

# 3726

## **Testing of Three Factory-Built Chimneys**

**Prepared for:**

**The Research Division  
Policy Development and Research Sector  
Canada Mortgage and Housing Corporation**

**by:**

**ORTECH International, Mississauga  
Principal Consultant: Colin A. McGugan  
CHMC Project Manager: Don Fugler**

**December 8, 1989**



# **D I S C L A I M E R**

THIS PROJECT WAS FUNDED BY THE CANADA MORTGAGE AND HOUSING CORPORATION AND ENERGY MINES AND RESOURCES CANADA. THE VIEWS EXPRESSED ARE THE PERSONAL VIEWS OF THE AUTHORS.

NEITHER THE CORPORATION NOR EMR ACCEPTS RESPONSIBILITY FOR THEM.

## **1.0 INTRODUCTION**

As part of a study of the performance of factory-built fireplaces, Canada Mortgage and Housing Corporation (CMHC) engaged ORTECH International to carry out laboratory testing of three factory-built chimneys connected to a factory-built fireplace.

Results of previous tests were reported in ORTECH Report ESC-89-18, "Performance Requirements and Design Guidelines for Fireplaces with Closed Combustion Chambers".

In that work, tests were carried out on fireplaces using type A chimneys. Concerns have been raised regarding operation of fireplaces with air-cooled chimneys. It was felt that a fireplace with an air-cooled chimney might be more prone to draft problems than a fireplace with an insulated chimney.

## **2.0 DESCRIPTION OF CHIMNEYS AND FIREPLACE**

Three chimneys were selected for additional testing with Fireplace E. Chimney A was an air-cooled chimney, with a 200 mm inside diameter and a 300 mm outside diameter. Cooling air was supplied through a 100 mm duct running from the base of the chimney to air intake hood on the exterior wall of the test room. Chimney B was a type A chimney, with a 200 mm inside diameter and a 250 mm outside diameter. Chimney C was a 650°C chimney, with a 200 mm inside diameter and a 300 mm outside diameter. The chimneys were tested in conjunction with a standard factory-built fireplace designed for use with the air-cooled chimney.

## **3.0 CHIMNEY TEST PROCEDURES**

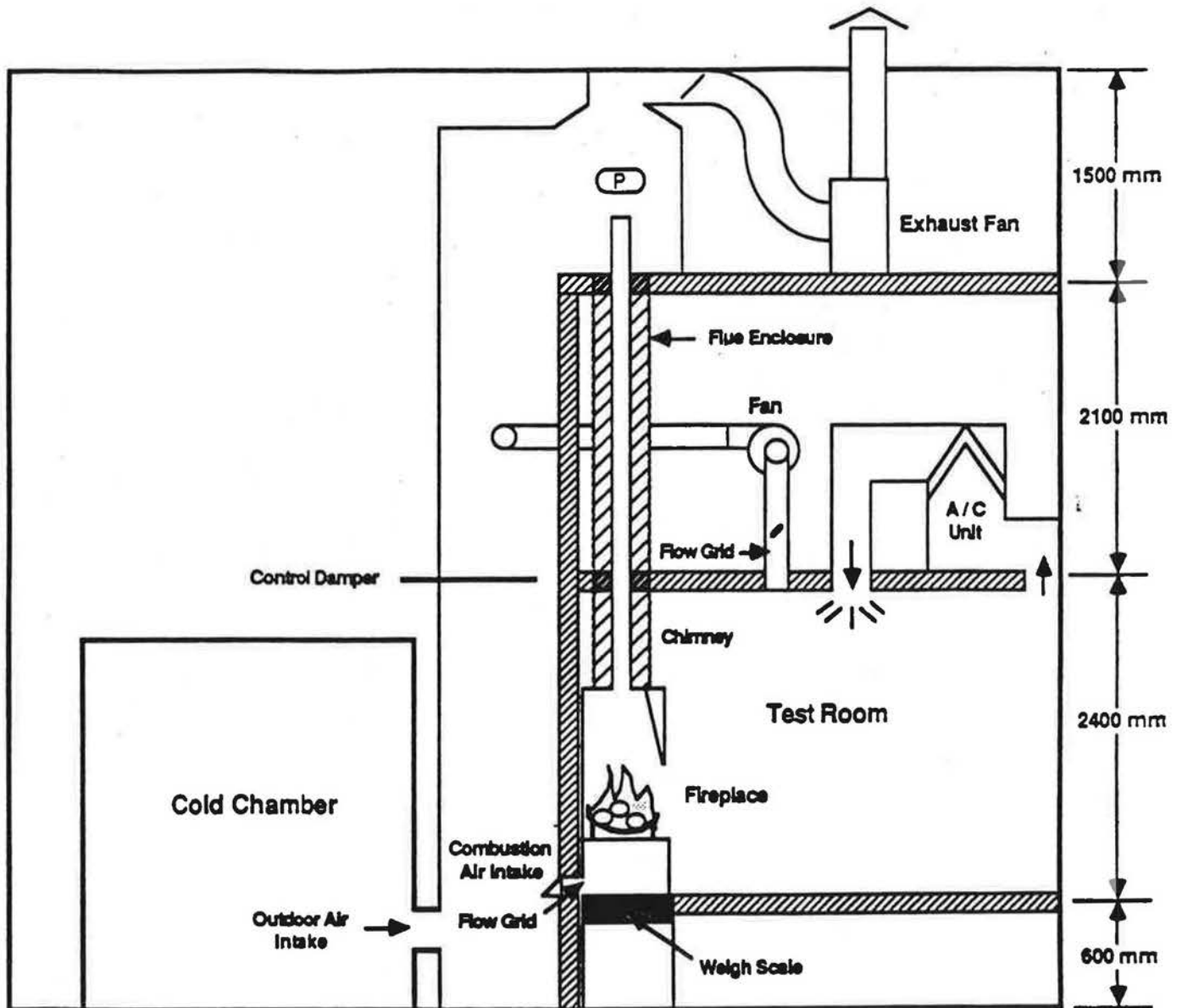
A standard factory-built fireplace designed for use with an air-cooled chimney was used for all of the chimney tests. The fireplace was installed in ORTECH's fireplace test facility shown in Figure 1. The fireplace was instrumented with thermocouples on the

inside surface of the fire chamber, and on the inlet and outlet of the circulation air plenum.

Thermocouples were installed on each of the test chimneys at a number of points. The chimneys were constructed from 0.91 m sections. Sets of thermocouples were placed 0.1 m from the base of each section, at a height of 1.2 m, and 0.1 m from the top of the chimney. Each set of thermocouples consisted of one placed in the centre of the flue, one mounted on the inside surface of the flue, and one mounted on the outside surface of the flue. Chimney A was tested as an inside chimney, installed in a flue enclosure, and as an outside chimney without an enclosure. Chimney B was tested as an inside chimney only, and chimney C was tested as an outside chimney only. For the outside installation, a 30 degree elbow of the same construction as the chimney was installed on the fireplace outlet, followed by 1.2 m of chimney to a second 30 degree elbow outside of the test room. From there, the chimney went straight up, along the outside of the test room in the outdoor air plenum. Figure 2 shows diagrams of the inside and outside installations.

#### 4.0 RESULTS OF CHIMNEY TESTS

The air-cooled chimney had some operating characteristics which were different from the type A and 650 chimneys. In general, the outside surface temperature of the type A and 650 chimneys decreases with height, as shown in Figure 3. With the air-cooled chimney, there was an initial increase in outside temperature with height, as shown in Figure 4. This increase was partially attributed to an increase in the temperature of the cooling air inside the chimney as it travelled up through the chimney.



**(P)** Pressure Measurement Point

**Figure 1: Cross Section of Fireplace Test Facility**

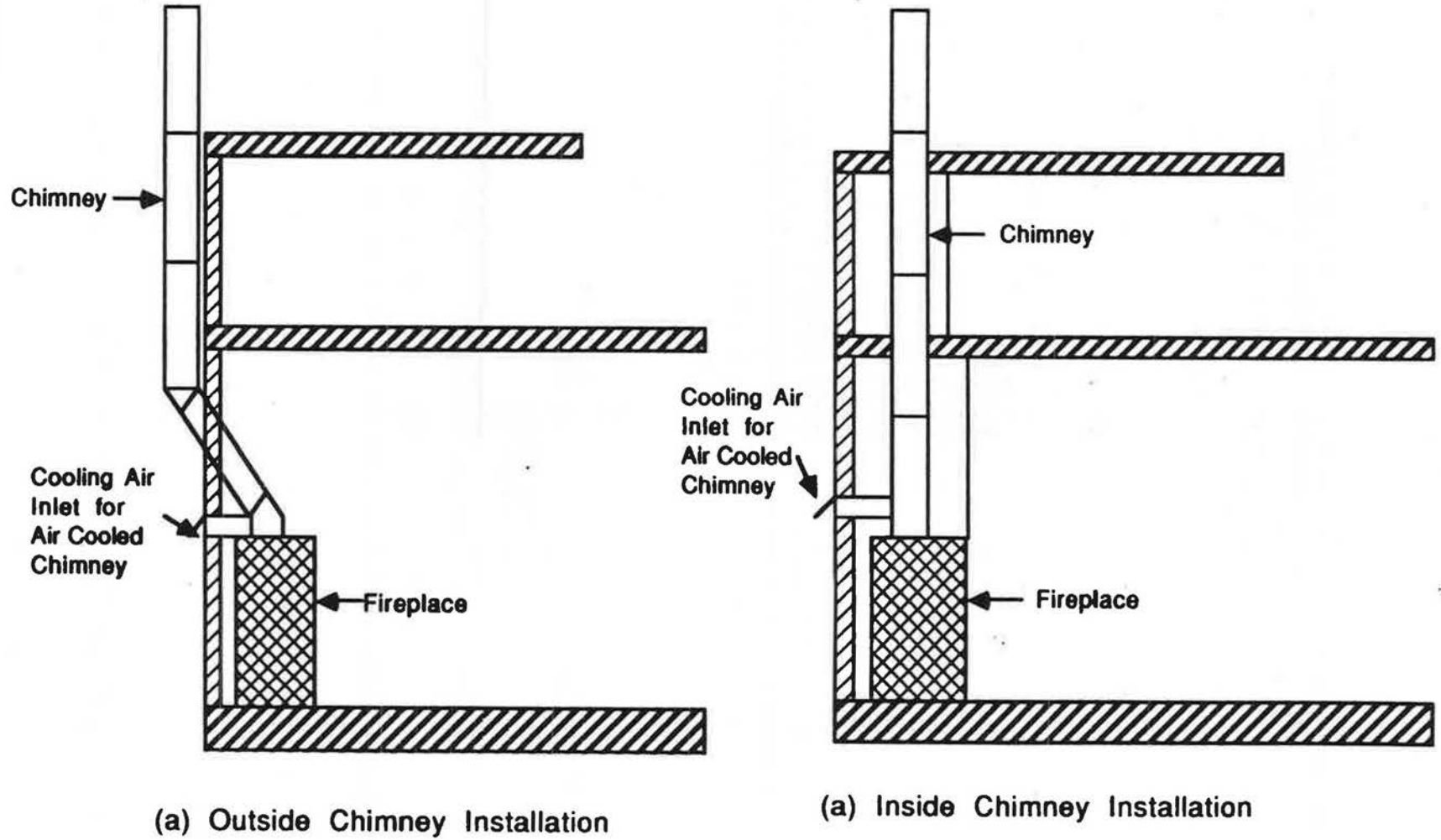
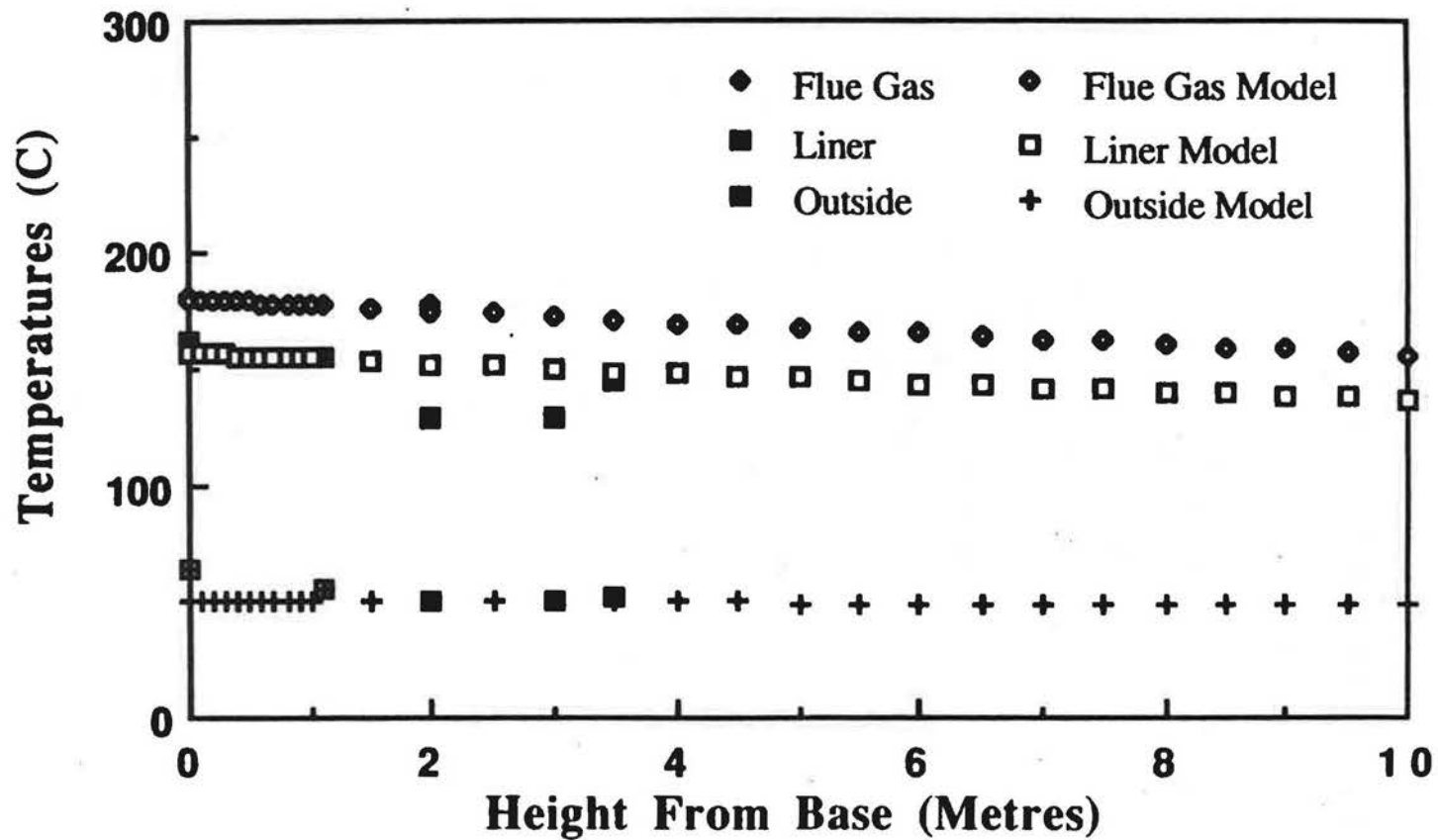


Figure 2: Diagrams of Chimney Installations

**Figure 3: Type A Chimney Temperatures**



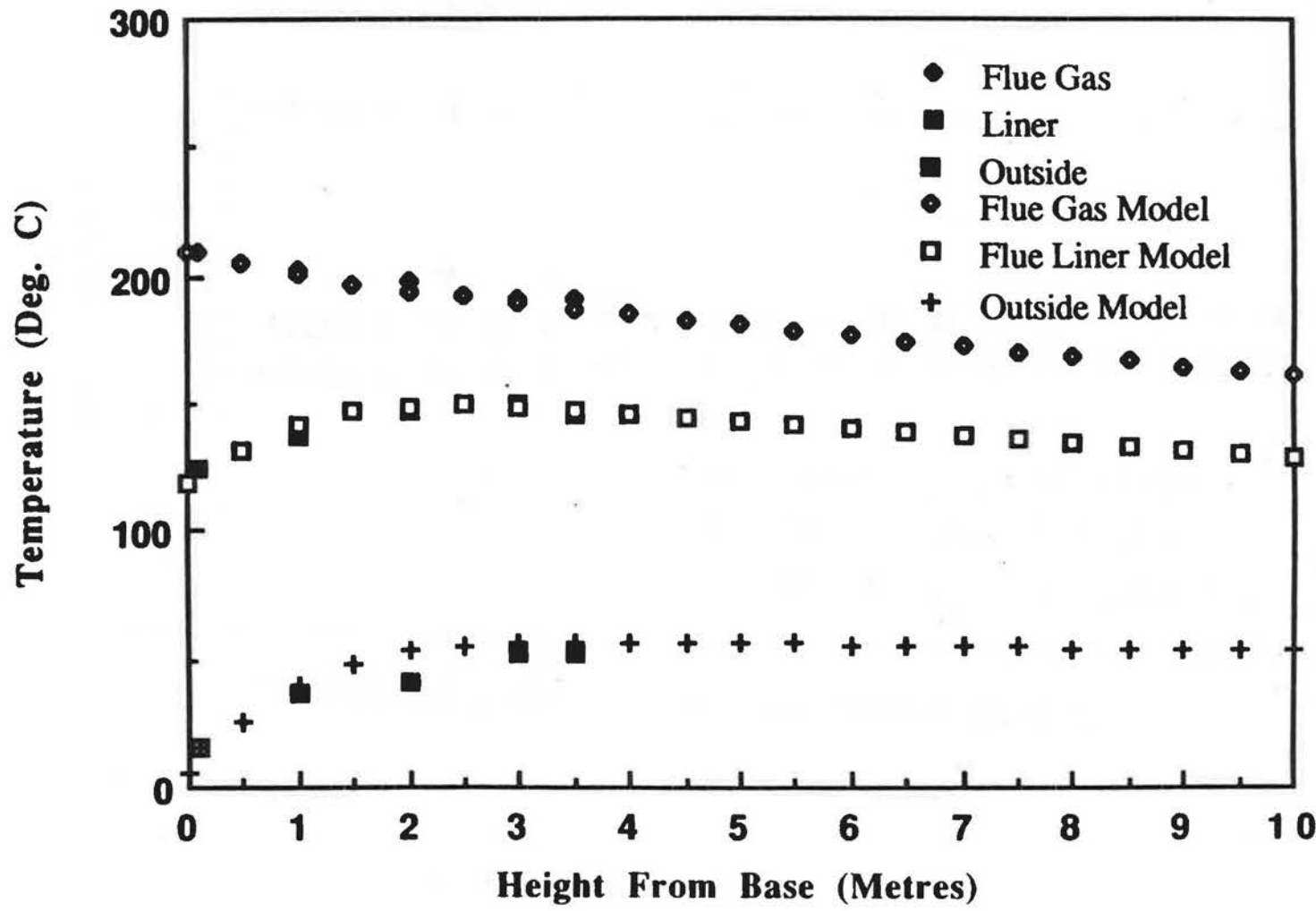


Figure 4: Aircooled Chimney Temperatures



The cooling airflow up the air-cooled chimney appeared to be in the range of 5 to 9 L/s for most cases. This would give an average velocity of 0.12 to 0.2 m/s compared to flue gas velocities in the order of 2 to 3 m/s. When the fire is burning, the mass flow rate of the cooling air is about 0.1 of the flue gas flow rate. Therefore, the heat given up from the flue gas by a temperature drop of 1°C would raise the temperature of the cooling air by 10°C. Figure 5 shows temperature in the air-cooled chimney for various cooling air temperatures, outdoor temperatures and flue flow rate. In 5(a), (b) and (c) the flue gas mass flow rate is about seven times the cooling air mass flow rate. In 5(a), in the first one metre of the chimney, the cooling air temperature increases by 73°C, while the flue gas temperature drops by 10°C. In 5(d) the flue gas to cooling air mass flow ratio is 28:1. In this case a cooling temperature rise of 52°C corresponds to a flue gas temperature drop of about 20°C. Going from a cooling air inlet temperature of 20°C down to a temperature of -40°C results in about a 4°C lower flue gas temperature. With the air-cooled chimney, the outside surface temperature at the base of the chimney is lower than that of the insulated chimneys. Therefore, heat loss from the chimney to the surroundings is lower for the air-cooled chimney. The cooling air entering the chimney is partially heated by energy that is conducted out through the wall of an insulated chimney. Figure 6 shows the projected energy flows for the insulated and air-cooled chimneys.

The overall heat transfer coefficient (U-value) was estimated for each of the chimneys by use of a simplified heat loss model. The heat loss was calculated using the equation:

$$Q = UA\Delta T$$

where Q is heat loss in watts

U is heat transfer coefficient W/(m<sup>2</sup>C)

A is area m<sup>2</sup>

$\Delta T$  is temperature difference between two points

Appendix 1 contains sample printouts of the equations used for the model in a computer spreadsheet format. Values of U were estimated from information in the ASHRAE Handbook of Fundamentals. Temperatures on flue surfaces, outside surfaces, and temperature drop of the flue gas due to heat loss were then calculated, and values compared with the experimental results. Using this method, it was estimated that the overall U-values for the 3 chimneys, based on inside surface area, are as follows:

|            |  |
|------------|--|
| Air-cooled | $U = 6.5 \text{ W}/(\text{m}^2\text{C})$ |
| Type A     | $U = 4 \text{ W}/(\text{m}^2\text{C})$   |
| 650        | $U = 2.7 \text{ W}/(\text{m}^2\text{C})$ |

These values are approximate, and could easily vary from actual values by  $\pm 0.5 \text{ W}/(\text{m}^2\text{C})$  or more, due to the fluctuating flue gas temperatures and flow rates encountered in the testing.

Appendix 2 contains some sample printouts of the model for each of the chimney types tested. For the insulated chimneys, the heat loss will depend on flue gas flow rate. For the air-cooled chimney, heat loss rate will depend on flue flow rate, cooling airflow rate and cooling air temperature. The interior surface temperatures of the flue in the air-cooled chimney appeared to respond to fluctuations in the flue gas temperature more quickly than the type A or 650 chimneys. The 650 chimney showed the least response of flue surface temperature to flue gas fluctuations.

Figures 7 to 9 show temperature for test runs for each of the chimney types tested.

During cool down, the flue surface temperature of the air-cooled chimney stayed below the flue gas temperature in most cases. In the type A and 650 chimneys, heat stored in the chimneys allowed the flue surface temperature to stay above the flue gas temperature during part of the cool down period.

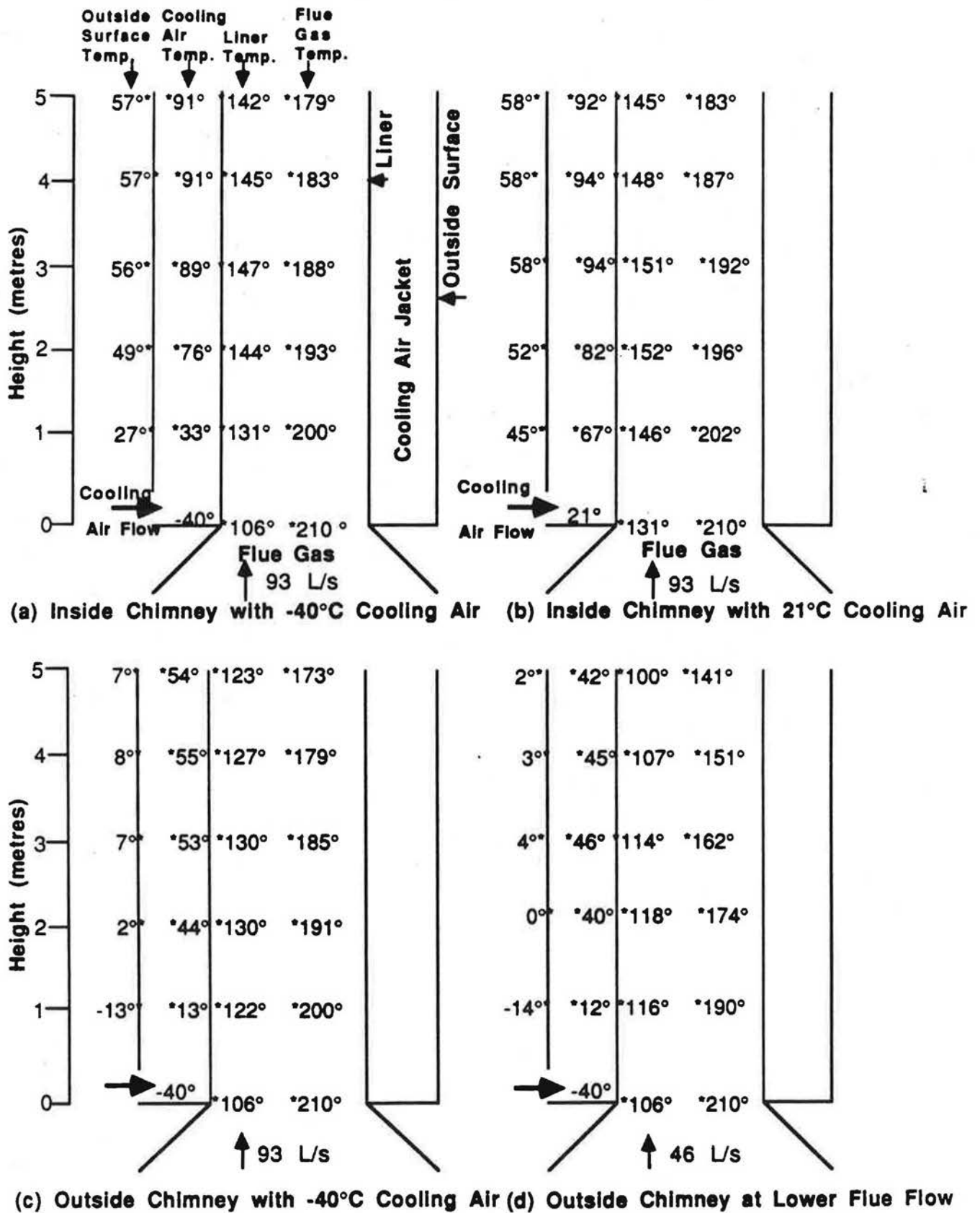
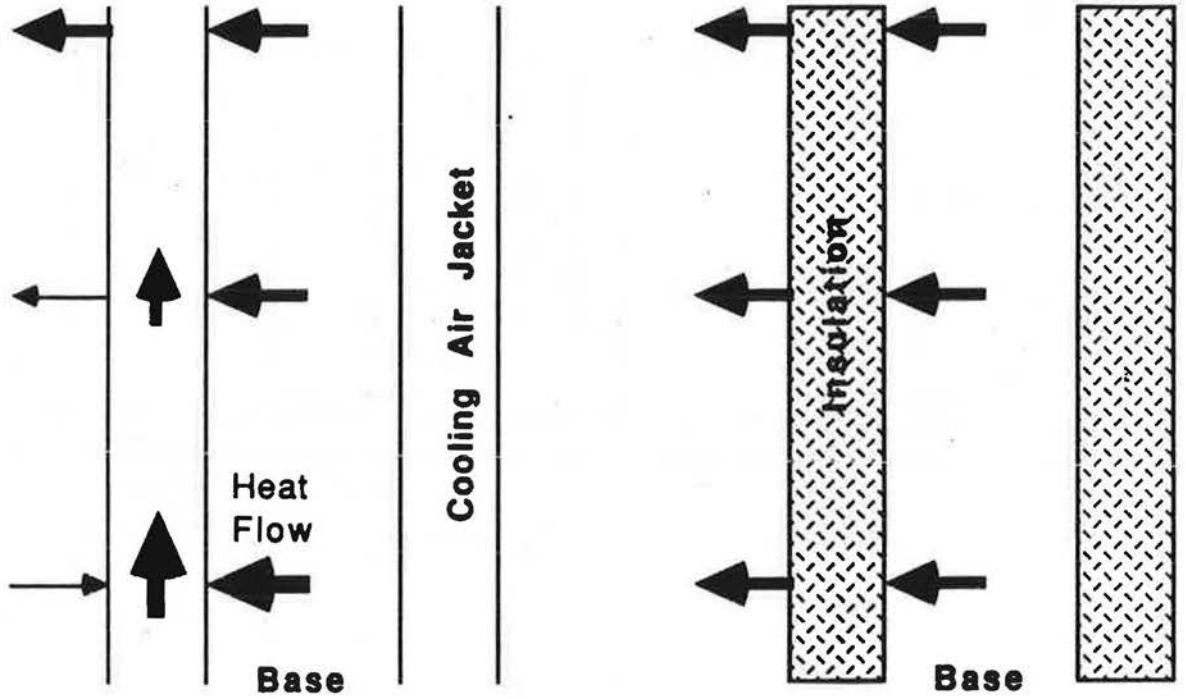


Figure 5: Temperatures in Air Cooled Chimney (from Model)

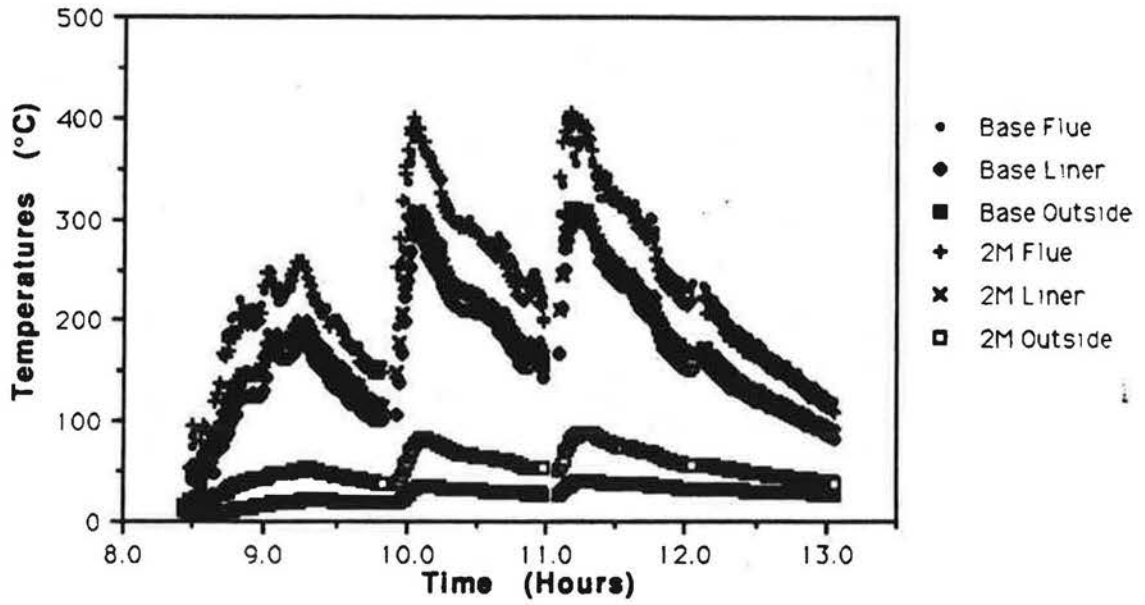


(a) Air Cooled Chimney

(b) Insulated Chimney

**Figure 6: Comparison of Heat Flows In Air-Cooled and Insulated Chimneys**

Figure 7: Temperatures in Air Cooled Chimney (Test 5)



(b) Expanded Section

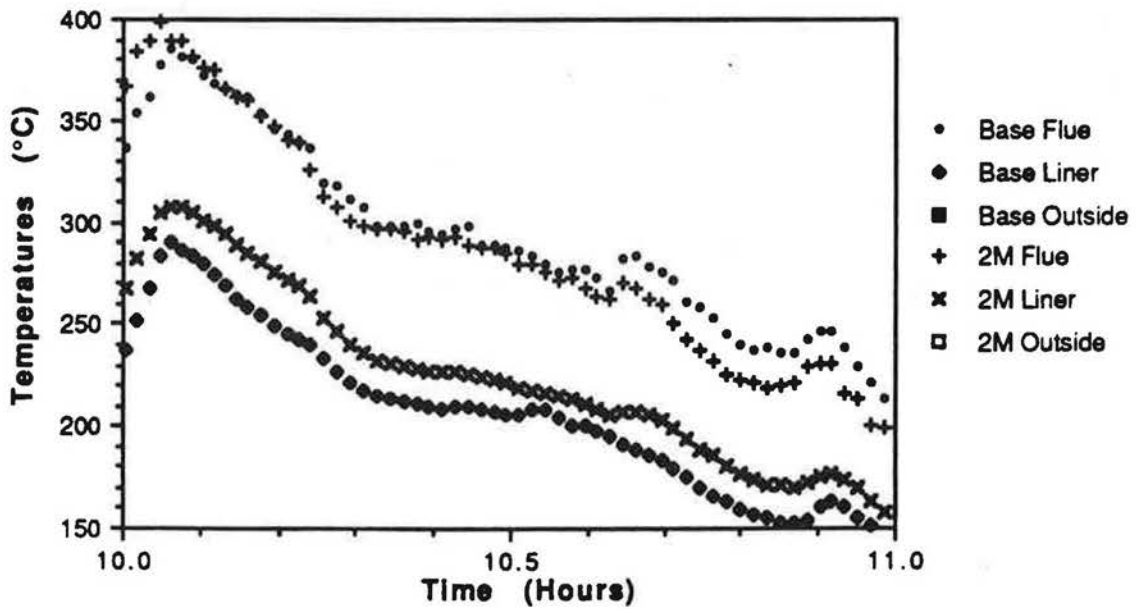
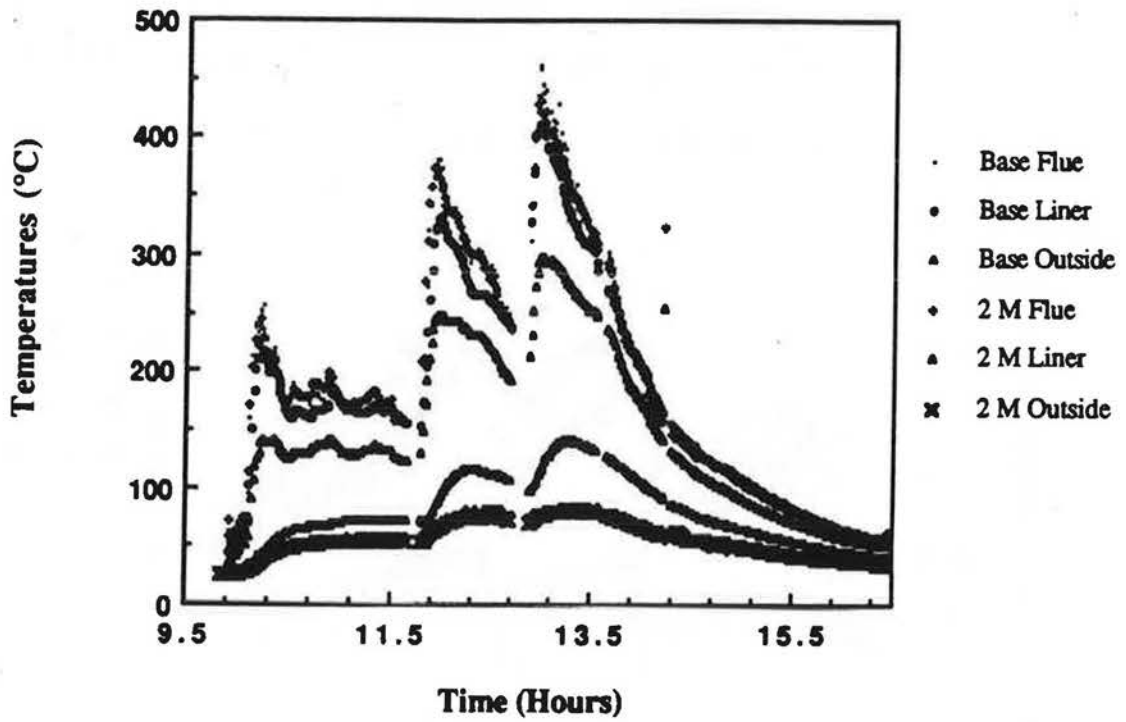


Figure 8: Temperatures In Type A Chimney (Test 7)



(b) Expanded Section

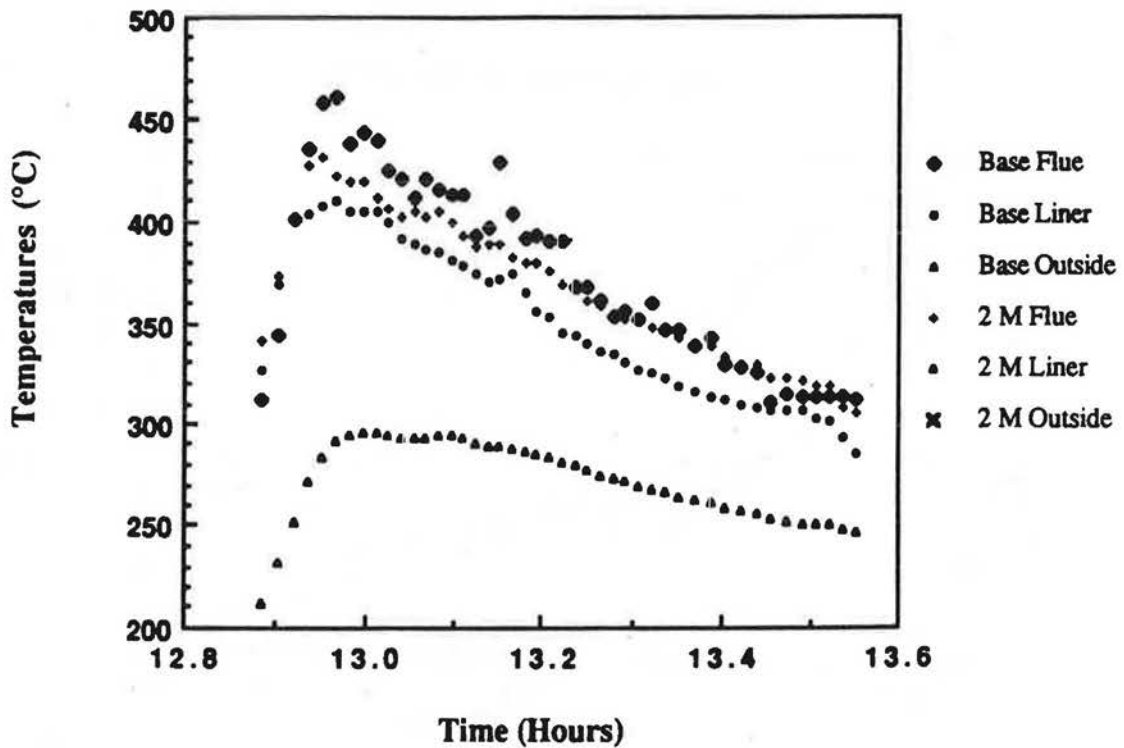
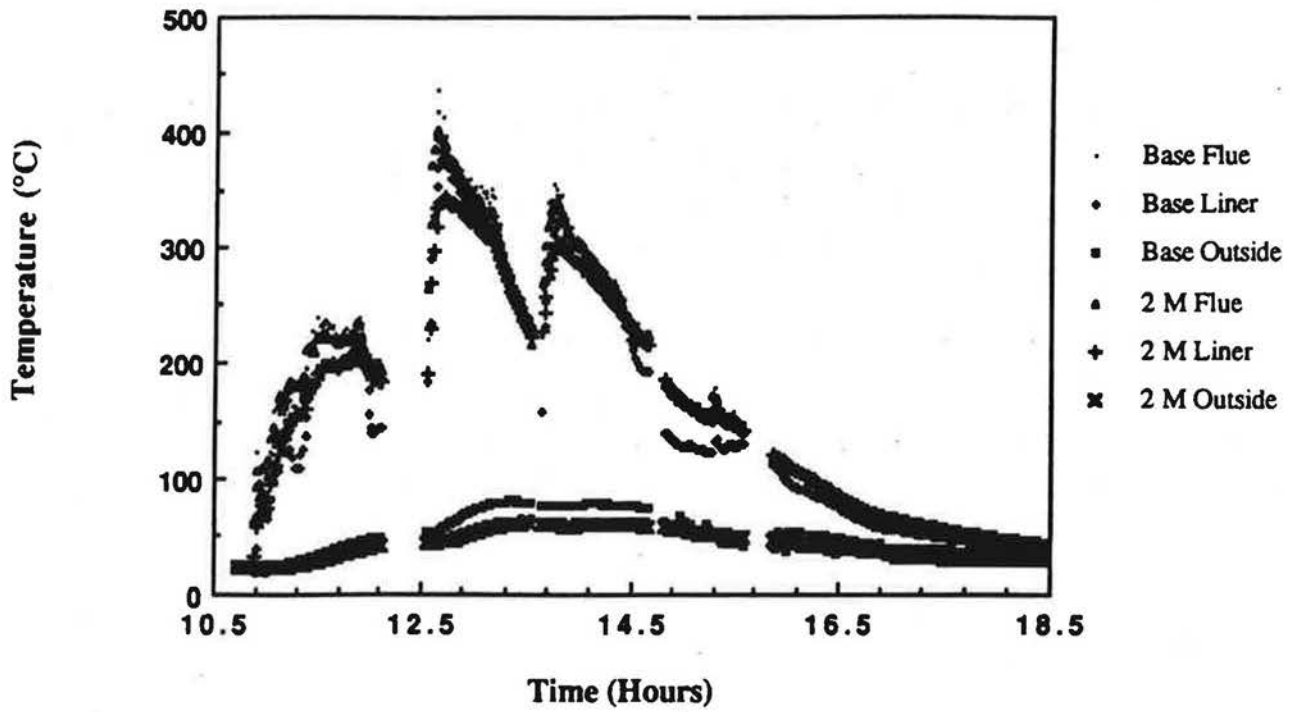
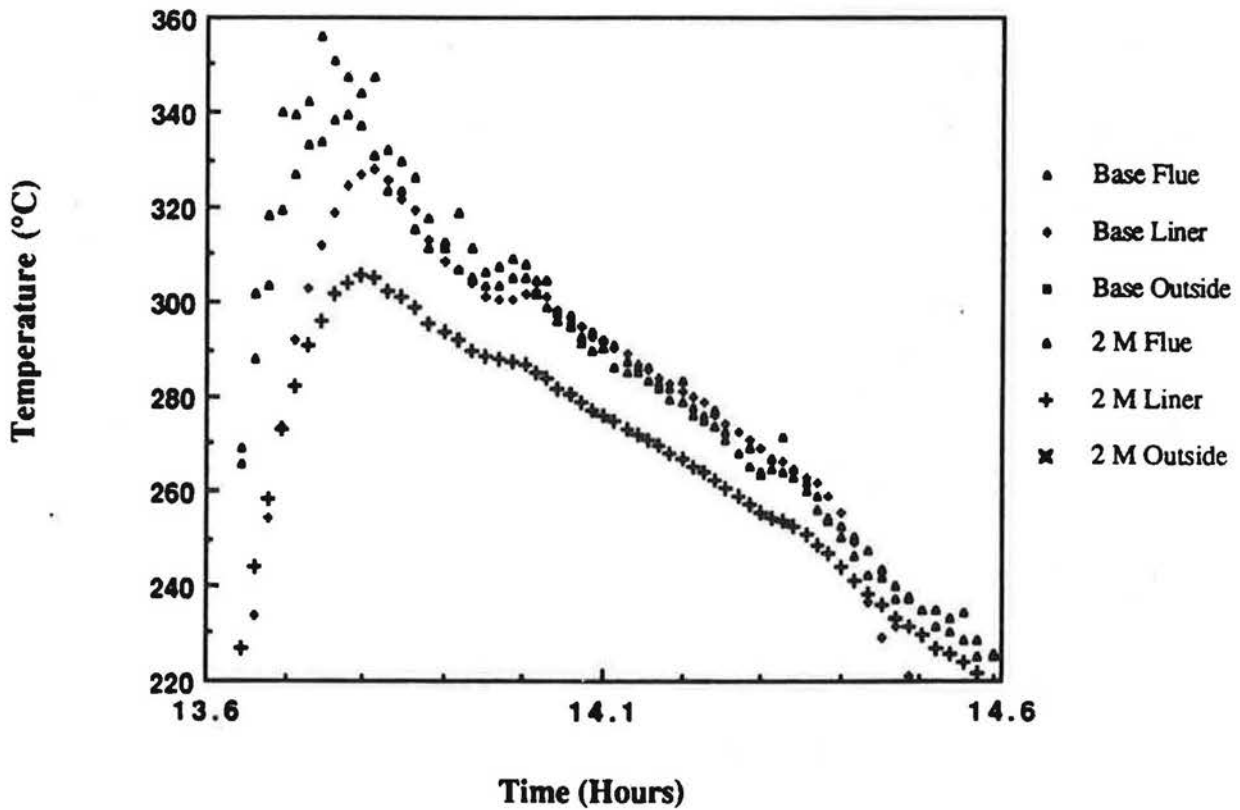


Figure 9: Temperatures in 650 Chimney (Test 11)



(b): Expanded Section



#### 4.0 DISCUSSION OF RESULTS

The air-cooled chimney appears to perform better at high flue mass flow rates, where heat loss from the flue gas does not reduce flue gas temperatures as much as at low flue gas flow rates. This appears to be most appropriate for the operating characteristics of the fireplace used in these tests. If the flue gas temperature is low to begin with, and flue gas flow rates are also low, a significant flue gas temperature drop could occur. This could be a major problem for chimneys connected to wood appliances which can operate at very low burn rates, such as Fireplaces C and D described in ORTECH Report ESC-89-18. The higher heat loss rate of the air-cooled chimney produces lower surface temperatures on the flue liner than for the Type A and 650°C chimneys. This could promote increased formation of creosote deposits on the flue surface. The air-cooled chimney also has less mass for heat storage, which means that flue surface temperatures follow changes in flue gas temperatures more closely than in the Type A and 650°C chimneys. This effect is apparent in the expanded sections of Figures 7, 8 and 9. In the 650°C chimney, the flue liner temperatures change gradually, while for the air-cooled chimney, flue liner temperature fluctuations are much greater. Also, the flue liner temperatures in the air-cooled chimney always stay below the flue gas temperature, even during cool down. For the Type A and 650°C chimneys, the flue gas temperatures and liner temperatures become very close during cool down. In systems where spillage is a problem during cool down, the air-cooled chimney will have a faster reduction in draft during cool down, and therefore will likely be prone to spillage earlier in the cool down cycle.

Another factor resulting from the higher heat loss rate of the air-cooled chimney is the higher exterior surface temperatures of this chimney near the top, as compared to the Type A and 650°C chimneys. With the insulated chimneys, the highest exterior temperatures occur at the base of the chimney. For the air-cooled chimney, the highest exterior temperatures will more likely occur about 3 metres above the base of the flue. Therefore, chimney enclosure construction might need to be different for the air-cooled chimney, as compared to insulated chimneys.

The results of this work might be useful in conjunction with computer simulator models for predicting performance at conditions other than those tested.



**APPENDIX 1**

**EQUATIONS USED IN CHIMNEY MODEL**

Air-Cooled Chimney Model

|    | A            | B                                     | C                              | D           | E  |
|----|--------------|---------------------------------------|--------------------------------|-------------|--|
| 3  |              |                                       |                                |             | 12   |
| 4  | Height Above | Flue Gas,                             | Cooling air                    | Outdoor air | Flue Liner                                     |
| 5  | Base M       | Temp C                                | Temp C                         | Temp C      | Temp C   |
| 6  | 0            | 210                                   | 20                             | 21          | $-B6-16/(E\$3*(A7-A6)*PI()*(8*25.4)/1000)$     |
| 7  | $-A6+0.1$    | $-B6-(16/(G6*293/(B\$6+273)*1.2))$    | $-C6+((16-J6)/(H6*1.2)-D6+0.1$ | $-D6+0.1$   | $-B7-17/(E\$3*(A8-A7)*PI()*(8*25.4)/1000)$     |
| 8  | $-A7+0.1$    | $-B7-(17/(G7*293/(B\$6+273)*1.2))$    | $-C7+((17-J7)/(H7*1.2)-D7+0.1$ | $-D7+0.1$   | $-B8-18/(E\$3*(A9-A8)*PI()*(8*25.4)/1000)$     |
| 9  | $-A8+0.1$    | $-B8-(18/(G8*293/(B\$6+273)*1.2))$    | $-C8+((18-J8)/(H8*1.2)-D8+0.1$ | $-D8+0.1$   | $-B9-19/(E\$3*(A10-A9)*PI()*(8*25.4)/1000)$    |
| 10 | $-A9+0.1$    | $-B9-(19/(G9*293/(B\$6+273)*1.2))$    | $-C9+((19-J9)/(H9*1.2)-D9+0.1$ | $-D9+0.1$   | $-B10-110/(E\$3*(A11-A10)*PI()*(8*25.4)/1000)$ |
| 11 | $-A10+0.1$   | $-B10-(110/(G10*293/(B\$6+273)*1.2))$ | $-C10+((110-J10)/(H10-D10+0.1$ | $-D10+0.1$  | $-B11-111/(E\$3*(A12-A11)*PI()*(8*25.4)/1000)$ |
| 12 | $-A11+0.1$   | $-B11-(111/(G11*293/(B\$6+273)*1.2))$ | $-C11+((111-J11)/(H11-D11+0.1$ | $-D11+0.1$  | $-B12-112/(E\$3*(A13-A12)*PI()*(8*25.4)/1000)$ |
| 13 | $-A12+0.1$   | $-B12-(112/(G12*293/(B\$6+273)*1.2))$ | $-C12+((112-J12)/(H12-D12+0.1$ | $-D12+0.1$  | $-B13-113/(E\$3*(A14-A13)*PI()*(8*25.4)/1000)$ |
| 14 | $-A13+0.1$   | $-B13-(113/(G13*293/(B\$6+273)*1.2))$ | $-C13+((113-J13)/(H13-D13+0.1$ | $-D13+0.1$  | $-B14-114/(E\$3*(A15-A14)*PI()*(8*25.4)/1000)$ |
| 15 | $-A14+0.1$   | $-B14-(114/(G14*293/(B\$6+273)*1.2))$ | $-C14+((114-J14)/(H14-D14+0.1$ | $-D14+0.1$  | $-B15-115/(E\$3*(A16-A15)*PI()*(8*25.4)/1000)$ |
| 16 | $-A15+0.1$   | $-B15-(115/(G15*293/(B\$6+273)*1.2))$ | $-C15+((115-J15)/(H15-D15+0.1$ | $-D15+0.1$  | $-B16-116/(E\$3*(A17-A16)*PI()*(8*25.4)/1000)$ |
| 17 | $-A16+0.5$   | $-B16-(116/(G16*293/(B\$6+273)*1.2))$ | $-C16+((116-J16)/(H16-D16+0.1$ | $-D16+0.1$  | $-B17-117/(E\$3*(A18-A17)*PI()*(8*25.4)/1000)$ |
| 18 | $-A17+0.5$   | $-B17-(117/(G17*293/(B\$6+273)*1.2))$ | $-C17+((117-J17)/(H17-D17+0.1$ | $-D17+0.1$  | $-B18-118/(E\$3*(A19-A18)*PI()*(8*25.4)/1000)$ |
| 19 | $-A18+0.5$   | $-B18-(118/(G18*293/(B\$6+273)*1.2))$ | $-C18+((118-J18)/(H18-D18+0.1$ | $-D18+0.1$  | $-B19-119/(E\$3*(A20-A19)*PI()*(8*25.4)/1000)$ |
| 20 | $-A19+0.5$   | $-B19-(119/(G19*293/(B\$6+273)*1.2))$ | $-C19+((119-J19)/(H19-D19+0.1$ | $-D19+0.1$  | $-B20-120/(E\$3*(A21-A20)*PI()*(8*25.4)/1000)$ |
| 21 | $-A20+0.5$   | $-B20-(120/(G20*293/(B\$6+273)*1.2))$ | $-C20+((120-J20)/(H20-D20+0.1$ | $-D20+0.1$  | $-B21-121/(E\$3*(A22-A21)*PI()*(8*25.4)/1000)$ |
| 22 | $-A21+0.5$   | $-B21-(121/(G21*293/(B\$6+273)*1.2))$ | $-C21+((121-J21)/(H21-D21+0.1$ | $-D21+0.1$  | $-B22-122/(E\$3*(A23-A22)*PI()*(8*25.4)/1000)$ |
| 23 | $-A22+0.5$   | $-B22-(122/(G22*293/(B\$6+273)*1.2))$ | $-C22+((122-J22)/(H22-D22+0.1$ | $-D22+0.1$  | $-B23-123/(E\$3*(A24-A23)*PI()*(8*25.4)/1000)$ |
| 24 | $-A23+0.5$   | $-B23-(123/(G23*293/(B\$6+273)*1.2))$ | $-C23+((123-J23)/(H23-D23+0.1$ | $-D23+0.1$  | $-B24-124/(E\$3*(A25-A24)*PI()*(8*25.4)/1000)$ |
| 25 | $-A24+0.5$   | $-B24-(124/(G24*293/(B\$6+273)*1.2))$ | $-C24+((124-J24)/(H24-D24+0.1$ | $-D24+0.1$  | $-B25-125/(E\$3*(A26-A25)*PI()*(8*25.4)/1000)$ |
| 26 | $-A25+0.5$   | $-B25-(125/(G25*293/(B\$6+273)*1.2))$ | $-C25+((125-J25)/(H25-D25+0.1$ | $-D25+0.1$  | $-B26-126/(E\$3*(A27-A26)*PI()*(8*25.4)/1000)$ |
| 27 | $-A26+0.5$   | $-B26-(126/(G26*293/(B\$6+273)*1.2))$ | $-C26+((126-J26)/(H26-D26+0.1$ | $-D26+0.1$  | $-B27-127/(E\$3*(A28-A27)*PI()*(8*25.4)/1000)$ |
| 28 | $-A27+0.5$   | $-B27-(127/(G27*293/(B\$6+273)*1.2))$ | $-C27+((127-J27)/(H27-D27+0.1$ | $-D27+0.1$  | $-B28-128/(E\$3*(A29-A28)*PI()*(8*25.4)/1000)$ |
| 29 | $-A28+0.5$   | $-B28-(128/(G28*293/(B\$6+273)*1.2))$ | $-C28+((128-J28)/(H28-D28+0.1$ | $-D28+0.1$  | $-B29-129/(E\$3*(A30-A29)*PI()*(8*25.4)/1000)$ |
| 30 | $-A29+0.5$   | $-B29-(129/(G29*293/(B\$6+273)*1.2))$ | $-C29+((129-J29)/(H29-D29+0.1$ | $-D29+0.1$  | $-B30-130/(E\$3*(A31-A30)*PI()*(8*25.4)/1000)$ |
| 31 | $-A30+0.5$   | $-B30-(130/(G30*293/(B\$6+273)*1.2))$ | $-C30+((130-J30)/(H30-D30+0.1$ | $-D30+0.1$  | $-B31-131/(E\$3*(A32-A31)*PI()*(8*25.4)/1000)$ |
| 32 | $-A31+0.5$   | $-B31-(131/(G31*293/(B\$6+273)*1.2))$ | $-C31+((131-J31)/(H31-D31+0.1$ | $-D31+0.1$  | $-B32-132/(E\$3*(A33-A32)*PI()*(8*25.4)/1000)$ |
| 33 | $-A32+0.5$   | $-B32-(132/(G32*293/(B\$6+273)*1.2))$ | $-C32+((132-J32)/(H32-D32+0.1$ | $-D32+0.1$  | $-B33-133/(E\$3*(A34-A33)*PI()*(8*25.4)/1000)$ |
| 34 | $-A33+0.5$   | $-B33-(133/(G33*293/(B\$6+273)*1.2))$ | $-C33+((133-J33)/(H33-D33+0.1$ | $-D33+0.1$  | $-B34-134/(E\$3*(A35-A34)*PI()*(8*25.4)/1000)$ |
| 35 | $-A34+0.5$   | $-B34-(134/(G34*293/(B\$6+273)*1.2))$ | $-C34+((134-J34)/(H34-D34+0.1$ | $-D34+0.1$  | $-B35-135/(E\$3*(A36-A35)*PI()*(8*25.4)/1000)$ |
| 36 | $-A35+0.5$   | $-B35-(135/(G35*293/(B\$6+273)*1.2))$ | $-C35+((135-J35)/(H35-D35+0.1$ | $-D35+0.1$  | $-B36-136/(E\$3*(A37-A36)*PI()*(8*25.4)/1000)$ |
| 37 | $-A36+0.5$   | $-B36-(136/(G36*293/(B\$6+273)*1.2))$ | $-C36+((136-J36)/(H36-D36+0.1$ | $-D36+0.1$  | $-B37-137/(E\$3*(A38-A37)*PI()*(8*25.4)/1000)$ |
| 38 | $-A37+0.5$   | $-B37-(137/(G37*293/(B\$6+273)*1.2))$ | $-C37+((137-J37)/(H37-D37+0.1$ | $-D37+0.1$  | $-B38-138/(E\$3*(A39-A38)*PI()*(8*25.4)/1000)$ |
| 39 | $-A38+0.5$   | $-B38-(138/(G38*293/(B\$6+273)*1.2))$ | $-C38+((138-J38)/(H38-D38+0.1$ | $-D38+0.1$  | $-B39-139/(E\$3*(A40-A39)*PI()*(8*25.4)/1000)$ |
| 40 | $-A39+0.5$   | $-B39-(139/(G39*293/(B\$6+273)*1.2))$ | $-C39+((139-J39)/(H39-D39+0.1$ | $-D39+0.1$  | $-B40-140/(E\$3*(A41-A40)*PI()*(8*25.4)/1000)$ |
| 41 | $-A40+0.5$   | $-B40-(140/(G40*293/(B\$6+273)*1.2))$ | $-C40+((140-J40)/(H40-D40+0.1$ | $-D40+0.1$  | $-B41-141/(E\$3*(A42-A41)*PI()*(8*25.4)/1000)$ |
| 42 | $-A41+0.5$   | $-B41-(141/(G41*293/(B\$6+273)*1.2))$ | $-C41+((141-J41)/(H41-D41+0.1$ | $-D41+0.1$  | $-B42-142/(E\$3*(A43-A42)*PI()*(8*25.4)/1000)$ |
| 43 | $-A42+0.5$   | $-B42-(142/(G42*293/(B\$6+273)*1.2))$ | $-C42+((142-J42)/(H42-D42+0.1$ | $-D42+0.1$  | $-B43-143/(E\$3*(A44-A43)*PI()*(8*25.4)/1000)$ |
| 44 | $-A43+0.5$   | $-B43-(143/(G43*293/(B\$6+273)*1.2))$ | $-C43+((143-J43)/(H43-D43+0.1$ | $-D43+0.1$  | $-B44-144/(E\$3*(A45-A44)*PI()*(8*25.4)/1000)$ |
| 45 | $-A44+0.5$   | $-B44-(144/(G44*293/(B\$6+273)*1.2))$ | $-C44+((144-J44)/(H44-D44+0.1$ | $-D44+0.1$  | $-B45-145/(E\$3*(A46-A45)*PI()*(8*25.4)/1000)$ |

Air-Cooled Chimney Model

|    | F            | G         | H            | I  | J   |
|----|--------------|-----------|--------------|--|---|
| 3  |              |           |              | Ui=6.5   | Uo=4.5  |
| 4  | Outside Surf | Flue Flow | Cooling Flow | Heat Loss                                      | Exterior  |
| 5  | Temp C       | L/s       | L/s          | Watts  | Heat loss                                       |
| 6  | =(C6+D6)/2   | =93/2     | 8            | =\$I\$2*(B6-C6)*(A7-A6)*PI()*(8*25.4)/1000     | =\$J\$2*(A7-A6)*PI()*(12*25.4/1000)*(C6-D6)     |
| 7  | =(C7+D7)/2   | =G\$6     | =H\$6        | =\$I\$2*(B7-C7)*(A8-A7)*PI()*(8*25.4)/1000     | =\$J\$2*(A8-A7)*PI()*(12*25.4/1000)*(C7-D7)     |
| 8  | =(C8+D8)/2   | =G\$6     | =H\$6        | =\$I\$2*(B8-C8)*(A9-A8)*PI()*(8*25.4)/1000     | =\$J\$2*(A9-A8)*PI()*(12*25.4/1000)*(C8-D8)     |
| 9  | =(C9+D9)/2   | =G\$6     | =H\$6        | =\$I\$2*(B9-C9)*(A10-A9)*PI()*(8*25.4)/1000    | =\$J\$2*(A10-A9)*PI()*(12*25.4/1000)*(C9-D9)    |
| 10 | =(C10+D10)/2 | =G\$6     | =H\$6        | =\$I\$2*(B10-C10)*(A11-A10)*PI()*(8*25.4)/1000 | =\$J\$2*(A11-A10)*PI()*(12*25.4/1000)*(C10-D10) |
| 11 | =(C11+D11)/2 | =G\$6     | =H\$6        | =\$I\$2*(B11-C11)*(A12-A11)*PI()*(8*25.4)/1000 | =\$J\$2*(A12-A11)*PI()*(12*25.4/1000)*(C11-D11) |
| 12 | =(C12+D12)/2 | =G\$6     | =H\$6        | =\$I\$2*(B12-C12)*(A13-A12)*PI()*(8*25.4)/1000 | =\$J\$2*(A13-A12)*PI()*(12*25.4/1000)*(C12-D12) |
| 13 | =(C13+D13)/2 | =G\$6     | =H\$6        | =\$I\$2*(B13-C13)*(A14-A13)*PI()*(8*25.4)/1000 | =\$J\$2*(A14-A13)*PI()*(12*25.4/1000)*(C13-D13) |
| 14 | =(C14+D14)/2 | =G\$6     | =H\$6        | =\$I\$2*(B14-C14)*(A15-A14)*PI()*(8*25.4)/1000 | =\$J\$2*(A15-A14)*PI()*(12*25.4/1000)*(C14-D14) |
| 15 | =(C15+D15)/2 | =G\$6     | =H\$6        | =\$I\$2*(B15-C15)*(A16-A15)*PI()*(8*25.4)/1000 | =\$J\$2*(A16-A15)*PI()*(12*25.4/1000)*(C15-D15) |
| 16 | =(C16+D16)/2 | =G\$6     | =H\$6        | =\$I\$2*(B16-C16)*(A17-A16)*PI()*(8*25.4)/1000 | =\$J\$2*(A17-A16)*PI()*(12*25.4/1000)*(C16-D16) |
| 17 | =(C17+D17)/2 | =G\$6     | =H\$6        | =\$I\$2*(B17-C17)*(A18-A17)*PI()*(8*25.4)/1000 | =\$J\$2*(A18-A17)*PI()*(12*25.4/1000)*(C17-D17) |
| 18 | =(C18+D18)/2 | =G\$6     | =H\$6        | =\$I\$2*(B18-C18)*(A19-A18)*PI()*(8*25.4)/1000 | =\$J\$2*(A19-A18)*PI()*(12*25.4/1000)*(C18-D18) |
| 19 | =(C19+D19)/2 | =G\$6     | =H\$6        | =\$I\$2*(B19-C19)*(A20-A19)*PI()*(8*25.4)/1000 | =\$J\$2*(A20-A19)*PI()*(12*25.4/1000)*(C19-D19) |
| 20 | =(C20+D20)/2 | =G\$6     | =H\$6        | =\$I\$2*(B20-C20)*(A21-A20)*PI()*(8*25.4)/1000 | =\$J\$2*(A21-A20)*PI()*(12*25.4/1000)*(C20-D20) |
| 21 | =(C21+D21)/2 | =G\$6     | =H\$6        | =\$I\$2*(B21-C21)*(A22-A21)*PI()*(8*25.4)/1000 | =\$J\$2*(A22-A21)*PI()*(12*25.4/1000)*(C21-D21) |
| 22 | =(C22+D22)/2 | =G\$6     | =H\$6        | =\$I\$2*(B22-C22)*(A23-A22)*PI()*(8*25.4)/1000 | =\$J\$2*(A23-A22)*PI()*(12*25.4/1000)*(C22-D22) |
| 23 | =(C23+D23)/2 | =G\$6     | =H\$6        | =\$I\$2*(B23-C23)*(A24-A23)*PI()*(8*25.4)/1000 | =\$J\$2*(A24-A23)*PI()*(12*25.4/1000)*(C23-D23) |
| 24 | =(C24+D24)/2 | =G\$6     | =H\$6        | =\$I\$2*(B24-C24)*(A25-A24)*PI()*(8*25.4)/1000 | =\$J\$2*(A25-A24)*PI()*(12*25.4/1000)*(C24-D24) |
| 25 | =(C25+D25)/2 | =G\$6     | =H\$6        | =\$I\$2*(B25-C25)*(A26-A25)*PI()*(8*25.4)/1000 | =\$J\$2*(A26-A25)*PI()*(12*25.4/1000)*(C25-D25) |
| 26 | =(C26+D26)/2 | =G\$6     | =H\$6        | =\$I\$2*(B26-C26)*(A27-A26)*PI()*(8*25.4)/1000 | =\$J\$2*(A27-A26)*PI()*(12*25.4/1000)*(C26-D26) |
| 27 | =(C27+D27)/2 | =G\$6     | =H\$6        | =\$I\$2*(B27-C27)*(A28-A27)*PI()*(8*25.4)/1000 | =\$J\$2*(A28-A27)*PI()*(12*25.4/1000)*(C27-D27) |
| 28 | =(C28+D28)/2 | =G\$6     | =H\$6        | =\$I\$2*(B28-C28)*(A29-A28)*PI()*(8*25.4)/1000 | =\$J\$2*(A29-A28)*PI()*(12*25.4/1000)*(C28-D28) |
| 29 | =(C29+D29)/2 | =G\$6     | =H\$6        | =\$I\$2*(B29-C29)*(A30-A29)*PI()*(8*25.4)/1000 | =\$J\$2*(A30-A29)*PI()*(12*25.4/1000)*(C29-D29) |
| 30 | =(C30+D30)/2 | =G\$6     | =H\$6        | =\$I\$2*(B30-C30)*(A31-A30)*PI()*(8*25.4)/1000 | =\$J\$2*(A31-A30)*PI()*(12*25.4/1000)*(C30-D30) |
| 31 | =(C31+D31)/2 | =G\$6     | =H\$6        | =\$I\$2*(B31-C31)*(A32-A31)*PI()*(8*25.4)/1000 | =\$J\$2*(A32-A31)*PI()*(12*25.4/1000)*(C31-D31) |
| 32 | =(C32+D32)/2 | =G\$6     | =H\$6        | =\$I\$2*(B32-C32)*(A33-A32)*PI()*(8*25.4)/1000 | =\$J\$2*(A33-A32)*PI()*(12*25.4/1000)*(C32-D32) |
| 33 | =(C33+D33)/2 | =G\$6     | =H\$6        | =\$I\$2*(B33-C33)*(A34-A33)*PI()*(8*25.4)/1000 | =\$J\$2*(A34-A33)*PI()*(12*25.4/1000)*(C33-D33) |
| 34 | =(C34+D34)/2 | =G\$6     | =H\$6        | =\$I\$2*(B34-C34)*(A35-A34)*PI()*(8*25.4)/1000 | =\$J\$2*(A35-A34)*PI()*(12*25.4/1000)*(C34-D34) |
| 35 | =(C35+D35)/2 | =G\$6     | =H\$6        | =\$I\$2*(B35-C35)*(A36-A35)*PI()*(8*25.4)/1000 | =\$J\$2*(A36-A35)*PI()*(12*25.4/1000)*(C35-D35) |
| 36 | =(C36+D36)/2 | =G\$6     | =H\$6        | =\$I\$2*(B36-C36)*(A37-A36)*PI()*(8*25.4)/1000 | =\$J\$2*(A37-A36)*PI()*(12*25.4/1000)*(C36-D36) |
| 37 | =(C37+D37)/2 | =G\$6     | =H\$6        | =\$I\$2*(B37-C37)*(A38-A37)*PI()*(8*25.4)/1000 | =\$J\$2*(A38-A37)*PI()*(12*25.4/1000)*(C37-D37) |
| 38 | =(C38+D38)/2 | =G\$6     | =H\$6        | =\$I\$2*(B38-C38)*(A39-A38)*PI()*(8*25.4)/1000 | =\$J\$2*(A39-A38)*PI()*(12*25.4/1000)*(C38-D38) |
| 39 | =(C39+D39)/2 | =G\$6     | =H\$6        | =\$I\$2*(B39-C39)*(A40-A39)*PI()*(8*25.4)/1000 | =\$J\$2*(A40-A39)*PI()*(12*25.4/1000)*(C39-D39) |
| 40 | =(C40+D40)/2 | =G\$6     | =H\$6        | =\$I\$2*(B40-C40)*(A41-A40)*PI()*(8*25.4)/1000 | =\$J\$2*(A41-A40)*PI()*(12*25.4/1000)*(C40-D40) |
| 41 | =(C41+D41)/2 | =G\$6     | =H\$6        | =\$I\$2*(B41-C41)*(A42-A41)*PI()*(8*25.4)/1000 | =\$J\$2*(A42-A41)*PI()*(12*25.4/1000)*(C41-D41) |
| 42 | =(C42+D42)/2 | =G\$6     | =H\$6        | =\$I\$2*(B42-C42)*(A43-A42)*PI()*(8*25.4)/1000 | =\$J\$2*(A43-A42)*PI()*(12*25.4/1000)*(C42-D42) |
| 43 | =(C43+D43)/2 | =G\$6     | =H\$6        | =\$I\$2*(B43-C43)*(A44-A43)*PI()*(8*25.4)/1000 | =\$J\$2*(A44-A43)*PI()*(12*25.4/1000)*(C43-D43) |
| 44 | =(C44+D44)/2 | =G\$6     | =H\$6        | =\$I\$2*(B44-C44)*(A45-A44)*PI()*(8*25.4)/1000 | =\$J\$2*(A45-A44)*PI()*(12*25.4/1000)*(C44-D44) |
| 45 | =(C45+D45)/2 | =G\$6     | =H\$6        | =\$I\$2*(B45-C45)*(A46-A45)*PI()*(8*25.4)/1000 | =\$J\$2*(A46-A45)*PI()*(12*25.4/1000)*(C45-D45) |

650 Chimney Model

|    | A            | B                                   | C                   | D  |
|----|--------------|-------------------------------------|---------------------|--|
| 3  |              |                                     |                     |  |
| 4  | Height Above | Flue Gas                            | Outdoor air         | Flue Liner                                       |
| 5  | Base M       | Temp C                              | Temp C              | Temp C   |
| 6  | 0            | 180                                 | 25                  | =B6-G6/(D\$2*(\$A7-\$A6)*PI()*(8*25.4)/1000)     |
| 7  | =A6+0.1      | =B6-(G6/(F6*293/(B\$6+273)*1.2))    | =C6+C\$2*(A7-A6)    | =B7-G7/(D\$2*(\$A8-\$A7)*PI()*(8*25.4)/1000)     |
| 8  | =A7+0.1      | =B7-(G7/(F7*293/(B\$6+273)*1.2))    | =C7+C\$2*(A8-A7)    | =B8-G8/(D\$2*(\$A9-\$A8)*PI()*(8*25.4)/1000)     |
| 9  | =A8+0.1      | =B8-(G8/(F8*293/(B\$6+273)*1.2))    | =C8+C\$2*(A9-A8)    | =B9-G9/(D\$2*(\$A10-\$A9)*PI()*(8*25.4)/1000)    |
| 10 | =A9+0.1      | =B9-(G9/(F9*293/(B\$6+273)*1.2))    | =C9+C\$2*(A10-A9)   | =B10-G10/(D\$2*(\$A11-\$A10)*PI()*(8*25.4)/1000) |
| 11 | =A10+0.1     | =B10-(G10/(F10*293/(B\$6+273)*1.2)) | =C10+C\$2*(A11-A10) | =B11-G11/(D\$2*(\$A12-\$A11)*PI()*(8*25.4)/1000) |
| 12 | =A11+0.1     | =B11-(G11/(F11*293/(B\$6+273)*1.2)) | =C11+C\$2*(A12-A11) | =B12-G12/(D\$2*(\$A13-\$A12)*PI()*(8*25.4)/1000) |
| 13 | =A12+0.1     | =B12-(G12/(F12*293/(B\$6+273)*1.2)) | =C12+C\$2*(A13-A12) | =B13-G13/(D\$2*(\$A14-\$A13)*PI()*(8*25.4)/1000) |
| 14 | =A13+0.1     | =B13-(G13/(F13*293/(B\$6+273)*1.2)) | =C13+C\$2*(A14-A13) | =B14-G14/(D\$2*(\$A15-\$A14)*PI()*(8*25.4)/1000) |
| 15 | =A14+0.1     | =B14-(G14/(F14*293/(B\$6+273)*1.2)) | =C14+C\$2*(A15-A14) | =B15-G15/(D\$2*(\$A16-\$A15)*PI()*(8*25.4)/1000) |
| 16 | =A15+0.1     | =B15-(G15/(F15*293/(B\$6+273)*1.2)) | =C15+C\$2*(A16-A15) | =B16-G16/(D\$2*(\$A17-\$A16)*PI()*(8*25.4)/1000) |
| 17 | =A16+0.5     | =B16-(G16/(F16*293/(B\$6+273)*1.2)) | =C16+C\$2*(A17-A16) | =B17-G17/(D\$2*(\$A18-\$A17)*PI()*(8*25.4)/1000) |
| 18 | =A17+0.5     | =B17-(G17/(F17*293/(B\$6+273)*1.2)) | =C17+C\$2*(A18-A17) | =B18-G18/(D\$2*(\$A19-\$A18)*PI()*(8*25.4)/1000) |
| 19 | =A18+0.5     | =B18-(G18/(F18*293/(B\$6+273)*1.2)) | =C18+C\$2*(A19-A18) | =B19-G19/(D\$2*(\$A20-\$A19)*PI()*(8*25.4)/1000) |
| 20 | =A19+0.5     | =B19-(G19/(F19*293/(B\$6+273)*1.2)) | =C19+C\$2*(A20-A19) | =B20-G20/(D\$2*(\$A21-\$A20)*PI()*(8*25.4)/1000) |
| 21 | =A20+0.5     | =B20-(G20/(F20*293/(B\$6+273)*1.2)) | =C20+C\$2*(A21-A20) | =B21-G21/(D\$2*(\$A22-\$A21)*PI()*(8*25.4)/1000) |
| 22 | =A21+0.5     | =B21-(G21/(F21*293/(B\$6+273)*1.2)) | =C21+C\$2*(A22-A21) | =B22-G22/(D\$2*(\$A23-\$A22)*PI()*(8*25.4)/1000) |
| 23 | =A22+0.5     | =B22-(G22/(F22*293/(B\$6+273)*1.2)) | =C22+C\$2*(A23-A22) | =B23-G23/(D\$2*(\$A24-\$A23)*PI()*(8*25.4)/1000) |
| 24 | =A23+0.5     | =B23-(G23/(F23*293/(B\$6+273)*1.2)) | =C23+C\$2*(A24-A23) | =B24-G24/(D\$2*(\$A25-\$A24)*PI()*(8*25.4)/1000) |
| 25 | =A24+0.5     | =B24-(G24/(F24*293/(B\$6+273)*1.2)) | =C24+C\$2*(A25-A24) | =B25-G25/(D\$2*(\$A26-\$A25)*PI()*(8*25.4)/1000) |
| 26 | =A25+0.5     | =B25-(G25/(F25*293/(B\$6+273)*1.2)) | =C25+C\$2*(A26-A25) | =B26-G26/(D\$2*(\$A27-\$A26)*PI()*(8*25.4)/1000) |
| 27 | =A26+0.5     | =B26-(G26/(F26*293/(B\$6+273)*1.2)) | =C26+C\$2*(A27-A26) | =B27-G27/(D\$2*(\$A28-\$A27)*PI()*(8*25.4)/1000) |
| 28 | =A27+0.5     | =B27-(G27/(F27*293/(B\$6+273)*1.2)) | =C27+C\$2*(A28-A27) | =B28-G28/(D\$2*(\$A29-\$A28)*PI()*(8*25.4)/1000) |
| 29 | =A28+0.5     | =B28-(G28/(F28*293/(B\$6+273)*1.2)) | =C28+C\$2*(A29-A28) | =B29-G29/(D\$2*(\$A30-\$A29)*PI()*(8*25.4)/1000) |
| 30 | =A29+0.5     | =B29-(G29/(F29*293/(B\$6+273)*1.2)) | =C29+C\$2*(A30-A29) | =B30-G30/(D\$2*(\$A31-\$A30)*PI()*(8*25.4)/1000) |
| 31 | =A30+0.5     | =B30-(G30/(F30*293/(B\$6+273)*1.2)) | =C30+C\$2*(A31-A30) | =B31-G31/(D\$2*(\$A32-\$A31)*PI()*(8*25.4)/1000) |
| 32 | =A31+0.5     | =B31-(G31/(F31*293/(B\$6+273)*1.2)) | =C31+C\$2*(A32-A31) | =B32-G32/(D\$2*(\$A33-\$A32)*PI()*(8*25.4)/1000) |
| 33 | =A32+0.5     | =B32-(G32/(F32*293/(B\$6+273)*1.2)) | =C32+C\$2*(A33-A32) | =B33-G33/(D\$2*(\$A34-\$A33)*PI()*(8*25.4)/1000) |
| 34 | =A33+0.5     | =B33-(G33/(F33*293/(B\$6+273)*1.2)) | =C33+C\$2*(A34-A33) | =B34-G34/(D\$2*(\$A35-\$A34)*PI()*(8*25.4)/1000) |
| 35 | =A34+0.5     | =B34-(G34/(F34*293/(B\$6+273)*1.2)) | =C34+C\$2*(A35-A34) | =B35-G35/(D\$2*(\$A36-\$A35)*PI()*(8*25.4)/1000) |
| 36 | =A35+0.5     | =B35-(G35/(F35*293/(B\$6+273)*1.2)) | =C35+C\$2*(A36-A35) | =B36-G36/(D\$2*(\$A37-\$A36)*PI()*(8*25.4)/1000) |
| 37 | =A36+0.5     | =B36-(G36/(F36*293/(B\$6+273)*1.2)) | =C36+C\$2*(A37-A36) | =B37-G37/(D\$2*(\$A38-\$A37)*PI()*(8*25.4)/1000) |
| 38 | =A37+0.5     | =B37-(G37/(F37*293/(B\$6+273)*1.2)) | =C37+C\$2*(A38-A37) | =B38-G38/(D\$2*(\$A39-\$A38)*PI()*(8*25.4)/1000) |
| 39 | =A38+0.5     | =B38-(G38/(F38*293/(B\$6+273)*1.2)) | =C38+C\$2*(A39-A38) | =B39-G39/(D\$2*(\$A40-\$A39)*PI()*(8*25.4)/1000) |
| 40 | =A39+0.5     | =B39-(G39/(F39*293/(B\$6+273)*1.2)) | =C39+C\$2*(A40-A39) | =B40-G40/(D\$2*(\$A41-\$A40)*PI()*(8*25.4)/1000) |
| 41 | =A40+0.5     | =B40-(G40/(F40*293/(B\$6+273)*1.2)) | =C40+C\$2*(A41-A40) | =B41-G41/(D\$2*(\$A42-\$A41)*PI()*(8*25.4)/1000) |
| 42 | =A41+0.5     | =B41-(G41/(F41*293/(B\$6+273)*1.2)) | =C41+C\$2*(A42-A41) | =B42-G42/(D\$2*(\$A43-\$A42)*PI()*(8*25.4)/1000) |
| 43 | =A42+0.5     | =B42-(G42/(F42*293/(B\$6+273)*1.2)) | =C42+C\$2*(A43-A42) | =B43-G43/(D\$2*(\$A44-\$A43)*PI()*(8*25.4)/1000) |
| 44 | =A43+0.5     | =B43-(G43/(F43*293/(B\$6+273)*1.2)) | =C43+C\$2*(A44-A43) | =B44-G44/(D\$2*(\$A45-\$A44)*PI()*(8*25.4)/1000) |
| 45 | =A44+0.5     | =B44-(G44/(F44*293/(B\$6+273)*1.2)) | =C44+C\$2*(A45-A44) | =B45-G45/(D\$2*(\$A46-\$A45)*PI()*(8*25.4)/1000) |

650 Chimney Model

|    | E   | F         | G  |
|----|---|-----------|--|
| 3  |   |           | 2.7  |
| 4  | Outside Surf  | Flue Flow | Heat Loss  |
| 5  | Temp C  | L/s       | Watts  |
| 6  | $-C6+G6/(E\$2*(\$A7-\$A6)*PI()*(12*25.4)/1000)$     | 72        | $-\$G\$2*(B6-C6)*(A7-A6)*PI()*(8*25.4)/1000$     |
| 7  | $-C7+G7/(E\$2*(\$A8-\$A7)*PI()*(12*25.4)/1000)$     | -F\$6     | $-\$G\$2*(B7-C7)*(A8-A7)*PI()*(8*25.4)/1000$     |
| 8  | $-C8+G8/(E\$2*(\$A9-\$A8)*PI()*(12*25.4)/1000)$     | -F\$6     | $-\$G\$2*(B8-C8)*(A9-A8)*PI()*(8*25.4)/1000$     |
| 9  | $-C9+G9/(E\$2*(\$A10-\$A9)*PI()*(12*25.4)/1000)$    | -F\$6     | $-\$G\$2*(B9-C9)*(A10-A9)*PI()*(8*25.4)/1000$    |
| 10 | $-C10+G10/(E\$2*(\$A11-\$A10)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B10-C10)*(A11-A10)*PI()*(8*25.4)/1000$ |
| 11 | $-C11+G11/(E\$2*(\$A12-\$A11)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B11-C11)*(A12-A11)*PI()*(8*25.4)/1000$ |
| 12 | $-C12+G12/(E\$2*(\$A13-\$A12)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B12-C12)*(A13-A12)*PI()*(8*25.4)/1000$ |
| 13 | $-C13+G13/(E\$2*(\$A14-\$A13)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B13-C13)*(A14-A13)*PI()*(8*25.4)/1000$ |
| 14 | $-C14+G14/(E\$2*(\$A15-\$A14)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B14-C14)*(A15-A14)*PI()*(8*25.4)/1000$ |
| 15 | $-C15+G15/(E\$2*(\$A16-\$A15)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B15-C15)*(A16-A15)*PI()*(8*25.4)/1000$ |
| 16 | $-C16+G16/(E\$2*(\$A17-\$A16)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B16-C16)*(A17-A16)*PI()*(8*25.4)/1000$ |
| 17 | $-C17+G17/(E\$2*(\$A18-\$A17)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B17-C17)*(A18-A17)*PI()*(8*25.4)/1000$ |
| 18 | $-C18+G18/(E\$2*(\$A19-\$A18)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B18-C18)*(A19-A18)*PI()*(8*25.4)/1000$ |
| 19 | $-C19+G19/(E\$2*(\$A20-\$A19)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B19-C19)*(A20-A19)*PI()*(8*25.4)/1000$ |
| 20 | $-C20+G20/(E\$2*(\$A21-\$A20)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B20-C20)*(A21-A20)*PI()*(8*25.4)/1000$ |
| 21 | $-C21+G21/(E\$2*(\$A22-\$A21)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B21-C21)*(A22-A21)*PI()*(8*25.4)/1000$ |
| 22 | $-C22+G22/(E\$2*(\$A23-\$A22)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B22-C22)*(A23-A22)*PI()*(8*25.4)/1000$ |
| 23 | $-C23+G23/(E\$2*(\$A24-\$A23)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B23-C23)*(A24-A23)*PI()*(8*25.4)/1000$ |
| 24 | $-C24+G24/(E\$2*(\$A25-\$A24)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B24-C24)*(A25-A24)*PI()*(8*25.4)/1000$ |
| 25 | $-C25+G25/(E\$2*(\$A26-\$A25)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B25-C25)*(A26-A25)*PI()*(8*25.4)/1000$ |
| 26 | $-C26+G26/(E\$2*(\$A27-\$A26)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B26-C26)*(A27-A26)*PI()*(8*25.4)/1000$ |
| 27 | $-C27+G27/(E\$2*(\$A28-\$A27)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B27-C27)*(A28-A27)*PI()*(8*25.4)/1000$ |
| 28 | $-C28+G28/(E\$2*(\$A29-\$A28)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B28-C28)*(A29-A28)*PI()*(8*25.4)/1000$ |
| 29 | $-C29+G29/(E\$2*(\$A30-\$A29)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B29-C29)*(A30-A29)*PI()*(8*25.4)/1000$ |
| 30 | $-C30+G30/(E\$2*(\$A31-\$A30)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B30-C30)*(A31-A30)*PI()*(8*25.4)/1000$ |
| 31 | $-C31+G31/(E\$2*(\$A32-\$A31)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B31-C31)*(A32-A31)*PI()*(8*25.4)/1000$ |
| 32 | $-C32+G32/(E\$2*(\$A33-\$A32)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B32-C32)*(A33-A32)*PI()*(8*25.4)/1000$ |
| 33 | $-C33+G33/(E\$2*(\$A34-\$A33)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B33-C33)*(A34-A33)*PI()*(8*25.4)/1000$ |
| 34 | $-C34+G34/(E\$2*(\$A35-\$A34)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B34-C34)*(A35-A34)*PI()*(8*25.4)/1000$ |
| 35 | $-C35+G35/(E\$2*(\$A36-\$A35)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B35-C35)*(A36-A35)*PI()*(8*25.4)/1000$ |
| 36 | $-C36+G36/(E\$2*(\$A37-\$A36)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B36-C36)*(A37-A36)*PI()*(8*25.4)/1000$ |
| 37 | $-C37+G37/(E\$2*(\$A38-\$A37)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B37-C37)*(A38-A37)*PI()*(8*25.4)/1000$ |
| 38 | $-C38+G38/(E\$2*(\$A39-\$A38)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B38-C38)*(A39-A38)*PI()*(8*25.4)/1000$ |
| 39 | $-C39+G39/(E\$2*(\$A40-\$A39)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B39-C39)*(A40-A39)*PI()*(8*25.4)/1000$ |
| 40 | $-C40+G40/(E\$2*(\$A41-\$A40)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B40-C40)*(A41-A40)*PI()*(8*25.4)/1000$ |
| 41 | $-C41+G41/(E\$2*(\$A42-\$A41)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B41-C41)*(A42-A41)*PI()*(8*25.4)/1000$ |
| 42 | $-C42+G42/(E\$2*(\$A43-\$A42)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B42-C42)*(A43-A42)*PI()*(8*25.4)/1000$ |
| 43 | $-C43+G43/(E\$2*(\$A44-\$A43)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B43-C43)*(A44-A43)*PI()*(8*25.4)/1000$ |
| 44 | $-C44+G44/(E\$2*(\$A45-\$A44)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B44-C44)*(A45-A44)*PI()*(8*25.4)/1000$ |
| 45 | $-C45+G45/(E\$2*(\$A46-\$A45)*PI()*(12*25.4)/1000)$ | -F\$6     | $-\$G\$2*(B45-C45)*(A46-A45)*PI()*(8*25.4)/1000$ |

**APPENDIX 2**

**SAMPLE PRINTOUTS OF CHIMNEY MODEL**

Air-Cooled Chimney Model

| Height Above<br>Base M | Flue Gas<br>Temp C | Cooling air<br>Temp C | Outdoor air<br>Temp C | Flue Liner<br>Temp C | Outside Surf<br>Temp C | Flue Flow<br>L/s | Cooling Flow<br>L/s | Ui=6.5             | Uo=4.5                |
|------------------------|--------------------|-----------------------|-----------------------|----------------------|------------------------|------------------|---------------------|--------------------|-----------------------|
|                        |                    |                       |                       |                      |                        |                  |                     | Heat Loss<br>Watts | Exterior<br>Heat loss |
| 0.00                   | 150.00             | 21.00                 | 21.00                 | 113.54               | 21.00                  | 110.00           | 5.00                | 53.53              | 0.00                  |
| 0.10                   | 149.41             | 29.95                 | 21.00                 | 115.65               | 25.48                  | 110.00           | 5.00                | 49.57              | 3.86                  |
| 0.20                   | 148.87             | 37.83                 | 21.00                 | 117.49               | 29.41                  | 110.00           | 5.00                | 46.08              | 7.25                  |
| 0.30                   | 148.37             | 44.69                 | 21.00                 | 119.07               | 32.85                  | 110.00           | 5.00                | 43.02              | 10.21                 |
| 0.40                   | 147.90             | 50.62                 | 21.00                 | 120.41               | 35.81                  | 110.00           | 5.00                | 40.37              | 12.76                 |
| 0.50                   | 147.46             | 55.70                 | 21.00                 | 121.53               | 38.35                  | 110.00           | 5.00                | 38.07              | 14.95                 |
| 0.60                   | 147.05             | 60.03                 | 21.00                 | 122.46               | 40.51                  | 110.00           | 5.00                | 36.11              | 16.82                 |
| 0.70                   | 146.66             | 63.68                 | 21.00                 | 123.21               | 42.34                  | 110.00           | 5.00                | 34.43              | 18.39                 |
| 0.80                   | 146.28             | 66.75                 | 21.00                 | 123.81               | 43.88                  | 110.00           | 5.00                | 33.00              | 19.72                 |
| 0.90                   | 145.93             | 69.32                 | 21.00                 | 124.28               | 45.16                  | 110.00           | 5.00                | 31.79              | 20.82                 |
| 1.00                   | 145.58             | 71.46                 | 21.00                 | 124.63               | 46.23                  | 110.00           | 5.00                | 30.76              | 21.74                 |
| 1.10                   | 145.25             | 73.22                 | 21.00                 | 124.89               | 47.11                  | 110.00           | 5.00                | 29.89              | 22.50                 |
| 1.20                   | 144.92             | 74.68                 | 21.00                 | 125.07               | 47.84                  | 110.00           | 5.00                | 29.15              | 23.13                 |
| 1.30                   | 144.61             | 75.87                 | 21.00                 | 125.18               | 48.43                  | 110.00           | 5.00                | 28.52              | 23.64                 |
| 1.40                   | 144.30             | 76.84                 | 21.00                 | 125.24               | 48.92                  | 110.00           | 5.00                | 27.99              | 24.06                 |
| 1.50                   | 144.00             | 77.62                 | 21.00                 | 125.24               | 49.31                  | 110.00           | 5.00                | 27.54              | 24.40                 |
| 1.60                   | 143.70             | 78.25                 | 21.00                 | 125.20               | 49.62                  | 110.00           | 5.00                | 27.16              | 24.67                 |
| 1.70                   | 143.41             | 78.74                 | 21.00                 | 125.14               | 49.87                  | 110.00           | 5.00                | 26.83              | 24.88                 |
| 1.80                   | 143.12             | 79.13                 | 21.00                 | 125.04               | 50.07                  | 110.00           | 5.00                | 26.55              | 25.05                 |
| 1.90                   | 142.84             | 79.44                 | 21.00                 | 124.92               | 50.22                  | 110.00           | 5.00                | 26.31              | 25.18                 |
| 2.00                   | 142.55             | 79.66                 | 21.00                 | 124.78               | 50.33                  | 110.00           | 5.00                | 26.10              | 25.28                 |
| 2.10                   | 142.27             | 79.83                 | 21.00                 | 124.62               | 50.41                  | 110.00           | 5.00                | 25.91              | 25.35                 |
| 2.20                   | 141.99             | 79.94                 | 21.00                 | 124.46               | 50.47                  | 110.00           | 5.00                | 25.75              | 25.40                 |
| 2.30                   | 141.72             | 80.01                 | 21.00                 | 124.28               | 50.50                  | 110.00           | 5.00                | 25.61              | 25.43                 |
| 2.40                   | 141.44             | 80.05                 | 21.00                 | 124.09               | 50.52                  | 110.00           | 5.00                | 25.48              | 25.44                 |
| 2.50                   | 141.17             | 80.05                 | 21.00                 | 123.90               | 50.53                  | 110.00           | 5.00                | 25.36              | 25.45                 |
| 2.60                   | 140.90             | 80.04                 | 21.00                 | 123.70               | 50.52                  | 110.00           | 5.00                | 25.25              | 25.44                 |
| 2.70                   | 140.63             | 80.00                 | 21.00                 | 123.49               | 50.50                  | 110.00           | 5.00                | 25.16              | 25.42                 |
| 2.80                   | 140.36             | 79.95                 | 21.00                 | 123.29               | 50.47                  | 110.00           | 5.00                | 25.07              | 25.40                 |
| 2.90                   | 140.09             | 79.88                 | 21.00                 | 123.07               | 50.44                  | 110.00           | 5.00                | 24.98              | 25.37                 |
| 3.00                   | 139.82             | 79.80                 | 21.00                 | 122.86               | 50.40                  | 110.00           | 5.00                | 24.91              | 25.34                 |
| 3.10                   | 139.56             | 79.71                 | 21.00                 | 122.65               | 50.36                  | 110.00           | 5.00                | 24.83              | 25.30                 |
| 3.20                   | 139.29             | 79.62                 | 21.00                 | 122.43               | 50.31                  | 110.00           | 5.00                | 24.76              | 25.26                 |
| 3.30                   | 139.03             | 79.52                 | 21.00                 | 122.21               | 50.26                  | 110.00           | 5.00                | 24.69              | 25.22                 |
| 3.40                   | 138.77             | 79.42                 | 21.00                 | 121.99               | 50.21                  | 110.00           | 5.00                | 24.63              | 25.17                 |
| 3.50                   | 138.50             | 79.31                 | 21.00                 | 121.77               | 50.15                  | 110.00           | 5.00                | 24.56              | 25.12                 |
| 3.60                   | 138.24             | 79.19                 | 21.00                 | 121.56               | 50.10                  | 110.00           | 5.00                | 24.50              | 25.08                 |
| 3.70                   | 137.98             | 79.08                 | 21.00                 | 121.34               | 50.04                  | 110.00           | 5.00                | 24.44              | 25.03                 |
| 3.80                   | 137.72             | 78.96                 | 21.00                 | 121.12               | 49.98                  | 110.00           | 5.00                | 24.38              | 24.98                 |
| 3.90                   | 137.46             | 78.84                 | 21.00                 | 120.90               | 49.92                  | 110.00           | 5.00                | 24.32              | 24.92                 |

Air-Cooled Chimney Model

| Height Above<br>Base M | Flue Gas<br>Temp C | Cooling air<br>Temp C | Outdoor air<br>Temp C | Flue Liner<br>Temp C | Outside Surf<br>Temp C | Flue Flow<br>L/s | Cooling Flow<br>L/s | Ui=6.5             | Uo=4.5                |
|------------------------|--------------------|-----------------------|-----------------------|----------------------|------------------------|------------------|---------------------|--------------------|-----------------------|
|                        |                    |                       |                       |                      |                        |                  |                     | Heat Loss<br>Watts | Exterior<br>Heat loss |
| 0.00                   | 200.00             | -40.00                | 25.00                 | 132.17               | -7.50                  | 110.00           | 4.00                | 99.59              | -28.01                |
| 0.10                   | 198.78             | -18.86                | 25.00                 | 137.27               | 3.07                   | 110.00           | 4.00                | 90.31              | -18.90                |
| 0.20                   | 197.68             | 0.87                  | 25.00                 | 142.06               | 12.94                  | 110.00           | 4.00                | 81.66              | -10.40                |
| 0.30                   | 196.69             | 18.80                 | 25.00                 | 146.41               | 21.90                  | 110.00           | 4.00                | 73.81              | -2.67                 |
| 0.40                   | 195.79             | 34.67                 | 25.00                 | 150.26               | 29.83                  | 110.00           | 4.00                | 66.86              | 4.17                  |
| 0.50                   | 194.98             | 48.38                 | 25.00                 | 153.55               | 36.69                  | 110.00           | 4.00                | 60.83              | 10.08                 |
| 0.60                   | 194.24             | 59.98                 | 25.00                 | 156.30               | 42.49                  | 110.00           | 4.00                | 55.71              | 15.07                 |
| 0.70                   | 193.57             | 69.60                 | 25.00                 | 158.54               | 47.30                  | 110.00           | 4.00                | 51.44              | 19.22                 |
| 0.80                   | 192.95             | 77.45                 | 25.00                 | 160.31               | 51.23                  | 110.00           | 4.00                | 47.93              | 22.60                 |
| 0.90                   | 192.37             | 83.76                 | 25.00                 | 161.68               | 54.38                  | 110.00           | 4.00                | 45.07              | 25.32                 |
| 1.00                   | 191.83             | 88.77                 | 25.00                 | 162.71               | 56.89                  | 110.00           | 4.00                | 42.76              | 27.48                 |
| 1.10                   | 191.32             | 92.70                 | 25.00                 | 163.45               | 58.85                  | 110.00           | 4.00                | 40.92              | 29.17                 |
| 1.20                   | 190.83             | 95.76                 | 25.00                 | 163.96               | 60.38                  | 110.00           | 4.00                | 39.45              | 30.49                 |
| 1.30                   | 190.35             | 98.11                 | 25.00                 | 164.28               | 61.55                  | 110.00           | 4.00                | 38.28              | 31.50                 |
| 1.40                   | 189.89             | 99.89                 | 25.00                 | 164.46               | 62.45                  | 110.00           | 4.00                | 37.34              | 32.27                 |
| 1.50                   | 189.45             | 101.24                | 25.00                 | 164.52               | 63.12                  | 110.00           | 4.00                | 36.60              | 32.85                 |
| 1.60                   | 189.01             | 102.24                | 25.00                 | 164.49               | 63.62                  | 110.00           | 4.00                | 36.01              | 33.28                 |
| 1.70                   | 188.58             | 102.96                | 25.00                 | 164.38               | 63.98                  | 110.00           | 4.00                | 35.53              | 33.59                 |
| 1.80                   | 188.16             | 103.48                | 25.00                 | 164.23               | 64.24                  | 110.00           | 4.00                | 35.14              | 33.82                 |
| 1.90                   | 187.74             | 103.83                | 25.00                 | 164.02               | 64.42                  | 110.00           | 4.00                | 34.82              | 33.97                 |
| 2.00                   | 187.32             | 104.06                | 25.00                 | 163.79               | 64.53                  | 110.00           | 4.00                | 34.55              | 34.07                 |
| 2.10                   | 186.91             | 104.19                | 25.00                 | 163.53               | 64.59                  | 110.00           | 4.00                | 34.32              | 34.12                 |
| 2.20                   | 186.50             | 104.24                | 25.00                 | 163.25               | 64.62                  | 110.00           | 4.00                | 34.13              | 34.15                 |
| 2.30                   | 186.10             | 104.24                | 25.00                 | 162.96               | 64.62                  | 110.00           | 4.00                | 33.97              | 34.14                 |
| 2.40                   | 185.69             | 104.19                | 25.00                 | 162.66               | 64.60                  | 110.00           | 4.00                | 33.82              | 34.12                 |
| 2.50                   | 185.29             | 104.11                | 25.00                 | 162.35               | 64.55                  | 110.00           | 4.00                | 33.69              | 34.09                 |
| 2.60                   | 184.89             | 104.00                | 25.00                 | 162.03               | 64.50                  | 110.00           | 4.00                | 33.57              | 34.04                 |
| 2.70                   | 184.50             | 103.87                | 25.00                 | 161.71               | 64.44                  | 110.00           | 4.00                | 33.45              | 33.99                 |
| 2.80                   | 184.10             | 103.73                | 25.00                 | 161.39               | 64.37                  | 110.00           | 4.00                | 33.35              | 33.93                 |
| 2.90                   | 183.71             | 103.58                | 25.00                 | 161.06               | 64.29                  | 110.00           | 4.00                | 33.25              | 33.86                 |
| 3.00                   | 183.31             | 103.41                | 25.00                 | 160.73               | 64.21                  | 110.00           | 4.00                | 33.15              | 33.79                 |
| 3.10                   | 182.92             | 103.24                | 25.00                 | 160.40               | 64.12                  | 110.00           | 4.00                | 33.06              | 33.72                 |
| 3.20                   | 182.53             | 103.07                | 25.00                 | 160.08               | 64.03                  | 110.00           | 4.00                | 32.97              | 33.64                 |
| 3.30                   | 182.14             | 102.89                | 25.00                 | 159.75               | 63.95                  | 110.00           | 4.00                | 32.89              | 33.56                 |
| 3.40                   | 181.76             | 102.71                | 25.00                 | 159.42               | 63.85                  | 110.00           | 4.00                | 32.80              | 33.48                 |
| 3.50                   | 181.37             | 102.53                | 25.00                 | 159.09               | 63.76                  | 110.00           | 4.00                | 32.72              | 33.41                 |
| 3.60                   | 180.99             | 102.34                | 25.00                 | 158.76               | 63.67                  | 110.00           | 4.00                | 32.63              | 33.33                 |
| 3.70                   | 180.60             | 102.16                | 25.00                 | 158.43               | 63.58                  | 110.00           | 4.00                | 32.55              | 33.25                 |
| 3.80                   | 180.22             | 101.97                | 25.00                 | 158.11               | 63.49                  | 110.00           | 4.00                | 32.47              | 33.17                 |
| 3.90                   | 179.84             | 101.79                | 25.00                 | 157.78               | 63.39                  | 110.00           | 4.00                | 32.39              | 33.09                 |



## Air-Cooled Chimney Model

| Height Above<br>Base M | Flue Gas<br>Temp C | Cooling air<br>Temp C | Outdoor air<br>Temp C | Flue Liner<br>Temp C | Outside Surf<br>Temp C | Flue Flow<br>L/s | Cooling Flow<br>L/s | Ui=6.5             | Uo=4.5                |
|------------------------|--------------------|-----------------------|-----------------------|----------------------|------------------------|------------------|---------------------|--------------------|-----------------------|
|                        |                    |                       |                       |                      |                        |                  |                     | Heat Loss<br>Watts | Exterior<br>Heat loss |
| 0.00                   | 200.00             | 25.00                 | 25.00                 | 150.54               | 25.00                  | 110.00           | 4.00                | 72.61              | 0.00                  |
| 0.10                   | 199.11             | 40.39                 | 25.00                 | 154.25               | 32.69                  | 110.00           | 4.00                | 65.86              | 6.63                  |
| 0.20                   | 198.31             | 53.58                 | 25.00                 | 157.41               | 39.29                  | 110.00           | 4.00                | 60.05              | 12.32                 |
| 0.30                   | 197.58             | 64.67                 | 25.00                 | 160.02               | 44.83                  | 110.00           | 4.00                | 55.15              | 17.09                 |
| 0.40                   | 196.91             | 73.81                 | 25.00                 | 162.12               | 49.40                  | 110.00           | 4.00                | 51.08              | 21.03                 |
| 0.50                   | 196.28             | 81.22                 | 25.00                 | 163.77               | 53.11                  | 110.00           | 4.00                | 47.75              | 24.22                 |
| 0.60                   | 195.71             | 87.14                 | 25.00                 | 165.02               | 56.07                  | 110.00           | 4.00                | 45.05              | 26.78                 |
| 0.70                   | 195.16             | 91.82                 | 25.00                 | 165.95               | 58.41                  | 110.00           | 4.00                | 42.88              | 28.79                 |
| 0.80                   | 194.64             | 95.47                 | 25.00                 | 166.61               | 60.24                  | 110.00           | 4.00                | 41.15              | 30.37                 |
| 0.90                   | 194.14             | 98.30                 | 25.00                 | 167.06               | 61.65                  | 110.00           | 4.00                | 39.77              | 31.58                 |
| 1.00                   | 193.66             | 100.46                | 25.00                 | 167.32               | 62.73                  | 110.00           | 4.00                | 38.67              | 32.52                 |
| 1.10                   | 193.20             | 102.09                | 25.00                 | 167.45               | 63.55                  | 110.00           | 4.00                | 37.80              | 33.22                 |
| 1.20                   | 192.74             | 103.32                | 25.00                 | 167.47               | 64.16                  | 110.00           | 4.00                | 37.11              | 33.75                 |
| 1.30                   | 192.29             | 104.22                | 25.00                 | 167.40               | 64.61                  | 110.00           | 4.00                | 36.55              | 34.13                 |
| 1.40                   | 191.85             | 104.86                | 25.00                 | 167.27               | 64.93                  | 110.00           | 4.00                | 36.10              | 34.41                 |
| 1.50                   | 191.42             | 105.31                | 25.00                 | 167.09               | 65.16                  | 110.00           | 4.00                | 35.73              | 34.61                 |
| 1.60                   | 190.99             | 105.62                | 25.00                 | 166.86               | 65.31                  | 110.00           | 4.00                | 35.43              | 34.74                 |
| 1.70                   | 190.57             | 105.80                | 25.00                 | 166.61               | 65.40                  | 110.00           | 4.00                | 35.17              | 34.82                 |
| 1.80                   | 190.14             | 105.90                | 25.00                 | 166.34               | 65.45                  | 110.00           | 4.00                | 34.96              | 34.86                 |
| 1.90                   | 189.73             | 105.92                | 25.00                 | 166.04               | 65.46                  | 110.00           | 4.00                | 34.77              | 34.87                 |
| 2.00                   | 189.31             | 105.90                | 25.00                 | 165.74               | 65.45                  | 110.00           | 4.00                | 34.61              | 34.86                 |
| 2.10                   | 188.90             | 105.83                | 25.00                 | 165.42               | 65.42                  | 110.00           | 4.00                | 34.47              | 34.83                 |
| 2.20                   | 188.48             | 105.73                | 25.00                 | 165.10               | 65.37                  | 110.00           | 4.00                | 34.34              | 34.79                 |
| 2.30                   | 188.07             | 105.61                | 25.00                 | 164.77               | 65.31                  | 110.00           | 4.00                | 34.22              | 34.74                 |
| 2.40                   | 187.67             | 105.47                | 25.00                 | 164.44               | 65.24                  | 110.00           | 4.00                | 34.11              | 34.68                 |
| 2.50                   | 187.26             | 105.32                | 25.00                 | 164.10               | 65.16                  | 110.00           | 4.00                | 34.00              | 34.61                 |
| 2.60                   | 186.86             | 105.16                | 25.00                 | 163.77               | 65.08                  | 110.00           | 4.00                | 33.90              | 34.54                 |
| 2.70                   | 186.45             | 104.98                | 25.00                 | 163.43               | 64.99                  | 110.00           | 4.00                | 33.80              | 34.46                 |
| 2.80                   | 186.05             | 104.81                | 25.00                 | 163.09               | 64.90                  | 110.00           | 4.00                | 33.71              | 34.39                 |
| 2.90                   | 185.65             | 104.62                | 25.00                 | 162.75               | 64.81                  | 110.00           | 4.00                | 33.62              | 34.31                 |
| 3.00                   | 185.25             | 104.44                | 25.00                 | 162.41               | 64.72                  | 110.00           | 4.00                | 33.53              | 34.23                 |
| 3.10                   | 184.85             | 104.25                | 25.00                 | 162.08               | 64.63                  | 110.00           | 4.00                | 33.45              | 34.15                 |
| 3.20                   | 184.46             | 104.06                | 25.00                 | 161.74               | 64.53                  | 110.00           | 4.00                | 33.36              | 34.07                 |
| 3.30                   | 184.06             | 103.87                | 25.00                 | 161.40               | 64.44                  | 110.00           | 4.00                | 33.27              | 33.99                 |
| 3.40                   | 183.67             | 103.68                | 25.00                 | 161.07               | 64.34                  | 110.00           | 4.00                | 33.19              | 33.90                 |
| 3.50                   | 183.28             | 103.49                | 25.00                 | 160.73               | 64.25                  | 110.00           | 4.00                | 33.11              | 33.82                 |
| 3.60                   | 182.89             | 103.30                | 25.00                 | 160.40               | 64.15                  | 110.00           | 4.00                | 33.02              | 33.74                 |
| 3.70                   | 182.50             | 103.11                | 25.00                 | 160.06               | 64.05                  | 110.00           | 4.00                | 32.94              | 33.66                 |
| 3.80                   | 182.11             | 102.92                | 25.00                 | 159.73               | 63.96                  | 110.00           | 4.00                | 32.86              | 33.57                 |
| 3.90                   | 181.72             | 102.73                | 25.00                 | 159.40               | 63.86                  | 110.00           | 4.00                | 32.78              | 33.49                 |

Air-Cooled Chimney Model

| Height Above<br>Base M | Flue Gas<br>Temp C | Cooling air<br>Temp C | Outdoor air<br>Temp C | Flue Liner<br>Temp C | Outside Surf<br>Temp C | Flue Flow<br>L/s | Cooling Flow<br>L/s | Ui=6.5             | Uo=4.5                |
|------------------------|--------------------|-----------------------|-----------------------|----------------------|------------------------|------------------|---------------------|--------------------|-----------------------|
|                        |                    |                       |                       |                      |                        |                  |                     | Heat Loss<br>Watts | Exterior<br>Heat loss |
| 0.00                   | 200.00             | -15.00                | 25.00                 | 139.24               | 5.00                   | 110.00           | 4.00                | 89.21              | -17.24                |
| 0.10                   | 198.91             | 4.53                  | 25.00                 | 143.98               | 14.76                  | 110.00           | 4.00                | 80.66              | -8.82                 |
| 0.20                   | 197.92             | 22.18                 | 25.00                 | 148.26               | 23.59                  | 110.00           | 4.00                | 72.92              | -1.21                 |
| 0.30                   | 197.04             | 37.74                 | 25.00                 | 152.02               | 31.37                  | 110.00           | 4.00                | 66.10              | 5.49                  |
| 0.40                   | 196.23             | 51.14                 | 25.00                 | 155.23               | 38.07                  | 110.00           | 4.00                | 60.21              | 11.26                 |
| 0.50                   | 195.50             | 62.42                 | 25.00                 | 157.89               | 43.71                  | 110.00           | 4.00                | 55.22              | 16.12                 |
| 0.60                   | 194.83             | 71.74                 | 25.00                 | 160.05               | 48.37                  | 110.00           | 4.00                | 51.08              | 20.14                 |
| 0.70                   | 194.22             | 79.32                 | 25.00                 | 161.75               | 52.16                  | 110.00           | 4.00                | 47.67              | 23.41                 |
| 0.80                   | 193.64             | 85.40                 | 25.00                 | 163.05               | 55.20                  | 110.00           | 4.00                | 44.91              | 26.03                 |
| 0.90                   | 193.10             | 90.22                 | 25.00                 | 164.02               | 57.61                  | 110.00           | 4.00                | 42.69              | 28.10                 |
| 1.00                   | 192.58             | 93.98                 | 25.00                 | 164.72               | 59.49                  | 110.00           | 4.00                | 40.91              | 29.72                 |
| 1.10                   | 192.09             | 96.90                 | 25.00                 | 165.19               | 60.95                  | 110.00           | 4.00                | 39.50              | 30.98                 |
| 1.20                   | 191.62             | 99.14                 | 25.00                 | 165.48               | 62.07                  | 110.00           | 4.00                | 38.37              | 31.95                 |
| 1.30                   | 191.16             | 100.84                | 25.00                 | 165.63               | 62.92                  | 110.00           | 4.00                | 37.47              | 32.68                 |
| 1.40                   | 190.71             | 102.12                | 25.00                 | 165.67               | 63.56                  | 110.00           | 4.00                | 36.76              | 33.23                 |
| 1.50                   | 190.27             | 103.06                | 25.00                 | 165.62               | 64.03                  | 110.00           | 4.00                | 36.19              | 33.64                 |
| 1.60                   | 189.83             | 103.74                | 25.00                 | 165.50               | 64.37                  | 110.00           | 4.00                | 35.72              | 33.93                 |
| 1.70                   | 189.40             | 104.22                | 25.00                 | 165.33               | 64.61                  | 110.00           | 4.00                | 35.35              | 34.14                 |
| 1.80                   | 188.98             | 104.55                | 25.00                 | 165.12               | 64.77                  | 110.00           | 4.00                | 35.04              | 34.28                 |
| 1.90                   | 188.56             | 104.75                | 25.00                 | 164.88               | 64.87                  | 110.00           | 4.00                | 34.78              | 34.36                 |
| 2.00                   | 188.15             | 104.86                | 25.00                 | 164.61               | 64.93                  | 110.00           | 4.00                | 34.56              | 34.41                 |
| 2.10                   | 187.74             | 104.90                | 25.00                 | 164.33               | 64.95                  | 110.00           | 4.00                | 34.37              | 34.43                 |
| 2.20                   | 187.33             | 104.88                | 25.00                 | 164.03               | 64.94                  | 110.00           | 4.00                | 34.21              | 34.42                 |
| 2.30                   | 186.92             | 104.83                | 25.00                 | 163.72               | 64.91                  | 110.00           | 4.00                | 34.06              | 34.40                 |
| 2.40                   | 186.51             | 104.74                | 25.00                 | 163.40               | 64.87                  | 110.00           | 4.00                | 33.93              | 34.36                 |
| 2.50                   | 186.11             | 104.62                | 25.00                 | 163.08               | 64.81                  | 110.00           | 4.00                | 33.81              | 34.31                 |
| 2.60                   | 185.71             | 104.49                | 25.00                 | 162.76               | 64.74                  | 110.00           | 4.00                | 33.70              | 34.25                 |
| 2.70                   | 185.31             | 104.34                | 25.00                 | 162.43               | 64.67                  | 110.00           | 4.00                | 33.60              | 34.19                 |
| 2.80                   | 184.91             | 104.18                | 25.00                 | 162.10               | 64.59                  | 110.00           | 4.00                | 33.50              | 34.12                 |
| 2.90                   | 184.52             | 104.02                | 25.00                 | 161.77               | 64.51                  | 110.00           | 4.00                | 33.40              | 34.05                 |
| 3.00                   | 184.12             | 103.84                | 25.00                 | 161.43               | 64.42                  | 110.00           | 4.00                | 33.31              | 33.97                 |
| 3.10                   | 183.73             | 103.67                | 25.00                 | 161.10               | 64.33                  | 110.00           | 4.00                | 33.22              | 33.90                 |
| 3.20                   | 183.33             | 103.48                | 25.00                 | 160.77               | 64.24                  | 110.00           | 4.00                | 33.13              | 33.82                 |
| 3.30                   | 182.94             | 103.30                | 25.00                 | 160.44               | 64.15                  | 110.00           | 4.00                | 33.05              | 33.74                 |
| 3.40                   | 182.55             | 103.12                | 25.00                 | 160.10               | 64.06                  | 110.00           | 4.00                | 32.96              | 33.66                 |
| 3.50                   | 182.17             | 102.93                | 25.00                 | 159.77               | 63.96                  | 110.00           | 4.00                | 32.88              | 33.58                 |
| 3.60                   | 181.78             | 102.74                | 25.00                 | 159.44               | 63.87                  | 110.00           | 4.00                | 32.80              | 33.50                 |
| 3.70                   | 181.39             | 102.55                | 25.00                 | 159.11               | 63.78                  | 110.00           | 4.00                | 32.71              | 33.42                 |
| 3.80                   | 181.01             | 102.37                | 25.00                 | 158.78               | 63.68                  | 110.00           | 4.00                | 32.63              | 33.34                 |
| 3.90                   | 180.63             | 102.18                | 25.00                 | 158.46               | 63.59                  | 110.00           | 4.00                | 32.55              | 33.26                 |

Air-Cooled Chimney Model

| Height Above<br>Base M | Flue Gas<br>Temp C | Cooling air<br>Temp C | Outdoor air<br>Temp C | Flue Liner<br>Temp C | Outside Surf<br>Temp C | Flue Flow<br>L/s | Cooling Flow<br>L/s | Ui=6.5             | Uo=4.5                |
|------------------------|--------------------|-----------------------|-----------------------|----------------------|------------------------|------------------|---------------------|--------------------|-----------------------|
|                        |                    |                       |                       |                      |                        |                  |                     | Heat Loss<br>Watts | Exterior<br>Heat loss |
| 0.00                   | 200.00             | -15.00                | 25.00                 | 139.24               | 5.00                   | 50.00            | 4.00                | 89.21              | -17.24                |
| 0.10                   | 197.60             | 4.53                  | 25.00                 | 143.04               | 14.76                  | 50.00            | 4.00                | 80.11              | -8.82                 |
| 0.20                   | 195.46             | 22.08                 | 25.00                 | 146.46               | 23.54                  | 50.00            | 4.00                | 71.94              | -1.26                 |
| 0.30                   | 193.54             | 37.44                 | 25.00                 | 149.42               | 31.22                  | 50.00            | 4.00                | 64.77              | 5.36                  |
| 0.40                   | 191.82             | 50.55                 | 25.00                 | 151.90               | 37.78                  | 50.00            | 4.00                | 58.62              | 11.01                 |
| 0.50                   | 190.27             | 61.50                 | 25.00                 | 153.88               | 43.25                  | 50.00            | 4.00                | 53.43              | 15.73                 |
| 0.60                   | 188.86             | 70.47                 | 25.00                 | 155.40               | 47.74                  | 50.00            | 4.00                | 49.13              | 19.59                 |
| 0.70                   | 187.57             | 77.68                 | 25.00                 | 156.52               | 51.34                  | 50.00            | 4.00                | 45.60              | 22.70                 |
| 0.80                   | 186.38             | 83.39                 | 25.00                 | 157.27               | 54.20                  | 50.00            | 4.00                | 42.73              | 25.16                 |
| 0.90                   | 185.26             | 87.84                 | 25.00                 | 157.73               | 56.42                  | 50.00            | 4.00                | 40.42              | 27.08                 |
| 1.00                   | 184.21             | 91.27                 | 25.00                 | 157.94               | 58.13                  | 50.00            | 4.00                | 38.56              | 28.55                 |
| 1.10                   | 183.20             | 93.86                 | 25.00                 | 157.95               | 59.43                  | 50.00            | 4.00                | 37.07              | 29.67                 |
| 1.20                   | 182.24             | 95.79                 | 25.00                 | 157.81               | 60.40                  | 50.00            | 4.00                | 35.87              | 30.50                 |
| 1.30                   | 181.31             | 97.20                 | 25.00                 | 157.54               | 61.10                  | 50.00            | 4.00                | 34.90              | 31.11                 |
| 1.40                   | 180.41             | 98.20                 | 25.00                 | 157.18               | 61.60                  | 50.00            | 4.00                | 34.11              | 31.54                 |
| 1.50                   | 179.53             | 98.88                 | 25.00                 | 156.74               | 61.94                  | 50.00            | 4.00                | 33.47              | 31.83                 |
| 1.60                   | 178.67             | 99.31                 | 25.00                 | 156.24               | 62.15                  | 50.00            | 4.00                | 32.93              | 32.02                 |
| 1.70                   | 177.82             | 99.55                 | 25.00                 | 155.70               | 62.27                  | 50.00            | 4.00                | 32.48              | 32.12                 |
| 1.80                   | 176.99             | 99.64                 | 25.00                 | 155.13               | 62.32                  | 50.00            | 4.00                | 32.09              | 32.16                 |
| 1.90                   | 176.17             | 99.62                 | 25.00                 | 154.54               | 62.31                  | 50.00            | 4.00                | 31.76              | 32.16                 |
| 2.00                   | 175.36             | 99.52                 | 25.00                 | 153.92               | 62.26                  | 50.00            | 4.00                | 31.47              | 32.11                 |
| 2.10                   | 174.55             | 99.35                 | 25.00                 | 153.30               | 62.17                  | 50.00            | 4.00                | 31.21              | 32.04                 |
| 2.20                   | 173.76             | 99.13                 | 25.00                 | 152.67               | 62.06                  | 50.00            | 4.00                | 30.97              | 31.94                 |
| 2.30                   | 172.97             | 98.87                 | 25.00                 | 152.03               | 61.94                  | 50.00            | 4.00                | 30.75              | 31.83                 |
| 2.40                   | 172.19             | 98.58                 | 25.00                 | 151.39               | 61.79                  | 50.00            | 4.00                | 30.54              | 31.71                 |
| 2.50                   | 171.42             | 98.28                 | 25.00                 | 150.75               | 61.64                  | 50.00            | 4.00                | 30.35              | 31.58                 |
| 2.60                   | 170.65             | 97.95                 | 25.00                 | 150.11               | 61.48                  | 50.00            | 4.00                | 30.17              | 31.44                 |
| 2.70                   | 169.89             | 97.62                 | 25.00                 | 149.47               | 61.31                  | 50.00            | 4.00                | 29.99              | 31.29                 |
| 2.80                   | 169.14             | 97.28                 | 25.00                 | 148.83               | 61.14                  | 50.00            | 4.00                | 29.82              | 31.14                 |
| 2.90                   | 168.39             | 96.93                 | 25.00                 | 148.19               | 60.96                  | 50.00            | 4.00                | 29.65              | 30.99                 |
| 3.00                   | 167.64             | 96.57                 | 25.00                 | 147.56               | 60.79                  | 50.00            | 4.00                | 29.49              | 30.84                 |
| 3.10                   | 166.90             | 96.22                 | 25.00                 | 146.93               | 60.61                  | 50.00            | 4.00                | 29.33              | 30.69                 |
| 3.20                   | 166.17             | 95.86                 | 25.00                 | 146.30               | 60.43                  | 50.00            | 4.00                | 29.17              | 30.53                 |
| 3.30                   | 165.44             | 95.50                 | 25.00                 | 145.67               | 60.25                  | 50.00            | 4.00                | 29.02              | 30.38                 |
| 3.40                   | 164.72             | 95.15                 | 25.00                 | 145.05               | 60.07                  | 50.00            | 4.00                | 28.87              | 30.23                 |
| 3.50                   | 164.00             | 94.79                 | 25.00                 | 144.44               | 59.90                  | 50.00            | 4.00                | 28.72              | 30.07                 |
| 3.60                   | 163.28             | 94.44                 | 25.00                 | 143.83               | 59.72                  | 50.00            | 4.00                | 28.57              | 29.92                 |
| 3.70                   | 162.57             | 94.08                 | 25.00                 | 143.22               | 59.54                  | 50.00            | 4.00                | 28.42              | 29.77                 |
| 3.80                   | 161.87             | 93.73                 | 25.00                 | 142.61               | 59.37                  | 50.00            | 4.00                | 28.27              | 29.62                 |
| 3.90                   | 161.17             | 93.38                 | 25.00                 | 142.01               | 59.19                  | 50.00            | 4.00                | 28.13              | 29.47                 |

## Air-Cooled Chimney Model

| Height Above<br>Base M | Flue Gas<br>Temp C | Cooling air<br>Temp C | Outdoor air<br>Temp C | Flue Liner<br>Temp C | Outside Surf<br>Temp C | Flue Flow<br>L/s | Cooling Flow<br>L/s | U <sub>i</sub> =6.5 | U <sub>o</sub> =4.5   |
|------------------------|--------------------|-----------------------|-----------------------|----------------------|------------------------|------------------|---------------------|---------------------|-----------------------|
|                        |                    |                       |                       |                      |                        |                  |                     | Heat Loss<br>Watts  | Exterior<br>Heat loss |
| 0.00                   | 200.00             | -15.00                | 25.00                 | 139.24               | 5.00                   | 100.00           | 7.00                | 89.21               | -17.24                |
| 0.10                   | 198.80             | -3.84                 | 25.00                 | 141.53               | 10.58                  | 100.00           | 7.00                | 84.08               | -12.43                |
| 0.20                   | 197.67             | 6.71                  | 25.00                 | 143.71               | 15.86                  | 100.00           | 7.00                | 79.24               | -7.88                 |
| 0.30                   | 196.61             | 16.61                 | 25.00                 | 145.74               | 20.81                  | 100.00           | 7.00                | 74.69               | -3.61                 |
| 0.40                   | 195.61             | 25.83                 | 25.00                 | 147.63               | 25.41                  | 100.00           | 7.00                | 70.45               | 0.36                  |
| 0.50                   | 194.67             | 34.34                 | 25.00                 | 149.36               | 29.67                  | 100.00           | 7.00                | 66.53               | 4.02                  |
| 0.60                   | 193.79             | 42.14                 | 25.00                 | 150.93               | 33.57                  | 100.00           | 7.00                | 62.92               | 7.39                  |
| 0.70                   | 192.95             | 49.25                 | 25.00                 | 152.34               | 37.13                  | 100.00           | 7.00                | 59.63               | 10.45                 |
| 0.80                   | 192.16             | 55.69                 | 25.00                 | 153.60               | 40.35                  | 100.00           | 7.00                | 56.63               | 13.23                 |
| 0.90                   | 191.41             | 61.49                 | 25.00                 | 154.70               | 43.24                  | 100.00           | 7.00                | 53.91               | 15.72                 |
| 1.00                   | 190.70             | 66.68                 | 25.00                 | 155.65               | 45.84                  | 100.00           | 7.00                | 51.46               | 17.96                 |
| 1.10                   | 190.02             | 71.30                 | 25.00                 | 156.47               | 48.15                  | 100.00           | 7.00                | 49.26               | 19.95                 |
| 1.20                   | 189.38             | 75.40                 | 25.00                 | 157.17               | 50.20                  | 100.00           | 7.00                | 47.29               | 21.72                 |
| 1.30                   | 188.75             | 79.02                 | 25.00                 | 157.74               | 52.01                  | 100.00           | 7.00                | 45.53               | 23.28                 |
| 1.40                   | 188.16             | 82.21                 | 25.00                 | 158.21               | 53.60                  | 100.00           | 7.00                | 43.96               | 24.65                 |
| 1.50                   | 187.58             | 84.99                 | 25.00                 | 158.59               | 55.00                  | 100.00           | 7.00                | 42.57               | 25.85                 |
| 1.60                   | 187.02             | 87.43                 | 25.00                 | 158.87               | 56.21                  | 100.00           | 7.00                | 41.33               | 26.90                 |
| 1.70                   | 186.48             | 89.54                 | 25.00                 | 159.08               | 57.27                  | 100.00           | 7.00                | 40.23               | 27.81                 |
| 1.80                   | 185.95             | 91.37                 | 25.00                 | 159.22               | 58.18                  | 100.00           | 7.00                | 39.25               | 28.60                 |
| 1.90                   | 185.44             | 92.94                 | 25.00                 | 159.30               | 58.97                  | 100.00           | 7.00                | 38.38               | 29.28                 |
| 2.00                   | 184.94             | 94.30                 | 25.00                 | 159.32               | 59.65                  | 100.00           | 7.00                | 37.61               | 29.86                 |
| 2.10                   | 184.45             | 95.45                 | 25.00                 | 159.30               | 60.23                  | 100.00           | 7.00                | 36.93               | 30.36                 |
| 2.20                   | 183.97             | 96.44                 | 25.00                 | 159.23               | 60.72                  | 100.00           | 7.00                | 36.32               | 30.78                 |
| 2.30                   | 183.50             | 97.27                 | 25.00                 | 159.13               | 61.13                  | 100.00           | 7.00                | 35.78               | 31.14                 |
| 2.40                   | 183.03             | 97.97                 | 25.00                 | 158.99               | 61.48                  | 100.00           | 7.00                | 35.30               | 31.44                 |
| 2.50                   | 182.58             | 98.55                 | 25.00                 | 158.83               | 61.77                  | 100.00           | 7.00                | 34.87               | 31.69                 |
| 2.60                   | 182.13             | 99.03                 | 25.00                 | 158.64               | 62.01                  | 100.00           | 7.00                | 34.48               | 31.90                 |
| 2.70                   | 181.68             | 99.42                 | 25.00                 | 158.43               | 62.21                  | 100.00           | 7.00                | 34.13               | 32.07                 |
| 2.80                   | 181.24             | 99.73                 | 25.00                 | 158.20               | 62.37                  | 100.00           | 7.00                | 33.82               | 32.20                 |
| 2.90                   | 180.80             | 99.98                 | 25.00                 | 157.96               | 62.49                  | 100.00           | 7.00                | 33.54               | 32.31                 |
| 3.00                   | 180.37             | 100.16                | 25.00                 | 157.70               | 62.58                  | 100.00           | 7.00                | 33.28               | 32.39                 |
| 3.10                   | 179.94             | 100.30                | 25.00                 | 157.43               | 62.65                  | 100.00           | 7.00                | 33.05               | 32.45                 |
| 3.20                   | 179.51             | 100.39                | 25.00                 | 157.15               | 62.69                  | 100.00           | 7.00                | 32.83               | 32.49                 |
| 3.30                   | 179.09             | 100.44                | 25.00                 | 156.86               | 62.72                  | 100.00           | 7.00                | 32.63               | 32.51                 |
| 3.40                   | 178.67             | 100.46                | 25.00                 | 156.57               | 62.73                  | 100.00           | 7.00                | 32.45               | 32.52                 |
| 3.50                   | 178.25             | 100.45                | 25.00                 | 156.27               | 62.73                  | 100.00           | 7.00                | 32.28               | 32.51                 |
| 3.60                   | 177.84             | 100.42                | 25.00                 | 155.96               | 62.71                  | 100.00           | 7.00                | 32.13               | 32.50                 |
| 3.70                   | 177.43             | 100.36                | 25.00                 | 155.65               | 62.68                  | 100.00           | 7.00                | 31.98               | 32.47                 |
| 3.80                   | 177.02             | 100.29                | 25.00                 | 155.33               | 62.64                  | 100.00           | 7.00                | 31.84               | 32.44                 |
| 3.90                   | 176.61             | 100.19                | 25.00                 | 155.01               | 62.60                  | 100.00           | 7.00                | 31.71               | 32.40                 |

Air-Cooled Chimney Model

| Height Above<br>Base M | Flue Gas<br>Temp C | Cooling air<br>Temp C | Outdoor air<br>Temp C | Flue Liner<br>Temp C | Outside Surf<br>Temp C | Flue Flow<br>L/s | Cooling Flow<br>L/s | Ui=6.5             | Uo=4.5                |
|------------------------|--------------------|-----------------------|-----------------------|----------------------|------------------------|------------------|---------------------|--------------------|-----------------------|
|                        |                    |                       |                       |                      |                        |                  |                     | Heat Loss<br>Watts | Exterior<br>Heat loss |
| 0.00                   | 400.00             | 25.00                 | 25.00                 | 294.02               | 25.00                  | 100.00           | 7.00                | 155.60             | 0.00                  |
| 0.10                   | 397.02             | 43.84                 | 25.00                 | 297.21               | 34.42                  | 100.00           | 7.00                | 146.55             | 8.12                  |
| 0.20                   | 394.23             | 61.66                 | 25.00                 | 300.24               | 43.33                  | 100.00           | 7.00                | 138.00             | 15.80                 |
| 0.30                   | 391.61             | 78.28                 | 25.00                 | 303.06               | 51.64                  | 100.00           | 7.00                | 130.01             | 22.96                 |
| 0.40                   | 389.15             | 93.56                 | 25.00                 | 305.61               | 59.28                  | 100.00           | 7.00                | 122.65             | 29.54                 |
| 0.50                   | 386.84             | 107.42                | 25.00                 | 307.88               | 66.21                  | 100.00           | 7.00                | 115.94             | 35.52                 |
| 0.60                   | 384.67             | 119.86                | 25.00                 | 309.83               | 72.43                  | 100.00           | 7.00                | 109.88             | 40.87                 |
| 0.70                   | 382.61             | 130.87                | 25.00                 | 311.47               | 77.94                  | 100.00           | 7.00                | 104.46             | 45.62                 |
| 0.80                   | 380.66             | 140.53                | 25.00                 | 312.80               | 82.76                  | 100.00           | 7.00                | 99.64              | 49.78                 |
| 0.90                   | 378.81             | 148.90                | 25.00                 | 313.84               | 86.95                  | 100.00           | 7.00                | 95.40              | 53.39                 |
| 1.00                   | 377.04             | 156.10                | 25.00                 | 314.60               | 90.55                  | 100.00           | 7.00                | 91.68              | 56.49                 |
| 1.10                   | 375.35             | 162.24                | 25.00                 | 315.12               | 93.62                  | 100.00           | 7.00                | 88.43              | 59.14                 |
| 1.20                   | 373.72             | 167.42                | 25.00                 | 315.42               | 96.21                  | 100.00           | 7.00                | 85.60              | 61.37                 |
| 1.30                   | 372.14             | 171.76                | 25.00                 | 315.51               | 98.38                  | 100.00           | 7.00                | 83.15              | 63.24                 |
| 1.40                   | 370.62             | 175.35                | 25.00                 | 315.43               | 100.18                 | 100.00           | 7.00                | 81.02              | 64.79                 |
| 1.50                   | 369.13             | 178.31                | 25.00                 | 315.21               | 101.66                 | 100.00           | 7.00                | 79.18              | 66.06                 |
| 1.60                   | 367.69             | 180.72                | 25.00                 | 314.85               | 102.86                 | 100.00           | 7.00                | 77.58              | 67.10                 |
| 1.70                   | 366.27             | 182.65                | 25.00                 | 314.38               | 103.82                 | 100.00           | 7.00                | 76.19              | 67.93                 |
| 1.80                   | 364.89             | 184.18                | 25.00                 | 313.82               | 104.59                 | 100.00           | 7.00                | 74.98              | 68.59                 |
| 1.90                   | 363.53             | 185.37                | 25.00                 | 313.18               | 105.18                 | 100.00           | 7.00                | 73.93              | 69.10                 |
| 2.00                   | 362.19             | 186.27                | 25.00                 | 312.47               | 105.63                 | 100.00           | 7.00                | 73.00              | 69.49                 |
| 2.10                   | 360.87             | 186.92                | 25.00                 | 311.71               | 105.96                 | 100.00           | 7.00                | 72.18              | 69.77                 |
| 2.20                   | 359.57             | 187.37                | 25.00                 | 310.90               | 106.18                 | 100.00           | 7.00                | 71.45              | 69.97                 |
| 2.30                   | 358.28             | 187.65                | 25.00                 | 310.06               | 106.32                 | 100.00           | 7.00                | 70.80              | 70.09                 |
| 2.40                   | 357.01             | 187.78                | 25.00                 | 309.19               | 106.39                 | 100.00           | 7.00                | 70.22              | 70.14                 |
| 2.50                   | 355.75             | 187.80                | 25.00                 | 308.29               | 106.40                 | 100.00           | 7.00                | 69.69              | 70.15                 |
| 2.60                   | 354.51             | 187.71                | 25.00                 | 307.37               | 106.36                 | 100.00           | 7.00                | 69.21              | 70.11                 |
| 2.70                   | 353.27             | 187.54                | 25.00                 | 306.44               | 106.27                 | 100.00           | 7.00                | 68.77              | 70.04                 |
| 2.80                   | 352.05             | 187.30                | 25.00                 | 305.49               | 106.15                 | 100.00           | 7.00                | 68.36              | 69.94                 |
| 2.90                   | 350.83             | 187.01                | 25.00                 | 304.54               | 106.00                 | 100.00           | 7.00                | 67.98              | 69.81                 |
| 3.00                   | 349.63             | 186.67                | 25.00                 | 303.57               | 105.83                 | 100.00           | 7.00                | 67.62              | 69.66                 |
| 3.10                   | 348.43             | 186.29                | 25.00                 | 302.61               | 105.64                 | 100.00           | 7.00                | 67.28              | 69.50                 |
| 3.20                   | 347.24             | 185.87                | 25.00                 | 301.64               | 105.44                 | 100.00           | 7.00                | 66.96              | 69.32                 |
| 3.30                   | 346.06             | 185.43                | 25.00                 | 300.66               | 105.22                 | 100.00           | 7.00                | 66.65              | 69.13                 |
| 3.40                   | 344.89             | 184.97                | 25.00                 | 299.69               | 104.98                 | 100.00           | 7.00                | 66.36              | 68.93                 |
| 3.50                   | 343.72             | 184.49                | 25.00                 | 298.72               | 104.75                 | 100.00           | 7.00                | 66.07              | 68.72                 |
| 3.60                   | 342.56             | 184.00                | 25.00                 | 297.75               | 104.50                 | 100.00           | 7.00                | 65.79              | 68.51                 |
| 3.70                   | 341.41             | 183.49                | 25.00                 | 296.78               | 104.25                 | 100.00           | 7.00                | 65.53              | 68.29                 |
| 3.80                   | 340.26             | 182.98                | 25.00                 | 295.81               | 103.99                 | 100.00           | 7.00                | 65.26              | 68.07                 |
| 3.90                   | 339.13             | 182.46                | 25.00                 | 294.85               | 103.73                 | 100.00           | 7.00                | 65.01              | 67.85                 |

Air-Cooled Chimney Model

| Height Above<br>Base M | Flue Gas<br>Temp C | Cooling air<br>Temp C | Outdoor air<br>Temp C | Flue Liner<br>Temp C | Outside Surf<br>Temp C | Flue Flow<br>L/s | Cooling Flow<br>L/s | Ui=6.5             | Uo=4.5                |
|------------------------|--------------------|-----------------------|-----------------------|----------------------|------------------------|------------------|---------------------|--------------------|-----------------------|
|                        |                    |                       |                       |                      |                        |                  |                     | Heat Loss<br>Watts | Exterior<br>Heat loss |
| 0.00                   | 400.00             | 25.00                 | 25.00                 | 294.02               | 25.00                  | 120.00           | 5.00                | 155.60             | 0.00                  |
| 0.10                   | 397.52             | 51.38                 | 25.00                 | 299.70               | 38.19                  | 120.00           | 5.00                | 143.63             | 11.37                 |
| 0.20                   | 395.24             | 75.78                 | 25.00                 | 304.95               | 50.39                  | 120.00           | 5.00                | 132.55             | 21.88                 |
| 0.30                   | 393.14             | 97.74                 | 25.00                 | 309.65               | 61.37                  | 120.00           | 5.00                | 122.57             | 31.34                 |
| 0.40                   | 391.20             | 116.98                | 25.00                 | 313.70               | 70.99                  | 120.00           | 5.00                | 113.79             | 39.63                 |
| 0.50                   | 389.41             | 133.43                | 25.00                 | 317.07               | 79.21                  | 120.00           | 5.00                | 106.22             | 46.72                 |
| 0.60                   | 387.74             | 147.18                | 25.00                 | 319.76               | 86.09                  | 120.00           | 5.00                | 99.82              | 52.65                 |
| 0.70                   | 386.18             | 158.46                | 25.00                 | 321.82               | 91.73                  | 120.00           | 5.00                | 94.49              | 57.51                 |
| 0.80                   | 384.70             | 167.53                | 25.00                 | 323.33               | 96.27                  | 120.00           | 5.00                | 90.11              | 61.42                 |
| 0.90                   | 383.30             | 174.72                | 25.00                 | 324.35               | 99.86                  | 120.00           | 5.00                | 86.55              | 64.52                 |
| 1.00                   | 381.95             | 180.33                | 25.00                 | 324.97               | 102.67                 | 120.00           | 5.00                | 83.66              | 66.93                 |
| 1.10                   | 380.65             | 184.65                | 25.00                 | 325.26               | 104.82                 | 120.00           | 5.00                | 81.33              | 68.79                 |
| 1.20                   | 379.39             | 187.91                | 25.00                 | 325.28               | 106.46                 | 120.00           | 5.00                | 79.45              | 70.20                 |
| 1.30                   | 378.16             | 190.34                | 25.00                 | 325.08               | 107.67                 | 120.00           | 5.00                | 77.94              | 71.24                 |
| 1.40                   | 376.96             | 192.10                | 25.00                 | 324.72               | 108.55                 | 120.00           | 5.00                | 76.71              | 72.00                 |
| 1.50                   | 375.78             | 193.35                | 25.00                 | 324.22               | 109.17                 | 120.00           | 5.00                | 75.70              | 72.54                 |
| 1.60                   | 374.62             | 194.18                | 25.00                 | 323.62               | 109.59                 | 120.00           | 5.00                | 74.87              | 72.90                 |
| 1.70                   | 373.47             | 194.71                | 25.00                 | 322.95               | 109.85                 | 120.00           | 5.00                | 74.17              | 73.13                 |
| 1.80                   | 372.33             | 194.99                | 25.00                 | 322.21               | 109.99                 | 120.00           | 5.00                | 73.59              | 73.25                 |
| 1.90                   | 371.20             | 195.08                | 25.00                 | 321.43               | 110.04                 | 120.00           | 5.00                | 73.08              | 73.29                 |
| 2.00                   | 370.09             | 195.02                | 25.00                 | 320.61               | 110.01                 | 120.00           | 5.00                | 72.64              | 73.26                 |
| 2.10                   | 368.98             | 194.86                | 25.00                 | 319.77               | 109.93                 | 120.00           | 5.00                | 72.25              | 73.19                 |
| 2.20                   | 367.88             | 194.61                | 25.00                 | 318.91               | 109.80                 | 120.00           | 5.00                | 71.90              | 73.08                 |
| 2.30                   | 366.79             | 194.29                | 25.00                 | 318.04               | 109.65                 | 120.00           | 5.00                | 71.58              | 72.95                 |
| 2.40                   | 365.70             | 193.93                | 25.00                 | 317.16               | 109.46                 | 120.00           | 5.00                | 71.28              | 72.79                 |
| 2.50                   | 364.63             | 193.53                | 25.00                 | 316.27               | 109.26                 | 120.00           | 5.00                | 71.00              | 72.62                 |
| 2.60                   | 363.55             | 193.10                | 25.00                 | 315.38               | 109.05                 | 120.00           | 5.00                | 70.73              | 72.43                 |
| 2.70                   | 362.49             | 192.64                | 25.00                 | 314.49               | 108.82                 | 120.00           | 5.00                | 70.47              | 72.24                 |
| 2.80                   | 361.42             | 192.18                | 25.00                 | 313.59               | 108.59                 | 120.00           | 5.00                | 70.23              | 72.04                 |
| 2.90                   | 360.37             | 191.70                | 25.00                 | 312.70               | 108.35                 | 120.00           | 5.00                | 69.99              | 71.83                 |
| 3.00                   | 359.32             | 191.21                | 25.00                 | 311.81               | 108.11                 | 120.00           | 5.00                | 69.75              | 71.62                 |
| 3.10                   | 358.27             | 190.72                | 25.00                 | 310.92               | 107.86                 | 120.00           | 5.00                | 69.53              | 71.41                 |
| 3.20                   | 357.23             | 190.22                | 25.00                 | 310.03               | 107.61                 | 120.00           | 5.00                | 69.30              | 71.19                 |
| 3.30                   | 356.20             | 189.72                | 25.00                 | 309.15               | 107.36                 | 120.00           | 5.00                | 69.08              | 70.98                 |
| 3.40                   | 355.17             | 189.22                | 25.00                 | 308.27               | 107.11                 | 120.00           | 5.00                | 68.86              | 70.76                 |
| 3.50                   | 354.14             | 188.72                | 25.00                 | 307.39               | 106.86                 | 120.00           | 5.00                | 68.64              | 70.55                 |
| 3.60                   | 353.12             | 188.22                | 25.00                 | 306.52               | 106.61                 | 120.00           | 5.00                | 68.42              | 70.33                 |
| 3.70                   | 352.11             | 187.72                | 25.00                 | 305.65               | 106.36                 | 120.00           | 5.00                | 68.21              | 70.12                 |
| 3.80                   | 351.10             | 187.22                | 25.00                 | 304.78               | 106.11                 | 120.00           | 5.00                | 68.00              | 69.90                 |
| 3.90                   | 350.09             | 186.72                | 25.00                 | 303.92               | 105.86                 | 120.00           | 5.00                | 67.79              | 69.69                 |

Type A Chimney Model

| Height Above<br>Base M | Flue Gas<br>Temp C | Outdoor air<br>Temp C | Flue Liner<br>Temp C | Outside Surf<br>Temp C | Flue Flow<br>L/s | U <sub>i</sub> =3  |
|------------------------|--------------------|-----------------------|----------------------|------------------------|------------------|--------------------|
|                        |                    |                       |                      |                        |                  | Heat Loss<br>Watts |
| 0.00                   | 245.00             | 25.00                 | 216.30               | 69.00                  | 150.00           | 42.13              |
| 0.10                   | 244.59             | 25.00                 | 215.94               | 68.92                  | 150.00           | 42.05              |
| 0.20                   | 244.17             | 25.00                 | 215.59               | 68.83                  | 150.00           | 41.97              |
| 0.30                   | 243.76             | 25.00                 | 215.23               | 68.75                  | 150.00           | 41.90              |
| 0.40                   | 243.35             | 25.00                 | 214.87               | 68.67                  | 150.00           | 41.82              |
| 0.50                   | 242.94             | 25.00                 | 214.51               | 68.59                  | 150.00           | 41.74              |
| 0.60                   | 242.53             | 25.00                 | 214.16               | 68.51                  | 150.00           | 41.66              |
| 0.70                   | 242.13             | 25.00                 | 213.81               | 68.43                  | 150.00           | 41.58              |
| 0.80                   | 241.72             | 25.00                 | 213.45               | 68.34                  | 150.00           | 41.50              |
| 0.90                   | 241.32             | 25.00                 | 213.10               | 68.26                  | 150.00           | 41.43              |
| 1.00                   | 240.91             | 25.00                 | 212.75               | 68.18                  | 150.00           | 41.35              |
| 1.10                   | 240.51             | 25.00                 | 212.40               | 68.10                  | 150.00           | 41.27              |
| 1.20                   | 240.11             | 25.00                 | 212.05               | 68.02                  | 150.00           | 41.20              |
| 1.30                   | 239.71             | 25.00                 | 211.70               | 67.94                  | 150.00           | 41.12              |
| 1.40                   | 239.31             | 25.00                 | 211.35               | 67.86                  | 150.00           | 41.04              |
| 1.50                   | 238.91             | 25.00                 | 211.01               | 67.78                  | 150.00           | 40.97              |
| 1.60                   | 238.51             | 25.00                 | 210.66               | 67.70                  | 150.00           | 40.89              |
| 1.70                   | 238.11             | 25.00                 | 210.32               | 67.62                  | 150.00           | 40.81              |
| 1.80                   | 237.72             | 25.00                 | 209.97               | 67.54                  | 150.00           | 40.74              |
| 1.90                   | 237.32             | 25.00                 | 209.63               | 67.46                  | 150.00           | 40.66              |
| 2.00                   | 236.93             | 25.00                 | 209.29               | 67.39                  | 150.00           | 40.59              |
| 2.10                   | 236.54             | 25.00                 | 208.95               | 67.31                  | 150.00           | 40.51              |
| 2.20                   | 236.15             | 25.00                 | 208.61               | 67.23                  | 150.00           | 40.44              |
| 2.30                   | 235.76             | 25.00                 | 208.27               | 67.15                  | 150.00           | 40.36              |
| 2.40                   | 235.37             | 25.00                 | 207.93               | 67.07                  | 150.00           | 40.29              |
| 2.50                   | 234.98             | 25.00                 | 207.59               | 67.00                  | 150.00           | 40.21              |
| 2.60                   | 234.59             | 25.00                 | 207.25               | 66.92                  | 150.00           | 40.14              |
| 2.70                   | 234.20             | 25.00                 | 206.92               | 66.84                  | 150.00           | 40.06              |
| 2.80                   | 233.82             | 25.00                 | 206.58               | 66.76                  | 150.00           | 39.99              |
| 2.90                   | 233.43             | 25.00                 | 206.25               | 66.69                  | 150.00           | 39.92              |
| 3.00                   | 233.05             | 25.00                 | 205.91               | 66.61                  | 150.00           | 39.84              |
| 3.10                   | 232.67             | 25.00                 | 205.58               | 66.53                  | 150.00           | 39.77              |
| 3.20                   | 232.29             | 25.00                 | 205.25               | 66.46                  | 150.00           | 39.70              |
| 3.30                   | 231.91             | 25.00                 | 204.92               | 66.38                  | 150.00           | 39.63              |
| 3.40                   | 231.53             | 25.00                 | 204.59               | 66.31                  | 150.00           | 39.55              |
| 3.50                   | 231.15             | 25.00                 | 204.26               | 66.23                  | 150.00           | 39.48              |
| 3.60                   | 230.77             | 25.00                 | 203.93               | 66.15                  | 150.00           | 39.41              |
| 3.70                   | 230.40             | 25.00                 | 203.60               | 66.08                  | 150.00           | 39.34              |
| 3.80                   | 230.02             | 25.00                 | 203.28               | 66.00                  | 150.00           | 39.26              |
| 3.90                   | 229.65             | 25.00                 | 202.95               | 65.93                  | 150.00           | 39.19              |

Type A Chimney Model

| Height Above<br>Base M | Flue Gas<br>Temp C | Outdoor air<br>Temp C | Flue Liner<br>Temp C | Outside Surf<br>Temp C | Flue Flow<br>L/s | U <sub>i</sub> =4  |
|------------------------|--------------------|-----------------------|----------------------|------------------------|------------------|--------------------|
|                        |                    |                       |                      |                        |                  | Heat Loss<br>Watts |
| 0.00                   | 245.00             | 25.00                 | 206.74               | 83.67                  | 150.00           | 56.18              |
| 0.10                   | 244.45             | 25.00                 | 206.28               | 83.52                  | 150.00           | 56.04              |
| 0.20                   | 243.90             | 25.00                 | 205.83               | 83.37                  | 150.00           | 55.90              |
| 0.30                   | 243.35             | 25.00                 | 205.38               | 83.23                  | 150.00           | 55.76              |
| 0.40                   | 242.80             | 25.00                 | 204.93               | 83.08                  | 150.00           | 55.62              |
| 0.50                   | 242.26             | 25.00                 | 204.48               | 82.94                  | 150.00           | 55.48              |
| 0.60                   | 241.72             | 25.00                 | 204.03               | 82.79                  | 150.00           | 55.34              |
| 0.70                   | 241.18             | 25.00                 | 203.58               | 82.65                  | 150.00           | 55.20              |
| 0.80                   | 240.64             | 25.00                 | 203.14               | 82.50                  | 150.00           | 55.06              |
| 0.90                   | 240.10             | 25.00                 | 202.69               | 82.36                  | 150.00           | 54.93              |
| 1.00                   | 239.57             | 25.00                 | 202.25               | 82.22                  | 150.00           | 54.79              |
| 1.10                   | 239.04             | 25.00                 | 201.81               | 82.08                  | 150.00           | 54.65              |
| 1.20                   | 238.51             | 25.00                 | 201.38               | 81.94                  | 150.00           | 54.52              |
| 1.30                   | 237.98             | 25.00                 | 200.94               | 81.79                  | 150.00           | 54.38              |
| 1.40                   | 237.45             | 25.00                 | 200.50               | 81.65                  | 150.00           | 54.25              |
| 1.50                   | 236.93             | 25.00                 | 200.07               | 81.51                  | 150.00           | 54.12              |
| 1.60                   | 236.40             | 25.00                 | 199.64               | 81.37                  | 150.00           | 53.98              |
| 1.70                   | 235.88             | 25.00                 | 199.21               | 81.24                  | 150.00           | 53.85              |
| 1.80                   | 235.36             | 25.00                 | 198.78               | 81.10                  | 150.00           | 53.72              |
| 1.90                   | 234.84             | 25.00                 | 198.35               | 80.96                  | 150.00           | 53.58              |
| 2.00                   | 234.33             | 25.00                 | 197.92               | 80.82                  | 150.00           | 53.45              |
| 2.10                   | 233.81             | 25.00                 | 197.50               | 80.68                  | 150.00           | 53.32              |
| 2.20                   | 233.30             | 25.00                 | 197.08               | 80.55                  | 150.00           | 53.19              |
| 2.30                   | 232.79             | 25.00                 | 196.65               | 80.41                  | 150.00           | 53.06              |
| 2.40                   | 232.28             | 25.00                 | 196.23               | 80.28                  | 150.00           | 52.93              |
| 2.50                   | 231.78             | 25.00                 | 195.81               | 80.14                  | 150.00           | 52.80              |
| 2.60                   | 231.27             | 25.00                 | 195.40               | 80.01                  | 150.00           | 52.67              |
| 2.70                   | 230.77             | 25.00                 | 194.98               | 79.87                  | 150.00           | 52.54              |
| 2.80                   | 230.26             | 25.00                 | 194.57               | 79.74                  | 150.00           | 52.41              |
| 2.90                   | 229.76             | 25.00                 | 194.15               | 79.60                  | 150.00           | 52.29              |
| 3.00                   | 229.27             | 25.00                 | 193.74               | 79.47                  | 150.00           | 52.16              |
| 3.10                   | 228.77             | 25.00                 | 193.33               | 79.34                  | 150.00           | 52.03              |
| 3.20                   | 228.27             | 25.00                 | 192.92               | 79.21                  | 150.00           | 51.91              |
| 3.30                   | 227.78             | 25.00                 | 192.51               | 79.07                  | 150.00           | 51.78              |
| 3.40                   | 227.29             | 25.00                 | 192.11               | 78.94                  | 150.00           | 51.65              |
| 3.50                   | 226.80             | 25.00                 | 191.70               | 78.81                  | 150.00           | 51.53              |
| 3.60                   | 226.31             | 25.00                 | 191.30               | 78.68                  | 150.00           | 51.40              |
| 3.70                   | 225.82             | 25.00                 | 190.90               | 78.55                  | 150.00           | 51.28              |
| 3.80                   | 225.34             | 25.00                 | 190.50               | 78.42                  | 150.00           | 51.16              |
| 3.90                   | 224.86             | 25.00                 | 190.10               | 78.29                  | 150.00           | 51.03              |



## Type A Chimney Model

| Height Above<br>Base M | Flue Gas<br>Temp C | Outdoor air<br>Temp C | Flue Liner<br>Temp C | Outside Surf<br>Temp C | Flue Flow<br>L/s | Ui=4               |
|------------------------|--------------------|-----------------------|----------------------|------------------------|------------------|--------------------|
|                        |                    |                       |                      |                        |                  | Heat Loss<br>Watts |
| 0.00                   | 300.00             | 25.00                 | 252.17               | 98.33                  | 150.00           | 70.22              |
| 0.10                   | 299.24             | 25.00                 | 251.54               | 98.13                  | 150.00           | 70.03              |
| 0.20                   | 298.48             | 25.00                 | 250.92               | 97.93                  | 150.00           | 69.83              |
| 0.30                   | 297.72             | 25.00                 | 250.29               | 97.73                  | 150.00           | 69.64              |
| 0.40                   | 296.97             | 25.00                 | 249.67               | 97.52                  | 150.00           | 69.45              |
| 0.50                   | 296.22             | 25.00                 | 249.05               | 97.32                  | 150.00           | 69.25              |
| 0.60                   | 295.47             | 25.00                 | 248.43               | 97.13                  | 150.00           | 69.06              |
| 0.70                   | 294.72             | 25.00                 | 247.82               | 96.93                  | 150.00           | 68.87              |
| 0.80                   | 293.98             | 25.00                 | 247.20               | 96.73                  | 150.00           | 68.68              |
| 0.90                   | 293.24             | 25.00                 | 246.59               | 96.53                  | 150.00           | 68.50              |
| 1.00                   | 292.51             | 25.00                 | 245.99               | 96.34                  | 150.00           | 68.31              |
| 1.10                   | 291.78             | 25.00                 | 245.38               | 96.14                  | 150.00           | 68.12              |
| 1.20                   | 291.05             | 25.00                 | 244.78               | 95.95                  | 150.00           | 67.93              |
| 1.30                   | 290.32             | 25.00                 | 244.18               | 95.75                  | 150.00           | 67.75              |
| 1.40                   | 289.60             | 25.00                 | 243.58               | 95.56                  | 150.00           | 67.56              |
| 1.50                   | 288.88             | 25.00                 | 242.98               | 95.37                  | 150.00           | 67.38              |
| 1.60                   | 288.16             | 25.00                 | 242.39               | 95.18                  | 150.00           | 67.20              |
| 1.70                   | 287.44             | 25.00                 | 241.80               | 94.98                  | 150.00           | 67.01              |
| 1.80                   | 286.73             | 25.00                 | 241.21               | 94.80                  | 150.00           | 66.83              |
| 1.90                   | 286.02             | 25.00                 | 240.63               | 94.61                  | 150.00           | 66.65              |
| 2.00                   | 285.32             | 25.00                 | 240.04               | 94.42                  | 150.00           | 66.47              |
| 2.10                   | 284.61             | 25.00                 | 239.46               | 94.23                  | 150.00           | 66.29              |
| 2.20                   | 283.91             | 25.00                 | 238.88               | 94.04                  | 150.00           | 66.11              |
| 2.30                   | 283.21             | 25.00                 | 238.31               | 93.86                  | 150.00           | 65.93              |
| 2.40                   | 282.52             | 25.00                 | 237.73               | 93.67                  | 150.00           | 65.76              |
| 2.50                   | 281.83             | 25.00                 | 237.16               | 93.49                  | 150.00           | 65.58              |
| 2.60                   | 281.14             | 25.00                 | 236.59               | 93.30                  | 150.00           | 65.40              |
| 2.70                   | 280.45             | 25.00                 | 236.02               | 93.12                  | 150.00           | 65.23              |
| 2.80                   | 279.76             | 25.00                 | 235.46               | 92.94                  | 150.00           | 65.05              |
| 2.90                   | 279.08             | 25.00                 | 234.89               | 92.76                  | 150.00           | 64.88              |
| 3.00                   | 278.40             | 25.00                 | 234.33               | 92.57                  | 150.00           | 64.71              |
| 3.10                   | 277.73             | 25.00                 | 233.77               | 92.39                  | 150.00           | 64.53              |
| 3.20                   | 277.05             | 25.00                 | 233.22               | 92.21                  | 150.00           | 64.36              |
| 3.30                   | 276.38             | 25.00                 | 232.66               | 92.03                  | 150.00           | 64.19              |
| 3.40                   | 275.71             | 25.00                 | 232.11               | 91.86                  | 150.00           | 64.02              |
| 3.50                   | 275.05             | 25.00                 | 231.56               | 91.68                  | 150.00           | 63.85              |
| 3.60                   | 274.38             | 25.00                 | 231.01               | 91.50                  | 150.00           | 63.68              |
| 3.70                   | 273.72             | 25.00                 | 230.47               | 91.33                  | 150.00           | 63.51              |
| 3.80                   | 273.06             | 25.00                 | 229.92               | 91.15                  | 150.00           | 63.34              |
| 3.90                   | 272.41             | 25.00                 | 229.38               | 90.98                  | 150.00           | 63.18              |

## 650 Chimney Model

| Height Above<br>Base M | Flue Gas<br>Temp C | Outdoor air<br>Temp C | Flue Liner<br>Temp C | Outside Surf<br>Temp C | Flue Flow<br>L/s | 2.70               |
|------------------------|--------------------|-----------------------|----------------------|------------------------|------------------|--------------------|
|                        |                    |                       |                      |                        |                  | Heat Loss<br>Watts |
| 0.00                   | 232.00             | 25.00                 | 207.70               | 56.05                  | 100.00           | 35.68              |
| 0.10                   | 231.49             | 25.00                 | 207.25               | 55.97                  | 100.00           | 35.59              |
| 0.20                   | 230.98             | 25.00                 | 206.80               | 55.90                  | 100.00           | 35.50              |
| 0.30                   | 230.47             | 25.00                 | 206.35               | 55.82                  | 100.00           | 35.41              |
| 0.40                   | 229.96             | 25.00                 | 205.90               | 55.74                  | 100.00           | 35.33              |
| 0.50                   | 229.46             | 25.00                 | 205.45               | 55.67                  | 100.00           | 35.24              |
| 0.60                   | 228.95             | 25.00                 | 205.01               | 55.59                  | 100.00           | 35.15              |
| 0.70                   | 228.45             | 25.00                 | 204.57               | 55.52                  | 100.00           | 35.07              |
| 0.80                   | 227.95             | 25.00                 | 204.13               | 55.44                  | 100.00           | 34.98              |
| 0.90                   | 227.45             | 25.00                 | 203.69               | 55.37                  | 100.00           | 34.89              |
| 1.00                   | 226.95             | 25.00                 | 203.25               | 55.29                  | 100.00           | 34.81              |
| 1.10                   | 226.46             | 25.00                 | 202.81               | 55.22                  | 100.00           | 34.72              |
| 1.20                   | 225.97             | 25.00                 | 202.37               | 55.15                  | 100.00           | 34.64              |
| 1.30                   | 225.48             | 25.00                 | 201.94               | 55.07                  | 100.00           | 34.55              |
| 1.40                   | 224.99             | 25.00                 | 201.51               | 55.00                  | 100.00           | 34.47              |
| 1.50                   | 224.50             | 25.00                 | 201.08               | 54.92                  | 100.00           | 34.39              |
| 1.60                   | 224.01             | 25.00                 | 200.65               | 54.85                  | 100.00           | 34.30              |
| 1.70                   | 223.53             | 25.00                 | 200.22               | 54.78                  | 100.00           | 34.22              |
| 1.80                   | 223.04             | 25.00                 | 199.79               | 54.71                  | 100.00           | 34.13              |
| 1.90                   | 222.56             | 25.00                 | 199.37               | 54.63                  | 100.00           | 34.05              |
| 2.00                   | 222.08             | 25.00                 | 198.95               | 54.56                  | 100.00           | 33.97              |
| 2.10                   | 221.60             | 25.00                 | 198.52               | 54.49                  | 100.00           | 33.89              |
| 2.20                   | 221.13             | 25.00                 | 198.10               | 54.42                  | 100.00           | 33.80              |
| 2.30                   | 220.65             | 25.00                 | 197.68               | 54.35                  | 100.00           | 33.72              |
| 2.40                   | 220.18             | 25.00                 | 197.27               | 54.28                  | 100.00           | 33.64              |
| 2.50                   | 219.71             | 25.00                 | 196.85               | 54.21                  | 100.00           | 33.56              |
| 2.60                   | 219.24             | 25.00                 | 196.43               | 54.14                  | 100.00           | 33.48              |
| 2.70                   | 218.77             | 25.00                 | 196.02               | 54.06                  | 100.00           | 33.40              |
| 2.80                   | 218.30             | 25.00                 | 195.61               | 53.99                  | 100.00           | 33.32              |
| 2.90                   | 217.83             | 25.00                 | 195.20               | 53.93                  | 100.00           | 33.24              |
| 3.00                   | 217.37             | 25.00                 | 194.79               | 53.86                  | 100.00           | 33.16              |
| 3.10                   | 216.91             | 25.00                 | 194.38               | 53.79                  | 100.00           | 33.08              |
| 3.20                   | 216.45             | 25.00                 | 193.97               | 53.72                  | 100.00           | 33.00              |
| 3.30                   | 215.99             | 25.00                 | 193.57               | 53.65                  | 100.00           | 32.92              |
| 3.40                   | 215.53             | 25.00                 | 193.16               | 53.58                  | 100.00           | 32.84              |
| 3.50                   | 215.07             | 25.00                 | 192.76               | 53.51                  | 100.00           | 32.76              |
| 3.60                   | 214.62             | 25.00                 | 192.36               | 53.44                  | 100.00           | 32.68              |
| 3.70                   | 214.17             | 25.00                 | 191.96               | 53.37                  | 100.00           | 32.60              |
| 3.80                   | 213.71             | 25.00                 | 191.56               | 53.31                  | 100.00           | 32.53              |
| 3.90                   | 213.26             | 25.00                 | 191.16               | 53.24                  | 100.00           | 32.45              |

## 650 Chimney Model

| Height Above<br>Base M | Flue Gas<br>Temp C | Outdoor air<br>Temp C | Flue Liner<br>Temp C | Outside Surf<br>Temp C | Flue Flow<br>L/s | 2.70               |
|------------------------|--------------------|-----------------------|----------------------|------------------------|------------------|--------------------|
|                        |                    |                       |                      |                        |                  | Heat Loss<br>Watts |
| 0.00                   | 360.00             | 0.00                  | 317.74               | 54.00                  | 100.00           | 62.05              |
| 0.10                   | 358.88             | 0.00                  | 316.75               | 53.83                  | 100.00           | 61.86              |
| 0.20                   | 357.77             | 0.00                  | 315.77               | 53.67                  | 100.00           | 61.67              |
| 0.30                   | 356.66             | 0.00                  | 314.80               | 53.50                  | 100.00           | 61.47              |
| 0.40                   | 355.56             | 0.00                  | 313.82               | 53.33                  | 100.00           | 61.29              |
| 0.50                   | 354.47             | 0.00                  | 312.86               | 53.17                  | 100.00           | 61.10              |
| 0.60                   | 353.38             | 0.00                  | 311.89               | 53.01                  | 100.00           | 60.91              |
| 0.70                   | 352.29             | 0.00                  | 310.94               | 52.84                  | 100.00           | 60.72              |
| 0.80                   | 351.21             | 0.00                  | 309.98               | 52.68                  | 100.00           | 60.54              |
| 0.90                   | 350.14             | 0.00                  | 309.04               | 52.52                  | 100.00           | 60.35              |
| 1.00                   | 349.07             | 0.00                  | 308.09               | 52.36                  | 100.00           | 60.17              |
| 1.10                   | 348.00             | 0.00                  | 307.15               | 52.20                  | 100.00           | 59.98              |
| 1.20                   | 346.94             | 0.00                  | 306.22               | 52.04                  | 100.00           | 59.80              |
| 1.30                   | 345.89             | 0.00                  | 305.29               | 51.88                  | 100.00           | 59.62              |
| 1.40                   | 344.84             | 0.00                  | 304.36               | 51.73                  | 100.00           | 59.44              |
| 1.50                   | 343.80             | 0.00                  | 303.44               | 51.57                  | 100.00           | 59.26              |
| 1.60                   | 342.76             | 0.00                  | 302.52               | 51.41                  | 100.00           | 59.08              |
| 1.70                   | 341.72             | 0.00                  | 301.61               | 51.26                  | 100.00           | 58.90              |
| 1.80                   | 340.69             | 0.00                  | 300.70               | 51.10                  | 100.00           | 58.72              |
| 1.90                   | 339.67             | 0.00                  | 299.79               | 50.95                  | 100.00           | 58.55              |
| 2.00                   | 338.65             | 0.00                  | 298.89               | 50.80                  | 100.00           | 58.37              |
| 2.10                   | 337.63             | 0.00                  | 298.00               | 50.64                  | 100.00           | 58.19              |
| 2.20                   | 336.62             | 0.00                  | 297.11               | 50.49                  | 100.00           | 58.02              |
| 2.30                   | 335.62             | 0.00                  | 296.22               | 50.34                  | 100.00           | 57.85              |
| 2.40                   | 334.61             | 0.00                  | 295.33               | 50.19                  | 100.00           | 57.67              |
| 2.50                   | 333.62             | 0.00                  | 294.45               | 50.04                  | 100.00           | 57.50              |
| 2.60                   | 332.63             | 0.00                  | 293.58               | 49.89                  | 100.00           | 57.33              |
| 2.70                   | 331.64             | 0.00                  | 292.71               | 49.75                  | 100.00           | 57.16              |
| 2.80                   | 330.65             | 0.00                  | 291.84               | 49.60                  | 100.00           | 56.99              |
| 2.90                   | 329.68             | 0.00                  | 290.98               | 49.45                  | 100.00           | 56.82              |
| 3.00                   | 328.70             | 0.00                  | 290.12               | 49.31                  | 100.00           | 56.66              |
| 3.10                   | 327.73             | 0.00                  | 289.26               | 49.16                  | 100.00           | 56.49              |
| 3.20                   | 326.77             | 0.00                  | 288.41               | 49.02                  | 100.00           | 56.32              |
| 3.30                   | 325.81             | 0.00                  | 287.56               | 48.87                  | 100.00           | 56.16              |
| 3.40                   | 324.85             | 0.00                  | 286.72               | 48.73                  | 100.00           | 55.99              |
| 3.50                   | 323.90             | 0.00                  | 285.88               | 48.58                  | 100.00           | 55.83              |
| 3.60                   | 322.95             | 0.00                  | 285.04               | 48.44                  | 100.00           | 55.66              |
| 3.70                   | 322.01             | 0.00                  | 284.21               | 48.30                  | 100.00           | 55.50              |
| 3.80                   | 321.07             | 0.00                  | 283.38               | 48.16                  | 100.00           | 55.34              |
| 3.90                   | 320.13             | 0.00                  | 282.55               | 48.02                  | 100.00           | 55.18              |