The main equation that we solve for the design of a geothermal loop length and well depth is listed below. This equation and the following pages are a part of the approximately 1,000 page calculation and report for this 96 unit, 107 ton housing project in Vancouver, BC, Canada.

$$L_h = \frac{q_a \times R_{ga} + \left(q_{lh} - 3.41 \times \overline{W_h}\right)\left(R_b + PLF_m R_{gm} + R_{gd} \times F_{sc}\right)}{t_g - \frac{t_{wi} + t_{wo}}{2} - t_p}$$

*Where,*

$F_{sc}$ = *short – circuit heat loss factor*

$L_h$ = *required bore lenght for heating* $(ft)$

$PLF_m$ = *part – load factor during design month*

$q_a$ = *net annual average heat transfer to the ground* $(Btu/h)$

$q_{lh}$ = *buiding design heating block load* $(Btu/h)$

$R_{ga}$ = *effective thermal resistance of of the ground, annual pulse* $(hr * ft *°F / Btu)$

$R_{gd}$ = *effective thermal resistance of the ground, daily pulse* $(h * ft *°F / Btu)$

$R_{gm}$ = *effective thermal resistance of the ground, monthly pulse* $(h * ft *°F / Btu)$

$R_b$ = *thermal resistnace of bore* $(h * ft *°F / Btu)$

$t_g$ = *undisturbed ground temperature* $(°F)$

$t_p$ = *temperature penalty for interference of adjacent bores* $(°F)$

$t_{wi}$ = *liquid temperature at heat pump inlet* $(°F)$

$t_{wo}$ = *liquid temperature at heat pump outlet* $(°F)$

$W_h$ = *power input at design heating load* $(W)$

The reference for this equation is, “Ground-Source Heat Pumps, Design of Geothermal Systems for Commercial and Institutional buildings”, Stephen P. Kavanaugh, Kevin Rafferty, ASHRAE, 1997, page 23, and ASHRAE Short Course, “Design of Commercial Ground-Source Heat Pumps, January 29, 2001, Atlanta, GA.

Summary of all House calculations for Mole Hill Housing, Vancouver, BC, Canada,

| MOLE HILL GEOTHERMAL SYSTEMS | | | 8-Jan-02 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Hse # | Area Sq.Ft. | Unit Cap. Tons | Act. Bore Feet | Calc.Load Btu/Hr | Calc.Bore Feet | Units Connected | Combined Actual | Combined Calculated | Conclusion |
| | | | | | | | | | |
| 11 | 6910 | 10 | 1500 | 145405 | 1204 | a | | | |
| 12 | 2922 | 5 | 750 | 78951 | 676 | a | 2250 | 1880 | OK |
| 13 | 3703 | 5 | 750 | 98266 | 905 | b | | | |
| 14 | 2818 | 5 | 750 | 66188 | 525 | b | 1500 | 1430 | OK |
| 15 | 4341 | 6 | 900 | 96577 | 847 | c | | | |
| 16 | 4674 | 6 | 900 | 100431 | 893 | c | | | |
| 17 | 4787 | 6 | 900 | 113904 | 1052 | c | 2700 | 2792 | OK |
| 18 | 4429 | 6 | 900 | 97878 | 862 | d | | | |
| 19 | 3001 | 6 | 900 | 95188 | 831 | d | | | |
| 20 | 3746 | 6 | 900 | 85871 | 720 | d | 2700 | 2413 | OK |
| 21 | 7153 | 10 | 1500 | 147504 | 1229 | e | 1500 | 1229 | OK |
| 22a | 4524 | 6 | 900 | 96969 | 852 | f | | | |
| 22b | 5047 | 7.5 | 1125 | 100942 | 862 | f | 2025 | 1714 | OK |
| 23 | 3234 | 5 | 750 | 88629 | 791 | g | | | |
| 24 | 4775 | 7.5 | 1125 | 114522 | 1023 | g | 1875 | 1814 | OK |
| 25 | 3212 | 5 | 750 | 78071 | 666 | h | | | |
| 26 | 3486 | 5 | 750 | 78418 | 670 | h | 1500 | 1336 | OK |
| | | 107 Tons | | | | | 16,050 feet<br>72 wells<br>223 feet average | | |

The following is a sample bore hole length calculation for Mole Hill Housing, Vancouver, BC, Canada, House 11,

Ground Source Heat Pumps Building H11 8-Jan-02

| Symbols | Descript. | Init. Entry | Calcs 1 | Calcs 2 | Bore Length |
|---|---|---|---|---|---|
| | | | | Actual | 1500 |
| $q_a$ | gd hl | 55.00 | $q_a$ x $R_{ga}$ | | |
| $R_{ga}$ | r gd | 0.33 | 18.1500[1] | | |
| $q_{th}$ | bldg hl | 145405.00 | $q_{th}$ x $W_h$ | | |
| $W_h$ | pwr input | 43920.80 | 101484.20[2] | | |
| $R_p$ | r pipe | 0.11 | | | |
| $PLF_m$ | part load | 30.00 | | | |
| $R_{gm}$ | r gd | 0.327 | | | |
| $R_{gd}$ | r gd | 0.23 | Rp + ((PLFm x Rgm) + (Rgd x Fsc)) | 1 + (2 x 3) | 4 divided by 5 |
| $F_{sc}$ | sht.circ. | 0 | 9.92[3] | 10232.09[4] | 1204 |
| $t_g$ | t grd | 54.00 | | | |
| $t_{wi}$ | t liquid in | 43.00 | | | |
| $t_{wo}$ | t liquid out | 48.00 | | $t_g$ - ($t_{mi}$ + $t_{mo}$)/2 - $t_p$ | |
| $t_p$ | int. penalty | 0.00 | | 8.50[5] | |
| $q_a$ | gd hl | | Ht.trans.from gd. | | |
| $R_{ga}$ | r gd | | R ground annual | | |
| $q_{th}$ | bldg hl | | Bldg.heat loss | | |
| $W_h$ | pwr input | | Power input | | |
| $R_p$ | r pipe | | R pipe | | |
| $PLF_m$ | part load | | Part load factor | | |
| $R_{gm}$ | r gd | | R ground daily | | |
| $R_{gd}$ | r gd | | R ground monthly | | |
| $F_{sc}$ | sht.circ. | | Short circuit factor | | |
| $t_g$ | t grd | | Ground temp. | | |
| $t_{wi}$ | t liquid in | | Temp to HP | | |
| $t_{wo}$ | t liquid out | | Temp from HP | | |
| $t_p$ | int. penalty | | Interference factor | | |

Equivalent Thermal Resistance

| | | | |
|---|---|---|---|
| 1 | 3650 days | | |
| 2 | 3650 + 30 days | | |
| f | 3650 + 30 + 0.167 days | | |
| $k_g$ | 1.3 btu/hr/ft/deg.F | | |
| $a_g$ | 0.75 $ft^2$/day | | |
| $d_{equ}$ | 0.18 ft | | |
| $Fo_f$ | 4 x 0.75 x 3680.167 / 0.0324 = | 340756.00 | $G_f$ 1.1500 |
| $Fo_1$ | 4 x 0.75 x 30.167 / 0.0324 = | 2793.00 | $G_1$ 0.0725 |
| $Fo_2$ | 4 x 0.75 x 0.167 / 0.0324 = | 15.50 | $G_2$ 0.3000 |
| $R_{ga}$ | (1.15 - 0.725) / 1.3 | =0.330 | |
| $R_{gm}$ | (0.725 - 0.30) / 1.3 | =0.327 | |
| $R_{gd}$ | 0.30 / 1.3 | =0.230 | |