Instructions
for

Building Tightness Limit Calculations for Acceptable Indoor Air Quality

[Program "BTL1"]

February, 1999 (V2.0)

Introduction

This program, BTL1, includes two calculation procedures; "BTL" and BTLa". BTL (Building Tightness Limits Based on ASHRAE 62-1989 and LBL Correlation Factors) is the older of the two procedures and is considered less accurate than the BTLa ("Building Tightness Limits and Ventilation Requiremt Based on ASHRAE 62, 119, & 136") method. The BTLa method of calculation requires more input information than the BTL method, but it is considered more accurate because it is based on more reliable data. Both methods are explained below.

BTL Calculation Procedure for Determining CFM_{50} Minimum

The objective of this calculation procedure is the determination of a target minimum CFM_{50} value. Awareness of this target value allows building energy analysts and weatherization workers to 1) stop the building tightening process when the target value is reached and 2) add mechanical ventilation if the building is made tighter than the target value.

Building Tightness Limits ("BTL") was developed to give weatherization crews a minimum tightness value for air-leakage and insulation work. The "BTL" method used for this TI-86 software is that which appeared in *Home Energy* magazine in the March/April, 1993 issue. This article—*Building Tightness Guidelines: When is a House Too Tight?*—was written by George Tsongas, Professor of Mechanical Engineering at Portland State University in Oregon. It is strongly recommended that you read this article before using the software. Mr. Tsongas' work was built on the research of others, including Max Sherman at Lawrence Berkeley Laboratory, and Gary Nelson at The Energy Conservatory.

The values calculated are based by the calculator program on ASHRAE Standard 62-1989, *Ventilation for Acceptable Indoor Air Quality*. This standard states that outdoor air requirements for residential living areas shall be "0.35 air changes per hour but not less that 15 cfm per person." **These procedures are not appropriate for commercial buildings.**

The calculations included here take into account:

1) The appropriate climate zone in North America.
2) The conditioned square footage of the house. The square footage used for the calculation for the building tightness limit should always correspond to the square footage base for the blower door test. For example, if the basement is not included in the square footage for the building tightness limit, the basement door should be closed when the blower door test is done to determine CFM_{50}.
3) The number of occupants, by design, i.e., the maximum number of people who could live in the house or the number of bedrooms plus one. Five occupants is the minimum for this calculation method. If you enter fewer than 5 for the number occupants, you will receive an error message.
4) The exposed height of the building. The choices are 1, 1.5, 2, or 3 stories. Cape Code and raised ranch style houses are usually considered to be 1.5 stories.
5) The exposure of the building.. The choices are 1=Well Shielded, 2=Normal, and 3=Exposed. The greater the exposure, the lower the CFM_{50} BTL.
6) The Lawrence Berkeley Laboratory (LBL) correlation factor, N. This number is displayed on the line above the Building Tightness Limit value on the TI-86 screen. This value is dependant on climate zone, building height, and exposure. If CFM_{50} is divided by N, the approximate $CFM_{natural}$ value is obtained.
7) The volume of the heated area of the house when the square footage is more than the number of occupants (by design) multiplied by 322 ft^2. If the calculation of building tightness limit must be done for a house based on 0.35 air changes per

hour, you will be prompted to enter ceiling height. The square footage you enter is multiplied by the ceiling height to yield the house volume.

The CFM_{50} BTL numbers calculated by the program are *minimum* tightness values when the house is under 50 Pascals of negative or positive pressure, typically created with a blower door.

BTLa Calculation Procedure based on ASHRAE 62, 119, and 136

The objective of this calculation procedure is the determination of 1) a target minimum Effective Leakage Area (ELA) value, 2) a target minimum CFM value, and 3) the mechanical ventilation required if the building is tighter than the target values. Awareness of these target values allows building energy analysts and weatherization workers to 1) stop the building tightening process when the target value is reached and 2) add mechanical ventilation if the building is made tighter than the target value.

As a secondary objective, this procedure calculates the values listed just below (in addition to those listed in the previous paragraph).

This calculation procedure determines:

Effective Leakage Area (ELA)
Equivalent Leakage Area (EqLA)
Estimated Natural CFM
Estimated Natural ACH
Estimated Natural CFM per Occupant
Minimum Target Effective Leakage Area
Minimum Target CFM
Minimum Target CFM_{50}
Mechanical Ventilation Required in CFM

The user inputs required are:

Building CFM_{50}
Leakage Flow Exponent (slope of leakage curve), the typical value is 0.65
Weather Factor (from Table 1, ASHRAE 136-1993, reproduced in these instructions)
Building Volume, ft^3
Building Occupied area, ft^2
Building Height, ft
Story Height, ft (the height of one floor level)
Occupant Count (either the number of occupants or bedrooms plus one, whichever is greater)

This procedure is based on ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers):

- *Standard for Acceptable Indoor Air Quality* (ANSI/ASHRAE 62-1989)
- *Air Leakage Performance for Detached Single-Family Residential Buildings* (ANSI/ASHRAE 119-1988 (RA 94)) [This document is partially based on the Canadian General Standards Board Standard CAN/CGSB-149.10-M86, *Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method*]
- *A Method of Determining Air Change Rates in Detached Dwellings*

(ANSI/ASHRAE 136-1993)
- *1997 ASHRAE Fundamentals Handbook*, page 25.21, equation 45, "Combining Residential Infiltration and Ventilation"

This procedure is designed to yield the same answers as the *Building Airtightness Test Analysis Program* (TECTITE Version 1.0), published by The Energy Conservatory in 1998. Because the Minneapolis Blower Door manufactured by The Energy Conservatory is the most widely used blower door in North America, WxWare Diagnostics has fashioned the ZipTest building diagnostics software after The Energy Conservatory and Minneapolis Blower Door procedures and calibrations.

Of the calculated values in this procedure, the Minimum Target Effective Leakage Area ("Target ELAmin" on the calculator screen) and Minimum Target CFM ("Target CFMmin" on the calculator screen) are the most reliable as a target values because they do not require the flow exponent (slope of the building leakage curve) for their determination. Use of the flow exponent—the range is generally between 0.5 and 1.0—is problematic because its value changes as the building is tightened; this makes any calculation procedure suspect that uses the flow exponent to establish a target tightness level. The CFM_{50} minimum target calculation value (number 9. on the "All Data" screen) is suspect for this reason. Therefore, it should not be used unless absolutely necessary.

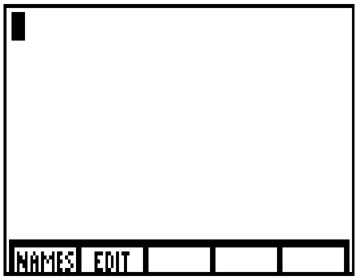
The calculation of the Minimum Target Effective Leakage Area takes into account the guidelines set by ASHRAE 62-1989—the dwelling envelope must provide either 0.35 air changes per hour (ACH) or 15 cubic feet per minute (CFM) per person, whichever is larger. **This method is not to be used for commercial applications.** The calculation of Minimum Target CFM ("Target CFMmin" on the calculator screen) also includes the ASHRAE 62-1989 guidelines.

If a dwelling is tighter than the ASHRAE 62-1989 guidelines, the ventilation necessary ("Vent CFM Needed") to bring the dwelling into compliance with the ASHRAE 62-1989 guidelines is displayed as number 8 on the screen of calculated values and the "All Data" screen. The determination of the required ventilation is based on an equation in *1997 ASHRAE Fundamentals Handbook*, page 25.21, equation 45, "Combining Residential Infiltration and Ventilation."

Acknowledgements

Thank you to Collin Olson and Rob Nevitt of The Energy Conservatory and to Max Sherman of Lawrence Berkeley Laboratory for their help in developing this software. Their assistance and expert advice made it possible.

BTL1-1

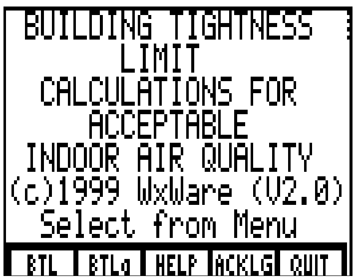


Turn the TI-86 calculator on.
Press **PRGM** (Programs).
You will see this menu on the screen.
Press **F1** for **NAMES.**
NOTE: It is best never to press EDIT, F2.
You will see the menu and sub-menu displayed in Panel BTL1-2."

BTL1-2

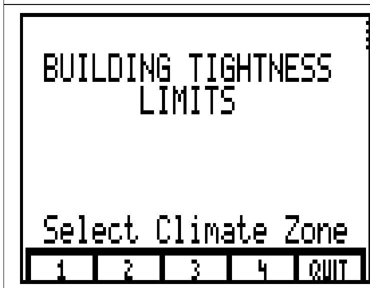
Press **F1, F2, F3, F4**, or **F5** for the program "BTL1." The menu key for this program will depend upon the number of programs loaded in the memory of you TI-86 calculator. For the screen at the left, four usable programs are loaded onto the calculator, "BTL1" (**F1**), "BTUDD" (**F2**), "DTL" (**F3**) and "Press" (**F5**). "Financ" is not usable (nor is "finexe" on the next menu set). "BTL1" will appear at the cursor location.
Press **ENTER**. **Note: The exact name of the program must appear at the**

BTL1-3



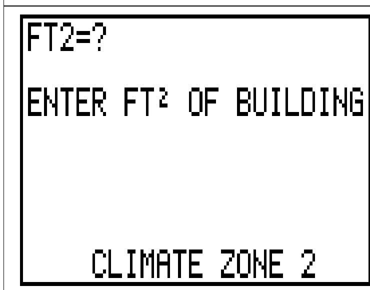
You will see this menu on the screen. This is the main menu screen.
F1, "BTL" to starts the Building Tightness Limits program.
F3, "HELP" lists instructions for this screen.
F2, "BTLa" starts the revised Building Tightness Limits program.
F4, "ACKLG " (Acknowledgments) selection lists the author of the program, etc.
F5, "QUIT" selection allows you to exit the program. Always exit the program by selecting **F5** from this menu; the decimal place is thereby set to

BTL1-4



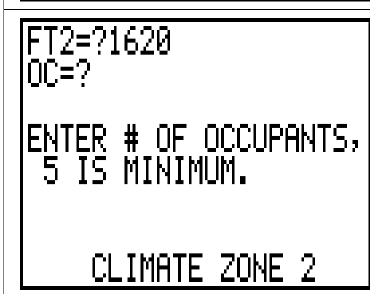
Select **F1, "**BTL," to start the Building Tightness Limits program.
You will see this menu on the screen.
You are asked to select your climate zone. Refer to the map of North America on page 15 for your appropriate climate zone number.
Note: If you select **F5, "**QUIT," you will exit the program. **DONE** will appear in the upper right corner of the screen If you want to re-enter the program, press **ENTER** or press **PRGM.**

BTL1-5



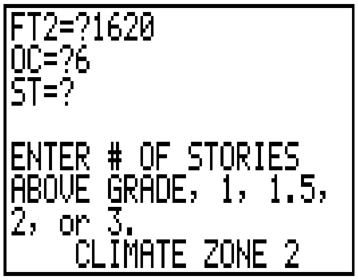
The climate zone you selected appears at the bottom of the screen.
Enter the heated square footage of the house. The value you enter will be displayed after the "**?**" This value is used to determine whether the building tightness limit is calculated using 15 cfm/person or 0.35 air changes per hour. If the square footage is greater than the number of occupants multiplied by 322 ft^2, 0.35 air changes per hour is used rather than 15 cfm per person.

BTL1-6



Enter the number of occupants—by design. It is common to count the number of bedrooms and multiply by two to determine the number of occupants for this procedure. *Five is the minimum number of occupants that may be entered.* Please refer to "Building Tightness Guidelines: When Is a House Too Tight?" by George Tsongas, *Home Energy,* March/April, 1993, pp. 18-24, for discussion and guidance.
Enter "6," for example, and press **ENTER**.

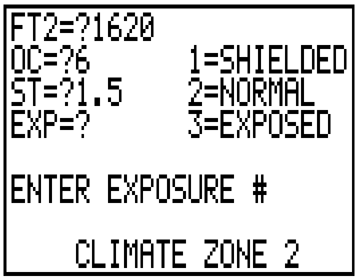
BTL1-7



You are prompted to enter the number of exposed stories of the house. Basements below grade generally should not be included in the number of stories. The value you enter will be displayed after the "**?**"

Enter "1.5" stories, for example, and press **ENTER**.

BTL1-8

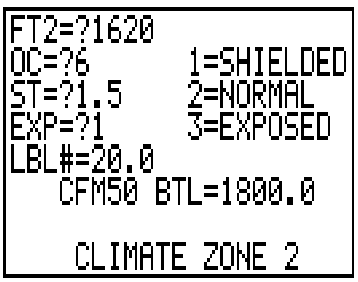


You are prompted to enter the appropriate exposure number for the house The value you enter will be displayed after the "**?**"

Enter "1," for example, and press **ENTER**.

The "EXP" or exposure value should be entered with care. "SHIELDED" is for buildings with significant blockage to the wind (trees or other buildings), "NORMAL" signifies buildings in a typical suburban setting (obstructions to the wind around building, but not dense), "EXPOSED" is for buildings with very

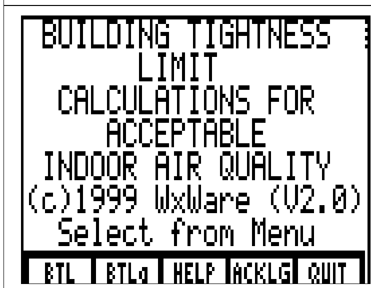
BTL1-9



"CFM50 BTL=1800.0" is displayed. This is the Building Tightness Limit (BTL) for this example house, i.e., at a blower door depressurization of 50 Pascals, the CFM_{50} minimum value is 1800.

Notice that all the values you entered are displayed on the screen, including the climate zone and the "LBL #" value (if CFM_{50} is divided by the LBL#, the approximate $CFM_{natural}$ results). This example has been calculated using 15 cfm per person.

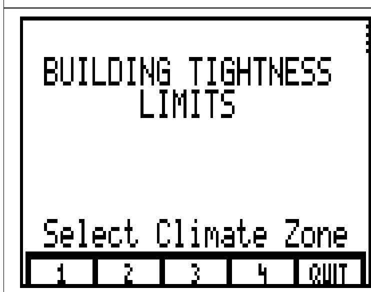
BTL1-10



Now enter values for a demonstration of a calculation for a house that exceeds the size limitations for the use of 15 cfm/person calculation procedure. Instead, the calculation for this example will use 0.35 air changes per hour.

Press **F1, BTL**. to begin the demonstration.

BTL1-11

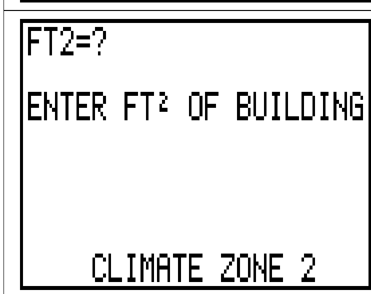


You are asked to select your climate zone. Refer to the map of North America on page 15 for the appropriate climate zone number.

If you select **F5, "**QUIT," you will return to the main menu screen.

Select **F2** for Climate Zone 2.

BTL1-12

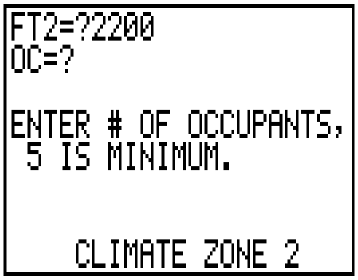


The climate zone you selected appears at the bottom of the screen.

Enter the heated square footage of the house. The value you enter will be displayed after the "**?**" This value is used to determine whether the building tightness limit is calculated using 15 cfm/person or 0.35 air changes per hour. If the square footage is greater than the number of people multiplied by 322 ft^2, 0.35 air changes per hour is used rather than 15 cfm per person.

As a demonstration, enter "2200 ft^2" and press **ENTER**.

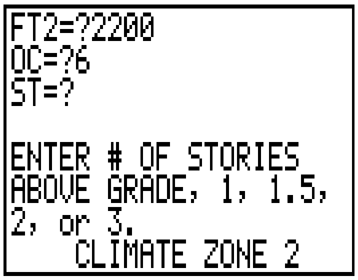
BTL1-13



Enter the number of occupants—by design. You may count the number of bedrooms and multiply by two, using five as a minimum product, to determine the number of occupants for this procedure.

Enter "6" for this demonstration and press **ENTER**.

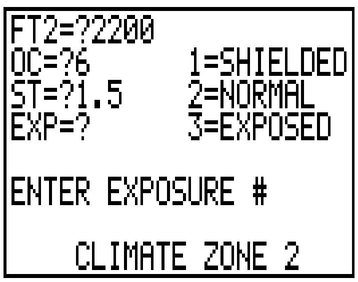
BTL1-14



You are prompted to enter the number of exposed stories of the house. Basements below grade generally should not be included in the number of stories. The value you enter will be displayed after the "**?**"

Enter "1.5" stories and press **ENTER**.

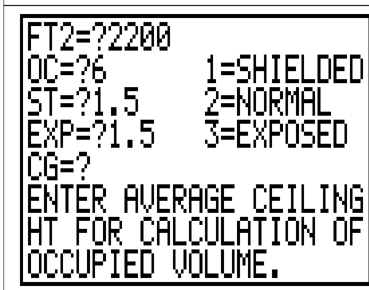
BTL1-15



You are prompted to enter the appropriate exposure number for the house. The value you enter will be displayed after the "**?**"

The "EXP" or exposure value should be entered with care. "SHIELDED" is for buildings with significant blockage to the wind (trees or other buildings), "NORMAL" signifies buildings in a typical suburban setting (obstructions to the wind around building, but not dense), "EXPOSED" is for buildings with very little wind blockage (meadow settings, lake-side, etc.).

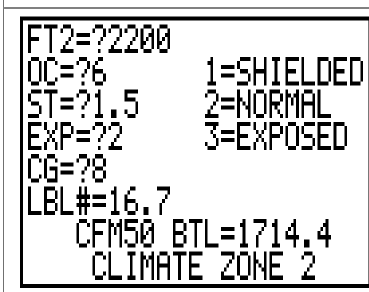
BTL1-16



You are prompted to enter the average ceiling height of the house. For this example, assume ceilings are eight feet high. The ceiling height is multiplied by the square footage you entered, yielding the volume of the house. Because the square footage of this demonstration house is greater then the number of occupants multiplied by 322 ft^2, the program is calculating the Building Tightness Limit using 0.35 air changes per hour rather than 15 cfm/person.

Enter "8" for this example and press **ENTER**.

BTL1-17

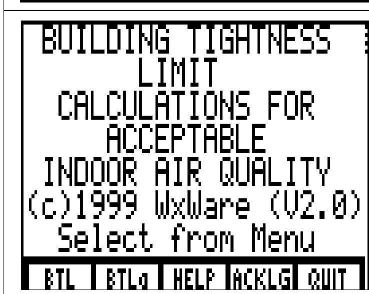


"CFM50 BTL=1714.4" is displayed. This is the Building Tightness Limit (BTL) for this demonstration house; at a blower door depressurization of 50 Pascals the CFM_{50} minimum value for acceptable air quality is 1714.4.

Notice that all the values you entered are displayed on the screen, including the climate zone and the LBL "N" number. This example has been calculated using 0.35 air changes per hour rather than 15 cfm per person.

Press **ENTER**

BTL-18

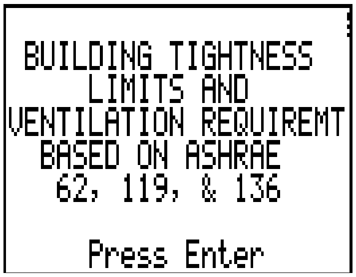


You will see the at the left screen displayed.

Select **F2, BTLa**.

Now we will look at the next calculation procedure which is a more accurate method of determining building tightness and required ventilation for tight buildings.

BTL1-19

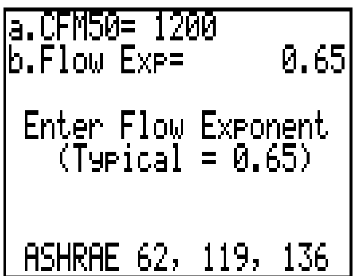


For an explanation of this procedure, refer to "**BTLa Calculation Procedure based on ASHRAE 62, 119, and 136**" on page 3 of this instruction manual.
Press **ENTER** to proceed to the next screen.

BTL1-20

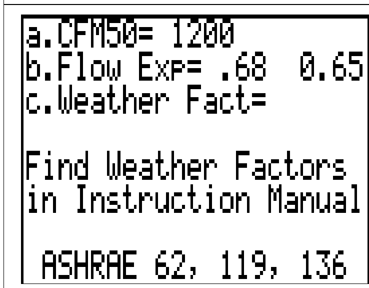
Enter "a.CFM50" of the building, whether it was measured by a single-point or multi-point blower door test.
Notice that "CFM50" on the display is preceded by the letter "a." This is the case for all the input values required for this procedure.
Notice that "ASHRAE 62, 119, 136" is at the bottom of the display. This is a reminder that you are working on this advanced procedure that includes these ASHRAE Standards.

BTL1-21



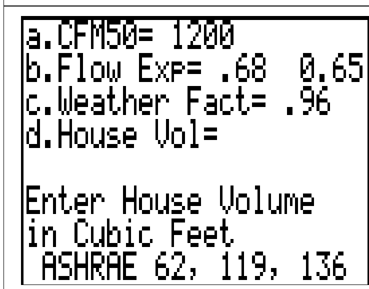
The next prompt, "b.Flow Exp," requires you to enter the flow exponent for the building (the slope of the air-leakage curve of the building). If you have performed a single-point blower door test on the building, enter ".65," the typical value of the flow exponent (displayed to the right on the screen as a reminder).
If you performed a multi-point blower door test, you will know the specific flow exponent for the building, usually within a range of 0.5 to 1.0. Enter this value.
For this example, enter ".68" and press **ENTER**.

BTL1-22



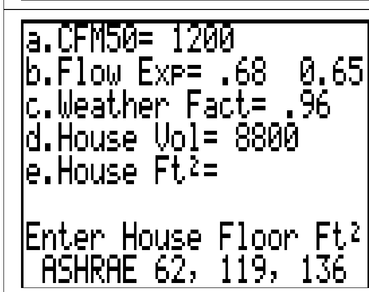
Enter the weather factor, "c.Weather Fact." These values are listed in this instruction manual on pages 16 through 18 for locations in Canada and the United States, designated as "W." These factors are used to estimate the natural air leakage for the purpose of determining the CFM ratings of added exhaust ventilation to meet the standard set by ASHRAE 62-1989. This calculation procedure can be found in ASHRAE 136-1993.
Enter ".96" for this example (Cleveland, Ohio) and press **ENTER**.

BTL1-23



Enter the building volume, "d.House Vol," in units of cubic feet. It is recommended that you include the basement if it is kept close to the indoor temperature. (If you include the basement here, you should open the basement to the main body of the house when you perform the blower door test).
Enter "8800" and press **ENTER** .

BTL1-24

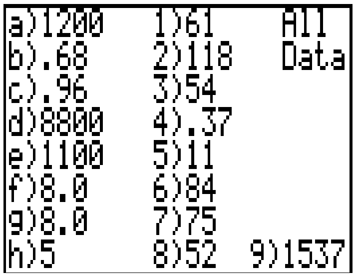


Enter the square footage of building floor area, "e.House Ft^2." If you included the basement in the volume figure, include the basement here also.
For this example, enter "1100" and press **ENTER** .

BTL1-25	a.CFM50= 1200 b.Flow Exp= .68 0.65 c.Weather Fact= .96 d.House Vol= 8800 e.House Ft^2= 1100 f.Bldg Ht, ft= ASHRAE 62, 119, 136	Enter the building height above grade in units of feet, "f.Bldg Ht, ft." For buildings with uneven above grade heights—walk-out basements, one and one-half story buildings—use the average height of the building. For this example enter "8" and press **ENTER** Notice that "ASHRAE 62,119, 136" remains at the bottom of the screen as a reminder of the methodology on which you are working.
BTL1-26	a.CFM50= 1200 b.Flow Exp= .68 0.65 c.Weather Fact= .96 d.House Vol= 8800 e.House Ft^2= 1100 f.Bldg Ht, ft= 8 g.Story Ht, ft= ASHRAE 62, 119, 136	Enter the average height of one story of the building, "g.Story Ht, ft." This value and the "Bldg Ht" from the previous entry (see Panel BTL1-37) determines the number of stories in the building. The resulting value (the number of stories) should not exceed three. For this example, enter "8" and press **ENTER**
BTL1-27	a.CFM50= 1200 b.Flow Exp= .68 0.65 c.Weather Fact= .96 d.House Vol= 8800 e.House Ft^2= 1100 f.Bldg Ht, ft= 8 g.Story Ht, ft= 8 h.Occupant Count= ▮	Enter the "h.Occupant Count" as the next and final input value for this procedure. Enter the number of occupants or the number of bedrooms plus one, whichever is larger. This value is used to determine the ventilation requirements for the dwelling. The greater the number of occupants or bedrooms, the greater the amount of fresh are required for acceptable indoor air quality. For the example, enter "5"
BTL1-28	a.CFM50= 1200 b.Flow Exp= .68 0.65 c.Weather Fact= .96 d.House Vol= 8800 e.House Ft^2= 1100 f.Bldg Ht, ft= 8 g.Story Ht, ft= 8 h.Occupant Count= 5	Review the input values you have entered before you press **ENTER**. Now, press **ENTER** and move on to the next screen which displays all the output values for the example problem. Note that all the input values are lettered (a. through h), and that on the next screen (Panel BTL1-29), all the output values are numbered (1. through 8.). Press **ENTER** to move to the next screen.
BTL1-29	1.ELA in^2=61 2.EqLA in^2=118 3.Estim Nat CFM=54 4.Estim Nat ACH=.37 5.Natural CFM/occ=11 6.Target ELAmin=84 7.Target CFMmin=75 8.Vent CFM Needed=52	On this screen, all the outputs are displayed except number 9. "1.ELA in^2" is equal to "61" for the example. ELA (Effective Leakage Area) was developed at Lawrence Berkeley Laboratory (LBL) and is used in their air leakage model. The ELA is defined as the area of a special nozzle-shaped hole (similar to the inlet of your blower door fan) that would leak the same amount of air as the building does at a pressure of 4 Pascals. In the Solver section of the TI-86, the Equation Nugget with the name "AELA" can be used to calculate ELA if you know the CFM_4 of the building. [continued on next panel]
BTL1-30	1.ELA in^2=61 2.EqLA in^2=118 3.Estim Nat CFM=54 4.Estim Nat ACH=.37 5.Natural CFM/occ=11 6.Target ELAmin=84 7.Target CFMmin=75 8.Vent CFM Needed=52	"2.EqLA in^2" is equal to "118" for the example. EqLA (Equivalent Leakage Area) is defined by researchers at the Canadian National Research Council as the area of a sharp-edged orifice that would leak the same amount of air as the building does at a pressure of 10 Pascals. In the Solver section of the TI-86, the Equation Nugget with the name "AEQLA" can be used to calculate EqLA if you know the CFM_{10} of the building. Typically, EqLA more closely approximates the physical characteristics of building airtightness than ELA. [continued on next panel]

BTL1-31	1.ELA in^2=61 2.EqLA in^2=118 3.Estim Nat CFM=54 4.Estim Nat ACH=.37 5.Natural CFM/occ=11 6.Target ELAmin=84 7.Target CFMmin=75 8.Vent CFM Needed=52	"3.Estim Nat CFM" (estimated natural CFM) is equal to 54 for the example. This calculated value is based on ELA, the Weather Factor (see Panel BTL1-34) and the dimensions of the building. It is the cubic feet per minute of air leakage based on natural forces such as wind pressure and differences in air density. "4. Estim Nat ACH" is equal to 0.37 for the example. This is merely the "Estim Nat CFM" multiplied by 60 minutes per hour and divided by the building volume in units of cubit feet. [continued on next panel]
BTL1-32	1.ELA in^2=61 2.EqLA in^2=118 3.Estim Nat CFM=54 4.Estim Nat ACH=.37 5.Natural CFM/occ=11 6.Target ELAmin=84 7.Target CFMmin=75 8.Vent CFM Needed=52	"5.Natural CFM/occ" (estimated natural CFM per occupant) is number 3, estimated natural CFM, divided by the "Occupant Count" (see Panel BTL1-27). In order to comply with ASHRAE 62-1989, this value must be at least 15 (15 CFM per person). If this value is less than 15, "8.Vent CFM Needed" (ventilation CFM needed to comply with ASHRAE 62-1989) will be a value greater than zero. Notice that for the example, outputs in the screen panel at the left that the CFM per occupant is 11 and "8.Vent CFM Needed" is equal to 52. [continued on next panel]
BTL1-33	1.ELA in^2=61 2.EqLA in^2=118 3.Estim Nat CFM=54 4.Estim Nat ACH=.37 5.Natural CFM/occ=11 6.Target ELAmin=84 7.Target CFMmin=75 8.Vent CFM Needed=52	"6.Target ELAmin" (target ELA minimum) is the minimum effective leakage area of the building that will satisfy ASHRAE 62-1989. If the building is made tighter than this, mechanical ventilation must be added to comply with ASHRAE 62-1989. This value is based on 0.35 air changes per hour or 15 CFM per person, whichever is larger. Notice in this example that the actual ELA, line 1, is 61 in^2 and the target ELA minimum, line 6, is 84in^2, thus the building is tighter than ASHRAE 62-1989. Mechanical ventilation must be added. [continued on next panel]
BTL1-34	1.ELA in^2=61 2.EqLA in^2=118 3.Estim Nat CFM=54 4.Estim Nat ACH=.37 5.Natural CFM/occ=11 6.Target ELAmin=84 7.Target CFMmin=75 8.Vent CFM Needed=52	"7.Target CFMmin" (target CFM minimum) is the minimum natural CFM that will satisfy ASHRAE 62-1989. This value is based on 0.35 air changes per hour or 15 CFM per person, whichever is larger. As with the ELA values for this example, the actual CFM, line 3, is less than the 75 CFM (line 7) required to comply with ASHRAE 62-1989, thus ventilation must be added. "8 Vent CFM Needed" (ventilation CFM needed) is the CFM of mechanical ventilation required to bring the below-compliance building into compliance with ASHRAE 62-1989. [continued on next panel]
BTL1-35	[intentionally left blank]	This value is calculated with a variation of equation 45 on page 25.21 in *1997 ASHRAE Fundamentals Handbook.* In the example problem, the amount of actual ventilation needed is 52 CFM. Notice that this value is significantly more than line 3 subtracted from line 7. **Note: Because estimated air leakage is based on blower door tests that may vary by as much as a factor of 2 from actual air leakage rates, ventilation guidelines should be used with caution.** [continued on next panel]
BTL1-36	[intentionally left blank]	**Note: Compliance with ASHRAE 62-1989 and the procedures of this ZipTest software do not guarantee that a moisture or indoor air quality problem will not develop. A healthy rate of ventilation may be more or less than the suggested estimate calculated here. Be cautions and use common sense.** Now, press ENTER to move to the "ALL DATA" screen

BTL1-37



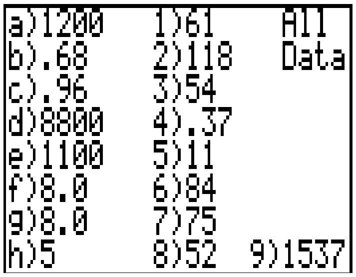
The "All Data" display lists all the your inputs and outputs for a calculation. This is presented as a summary for your convenience. The letters and numbers correspond with the line letters (inputs) and numbers (outputs) on the two previous calculator displays.

a) CFM_{50} from blower door test (see Panel BTL1-20).

b) Flow exponent from blower door test or 0.65 (see Panel BTL1-21).

c) Weather factor from pages 16 through 18 (see Panel BTL1-22).

BTL1-38



e) House square footage (see Panel BTL1-24).

f) Building height (see Panel BTL1-25).

g) Story height (see Panel BTL1-26).

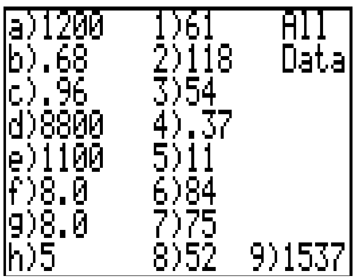
h) Occupant count (see Panel BTL1-27).

1) Actual ELA (effective leakage area) (see Panel BTL1-29).

2) Actual EqLA (equivalent leakage area) (see Panel BTL1-30)

3) Estimated actual natural CFM (see Panel BTL1-31).

BTL1-39



5) Estimated actual natural CFM per occupant (see Panel BTL1-32).

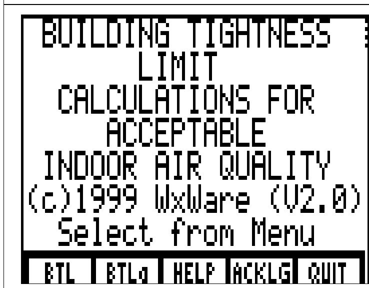
6) Target minimum ELA for compliance (see Panel BTL1-33).

7) Target minimum CFM for compliance (see Panel BTL1-34).

8) Mechanical ventilation CFM needed for compliance(see Panels BTL1-34 & 35).

9) Target minimum CFM_{50} value. This is the only place this output appears. This is meant to minimize the importance of this value because it is problematic to use it as a house tightening target (see page 4). If you must

BTL1-40

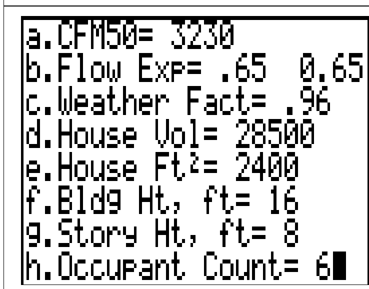


Now, let's look at another example that does not require added mechanical ventilation.

Press **ENTER** to return to the main screen.

Press **F2** for "BTLa" and press **ENTER** to go to the first of the inputs.

BTL1-41

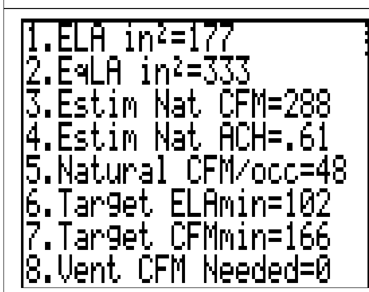


All of the inputs are listed here. You can enter all of these if you wish. Go ahead, have another go at it; practice helps.

Notice that this house is not as tight and it is larger than the last example house.

Press **ENTER** after you enter all the input data. This will advance you to the output display.

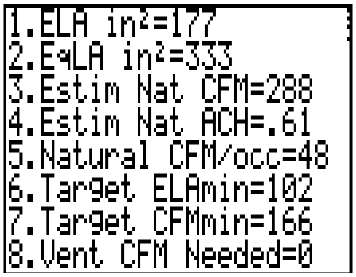
BTL1-42



All the outputs, except target minimum CFM_{50} are listed on the output display.

Notice that no mechanical ventilation (line 8) is called for. The natural CFM per occupant, line 5, exceeds the ASHRAE 62-1989 minimum of 15 and the estimated natural ACH , line 4, exceeds the minimum 0.35. The actual ELA, line 1, exceeds the target minimum ELA on line 6. This house can be significantly tightened before the ASHRAE 62-1989 minimum values are reached. [continued on next panel]

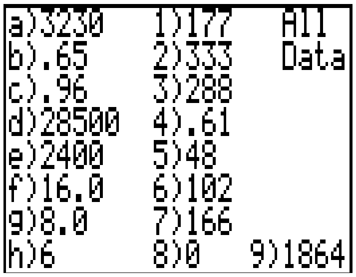
BTL1-43



The strategy for weatherizing this building would be to 1) prepare the house for insulation (seal attic bypasses, etc.) , 2) insulate the walls and attic (if not already insulated), and 3) perform another blower door test. If the ELA (line 1) is now close, but not less than the target minimum ELA (line 6) tightening should stop. If the actual ELA is not yet close to the value of 102 in^2 on line 6, tightening should continue until it is no longer cost-effective or until the "Target ELAmin" is reached.

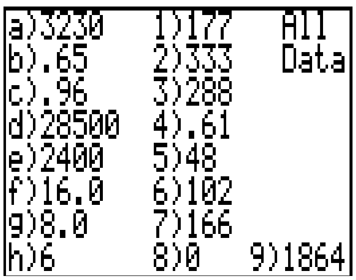
Press to move to the "All Data" display.

BTL1-44



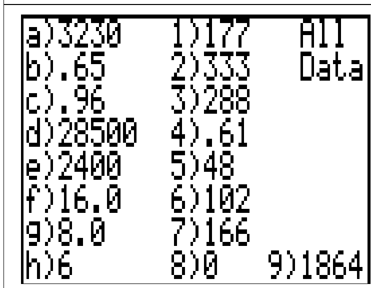
a) CFM50 from blower door test (see Panel BTL1-20).
b) Flow exponent from blower door test (see Panel BTL1-21).
c) Weather factor from pages 16 through 18 (see Panel BTL1-22).
d) House volume (see Panel BTL1-23).
e) House square footage (see Panel BTL1-24).
f) Building height (see Panel BTL1-25).
g) Story height (see Panel BTL1-26).

BTL1-45



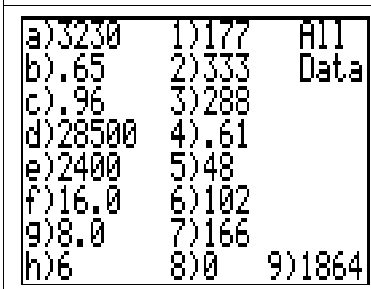
2) Actual EqLA (equivalent leakage area) (see Panel BTL1-30).
3) Estimated actual natural CFM (see Panel BTL1-31).
4) Estimated actual natural ACH (see Panel BTL1-31).
5) Estimated actual natural CFM per occupant (see Panel BTL1-32).
6) Target minimum ELA for compliance (see Panel BTL1-33).
7) Target minimum CFM for compliance (see Panel BTL1-34).
8) Mechanical ventilation CFM needed for compliance (see Panels BTL1-34 & 35)

BTL1-46



The "All Data" display for this calculation method is first mentioned in panel BTL1-37. If you have the Texas Instruments Graph Link for the TI-86, you can print this display, or any other, on your computer's printer. The Graph Link allows you to connect your TI-86 to your computer with a special cable. The companion Graph Link software for the PC or Mac allows storage of your TI-86 programs on your computer. Contact WxWare Diagnostics for more information about the Graph Link cable and software.

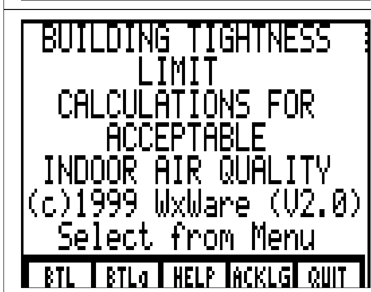
BTL1-47



The TI-86 does not allow storage of this "All Data" display out in the field unless you have the Graph Link cable and software and a portable PC or Mac computer in the field. You cannot store the display in the TI-86 for recall and printing later. You can, of course, re-enter the input data back at your office and then print the screen with the use of Graph Link and your computer and printer.

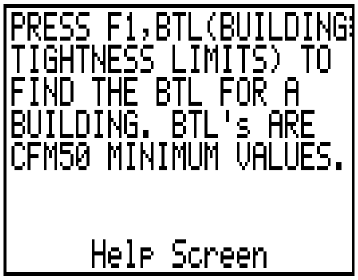
A printed display such as the one at the left can be included as a graphic in reports to clients or reports saved for a client's file.

BTL1-48



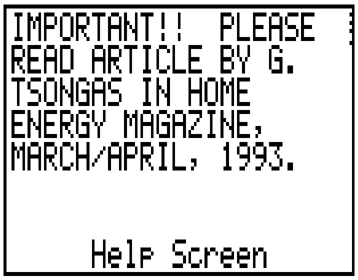
Press **ENTER** to return to the home screen.
Notice that **F3** is the "HELP" section of the menu.
Also, notice that **F4** is the "ACKLG" (acknowledgement) section.
Let's take a look at this section.
Press **F3** to advance to the "HELP" section.

BTL1-49



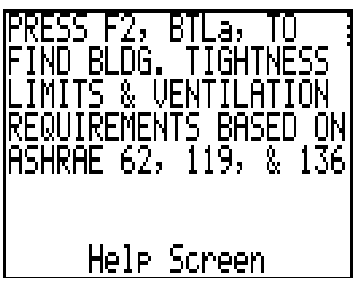
It is recommended that the house never be tightened to a CFM_{50} value less that the calculated BTL.
Press **ENTER**.

BTL1-50



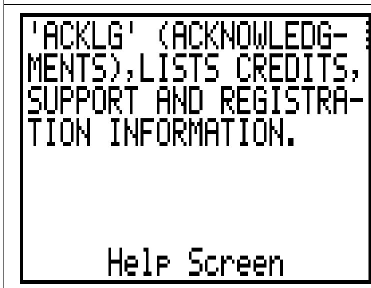
Please do read this article to get a thorough understanding Building Tightness Limits methods and background.
Press **ENTER**.

BTL1-51



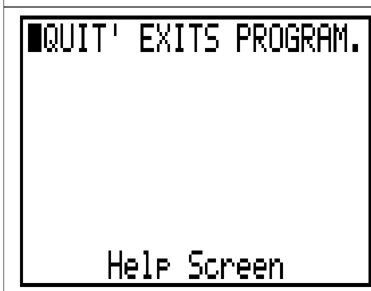
For a background of this calculation method for ELA, EqLA, CFM, mechanical ventilation size, etc., see the listed ASHRAE Standards and the ASHRAE *1997 Fundamentals Handbook*, page 25.21, equation 45.
Press **ENTER**.

BTL1-52



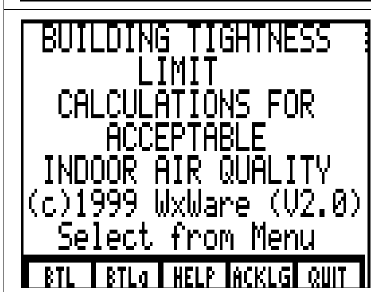
You will see the screen at the left displayed.
Press **ENTER**.

BTL1-53



Always exit the program by selecting **F5** from the main menu; the decimal place is thereby set to "floating," whereas within the BTL1 program it is set to zero or one decimal place. If you exit by another means, the decimal place setting will remain at zero or one.
Press **ENTER**.

BTL1-54



Select **F4,** "ACKLG," (acknowledgments).

BTL1-55	THIS BLDG. TIGHTNESS LIMITS PROGRAM IS BASED ON WORK OF G. TSONGAS, G.NELSON AND M. SHERMAN. THANK YOU TO EACH OF THEM.	Press **ENTER**.
BTL1-56	THIS PROGRAM WAS WRIT TEN BY RICK KARG(207) 725-6723.IF YOU PURCH ASED THIS PROGRAM FRO M WxWare, YOU ARE A R EGISTERED USER, ENTIT LED TO SUPPORT AND UP DATE NOTIFICATION.	You will see the screen at the left displayed Press **ENTER**.
BTL1-57	TO REGISTER YOUR COPY CONTACT WxWare AT 220 MEADOW ROAD, TOPSHAM, MAINE 04086: E-MAIL rjkarg@karg.com: OR 207-725-6723. (Feb, 1999)	Press **ENTER**.
BTL1-58	BUILDING TIGHTNESS LIMIT CALCULATIONS FOR ACCEPTABLE INDOOR AIR QUALITY (c)1999 WxWare (V2.0) Select from Menu BTL | BTLa | HELP | ACKLG | QUIT	Press **F5,** "QUIT."**Note: Always exit the program by pressing the QUIT menu button; this automatically resets the decimal place for calculator use.** **Note: If you make a mistake while entering data before you press ENTER, use the arrow buttons to move the cursor over the erroneous entry and type the correct entry. If you notice you have made a mistake after you have pressed ENTER, press the "2nd" button, the "QUIT" button (next to the "2nd" button), and then ENTER. This will return you to the main menu.**
BTL1-59	Done	If you want to re-enter the program, simply press **ENTER.** **Note: The TI-86 automatically shuts off after two minutes of non-use. When you turn it back on, you will be able to pick up right where it shut off.**
BTL1-60		

BUILDING TIGHTNESS LIMITS CLIMATE ZONE MAP

(For use with BTL method)

Values of the Weather Factor, W, for Canadian and U.S. Locations

(Reproduced from *A Method of Determining Air Change Rates in Detached Dwellings*, ANSI/ASHRAE 136-1993
(For use with BTLa method)

VALUES OF THE WEATHER FACTOR *W* FOR CANADIAN AND U.S. LOCATIONS

Note: "Source" indicates the source of the Weather data.

WYEC[2] = weather year for energy calculations
TMY[3] = typical meteorological year
CAN[4] = average of the ten recent years of weather data

City, State	w[ACH]	Source
Adak, AK	1.16	TMY
Annette, AK	0.94	TMY
Bethel, AK	1.21	TMY
Big Delta, AK	0.99	TMY
Fairbanks, AK	0.90	TMY
Gulkana, AK	0.95	TMY
Homer, AK	0.87	TMY
Juneau, AK	0.95	TMY
King Salmon, AK	1.09	TMY
Kodiak, AK	0.93	TMY
McGrath, AK	0.90	TMY
Summit, AK	1.12	TMY
Birmingham, AL	0.69	TMY
Mobile, AL	0.76	TMY
Calgary, AB	0.94	CAN
Edmonton, AB	0.88	CAN
Fort Smith, AR	0.76	TMY
Little Rock, AR	0.75	TMY
Phoenix, AZ	0.68	TMY
Prescott, AZ	0.81	TMY
Tucson, AZ	0.79	TMY
Winslow, AZ	0.82	TMY
Yuma, AZ	0.77	TMY
Castlegar, BC	0.71	CAN
Fort St. John, BC	0.93	CAN
Prince Rupert, BC	0.88	CAN
Vancouver, BC	0.78	WYEC
Victoria, BC	0.69	CAN
Williams Lake, BC	0.83	CAN
Arcata, CA	0.74	TMY
Bakersfield, CA	0.68	TMY
China Lake, CA	0.67	TMY
Dagget, CA	0.90	TMY
El Toro, CA	0.57	TMY
Fresno, CA	0.69	TMY
Long Beach, CA	0.64	TMY
Los Angeles, CA	0.66	TMY
Mount Shasta, CA	0.78	TMY
Point Mugu, CA	0.63	TMY
Red Bluff, CA	0.81	TMY
Sacramento, CA	0.75	TMY
San Diego, CA	0.67	TMY
San Francisco, CA	0.92	TMY
Santa Maria, Ca	0.70	TMY
Sunnyvale, CA	0.63	TMY

City, State	w[ACH]	Source
Colorado Springs, CO	0.98	TMY
Denver, CO	0.87	TMY
Eagle, CO	0.80	TMY
Grand Junction, CO	0.87	TMY
Pueblo, CO	0.85	TMY
Hartford, CT	0.86	TMY
Washington, DC	0.76	TMY
Wilmington, DE	0.84	TMY
Apalachicola, FL	0.63	TMY
Daytona, FL	0.73	TMY
Jacksonville, FL	0.77	TMY
Miami, FL	0.69	TMY
Orlando, FL	0.73	TMY
Tallahassee, FL	0.63	TMY
Tampa, FL	0.75	TMY
Augusta, GA	0.69	TMY
Atlanta, GA	0.75	TMY
Savannah, GA	0.75	TMY
Hilo, HI	0.60	TMY
Honolulu, HI	0.81	TMY
Lihue, HI	0.94	TMY
Burlington, IA	0.90	TMY
Des Moines, IA	0.93	TMY
Mason City, IA	1.01	TMY
Sioux City, IA	0.99	TMY
Boise, ID	0.87	TMY
Lewiston, ID	0.71	TMY
Pocatello, ID	0.95	TMY
Chicago, IL	0.93	TMY
Moline, IL	0.86	TMY
Springfield, IL	0.93	TMY
Evansville, IN	0.76	TMY
Fort Wayne, IN	0.92	TMY
Indianapolis, IN	0.86	TMY
South Bend, IN	0.89	TMY
Dodge City, KS	1.11	TMY
Goodland, KS	1.09	TMY
Topeka, KS	0.87	TMY
Lexington, KY	0.80	TMY

Values of the Weather Factor, W, for Canadian and U.S. Locations

(Reproduced from *A Method of Determining Air Change Rates in Detached Dwellings*, ANSI/ASHRAE 136-1993
(For use with BTLa method)

VALUES OF THE WEATHER FACTOR *W* FOR CANADIAN AND U.S. LOCATIONS

City, State	w[ACH]	Source
Baton Rouge, LA	0.70	TMY
Lake Charles, LA	0.72	TMY
New Orleans, LA	0.71	TMY
Shreveport, LA	0.77	TMY
Boston, MA	1.07	TMY
Churchill, MB	1.24	CAN
Thompson, MB	0.92	CAN
Baltimore, MD	0.82	TMY
Bangor, ME	0.75	TMY
Caribou, ME	1.00	TMY
Portland, ME	0.91	TMY
Alpena, MI	0.82	TMY
Detroit, MI	0.92	TMY
Flint, MI	0.90	TMY
Grand Rapids, MI	0.89	TMY
Sault Ste Marie, MI	0.95	TMY
Traverse City, MI	0.94	TMY
Duluth, MN	1.00	TMY
International Falls, MN	0.98	TMY
Minneapolis, MN	0.97	TMY
Rochester, MN	1.03	TMY
Kansas City, MO	0.85	WYEC
Springfield, MO	0.95	TMY
St. Louis, MO	0.87	TMY
Jackson, MS	0.68	TMY
Meridian, MS	0.62	TMY
Billings, MT	1.07	TMY
Cut Bank, MT	1.04	TMY
Dillon, MT	0.90	TMY
Glasgow, MT	1.02	TMY
Great Falls, MT	1.05	TMY
Helena, MT	0.89	TMY
Lewistown, MT	0.90	TMY
Missoula, MT	0.79	TMY
Saint John, NB	0.95	CAN
Asheville, NC	0.69	TMY
Cape Hatteras, NC	0.94	TMY
Charlotte, NC	0.74	TMY
Greensboro, NC	0.72	TMY
Raleigh, NC	0.72	WYEC
Bismarck, ND	0.99	TMY
Fargo, ND	1.10	TMY
Grand Island, NE	1.06	TMY
North Platte, NE	0.95	TMY
Omaha, NE	0.87	TMY
Scottsbluff, NE	0.99	TMY

City, State	w[ACH]	Source
Stephenville, NF	1.03	CAN
Concord, NH	0.76	TMY
Lakehurst, NJ	0.70	TMY
Albuquerque, NM	0.80	TMY
Clayton, NM	1.06	TMY
Roswell, NM	0.86	TMY
Truth or Conseq, NM	0.79	TMY
Tucumcari, NM	0.87	TMY
Shearwater, NS	0.87	CAN
Baker Lake, NT	1.25	CAN
Fort Smith, NT	0.92	CAN
Inuvik, NT	1.01	CAN
Elko, NV	0.77	TMY
Ely, NV	0.98	TMY
Las Vegas, NV	0.81	TMY
Lovelock, NV	0.78	TMY
Reno, NV	0.75	TMY
Tonopah, NV	0.90	TMY
Winnemucca, NV	0.84	TMY
Yucca Flats, NV	0.77	TMY
Buffalo, NY	0.99	TMY
Massena, NY	0.90	TMY
New York Cen. Pk, NY	0.98	TMY
New York LaGuar., NY	0.99	TMY
Rochester, NY	0.92	TMY
Syracuse, NY	0.88	TMY
Akron, OH	0.91	TMY
Cincinnati, OH	0.84	TMY
Cleveland, OH	0.96	WYEC
Columbus, OH	0.86	TMY
Dayton, OH	0.86	TMY
Toledo, OH	0.90	TMY
Youngstown, OH	0.92	TMY
Oklahoma City, OK	1.05	TMY
Tulsa, OK	0.93	TMY
Kapuskasing, ON	0.92	CAN
Sault Ste. Marie, ON	0.90	CAN
Thunder Bay, ON	0.86	CAN
Toronto, ON	0.82	WYEC
Windsor, ON	0.87	CAN
Astoria, OR	0.85	TMY
Medford, OR	0.67	TMY
North Bend, OR	0.90	TMY
Portland, OR	0.76	TMY
Redmond, OR	0.80	TMY
Salem, OR	0.80	TMY

Values of the Weather Factor, *W*, for Canadian and U.S. Locations

(Reproduced from *A Method of Determining Air Change Rates in Detached Dwellings*, ANSI/ASHRAE 136-1993
(For use with BTLa method)

VALUES OF THE WEATHER FACTOR *W* FOR CANADIAN AND U.S. LOCATIONS

City, State	w[ACH]	Source
Allentown, PA	0.80	TMY
Erie, PA	1.00	TMY
Harrisburg, PA	0.76	TMY
Philadelphia, PA	0.85	TMY
Pittsburgh, PA	0.85	TMY
Charlottetown, PE	1.04	CAN
Quebec, PQ	0.84	CAN
Schefferville, PQ	1.13	CAN
Sept Iles, PQ	0.96	CAN
Montreal, PQ	0.86	WYEC
Providence, RI	0.91	TMY
Charleston, SC	0.77	TMY
Columbia, SC	0.67	TMY
Greenville, SC	0.69	TMY
Huron, SD	1.09	TMY
Pierre, SD	1.00	TMY
Sioux Falls, SD	1.05	TMY
Regina, SK	1.05	CAN
Saskatoon, SK	0.98	CAN
Chattanooga, TN	0.64	TMY
Knoxville, TN	0.68	TMY
Memphis, TN	0.78	TMY
Nashville, TN	0.74	WYEC
Abilene, TX	1.05	TMY
Amarillo, TX	1.14	TMY
Austin, TX	0.80	TMY
Brownsville, TX	0.90	TMY
Corpus Christi, TX	0.86	TMY
El Paso, TX	0.76	TMY

City, State	w[ACH]	Source
Fort Worth, TX	0.89	TMY
Houston, TX	0.81	TMY
Kingsville, TX	0.72	TMY
Laredo, TX	0.91	TMY
Lubbock, TX	1.00	TMY
Lufkin, TX	0.64	TMY
Midland Odessa, TX	0.96	TMY
Port Arthur, TX	0.79	TMY
San Angelo, TX	0.84	TMY
San Antonio, TX	0.83	TMY
Sherman, TX	0.80	TMY
Waco, TX	0.92	TMY
Wichita Falls, TX	0.99	TMY
Cedar City, UT	0.81	TMY
Salt Lake City, UT	0.87	TMY
Norfolk, VA	0.84	TMY
Richmond, VA	0.75	TMY
Roanoke, VA	0.74	TMY
Olympia, WA	0.77	TMY
Seattle, WA	0.85	TMY
Spokane, WA	0.87	TMY
Yakima, WA	0.81	TMY
Eau Claire, WI	0.93	TMY
Green Bay, WI	0.94	TMY
La Crosse, WI	0.86	TMY
Madison, WI	0.91	TMY
Milwaukee, WI	1.00	TMY
Charleston, WV	0.66	TMY
Casper, WY	1.15	TMY
Cheyenne, WY	1.08	TMY
Rock Springs, WY	0.98	TMY
Sheridan, WY	0.83	TMY
Whitehorse, YT	0.94	CAN