designer spacing information
- The program being developed will
  - Be based on fundamental heat transfer principles and the fundamental solution technique called the finite volume numerical model
  - Cost comparisons will be done
  - Detailed temperature profiles will be computed and presented
- Project is on schedule

Supplemental Slides

GTP Goals not outlined in MYRD&D (continued)

- DOE criteria for Ground Source Heat Pumps
  - Reduce levelized cost of electricity ($/ton) by 30% by 2016
- We do believe that our program will lower the costs of geothermal systems.
  - A more accurate model that does not over or under size the geothermal system will have the effect of lowering costs
- We also hope that this program will be used to improve current geothermal designs
- Better computer models that can be used commercially are needed