

## ResLoad11.xls Instructions – A 12-Step Method to Well Conditioned Homes

ResLoad11.xls is a cooling and heating load calculation program for residential buildings with one or two zones. It is based on the procedures outlined in the 2001 *ASHRAE Handbook of Fundamentals* and the ASHRAE publication *HVAC Simplified* (Kavanaugh, 2006). There is no cost for the program. The cooling and heating loads for buildings with more than two zones can be calculated with another free program, *TideLoad*.

Satisfied users are welcome to express their support for these programs and other programs provided by Energy Information Services ([www.geokiss.com](http://www.geokiss.com)) by donating to the Tuscaloosa, Alabama Affiliate of Habitat for Humanity (1120 35<sup>th</sup> St., Tuscaloosa, AL 35401).

The ResLoad11 has several “Read Me” cells that will guide users through steps for this program. To further assist new users of this program, the cooling and heating load of an example building (see figure below) will be calculated. The drawing has several items that provide information that is used to describe the building. Page 2 is the completed cooling and heating load calculation form for this home. It will be referenced in the step-by-step instructions that follow. The building has only one zone, so the information for the second zone will be blank.

**Note: The pale yellow input cells are input screens and the light blue cells are calculated values. Do not type in the light blue cells unless you want to override the calculation.**

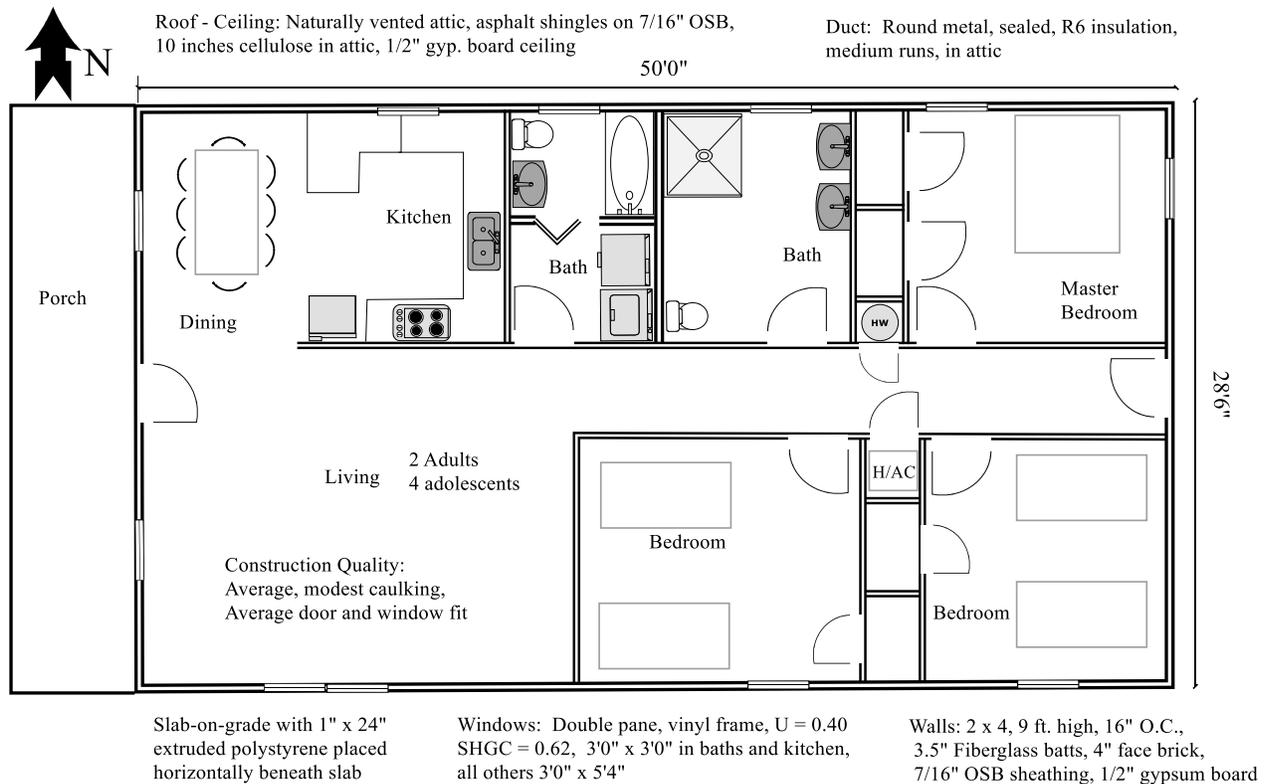


Figure 1 – Floor Plan and Construction Description of Example Building



## A Note on Excel Programs Containing Macros

Most of the programs available with *HVAC Simplified* (ASHRAE, 2006) and from the *geokiss.com* website contain *MS Visual Basic* macros to perform the more complex calculations. Since macros from unfamiliar sources may contain viruses, the default *MS Excel* security level is set at "High". For Office 2003 and earlier products, the user must set the security level to "Medium" or "Low" for the programs to operate. In some networks, resetting the security levels must be performed by the Network Manger.

To reset the security level for Excel 2003 and earlier versions,

1. If the program containing the macros is open, close it and exit Excel.
2. Re-open Excel, click on "Tools" on the main tool bar, select "Macro", select "Security."
3. Reset security level to Medium (recommended) or Low
4. Exit Excel
5. Re-open Excel
6. Run program

For 2007 Office products, the terminology "trust" has replaced "security" and the procedure has been changed (as you might expect). To change the "trust" settings:

1. Open Excel
2. Click the Office Button (top left corner of screen)
3. Click on "Excel Options" button @ the bottom of the pop-up window
4. Click on "Trust Center"
5. Click on "Trust Center Settings"
6. Click on " Enable all macros.."
7. Open and Run the programs
8. An option would be to reset the trust setting by repeating steps 1 thru 5 and,
9. Click on " Disable macros with notification"

### Step 1 – Enter Weather Data

Go to the worksheet labeled ‘Weather’. For the location nearest the building, copy the city name, elevation, latitude and 4 outdoor temperatures. Return to the ‘Main’ worksheet, click on the cell to the right of ‘Location’, and paste the seven values. Click on ‘Weather Read Me’ cell for more details. Users with access to weather data can create additional entries on the ‘Weather’ worksheet that more closely represent their local climate.

### Step 2 - Enter the Indoor Temperatures

Standard winter indoor temperature is 70 F and summer is 75 F (dry bulb) and 63 F (wet bulb). Other values can be entered but it is suggested users should select the two ‘Read Me’ cells in the temperature columns for additional details and explanations. Note the indoor and outdoor relative humidity will be displayed when steps 1 and 2 are completed.

### Step 3 – Enter General Data: Floor Areas and Heights, Tightness, and Mechanical Ventilation

- The floor area can be calculated by inserting ‘=50\*28.5’ into the cell to the right of the ‘Aflr1’ cell. This will compute the floor area from the width (50 ft.) and depth (28’6” = 28.5 ft.) values that appear on the drawing.
- A value of ‘ 9’ is entered in the cell to the right of “CeilHt1” cell since the ceiling height is 9 ft.
- Select the cell to the right of the ‘Leakage1’ and descriptions of the leakage (infiltration) classes of buildings will appear. Then select the drop down arrow to the right of the cell and the four choices will appear. The description of the construction quality for the example building is best described by ‘Medium’ click on it and the infiltration rate will be computed and displayed.
- Buildings can also be ventilated to comply with codes or to continuously exhaust kitchens or bathrooms. If additional ventilation air is required, the airflow of the fan in cubic feet per minute (cfm) is entered in the cell to the right of the ‘MechVent1’ cell. Another option is to leave this cell blank and enter the number of bedrooms in the cell to the right of the ‘Bedrms1’ cell. This will compute the airflow required to comply with the ASHRAE residential ventilation code.
- A great deal of energy can be saved when mechanical ventilation is used by placing a Heat Recovery Unit (a.k.a. Energy Recovery Unit if humidity is also being transferred) on the fan exhaust to transfer some of the heat (or cool) to the incoming ventilation air. Select the nearby ‘Read Me’ cell for more details.
- The mechanical ventilation rate will be displayed in ‘cfm’ and air changes per hour (ACH)

For this example no Mechanical Ventilation is provided. Also no data is entered for zone 2 since the home will have only one cooling and heating unit.

### Step 3 – Enter Window Descriptions and Areas to Calculate Heat Gain and Loss

New windows will have a label of the Solar Heat Gain Coefficient (SHGC) and U-value.

- These values should be entered for the directions that windows are facing. In this case windows face North, East, South and West. The information on the drawing indicates SHGC = 0.62 and U= 0.4 (Btu/hr-ft<sup>2</sup>-°F). Values are entered for the four directions.
- If SHGC and U-values are not given, two cells appear above the input columns that have typical window descriptions in drop down boxes that can be selected to estimate Solar Heat Gain Coefficients and U-value.
- The program computes the value Glass Load Factor for the cooling load which considers the effects of solar radiation, the conduction of heat through the glass and frame, the direction the window faces, the local latitude, and the maximum and minimum daily temperature.
- This value is multiplied by the window area to obtain the cooling load. In the winter the U-value is multiplied by the area and the indoor-outdoor temperature to obtain the heat loss.
- The window areas are the entered beginning with the windows facing north, which include three at 3'0" x 3'0" (kitchen, 2 baths) and one at 3'0" x 5'4". In the Area cell in the row labeled North, '=3\*3.0\*3.0+3.0\*5.3' is input. A value of 42.9 (ft<sup>2</sup>) appears.
- The procedure is repeated for the remaining directions that windows face.
- If a wall contains windows with different values of SHGC and U, copy the row for that direction from the SHGC column to the column labeled 'qh(kBtu/h)' into one of the rows labeled 'Other'. (If both the 'Other' rows are used for this purpose, the cells can be pasted into a row for an unused direction.) This will allow different values for SHGC and U to be entered for the different window types facing the same direction.

Note that values appear in cells in the next columns to the right that are the cooling sensible load [labeled  $q_{c,Sen}$ (kBtu/h)] and the winter heat loss [qh(kBtu/h)] in each direction. The values are given in kBtu/h (or 1000 Btu/h), to avoid the larger number if answers were expressed in Btu/h. There are no values in the columns labeled  $q_{c,Lat}$ (kBtu/h) since no latent heat (moisture) is transferred through the window glass. For an explanation of sensible and latent heat, select cells labeled "What is sensible heat?" and 'What is latent heat?' at the top of the spreadsheet.

### Step 3A – Take Credit for Shaded Windows – Optional

One of the most effective methods of reducing cooling requirements is shading (i.e. Trees or Wide Porches). In the northern hemisphere the summer sun does not shine on north windows (except briefly early in the morning and late afternoon). A shaded window facing other

directions can be treated as a north window to permit credit to be taken for the cooling load reduction while allowing the winter heat loss computation to be unaffected. Users can either add the shaded window area to the north window area or copy the north window row (21) and paste the contents in one of the rows labeled 'Other' (rows 30 or 31). The values for the shaded area are then entered to compute the heat gain and loss.

#### Step 4 –Enter Wall and Door U-values and Areas to Calculate Heat Gain and Loss

The heat transfer through walls is a function of the temperature difference between the outside temperature and indoor temperature, the area of the wall (not including the area of windows and doors), and the overall heat transmission coefficient. In the summer, solar radiation raises the surface temperature of the wall, so the “equivalent” outside temperature must be adjusted upward depending on the direction the wall faces and the local latitude. This is accomplished with the Cooling Load Temperature Difference (CLTD). Since the sun is not a significant factor (nighttime /early morning) when the heat loss is greatest, the outdoor-temperature difference can be used for walls facing any direction.

- Select the worksheet 'U (or R) Calc' for assistance in computing the U-value via finding its inverse, total resistance. The value is found by first adding the resistances of all the wall components.
- Since walls are composites that contain heat flow paths through wood (or metal) frames and insulated cavities, the resistances of each path must be computed and the total resistance adjusted relative to the percentage of area of each path. Frame walls are typically 15% to 20% frame and 80% to 85% insulation. Note that a wood 2 x 4" is actually 1.5" thick and 3.5" wide and a 2 x 6" is 1.5" thick and 5.5" wide.
- Table 1 is the portion of the 'U (or R) Calc' worksheet that is used for frame walls. Table 2 is the worksheet that contains the R-value of different materials and components. Note the values used for this example are highlighted in red.
- In the row labeled 'R-Insul. Path', enter percentage of insulation area of a frame wall with 2 x 4 s on 16 inch centers (approximately 80%), and the thermal resistances of the outside air film (0.25), 4" thick face brick (0.45), the 3.5" thick cavity filled with fiberglass insulation (13.0), the 7/16" OSB (0.62), the 1/2" gypsum board (0.45) and the inside air film (0.68).
- Repeat this in the row labeled 'R-Frame Path' using 20% area and leave the Insulation cell blank and enter the resistance of 3.5" of pine [=3.5 inches x 0.94 R/inch (=3.29)].
- The program will add the component resistances for each path, invert these sums, and use the ratio of the percentage of the wall areas that are insulation and frame to compute the composite U-value of 0.087 Btu/hr-ft<sup>2</sup>-°F. The user returns to the Main worksheet and enters 0.087 for all walls (cells B33-B40).



(except briefly early in the morning and late afternoon). A shaded wall facing other directions can be treated as a north wall to permit credit to be taken for the cooling load reduction while allowing the winter heat loss computation to be unaffected. Users can either add the shaded wall (and door) area to the north wall area or copy the north wall row (32) and paste the contents in one of the rows labeled 'Other' (rows 41 or 42). The values for the shaded area are then entered to compute the heat gain and loss.

#### Step 5 – Enter Roof/Ceiling U-value(s) and Area(s) to Calculate Heat Gain and Loss

As with walls, heat transfer through the roof/ceiling is a function of the temperature difference between the outside temperature and indoor temperature, the area of the roof or ceiling, and the overall heat transmission coefficient. Calculation of the U-value is complicated by the method used to ventilate the attic and the possibility that the air distribution system could be located in this space. The Cooling Load Temperature Difference (CLTD) is also used for the roof/ceiling but the impact of the duct work is accounted for in the last step of the overall procedure. This is due to the fact that duct heat gain must account for leakage which contains both sensible and latent gains. There are several options for the R-value of the attic space that depend on the method (and rate in  $\text{cfm}/\text{ft}^2$ ) of ventilation and the presence of reflective insulation that improves resistance to summer heat gain. For winter heat loss, the impact on roof temperature is not a significant factor when the heat loss is greatest and the outdoor-temperature difference can be used for roof/ceiling calculations.

- Select the worksheet 'U (or R) Calc' for assistance in computing the U-value via finding its inverse, total resistance. The value is found by first adding the resistances of all the wall components.
- Although roofs/ceilings contain composite heat flow paths, the impact of considering them as a single path is negligible. See the cross-section drawing on the 'U (or R) Calc' worksheet.
- As shown in Table 3, the section labeled 'R-Value and U-Value Calculator – Solid Wall or Roof' from the 'U (or R) Calc' worksheet is used. In the top row labeled 'R(Total)=', enter the thermal resistances of the outside air film (0.25), asphalt shingles (0.44), 10" of loose fill cellulose (34 – interpolated between value of 27 for 8" and 41 for 12" thicknesses), a naturally vented attic (2.7), 7/16" OSB (0.62), 1/2" gypsum board (0.45), and the inside air film (0.68).
- The program sums these components to be a R-value of 39.14 which is inverted to a U-value of  $0.026 \text{ Btu}/\text{hr}\cdot\text{ft}^2\cdot^\circ\text{F}$ . The user returns to the Main worksheet and enters 0.026 (cell B54).
- A second row (55) is available if the home has zones or areas with different types of roof/ceilings.

<b>R-Value and U-Value Calculator - Solid Wall or Roof</b>							
	Out. Surface	Shingles	Insulation	AtticNVent	OSB	Int. Finish	In. Surf.
R(Total)=	0.25	0.44	34	2.7	0.62	0.45	0.68
R(Total)=	39.14	hr.sq.ft.F/Btu					
U (Overall)=	0.026	Btu/hr.sq.ft.F					

Table 3 – U-Value Worksheet for Roof/Ceiling

**Step 6 –Enter Partition U-value(s) and Area(s) to Calculate Heat Gain and Loss**

Rows are included for walls that face unconditioned enclosed spaces not exposed directly to the outdoors. An example would be an attached garage in which the exterior door is kept closed. A computation for the CLTD of these types of spaces is included so that the user needs only to enter the U-value and area. This computation assumes the exterior walls and ceiling of this space are insulated. If the exterior door(s) normally remain open and /or there is no insulation in the exterior walls of the unconditioned space, the partition walls (facing the conditioned space) should be treated as a north wall in Step 4. This can be accomplished by copying the north wall row (32) and pasting the contents in one of the rows labeled ‘Other’ (rows 41 or 42). The values for the partition area are then entered to compute the heat gain and loss from the home to the unconditioned space. The example home has no attached garage or space so the partition area is left blank.

**Step 7 – Enter Floor U-value and Area or UP-Value and Perimeter to Calculate Gain and Loss**

The program permits the computation of crawl space (or basement) and slab-on-grade heat loss. Heat gains through slab-on-grade floors are typically neglected. Heat gains through crawl space walls are small but can not be neglected, especially if crawl space (or basement) floors are high or the duct system is in this space. Heat losses can however be significant for both floor types.

The insulation for crawl spaces can be located in the floor or crawl space wall as shown in Figure 2. If the insulation is in the floor the U-value is computed as explained in Step 4 for walls and the area used is the floor area. If the insulation is place vertically inside or outside the crawl space wall, the area is found by multiplying the perimeter by the average wall height. A conservative U-value is to invert the sum of the inside and outside film resistances, the wall resistance and the insulation resistance. This will neglect the insulation value of the ground. Note that local codes may restrict the location of insulation to protect from termite damage.

Slab-on-grade insulation options are even more limited because of potential termite damage. Vertical exterior insulation is a more desirable thermal arrangement but may be restricted. Horizontal placement as shown in Figure 2 may not be as effective because of the low resistance thermal path as the base of the wall. The insulation can not be extended to the exterior due to structural concerns. Options for insulation are widths of 24 and 48 inch and R-values of either 5 or 10 which represents the values for 1 inch and 2 inch extruded polystyrene. Expanded

polystyrene (bead board) is not recommended for below grade insulation because it will absorb moisture and become ineffective insulation.

A drop down box permits the selection of ‘no insulation’, ‘vertical’ placement or ‘horizontal’ placement. A second drop down box permits the selection of insulation width and R-value. These selections will generate a UP-value (rather than a U-value) which requires the user to input the slab perimeter rather than the area. UP-value may also be referred to as the F-factor.

	U(Btu/h-ft <sup>2</sup> -F)	CLTD	Area (ft <sup>2</sup> )	qC <sub>Sen</sub> (kBtu/h)	qC <sub>Lat</sub> (kBtu/h)	qh(kBtu/h)
<b>Crawl Space</b>	0.067	Read Me	12.6	0.0	0.0	0.0
<b>Slab</b>		UP	Perim.			
No slab? Perim.=0	Horizontal	R5 x 24 in	0.7	160		5.6

Table 4 – Main Worksheet for Floor Heat Transfer Calculation

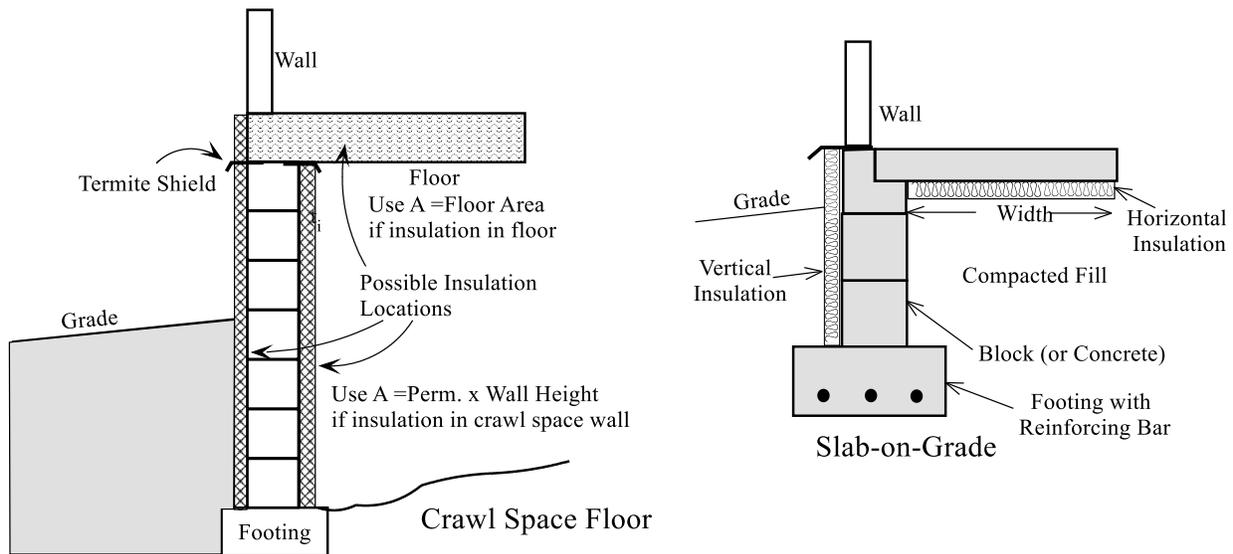


Figure 2 – Insulation Locations for Floors and Slabs

### Step 8 – Review (or Override) Results for Infiltration/Ventilation Heat and Moisture Gains and Heat Losses

The values for summer and winter infiltration rates are expressed in the infiltration rows in terms of both ACH (air changes per hour) and cfm (cubic feet per minute). The volume of the building in cubic feet (floor area x wall height) is also shown and represents one air change. **This computation represents perhaps the heat loss and gain component with the greatest amount of uncertainty.** A much more accurate determination of the infiltration rate can be made with the use of a blower door. This system installs a blower and flow measurement device in an exterior door. The building is pressure is elevated and flow through the door (and out the

building leak sites) is measured. The infiltration rate is computed by correlating the flow that would be experienced under normal winter and summer building pressure differences. These values can be entered into the cells for ACH or cfm and will overwrite the values computed with the less accurate computations.

Also note the summer infiltration rate contains both sensible and latent (moisture) heat gains.

### Step 9 – Enter People and Internal Loads to Compute Sensible and Latent Heat Gains

Often high efficiency equipment can be operated in modes that do not provide adequate dehumidification and many homes are better insulated so sensible loads are lowered but internal latent loads remain. ResLoad11 has been developed to more accurately predict latent loads (most other residential load calculations compute sensible load and guess the latent load fraction). The input for people contains drop down boxes for the age, activity level, and number of occupants. It is suggested that each occupant be entered into the zone where they are most likely to be during the period of peak cooling load. Note that these loads do not affect the heat loss calculation since they are heat gains and will be beneficial in the winter.

People	Number	Activity	Btu/h-per	(Latent)	QC <sub>Sen</sub> (kBtu/h)	QC <sub>Lat</sub> (kBtu/h)
Children	1	Very Active	150	300	0.2	0.3
Adolescents		Normal	175	188	0.0	0.0
Adults	2	Normal	250	250	0.5	0.5
<b>Internal (AVG)</b>						
Sensible		Medium Load			3.1	
Latent		Medium Load				2.6
<b>Other</b> <span style="color: red;">Read Me</span>						

Table 5 – Main Worksheet for People and Internal Heat Gains

A drop down box is also provided for the sensible and latent (moisture) heat gains for equipment, lights, and moisture generating activity. Clicking on the cells will bring up a description of example ‘Heavy’, ‘Medium’, and ‘Light’ loads. An additional row is provided for any other sensible or latent loads that might be present. User must enter the values in the pale yellow cells in kBtu/h (1000 Btu/h) and a grey cell is provided for an optional entry for the description of the load.

### Step 10 – Enter Duct Description, Location and Equipment Type to Compute Sensible and Latent Heat Gains and Losses

Duct gains and losses are a major contributor to overall loads. ResLoad performs an elaborate energy balance on attics and crawlspaces to determine the temperature in these spaces that includes duct heat transfer, duct leakage, and the temperature inside the duct (which varies with equipment choice (furnaces deliver much warmer air than air heat pumps). Therefore, in

addition to cells for entering the R-value of the duct insulation, drop down boxes are provided to input the location of the duct, the level of duct sealing, the relative area of the duct to the building floor area, and the type of equipment used to heat and cool the space. An option is provided to locate the duct inside the conditioned space, which is a highly recommended choice for energy efficient buildings.

Rduct (h-ft <sup>2</sup> -°F/Btu)	Duct Location	Run Length	Type&Sealing	HVAC Type	qC <sub>Sen</sub> (kBtu/h)	qh(kBtu/h)
6	NatVentAttic	Medium	RoundMetSealed	AC&Furnace	3.3	5.7
6	UnventedAttic	Medium	RoundMetSealed	←Zone 2		

Table 6 – Main Worksheet for Duct Heat Gain and Loss

### Step 11 – Analyze Results for Total Heat Gains and Losses

ResLoad11 sums the sensible and latent heat gains and heat losses for all components in both zones so that the cooling and heating requirements for each zone can be known. The zone totals are added to compute the total for the house. Since this example is for a single zone home the House Total and the Single Zone are the same. In cooling both the sensible and latent loads are provided and added to compute the total cooling. The sensible heat ratio (SHR) is provided (Sensible Cooling/Total Cooling). This ratio is important in selecting equipment that will both meet the total requirement and the dehumidification loads. Equipment should be selected that meets are slightly exceeds the total cooling requirement but has a SHR equal to or below the SHR computed by ResLoad11. Note that a lower SHR indicates a lower sensible capacity which means a larger latent (dehumidification) capacity.

		House Total		Single Zone House
<b>Total Heating</b>	qh <sub>House</sub> =	34.0	kBtu/h	qh <sub>Zone1</sub> = 34.0 kBtu/h
Sensible Cooling	qC <sub>SensibleHouse</sub> =	20.5	kBtu/h	qC <sub>Sensible-Z1</sub> = 20.5 kBtu/h
Latent Cooling	qC <sub>LatentHouse</sub> =	7.0	kBtu/h	qC <sub>Latent-Z1</sub> = 7.0 kBtu/h
<b>Total Cooling</b>	qC <sub>TotalHouse</sub> =	27.4	kBtu/h	qC <sub>Total-Zone1</sub> = 27.4 kBtu/h
Sens. Heat Ratio	What is SHR?	0.75		SHR <sub>Zone1</sub> 0.75

Table 7 – Main Worksheet Output for Total Heat Gains and Loss

### Step 12 – Minimizing Heat Gains and Losses

Users are encourage to analyze the component losses and adjust the construction techniques to improve the energy uses of the home.

### Step 12A – Tighten the house from ‘Medium’ to ‘Tight’ (Cell G9)

		House Total		Single Zone House
<b>Total Heating</b>	qh <sub>House</sub> =	29.9	kBtu/h	qh <sub>Zone1</sub> = 29.9 kBtu/h
Sensible Cooling	qC <sub>SensibleHouse</sub> =	19.7	kBtu/h	qC <sub>Sensible-Z1</sub> = 19.7 kBtu/h
Latent Cooling	qC <sub>LatentHouse</sub> =	6.2	kBtu/h	qC <sub>Latent-Z1</sub> = 6.2 kBtu/h
<b>Total Cooling</b>	qC <sub>TotalHouse</sub> =	25.9	kBtu/h	qC <sub>Total-Zone1</sub> = 25.9 kBtu/h
Sens. Heat Ratio	What is SHR?	0.76		SHR <sub>Zone1</sub> 0.76

This reduces the cooling load from 27.4 to 25.9 kBtu/h and the heat loss from 34.0 to 29.9 kbtu/h.

Step 12B – Move the duct into the conditioned space (Cell B79)

		House Total		Single Zone House		
<b>Total Heating</b>	$q_{h_{House}} =$	24.2	kBtu/h	$q_{h_{Zone1}} =$	24.2	kBtu/h
Sensible Cooling	$q_{C_{SensibleHouse}} =$	16.4	kBtu/h	$q_{C_{Sensible-Z1}} =$	16.4	kBtu/h
Latent Cooling	$q_{C_{LatentHouse}} =$	6.2	kBtu/h	$q_{C_{Latent-Z1}} =$	6.2	kBtu/h
<b>Total Cooling</b>	$q_{C_{TotalHouse}} =$	22.6	kBtu/h	$q_{C_{Total-Zone1}} =$	22.6	kBtu/h
Sens. Heat Ratio	What is SHR?	0.73		SHR <sub>Zone1</sub>	0.73	

This reduces the cooling load from 25.9 to 22.6 kBtu/h and the heat loss from 29.9 to 24.2 kBtu/h.

Step 12C – Replace Horizontal R5 Slab insulation with R10 Vertical (Cells B79)

		House Total		Single Zone House		
<b>Total Heating</b>	$q_{h_{House}} =$	23.0	kBtu/h	$q_{h_{Zone1}} =$	23.0	kBtu/h
Sensible Cooling	$q_{C_{SensibleHouse}} =$	16.4	kBtu/h	$q_{C_{Sensible-Z1}} =$	16.4	kBtu/h
Latent Cooling	$q_{C_{LatentHouse}} =$	6.2	kBtu/h	$q_{C_{Latent-Z1}} =$	6.2	kBtu/h
<b>Total Cooling</b>	$q_{C_{TotalHouse}} =$	22.6	kBtu/h	$q_{C_{Total-Zone1}} =$	22.6	kBtu/h
Sens. Heat Ratio	What is SHR?	0.73		SHR <sub>Zone1</sub>	0.73	

The cooling load is unchanged and the heat loss from 24.2 to 23.0 kBtu/h.