ZipTest Pro^{2}™

Building Diagnostics Software

for

Texas Instruments TI-86 Calculator

Specifications

and

Instructions

Warnings! Warnings!

- Do not attempt to transfer the programs and routines from one TI-86 to another; you might corrupt them. This can be especially problematic if you cause subtle corruption—resulting in incorrect answers—rather than catastrophic corruption, which is obvious. Contact WxWare Diagnostics for assistance.
- Do not press the “2nd” key, “MEM” (memory) and then “DELET” (delete). Doing so might delete part or all of the ZipTest Pro software.
- The ZipTest Pro programs loaded into your TI-86 calculator (BTL1, BTUDD, and Press) are edit-protected to prevent corruption. If you attempt to edit them, you will receive an error message.
- If the batteries in the TI-86 are cold—and thus weak—you might not see anything on the screen display. If the batteries are in this condition rather than dead, you will be able to see items on the display if you press the “2nd” key and release it and then press and hold the up arrow/cursor key until you can see items on the screen. To decrease the display contrast, press the “2nd” key and then release it. Then press and hold the down arrow/cursor key until the screen contrast pleases you. As the batteries warm up, you might have to adjust the contrast again. See the *TI-86 Graphing Calculator Guidebook*, page 17, for more information.
- The TI-86 is powered by four AAA batteries and one lithium back-up battery. The lithium back-up supplies power when you replace the four AAA batteries. If the lithium battery is dead when you replace the four AAA batteries, you will lose the ZipTest Pro software that is loaded in the RAM memory. See pages 16 through the middle of page 18 in the *TI-86 Graphing Calculator Guidebook* for more information.
- Do not add 1) programs, 2) SOLVER equations—Equation Nuggets, 3) strings, 4) lists, or 5) constants without first contacting WxWare Diagnostics. If you add variables to the calculator loaded with the ZipTest Pro software, your new variables might be the same as some of those that are already included in ZipTest Pro. This could corrupt the programs and routines.

ZipTest Pro²™

Building Diagnostics Software

for

Texas Instruments TI-86 Calculator

Specifications and Instructions

WxWare Diagnostics
Building Analysis Tools

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SOFTWARE LICENSE AGREEMENT AND LIMITED WARRANTY

LICENSE AGREEMENT

In return for the payment of the one-time fee for this software product, the Customer receives from WxWare Diagnostics a license to use the product subject to the following terms and conditions:

1. The product may be used without time limit on one TI-86 calculator.
2. A separate license agreement and fee is required for each TI-86 calculator on which the product is used.
3. The software product may not be duplicated or copied except for archive purposes. All copies made must bear the copyright notices contained in the original.
4. This license and software product may be transferred to a third party provided the third party agrees to all the terms of this License Agreement and the Customer does not retain any copies of the software product.
5. Purchase of this license does not transfer any right, title, or interest in the software product to the Customer except as specifically set forth in this License Agreement. The Customer is on notice that the software product is protected under the copyright laws.
6. WxWare Diagnostics reserves the right to terminate this license upon breach.

LIMITED WARRANTY

WxWare Diagnostics warrants for a period of ninety days from the date of purchase that the software product will execute its programming instruction when properly used. WxWare Diagnostics does not warrant the Texas Instruments TI-86 calculator (see the Texas Instruments warranty information).

The Customer must notify WxWare Diagnostics in writing of any warranty claim not later than thirty days after the expiration of the warranty period.

WxWare Diagnostics makes no other express warranty, whether written or oral with respect to this product. This warranty gives specific legal rights, and you may also have other rights which vary from state to state, or province to province.

The remedies provided above are the Customer's sole and exclusive remedies. In no event shall WxWare Diagnostics be liable for any direct, indirect, special, incidental, or consequential damages (including lost profit) whether based on warranty, contract, tort, or any other legal theory. Some states or provinces do not allow the exclusion or limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you.

Warranty Services may be obtained from:

WxWare Diagnostics
220 Meadow Road
Topsham, ME 04086
207-725-6723
Fax: 207-725-7818
E-mail: rjkarg@karg.com

INTRODUCTION

The Texas Instruments TI-86 graphics calculator is a powerful, durable and inexpensive calculator/computer. It has been used successfully in the field for calculating values needed for diagnostic studies in the areas of residential and commercial weatherization work, new construction, and heating, ventilating, and air-conditioning. To insure the most effective and accurate use of the TI-86 and the ZipTest Pro^2 software, please read the *TI-86 Graphing Calculator Guidebook* and this ZipTest Pro^2 instruction book.

ORDERING INFORMATION

This software my be ordered pre-loaded into a Texas Instruments TI-86 calculator or loaded into your TI-86 calculator. For orders, please contact:

WxWare Diagnostics
220 Meadow Road
Topsham, Maine 04086

207-725-6723
Fax: 207-725-7818
E-mail: rjkarg@karg.com

If you ordered the software from WxWare, you are a registered user. If you have the software but have not registered, send a check for the cost of the software to the above address, along with your name, address, TI-86 calculator serial number, and program date.

SUPPORT AND UPDATES

Support is available to registered users only. You may:

1) Write to us at the above address,
2) Call 207-725-6723, or
3) Fax: 207-725-7818. or
4) E-mail: rjkarg@karg.com

If you are a registered user, you will be informed of program updates by mail.

WxWare has attempted to make the program calculations accurate, but it does not guarantee the accuracy of the calculations.

For information, updates, and frequently asked questions (FAQ), check our Web site at www.karg.com/software.htm. These instructions are available in Adobe Acrobat format on the Web site.

SOFTWARE TRAINING

Training for the use of ZipTest Pro^2 software is available for groups. Contact Rick Karg for information.

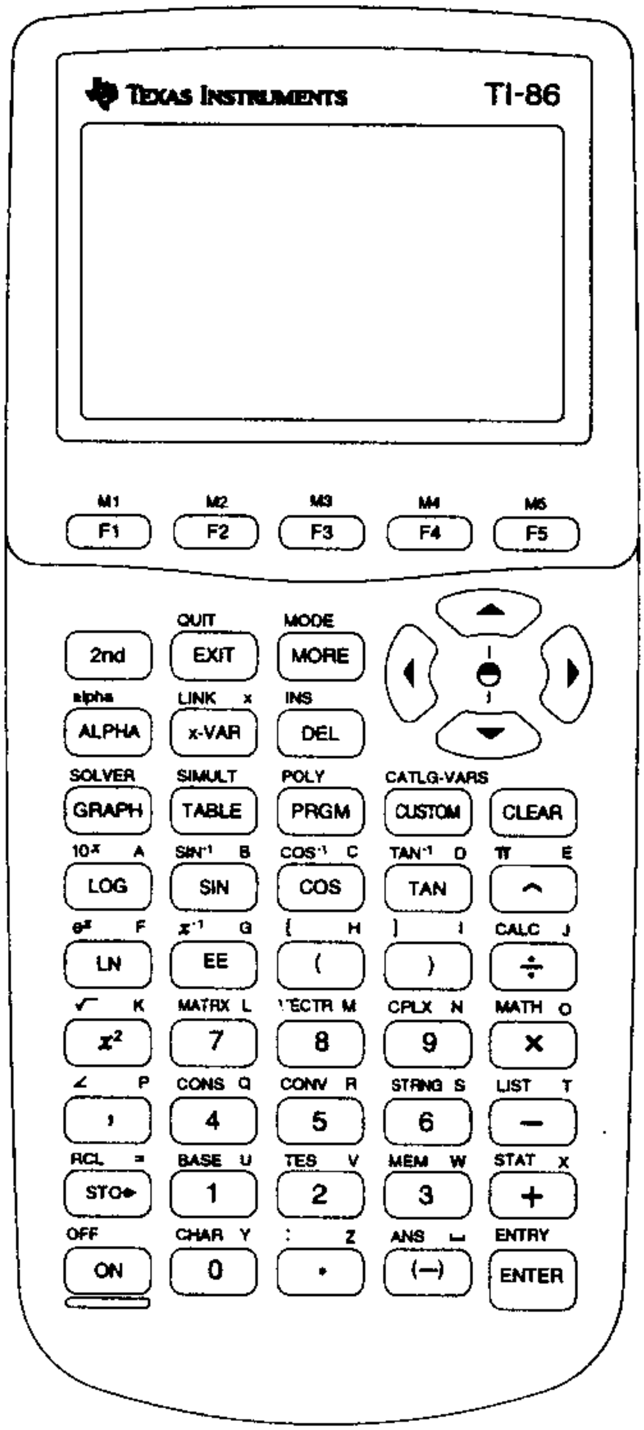
PROGRAM OPERATION

Follow the instructions in this booklet for operation of the software. Pictures of the TI-86 screens appear on the left side of the instruction pages and explanations to the right of each picture

Please read at least the first two sections of the Texas Instruments *TI-86 Graphing Calculator Guidebook* before using the calculator and ZipTest Pro^2 software,

Texas Instruments

TI-86 Graphing Calculator/Computer



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Acceptable Indoor Air Quality

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with sub-programs

BTL

BTLa

62.2

April 2004 (V3.0)

Introduction

This program, BTL1, includes three calculation procedures; "BTL", "BTLa" and "62.2". BTL (Building Tightness Limits Based on ASHRAE 62-2001 and LBL Correlation Factors) is the oldest of the three 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.

Finally, the "62.2" method of calculation is similar to the BTLa method of calculation, but is based on the most recent ASHRAE standard, *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings* (Standard 62.2-2003). This latest ASHRAE standard for residential ventilation — the first that is exclusively for residential buildings — renders the previous two methods (BTL and BTLa) obsolete. However, we decided to keep them as a part of the ZipTest Pro² software package because many analysts are using these methods. **Analysts in the field should make every attempt to convert to the use of the latest method, "62.2", based on the most recent ASHRAE Standard 62.2-2003.**

"BTL" Calculation Procedure for Determining CFM_{50} Minimum

The objective of this calculation procedure is the determination of a minimum CFM_{50} value. Awareness of this value allows building energy analysts and weatherization workers to add mechanical ventilation if the building is made tighter than the threshold BTL 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 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 by the calculator program are based on ASHRAE Standard 62-2001, *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.**

Please note, this method is based on an obsolete section of ASHRAE Standard 62-2001 that has been replaced by another ASHRAE Standard, *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings*, Standard 62.2-2003.

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 Cod 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 represent tightness values when the house is under 50 Pascals of negative or positive pressure, typically created with a blower door. If the house is made tighter than the BTL value, continuously operating ventilation must be installed in order to comply with ASHRAE 62.

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

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

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

Effective Leakage Area (ELA).
Equivalent Leakage Area (EqLA).
Estimated Natural CFM.
Estimated Natural ACH.
Estimated Natural CFM per Occupant.
Minimum Effective Leakage Area.
Minimum CFM.
Minimum CFM_{50}, below which continuously operating ventilation must be installed for compliance with ASHRAE 62.
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 Occupied area, ft^2.
Building Volume, ft^3.
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 62-2001).
- *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).
- Palmiter, L., and P. Francisco. 1996. *Modeled and Measured Infiltration: Phase III, A Detailed Case Study of Three Homes*. Palo Alto, CA: Electric Power Research Institute.

Of the calculated values in this procedure, the Minimum Effective Leakage Area ("ELA min" on the calculator screen) and Minimum CFM ("CFM min" on the calculator screen) are the most reliable 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. The CFM_{50} minimum 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 Effective Leakage Area takes into account the guidelines set by ASHRAE 62-2001—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 intended for use in commercial applications.** The calculation of Minimum CFM ("CFMmin" on the calculator screen) also includes the ASHRAE 62-2001 guidelines.

If a dwelling is tighter than the ASHRAE 62-2001 guidelines, the ventilation necessary ("Vent CFM Needed") to bring the dwelling into compliance with the ASHRAE 62-2001 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 the paper by Palmiter, L., and P. Francisco (1996) referenced above.

Please note, this method is based on an obsolete section of ASHRAE Standard 62-2001 that has been replaced by another ASHRAE Standard, *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings*, Standard 62.2-2003.

"62.2" Calculation Procedure based on ASHRAE 62.2, 119, and 136

This final procedure is based on the most recent ventilation standard for residential buildings published by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings*, Standard 62.2-2003. The objective of this procedure is the determination of the mechanical or intermittent ventilation requirements for low-rise residential (three stories or less) buildings.

This method uses calculation procedures that are, for the most part, the same as the BTLa procedure. However, the calculations for the final ventilation requirements are different. As a result of these differences, more houses will require mechanical ventilation than required by the BTLa method, but the required ventilation rate will usually be of a lower magnitude.

This procedure calculates the values listed below:

Effective Leakage Area (ELA).
Equivalent Leakage Area (EqLA).
Estimated Natural CFM.
Estimated Natural ACH.
Estimated Natural CFM per Occupant.
Mechanical Ventilation Required in CFM for intermittent ventilation operating 50 percent on-time when the building is closed up for central heating or cooling.
Mechanical Ventilation Required in CFM for intermittent ventilation operating 75 percent on-time when the building is closed up for central heating or cooling.
Mechanical Ventilation Required in CFM for continuously operating ventilation, in other words, the ventilation is always operating when the building is closed up for central heating or cooling.
The infiltration (air leakage) credit applied to the ventilation requirement.

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 Occupied area, ft^2.
Building Volume, $ft^{3.}$
Building Height above grade, 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):

- *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings* (ANSI/ASHRAE 62.2-2003).
- *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).

The basic requirement for this method is expressed by this equation:

$$Ventilation_{CFM} = 0.01A + (7.5\ CFM\ per\ Occupant)$$

Where:

A = oppupiable floor area in square feet.
Occupant = number of bedrooms plus one or actual number of occupants, whichever is larger.

An infiltration (air leakage) credit is calculated if the estimated natural infiltration is more than two times the floor area/100. In these cases, the infiltration credit is:

$$Infiltration\ Credit_{CFM} = \left(0.5\left[Natural\ Air\ Leakage_{CMF} - \left\{\frac{2A}{100}\right\}\right]\right)$$

This infiltration credit is subtracted from the Ventilation$_{CFM}$ calculated by the equation at the bottom of the previous page.

For the information of the user, this infiltration credit is reported as number "9)" on the screen display that lists all the inputs and outputs for the 62.2 program.

This method is not intended for use in commercial applications.

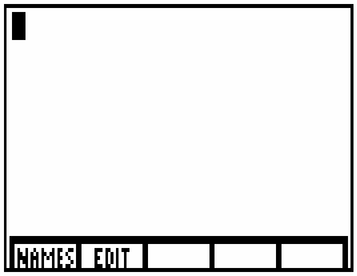
Acknowledgements

Thanks 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.

Note about ASHRAE 62 Standard

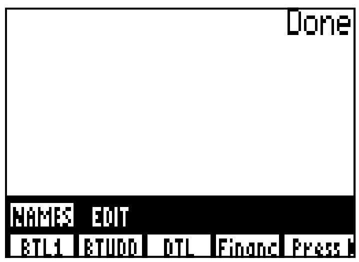
As a result of the publication of ASHRAE 62.2, a Standard for residential buildings only, the residential section in ASHRAE 62 has become obsolete. Within the next few years all references to residential indoor air quality and ventilation will be removed from ASHRAE 62 and it will be renamed ASHRAE 62.1 . At the time of the publication of this ZipTest Pro² instruction manual, the official designation was ASHRAE 62.

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

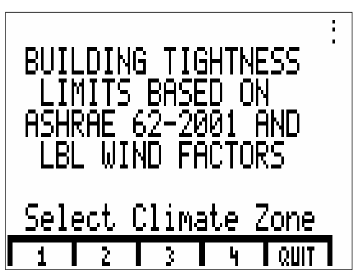


- Press **F1, F2, F3, F4**, or **F5** for the program "BTL1." The menu key for this program will depend upon the number of programs loaded in the memory of your TI-86 calculator. For the screen at the left, four usable programs are loaded onto the calculator, "BTL1" (**F1**), "BTUDD" (**F2**), "DTL" (**F3**) and "Press" (**F5**). Press **ENTER**. **Note: The exact name of the program must appear at the cursor position, if not you will receive an error message.**

BTL1-3

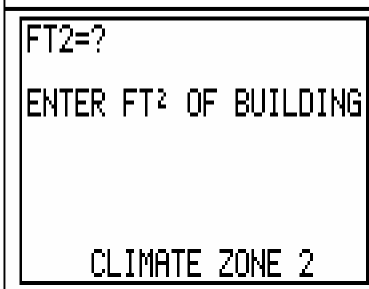
- You will see this menu on the screen. This is the main menu screen.
- **F1, "**BTL" to starts the Building Tightness Limits program.
- **F2, "**BTLa" starts the advanced Building Tightness Limits program.
- **F3, "**62.2" starts the latest (2004) program.
- **F4, "**ACKLG " (Acknowledgments) selection 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 "floating," whereas within the **BTL** program it is set to one place.

BTL1-4



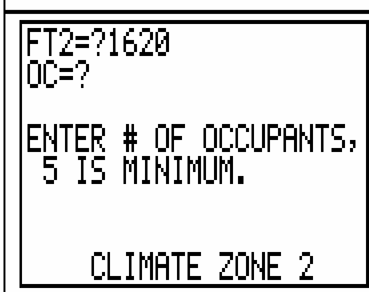
- Select **F1, "**BTL," to start the Building Tightness Limits program.
- You will see this menu on the screen.
- You are asked to select your climate zone. Refer to the map of North America on page 20 for your appropriate climate zone number.
- Note: If you select **F5, "**QUIT," you will exit the program. **DONE** will appear in the upper right corner of the screen If you want to re-enter the program, press **ENTER** or press **PRGM.**
- As a demonstration, select **F2** for climate zone 2.

BTL1-5



- The climate zone you selected appears at the bottom of the screen.
- Enter the conditioned 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.
- Enter "1620," for example, and press ENTER.

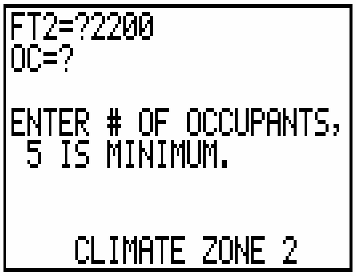
BTL1-6



- Enter the number of occupants—by design. It is common to count the number of bedrooms and add one 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**.

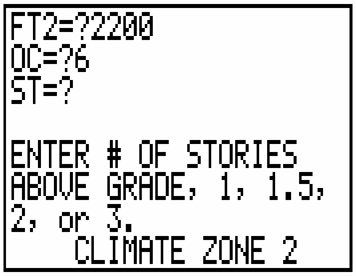
BTL1-7	FT2=?1620 OC=?6 ST=? ENTER # OF STORIES ABOVE GRADE, 1, 1.5, 2, or 3. CLIMATE ZONE 2	• You are prompted to enter the number of exposed stories of the house. Basements below grade generally should not be included in the number of stories. The value you enter will be displayed after the "**?**" • Enter "1.5" stories, for example, and press **ENTER**.
BTL1-8	FT2=?1620 OC=?6 1=SHIELDED ST=?1.5 2=NORMAL EXP=? 3=EXPOSED ENTER EXPOSURE # CLIMATE ZONE 2	• 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 little wind blockage (meadow settings, lake-side, etc.).
BTL1-9	FT2=?1620 OC=?6 1=SHIELDED ST=?1.5 2=NORMAL EXP=?1 3=EXPOSED LBL#=20.0 CFM50 BTL=1800.0 CLIMATE ZONE 2	• "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. • Press **ENTER**
BTL1-10	BUILDING TIGHTNESS LIMIT & VENTILATION CALCULATIONS FOR ACCEPTABLE INDOOR AIR QUALITY (c)2004 WxWare (V3.0) Select from Menu BTL | BTLa | 62.2 | ACKLG | QUIT	• 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	BUILDING TIGHTNESS LIMITS BASED ON ASHRAE 62-2001 AND LBL WIND FACTORS Select Climate Zone 1 | 2 | 3 | 4 | QUIT	• You are asked to select your climate zone. Refer to the map of North America on page 20 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	FT2=? ENTER FT² OF BUILDING CLIMATE ZONE 2	• 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



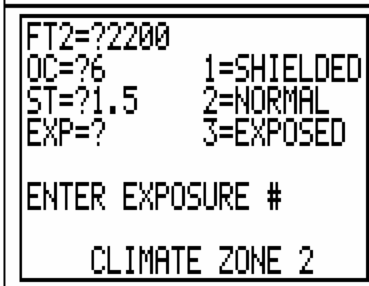
- Enter the number of occupants—by design. You may count the number of bedrooms and add one, using five as a minimum product, to determine the number of occupants for this procedure.
- Enter "6" for this demonstration and press **ENTER**.

BTL1-14



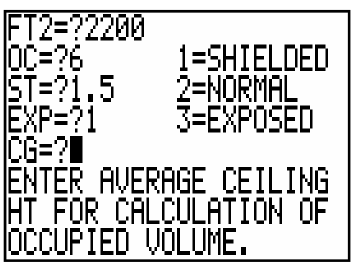
- You are prompted to enter the number of exposed stories of the house. Basements below grade generally should not be included in the number of stories. The value you enter will be displayed after the "**?**"
- Enter "1.5" stories and press **ENTER**.

BTL1-15



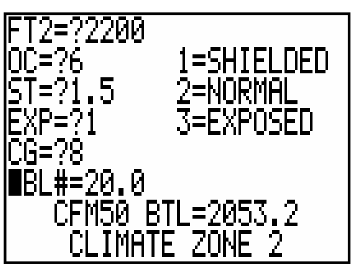
- You are prompted to enter the appropriate exposure number for the house. The value you enter will be displayed after the "**?**"
- The "EXP" or exposure value should be entered with care. "SHIELDED" is for buildings with significant blockage to the wind (trees or other buildings), "NORMAL" signifies 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



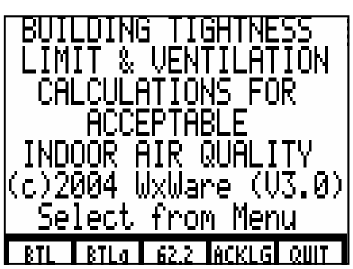
- You are prompted to enter the average ceiling height of the house. For this example, assume ceilings are eight feet high. The ceiling height is multiplied by the square footage you entered, yielding the volume of the house. Because the square footage of this demonstration house is greater then the 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=2053.2" 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 2053.2.
- 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**

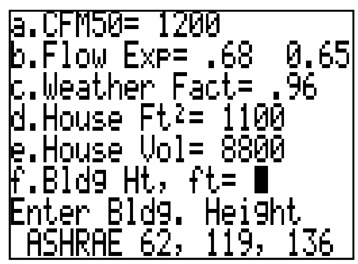
BTL-18



- You will see the at the left screen displayed.
- Select **F2, BTLa**.
- Now we will look at the next calculation procedure which is generally a more accurate method of determining building tightness and required ventilation for tight buildings.

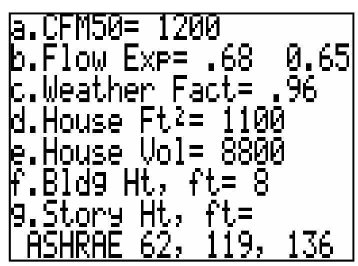
BTL1-19	BUILDING TIGHTNESS LIMITS AND VENTILATION REQUIREMT BASED ON ASHRAE 62, 119, & 136 Press Enter	• For an explanation of this procedure, refer to "**BTLa Calculation Procedure based on ASHRAE 62, 119, and 136**" on page 3 of this instruction manual. • Press **ENTER** to proceed to the next screen.
BTL1-20	a.CFM50= Enter CFM50 of Building ASHRAE 62, 119, 136	• 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." All the input values for this procedure are preceded with a lower-case letter, a through h. • 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. • For this example, enter 1200 and press ENTER.
BTL1-21	a.CFM50= 1200 b.Flow Exp= ▮ 0.65 Enter Flow Exponent (Typical = 0.65) ASHRAE 62, 119, 136	• 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.
BTL1-22	a.CFM50= 1200 b.Flow Exp= .68 0.65 c.Weather Fact= ▮ Find Weather Factors in Instruction Manual ASHRAE 62, 119, 136	• Enter the weather factor, "c.Weather Fact." These values are listed in this instruction manual on pages 21 through 23 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 62-2001. This calculation procedure can be found in ASHRAE 136-1993. • Enter ".96" for this example (Cleveland, Ohio) and press **ENTER**.
BTL1-23	a.CFM50= 1200 b.Flow Exp= .68 0.65 c.Weather Fact= .96 d.House Ft²= ▮ Enter House Floor Ft² ASHRAE 62, 119, 136	• Enter the square footage of building floor area, "d.House Ft²." 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). • For this example, enter "1100" and press **ENTER** .
BTL1-24	a.CFM50= 1200 b.Flow Exp= .68 0.65 c.Weather Fact= .96 d.House Ft²= 1100 e.House Vol= ▮ Enter House Volume in Cubic Feet	• Enter the building volume, "e.House Vol," in units of cubic feet. If you included the basement in the volume figure, include the basement here also. • Enter "8800" (this value assumes a ceiling height of eight feet) and press **ENTER .**

BTL1-25



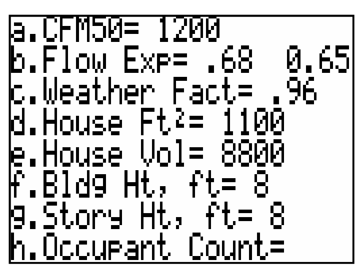
- Enter the building height above grade in units of feet, "f.Bldg Ht, ft." For buildings with uneven above grade heights—walk-out basements, one and one-half story buildings—use the average height of the building.
- For this example enter "8" and press **ENTER**
- Notice that "ASHRAE 62, 119, 136" remains at the bottom of the screen as a reminder of the methodology on which you are working.

BTL1-26



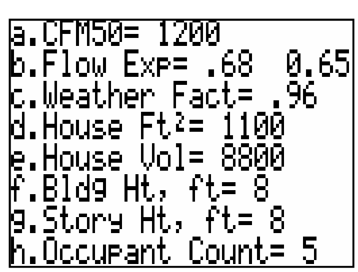
- Enter the average height of one story of the building, "g.Story Ht, ft." This value and the "Bldg Ht" from the previous entry determines the number of stories in the building. The resulting value (the number of stories) should not exceed three.
- For this example, enter "8" and press **ENTER**

BTL1-27



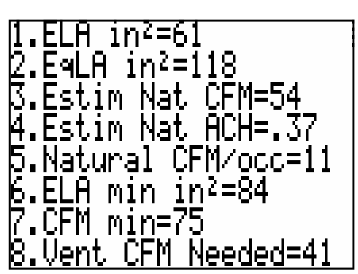
- Enter the "h.Occupant Count" as the next and final input value for this procedure. Enter the number of occupants or the number of bedrooms plus one, whichever is larger. This value is used to determine the ventilation requirements for the dwelling. The greater the number of occupants or bedrooms, the greater the amount of fresh air required for acceptable indoor air quality.
- For the example, enter "5"

BTL1-28



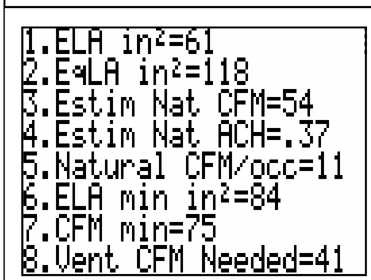
- Review the input values you have entered before you press **ENTER**.
- Now, press **ENTER** and move on to the next screen which displays all the output values for the example problem.
- Note that all the input values are lettered (a. through h), and that on the next screen (Panel BTL1-29), all of the output values (answers) are numbered (1. through 8.).
- Press **ENTER** to move to the next screen.

BTL1-29



- 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]

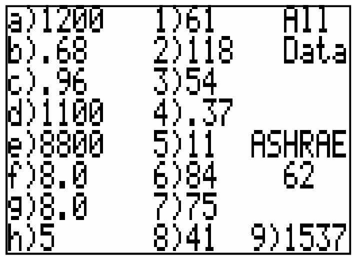
BTL1-30



- "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]

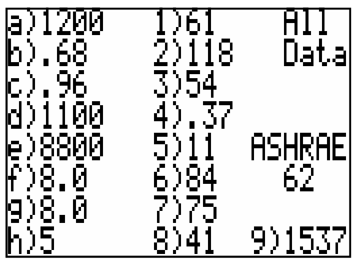
BTL1-31	1.ELA in^2=61 2.EqLA in^2=118 3.Estim Nat CFM=54 4.Estim Nat ACH=.37 5.Natural CFM/occ=11 6.ELA min in^2=84 7.CFM min=75 8.Vent CFM Needed=41	• "3.Estim Nat CFM" (estimated natural CFM) is equal to 54 for the example. This calculated value is based on ELA, the Weather Factor (see Panel BTL1-34) 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.ELA min in^2=84 7.CFM min=75 8.Vent CFM Needed=41	• "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 62-2001, 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 62-2001) 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 41. [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.ELA min in^2=84 7.CFM min=75 8.Vent CFM Needed=41	• "6.ELA min" (ELA minimum) is the minimum effective leakage area of the building that will satisfy ASHRAE 62-2001. If the building is made tighter than this, mechanical ventilation must be added to comply with ASHRAE 62-2001. 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 ELA minimum, line 6, is 84in^2, thus the building is tighter than ASHRAE 62-2001. Mechanical ventilation should 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.ELA min in^2=84 7.CFM min=75 8.Vent CFM Needed=41	• "7.CFMmin" (CFM minimum) is the minimum natural CFM that will satisfy ASHRAE 62-2001. 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 62-2001, thus ventilation should 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 62-2001. [continued on next panel]
BTL1-35	[intentionally left blank]	**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 62-2001 and the procedures of this ZipTest Pro[2] software do not guarantee that moisture or indoor air quality problems 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



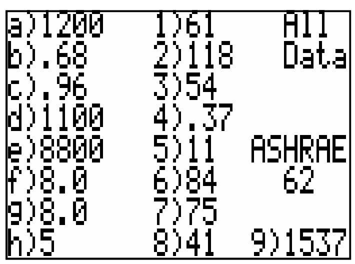
- The “All Data” display lists all the your inputs and outputs for a calculation. This is presented as a summary for your convenience. The letters and numbers correspond with the line letters (inputs) and numbers (outputs) on the two previous calculator displays.
- a) CFM_{50} from blower door test (see Panel BTL1-20).
- b) Flow exponent from blower door test or 0.65 (see Panel BTL1-21).
- c) Weather factor from pages 21 through 23 (see Panel BTL1-22).
- d) House square footage (see Panel BTL1-23). [continued on next panel]

BTL1-38



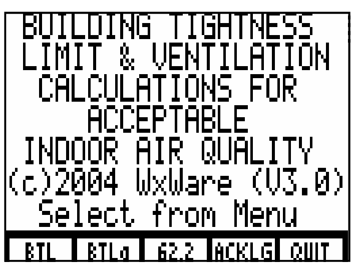
- e) House volume (see Panel BTL1-24).
- f) Building height (see Panel BTL1-25).
- g) Story height (see Panel BTL1-26).
- h) Occupant count (see Panel BTL1-27).
- 1) Actual ELA (effective leakage area) (see Panel BTL1-29).
- 2) Actual EqLA (equivalent leakage area) (see Panel BTL1-30)
- 3) Estimated actual natural CFM (see Panel BTL1-31).

BTL1-39



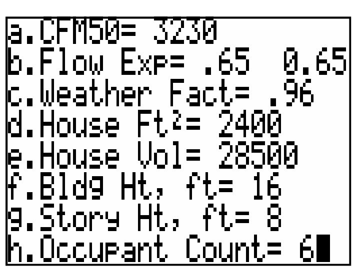
- 5) Estimated actual natural CFM per occupant (see Panel BTL1-32).
- 6) Minimum ELA for compliance (see Panel BTL1-33).
- 7) Minimum CFM for compliance (see Panel BTL1-34).
- 8) Mechanical ventilation CFM needed for compliance(see Panels BTL1-34 & 35).
- 9) Minimum CFM_{50} value. This is the only place 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 use it, please do so with caution.

BTL1-40



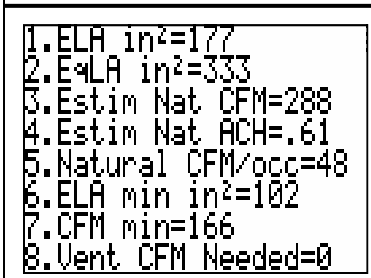
- Now, let’s look at another example that does not require added mechanical ventilation.
- Press **ENTER** to return to the main screen.
- Press **F2** for “BTLa” and press **ENTER** to go to the first of the inputs.

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



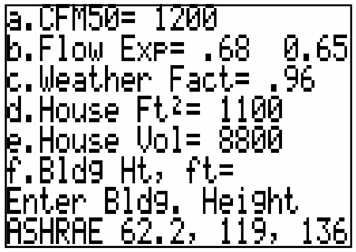
- All the outputs, except target minimum CFM_{50} are listed on the output display.
- Notice that no mechanical ventilation (line 8) is called for. The natural CFM per occupant, line 5, exceeds the ASHRAE 62-2001 minimum of 15 and the estimated natural ACH , line 4, exceeds the minimum 0.35. The actual ELA, line 1, exceeds the minimum ELA on line 6. This house can be significantly tightened before the ASHRAE 62-2001 minimum values are reached.

[continued on next panel]

BTL1-43	1.ELA in²=177 2.EqLA in²=333 3.Estim Nat CFM=288 4.Estim Nat ACH=.61 5.Natural CFM/occ=48 6.ELA min in²=102 7.CFM min=166 8.Vent CFM Needed=0	• 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 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 "ELAmin" is reached. • Press ENTER to move to the "All Data" display.
BTL1-44	a)3230 1)177 All b).65 2)333 Data c).96 3)288 d)2400 4).61 e)28500 5)48 ASHRAE f)16.0 6)102 62 g)8.0 7)166 h)6 8)0 9)1864	• 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 21 through 23 (see Panel BTL1-22). • d) House square footage (see Panel BTL1-23). • e) House volume (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 (see Panel BTL1-29).**
BTL1-45	a)3230 1)177 All b).65 2)333 Data c).96 3)288 d)2400 4).61 e)28500 5)48 ASHRAE f)16.0 6)102 62 g)8.0 7)166 h)6 8)0 9)1864	• 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) Minimum ELA for compliance (see Panel BTL1-33). • 7) 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 (see Panel BTL1-39).
BTL1-46	a)3230 1)177 All b).65 2)333 Data c).96 3)288 d)2400 4).61 e)28500 5)48 ASHRAE f)16.0 6)102 62 g)8.0 7)166 h)6 8)0 9)1864	• 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	a)3230 1)177 All b).65 2)333 Data c).96 3)288 d)2400 4).61 e)28500 5)48 ASHRAE f)16.0 6)102 62 g)8.0 7)166 h)6 8)0 9)1864	• 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	BUILDING TIGHTNESS LIMIT & VENTILATION CALCULATIONS FOR ACCEPTABLE INDOOR AIR QUALITY (c)2004 WxWare (V3.0) Select from Menu BTL | BTLa | 62.2 | ACKLG | QUIT	• Press **ENTER** to return to the home screen. • **F3** takes you to the calculations for the latest ASHRAE Standard 62.2, *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings.* • Let's take a look at this newest program.

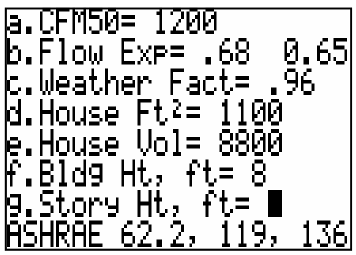
BTL1-49	Ventilation Requirements Based on ASHRAE 62.2, 119, & 136 Press Enter	• This program has the same inputs and most of the same outputs as the BTLa program. It is important to understand that this program does not determine a building tightness limit, as BTL and BTLa do (the tightness limit for these two programs calculates the CFM_{50} threshold below which continuously operating ventilation is needed and above which it is not).
BTL1-50	a.CFM50= ▮ Enter CFM50 of Building ASHRAE 62.2, 119, 136	• 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." All the input values for this procedure are preceded with a lower-case letter, a through h. • Notice that "ASHRAE 62.2, 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. • For this example, enter 1200 and press ENTER.
BTL1-51	a.CFM50= 1200 b.Flow Exp= ▮ 0.65 Enter Flow Exponent (Typical = 0.65) ASHRAE 62.2, 119, 136	• 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.
BTL1-52	a.CFM50= 1200 b.Flow Exp= .68 0.65 c.Weather Fact= Find Weather Factors in Instruction Manual ASHRAE 62.2, 119, 136	• Enter the weather factor, "c.Weather Fact." These values are listed in this instruction manual on pages 21 through 23 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 62-2001. This calculation procedure can be found in ASHRAE 136-1993. • Enter ".96" for this example (Cleveland, Ohio) and press **ENTER**.
BTL1-53	a.CFM50= 1200 b.Flow Exp= .68 0.65 c.Weather Fact= .96 d.House Ft²= ▮ Enter House Floor Ft² ASHRAE 62.2, 119, 136	• Enter the square footage of building floor area, "d.House Ft²." This should be the conditioned floor area; the part of the building that is capable of being thermally conditioned for the comfort of the occupants. (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). • For this example, enter "1100" and press **ENTER** .
BTL1-54	a.CFM50= 1200 b.Flow Exp= .68 0.65 c.Weather Fact= .96 d.House Ft²= 1100 e.House Vol= Enter House Volume in Cubic Feet	• Enter the building volume, "e.House Vol," in units of cubic feet. If you included the basement in the volume figure, include the basement here also. • Enter "8800" (this value assumes a ceiling height of eight feet) and press **ENTER** .

BTL1-55



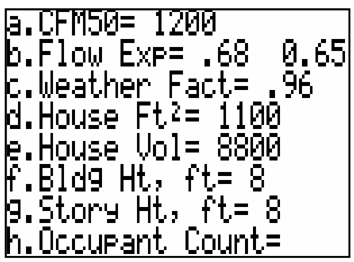
- Enter the building height above grade in units of feet, "f.Bldg Ht, ft." For buildings with uneven above grade heights—walk-out basements, one and one-half story buildings—use the average height of the building.
- For this example enter "8" and press **ENTER**
- Notice that "ASHRAE 62,119, 136" remains at the bottom of the screen as a reminder of the methodology on which you are working.

BTL1-56



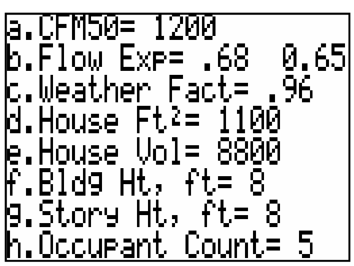
- Enter the average height of one story of the building, "g.Story Ht, ft." This value and the "Bldg Ht" from the previous entry (see Panel BTL1-37) determines the number of stories in the building. The resulting value (the number of stories) should not exceed three.
- For this example, enter "8" and press **ENTER**

BTL1-57



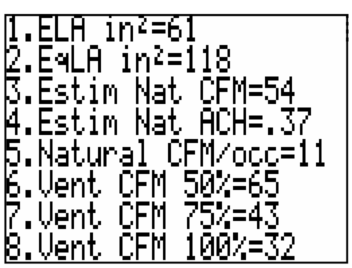
- Enter the "h.Occupant Count" as the next and final input value for this procedure. Enter the number of occupants or the number of bedrooms plus one, whichever is larger. This value is used to determine the ventilation requirements for the dwelling. The greater the number of occupants or bedrooms, the greater the amount of fresh air required for acceptable indoor air quality.
- For the example, enter "5"

BTL1-58



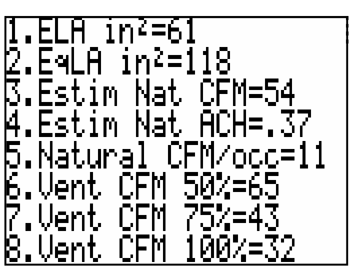
- Review the input values you have entered before you press **ENTER**.
- Now, press **ENTER** and move on to the next screen which displays all the output values for the example problem.
- Note that all the input values are lettered (a. through h), and that on the next screen (panel BTL1-59), all of the output values are numbered (1. through 8.).
- Press **ENTER** to move to the next screen.

BTL1-59



- On this screen, all the outputs are displayed except number 9.
- "1.ELA in²" 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]

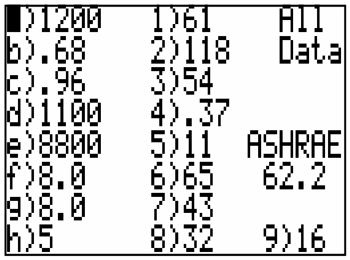
BTL1-60



- "2.EqLA in²" 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]

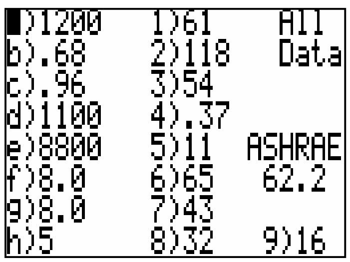
BTL1-61	1.ELA in^2=61 2.EqLA in^2=118 3.Estim Nat CFM=54 4.Estim Nat ACH=.37 5.Natural CFM/occ=11 6.Vent CFM 50%=65 7.Vent CFM 75%=43 8.Vent CFM 100%=32	• "3.Estim Nat CFM" (estimated natural CFM) is equal to 54 for the example. This calculated value is based on ELA, the Weather Factor (see Panel BTL1-34) 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]
BTL1-62	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.Vent CFM 50%=65 7.Vent CFM 75%=43 8.Vent CFM 100%=32	• "5.Natural CFM/occ" (estimated natural CFM per occupant) is number 3, estimated natural CFM, divided by the "Occupant Count" • "6.Vent CFM 50%" is equal to 65 for the example. This means that intermittent ventilation operating 50 percent of the time requires 65 CFM when the house is closed up if the ventilation is to comply with the ASHRAE Standard 62.2-2003. **Note: This intermittent ventilation MUST operate at least once every three hours; if it does not, this CFM rate must be doubled.** [continued on next panel]
BTL1-63	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.Vent CFM 50%=65 7.Vent CFM 75%=43 8.Vent CFM 100%=32	• "7.Vent CFM 75%" is equal to 43 for the example. This means that intermittent ventilation operating 75 percent of the time requires 43 CFM when the house is closed up if the ventilation is to comply with the ASHRAE Standard 62.2-2003. **Note: This intermittent ventilation MUST operate at least once every three hours; if it does not, this CMF rate must be multiplied by 1.33.** • "8.Vent CFM 100%" is equal to 32 for the example. This means that **continuously operating** ventilation of 32 CFM is required when the house is closed up in order to comply with ASHRAE Standard 62.2-2003. [continued on next panel]
BTL1-64	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.Vent CFM 50%=65 7.Vent CFM 75%=43 8.Vent CFM 100%=32	• We designed this program to report three levels of ventilation for compliance with AHRAE Standard 62.2-2003, the first two for intermittent ventilation and the third for continuously operating ventilation. This gives the field analyst more flexibility for compliance. For example, if this hypothetical house already had a bathroom exhaust fan with an actual ventilation rate of 60 CFM, operating this fan 50 to 75 percent of the time when the house is closed up, will comply with the ASHRAE 62.2-2003 as long as the fan operates at least once every three hours. [continued on next panel]
BTL1-65	[intentionally left blank]	In such a case, the occupants must be instructed regarding the importance of operating the bathroom exhaust fan at least 75 percent of the time. On the other hand, if there is no exhaust ventilation installed during the initial analysis, a continuously operating 32 CFM exhaust fan can be installed in the bathroom or central hallway for compliance.
BTL1-66	[intentionally left blank]	• **Note: Compliance with ASHRAE 62.2-2003 and the procedures of this ZipTest Pro^2 software do not guarantee that moisture or indoor air quality problems 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

BTL1-67



- 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 BTL1-51).
- b) Flow exponent from blower door test or 0.65 (see Panel BTL1-51).
- c) Weather factor from pages 21 through 23 (see Panel BTL1-52).
- d) House square footage (see Panel BTL1-53). [continued on next panel]

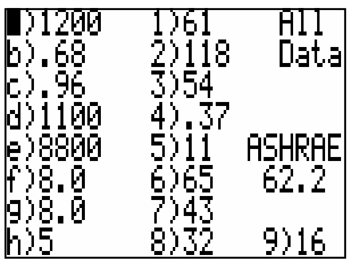
BTL1-68



- e) House volume (see Panel BTL1-54).
- f) Building height (see Panel BTL1-55).
- g) Story height (see Panel BTL1-56).
- h) Occupant count (see Panel BTL1-57).
- 1) Actual ELA (effective leakage area) (see Panel BTL1-59).
- 2) Actual EqLA (equivalent leakage area) (see Panel BTL1-60)
- 3) Estimated actual natural CFM (see Panel BTL1-61).
- 4) Estimated actual natural ACH (see Panel BTL1-31).

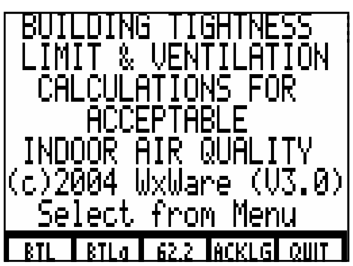
[continued on next panel]

BTL1-69



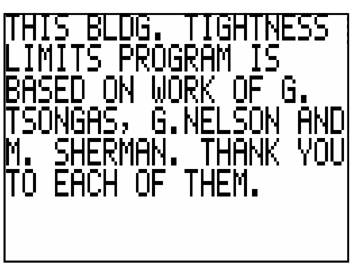
- 5) Estimated actual natural CFM per occupant (see Panel BTL1-62).
- 6) Ventilation requirement, 50% on-time (see Panel BTL1-62).
- 7) Ventilation requirement, 75% on-time (see Panel BTL1-63).
- 8) Mechanical ventilation requirement, always-on when the house is closed up (see panel BTL1-63).
- 9) This is the “infiltration credit” used in the ASHRAE 62.2-2003 procedure. This amount is subtracted from the **gross** continuous-ventilation requirement (48 in this example) to calculate number 8 (in this example, 32 CFM).

BTL1-70



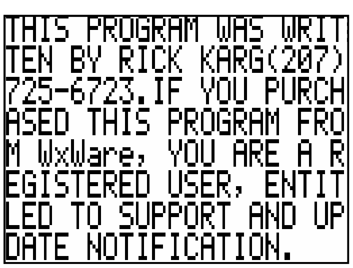
- Press **ENTER** to return to the main screen.
- From the main screen press **ACKLG** (acknowledgements).

BTL1-71



- Press **ENTER**.

BTL1-72

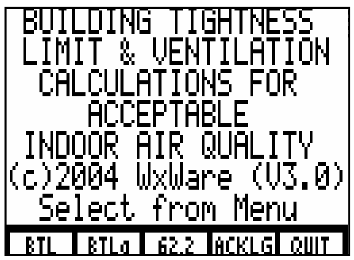


- Press **ENTER**.

BTL1-73

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

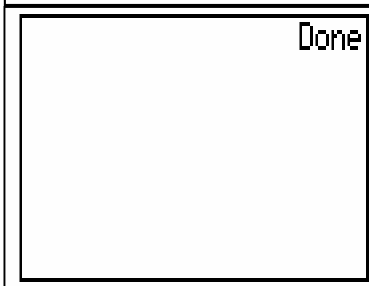
BTL1-74



- 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.

This is very important!

BTL1-75



- 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 was shut off.**

This is very important!

BTL1-76

[intentionally left blank]

BTL1-77

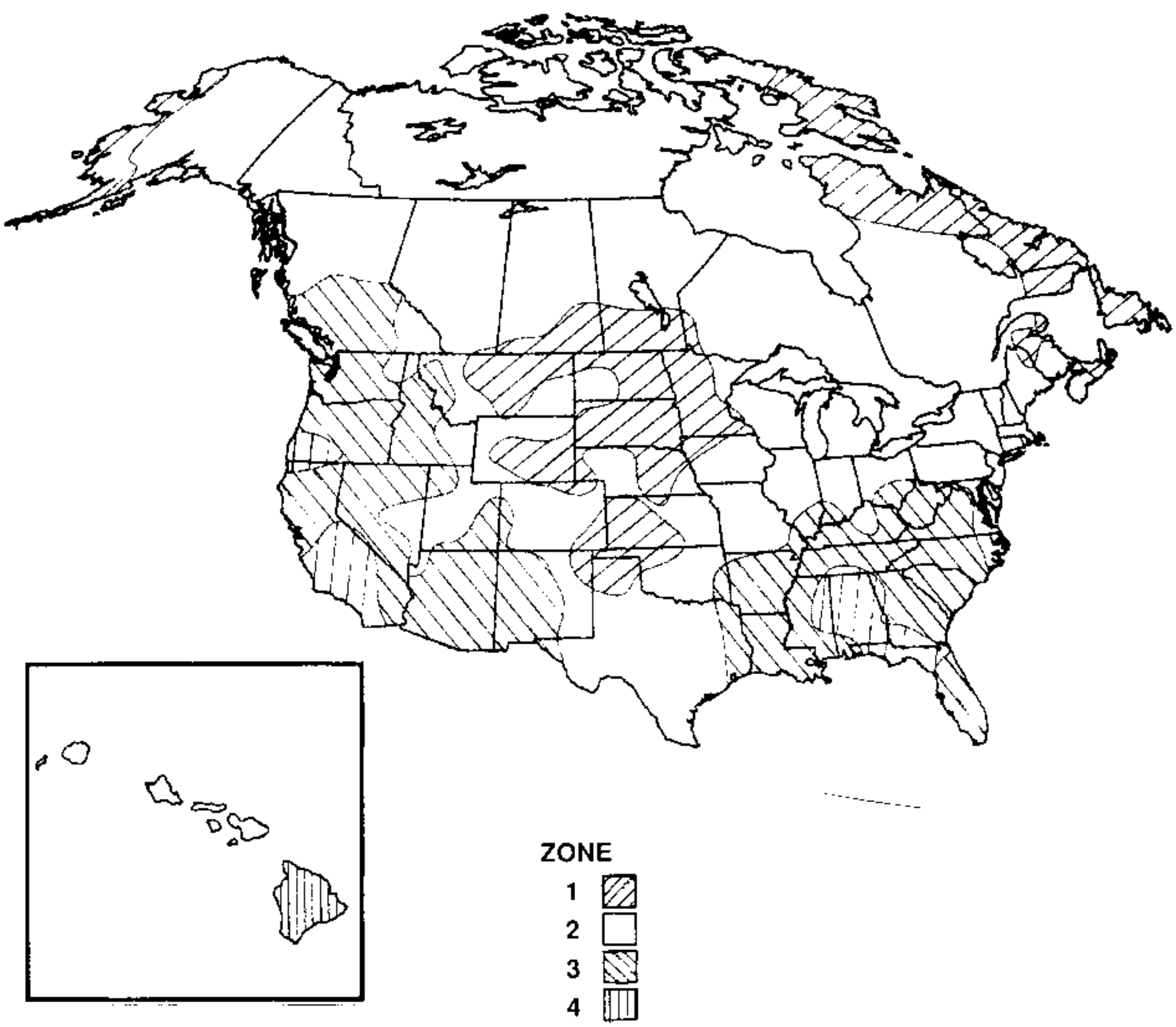
[intentionally left blank]

BTL1-78

[intentionally left blank]

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 and 62.2 methods)

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 and 62.2 methods)

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 and 62.2 methods)

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

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Instructions
for

Energy Index Calculations
in units of Btu/Ft^2,DD

Program "BTUDD"
with sub-programs
W/FQ
W/F$

November 1999 (V1.6)

INTRODUCTION

This software program, BTU/Ft^2, DD (British thermal units/square foot, degree day), is intended to be used as an initial diagnostic tool for dwellings in all heating-climate zones. The lower the number, the more efficient the building.

The software program will calculate BTU/Ft^2, DD from:

1) the <u>quantity</u> of space-heating fuel used in one year and
2) the total <u>cost</u> of space-heating fuel used in one year.

The fuels included are:

1) #2 Oil at 138,690 Btu input per gallon.
2) #1 Oil at 134,000 Btu input per gallon.
3) Natural Gas at 100,000 Btu input per therm.
4) Electricity at 3412 Btu input per kWh.
5) LPG at 91,500 Btu input per gallon.
6) Wood at 21,000,000 Btu input per cord.
7) K-1 kerosene at 126,000 Btu input per gallon.

The BTU/Ft^2,DD values are intended for space heating fuel use only. If a space-heating system also produces domestic hot water, the hot water fuel usage must be subtracted from the total fule use or cost before BTU/Ft^2,DD is calculated. See the instructions below for a method for calculation of domestic hot water fuel usage.

With experience, you will develop an idea of BTU/Ft^2, DD number ranges for efficient, average, and inefficient buildings. Use these numbers for the initial appraisal of the work the building will require. Keep a record of the BTU/Ft^2, DD values so that you can develop good, average and poor ranges for your area. The numbers generally will not be influenced by fuel type.

The BTU/Ft^2, DD values can also serve to find unusual problems. For example, if a building is heated with an oil-fired boiler, is tighter than average, and has better than average insulation levels, we would expect a low BTU/Ft^2, DD value. However, if the value is high, it could indicate a number of problems such as 1) a very inefficient oil-fired boiler, 2) a buried oil tank that is leaking into the ground, or 3) clients keeping windows or doors open during the heating season, etc.

If a building has more than one space heating fuel, calculate the BTU/Ft^2, DD for each fuel and add the values together to get the total BTU/Ft^2, DD for the building.

Read at least the first few chapters in the *TI-86 Graphing Calculator Guidebook* for basic information about operating the TI-86 calculator.

DOMESTIC HOT WATER USE CALCULATION.

The calculated value for BTU/Ft^2, DD should include only fuel used for space heat. Fuel used for domestic water heating, lights, cooking, air-conditioning, etc. must be subtracted from any fuel-use figures before the BTU/Ft^2, DD calculation is done on the TI-86 calculator.

If a building has a combination space heating/domestic water heating system (tankless coil, indirect-fired hot water with storage, etc.) the space heating usage is found by subtracting the domestic hot water usage or cost from the annual fuel quantity or cost. This *base usage* (for electric heat, base load also includes electrical consumption for lighting, refrigeration, etc.) can be estimated by examining non-heating season bills, calculating the monthly base usage, and then subtracting this twelve-month base usage from the total fuel consumption or cost. The result is the fuel quality or cost for space heating.

If you don't have a complete history of fuel usage for the calculation of base usage, the following method can be used to estimate domestic hot water usage. (This equation is programmed into the SOLVER section of your TI-86 calculator as Equation Nugget "AH20").

$$Q = \frac{gal/yr \times (T_{out} - T_{in}) \times 8.34\ lbs/gal \times 1\ Btu/lb,^{0}F}{Eff \times C}$$

where:

Q = energy per year for domestic hot water, in appropriate fuel units.
gal/yr = estimated gallons of hot water used in one year.
T_{out} = output temperature of water from the water heating appliance, ^{0}F.
T_{in} = input temperature of water to the water heating appliance, ^{0}F.
8.34 lbs/gal = the weight of water per gallon.
1 Btu/lb,^{0}F = the specific heat of water.
Eff = seasonal efficiency of water heating appliance, as a decimal.
C = conversion factor for energy source of water heating appliance,
138,690 for #2 oil,
134,000 for #1 oil,
100,000 for natural gas,
3412 for electricity,
91,500 for liquefied petroleum gas,
21,000,000 for firewood, dry hardwood, and
126,000 for K-1 kerosene.

Gallons of hot water use per day in North America averages about 62 gallons per household. Two adults in a household use from 30 to 60 gallons per day. A household with two adults and two children might have an average daily use as high as 90 gallons per day. Households with very young children often use more than average, elderly people often use less than average. To get the figure for gal/yr, estimate the gallons per day and multiply it by the number of days the family is a home during the year (usually 365).

For T_{out}, the output temperature of water from the water heating appliance, ^{0}F, you can take the time to measure this temperature with a thermometer, or you can estimate it. For residential buildings it is usually between 120^{0}F and 140^{0}F. For T_{in}, the input temperature of water to the water heating appliance, ^{0}F, subtract the latitude from 90 for an estimate of this water temperature (usually 40^{0}F to 50^{0}F.

The efficiency of the water heating appliance is difficult to estimate for there are only a few field studies that have examined combination unit efficiencies. One study found that efficiencies of indirect-fired storage systems (boiler for space heating and domestic water heating with a separate storage tank for domestic hot water) were 51% to 79% during the heating season and 47% to 58% during the non-space heating months.* The greater the use of domestic hot water, the higher the efficiency. The efficiencies for tankless coil systems (no storage) are usually lower than indirect-fired storage systems.

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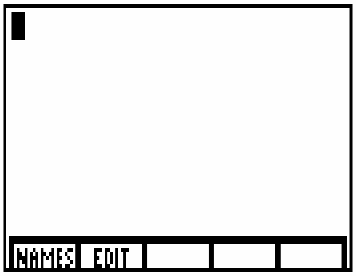
* Subherwal, B.R., "Combination Water-Heating/Space-Heating Appliance Performance" in *ASHRAE Technical Data Bulletin: Residential Heating and Cooling*, Jan. 1987, pp. 185-202.

BTUDD-1

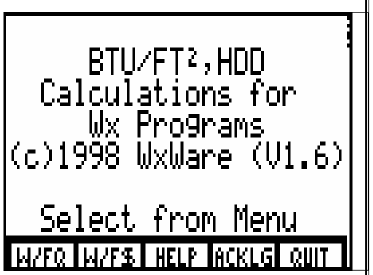


- Turn the TI-86 calculator on.
- Press **PRGM** (Programs).
- You will see this menu on the screen.
- Press **F1** for "NAMES."
- **NOTE: It is best never to press EDIT, F2.**

BTUDD-2

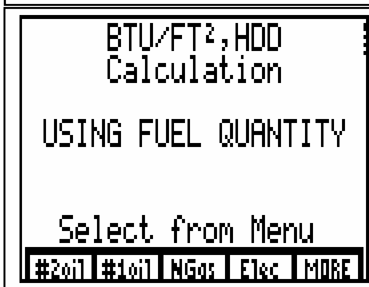
- You will see this menu on the screen.
- Press **F1, F2, F3, F4**, or **F5** for the program "BTUDD." The menu key for this program will depend upon the number of programs loaded into the memory of your TI-86 calculator. "BTUDD" will appear at the cursor location.
- Press **ENTER**. Note: The exact name of the program must appear at the cursor position; if not, you will receive an error message.

BTUDD-3



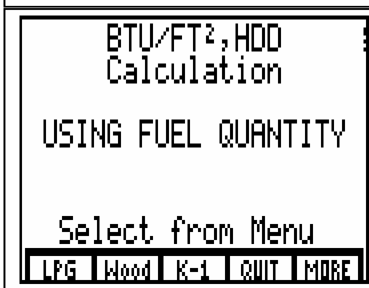
- You will see this main menu on the screen.
- "W/FQ" (with fuel quantity) selection is for finding BTU/Ft^2, DD if you have the annual fuel use figure for a fuel type.
- "W/F$" (with fuel dollars) selection is for finding BTU/Ft^2, DD if you have the annual dollars spent for a fuel type.
- "HELP" lists instructions for this program.
- "ACKLG" (Acknowledgments) selection lists the author of the program, etc.
- "QUIT" selection allows you to exit the program

BTUDD-4



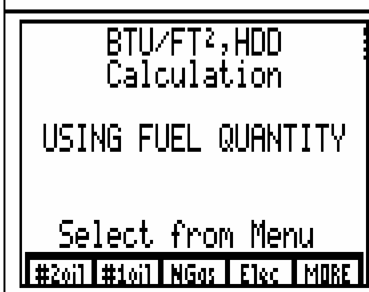
- Select "W/FQ" (with fuel quantity).
- You will see this menu on the screen.
- **F1** is for "#2 oil," **F2** for "#1 oil," **F3** for "NGas" (natural gas), **F4** for "Elec" (electric) heat.
- Select **F5**, "MORE**,"** for more choices of space-heating fuels.

BTUDD-5



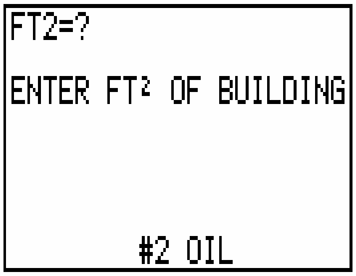
- You will see this menu on the screen.
- **F1** is for "LPG," **F2** for "Wood," **F3** for **K-1**, **F4** for "QUIT," or **F5** for "MORE" (this will return you to the previous main menu screen).
- If you select **F4, "**QUIT," you will return to the main menu screen.

BTUDD-6



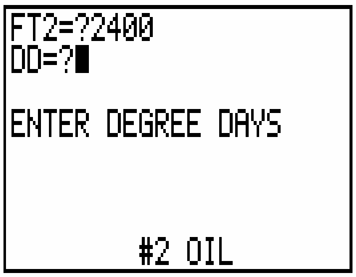
- As a demonstration, press **F1** for "#2 oil."

BTUDD-7



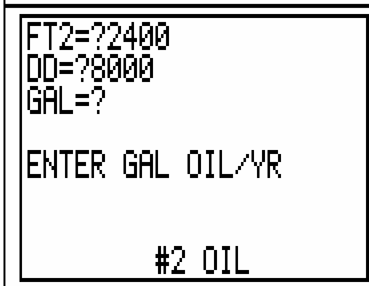
- You will see the screen at the left displayed .
- You are asked to "ENTER FT² OF BUILDING." Enter the square feet of the *occupied* area of the building. When you enter the square footage, the value will be displayed after the **"?"**
- Notice that "#2 OIL" is displayed at the bottom of the screen as a reminder of your fuel selection.
- Press **ENTER**.

BTUDD-8



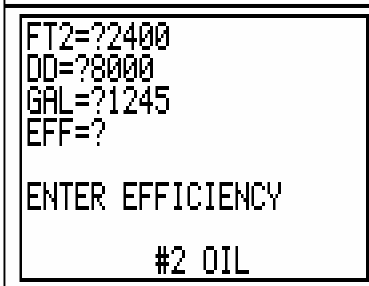
- You are asked to "ENTER DEGREE DAYS." Enter the heating degree days, base 65°F, for the location of the building. When you enter the heating degree days, the value will be displayed after the "**?**"
- Press **ENTER**.

BTUDD-9



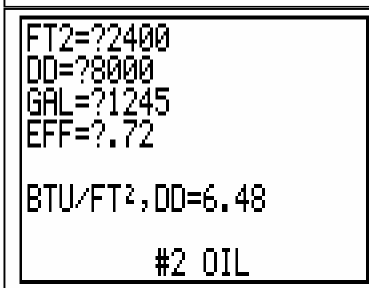
- You are asked to "ENTER GAL OIL/YR." Enter the gallons of #2 oil used in one year for space heating only. If your fuel use figure includes fuel for domestic hot water, subtract this amount from the total to get space heating fuel quantity (see page 26 for instructions). When you enter the gallons of oil used, the value will be displayed after the "**?**"
- Press **ENTER**

BTUDD-10



- You are asked to "ENTER EFFICIENCY." Enter the estimated <u>seasonal efficiency</u> for the oil heating system. When you enter the seasonal efficiency, the value will be displayed after the "**?**" Enter the efficiency as a decimal.
- Note: If you enter "1.00," your answer will be a BTU/Ft², DD *input* value. If you enter a decimal efficiency number, i.e.," 0.72," your answer will be a BTU/Ft², DD *output* value.
- Press **ENTER**.

BTUDD-11

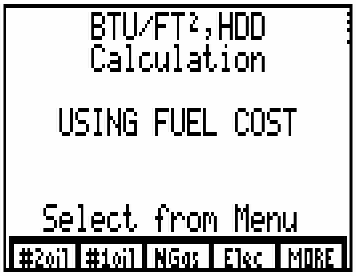


- Notice the answer is displayed on the screen after "BTU/Ft2, DD=".
- All of the values you entered are displayed on the screen.
- Enter the BTU/Ft², DD on your audit form, if required.
- Each of the other fuels—#1oil, NGas, Elec, LPG, Wood, and K-1—work in the same manner when you select **F1**, "W/FQ" from the main menu.
- Press **ENTER** to return to main menu.

BTUDD-12

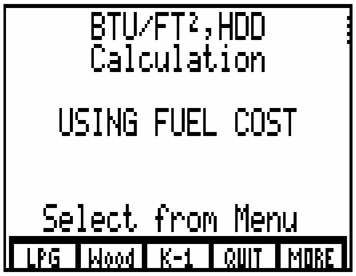
- Your will see the screen at the left displayed , the main menu screen.
- As another demonstration, select **F2,** "W/F$" (with fuel dollars), the selection for finding BTU/Ft², DD if you know the annual dollars spent for a fuel type.
- Do not use this routine unless you must. Using "W/FQ" is more accurate because one less variable—fuel cost per unit—is required.

BTUDD-13



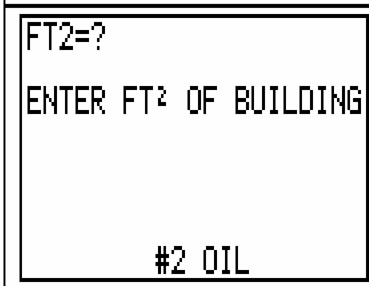
- You will see this menu on the screen.
- **F1** is for "#2 oil," **F2** for "#1 oil," **F3** for "NGas" (natural gas), **F4** for "Elec" (electric) heat.
- Select **F5**, "MORE," for more choices of space-heating fuels.

BTUDD-14



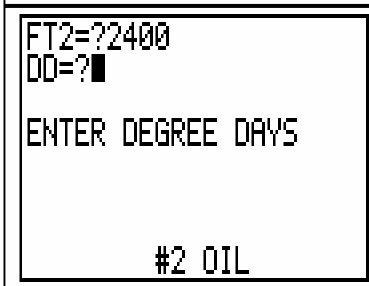
- **F1** is for "LPG," **F2** for "Wood," **F3** for "K-1," **F4** for "QUIT," or **F5** for "MORE" (this will return you to the previous menu screen).
- If you select **F4, "**QUIT," you will return to the main menu screen.
- Select **F5, "**MORE," and then select **F1, "**#2oil," for #2 Oil.

BTUDD-15



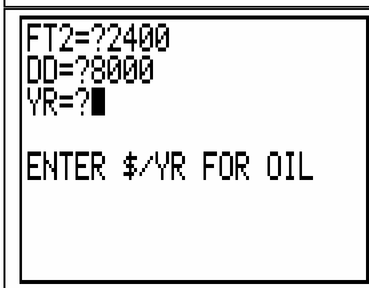
- You are asked to "ENTER FT² OF BUILDING." Enter the square feet of the *occupied* area of the building. When you enter the square footage, the value will be displayed after the "**?**"
- Notice that "#2 OIL" is displayed at the bottom of the screen as a reminder of your fuel selection.
- Press **ENTER**.

BTUDD-16



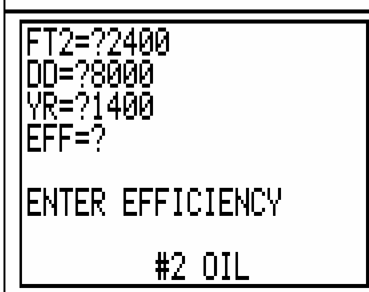
- You are asked to "ENTER DEGREE DAYS." Enter the heating degree days, base 65°F, for the location of the building. When you enter the heating degree days, the value will be displayed after the "**?**"
- Press **ENTER**.

BTUDD-17



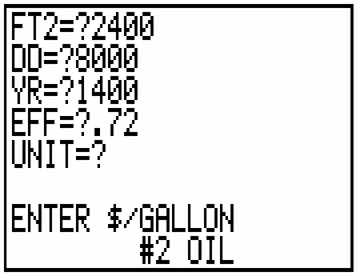
- Enter the cost in one heating season for #2 oil used for space heating. If your fuel cost figure includes fuel for domestic hot water, subtract this amount from the total to get space heating fuel dollars. When you enter the seasonal cost for oil, the value will be displayed at the "**?**"
- Press **ENTER**.

BTUDD-18



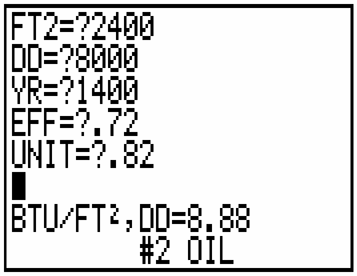
- You are asked to "ENTER EFFICIENCY." Enter the estimated *seasonal efficiency* for the oil heating system. When you enter the seasonal efficiency, the value will be displayed after the "**?**" Enter the efficiency as a decimal.
- Note: If you enter "1.00," your answer will be a BTU/Ft², DD *input* value. If you enter a decimal efficiency number, i.e.," 0.72," your answer will be a BTU/Ft², DD *output* value.
- Press **ENTER**.

BTUDD-19



- You will see this menu on the screen.
- You are asked to "ENTER $/GALLON." Enter the average cost per gallon for the last heating season. Obtain the cost per gallon from the client or the fuel oil dealer.
- Press **ENTER**.

BTUDD-20

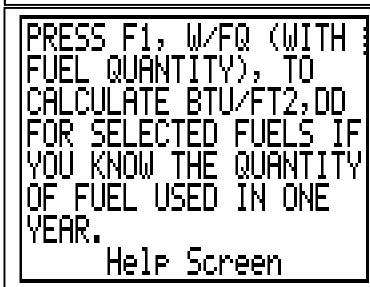


- Notice the answer is displayed on the screen after "BTU/Ft², DD="
- All of the values you entered are displayed on the screen.
- Enter the BTU/Ft², DD on your form, if required.
- Each of the other fuels—#1oil, NGas, Elec, LPG, Wood, and K-1—work in the same manner when you select **F2**, "W/F$," from the main menu.
- Press **ENTER** to return to main menu.

BTUDD-21

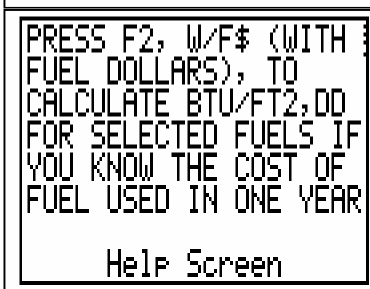
- From the main menu, select **F3, "**HELP."
- You will see the screen at the left displayed.
- Press **ENTER**.

BTUDD-22



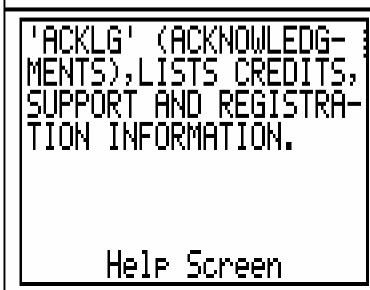
- You will see the screen at the left displayed.
- Press **ENTER**.

BTUDD-23



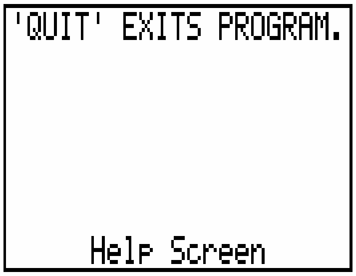
- You will see the screen at the left displayed.
- Press **ENTER**.

BTUDD-24



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

BTUDD-25

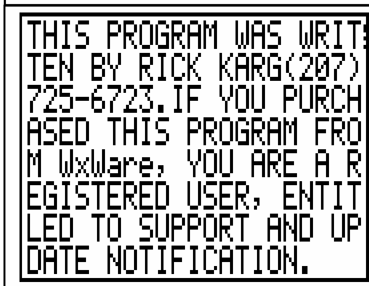


- You will see the screen at the left displayed.
- Press **ENTER**.
- **Note:** If you make a mistake while entering data before you press **ENTER**, use the arrow buttons to move the cursor over the erroneous entry and type the correct entry. If you notice you have made a mistake after you have pressed **ENTER**, press the **2nd** button, the **QUIT** button (next to the **2nd** button), and then **ENTER**. This will return you to the main menu.

BTUDD-26

- Select **F4, "**ACKLG," Acknowledgments.

BTUDD-27



- Press **ENTER**.

BTUDD-28

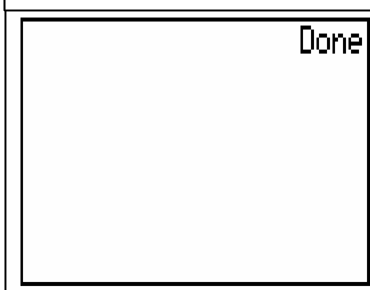
- Press **ENTER**.

BTUDD-29

- You will see the screen at the left displayed.
- To exit the program, select **F5,** "QUIT."
- **Note: Always exit the program by pressing "QUIT;" this automatically resets the decimal place for calculator use.**

This is very important!

BTUDD-30



- You will see the screen at the left displayed.
- Press **ENTER** if you want to re-enter the program.
- If you want to reenter 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.

Instructions
for

Combustion Venting Safety Calculations

Program "DTL"
(Depressurization Tightness Limit)

Solving for

CFM_{50} DTL

Maximum CFM exhaust ventilation

Resulting negative pressure, ΔP

November 2002 (V1.2)

Combustion Venting Safety: Depressurization Tightness Limits (DTL) Program

This program, DTL (Depressurization Tightness Limits), includes three calculation procedures; you may solve for CFM_{50}, CFM or ΔP. The primary purpose of this program is to allow you to determine if vented combustion appliances will vent properly from a house while all the appliances that exhaust air (bathroom and kitchen exhaust fans, clothes dryers, etc.) are operating. The is calculations are based on the equation:

$$CFM = (CFM_{50}/50^{Fx})(\Delta P^{Fx})$$

where:

CFM = total cubic feet per minute flow rate of actual mechanical exhaust from building;

CFM_{50} = the tested blower door CFM_{50} of the building;

ΔP = the pressure difference between the indoors and outdoors of the building in units of negative Pascals (enter as a positive value);

Fx = the flow exponent (slope of the leakage curve) of the tested building. The typical value for the flow exponent is 0.65. The typical range for the flow exponent is 0.5 to 1.0. A flow exponent of 0.5 characterizes a building with large leaks through which air flows in a turbulent fashion. A flow exponent of 1.0 characterizes a building with small leaks through which air flows in a laminar fashion. If you perform a single-point blower door test, use 0.65 as the flow exponent. If you perform a multi-point blower door test, you will know the flow exponent for the building in question. Use this specific flow exponent.

This program allows you to solve for CFM_{50}, CFM, and ΔP. Solving for CFM_{50} is the most often used routine. To solve for CFM_{50} you must choose the ΔP target value to use. Many energy auditing and weatherization programs select a ΔP = -5 Pascals as the target pressure difference created by the operation of exhaust appliances. This is because common practice and testing has demonstrated that a negative pressure between indoor and outdoors of a greater negative magnitude than -5 Pascals (i.e., -6, -7, -8, etc.) will cause backdrafting of natural draft combustion appliances. On the other hand, if the combustion appliance zone (CAZ) contains only a natural draft water heater, it might be best to use a value of -2.

The tighter a weatherization crew makes a house (reduction of CFM_{50}), the greater the magnitude of the negative pressure created by a given total cfm of the exhaust appliances. Therefore, many weatherization programs use a depressurization tightness limit, DTL, to determine the limit to house tightening. This is done by solving for CFM_{50}. The depressurization tightness limit, DTL, is often used in combination with the Building Tightness Limit, BTL (see explanation of this program on page 2). DTL establishes a tightness limit for the sake of proper drafting of draft combustion appliances, while BTL establishes a tightness limit for the sake of acceptable indoor air quality for the occupants. When both of these tightness limits are established for a house, the larger of the two, expressed as CFM_{50}, should be used as the weatherization tightness limit. A third tightness limit to keep in mind is the Weatherization Cost-Effective Guideline (WCEG), another program in this software package. The explanation of WCEG begins on page 59.

The depressurization tightness limit calculation is not required if a house:

1) has no combustion appliances, such as an all-electric house
2) has only direct-vent (sealed-combustion) appliances. These appliances exhaust all their combustion air to the outdoors and receive all their combustion supply air from the outdoors through a dedicated pipe running from the outdoors directly to the appliance.

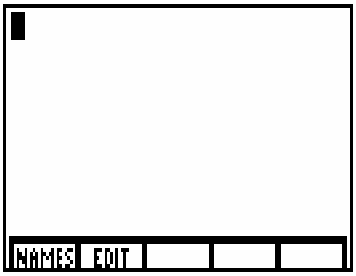
A gas-fired range/oven, or other unvented combustion appliance, is not affected by negative pressures in a house because it is not vented—or coupled—to the outdoors, so the indoor-outdoor pressure difference is irrelevant for unvented combustion appliances.

This program also includes a routine that allows you to solve for cfm, the sum of the actual exhaust rate for all exhaust appliances operating simultaneously. This method allows you to determine the maximum exhaust rate for a house with a given CFM_{50} or a target CFM_{50} tightness level. Again, you must select the target ΔP in units of Pascals. This is a helpful procedure if you are going to install any additional exhaust devices and wonder what cfm exhaust rate will create a negative pressure of a higher magnitude than your target ΔP.

Finally, you can solve for ΔP in units of negative Pascals. If you know the sum of the actual cfm of exhaust appliances and the CFM_{50} of the house, you can determine the resulting negative ΔP in Pascals. This routine helps you determine if the combustion appliances are in danger of backdrafting when all the exhaust fans are operating simultaneously.

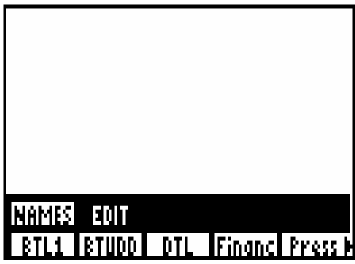
The value of Fx, the flow exponent, can significantly influence the answers to the three routines included in this program. If you know the value for Fx, use it. The only way you can determine this value for a particular house is by performing an multi-point blower door test (see page 83 of this instruction manual). Be aware that as a house is tightened, the Fx value changes because the size of the holes in the envelope is altered.

DTL-1



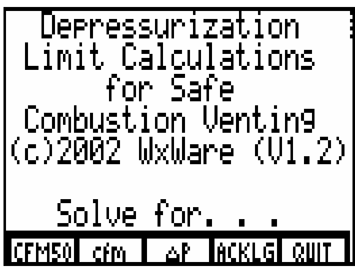
- Turn the TI-86 calculator on.
- Press **PRGM** (Programs).
- You will see this menu on the screen.
- Press **F1** for "NAMES."
- **NOTE:** It is best never to press "EDIT," **F2.**

DTL-2



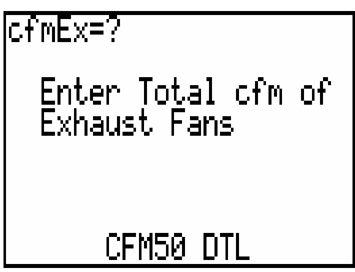
- You will see this menu and sub-menu on the screen.
- Press **F1, F2, F3, F4**, or **F5** for the program **DTL**. The menu key for this program will depend upon the number of programs loaded in the memory of your TI-86 calculator.
- "DTL" will appear at the cursor location.
- Press **ENTER**. **Note: The exact name of the program must appear at the cursor position, if it does not, you will receive an error message.**

DTL-3



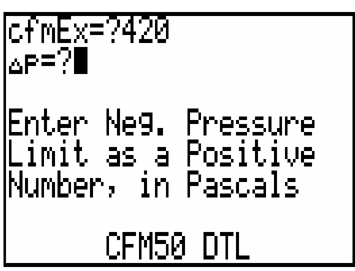
- You will see this menu on the screen. This is the main menu screen.
- Select **F1,** "CFM50," to solve for CFM_{50} depressurization tightness limit.
- Select **F2,** "cfm," to solve for cfm exhaust limit of house exhaust appliances.
- Select **F3,** "ΔP," to solve for resulting ΔP from existing CFM_{50} and exhaust cfm.
- Select **F4,** "ACKLG," to view program acknowledgements.
- Select **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 "floating."

DTL-4



- Select **F1,** "CFM50," to solve for CFM_{50} depressurization tightness limit.
- You will see this menu on the screen.
- Enter the actual, total cfm exhaust rate of all the exhaust appliances in the house. You may include appliances that are not yet installed, such as a dryer.
- For this example, assume the house has two bathroom exhaust fans at 50 cfm each, a kitchen range hood at 100 cfm, a workshop exhaust fan of 100 cfm, and a dryer to be installed of 120 cfm.
- Enter the total cfm of "420" and press **ENTER**.

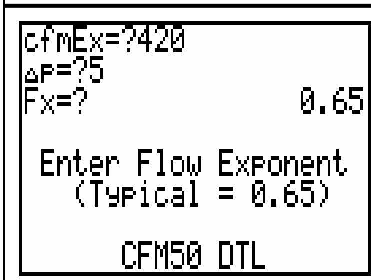
DTL-5



- Now you must enter the target ΔP in units of Pascals. This is the allowable difference between the indoor and outdoor pressure. You must choose this value for the safe operation of the natural draft combustion appliances. Most auditors for weatherization programs use a ΔP = -5 Pascals, plus or minus one. **This number is actually negative, but it is always entered as a positive number at this prompt.**
- Notice that there is an instructive comment on the screen under the prompt.
- Enter "5" and then press **ENTER**.

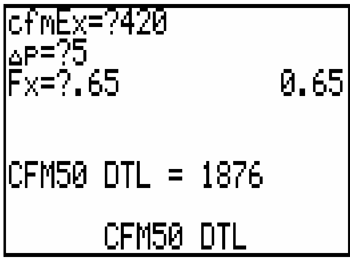
This is very important!

DTL-6



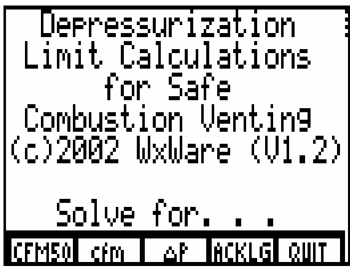
- Next you must enter the flow exponent, "Fx." This is the slope of the leakage curve of the house. There is a reminder value—0.65—to the right of the prompt for "Fx" as a reminder of the typical flow exponent value.
- If you know the actual flow exponent for the house as a result of conducting a multi-point blower door test, enter the actual value.
- Notice that "CFM50 DTL" appears at the bottom of the screen as a reminder of the routine on which you are working.
- For this example, enter ".65" and press **ENTER**.

DTL-7



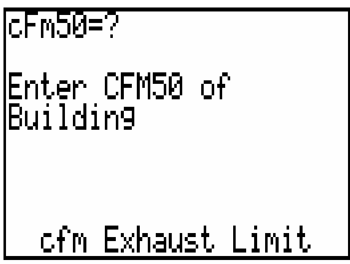
- With all three of the inputs entered, the CFM50 DTL answer of 1876 is displayed. Notice that the input values are displayed along with the answer.
- This CFM_{50} depressurization tightness limit is the house tightness level that corresponds with a ΔP = -5, a cfm of exhaust appliances = 420, and a flow exponent of 0.65. The house should not be tightened to a lever below 1876 CFM_{50}.
- Press **ENTER** and we will try the next routine.

DTL-8



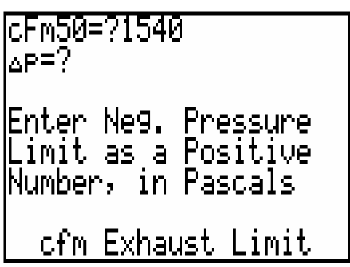
- Back to the home screen.
- Press **F2** for the "cfm" routine. This allows you to solve the cfm exhaust appliance limit for the house.

DTL-9



- At the bottom of the screen, notice the reminder of the routine on which you are working—"cfm Exhaust Limit."
- Enter the actual or the expected target of the house CFM_{50}.
- For this example, enter "1540" and press **ENTER.**

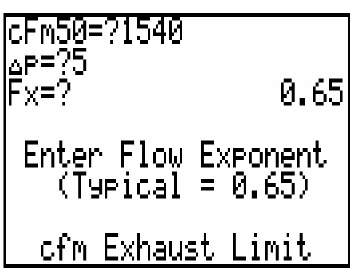
DTL-10



- Now you must enter the target ΔP in units of Pascals. This is the difference between the indoor and outdoor pressure allowable. You must choose this value for the safe operation of the combustion appliances. Many auditors for weatherization programs use a ΔP = -5 Pascals, plus or minus one. **This number is actually negative, but it is always entered as a positive number at this prompt.**
- Notice that there is an instructive comment on the screen under the prompt.
- For this example enter "5" and press **ENTER**.

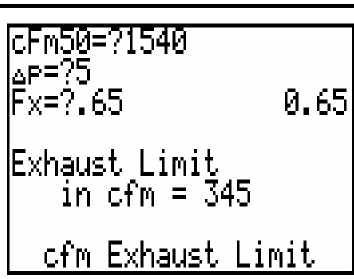
This is very important!

DTL-11



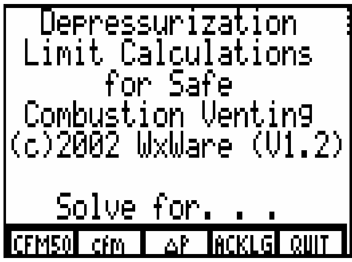
- Next you must enter the flow exponent, "Fx." This is the slope of the leakage curve of the house. There is a reminder value—0.65—to the right of the prompt for "Fx" as a reminder of the typical flow exponent value.
- If you know the actual flow exponent for the house as a result of conducting a multi-point blower door test, enter the actual value.
- For this example, enter ".65" and press **ENTER**.

DTL-12



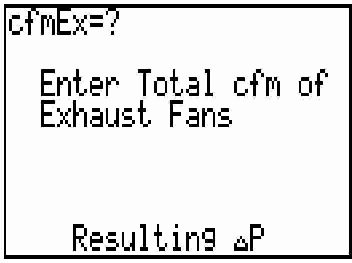
- With all three of the inputs entered, the "cfm Exhaust Limit" answer of 345 is displayed. Notice that the input values are displayed along with the output.
- This cfm exhaust limit corresponds with a ΔP = -5, a CFM_{50} of 1540, and a flow exponent of 0.65. This house should not have exhaust fans installed with a total cfm greater than 345.
- Press **ENTER** and we will try the next routine.

DTL1-13



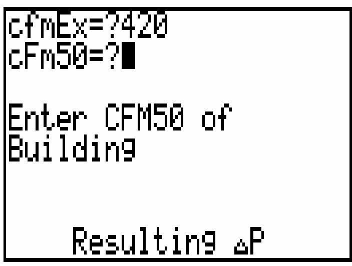
- Back to the home screen.
- Press **F3** for the "ΔP" routine. This allows you to solve for the resulting ΔP, the difference in Pascals of pressure between the indoors and outdoors of the house. You can quickly determine whether the vented combustion appliances in a house are likely to backdraft.

DTL-14



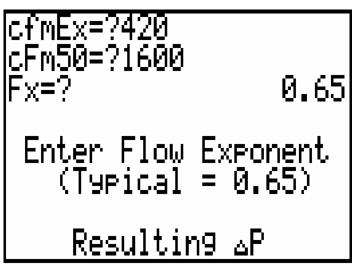
- Enter the actual, total cfm exhaust rate of all the exhaust appliances in the house. You may include appliances that are not yet installed, such as a dryer.
- For this example, assume the house has two bathroom exhaust fans at 50 cfm each, a kitchen range hood at 100 cfm, a workshop exhaust fan of 100 cfm, and a dryer to be installed of 120 cfm.
- At the bottom of the screen, notice the reminder of the routine on which you are working—"Resulting ΔP."
- Enter the total cfm of "420" and press **ENTER**.

DTL-15



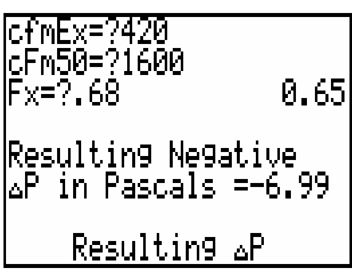
- Enter the actual or the expected target of the house CFM_{50}.
- For this example, enter "1600" and press **ENTER.**
- Notice that there is a instructive comment on the screen under the prompt line.

DTL-16



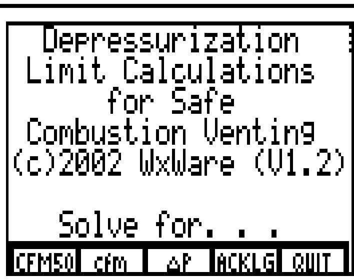
- Next you must enter the flow exponent, "Fx." This is the slope of the leakage curve of the house. There is a reminder value—0.65—to the right of the prompt for "Fx" as a reminder of the typical flow exponent value.
- If you know the actual flow exponent for the house as a result of conducting a multi-point blower door test, enter the actual value.
- For this example, enter ".68" and press **ENTER**.

DTL-17



- With all three of the inputs entered, the "Resulting ΔP" answer of –6.99 is displayed. Notice that the input values are displayed along with the output.
- This resulting ΔP" corresponds with a cfm exhaust rate of 420, a CFM_{50} of 1600, and a flow exponent of 0.68. When the exhaust appliances are operating in this house, they are likely to interfere with the proper venting of natural draft appliances.
- Press **ENTER**.

DTL-18



- Once again, back to the home screen.
- Press **F4** for "ACKLG" (acknowledgements).

DTL1-19

- This is the first of three acknowledgements screens.
- Press **ENTER**.

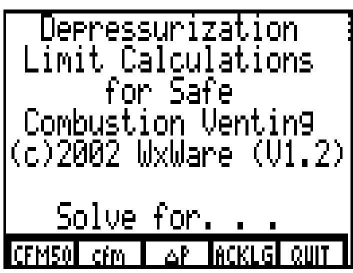
DTL-20

- This is the second of three acknowledgements screens.
- Press **ENTER**.

DTL-21

- This is the third of three acknowledgements screens.
- Press **ENTER**.

DTL-22



- Back again to the home screen.
- Press **F5** for "QUIT."
- Always exit any program by pressing "QUIT." This resets the decimal place to floating for the proper operation of the TI-86.

DTL-23

You will now see this display. You have now properly exited from the DTL program.

DTL-24

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Instructions
for

Pressure Diagnostics

Program "Press"

Solving for

Minneapolis Blower Door™, Model 3

Duct Blaster™

Basic Zone Pressure Diagnostics (ZPD)
(Hole, Door, and Vent methods)
Duct Series Leakage Testing
(Add-a-Hole, Blower door subtraction,
Full-Nelson, and Nelson with NFR Twist)

September 2002 (V3.2)

INTRODUCTION

This software program, "Press," is intended to be used as a diagnostic tool for residential and commercial weatherization and new construction analysis.

Procedures included in this program are:

1) Calculation of CFM_{50} for Minneapolis Blower Door®, Model 3. Can't-Reach-Fifty values and temperature adjustments are incorporated into the program.
2) Calculation of building CFM_{50} zone pressure diagnostics, basic methods (the ZipTest Pro² software package also include an advanced zone pressure diagnostics program, ZPDa):
   - Hole Method.
   - Door Method.
   - Vent Method.
3) Calculation of Minneapolis Duct Blaster™ Flow Rates, both older (serial numbers from O-591) and newer (serial numbers from 592 and up) models.
4) Calculation of Duct CFM_{50} Series Leakage Values (Building/Duct, Duct/Outdoors, Total Path):
   - Add-a-Hole Method.
   - Blower-Door-Subtraction Method.
   - Full-Nelson Method.
   - Nelson-with-NFR-Twist Method.

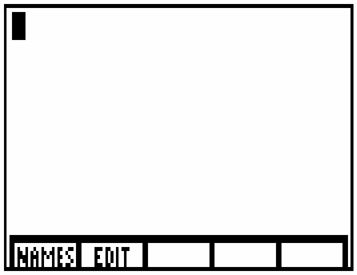
For more information about these test procedures, consult the following documents:

- *Minneapolis Blower Door® Manual, Model 3,* the Energy Conservatory.
- *Minneapolis Duct Blaster® Manual*, the Energy Conservatory.
- *Pressure Diagnostics,* Michael Blasnik and Jim Fitzgerald.
- *The Airflow Diagnostic Procedure*, John Tooley and Neil Moyer.
- "Building Tightness Guidelines: When Is a House Too Tight?" George Tsongas, *Home Energy*, March/April, 1993

PROGRAM OPERATION

Follow the instructions beginning on page 43. Pictures of the TI-86 screens appear on the left side of pages 43 through 58 with explanations at the right of each picture.

Press-1



- Turn the TI-86 calculator on.
- Press **PRGM** (Programs).
- You will see this menu on the screen.
- Press **F1** for "NAMES."

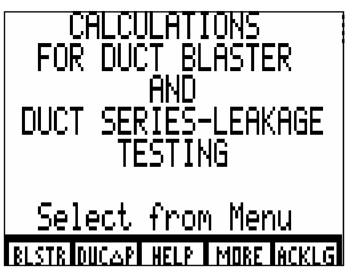
Press-2

- You will see this menu on the screen.
- Press **F1, F2, F3, F4,** or **F5** for the program "Press." The menu key for this program will depend upon the number of programs loaded into the memory of your TI-86 calculator.

Press-3

- You will see this menu on the screen.
- "Mbd3," **F1**, is for the calculation of CFM_{50} with the Minneapolis Blower Door™, Model 3.
- "ZPD," **F2,** is for the calculation of basic Building Zone Pressure Diagnostics. This routine includes the basic hole, door, and vent methods. For the Advanced Zone Pressure Diagnostics method, run the ZPDa program.
- "HELP," **F3,** lists instructions for this screen.

Press-4



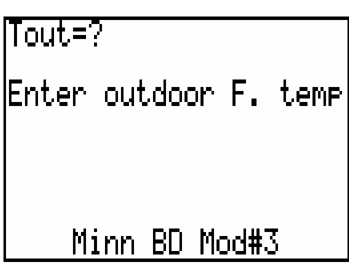
- Select "MORE," **F4** and you will see this menu on the screen.
- "BLSTR," **F1**, calculates Minneapolis Duct Blaster™ Flow Rates.
- "DUCΔP," **F2**, is for the calculation of Duct Series Leakage Testing.
- "HELP," **F3**, lists simple instructions.
- "MORE," **F4**, moves you to the previous (main) screen.
- "ACKLG," **F5,** Acknowledgments selection lists the authors of the program, etc.

Press-5

- Select "MORE," **F4** and you will see this menu on the screen.
- As a demonstration, press "Mbd3," **F1,** for Minneapolis Blower Door™, Model 3.
- **Note: This calculation procedure does not work for the Minneapolis Blower Door™, Model 2 or any other blower door brand.**

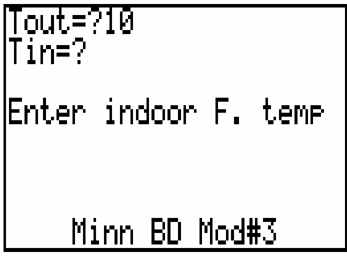
This is very important!

Press-6



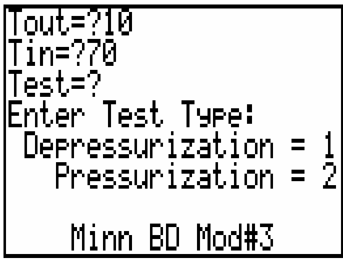
- You will see this on the screen.
- Enter "Tout," the outdoor temperature (F^0). If the temperature is below zero, enter a negative sign in front of the temperature by using the key, **(-),** just to the left of the **ENTER** key.
- Notice that there is a short instruction on the screen below the prompt line.
- Notice that "Minn BD Mod#3" is at the bottom of the screen as a reminder of the routine you are calculating.
- Enter "10" and press **ENTER**.

Press-7



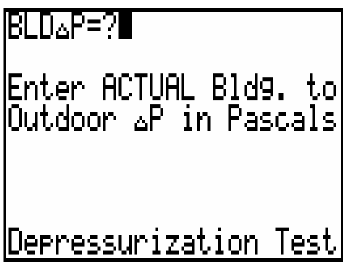
- Enter "Tin," the indoor temperature (F^0).
- If the temperature is different indoors than it is outdoors, the blower door CFM_{50} value will be influenced because of the different air densities. The magnitude of the difference is dependent on the degree of temperature difference.
- Enter "70" and press **ENTER**.

Press-8



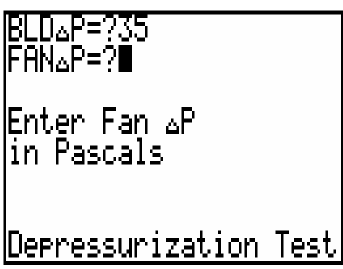
- You will see this menu on the screen.
- Now you must enter "1" for a depressurization blower door test or enter "2" for a pressurization blower door test.
- This question is necessary because the CFM_{50} results are temperature-corrected. See panel explanation "Press-7" just above, for a brief explanation.
- Enter "1" and then press **ENTER.**

Press-9



- Enter "BLDDP," the pressure difference between the inside and the outside of the building, in units of Pascals. Although this pressure will usually be negative, do not enter a negative sign before the pressure difference value.
- If you are not able to reach 50 Pascals of depressurization difference in a building, enter the lower value. The program will automatically extrapolate the answer to a level of 50 Pascals depressurization difference. In other words, the "Can't-Reach-Fifty" multipliers are incorporated.
- Enter "35" and press ENTER.

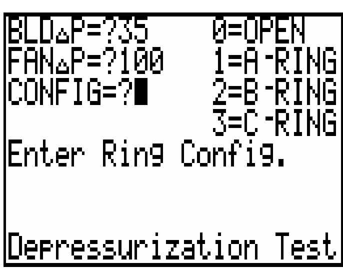
Press-10



- "FANDP," fan pressure, in Pascals, is prompted next.
- Enter a fan pressure of "100" and then press ENTER.
- **Note: If you notice you have made a mistake after you have pressed ENTER, press the "2nd" button, the "QUIT" button (next to the the "2nd" button), and then ENTER. This will return you to the main menu.**
- Notice that "Depressurization Test" is at the bottom of the screen as a reminder of the routine you are calculating.

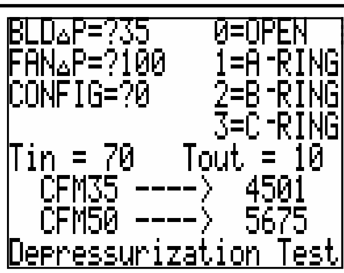
This is very important!

Press-11



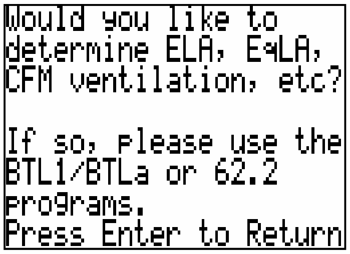
- "CONFIG," the Configuration of the blower door fan must be entered now. The four choices are listed on the right side of the screen.
- Enter "0" for an open fan configuration (no rings used). Note: If you cannot reach a house pressure difference of 50 Pascals, the "CONFIG" must always be "0."
- Press **ENTER.**

Press-12



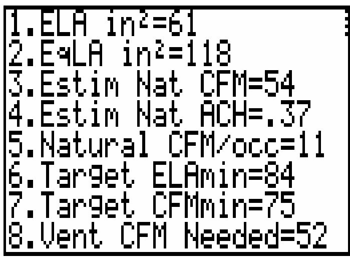
- The Fan Flow and the CFM_{50} answers are displayed along with all the data you entered.
- The "CFM35" of 4501 . The extrapolated "CFM50" displayed is 5675 (Can't-Reach-Fifty values are a part of this calculation procedure). Both of these resulting values, CFM_{35} and CFM_{50} are temperature-compensated.
- For most purposes, the "CFM50" value is the most important result.
- Press **ENTER.**

Press-13



- After pressing **ENTER** you will see this display.
- This is a reminder that another program included in the ZipTest Pro[2] software can calculate these values and others for you. To get to this program, you must exit from the “Press” program that you are now in and go to the “BTL1” program and then to the “BTLa” or the “62.2” routine.
- When you press **ENTER**, you will be returned to the home screen of the pressure diagnostics program, “Press.”

Press-14

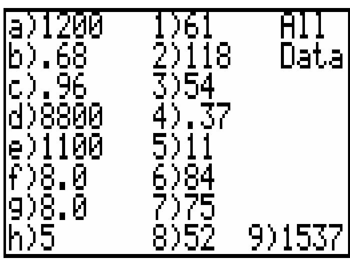


[Please Note: this panel does not follow the above panel Press-13, it is a sample from the BTL1 program/BTLa routine]

With the “BTL1” program/”BTLa” routine you can calculate:

1. ELA, Effective Leakage Area in square inches (see panel BTL1-29, pg 11).
2. EqLA, Equivalent Leakage Area in square inches. (see panel BTL1-30, pg 11).
3. Estimated Natural CFM (see panel BTL1-31, pg 12).
4. Estimated Natural ACH (see panel BTL1-31, pg 12).
5. Natural CFM/occ (see panel BTL1-32, pg 12). [continued next panel]

Press-15



[Please Note: this panel does not follow the above panel Press-13, it is a sample from the BTL1 program/BTLa routine]

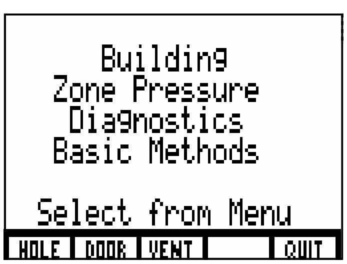
6. ELA minimum (see panel BTL1-33, pg 12).
7. CFM minimum (see panel BTL1-34, pg 12).
8. Ventilation CFM needed (see panels BTL1-34 & 35, pg 12).
9) Minimum CFM_{50} value (see panel BTL1-39, pg 13).

[End of sample screens from the “BTL1” program/”BTLa” routine]

Press-16

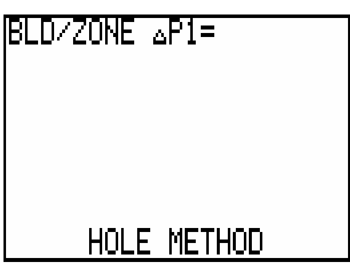
- Back to the home screen of the pressure diagnostics program, “Press.”
- Now select, “ZPD,” **F2** for “Building Zone Pressure Diagnostics, basic methods.”

Press-17



- You will see the Building Zone Pressure Diagnostics menu.
- “HOLE,” **F1**, calculates the Hole Method (creating a measured hole between the building and the zone or between the zone and the outdoors).
- “DOOR,” **F2**, calculates the Door Method (opening a door between the building and the zone or between the zone and the outdoors).
- “VENT,” **F3**, calculates the Vent Method, (used primarily for attics).
- Press “HOLE,” **F1.** for the Hole Series Leakage Method.

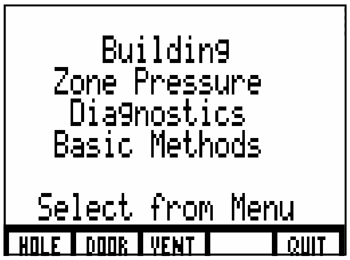
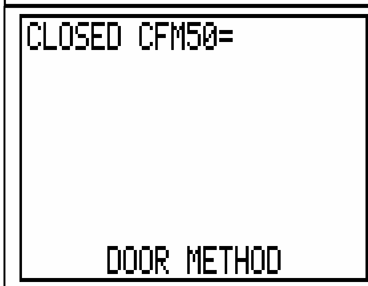
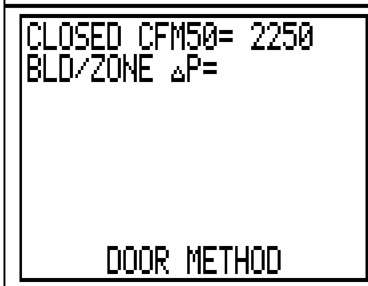
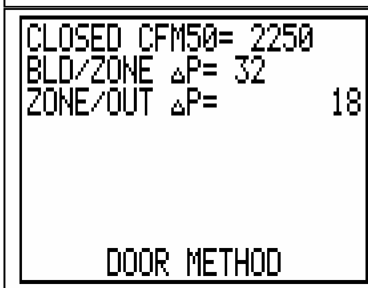
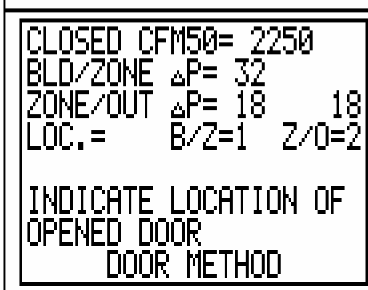
Press-18



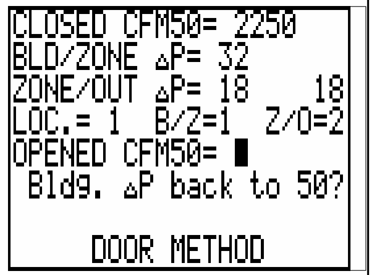
- You will see this screen, prompting for building/zone DP1. The building should be at 50 Pascals of pressure while the building/zone DP1 is measured.
- Note: If you are not able to obtain a building pressure difference of 50 Pascals, this procedure will not work (Note: the advanced zone pressure diagnosis program, ZPDa, will work).
- The Building Hole Method works best when the second measured building/zone or zone/outdoors pressure is 15-35 Pascals and the pressure drop resulting from the creation of the hole is 15-25 Pascals.

This is very important!

Press-19	BLD/ZONE ΔP1= 35 ZONE/OUT ΔP1= 15 HOLE METHOD	• Enter "35" as the "BLD/ZONE ΔP1." • Press **ENTER**. • Now you are prompted to enter the "Zone/Out ΔP1."Notice that the number "15" is displayed at the right. This is the value of the building/zone pressure subtracted from 50 building/outdoors pressure. • Enter "15" as "ZONE/OUT ΔP1." • "BLD/ZONE ΔP1" plus "ZONE/OUT ΔP1" should equal 50, plus or minus 2. • Press **ENTER**.
Press-20	BLD/ZONE ΔP1= 35 ZONE/OUT ΔP1= 15 15 LOC.= B/Z=1 Z/O=2 INDICATE LOCATION OF CREATED HOLE HOLE METHOD	• Indicate the location of the measured hole, between the building and the zone or between the zone and the outdoors. It is a good idea to create the hole in the tightest air barrier (that between the building and zone or that between the zone and the outdoors). This is because we should drop the pressure across the barrier in which the hole is created by 15 or more Pascals. For our example, it is best to create a hole from the building to the zone where we have a ΔP1 of 35 Pascals. • Enter "1" and press **ENTER**.
Press-21	BLD/ZONE ΔP1= 35 ZONE/OUT ΔP1= 15 15 LOC.= 1 B/Z=1 Z/O=2 ADDED HOLE, IN²= HOLE METHOD	• Enter the square inches of the added hole. • For our example, we will use 130 square inches. • Press **ENTER**.
Press-22	BLD/ZONE ΔP1= 35 ZONE/OUT ΔP1= 15 15 LOC.= 1 B/Z=1 Z/O=2 ADDED HOLE, IN²= 130 BLD/ZONE ΔP2= Bldg. ΔP back to 50? HOLE METHOD	• Enter the new (with-hole) building to zone pressure, "BLD/ZONE DP2." • NOTE: **It is very important that the *building to outdoors* pressure be brought back up to 50 Pascals after the creation of the hole and before the DP2 readings are taken**. There is a reminder on the screen. • If you are not able to get the building to outside pressure back up to 50 Pascals, make the hole smaller. If you are still not able to get the building to outside pressure back to 50 Pascals, this method is not workable. *This is very important!*
Press-23	BLD/ZONE ΔP1= 35 ZONE/OUT ΔP1= 15 15 LOC.= 1 B/Z=1 Z/O=2 ADDED HOLE, IN²= 130 BLD/ZONE ΔP2= 28 ZONE/OUT ΔP2= 22 HOLE METHOD	• Enter the new (with-hole) zone to outdoor pressure, "ZONE/OUT ΔP2." • Notice that to the right of "ZONE/OUT ΔP2" the suggested pressure is displayed. Your measured "ZONE/OUT ΔP2" should be within 2 Pascals of this displayed number. • Enter "22" and press **ENTER**.
Press-24	CFM50's BLD/ZONE ----> 2205 ZONE/OUT ----> 3824 TOTAL PATH --> 1749 ENTERED DATA: 35 15 1 130 28 22 HOLE METHOD	• The CFM_{50} "BLD/ZONE, ZONE/OUT," and "TOTAL PATH" values are displayed. • Notice that the "ENTERED DATA" is displayed in the order in which it was entered on the previous screen. • Dividing the "BLD/ZONE" CFM_{50} by 10 yields the approximate square inches of leakage between the building and the zone, for this example 220 in^2. This may also be done for the zone-to-outdoor CFM_{50}. • The TOTAL PATH will always be less than the CFM_{50} values of the BLD/ZONE and ZONE/OUT. Press **ENTER**.

Press-25		• The main menu is displayed. • Press "ZPT," **F2**, for Building Zone Pressure Diagnostics.
Press-26		• Press "DOOR," **F2**, for the Door Method. • For this test, a door or other openable panel is closed for the first set of pressure readings and opened for the second set of pressure readings. The size of the door or openable panel does not need to be measured. • If the initial, closed pressure readings are close to 50 or 0, this method may not work well.
Press-27		• Enter the initial building CFM_{50}. This is a value that you might already know if you have done a single- or multi-point blower door test on the building. • This initial CFM_{50}. should be 200 and preferably 400 or more for this test to work well. • Enter "2250" and press **ENTER**.
Press-28		• Measure the building-to-zone pressure, "BLD/ZONE ΔP." • Enter "32" and press **ENTER**.
Press-29		• Measure the zone-to-outdoors pressure, "ZONE/OUT ΔP." • Notice that the suggested "ZONE/OUT ΔP" pressure is displayed at the right. Your measured "ZONE/OUT ΔP" should be within 2 Pascals of this displayed number. • Enter "18" and press **ENTER**.
Press-30		• Indicate the location of the opened door or panel, between the building and the zone or between the zone and the outdoors. It is a good idea to open a door, window, or panel in the tightest air barrier (that between the building and zone or that between the zone and the outdoors). For our example, it is best to create a hole from the building to the zone where we have a ΔP of 32 Pascals. • Enter "1" and press **ENTER**.

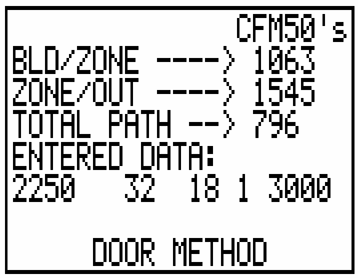
Press-31



- Now enter the CFM_{50} with the door opened.
- **NOTE: It is very important that the *building to outdoors* pressure be brought back up to 50 Pascals after the door, window, or panel is opened and before the opened CFM_{50} reading is taken.**
- The pressure across the barrier in which you created the opening should be less than one (1) Pascal, otherwise the method will not be accurate.
- Measure the building CFM_{50} with the door, window, or panel opened.
- For the example, enter "3000" and press ENTER.

This is very important!

Press-32

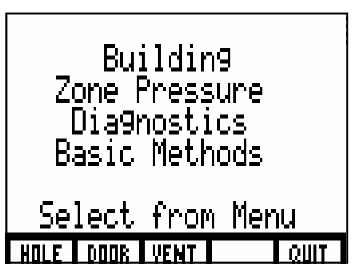


- The CFM_{50} "BLD/ZONE, ZONE/OUT," and "TOTAL PATH" values are displayed.
- Notice that the "ENTERED DATA" is displayed in the order in which it was entered. See panel "Press-37" for the order of entry.
- Dividing the BLD/ZONE CFM_{50} by 10 yields the approximate square inches of leakage between the building and the zone, for this example 106 in^2. This may also be done for the zone-to-outdoor CFM_{50}.
- The "TOTAL PATH" will always be less than the CFM_{50} values of the "BLD/ZONE" and "ZONE/OUT." Press **ENTER**.

Press-33

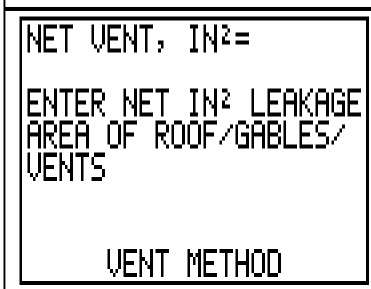
- The main menu is displayed.
- Press "ZPD," **F2**, for Building Zone Pressure Diagnostics, basic methods.

Press-34



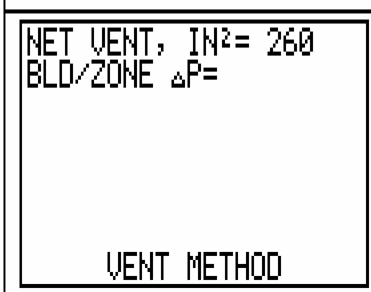
- Press "VENT," **F3**, for the Vent Method.
- For this test, the openings in the attic are measured or estimated. The building-to-zone and the zone-to-the outdoor pressures are measured. This method is weak because of the difficulty of measuring the openings in most attics (zone-to-outdoors). However, this method is faster than the other two—"HOLE" or "DOOR."
- The pressure across the ceiling (building-to-zone) should not be much less

Press-35



- "Enter net square inches of leakage area of roof/gables/vents. This is often difficult to measure or estimate. Do the best you can.
- For the example, enter "260" and press **ENTER**.

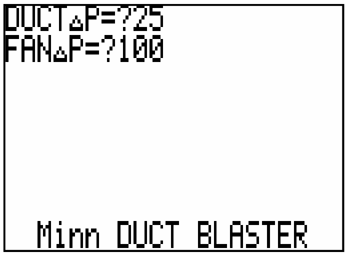
Press-36



- With the building to outside pressure at 50 Pascals, measure the building-to-zone pressure difference. This pressure should be close to 50 Pascals.
- For the example, enter "28" and press **ENTER**.

Press-37	NET VENT, IN²= 260 BLD/ZONE ΔP= 28 ZONE/OUT ΔP= 22 VENT METHOD	• Enter the zone-to-outdoor pressure difference. • The measured zone-to-outdoor pressure should be within 2 of the pressure difference displayed at the right on the screen. • Enter "22" and press **ENTER.**
Press-38	NET VENT, IN²= 260 BLD/ZONE ΔP= 28 ZONE/OUT ΔP= 22 22 CFM50's BLD/ZONE ----> 2033 ZONE/OUT ----> 2192 TOTAL PATH --> 1395 VENT METHOD	• The CFM_{50} values are displayed for building-to-zone, zone-to-outdoors, and total path. • The "Total Path" value for the vent method, the hole method, and the door method will always be less than the building-to-zone or the zone-to-outdoor CFM_{50} values. The Total Path figure includes the combined air-flow resistance of the building-to-zone barrier and the zone-to-outdoor barrier. • This ends the basic zone pressure diagnostics examples.
Press-39	CALCULATIONS FOR DUCT BLASTER, BLOWER DOOR & ZONE PRESSURE TESTING (c)2002 WxWare (V3.2) Select from Menu Mbd3 ZPD HELP MORE QUIT	• You will see the main screen displayed. • Press "MORE," **F4**, to move to the other primary menu.
Press-40	CALCULATIONS FOR DUCT BLASTER AND DUCT SERIES-LEAKAGE TESTING Select from Menu BLSTR DUCΔP HELP MORE ACKLG	• Press "BLSTR," **F1**, for Minneapolis Duct Blaster™ Flow Rate calculations. • The Duct Blaster is a calibrated air flow measurement system used to test the airtightness of forced air distribution systems. See the *Minneapolis Duct Blaster™ Operation Manual* for discussion of proper use of the Duct Blaster™. The Duct Blaster™ may also be used as a powered flow hood and as a small blower door. The Duct Blaster is manufactured by The Energy Conservatory.
Press-41	TYPE=? SERIAL #s 0-591 = 1 592 & Up = 2 Minn DUCT BLASTER	• As of March 1995, The Energy Conservatory (TEC) began producing a duct blaster with a different calibration than the original. The WxWare ZipTest Pro² software can calculate flow rates for both types. • Serial numbers 0 - 591 are designated in the ZipTest Pro² program as Type 1 (these are white in color), serial numbers from 592 and higher are Type 2 (TEC calls these "series B" duct blasters). They are black in color. • After you enter the Type number "2", press **ENTER** to move to the next screen.
Press-42	DUCTΔP=? Minn DUCT BLASTER	• Now enter the duct pressure. The reference pressures for testing usually are 25 Pascals, 50 Pascals, or the average actual operating pressure of the duct system. • If you are not able to reach 25 Pascals, enter the value that was reached. The program will calculate the CFM_{25} from the data that you provide. (The program assumes the flow exponent, n=0.65). • Enter "25" and press **ENTER.**

Press-43

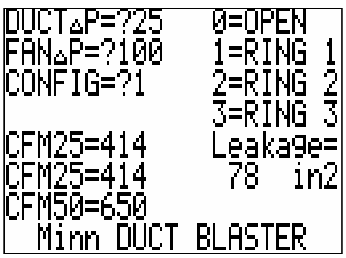


- Enter the Duct Blaster™ fan pressure.
- For the example, enter "100" and press **ENTER.**

Press-44

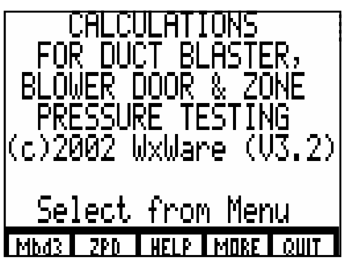
- Finally, enter the Duct Blaster™ configuration that you used.
- Enter "1" for this example and press **ENTER.**

Press-45



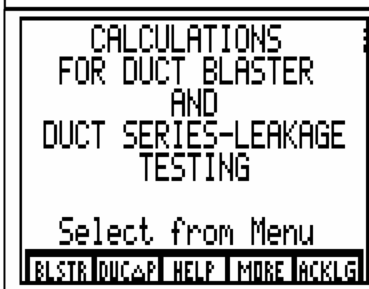
- The flow of the Duct Blaster™ fan is given and the CFM_{25} and CFM_{50} of the duct system tested. If the maximum duct pressure attainable were 23 Pascals, the first "CFM25=" value would be "CFM23=" instead. Notice that the approximate leakage area — in square inches — is also listed on the screen.
- Press **ENTER.**

Press-46



- Once again, back to the main menu.
- Press "MORE," **F4**, to go to the other primary menu.

Press-47



- Press "DUC∆P," **F2**, for the Duct Series Leakage Tests menu.

Press-48

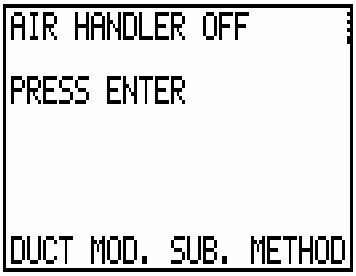
- "HOLE," **F1**, calculates duct leakage using the Add-a-Hole Method.
- "MODBD," **F2**, calculates duct leakage using the Blower-Door-Subtraction Method.
- "NELSN," **F3**, calculates duct leakage using the Full-Nelson Method.
- "TWIST," **F4**, calculates duct leakage using the Nelson-with-NFR-Twist Method (NFR is Natural Florida Retrofit).
- Press **F1** for Add-a-Hole Method.

Press-49	AIR HANDLER OFF SEAL REG. AND GRILLES PRESS ENTER DUCT HOLE METHOD	• This screen displays instructions for Add-a-Hole Method. • This method is similar to the Building Hole Method. • The method works best when the duct leakage is less than 200 CFM_{50} and there is little leakage to the building. • The area of the added hole should be less that 50% of the cross-sectional area of the smallest duct in the path between the hole and the air handler. • Press **ENTER**.
Press-50	BLD/DUC ΔP1= 36 DUC/OUT ΔP1= 14 14 LOC.= █ B/D=1 D/O=2 INDICATE LOCATION OF CREATED HOLE	• Enter the building-to-duct pressure difference, "36" for our example. • Enter the duct-to-outdoors pressure difference, "14" for our example. • Indicate the location of added hole, building-to-duct or duct-to-outdoor, "1" for the example.
Press-51	BLD/DUC ΔP1= 36 DUC/OUT ΔP1= 14 14 LOC.= 1 B/D=1 D/O=2 ADDED HOLE, IN²= 10 HOLE ΔP= 26 BLD/DUC ΔP2= 27 DUC/OUT ΔP2= █ 23	• Enter the size of the added hole. For our example "10" square inches. The hole can be created in a seal that was applied to a register or grille. • Measure and enter the hole pressure, "26" for the example. • Measure and enter the "BLD/DUC ΔP2," the building to duct pressure after the hole is made. For the example "27." • Measure and enter the "DUC/OUT ΔP2," the duct to outdoors pressure after the hole is made. For the example "23." • Press **ENTER.**
Press-52	CFM50's BLD/DUCT ----> 122 DUCT/OUT ----> 225 ENTERED DATA: 36 14 1 10 26 27 23 DUCT HOLE METHOD	• The Building to Duct CFM50 and the Duct to outdoors CFM50 are displayed. • Notice that the "ENTERED DATA" is displayed in the order in which it was entered. Refer to Panels Press-50 and Press-51 for the labels for the entered data. • Press **ENTER**.
Press-53	CALCULATIONS FOR DUCT BLASTER, BLOWER DOOR & ZONE PRESSURE TESTING (c)2002 WxWare (V3.2) Select from Menu MbG3 | ZPD | HELP | MORE | QUIT	• The main menu is displayed. • Press "MORE," **F4,** for another example of Duct Series Leakage testing.
Press-54	CALCULATIONS FOR DUCT BLASTER AND DUCT SERIES-LEAKAGE TESTING Select from Menu BLSTR | DUCΔP | HELP | MORE | ACKLG	• The other primary menu is displayed. • Press "DUCΔP," **F2**, for the Duct Series Leakage menu.

Press-55

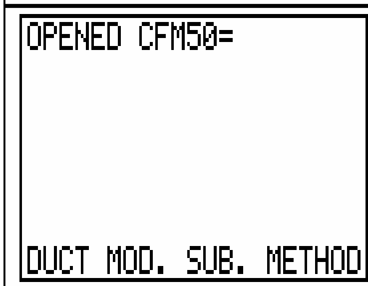
- The Duct Series Leakage menu is displayed.
- Press "MODSB," **F2**, for the Duct Modified Subtraction Method calculation.
- The method works best when the duct leakage is less than 200 CFM_{50}

Press-56



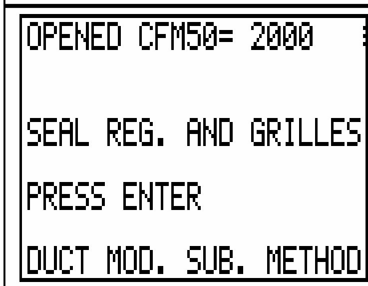
- Air handler should be off.
- Press **ENTER**.

Press-57



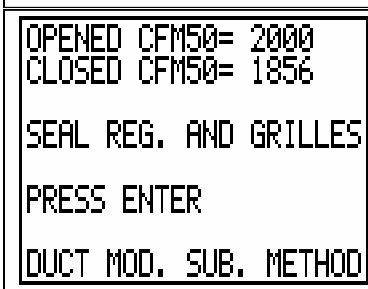
- With the blower door, measure the CFM_{50} with the duct system open to the building, i.e. not taped or sealed.
- For the example, enter "2000" and press **ENTER.**

Press-58



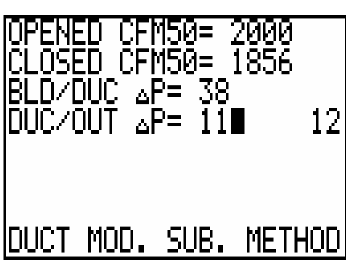
- Now seal registers and grilles and measure the CFM_{50} with the blower door.
- Press **ENTER.**

Press-59



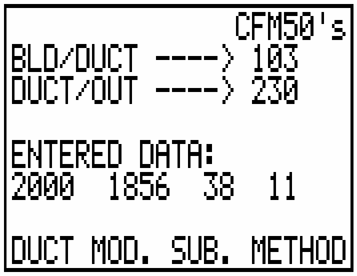
- Now enter the Closed CFM50 (registers and grilles sealed). For the example enter "1856."
- Press **ENTER**.

Press-60



- Enter the building-to-duct pressure difference with the registers and grilles sealed. For the example, enter "38."
- Press **ENTER**.
- Enter the duct-to-outdoor pressure difference with the registers and grilles sealed.
- Press **ENTER**.

Press-61

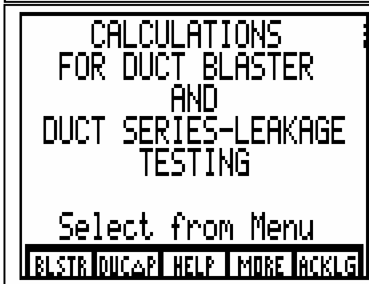


- The CFM_{50} values for the building-to-duct and the duct-to-the outdoor are displayed.
- Notice that the "ENTERED DATA" is displayed in the order in which it was entered. Refer to Panels Press-59 and Press-60 for the input labels.
- Press **ENTER**.

Press-62

- Back to the main menu.
- Press "MORE," **F4**, and we will try another example.

Press-63

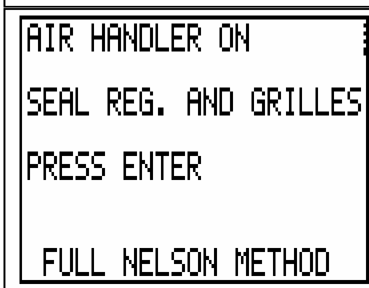


- Press "DUCΔP," **F2** for Duct Series Leakage Tests.

Press-64

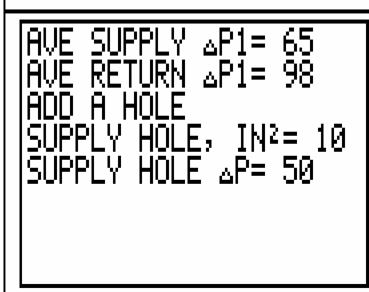
- Press "NELSN," **F3,** for an example of the Full-Nelson Method.
- This method is experimental. Act accordingly with the results. This method provides insight into the relative leakiness of the return and supply sides of the duct system in terms of CFM_{50}.

Press-65



- Instructions for Full-Nelson Method are displayed.
- Note that high pressures may be created in the duct system. These pressures could damage the duct system.
- Press **ENTER.**

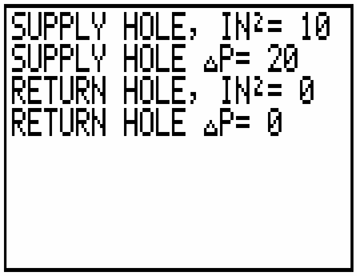
Press-66



- Enter the average supply duct pressure, for the example, "65" Pascals.
- Enter the average return duct pressure, for the example, "98" Pascals.
- Add a hole to either the supply side or the return side.
- Enter the Supply Hole size, for the example, "10" square inches.
- Enter the Supply Hole Pressure Difference, for the example, "50" Pascals.

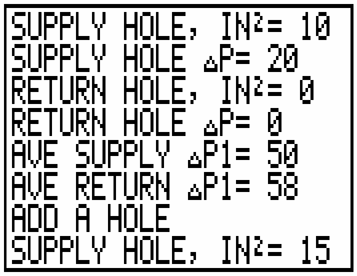
Press-67	AVE RETURN ΔP1= 98 ADD A HOLE SUPPLY HOLE, IN^2= 10 SUPPLY HOLE ΔP= 50 RETURN HOLE, IN^2= 0 RETURN HOLE ΔP= 0 AVE SUPPLY ΔP2= 55 AVE RETURN ΔP2= 102	• Enter the return hole size, for the example, no return hole is made, so "0" is entered. • Enter the return hole pressure difference. If no return hole is added, the return hole pressure difference will be "0." • Enter the average supply pressure, "AVE SUPPLY ΔP2" after the hole is made. For the example enter "55." • Enter the average return pressure, "AVE RETURN ΔP2" after the hole is made. For the example enter "102." Press **ENTER**.
Press-68	CFM50's RETURN ---> 375 SUPPLY ---> 490 TOTAL ----> 865 FULL NELSON METHOD	• The return duct CFM_{50}, supply duct CFM_{50}, and the total CFM_{50} are displayed. • Press **ENTER**.
Press-69	CALCULATIONS FOR DUCT BLASTER, BLOWER DOOR & ZONE PRESSURE TESTING (c)2002 WxWare (V3.2) Select from Menu Mbd3 | ZPD | HELP | MORE | QUIT	• Back to the main menu. • Press "MORE," **F4**, for one last example.
Press-70	CALCULATIONS FOR DUCT BLASTER AND DUCT SERIES-LEAKAGE TESTING Select from Menu BLSTR | DUCΔP | HELP | MORE | ACKLG	• The other primary menu is displayed. • Press "DUCΔP," **F2**, for Duct Series Leakage Tests.
Press-71	DUCT SERIES-LEAKAGE TESTS Select from Menu HOLE | MODSB | NELSN | TWIST | QUIT	• Press "TWIST," **F4,** for an example of the Nelson-with-NFR-Twist Method (NFR is Natural Florida Retrofit). • **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.**
Press-72	AIR HANDLER ON SEAL REG. AND GRILLES PRESS ENTER NFR TWIST METHOD	• Instructions for the Nelson-with-NFR-Twist Method are displayed. • Note that high pressures may be created in the duct system. These pressure could damage the duct system. • This method is similar to the Full-Nelson method, except a hole is added to relieve pressure in the ducts. • Press **ENTER.**

Press-73



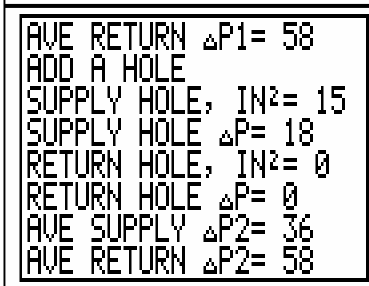
- Enter the initial added supply hole. For the example, enter "10" square inches.
- Enter the pressure across the supply hole. For the example, enter "20."
- Enter the return hole. In the example, a return hole is not added, so enter "0."
- Enter the return hole pressure difference. If no return hole is added, the pressure difference across the hold is "0."

Press-74



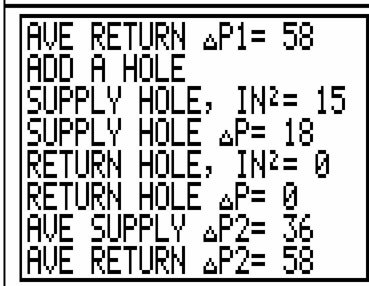
- Enter the average supply pressure difference, "AVE SUPPLY ΔP1" for the example is "50."
- Enter the average return pressure difference, "AVE RETURN ΔP1" for the example is "58."
- Add a hole to either or both sides of the duct system. For the example a supply hole is added, "15." Note that the supply hole went from the initial 20 square inches to 15 square inches. Use the actual hole size, not the change in hole size (in this case, a reduction of 5 square inches).

Press-75



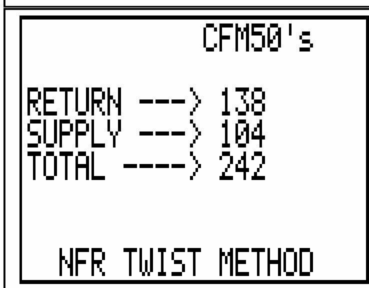
- (The screen has been scrolled up five lines).
- Enter the pressure across the supply hole, "SUPPLY HOLE ΔP." For the example enter "18."
- Enter the return hole size. For the example, enter "0."
- Enter the return hole pressure difference. If no hole is made, the return hole pressure difference is "0."

Press-76



- Enter the average supply pressure difference after the second hole is added, "AVE SUPPLY ΔP2." For our example this is "36."
- Enter the average return pressure difference after the second hole is added, "AVE RETURN ΔP2." For our example this is "58."
- Press **ENTER**.

Press-77

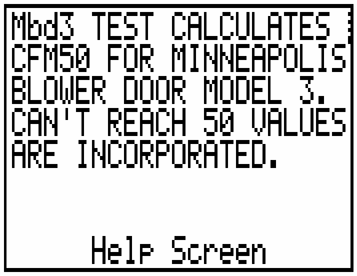


- The return duct CFM_{50}, supply duct CFM_{50}, and the total CFM_{50} are displayed.
- This ends the Duct Series Leakage Test examples.
- Press **ENTER**.

Press-78

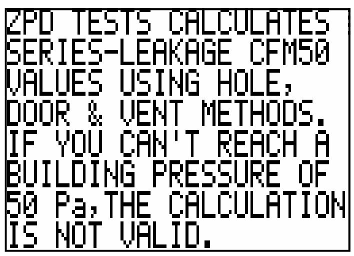
- Once again, back to the main menu.
- Press "HELP," **F3.**
- This feature gives simple help messages for the main menu shown at the left.

Press-79



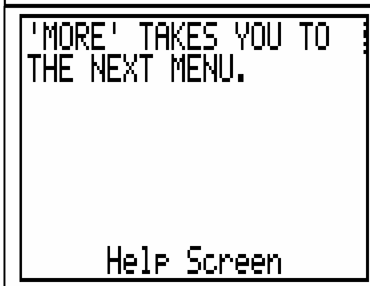
- The “Mbd3,” **F1**, menu item.
- Press **ENTER**.

Press-80



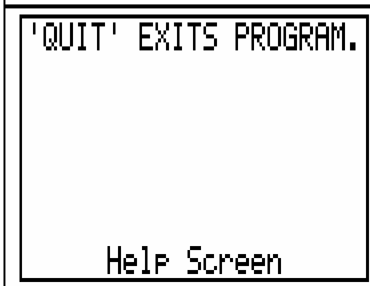
- The “ZPD,” **F2**, menu item.
- Press **ENTER.**

Press-81



- The “MORE,” **F4**, menu item.
- Press **ENTER**.

Press-82

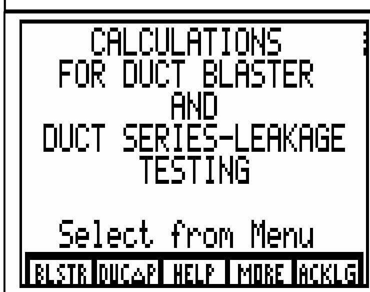


- And the “QUIT,” **F4**, menu item.
- Always exit this and other TI-86 programs by pressing the “QUIT” menu key. This resets the decimal place to “float” so that you can perform accurate calculations with the calculator functions of the TI-86.
- Press **ENTER.**

Press-83

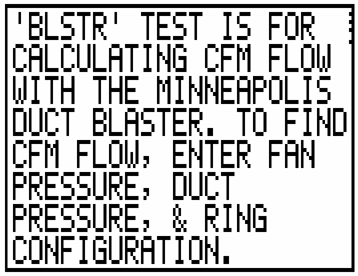
- And, back to the main menu screen.
- Press “MORE,” **F4,** for the other primary menu screen.

Press-84



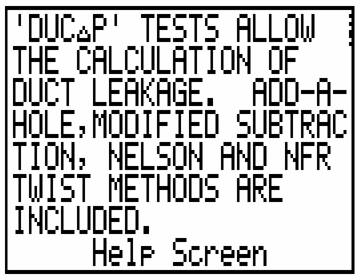
- There is a “HELP,” **F3**, button on this menu also.
- Go ahead, press it.

Press-85



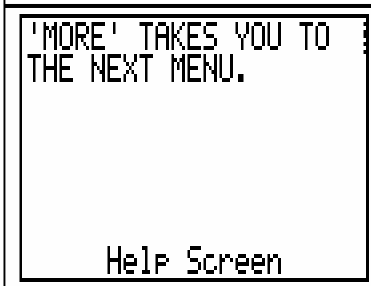
- The "BLSTR," **F1**, menu item.
- Press **ENTER**.

Press-86



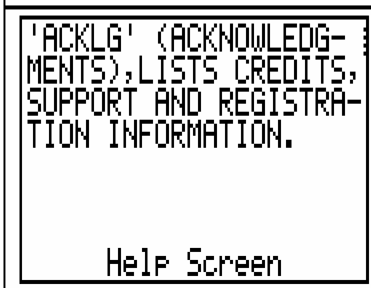
- The "DUC∆P," **F2**, menu item.
- Press **ENTER**.

Press-87



- The "MORE," **F4**, menu item.
- Press **ENTER.**

Press-88

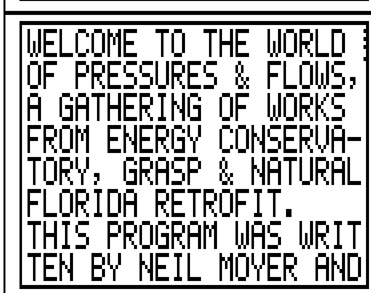


- The "ACKLG," **F4,** menu item.
- Press **Enter.**

Press-89

- Now we are back to one of the primary screens.
- Press "ACKLG," **F5**. This is the acknowledgments section.

Press-90



- This is the first acknowledgments screen.
- Press **ENTER**.

Press-91	RICK KARG (207) 725- 6723.IF YOU PURCHASED THIS PROGRAM FROM WxWare, YOU ARE A REGISTERED USER,ENTIT LED TO SUPPORT AND UP DATE NOTIFICATION.	• This is the second acknowledgments screen. • Press **ENTER**.
Press-92	TO REGISTER YOUR COPY CONTACT WxWare AT 220 MEADOW ROAD, TOPSHAM, MAINE 04086: E-MAIL rjkarg@karg.com: OR 207-725-6723. (September 2002)	• This is the third acknowledgments screen. • Press **ENTER.**
Press-93	CALCULATIONS FOR DUCT BLASTER, BLOWER DOOR & ZONE PRESSURE TESTING (c)2002 WxWare (V3.2) Select from Menu Mbd3 ZPD HELP MORE QUIT	• Once again, back to the main menu screen. • Press "QUIT," **F5**. • **Note: Always exit the program by pressing QUIT; this automatically resets the decimal place for calculator use.**
Press-94	Done	• You have now exited from the program. • If you want to get back to the program quickly after pressing "QUIT," 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.
Press-95	[intentionally left blank]	
Press-96	[intentionally left blank]	

Instructions for

Weatherization Cost-Effective Guidelines for House Tightening

Program "WCEG"

This program was first written under contract with the Wisconsin Low-Income Weatherization Program in 1999.
Thank you to the managers of the Wisconsin Low-Income Weatherization Program for permission to adapt this software program to all areas of the United States.

September 2002 (v. 2.0)

Weatherization Cost-Effective Guidelines Program for House Tightening (WCEG)

This program was written for the Wisconsin low-income weatherization program in 1999 and later adapted for all areas of the United States. The program is useful for blower-door directed air sealing to reduce energy loss and client discomfort due to air leakage during the heating season. The calculations are based on the equation:

CEG = {[26 x 100 x HDD x (UnitFuelCost/BtuPerUnitFuel)]/(LBL# x FuelEff)} x 0.6 x PBper

where:

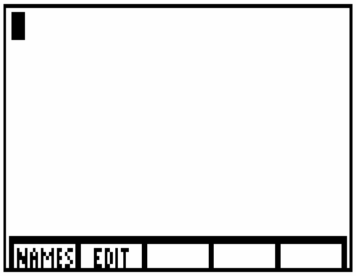
- CEG = Cost-Effective Guideline for air sealing per 100 CFM_{50}.
- HDD = Heating Degree Days, base 65 degrees.
- UnitFuelCost = cost, in dollars, per unit of fuel. The fuel choices are natural gas, numbers 1 and 2 oil, LPG (propane), electric, kerosene (K-1), wood, and coal.
- BtuPerUnitFuel = the British thermal units per unit of fuel. These are assumed to be:
  1) Natural Gas at 100,000 Btu input per therm.
  2) #1 Oil at 134,000.
  3) #2 Oil at 138,690 Btu input per gallon.
  4) LPG at 91,500 Btu input per gallon.
  5) Electricity at 3412 Btu input per kWh.
  6) K-1 kerosene at 126,000 Btu input per gallon.
  7) Wood at 21,000,000 Btu input per cord (dry, mixed hardwood).
  8) Coal at 25,000,000 Btu input per ton.
- LBL# = the Lawrence Berkeley Laboratory correlation coefficient. This is based on the selected climate zone, number of house stories, and house exposure.
- FuelEff = Heating system *seasonal* efficiency.
- PBper = reasonable payback period for air sealing activities.

Constants are entered into the TI-86 calculator memory for this program. These constant values are used in the WCEG program, but are not actually entered in the program; they are entered in the "CONS" section of the TI-86. To view these constant values, press the **2nd** key and then **CONS** (the second function of the **4** key). Then press **F3** for "USER." This will allow you to view the constant values. The numerical values of these constants can be changed when necessary by pressing **F2** for "EDIT". It is very important that you confirm the validity of all the constant values below before using the program.

Constants for the WCEG program include (constant value when software was purchased):
CCOAL = the cost per ton of coal ($100.00).
CELEC = the cost per kWh of electricity ($0.07).
CKERO = the cost per gallon of K-1 kerosene ($1.60).
CLPG = the cost per gallon of LPG or propane ($1.00).
CNG = the cost per therm (100,000 Btu) of natural gas ($0.75).
COIL = the cost per gallon of number 2 fuel oil ($1.20).
COILL = the cost per gallon of number 1 fuel oil (1.30).
CWOOD = the cost of wood per full cord, cut, split, delivered and dry ($160).
COM = the cost of materials per worker hour ($25.00).
LBRT = the cost of labor per worker hour ($15.00).
PB = reasonable payback period for air sealing activities (10).

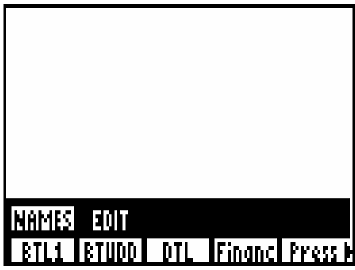
Follow the instructions on the following pages in order to learn how to use the program. Contact WxWare Diagnostics if you have difficulty with the instructions or with the software program.

WCEG-1



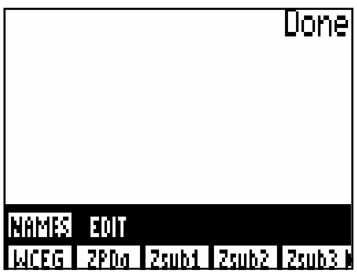
- Turn the TI-86 calculator on.
- Press **PRGM** (Programs).
- You will see this menu on the screen.
- Press **F1** for "NAMES."
- **NOTE:** It is best never to press "EDIT," **F2.**

WCEG-2



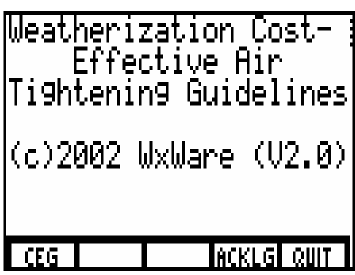
- You will see this menu and sub-menu on the screen.
- Press the **MORE** key to move to the next menu set.

WCEG-3



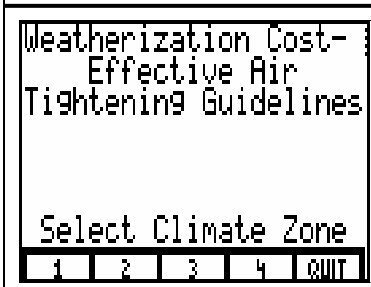
- "WCEG" will appear above the **FI** key.
- Press F1 to load the "WCEG" program.
- "WCEG" will appear at the cursor location.
- Press ENTER. **Note: The exact name of the program must appear at the cursor position, if not, you will receive an error message.**

WCEG-4



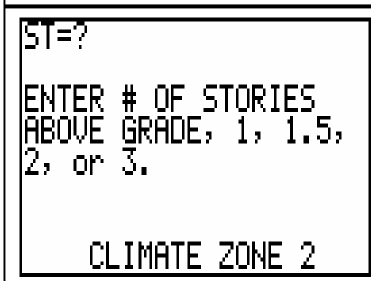
- F1, "CEG" starts the Weatherization Cost-Effective Guideline program for cost-effective air sealing.
- You will see this main menu screen.
- **F4**, "ACKLG" (Acknowledgments) selection lists the author of the program, etc.
- F5, "Quit" selection allows you to exit the program. Always exit the program by selecting F5 from this menu; the decimal place is thereby set to "floating," which you will prefer when you do mathematical calculations.
- Press the **F1** key to start the program.

WCEG-5



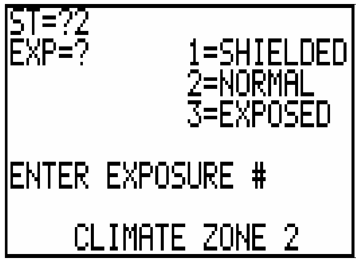
- Select the climate zone from the menu at the bottom of the screen. Check the map on page 20 to find your climate zone. The four climate zones have to do with average wind speed.
- To move back to the main menu screen, press **FI** for "QUIT."
- Select **F2** for climate zone two.
- This will move you on to the next screen.

WCEG-6



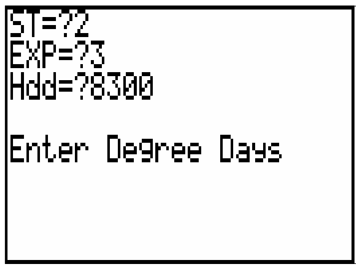
- You are prompted to enter the number of exposed stories of the house. Basements below grade generally should not be included in the number of stories. The value you enter will be displayed after the "**?**"
- Do not enter any numbers other than 1, 1.5, 2, or 3. Notice the instruction on the screen. Also, notice that your selected climate zone is listed at the bottom of the screen.
- Enter "2" stories, for example, and press **ENTER**. This will move you to the next screen.

WCEG-7



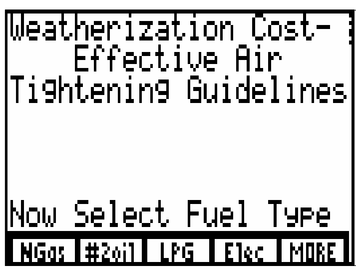
- You are prompted to enter the appropriate exposure number for the house. The value you enter will be displayed after the "?".
- The "EXP" or exposure value should be entered with care. "SHIELDED" is for buildings with significant blockage to the wind (trees or other buildings), "NORMAL" signifies buildings 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.).
- Enter "3," for example, and press **ENTER**.

WCEG-8



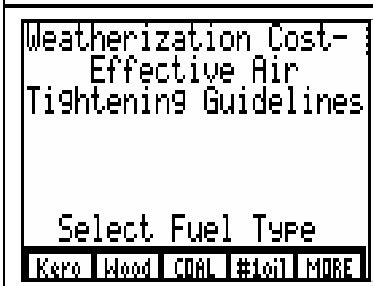
- You are prompted to enter the appropriate heating degree day value, base 65 degrees, for the locality. The value you enter will be displayed after the "?"
- Enter 8300 and press **ENTER** to move to the next screen.

WCEG-9



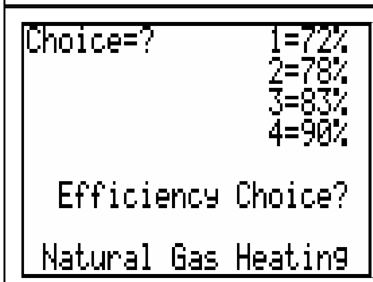
- You are now asked to select the fuel type. Notice that **F5** is for "MORE."
- "NGas" is natural gas, "#2oil" is number 2 oil, "LPG" is liquefied petroleum gas or propane, "Elec" is electric heat.
- Press **F5** for "MORE".

WCEG-10



- This moves you to the additional fuel selections of kerosene, wood, coal, and #1 oil. Other selections on the second menu set are "QUIT" and "MORE," which take you back to the first menu set.
- "KERO" is kerosene or K1, "Wood" is wood heat, "COAL" is coal heat and "#1oil is number 1 oil.
- Press **F5** ("More") to move back to the previous fuel menu.
- Select **F1** for natural gas to move to the next screen.

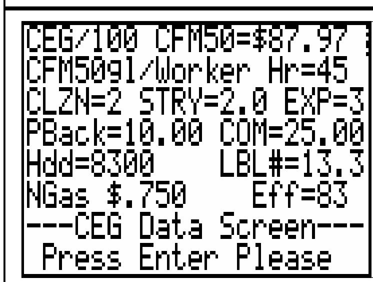
WCEG-11



- You are prompted to enter the ***seasonal*** efficiency of the heating system. For natural gas you have four choices, "1" for 72%, "2" for 78%, "3" for 83%, and "4" for 90%.
- As you use this program, you will notice that there are various fuel efficiency choices for each fuel.
- ***If you are installing a new heating system, use the fuel type and efficiency—seasonal or AFUE—of the new system.***
- Press "3" for 83 percent and **ENTER** to move to the next screen.

This is very important!

WCEG-12



- This is the CEG Data Screen, as listed at the bottom of the screen.
- "CEG/100 CFM50=$87.97" is the cost-effective tightening guideline, a program output, for this example house. This means that if your crew is able to reduce the CFM_{50} by 100 for less than $87.97, it is cost-effective. A CFM_{50} reduction of 100 costing more than $87.97 is not cost-effective.
- The next line, "CFM50gl/Worker Hour=45" is the CFM_{50} tightening guideline (gl) per worker for this job. This means that each worker must reduce CFM_{50} by at least 45 per hour to be cost-effective. [continued on next panel]

WCEG-13

```
CEG/100 CFM50=$87.97
CFM50gl/Worker Hr=45
CLZN=2 STRY=2.0 EXP=3
PBack=10.00 COM=25.00
Hdd=8300    LBL#=13.3
NGas $.750    Eff=83
---CEG Data Screen---
 Press Enter Please
```

- "CLZN" is the selected climate zone.
- "STRY" is the selected number of house stories.
- "EXP" is the selected exposure of the house.
- "Pback" is the selected payback for the analysis (a program constant). This might be set to a different number for your program.
- "COM" is the selected cost of materials per hour (a program constant). This might be set to a different number for your program.
- "Hdd" is the entered heating degree days, base 65 degrees Fahrenheit.

[continued next panel]

WCEG-14

```
CEG/100 CFM50=$87.97
CFM50gl/Worker Hr=45
CLZN=2 STRY=2.0 EXP=3
PBack=10.00 COM=25.00
Hdd=8300    LBL#=13.3
NGas $.750    Eff=83
---CEG Data Screen---
 Press Enter Please
```

- "LBL#" is the calculated Lawrence Berkeley Laboratory number. This is the number the CFM_{50} value is divided to yield the $CFM_{natural}$ value.
- "NGas" is the cost per unit of fuel, in this case, the cost per therm of natural gas (a program constant).
- "Eff" is the selected *seasonal* efficiency of the heating system.
- If you want to print this screen, you have all the inputs and outputs here. You must have the Texas Instruments Graph Link to print a screen.
- Press **ENTER** to move to the next screen.

WCEG-15

```
Last CFM50 reduction
cost effective?

CEG/100 CFM50=$87.97
CFM50gl/Worker Hr=45


Press Enter to Answer
```

- You are asked if you would like to check to determine if the last CFM_{50} tightening session was cost-effective or not.
- For your convenience, the first two output lines of the previous screen are listed on lines four and five (the blank line is counted here).
- Press **ENTER** to proceed.

WCEG-16

```
Choice=?

1=Do Cost-Effect Test
2=To Home Screen
3=To CEG Data Screen


CEG Cost-Effect. Test
```

- You are now prompted to make one of three choices: 1 = do a cost-effective calculation to determine if your last air tightening session was cost-effective or not; 2 = quit the program and go back to the program home screen; or 3 = go back to the "CEG Data Screen" (for this example this is the screen pictured in panels WCEG-12 through WCEG-14).
- Choice number 2 requires no explanation.
- Try choice number 3 by pressing "3" and then ENTER.
- Now enter "1" for your "Choice=" and press ENTER.

WCEG-17

```
Reduc=?

CFM50 Reduction from
Crew Air Sealing?
```

- As the instruction on line three states, enter the last CFM_{50} reduction accomplished by the crew (not each worker, but the entire crew). The number of workers making up the crew will be entered next).
- This reduction is determined by a single-point blower door test.
- For this example, enter "200" and press **ENTER**.

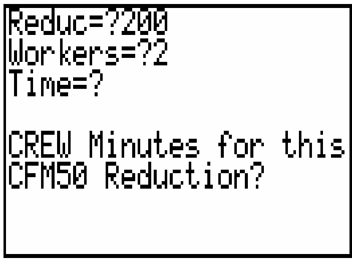
WCEG-18

```
Reduc=?200
Workers=?

Number of Workers in
Crew for this
CFM50 Reduction?
```

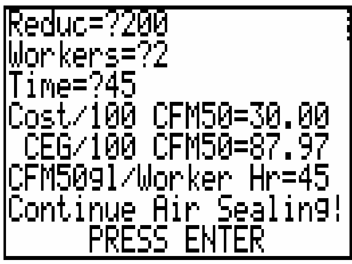
- You are prompted to enter the number of workers on your air-sealing crew.
- For this program, we have used the term "worker" for one air-sealing person. The term "crew" signifies the group of workers performing air-sealing.
- Enter "2" and press **ENTER** to move to the next screen.

WCEG-19



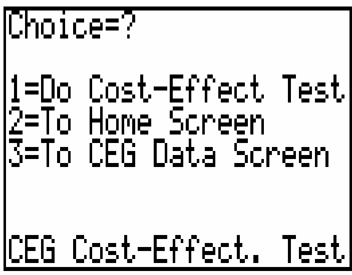
- Now you are asked to enter the time it took to accomplish the reduction in CFM_{50}. Enter the time in minutes, not hours. If the crew of two worked for 45 minutes, enter “45”.
- For this example, enter “45” minutes for the time it took to reduce the CFM_{50} by 200.
- Press ENTER to move on the next screen and see the results of the cost-effective test.

WCEG-20



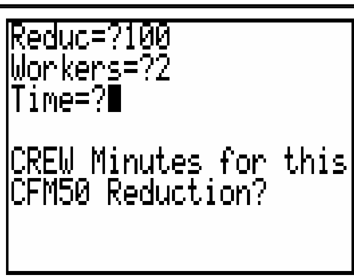
- The second to the last line on the screen states “Continue Air Sealing!” This is because the cost of the last CFM_{50} reduction was $30.00 per 100 CFM_{50} (see line four on the screen at the left). The cost-effective guideline per 100 CFM_{50} reduction for this job is $87.97 (see line five on the screen at the left). Since the actual cost per 100 CFM_{50} reduction is less than the guideline of $87.97, continue air sealing.
- Press **ENTER** and we will continue with our air-sealing example.

WCEG-21



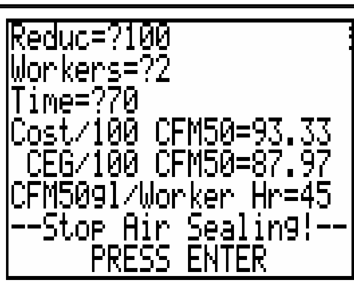
- At the “Choice=?” prompt, enter “1” for another cost-effective test.
- Press **ENTER**.

WCEG-22



- At the “Reduc=?” prompt, enter 100 and press **ENTER**.
- At the “Workers=?” prompt, enter 2 and press **ENTER.**
- At the “Time=?” prompt, enter 70 minutes and press **ENTER**.

WCEG-23



- This air sealing session was not cost-effective (the “**Cost**/100 CFM50=93.33” is greater than the “**CEG**/100 CFM50=87.97), so “Stop Air Sealing!” In other words, the cost was greater than the savings.
- Actually, you might want to continue air sealing if you think your next session can be cost-effective. This is likely to be the case if you just discovered a large hole that will be easy to seal. However, generally air sealing is—and should be—a progressive process, that is, you seal the large,

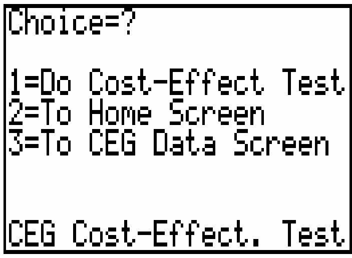
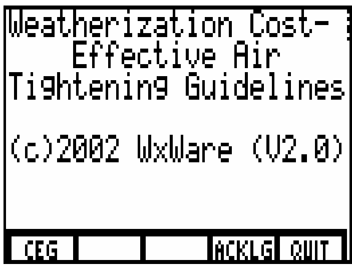
[continued on next panel]

WCEG-24

[intentionally left blank]

productive holes first, then move on to the medium holes, and then to the small holes. In reality, the air sealing process is not always progressive. If you think you crew has air sealed in a progressive manner, stop your air sealing activities at this time. However, if you think you can be cost-effective during your next session, for whatever the reason, proceed with another air sealing session.

- Press **ENTER**.

WCEG-25		• This takes us back to the "CEG Cost-Effect. Test" screen. • Now, let's quit the program by selecting "2" and then pressing **ENTER**.
WCEG-26		• This returns us to the main menu screen for this program. • "QUIT" the program by pressing **F5**.
WCEG-27		• We have exited the program correctly. • If you want to get back to the program right away, just press **ENTER**. This will take you back to the main menu screen of the CEG program (the last program you worked with on the TI-86 calculator)>
WCEG-28	[intentionally left blank]	
WCEG-29	[intentionally left blank]	
WCEG-30	[intentionally left blank]	

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Instructions
for

Advanced
Zone Pressure Diagnostics

Program "ZPDa"

April 2004 (v. 1.0)

INTRODUCTION

This advanced zone pressure diagnostics software is based on *An Investigation into Zone Pressure Diagnostic Protocols for Low Income Weatherization Crews*, December 2001, prepared by the Center for Energy and Environment for the Energy Center of Wisconsin, Scott Pigg, project manager. The Executive Summary of this report states:

> Zone pressure diagnostics (ZPDs) have become an established tool for low-income weatherization programs in diagnosing indirect air leakage paths in houses. Other programs, such as the American Lung Association's Health House, use ZPDs to establish performance specifications. Despite widespread use, there are substantial differences in the way field personnel decide when to use ZPDs, which of the three methods to use, and how to make the best measurements. A project team comprised of staff from the Center for Energy and Environment, Michael Blasnik & Associates, and the Energy Conservatory developed and tested protocols for ZPDs used by weatherization crews and developed methods for determining the accuracy of ZPDs.
>
> ZPDs are used to identify and measure series leaks or leaks that pass through several zones of the house. For example, air leaking through the attic roof must first move from the living space into the attic through the attic floor. ZPDs measure the pressure difference between the living space and the bordering zone (the attic) and the bordering zone and the outdoors. The techniques rely on the principle that the ratio of the pressure difference across the interior and exterior boundaries of a series leak is a direct function of their leakage area.

The results of the *An Investigation into Zone Pressure Diagnostic Protocols for Low Income Weatherization Crews* included many improvements to both the methodology used to collect ZPD measurements and the calculation procedures used to estimate the magnitude of air leakage from selected zones. To learn more about these new and advanced ZPD methods, we recommend that you download, use, and study the instructions for The Energy Conservatory's ZPD Calculation Utility (ZPDCU). This free Windows software is available at http://www.energyconservatory.com/products/products8.htm. The ZipTest Pro^2 version, ZPDa, is based on this Windows version.

If you are to use these techniques and this program properly, you should have a good working knowledge of basic zone pressure diagnostic testing. These are some of the important improvements of this advanced zone pressure diagnostics methods over the basic method:

- You no longer must reach a pressure difference from the house to the outdoors of 50 Pascals. The advanced method allows you to use lower house pressures, although for the sake of accuracy, use a house pressure as close to 50 Pascals as possible.
- When you select "Door" as the opening type for this advanced method (similar to using the "door" method of the older basic ZPD), you are no longer required to have a zero pressure drop across the pressure boundary within which the door is located.

Here is a practical example (thanks to Collin Olson) demonstrating the advantages above: Let's say that you use Ring A on you Minneapolis Blower Door, Model 3 to measure the CFM_{50} and an attic-to-outdoor pressure of –4 Pascals.

You decide to crack open the attic hatch until you get a good pressure shift. So now with the hatch open, the attic-to-outdoor pressure is –16. However, there is no way you can measure the square inches of attic opening, the darn thing is too irregular. If you select "Door" as the opening type in this ZipTest Pro^2 ZPDa program, you will not be asked to enter a square inch area, so the irregular opening problem vanishes.

Now you crank up your blower door to get a CFM_{50} reading with this hole open, but you find that with the blower door Ring A (it is best to stick with the same Ring you used for the no-opening blower door test, but you don't have to), you can only reach a house pressure of –35 Pascals. This is not a problem with the advanced method; continue your test for your final results. You can also repeat this test with the hatch completely removed.

Companion ZPDa Forms

Two forms are included at the end of this chapter to assist you when you are doing a ZPDa analysis. The first form on page 81 is an aid for an analysis of one zone. The second form on page 82 is helpful for an analysis of from two to four zones. **We strongly recommend that you use these forms. They will also provide documentation of your testing.**

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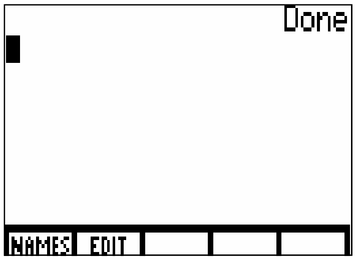
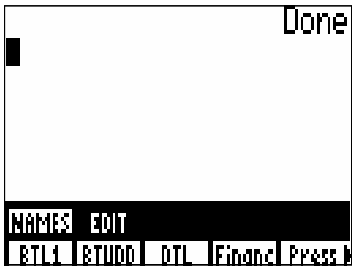
ZPDa-1



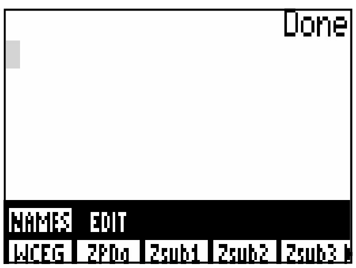
- Turn the TI-86 on by pressing the **ON** key.
- Then press the **PRGM** (Programs) key. You will see the screen at the left on your calculator.
- Now press F1 for **NAMES.**
- **Note: It is best never to press F2 for EDIT.**

ZPDa-2



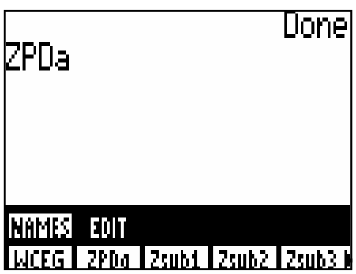
- Notice the sub-menu on the bottom of the display screen. The program we are looking for — ZPDa — is not on this first sub-menu set. Press the **MORE** key to move to the second sub-menu set.

ZPDa-3



- Notice that the “ZPDa” program is on this second sub-menu set above the F2 key.
- Notice the names above the F3, F4, and F5 keys. These “Zsubx” are not really programs but subroutines for the “ZPDa” program. There are eight of these subroutines — if you press the MORE key, the third sub-menu will show five more — that you should not call up because you will get an error message.
- Press the F2 key only once to start the “ZPDa” program.

ZPDa-4

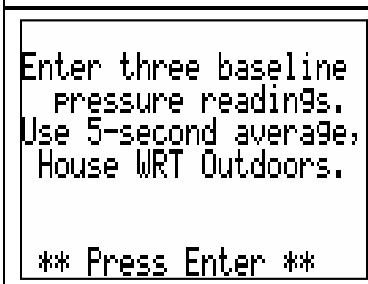


- You will now see “ZPDa” at the top left of the calculator display. Make sure that the only “ZPDa” is at the top left. When you press **ENTER** it instructs the calculator to look for and run the “ZPDa” program, so make sure there are no extraneous numbers or letters listed on this line on the display.
- Press **ENTER**.

ZPDa-5

- This is the home screen for the Advanced Zone Pressure Diagnostics program.
- Select **F1**, “ZPD”, to start the program routine.
- Select **F4**, “ACKLG”, (acknowledgements) to see who wrote the program.
- Select **F5**, “QUIT”, to quit the program. Always exit the program by selecting **F5** from this menu; this resets the decimal place is thereby set to “floating”.
- Press **F1** to start the “ZPD” routine.

ZPDa-6



- This display is informational only; it alerts you about what is coming up next so that you can prepare. These three baseline pressures are taken in a manner similar to a baseline pressure preceding a blower door test — house closed up, blower door fan plugged, and no openings made.
- These baseline pressures are used to determine the degree of measurement error from wind during the advanced zone pressure diagnostics testing.
- Press **ENTER** to go to the next display.

ZPDa-7

```
Baseline 1 is ⁻3.5
Baseline 2 is .4
Baseline 3 is ⁻1.4█
```

- For this example, at the left we have entered the 5-second baseline pressures of –3.5, 0.4, and –1.4 (Important: When you enter a negative number, you must use the key to the left of the ENTER key, not the subtraction operation key).
- This is a good time to mention the ZPDa test companion forms at the end of this chapter. The first of the two forms is for testing one zone only and the second form is for testing two through four zones. **Make as may photocopies of this ZPDa form as you wish.** Enter these example baseline pressures and other information on a copy of the second of these forms to help you keep things straight. This will also provide a record of each test.

ZPDa-8

```
Baseline 1 is ⁻3.5
Baseline 2 is .4
Baseline 3 is ⁻1.4

Average Baseline=⁻1.5
Baseline Flux=2.5
 ** Press Enter **
```

- After entering the three baseline pressures, in Pascals, press the **ENTER** key.
- You will see the display at the left on your TI-86 screen.
- Notice that the "Average Baseline=-1.5" and the "Baseline Flux=2.5".
- Enter these two calculated values on the ZPDa form. Note that all calculated values on the ZPDa forms have names that are in *italics*.
- Press **ENTER**.

ZPDa-9

```
Number of Zones=

  Enter number of
  zones to monitor.


 Enter 1, 2, 3, or 4
```

- Here you must enter the number of zones you wish to test. In the this software you may enter one through four zones, each designated by the numbers 1 to 4. Use the ZPDa form to name the zone numbers.
- Let's assume for this example that we are testing four zones:

1 = attic
2 = garage
3 = crawl space
4 = basement

ZPDa-10

```
Number of Zones=4

  Enter number of
  zones to monitor.


 Enter 1, 2, 3, or 4
```

- Press the "4" key to designate the number of zones you want to include in this test. You cannot change this unless you start the program over, so make sure you enter the right number.
- **Note: We recommend that you fill out as much of the ZPDa form before you start entering your data into the ZPDa program. This will help you plan you test and ensure that you gather all the house data necessary.**
- After you have pressed the "4" key, press **ENTER** to move to the next screen.

This is very important!

ZPDa-11

```
Enter blower door
data BEFORE adding
an opening.



 ** Press Enter **
```

- This screen informs you that it is time to enter your whole house blower door test data. This is the blower door test BEFORE you add any openings for the zone pressure diagnostics testing (later in the program you will have to enter house blower door data with an opening made in one of the zones).
- Press **ENTER** to start the blower door data entry.

ZPDa-12

```
Tout=?50

Enter outdoor F. temp



    Minn BD Mod#3
```

- For this example, enter an outdoor temperature — "Tout" — of 50 degrees.
- The program will automatically adjust your blower door readings for outdoor/indoor temperature differences. Notice there are simple instructions on the display. We include these whenever possible.
- By the way, this program works only with the Minneapolis Blower Door, Model 3 manufactured by The Energy Conservatory (notice the abbreviation for this blower door at the bottom of the display).

Panel	Calculator display	Instructions
ZPDa-13	Tout=?50 Tin=?70 Enter indoor F. temp Minn BD Mod#3	• Now enter the indoor temperature — "Tin" — of 70 degrees. • Notice the short instruction on the display. • Note: It is a very good idea to look at the values you have entered before you press ENTER, because after you press ENTER you cannot go back and change your entry. If you notice that you have made an entry mistake after pressing ENTER, you must press the 2nd key, then QUIT (the second function of EXIT), and then ENTER. This takes you back to the beginning of the program and you must start over. *This is very important!*
ZPDa-14	Tout=?50 Tin=?70 Type = 1 Enter Test Type: Depressurization = 1 Pressurization = 2 Minn BD Mod#3	• Press ENTER. • Because we are temperature adjusting the blower door readings, it is necessary to ask whether the blower door test is depressurizing or pressurizing the house. Normally we depressurize, as we are assuming in this example. • **Note: If you make an entry mistake and notice it before pressing enter, move the cursor over the erroneous entry and re-type the correct one.** • Press **1** for depressurization and then press the **ENTER** key.
ZPDa-15	HSEΔP=?-52 Enter ACTUAL house to outdoor ΔP in Pascals Use negative sign (-) Depressurization test	• Now you must enter the pressure difference, the house with reference to the outdoors, created by the blower door. Please notice the instruction on the screen. Because we are performing a depressurization blower door test for this example, we MUST put a negative sign in front of the pressure difference of 52 Pascals. Notice at the bottom of the display we are reminded that we are doing a depressurization test requiring a negative sign. Note: The negative sign is just to the left of the ENTER key on the TI-86 calculator. [continued on next panel] *This is very important!*
ZPDa-16	HSEΔP=?-52 FANΔP=?135 Enter fan ΔP in Pascals Depressurization test	**The "HSEΔP" (house pressure) should ideally be from 45 to 55 Pascals for the whole house test and the pressure readings taken in each of the zones we are testing (see panel ZPDa-23 to 26). If you cannot reach at least 45 Pascals, take these readings at the highest achievable pressure.** • Now enter the blower door fan pressure difference — "FANΔP" — without a negative sign, in units of Pascals. • Press **ENTER**.
ZPDa-17	HSEΔP=?-52 0=OPEN FANΔP=?135 1=A-RING CONFIG=?1 2=B-RING 3=C-RING Enter Ring Config. Depressurization test	• Enter the blower door fan configuration — "CONFIG". There is a menu of the choices on the upper right corner of the display. • Enter **1** for our example and then go to the next screen by pressing the **ENTER** key. • Remember to write all this data on your ZPDa form as you proceed through the testing.
ZPDa-18	HSEΔP=?-52 0=OPEN FANΔP=?135 1=A-RING CONFIG=?1 2=B-RING 3=C-RING Tin = 70 Tout = 50 CFM50.5 --> 2007.7 CFM50 --> 1994.7 Depressurization test	• This next display shows the blower door data you entered and the results of the blower door test, temperature adjusted and baseline adjusted. Notice that the "HSEΔP" (house pressure) in panel ZPDa-17 was entered as "-52". Well, the average house baseline for the test of –1.5 (see panel ZPDa-8) was subtracted from –52 Pascals to yield a net house ΔP of –50.5. This is why we have "CFM50.5 —> 2007.7" and an adjusted "CFM50 —> 1994.7". Both of these CFM values are adjusted for temperature differences between outdoors and indoor.

ZPDa-19	baseline = 2.1 Enter zone BASELINE pressure for zone 1 of 4, NO opening. Zone WRT Outdoors	• Now you must enter the baseline pressures, in Pascals, for each of the four zones in this example. **Notice that these baseline pressure are taken from the zone WRT (with reference to) the outdoors, no openings have yet been created for the zone pressure diagnostics testing, the blower door is off, and the blower door fan is closed.** • Notice the instruction on the display indicates that this baseline pressure is for "zone 1 of4". This should help you enter the right values for each zone. • Press ENTER to move to the next screen.
ZPDa-20	baseline = 2.4 Enter zone BASELINE pressure for zone 2 of 4, NO opening. Zone WRT Outdoors	• The next baseline pressure should now be entered. Enter the number shown at the left. • Notice that the instruction now states "zone 2 of 4". As we named the four zones for this ZPDa test, zone 2 is the garage (see panel ZPDa-9). • Press **ENTER** to move to the next screen and enter the next baseline pressure.
ZPDa-21	baseline = -1.3 Enter zone BASELINE pressure for zone 3 of 4, NO opening. Zone WRT Outdoors	• For "zone 3 of 4" enter "-1.3". As we mentioned earlier, the negative key for the negative sign before this number is just to the left of the **ENTER** key on the TI-86 keyboard. • Press ENTER to move to the next screen.
ZPDa-22	baseline = -2.1 Enter zone BASELINE pressure for zone 4 of 4, NO opening. Zone WRT Outdoors	• For the final baseline entry, "zone 4 of 4", enter "-2.1", again using the negative sign key just to the left of the **ENTER** key. • If we had decided to work on just three zones for this zone pressure diagnostics test and entered "Number of Zones" as 3 (see panels ZPDa-9 and 10), rather than four, only three screens would have come up for baseline readings. The "Number of Zones" we enter determines the number of times we are asked for "baseline" and "BD-on press." before and after we add a temporary test opening. Press **ENTER**.
ZPDa-23	BD-on press.= -15.3 Enter BLOWER DOOR-ON pressure for zone 1 of 4, NO opening. With NO opening Zone WRT Outdoors	• Notice that now we must enter "BD-on press" readings, in Pascals, while the blower door is running, **but there is no opening made yet for the analysis.** • Again, the instruction on the display states this is the entry for "zone 1 of 4" to assist you in entering the proper values. • Enter "-15.3". • Press ENTER to move to the next screen.
ZPDa-24	BD-on press.= -13.5 Enter BLOWER DOOR-ON pressure for zone 2 of 4, NO opening. With NO opening Zone WRT Outdoors	• Enter "-15.3" for "zone 2 of 4". • Press **ENTER**.

ZPDa-25

```
BD-on press.= -2.1

Enter BLOWER DOOR-ON
pressure for zone 3
of 4, NO opening.

  With NO opening
 Zone WRT Outdoors
```

- Enter "-2.1 for "zone 3 of 4".
- Of course, in order to gather this pressure data you must have a pressure hose in each of the zones and another hose connected to the outdoors. It is a very good idea to use different color hoses for each of the zones so that you can keep things straight. And don't forget to enter all your data on the ZPDa form for each analysis.
- Press **ENTER.**

ZPDa-26

```
BD-on press.= -46

Enter BLOWER DOOR-ON
pressure for zone 4
of 4, NO opening.

  With NO opening
 Zone WRT Outdoors
```

- Enter "-46 for "zone 4 of 4". Earlier we designated zone 4 as the basement in this example analysis (see panel ZPDa-9). This high value from the "Zone WRT Outdoors" indicates that the basement walls are a **relatively** tight pressure barrier compared with the pressure barrier between the main house and the basement (the basement ceiling).
- Press **ENTER.**

ZPDa-27

```
   BaseLn BD-On  Diff
Hse -1.5  -52.0 -50.5
Zn1 2.1   -15.3 -17.4
Zn2 2.4   -13.5 -15.9
Zn3 -1.3  -2.1  -.8
Zn4 -2.1  -46.0 -43.9

Data With No Opening
```

- Now we see the tabular results of all of our work up to this point! On the far left of the table are the row designations for the house ("Hse"), zone 1 ("Zn1"), zone 2 ("Zn2"), etc.
- The column "BaseLn" lists the entered baseline pressures (the one for the house is the average of the three baseline pressures entered for the house — see panel ZPDa-8).
- The next column "BD-On" lists the blower door-on pressures for each zone.

[continued on next panel]

ZPDa-28

[Intentionally left blank]

- Finally, the last column "Diff" lists the actual zone pressures, the "BaseLn" values subtracted from the "BD-On" values. These net pressure values are used for the program calculations.
- Notice at the bottom of the display there is a reminder that no openings have been created yet.
- Press **ENTER.**

ZPDa-29

```
CFM50=1995    Hole
            Location
Zn H/Z Z/O H/Z   Z/O
1  32  18  Best  OK
2  33  17  Best  OK
3  49  1   Best  No
4  4   46  No    Best
Min pressure shift=10
```

- This table shows the zones — 1 through 4 for this example, the house-to-zone pressures ("H/Z"), the zone-to-outdoors pressures ("Z/O"), and the best place for the location for a temporary opening for the analysis. These suggested opening location guidelines are for your convenience. This example display includes a three possibilities under "Hole Location"; Best, OK, or No.
- "Best" indicates that adding an opening here, say house-to-zone for zone 1, will produce the best zone leakage estimates and allows for the largest possible change in zone pressure.

[continued on next panel]

ZPDa-30

[Intentionally left blank]

- "OK" indicates opening a hole in this pressure boundary will give reliable zone leakage estimates, but the estimates will not be as certain as the "Best" designation.
- "No" indicates that reliable estimates of zone leakage cannot be achieved by opening a temporary hole in these pressure boundaries because the boundary is too leaky to allow the minimum pressure change ("Min pressure shift").

[continued on next panel]

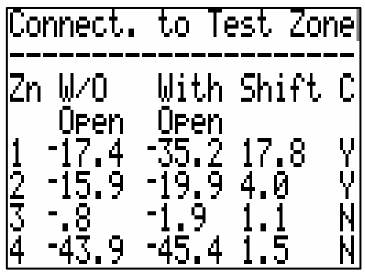
ZPDa-31	CFM50=1995 Hole Location Zn H/Z Z/O H/Z Z/O 1 32 18 Best OK 2 33 17 Best OK 3 49 1 Best No 4 4 46 No Best Min pressure shift=10	• Note: This is the same display as panel ZPDa-29. • You may select any of the four zones to analyze; this table instructs you when to make the temporary opening for the most reliable test results. • Notice that the CFM_{50} value of the whole house blower door test (no openings) is at the top left on this display as a reminder. • Also notice that at the bottom of the screen is an important value, the "Min pressure shift=10". When you create a temporary opening for your zone pressure diagnostics testing, the shift across [continued on next panel]
ZPDa-32	[Intentionally left blank]	the pressure boundary through which you create the opening must be at least 10 Pascals (for this example) to achieve reliable results. The minimum pressure shift is four times the estimated baseline fluctuation (see "Baseline Flux" in panel ZPDa-8). • Don't forget to record the minimum pressure shift on the ZPDa form. You will notice that there is no entry area on the ZPDa forms for Best, OK, and No. With experience, you will be able to quickly examine the data already recorded on the form to determine the best pressure boundary for an opening. • Press ENTER.
ZPDa-33	Zone #=1 Of 4 zones, which do you want to analyze? Min pressure shift=10	• Now you must decide which zone (of a total of four for this example) you want to analyze by adding an opening. For this example we will analyze zone 1. • Notice the instruction on the display. Also, as a reminder, the minimum pressure shift is displayed at the bottom of the screen. This value should have already been recorded on your ZPDa form. • On the next two or three screens you will enter information about the temporary opening you are making. • Press ENTER.
ZPDa-34	Zone #=1 Location=1 1=H/Z 2=Z/O Where will you make the temporary opening Min pressure shift=10	• Select the location for the temporary opening. Guidance for this is displayed for this example on panel ZPDa-31; the best pressure boundary for the opening is between the house and the zone (H/Z). • Notice the minimum pressure shift, in Pascals, is displayed at the bottom of the screen as a reminder. This means that when you make the opening, you should drop the pressure across this pressure boundary by at least 10 Pascals for reasonable accuracy. • Press **ENTER**.
ZPDa-35	Zone #=1 Location=1 1=Orifice Hole Type=2 2=Hatch 3=Partial 4=Door 5=Rough Select Hole Type	• You must enter the opening type here. Please see **The Five Types of Temporary Openings** on page 80 at the end of this chapter for an explanation of the hole types and uses. • Unless you enter "4" for "Door", you will next be asked for the opening size. On the ZPDa forms these opening types are merely designated as "OHPDR" so that you can easily circle the hole type you use. • Enter "2" for "Hatch" and then press ENTER.
ZPDa-36	Hole Size=120 Enter hole size in free square inches.	• Enter the hole size in square inches. If the hole is covered by a louver or a screen, do your best to determine and enter the *free* square inches of opening. The more accurate your measurement, the less uncertain your results will be. • Remember, you must drop the pressure difference across the pressure boundary in which you make the opening by at least the minimum pressure shift (for this example, 10 Pascals). Make the hole larger if you need to increase the pressure shift. • Enter "120" and then press ENTER.

Panel	Screen	Instructions
ZPDa-37	Enter blower door data AFTER adding an opening. ** Press Enter **	• Now it is time to enter the blower door information with the temporary hole open. • Press **ENTER**.
ZPDa-38	HSE∆P=?-50 Enter ACTUAL house to outdoor ∆P in Pascals Use negative sign (-) Depressurization test	• Notice that you are not asked to enter the outdoor, indoor, or test type again as you were for the first blower door test. This data is held in the memory of the TI-86 for this second hole-open blower door test. • The "HSEDP" (house pressure) should ideally be from 45 to 55 Pascals for the whole house test and the pressure readings taken in each of the zones we are testing (see panel ZPDa-42 to 49). If you cannot reach at least 45 Pascals, take these readings at the highest achievable pressure. • Enter "-50" for this example. Don't forget to enter the negative sign for the house pressure when performing a depressurization test. Press **ENTER**.
ZPDa-39	HSE∆P=?-50 FAN∆P=?200 Enter fan ∆P in Pascals Depressurization test	• Enter the fan pressure of "200" Pascals for this example. • Press **ENTER**.
ZPDa-40	HSE∆P=?-50 0=OPEN FAN∆P=?200 1=A-RING CONFIG=?1 2=B-RING 3=C-RING Enter Ring Config. Depressurization test	• Enter the fan configuration of 1. You should try to use the same blower door fan ring on this hole-open blower door test as you did on the first one. Use the same ring as long as you can reach a house pressure difference of at least 35 Pascals. This will result in a narrower range of minimum and maximum zone leakage results. **However, if you must change rings for the blower door test with a hole opened, do so; you will only suffer some decrease in accuracy.** • Press **ENTER**.
ZPDa-41	HSE∆P=?-50 0=OPEN FAN∆P=?200 1=A-RING CONFIG=?1 2=B-RING 3=C-RING Tin = 70 Tout = 50 CFM50.5 --> 2438.7 CFM50 --> 2422.9 Depressurization test	• Here is all the data you entered and the results for the second blower door test. Notice that the temperature values you entered for the first blower door test are listed here. We are assuming that the temperatures have not changed for the second of two blower door tests. • As a result of adding a temporary opening in the attic floor by removing a hatch, the house CFM_{50} value increased from 1995 to 2423.
ZPDa-42	baseline = 1.5 Enter zone BASELINE pressure for zone 1 of 4, WITH opening. Zone WRT Outdoors	• Now the baseline values must be entered for the zones. The blower door must be off and the blower closed, however, the hole should be open to the size already entered in the calculator and recorded on the ZPDa form. • Enter the zone with reference to outdoors baseline pressure difference for zone 1 of 4. For this example this is 1.5 Pascals. • Press **ENTER**.

ZPDa-43	baseline = 1.4 Enter zone BASELINE pressure for zone 2 of 4, WITH opening. Zone WRT Outdoors	• Enter the zone with reference to outdoors baseline pressure difference for zone 2 of 4. For this example this is 1.4 Pascals. • Press **ENTER**.
ZPDa-44	baseline = -1.2 Enter zone BASELINE pressure for zone 3 of 4, WITH opening. Zone WRT Outdoors	• Enter the zone with reference to outdoors baseline pressure difference for zone 3 of 4. For this example this is -1.2 Pascals. • Press **ENTER**.
ZPDa-45	baseline = -1.8 Enter zone BASELINE pressure for zone 4 of 4, WITH opening. Zone WRT Outdoors	• Enter the zone with reference to outdoors baseline pressure difference for zone 4 of 4. For this example this is -1.8 Pascals. • Press **ENTER**.
ZPDa-46	BD-on press.= -33.7 Enter BLOWER DOOR-ON pressure for zone 1 of 4, WITH opening. With Opening Zone WRT Outdoors	• Now enter the zone pressures with the blower door operating and the hole of a specified size (or a door of a non-specified size) open. • Enter the zone with reference to outdoors pressure difference for zone 1 of 4. For this example this is –33.7 Pascals. • Because this is a depressurization test, all for of these example zone pressures will be negative. • Press **ENTER**.
ZPDa-47	BD-on press.= -18.5 Enter BLOWER DOOR-ON pressure for zone 2 of 4, WITH opening. With Opening Zone WRT Outdoors	• Enter the zone with reference to outdoors pressure difference for zone 2 of 4. For this example this is –18.5 Pascals. • Press **ENTER**.
ZPDa-48	BD-on press.= -3.1 Enter BLOWER DOOR-ON pressure for zone 3 of 4, WITH opening. With Opening Zone WRT Outdoors	• Enter the zone with reference to outdoors pressure difference for zone 3 of 4. For this example this is –3.1 Pascals. • Press **ENTER**.

ZPDa-49	BD-on press.= -47.2 Enter BLOWER DOOR-ON pressure for zone 4 of 4, WITH opening. With Opening Zone WRT Outdoors	• Enter the zone with reference to outdoors pressure difference for zone 4 of 4. For this example this is –47.2 Pascals. • Press **ENTER** to move on to the tabulated results of the baseline and zone pressures.
ZPDa-50	BaseLn BD-On Diff Hse -1.5 -50.0 -48.5 Zn1 1.5 -33.7 -35.2 Zn2 1.4 -18.5 -19.9 Zn3 -1.2 -3.1 -1.9 Zn4 -1.8 -47.2 -45.4 Data With Opening	• Here are the results for the baseline and zone pressure differences, and the net zone pressures ("Diff") for each of the four zones in this example and the house. Notice, as indicated at the bottom of the display, these are the pressures with the opening, in this case between the house and the attic (zone 1). • Press **ENTER**.
ZPDa-51	Calculating Results.. Progress -------	• As you can see from this display, the humble TI-86 is working very hard to calculate the results of your zone pressure analysis. The work-in-progress graphic at the bottom of the display indicates the heavy work being accomplished. Be patient. **You do not have to press ENTER here; when the calculations are complete, the results will be displayed.**
ZPDa-52	Results for Zone 1 -------------------- CFM50 CFM50 ----- ----- H/Z 444 to 972 Z/O 747 to 1404 Path 349 to 726	• Here are the results we have be working for! This screen shows the house-to-zone ("H/Z") CFM_{50} range, the zone-to-outdoors ("Z/O") CFM_{50} range, and the total path ("Path") CFM_{50} range. **If you divide the house-to-zone and the zone-to-outdoors CFM_{50} values by 10, you get an approximate range of leakage area in square inches.** • Notice the reminder at the top of the display that these are the results for zone 1, in this example this is the attic. • The total path range values will always be less [continued on next panel]
ZPDa-53	[Intentionally left blank]	than the house-to-zone or zone-to-outdoors range values. This is because the total path includes the impact of **both** the pressure boundaries. This is a very powerful analysis and has many advantages over the basic zone pressure diagnostics procedure (see the ZPD sub-program in the PRESS section of the ZipTest Pro² software package). • Press ENTER.
ZPDa-54	Connect. to Test Zone -------------------- Zn W/O With Shift C Open Open 1 -17.4 -35.2 17.8 Y 2 -15.9 -19.9 4.0 Y 3 -.8 -1.9 1.1 N 4 -43.9 -45.4 1.5 N	• This is a powerful feature of advanced zone pressure diagnostics, the connection of zones. The title of this table is "Connection to Test Zone". • The column headings, for left to right are: Zone ("Zn") Zone pressure **without** opening made ("W/O Open") Zone pressure **with** opening ("With Open") The pressure shift in the zone as a result of the hole being opened ("Shift") [continued on next panel]

ZPDa-55



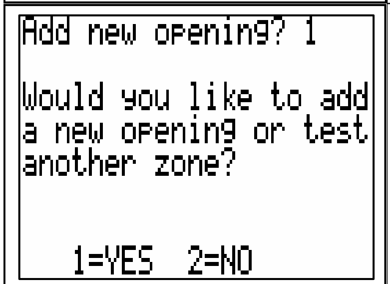
[continued from panel ZPDa-54] (This is the same screen as in panel ZPDa-54.) Connection to the tested zone — in this case, zone 1 — or not ("C"). If a connection between the tested zone and another zone is indicated, a "Y" for YES is displayed. If no connection was found, an "N" for NO is displayed. Notice that there is a "Y" for YES for zone 1. This is indicating that zone 1 — the tested zone — is connected to itself. No surprise! Notice that a connection between zone 2 and zone 1 — the tested zone — had been detected. This is powerful information. [continued on next panel]

ZPDa-56

[Intentionally left blank]

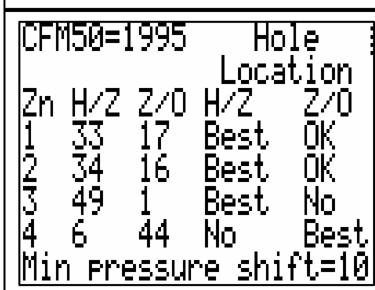
- If you select only one zone for your analysis (go back and look at panel ZPDa-10), the "Connect. To Test Zone" screen will not appear. Because of the one-zone analysis, there is no point in displaying a screen that will show you what you already know; the zone you tested is connected to itself.
- If you select two, three, or four zones to analyze, this Connect. To Test Zone" screen will only show that number of zones.
- Press ENTER.

ZPDa-57



- The program step above in panel ZPDa– 55, the connection display, is the last step of the program. You may end your testing of this house here by pressing "2" to return to the home screen of the ZPDa program — see panel ZPDa-58 — or you may test another zone or try a new opening size or type in the zone you just tested.
- If you press "1" for "YES", the program will take you back to the screen displayed in ZPDa-panel 58, showing the results of the blower door test with no opening made, the baseline and zone pressures, [continued on next panel]

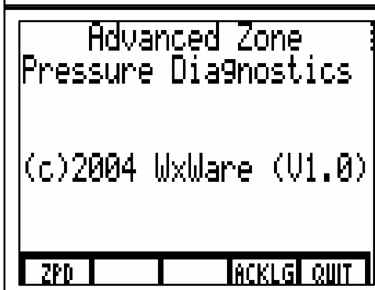
ZPDa-58



and the minimum pressure shift. If you have used one of the ZPDa forms during your analysis, it will be much easier to start again at this point and test another zone.

- The screen to the left is a reminder of the initial analysis setup. Proceed from here to test one, two, or three more zones based on your initial readings.

ZPDa-59



- If you select "2" for "NO" at the screen displayed in panel ZPDa-57, you will be taken back to the home screen for the ZPDa program displayed at the left. The initial data entered for the house you were analyzing will be lost.

ZPDa-60

[Intentionally left blank]

The Five Types of Temporary Openings*

When entering information about the temporary added openings, you will then need to select an opening type and enter an opening area in square inches (Note: As an exception here, you are not asked to enter the area if your opening selection is "Door"). Of the five opening types, the percent bias or the level of uncertainty increases from "orifice" to "rough opening". This means that if you use an "orifice" type opening there will be less uncertainty in your results than if you use a "hatch". The results from using a "hatch" type opening will be less uncertain than using a "rough opening". A level of bias or uncertainty does not apply to a "door" type opening for there is no need to determine the size of a door opening.

If you select the opening type that most closely represents the one you are actually using, the accuracy of your analysis will increase. There are five opening types to choose from.

<u>Orifice</u>
An orifice is defined as a carefully measured opening cut into a thin, flat material such as cardboard, sheet metal, or thin plywood. When you select "orifice", you will then be asked for opening size.

Some analysts carry a number of orifices with them to use during ZPD testing. These pieces of cardboard, sheet metal, or thin wood paneling are then fit into attic hatches and other existing openings for creating openings of a known size.

Other requirements of an orifice are:
- The smallest dimension of the opening should not be less than 10 times the thickness of the orifice material, for example, for ½-inch cardboard, the smallest opening dimension should not be less than 5 inches.
- The hole cut into the orifice should not be bigger than ½ the outside dimension of the orifice material, for example, for a 2-inch by 3-inch wide piece of plywood, the orifice hole should not have dimensions bigger than 1 inch by 1.5 inches.
- There should be no obstructions to airflow on either side of the opening within 2-times the largest dimension of the orifice opening, for example, for a 10-inch by 8-inch opening, no obstructions within 20 inches.

<u>Hatch</u>
A hatch is defined as a <u>fully opened</u> rectangular access hatch or small door with an easily measurable opening area. A typical attic hatch is an example. When you select "hatch", you will then be asked for opening size.

<u>Partial Opening</u>
A partial opening is defined as a <u>partially opened</u> access hatch or small door. The partial opening makes the opening area more difficult to measure. This might be an attic hatch that is lifted up at one side to create an opening.

<u>Rough Opening</u>
A rough opening is defined as a hatch or door with an irregular opening which makes it very difficult to accurately measure the opening area, for example, a partially opened hatch with fiberglass insulation attached to the back of the hatch door.

<u>Door</u>
Select this option when using a completely open, full-sized door as your opening. When selecting this option, you will not be asked to enter an opening size, and the opening area will not be used in the leakage estimate calculation.

Because the choice of a "door" type opening does not require the calculation or entry of the opening size, this entry eliminates the mathematical bias or uncertainty associated with the other opening types.

* Source: The Energy Conservatory's ZPD Calculation Utility (ZPDCU) Help section. This free Windows software is available at http://www.energyconservatory.com/products/products8.htm.

ZPDa Form for Single Test Zone

Advance Zone Pressure Diagnostics Testing for ZipTest Pro² Software

Initial Data Table				
Job #:	Job Name:		Analyst Name:	Date:
3 Baseline pressure readings: ( ) ( ) ( )			*Average Baseline:*	*Baseline flux:*
Blower Door Test Data with NO Opening				
Tout:	Tin:	Depressurization Test: ☐		Pressurization Test: ☐
House ΔP:	Blower ΔP:	Configuration: Open A B		*CFM_{50}:*

Zone Data with NO opening		Zone Pressure with NO opening Zone to Outdoors			Comments
Zone Name		Baseline Pascals	Pressure Pascals	*Pressure Diff, Pa*	
	House				
1					
Minimum pressure shift when adding opening:					

Zone Pressure Testing Data Table 1			(data gathered from making an opening)
ZPDa Test #:			
Blower Door Test Data with Opening			
House ΔP:	Blower ΔP:	Configuration: Open A B	*CFM_{50}:*

Zone Data with Opening					Zone Pressures with Opening Zone to Outdoors			Comments
Zone Name		Opening Location	Opening Type[1]	Opening Size, in²	Baseline Pascals	Pressure Pascals	*Pressure Diff., Pa*	
	House							
1		H/Z Z/O	OHPDR					

H/Z CFM_{50}: to	*Z/O CFM_{50}: to*	*Total Path CFM_{50}: to*
H/Z in² leakage: to	*Z/O in² leakage: to*	

Zone Pressure Testing Data Table 2			(data gathered from making an opening)
ZPDa Test #:			
Blower Door Test Data with Opening			
House ΔP:	Blower ΔP:	Configuration: Open A B	*CFM_{50}:*

Zone Data with Opening					Zone Pressures with Opening Zone to Outdoors			Comments
Zone Name		Opening Location	Opening Type[1]	Opening Size, in²	Baseline Pascals	Pressure Pascals	*Pressure Diff., Pa*	
	House							
1		H/Z Z/O	OHPDR					

H/Z CFM_{50}: to	*Z/O CFM_{50}: to*	*Total Path CFM_{50}: to*
H/Z in² leakage: to	*Z/O in² leakage: to*	

[1] Opening types are O=Orifice, H=Hole, P=Partial, D=Door, and R=Rough. See software instructions for explanation.
Values with names in *italics* are calculated by the ZPDa program, a part of the ZipTest Pro² software package.

ZPDa Form for Two through Four Test Zones

Advance Zone Pressure Diagnostics Testing for ZipTest Pro[2] Software

Initial Data Table					
Job #:	Job Name:		Analyst Name:		Date:
3 Baseline pressure readings: ( ) ( ) ( )			*Average Baseline:*		*Baseline flux:*
Blower Door Test Data with NO Opening					
Tout:	Tin:		Depressurization Test: ☐		Pressurization Test: ☐
House ΔP:	Blower ΔP:		Configuration: Open A B		*CFM₅₀:*

Zone Data with NO opening		Zone Pressure with NO opening Zone to Outdoors			Comments
Zone Name		Baseline Pascals	Pressure Pascals	*Pressure Diff, Pa*	
	House				
1					
2					
3					
4					
Minimum pressure shift when adding opening:					

Zone Pressure Testing Data Table 1 (data gathered from making an opening)			
ZPDa Test #:			
Blower Door Test Data with Opening			
House ΔP:	Blower ΔP:	Configuration: Open A B	*CFM₅₀:*

Zone Data with Opening						Zone Pressures with Opening Zone to Outdoors			*Connected to tested zone? Yes or No*
Zone Name		Test Zone	Opening Location	Opening Type[1]	Opening Size, in²	Baseline Pascals	Pressure Pascals	*Pressure Diff., Pa*	
	House								
1		☐	H/Z Z/O	OHPDR					*Y N*
2		☐	H/Z Z/O	OHPDR					*Y N*
3		☐	H/Z Z/O	OHPDR					*Y N*
4		☐	H/Z Z/O	OHPDR					*Y N*

H/Z CFM₅₀: to	*Z/O CFM₅₀: to*	*Total Path CFM₅₀: to*
H/Z in² leakage: to	*Z/O in² leakage: to*	

Zone Pressure Testing Data Table 2 (data gathered from making an opening)			
ZPDa Test #:			
Blower Door Test Data with Opening			
House ΔP:	Blower ΔP:	Configuration: Open A B	*CFM₅₀:*

Zone Data with Opening						Zone Pressures with Opening Zone to Outdoors			*Connected to tested zone? Yes or No*
Zone Name		Test Zone	Opening Location	Opening Type[1]	Opening Size, in²	Baseline Pascals	Pressure Pascals	*Pressure Diff., Pa*	
	House								
1		☐	H/Z Z/O	OHPDR					*Y N*
2		☐	H/Z Z/O	OHPDR					*Y N*
3		☐	H/Z Z/O	OHPDR					*Y N*
4		☐	H/Z Z/O	OHPDR					*Y N*

H/Z CFM₅₀: to	*Z/O CFM₅₀: to*	*Total Path CFM₅₀: to*
H/Z in² leakage: to	*Z/O in² leakage: to*	

[1] Opening types are O=Orifice, H=Hole, P=Partial, D=Door, and R=Rough. See software instructions for explanation.

Values with names in *italics* are calculated by the ZPDa program, a part of the ZipTest Pro[2] software package.

Instructions
for

Multi-Point Blower Door
and
Duct Blower Testing

(Power Regression Analysis)

INTRODUCTION

Using the "STAT" (statistics) feature of the calculator allows you to perform multi-point blower door testing with the use of power regression analysis. This feature calculates the house leakage curve, the house constant, the flow exponent, the correlation coefficient, solves for any house pressure or CFM, draws a scatter plot of the data points, draws the regression equation, and allows you to trace the regression equation line to find values. This process is explained in the following instructions.

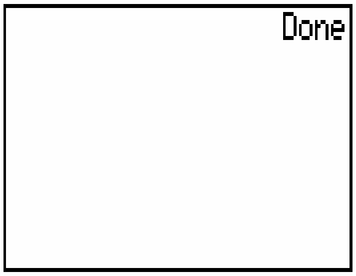
Multi-point duct blower analysis can also be performed.

Read the Chapters 11 and 14 in the Texas Instruments *TI-86 Graphing Calculator Guidebook* for more information about these features.

PROGRAM OPERATION

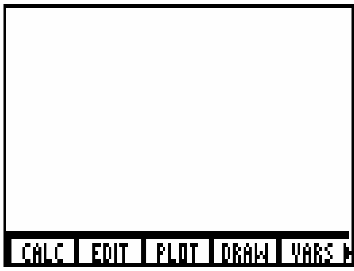
Follow the instructions beginning on page 85. Pictures of the TI-86 screens appear on the left side of pages 85 through 88 with explanations to the right of each picture.

Regress-1



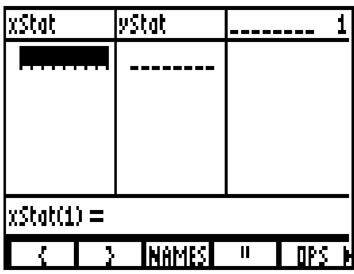
- When you turn your TI-86 calculator on, it is likely that the display will look liked this.
- This routine explained here is used for multi-point blower door or duct blower testing. Multi-point means that CFM flow readings are taken at different pressures, usually at least six different house pressures are used for a test.
- A regression analysis is performed on the data pairs. More on this latter.
- Press the **2nd** key (it is a pumpkin color) and then the **STAT** key (just above the **ENTER** key. The first function of this key is **+**).

Regress-2



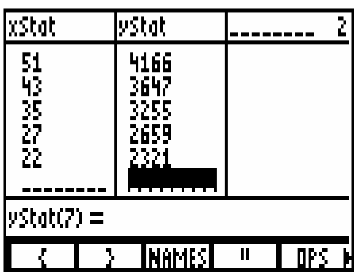
- You will see this menu on the screen.
- "CALC," **F1,** for calculating regressions.
- "EDIT," **F2,** for editing and entering data.
- "PLOT," **F3**, for plotting functions.
- "DRAW," **F4**, for graphing regression lines and scatter plot diagrams.
- "VARS," **F5,** lists all the statistical tests available.
- Notice the right-pointing arrow to the right of "VAR." This indicates more menu items, Press **MORE** to access "FCST," **F1** for forecasting.

Regress-3



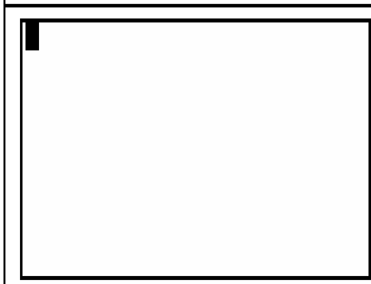
- Press **MORE** to return to the first menu set.
- Press **F2** for "EDIT".
- Notice the table on the display. We will use the first two columns only. Notice the number in the upper right corner signifying the column in which the cursor is located.
- The first column "xStat" will be used to signify house or duct pressure difference, ΔP, usually between the indoors and outdoors.
- The second column "yStat" will be used to signify blower door or duct analyzer CFM flow rate.

Regress-4



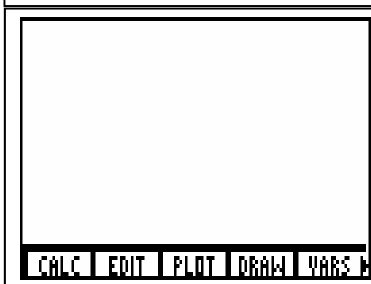
- Place the cursor on the first position in column one (where the 51 is at the left). Type in "51," house first house pressure. Press **ENTER** and then move the cursor to the first position in the second column. Type in "4166," the corresponding CFM flow at a ΔP of 51. Press **ENTER**.
- Continue to enter all six data pairs that you see to the left. These are the actual data pairs for a blower door test performed in Ohio.
- Notice that at the bottom left of the display, just above the menu, the location of the cursor is indicated along with your entry.

Regress-5



- The data pairs entered will remain here until you change them. If you need to change a number, place the cursor over the incorrect number, punch in the correct one, and press **ENTER**.
- Now that the data pairs are entered, we must perform a regression analysis on the data. The regression analysis line is often referred to as the house leakage curve. More on this later.
- To perform the regression analysis, we must exit this screen and come back again—clumsy, isn't it? Press the **EXIT** key and you will see a blank screen.

Regress-6

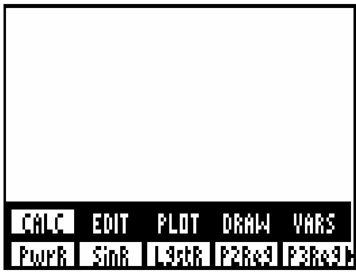


- OK, here we go. Press the **2nd** key and then the **STAT** key.
- You will see the **STAT** menu screen, as at the left.
- Press **F1** for "CALC" to the we can perform the regression analysis on the data pairs that we entered at panel "Regress-4." The data we entered is still there, if you want to make sure, press **F2** for "EDIT." If you check on this, you must exit again and then go back to the **STAT** menu to perform the regression analysis. The designers at Texas Instruments won't allow us to go to the "CALC" function directly from the "EDIT" function.

Regress-7

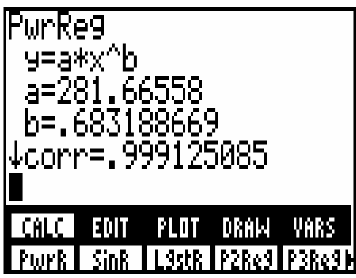
- Press **F1** for "CALC." Notice that the primary menu moves up and a secondary menu is displayed for "CALC" (notice that "CALC" is highlighted).
- At the right-most menu item, **F5** "ExpR" there an arrow pointing to the right indicating that there are more menu items. Press the **MORE** key to go to the next set of five menu items on the "CALC" secondary menu.

Regress-8



- We must perform a <u>power</u> regression analysis on the data pairs. This is because a power regression fits the model of our flow equation: CFM = HC x ΔP^{Fx}, where CFM = cubic feet per minute flow rate; HC = the house constant (the flow rate when ΔP = 1); ΔP = the pressure difference between the indoors and outdoors; and Fx = the flow exponent, which is dependent upon the type of hole through which the air is flowing. Fx usually is between 0.5 (large openings, thus turbulent air flow) and 1.0 (small cracks, thus laminar air flow).

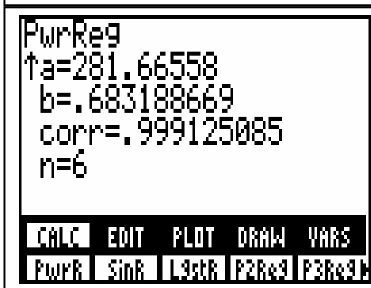
Regress-9



- Press **F1** "PwrR" (second menu set for "CALC") and then **ENTER** to perform a power regression analysis on the data pairs we entered.
- After a few seconds you will see the display at the left.
- "PwrReg" indicates that we performed a power regression on the data.
- "y=a*x^b" indicates the equation form (see panel "Regress-8").
- "a=281.66558" is the house constant, the CFM flow rate when ΔP = 1.
- "b=.683188669" is the flow exponent (see panel "Regress-8"). If we performed blower door tests on 100 dwellings, we would find

[continued on next panel]

Regress-10



that the average flow exponent would be 0.65, so we assume an 0.65 flow exponent when we do a single-point blower door test. But when we do a multi-point test, the power regression analysis determines the specific flow exponent for the house. As we weatherize a house, the flow exponent changes because we alter the character of the holes through which the air flows.

- The display has been scrolled down one from that displayed in panel "Regress-9" in order to display the last line.

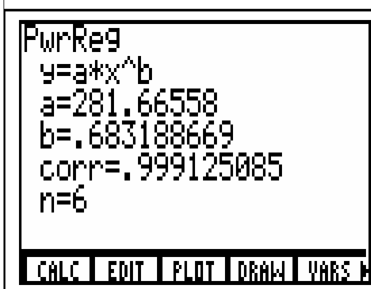
[continued on next panel]

Regress-11

[intentionally left blank]

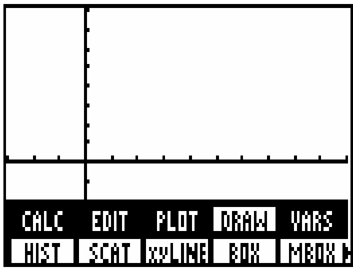
- "corr=.999125085" is the correlation coefficient. This number should be 0.99 or greater. If it is less than 0.99, do the blower door testing again. A value of less than 0.99 indicates a bad fit of the data pairs to the house leakage curve. Windy conditions often cause a correlation coefficient value to be less than 0.99.
- "n=6" simply indicates the number of data pairs we entered. It is suggested you use six to eight data pairs for a blower door or duct blower multi-point test.

Regress-12



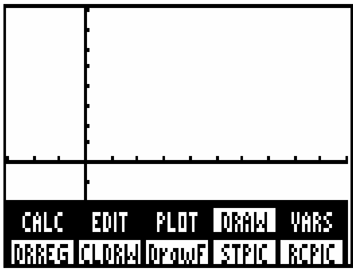
- Press **EXIT** one time. This will hide the secondary "CALC" menu sets.
- If you need to correct the data pairs or enter new ones for a different house, press **F2** for "EDIT" (see panels "Regress-4" through "Regress-6").
- Now, let's see what else we can do with our data pairs.
- Press **F4**, "DRAW" to go to the "DRAW" secondary menu so that we can draw the house leakage curve.

Regress-13



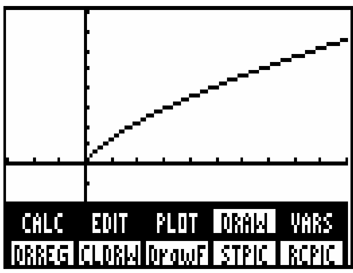
- You will see the screen at the left. Notice the secondary "DRAW" menu ("DRAW" is highlighted).
- **F2**, "SCAT" draws a scatter diagram of the data pairs. Try it.
- **F3**, "xyLINE" connects the data pairs with a line. Try it.
- Notice that there is a right-pointing arrow in the right-most sub-menu cell, indicating that there is another menu set.
- Press **MORE.**

Regress-14



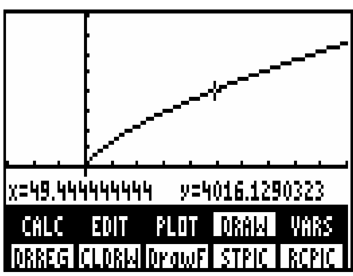
- The secondary menu set has now changed.
- The two items that are useful to use in the secondary menu are **F1,** "DRREG" (draw regression line) and **F2**, "CLDRW" (clear drawing).
- The parameters of the graphing functions of the TI-86 are set so that the regression drawing—the house leakage curve—will fit within the pictured x and y coordinates.
- Press **F1,** "DRREG."

Regress-15



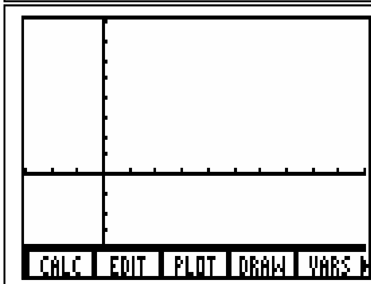
- Within a few seconds you will notice that the house leakage curve appears on the screen. The vertical axis, y, represents CFM flow, the horizontal axis, x, represents ΔP.
- The "DRAW" features use the most recent blower door test data entered.
- If you want to watch the line drawing again, press **F2**, "CLDRW" to clear the drawing and then press **F1,** "DRREG" again. Some ZipTest Pro² users have become addicted to this action, so be cautions, don't overdo it!
- All the data pairs fall on the regression line.

Regress-16



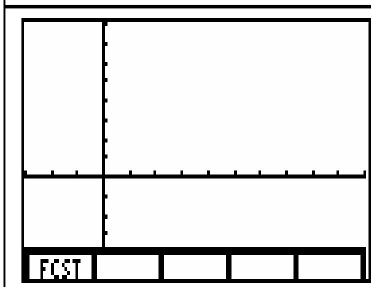
- Now for some more fun, press the up cursor key. You will notice the crosshair cursor moving upward and the x (ΔP) and y (CFM flow) coordinates appear above the menu bars. Tracing the leakage curve with the cursor characterizes the house for which you have entered data.
- When you are finished with this intriguing feature, press **F2,** "CLDRW" to clear the drawing.
- Now press **EXIT** once to hide the secondary "DRAW" menu.

Regress-17



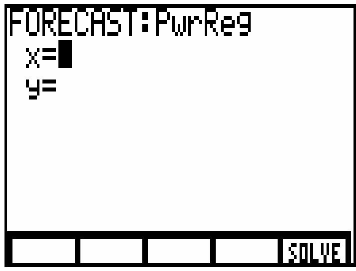
- Now you will see the primary "STAT" menu and the x and y coordinates on the screen.
- Notice that there is another menu set indicated by the right-pointing arrow in the right-most menu cell.
- Press the **MORE** key once to move to the next menu set.

Regress-18



- The only menu item in this set is **F1**, "FCST" (forecast).
- This is a very powerful feature that allows precise movement along and beyond the house leakage curve. If we enter any value for x (ΔP), we can find any corresponding y (CFM flow) value. If we enter any value for y (CFM flow), we can find any corresponding value for x (ΔP). This allows us to find CFM_4 for effective leakage area (ELA), CFM_{10} for equivalent leakage area (EqLA), or CFM_{50}

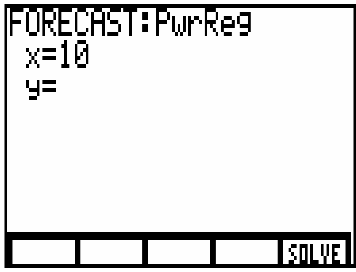
Regress-19



- Notice the menu structure changes. This is the forecast function. It utilizes the most recent blower door data pairs entered. **Note: You must do a power regression calculation ("CALC" and then "PwrR") before you can forecast with the entered data.**
- The only menu item is at **F5**, "SOLVE." When you press **F5**, "SOLVE," the forecast feature will solve for x (DP) or y (CFM flow). After you enter a value for x or y, position the cursor on the other line and press **F5** for the solution.

This is very important!

Regress-20

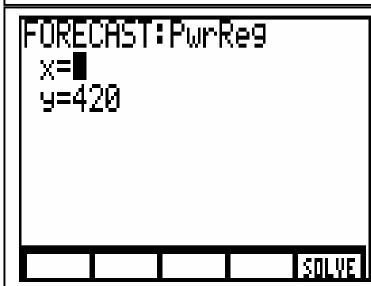


- Let's try an example.
- At "x" enter the building pressure for which you want a CFM flow. For our example, enter "10" Pascals of building pressure.
- Press **ENTER** or the down arrow once to move the cursor to the y position. Remember, y is the CFM for at the corresponding ΔP entered at "x=".

Regress-21

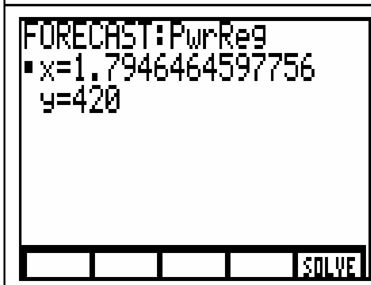
- Press **F5**, "SOLVE," for the answer or "1358." In other words, the CFM_{10} of this house is 1358.
- This can now be plugged into the Equation Nugget "AEQLA" (see panel Nugget-53 on page 99) to find the equivalent leakage area (EqLA) of this house.
- You can also find the CFM_4 for this house with this forecast function. The CFM_4 is needed to find the effective leakage area (ELA) (see panel Nugget-52 on page 99).

Regress-22



- Now let's try something else that is useful to know.
- Let's assume that this house has a total actual exhaust rate from all the exhaust appliances (kitchen fans, bathroom fans, vented dryer, etc.) of 420 CFM. Because the forecast function finds points on the house leakage curve, if we know the value for y, a CFM flow rate (in this case, 420), we can find the corresponding value for x—the resulting ΔP.
- Enter "420" at "y=" and then move the cursor up to the "x=" line. If you want to clear a previous x entry, press **CLEAR**, but you don't have to.

Regress-23



- Press **F5,** "SOLVE," to solve for the corresponding x value, ΔP.
- The resulting "1.7946" is not enough to cause a problem. After all, this is a house that is quit leaky; it probably has not yet been weatherized. Of course, this value for x is a negative ΔP, although a negative sign is not shown before the 1.7946.
- Let's look at this in another way. We can find the Depressurization Tightness Limit (DTL) for this house. This is the exhaust fan rate above which backdrafting of natural draft appliances might backdraft.

Regress-24

- The maximum ΔP allowed by many audit and weatherization programs is -5, meaning negative pressure in excess of -5 Pascals creates a possible hazard to occupants from backdrafting combustion gases.
- Enter "5," not "-5." Move the cursor to "y=" and press **F5,** "SOLVE."
- We have found that the Depressurization Tightness Limit (DTL) for this house is 846 CFM. In other words, exhaust fans totaling more than 846 CFM may cause combustion appliance backdrafting.
- If this house is tightened, this DTL will be reduced. Press **EXIT** to leave "STAT."

Instructions
for

Equation Nuggets

April 2004 (V3.2)

INTRODUCTION

The fifty equations loaded into the SOLVER equation section were selected for their relevance to building diagnostics in both the residential and commercial sectors. Each of the equations is explained in this chapter. There is a three-page list of the equations at the end of this chapter that includes the equation names and the equations exactly as they are entered in the calculator. This might be a helpful list to carry around with you when you are analyzing dwellings.

The powerful SOLVER equation feature of the TI-86 calculator allows you to solve for <u>any</u> of the variables of an equation as long as values for all of the other variables are entered. No rewriting of the equation is necessary. You can do "what if" analysis, guess answers and quickly find the right one.

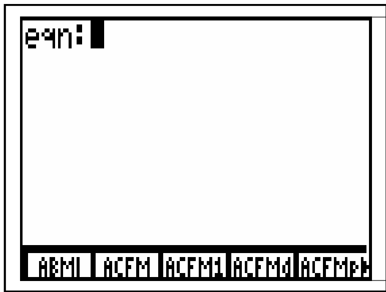
An extremely useful feature of the TI-86 calculator is that variable values from one equation or program are automatically saved to memory until the value is changed by a new value keyed in by the user. A few examples for clarity: If you wish to calculate the dew point temperature of the air in a building, you must first use SOLVER equation "AHRAT" to calculate the humidity ratio, the variable for which is "HuRa." If you solve for "HuRa" and then move to the SOLVER Equation Nugget "ADEWP," the variable "HuRa" in this second equation will not have to be entered, it will already be there.

A second example of this memorized-variable-value feature: You are performing zone pressure diagnostics on a building with the use of the pressure diagnostics (Press) program in the TI-86 calculator. Using the "hole method" you find the building-to-zone pressure is 37 Pascals and the zone-to-outside pressure is 13 Pascals. You enter each of these as program inputs to find building-to-zone, zone-to-outside, and total-path CFM_{50} values. Now you want to find the building-to-zone leakage as a percentage of the zone-to-outside leakage. When you call up the SOLVER Equation Nugget "ASERP" for this purpose, you will find that the needed building-to-zone and zone-to-outside pressure values are already loaded for you; no need to enter them.

Equation Selection

The EQUATION NUGGETS were collected and programmed by Rick Karg of WxWare Diagnostics, a division of R.J. Karg Associates, with the valuable help of Neil Moyer.

Nugget-1



- Activate the TI-86 be pressing the **ON** button.
- Press the light orange **2nd** button, and then press the **SOLVER** button (this is the second function of the **GRAPH** button).
- You will see the screen at the left. The first menu set of equations available to you are displayed at the bottom of the screen. **Each useful SOLVER equation begins with the letter "A."** The equations are listed in alphabetical order. Press the **MORE** button.

Nugget-2

- The second menu set of five SOLVER equation names is displayed.
- For a quick overview of all fifty equations, refer to the equations lists on pages 107 through 109.
- Press the **MORE** button.

Nugget-3

- The third menu set of five SOLVER equation names is displayed.
- Press the **MORE** button.

Nugget-4

- The fourth menu set of five SOLVER equation names is displayed.
- Press the **MORE** button.

Nugget-5

- The fifth menu set of five SOLVER equation names are displayed.
- Press the **MORE** button.

Nugget-6

- The sixth menu set of five SOLVER equation names is displayed.
- Press the **MORE** button until you have gone through all the equations—fifty on ten menu sets—that begin with "A." **Equations after this (that do not begin with "A") are not intended for your use here.**
- You can freely move through this list of SOLVER equations to get to the equation you need.
- Press **MORE** until you get back to the first set of five SOLVER equations, beginning with "ABMI."

This is very important!

Nugget-7

- Press the orange **2nd** button, and then press the **RCL** (recall) key (this is the second function of the **STO>** key). **This is the method you <u>must</u> use to call up a SOLVER equation; there is no other way.** You cannot just press the chosen menu key without the **RCL** key.
- You will see the screen at the right displayed on you calculator.
- Notice the "Rcl" (recall) is displayed at the bottom left just above the equation menu.
- Press **F1** for "ABMI."

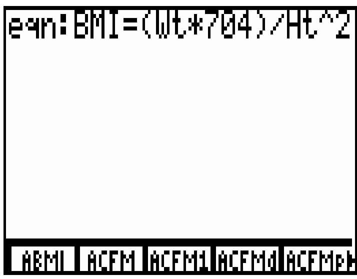
This is very important!

Nugget-8

- Notice that "ABMI" is now displayed at the bottom of your screen to the right of "Rcl".
- Press **ENTER**.

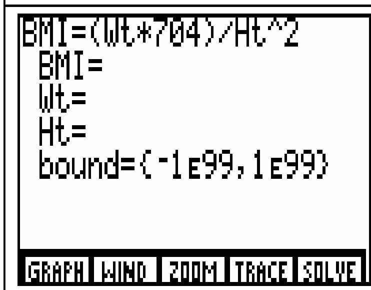
- <u>**ABMI** is the body mass index equation.</u> It has nothing to do with building diagnostics; it will show you whether you are a healthy weight (BMI less than 25), overweight (BMI from 25 to 30), or obese (BMI above 30). It is important that building diagnosticians watch their weight, right?

Nugget-9



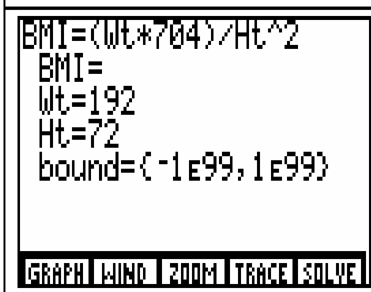
- The "ABMI" equation is now loaded into the SOLVER feature of the calculator; the SOLVER working area.
- This powerful feature allows you to solve for any variable in the equation if you enter values for all the other variables (there is no need to rewrite the equation to do this).
- Notice that the equation seems to extend beyond the right side of the screen. Use your right arrow (cursor) button to view the rest of the equation. Use the left arrow button to move back.

Nugget-10



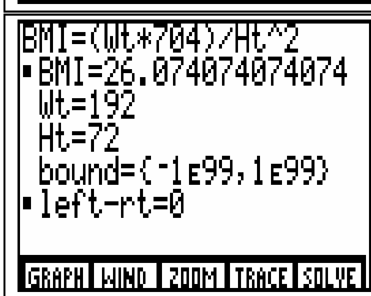
- Press the down arrow button once or the **ENTER** button.
- The three variables for this equation — "BMI, Wt," and "Ht" — are listed.
- Ignore the "bound" line of information.
- Notice that the menu changed at the bottom of the screen when you pressed **ENTER** or the down arrow button once. Of these displayed menu features, "SOLVE" is the one you will use the most. For instructions regarding "GRAPH, WIND, ZOOM," and "TRACE," see the TI-86 instruction manual.

Nugget-11



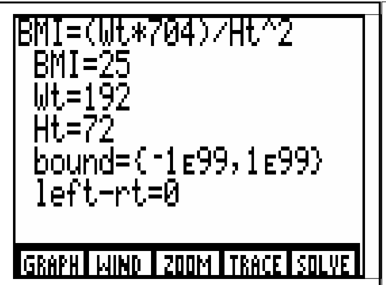
- Let's assume you weigh 192 pounds and you are six feet tall (72 inches). Let's find your body mass index to determine if you are a healthy weight.
- Enter 192 on the "Wt" (weight) line. This should be in units of pounds. Move the cursor to the proper line with the cursor arrow keys on the TI-86.
- Enter 72 on the "Ht" (height) line. Your height must be entered in units of inches.
- **If you make a mistake, just type over it or position the cursor over the mistake and press the DEL (delete) button.**

Nugget-12



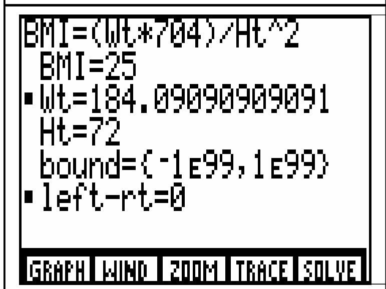
- Now move the cursor to the line for "BMI" (body mass index).
- With the cursor on the "BMI" line, press **F5** for "SOLVE."
- The body mass index is just over twenty-six. You're overweight!
- Let's find out what your weight must be to have a healthy BMI of 25.
- Go to the next panel, "Nugget-13."

Nugget-13



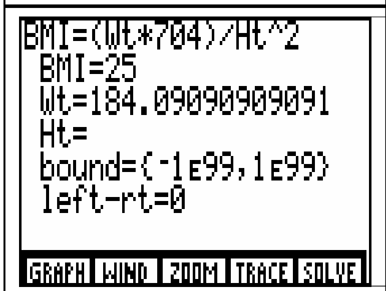
- Enter 25 on the "BMI" line.
- Move the cursor to the "Wt" line below. There is no need to clear the "192" value from the previous example. You may do so by pressing the **CLEAR** key; this clears the line where the cursor is located.
- With the cursor on the "Wt" line, press **F5** for "SOLVE."

Nugget-14



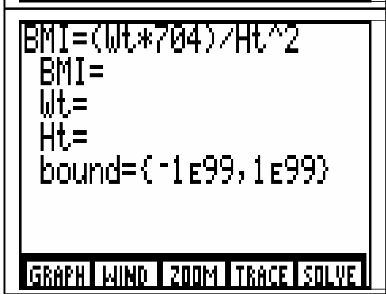
- You see that you must get your weight down to 184 pounds for a body mass index of 25.
- The body mass index can be helpful and fun at parties, but the important point here is getting the Equation Nuggests to work for you. Notice that you can solve for any of the variables by assigning values to the others—a very powerful feature!
- Notice the small black square to the left of "Wt," indicating the last variable for which you pressed the **F1**, "SOLVE."

Nugget-15



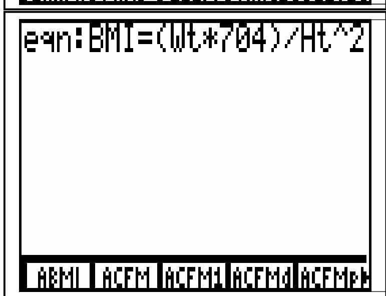
- It is recommended that you delete the values for each variable before you move on to another Equation Nugget. This frees memory in the calculator.
- Place the cursor on the "Ht" line and then press the **CLEAR** key. The value for the "Ht" variable will be deleted.

Nugget-16



- Now delete the variable values for the others, "Wt" and "BMI."

Nugget-17



- Move the cursor to the top line. Notice that the lower lines disappear.
- **It is very important to delete one Equation Nugget from the working area of the SOLVER function before you load another one into the working area.** One equation loaded over another can result in the mixing of the equation variables, yielding strange and meaningless answers.
- So, with the cursor on the top line, press **CLEAR**.

This is very important!

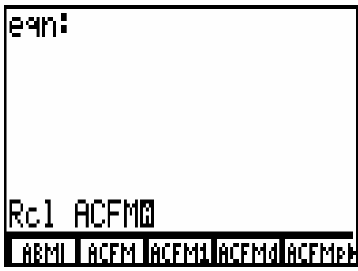
Nugget-18

- Now the calculator is ready to load another Equation Nugget in the working area of SOLVER.

Nugget-19

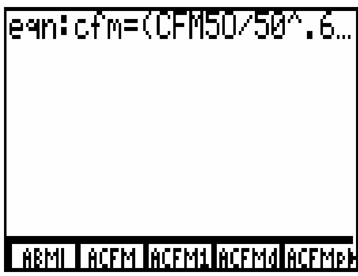
- Let's try the next Equation Nugget.
- Press the orange **2nd** key and then the **RCL** key. You will see the "Rcl" (recall) at the bottom left of the display, as on the example display at the left.
- Press F2 for "ACFM."

Nugget-20



- Notice that "ACFM" is now displayed at the bottom of your screen to the right of "Rcl".
- Press **ENTER**. The **"**ACFM" equation is now loaded into the SOLVER feature of the calculator.

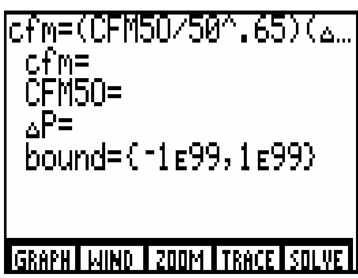
Nugget-21



<u>ACFM (pressure created by exhaust devices)</u>
cfm = cubic feet per minute of exhaust appliances.
CFM50 = blower door test results at 50 Pascals pressure.
ΔP = pressure difference between indoors and outdoors created by operation of exhaust fans (shown as positive number, but actually is negative).

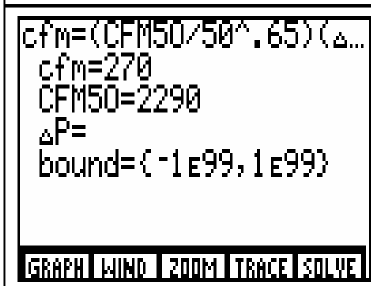
- Press the down arrow button once or the **ENTER** button.

Nugget-22



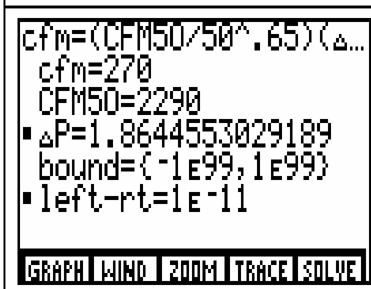
- The three variables for this equation—cfm, CFM50, and ΔP—are listed.
- Ignore the "bound" line of information.
- Notice that the menu changed at the bottom of the screen when you pressed **ENTER** or the down arrow button once. Of these displayed menu features, "SOLVE" is the one you will use the most. For instructions regarding "GRAPH, WIND, ZOOM," and "TRACE," see the TI-86 instruction manual.

Nugget-23



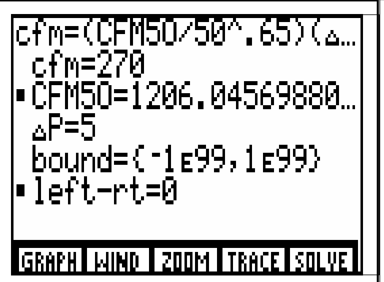
- Let's assume a 1500 square foot dwelling with a CFM_{50} of 2290 has a kitchen vent fan (100 cfm) and a bathroom vent fan (50 cfm). Will venting the existing unvented dryer cause excessive negative pressure in the house? We can't actually test for this until the dryer is vented. This equation can help. The existing exhaust fans plus 120 cfm for the dryer add up to 270 cfm if they are all operating at the same time.
- Enter 270 on the "cfm" line.
- Enter 2290 on the "CFM50" line.

Nugget-24



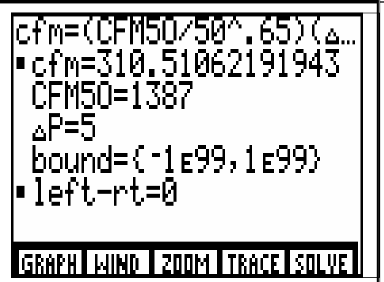
- Move from line to line by using the arrow buttons.
- If you make a mistake, just type over it or position the cursor over the mistake and press the DEL (delete) button.
- Move the cursor to the "DP" line.
- With the cursor on the "DP" line, press F5, "SOLVE."
- The house pressure created by all the included exhaust appliances running at the same time is displayed (this equation assumes a building flow exponent of 0.65. If you know the actual building flow exponent value, you may change the equation).

Nugget-25



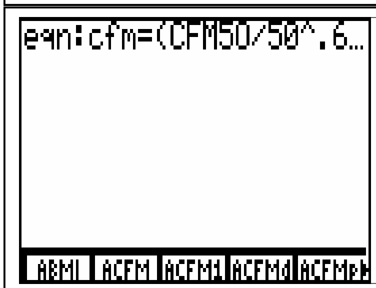
- You may solve for any of the three variables in this equation.
- Notice that a small, square bullet is displayed to the left of the variable for which you last solved.
- Another example: Suppose we assume that -5 Pascals is the highest negative pressure this building can tolerate without backdrafting problems. Enter 5 on the "ΔP" line (no need to enter a negative sign).
- Move the cursor to the "CFM50" line and press "SOLVE," **F5**. We have found that if we tighten to 1206 CFM_{50}, the exhausting units will create a -5 Pa.

Nugget-26



- Another example: Let's assume the Building Tightness Limit (BTL) for this house is 1387 CFM_{50} (this can be calculated with the BTL or BTLa programs loaded in your TI-86 calculator). Enter "1387" on the "CFM50" line.
- We want to find the maximum cfm we can exhaust from this building without creating more than -5 Pascals of pressure.
- With 5 entered on the "∆P" line, move the cursor up to the "cfm" line. Press "SOLVE," **F5**, to find the answer of 310 cfm.
- Now delete the variable values on the three variable lines.

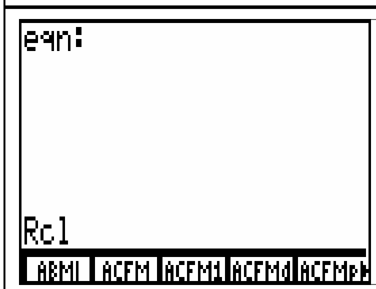
Nugget-27



- Move the cursor up to the top line, the equation line. You may change the equation for your use, but your changes will be temporary. You cannot change the equation in the memory, so the next time you call it up, the answer will not reflect your changes.
- **NOTE: Before calling another equation up, locate the cursor on the equation line (the top line) and press the CLEAR button (just below the down arrow button). This is very important.**

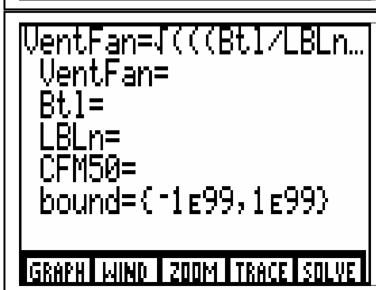
This is very important!

Nugget-28



- The equation is cleared.
- To call another equation, press the light orange **2nd** button, and then press the RCL button (this is the second function of the **STO>** button).
- Your screen will look like the picture at the left.
- When you press one of the menu buttons at the bottom of the screen, the SOLVER equation name will appear to the right of "Rcl." Then press **ENTER** to load that equation into the SOLVER.
- The **MORE** button advances the SOLVER equation menu.

Nugget-29



- The next Equation Nugget is "ACFM1."

<u>**ACFM1** (determination of vent fan size when house is "too tight")</u>

VentFan = required cfm of continuously operating exhaust fan.

Btl = Building Tightness Limit as determined with the "BTL1" program, BTL routine (a program loaded with the ZipTest Pro² software).

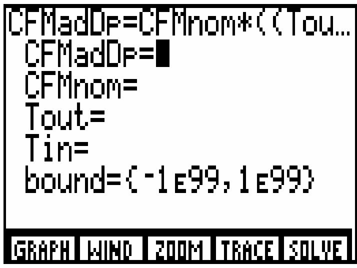
LBLn = Lawrence Berkeley Lab. correlation number as determined by the BTL program.

CFM50 = actual blower door test result at 50 Pascals of pressure.

Nugget-30

- For example, assume the "Btl" = 1300, the "LBLn" = 15, and "CFM50" = 900. The house is tighter (900 CFM_{50}) than the Building Tightness Limit (1300 CFM_{50}). Because of this, the building requires continuously operating ventilation when the house is closed up.
- Solving for "VentFan," we find that the required fan CFM is about 62.
- Now clear the variable values and the equation on the top line. We will now move on to the next equation.

Nugget-31



<u>**ACFMd** (*depressurization* blower door result temperature-adusted)</u>

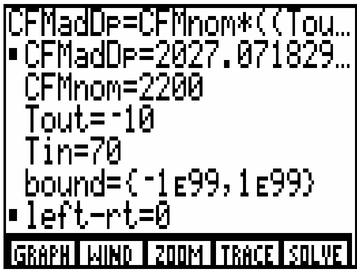
CFMadDp = blower door CFM temperature adjusted for **depressurization** test.

CFMnom = nominal blower door reading before temperature adjustment.

Tout = temperature indoors, °F.

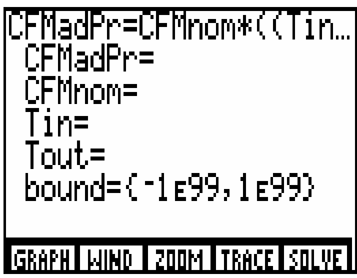
Tin = temperature outdoors, °F.

Nugget-32



- For example, assure the "CFMnom" = 2200, "Tout" = -10, and "Tin" = 70. Note that to enter a negative number you must use the key to the left of the **ENTER** key, not the subtraction key that is two above the **ENTER** key.
- Move the cursor to the "CFMadDp" line and press **F5** for "SOLVE."
- The temperature-adjusted CFM is 2027, less than the nominal 2200. This adjustment is for a depressurization test.
- Clear the variable values and the equation before moving on to another.

Nugget-33



<u>**ACFMp** (*pressurization* blower door result temperature-adusted)</u>

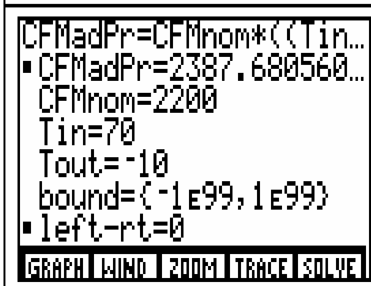
CFMadPr = blower door CFM temperature adjusted for **pressurization** test.

CFMnom = nominal blower door reading before adjustment.

Tout = temperature indoors, °F.

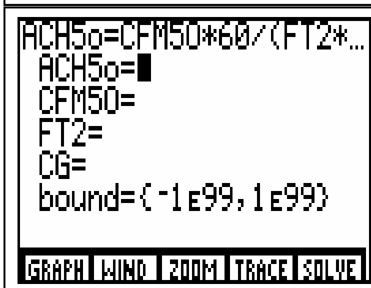
Tin = temperature outdoors, °F.

Nugget-34



- For example, assure the "CFMnom" = 2200, "Tout" = -10, and "Tin" = 70. Note that to enter a negative number you must use the key to the left of the ENTER key, not the subtraction key that is two above the ENTER key.
- Move the cursor to the "CFMadPr" line and press **F5** for "SOLVE."
- The temperature-adjusted CFM is 2387, more than the nominal 2200. This adjustment is for a pressurization test.
- Clear the variable values and the equation before moving on to another.
- Press MORE to move to the next set of five Equation Nuggets.

Nugget-35



<u>**ACH50** (air changes per hour at 50 Pascals building pressure from CMF_{50})</u>

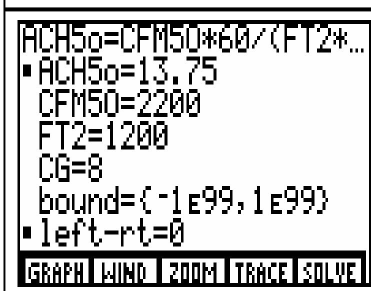
ACH5o = is air changes per hour at 50 Pascals of building pressure.

CFM50 = is the CFM of the building at 50 Pascals of building pressure.

FT2 = is the square feet of occupied building area.

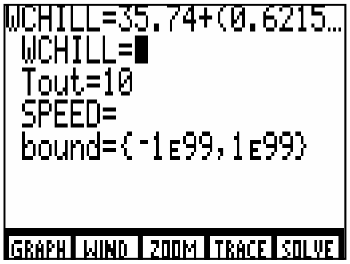
CG = is the ceiling height (FT2 x CG = volume).

Nugget-36



- For example, if the ceiling height, "CG," is 8 feet, the square footage of the conditioned house, "FT2," is 1200, and the "CFM50" is 2200, the "ACH5o" value is 13.75. This is the Air Change per Hour at 50 Pascals of pressure difference between the indoors and outdoors.

Nugget-37



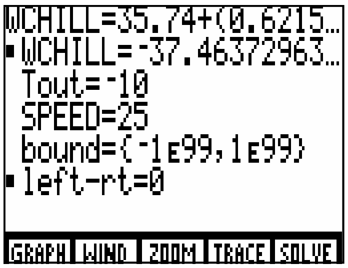
<u>ACHIL (equivalent wind chill temperature)</u>

Tout = temperature in degrees Fahrenheit. If the temperature is below zero, enter a negative sign before the number (you must use the negative-sign button to the left of the **ENTER** button).

SPEED = wind speed in miles per hour (this can be calculated with the "AIRSP" equation included in the Equation Nuggets).

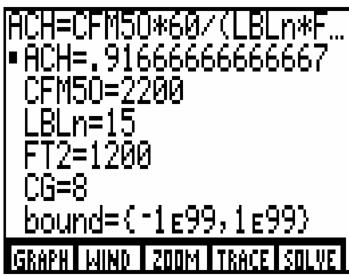
- This is the wind chill temperature spoken of by weather forecasters.

Nugget-38



- Try the example displayed at the left. Remember that the negative temperature "Tout" must be entered by using the **(-)** key to the left of the **ENTER** key.
- Note: This wind chill equation has been used since 2001 by the National Weather Service.

Nugget-39



<u>ACHN (building air change per hour at natural pressure)</u>

CFM50 = CFM_{50} from the blower door test.

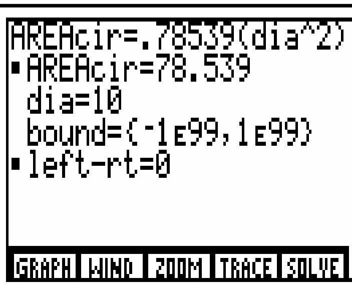
LBLn = Lawrence Berkeley Laboratory correlation factor. This number is displayed by the Building Tightness Limits "BTL1" program, "BTL" routine.

FT2 = square footage of the house.

CG = ceiling height (FT^2 x CG = volume).

- Run through the example at the left, solving for "ACH."

Nugget-40



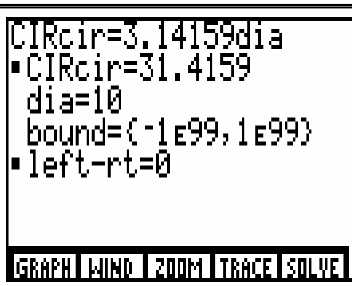
<u>ACIRa (area of a circle)</u>

AREAcir = the area of the circle.

dia = diameter of circle.

- Work out the example at the left.

Nugget-41



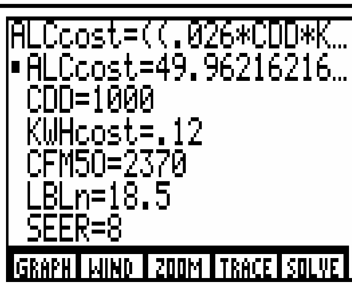
<u>ACIRc (circumference of a circle)</u>

CIRcir = the circumference of the circle.

dia = diameter of circle.

- Work out the example at the left.

Nugget-42



<u>ACLG1 (annual cooling cost of air leakage)</u>

ALCcost = annual cooling cost in dollars.

CDD = cooling degree days.

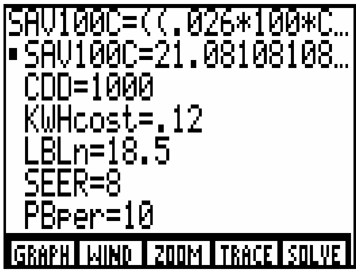
KWHcost = kiloWatt hour cost of electricity.

CFM50 = CFM_{50} from the blower door test

LBLn = Lawrence Berkeley Laboratory correlation factor. This number is displayed by the Building Tightness Limits "BTL1" program, "BTL" routine.

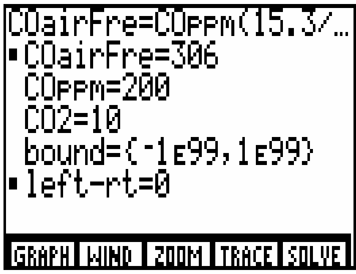
SEER = seasonal energy efficiency ratio for cooling equipment.

Nugget-43



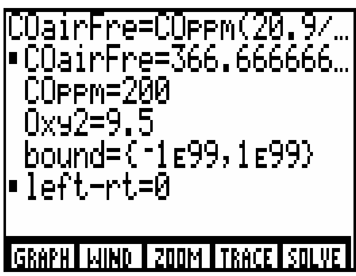
ACLG2 <u>(cooling cost-effectiveness guideline for air sealing)</u>
SAV100C = cooling cost-effectiveness guideline per 100 CFM_{50} reduction.
CDD = cooling degree days.
KWHcost = kiloWatt hour cost of electricity.
LBLn = Lawrence Berkeley Laboratory correlation factor. This number is displayed by the Building Tightness Limits "BTL1" program, "BTL" routine.
SEER = seasonal energy efficiency ratio for cooling equipment.
PBper = reasonable payback period for weatherization measure.

Nugget-44



ACO2O <u>(air-free carbon monoxide from as-measured carbon monoxide and carbon dioxide for a number 2 oil appliance)</u>
COairFre = air-free carbon monoxide in units of parts per million (ppm).
COppm = as-measured carbon monoxide in units of ppm.
CO2 = percentage carbon monoxide in flue gas (as a percentage, i.e. enter 10% as 10, not as 0.10).

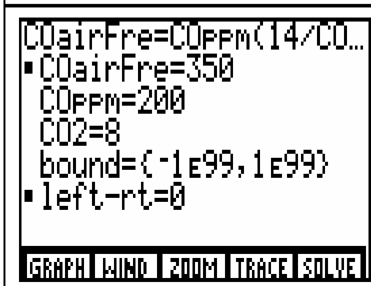
Nugget-45



ACOAR <u>(air-free carbon monoxide from as-measured carbon monoxide and oxygen percentage in flue gas, any fuel)</u>
COairFre = air-free carbon monoxide in units of parts per million (ppm).
COppm = as-measured carbon monoxide in units of ppm.
Oxy2 = percentage of oxygen in measured air sample (enter 9.5% as 9.5).

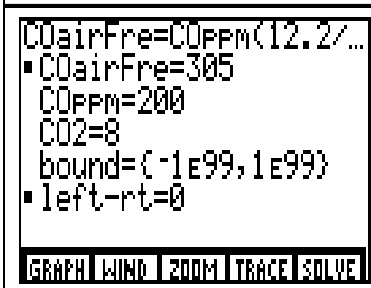
- Comment: To find a CO air free value in a vent, for example, measure the ppm concentration of CO in the vent. Then measure the percent oxygen. Use this equation to find the air-free level of carbon monoxide.

Nugget-46



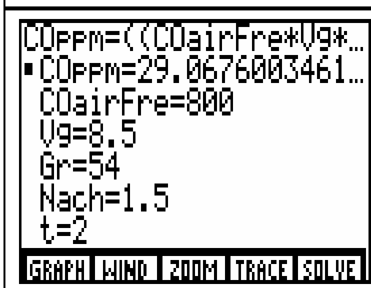
ACOLP <u>(air-free carbon monoxide from as-measured carbon monoxide and carbon dioxide for a liquified propane, LP, appliance)</u>
COairFre = air-free carbon monoxide in units of parts per million (ppm).
COppm = as-measured carbon monoxide in units of ppm.
CO2 = percentage carbon monoxide in flue gas (as a percentage, i.e. enter 8% as 8, not as 0.8).

Nugget-47



ACONG <u>(air-free carbon monoxide from as-measured carbon monoxide and carbon dioxide for a natural gas appliance)</u>
COairFre = air-free carbon monoxide in units of parts per million (ppm).
COppm = as-measured carbon monoxide in units of ppm.
CO2 = percentage carbon monoxide in flue gas (as a percentage, i.e. enter 8% as 8, not as 0.8).

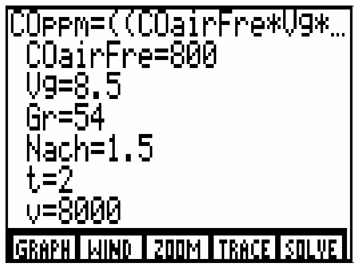
Nugget-48



ACORM <u>(for determining the carbon monoxide concentrations in a room from an unvented natural gas or propane appliance, such as a gas range/oven)</u>
COppm = resulting room CO concentration in parts per million (ppm).
COairFre = air-free CO released from gas appliance in ppm.
Vg = ft^3 of flue gas per ft^3 of fuel gas (8.5 ft^3 for natural gas, 21.8 ft^3 for propane).
Gr = gas flow rate in ft^3/hr. This equals $\frac{\text{input rate (Btu/hr)}}{\text{heat value of fuel (Btu/ft}^3\text{)}}$

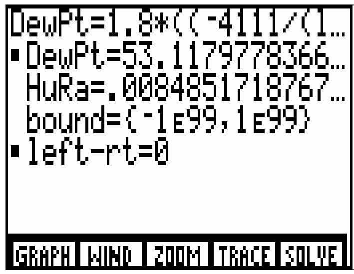
See next panel

Nugget-49



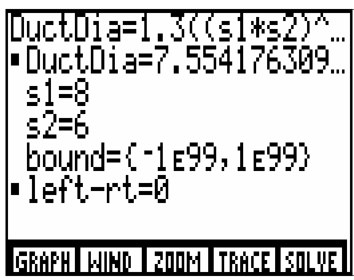
ACORM continued. (display is scrolled one line from panel "Nugget-48" at the bottom of the previous page).
Nach = natural air changes per hour of room or of house.
t = time interval, in hours.
v = volume of room or of house, in ft^3.

Nugget-50



ADEWP (dewpoint temperature determination)
DewPt = air dew point temperature, ^{0}F.
HuRa = humidity ratio, the ratio of the mass of water vapor to the mass of dry air. Also called the mixing ratio. Note: the humidity ratio is caluculated by the "AHRAT" Equation Nugget by inputting air temperature and relative humidity.

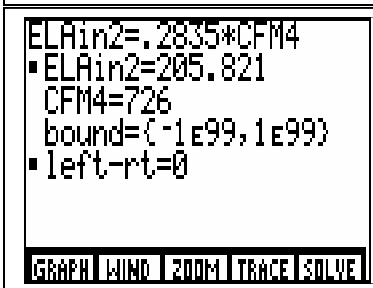
Nugget-51



ADUCT (round duct diameter to rectangular)
DuctDia = equivalent round duct diameter.
s1 = one rectangular dimension of the duct .
s2 = other rectangular dimension of the duct.

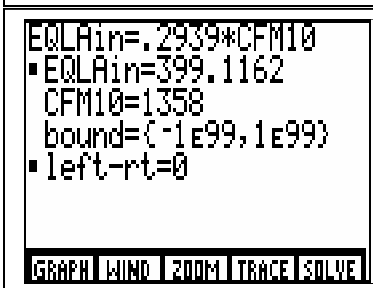
- Remember, you can enter any two variables here and solve for the third. This is a very useful equation for ductwork design, installation, and retrofit.

Nugget-52



AELA (effective leakage area from CFM_4)
ELAin2 = Effective Leakage Area, in^2 (Lawrence Berkeley Labs).
CFM4 = CFM at 4 Pascals of building pressure. This value can be calculated using a multi-point blower door test. You must know the house constant and the "Fx" number (flow exponent). This is explained later in this instruction document and can be calculated with a blower door and the TI-86 calculator. The Equation Nugget "AIREQ" is also useful for this calculation. This test was developed by Lawrence Berkeley Laboratory.

Nugget-53



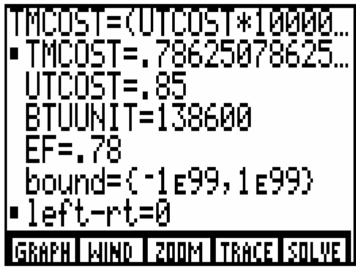
AEQLA (equivalent leakage area from CFM_{10})
EqLAin = Equivalent Leakage Area, in^2.
CFM10 = CFM at 10 Pascals of building pressure. See the comments above in panel "Nugget-52." This test was developed by National Research Council of Canada.

Nugget-54

AFCOM (payments on loan, interest, principle, periods)
PI = principle and interest or payment per period, usually each month.
PRIN = the principle or amount of the loan, or present value.
i = interest payment per period (per). A 12% annual interest rate on a loan paid back monthly is 0.12/12 months per year = 0.01, as in the example.
per = the number of periods of the loan. A five year load with monthly payments has a "per" = 60, as in the example at the left.

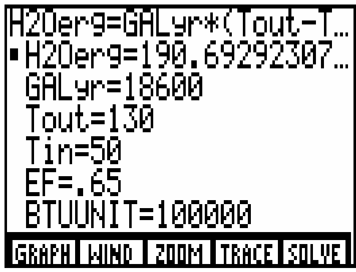
- Remember, you can solve for any of these variables by entering the others.

Nugget-55



<u>AFUEL</u> <u>(per therm cost of fuel)</u>
TMCOST = per unit cost of fuel, in dollars and cents.
UTCOST = per unit cost of fuel under consideration, in dollars and cents.
BTUUNIT = British thermal units (BTU) per unit of fuel under consideration, input value.
EF = <u>seasonal</u> efficiency of the space heating unit. Use decimal points. If you enter 1.00, you will get <u>input</u> cost per therm; if you enter seasonal efficiency, you will get <u>output</u> cost per therm.

Nugget-56



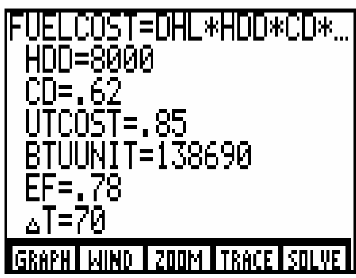
<u>AH2O (annual domestic water heating energy consumption)</u>
H2Oerg = energy per year for water heating, in fuel units.
GALyr = gallons of hot water used per year.
Tout = hot water output temperature from heater, ^{0}F.
Tin = water input temperature, ^{0}F.
EF = efficiency of water heating appliance.
BTUUNIT = per unit input value of water heating fuel.

Nugget-57

<u>AHET1</u> <u>(annual space heating cost)</u>
FUELCOST = annual space heating fuel cost, in dollars.
DHL = calculated design heat load of building, in Btu/hr. Use an acceptable method of calculation.
HDD = heating degree days, base 65°F.
CD = empirical correction factor for HDD_{65}. Refer to page 106 of this document for appropriate CD values for your area.
UNITCOST = unit cost of fuel, e.g., per gallon of oil, per therm natural gas.

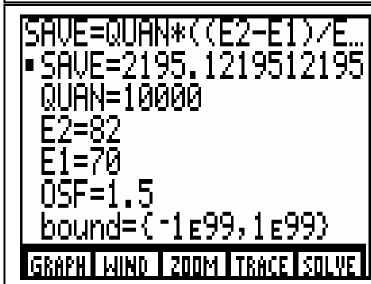
See next panel

Nugget-58



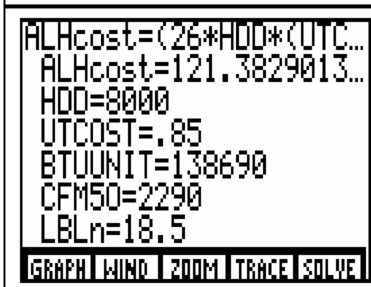
AHET1 continued. (The screen has been scrolled up two lines)
BTUUNIT = input value per unit of fuel, e.g., per gallon of oil.
EF = <u>Seasonal</u> efficiency of the space heating unit. Include losses from distribution system. Note: seasonal efficiency is always less than steady-state efficiency (that which is calculated with a flue-gas analysis tester).
ΔT = the design temperature difference. This value should be the same design temperature difference used to calculate the design heat load (DHL) of the building.

Nugget-59



<u>AHET2</u> <u>(savings from heating system efficiency improvements)</u>
SAVE = cost or quantity of fuel saved from efficiency improvements.
QUAN = cost or quantity of fuel consumed <u>before</u> efficiency improvements.
E2 = <u>steady-state</u> efficiency as a result of efficiency improvements.
E1 = <u>steady-state</u> efficiency before efficiency improvements.
OSF = Off-Cycle Factor: hot air systems, 1.2 to 1.4; hot water systems, 1.4 to 1.6; steam systems, 1.6 to 1.8.

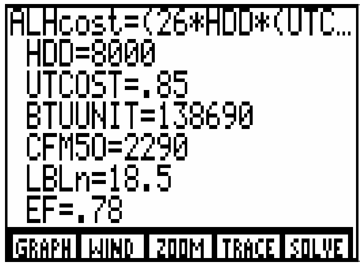
Nugget-60



<u>AHET3</u> <u>(annual heating costs of air leakage)</u>
ALHcost = annual heating cost of air leakage, in dollars.
HDD = Heating degree days, base 65°F.
UTCOST = Unit cost of heating fuel, e.g., cost per therm of natural gas.
BTUUNIT = Input value per unit of fuel, e.g., per therm of natural gas.
CFM50 = CFM_{50} from the blower door test.
LBLn = Lawrence Berkeley Lab. correlation factor. This number is displayed by the Building Tightness Limits "BTL1" program, "BTL" routine.

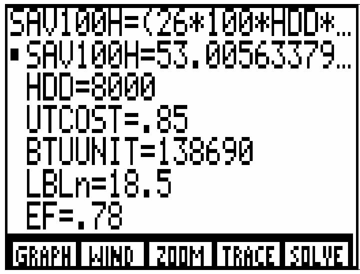
See next panel

Nugget-61



AHET3, *continued.* (The screen has been scrolled up one line).
EFF = <u>Seasonal</u> efficiency of the space heating unit. Include losses from the distribution system. Note: seasonal efficiency is always less than steady-state efficiency (that which is measured with a flue-gas analysis tester).

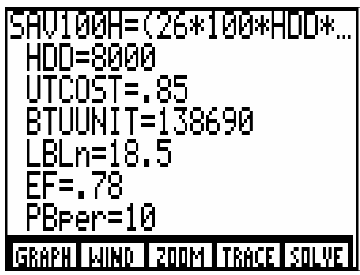
Nugget-62



<u>**AHET4** (heating cost-effectiveness guideline for air sealing)</u>
SAV100H = Heating Cost-Effectiveness Guideline per 100 CFM_{50} reduction
HDD = Heating degree days, base 65°F.
UTCOST = Unit cost of heating fuel, e.g., cost per therm of natural gas.
BTUUNIT = Input value per unit of fuel, e.g., per therm of natural gas.
LBLn = Lawrence Berkeley Lab. correlation factor. This number is displayed by the Building Tightness Limits "BTL1" program "BTL" routine.

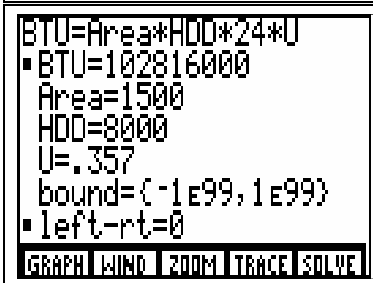
See next panel

Nugget-63



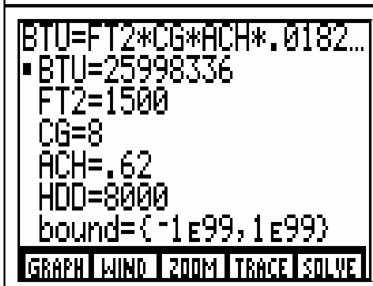
AHET4 continued. (The screen has been scrolled up one line).
EF = <u>Seasonal</u> efficiency of the space heating unit. Include losses from distribution system. Note: seasonal efficiency is always less than steady-state efficiency (that which is calculated with a flue-gas analysis tester).
PBper = Reasonable payback period for weatherization measures.
•Comment: The weatherization crew should continue to seal the building until cost of 100 CFM_{50} reduction is equal to the Cost-Effective Guideline for 100 CFM_{50} reduction. **See ZipTest Pro² program "WCEG."**

Nugget-64



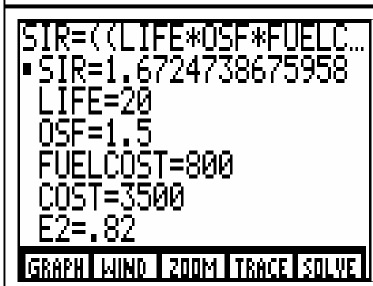
<u>**AHET5** (transmission heat transfer through a surface)</u>
BTU = transmission heat loss per year through a surface area (Btu/yr).
Area = surface area in square feet.
HDD = heating degree days, base 65°F.
U = thermal transmittance, U-factor. The inverse of R-value.
Comment: Use this equation to calculate Btu/hr savings resulting from a decrease in U-factor (increase in R-value).

Nugget-65



<u>**AHET6** (air leakage heat loss per year)</u>
BTU = air leakage heat loss (Btu/yr). **FT2 =** square feet area of building floor.
CG = ceiling height. (FT2 x CG yields building volume).
ACH = air changes per hour, natural. See Equation Nugget "ACHN."
HDD = heating degree days, base 65°F.
•Comment: For this equation, a CFM_{50} value is not needed as it is in "ACHN." If you know a pre-weatherization ACH and a post-weatherization ACH, subtract the post-value from pre-value and enter the remainder as "ACH."

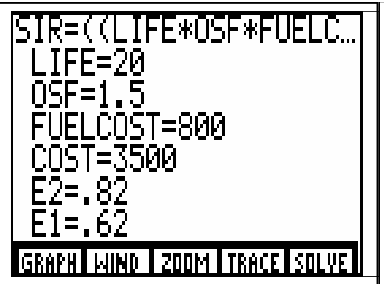
Nugget-66



<u>**AHET7** (analysis for heating system replacement)</u>
SIR = savings-to-investment ratio.
LIFE = reasonable life of upgrade equipment or replacement heating system. May also use for this variable the Uniform Present Value (UPV) which represents a discounted life value.
OSF = Off-Cycle Factor: hot air systems, 1.2 to 1.4; hot water systems, 1.4 to 1.6; steam systems, 1.6 to 1.8.

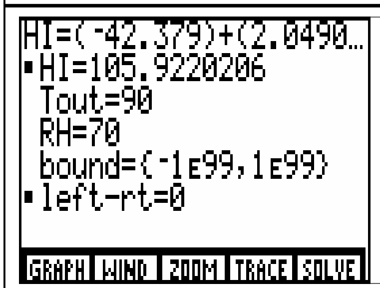
See next panel

Nugget-67



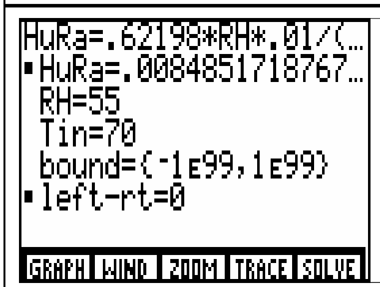
AHET7, *continued.* (The screen has been scrolled up one line).
FUELCOST = annual space heating cost **before** upgrade or replacement.
COST = total cost of upgrading or replacing heating system, dollars.
E2 = steady-state efficiency **after** upgrade or replacement.
E1 = steady-state efficiency **before** upgrade or replacement.

Nugget-68



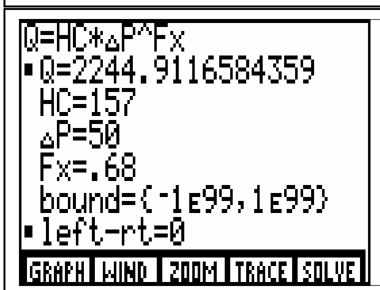
AHI (heat index or apparent temperature)
HI = heat index or apparent temperature, used by weather reporters during hot and humid weather.
Tout = temperature outdoors, ^oF.
RH = relative humidity, as a percentage (enter 70% as 70, not as 0.70).

Nugget-69



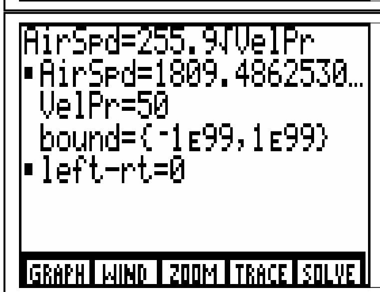
AHRAT (humidity ratio)
HuRa = humidity ratio, the mass of mater vapor to the mass of dry air.
RH = relative humidity. Measure this with a good sling psychrometer or digital humidity gauge (inexpensive devices might give inaccurate readings).
Tin = Temperature, °F. This may be indoor or outdoor temperature.
•Comment: the humidity ratio, "HuRa," is required for the dewpoint calculation, Equation Nugget "ADEWP."

Nugget-70



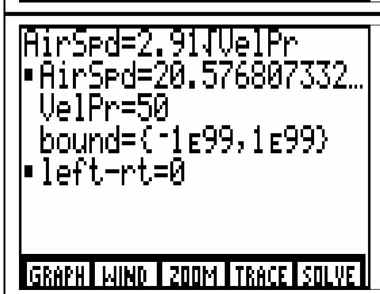
AIREQ (building air flow rate, air equation)
Q = building air leakage flow rate.
HC = house constant. This value can be calculated using a multi-point blower door test (the TI-86 can perform this test).
ΔP = building pressure, Pascals.
Fx = building flow exponent. This also can be determined with a multi-point blower door test.

Nugget-71



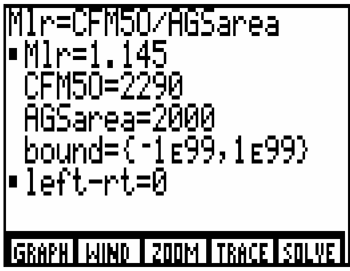
AIRSF (air speed in units of feet per minute)
AirSpd = air speed in units of feet per minute.
VelPr = velocity pressure, in Pascals
- Comment: This equation is for sea-level air density. This equation will give the pressure against the side of a building, in Pascals, if the wind speed at the side of the building is known. Also, you can measure the velocity pressure of moving air with a digital pressure gauge, enter the value into the equation, and solve for "AirSpd."

Nugget-72



AIRSP (air speed in units of miles per hour)
AirSpd = Air speed, mph.
VelPr = Velocity pressure, in Pascals
- Comment: This equation is for sea-level air density. This equation will give the pressure against the side of a building, in Pascals, if the wind speed at the side of the building is known. Also, you can measure the velocity pressure of moving air with a digital pressure gauge, enter the value into the equation, and solve for "AirSpd."

Nugget-73



<u>**AMLR** (Minneapolis leakage ratio)</u>

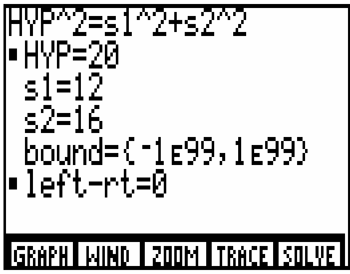
Mlr = Minneapolis leakage ratio.

CFM50 = CFM_{50} from blower door test.

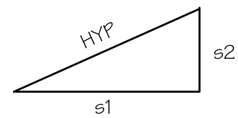
AGSarea = Above grade surface area of building. Include above grade walls, windows, doors, attic floors, and other floors over unconditioned space.

- Comment: For houses with MLR values greater than 1.0, large cost-effective reductions in air leakage can be made. If the MLR is in the range of 0.5 to 1.0, it is more difficult to achieve cost-effective reductions.

Nugget-74



<u>**APYTH** (Pythagorean theorem)</u>



HYP = Pythagorean theorem

s1 = side 1 of right triangle, in units of length.

s2 = side 2 of right triangle in units of length.

- Comment: The theorem is: The square of the hypotenuse of a right triangle is equal to the sum of the squares of the other two sides. A great equation to know for construction work, i.e., for finding right angles. Multiples of 3, 4, and 5 always work out perfectly. This is Leslie's (my wife) favorite equation.

Nugget-75

<u>**AREFR** (saving-to-investment ratio for refrigerator replacement)</u>

SIR = Saving-to-Investment Ratio for the refrigerator replacement.

kWhyrOld = kWh/yr refrigerator usage NOT adjusted for temperature differences. This value is the metered usage or the estimated usage from the manufacturer or the AHAM directory of refrigerators. If the refrigerator is metered, the metering time should be at least two hours.

AAAT = the Average Annual Ambient Temperature to which the refrigerator is exposed. This is an estimate of the average

See next panel

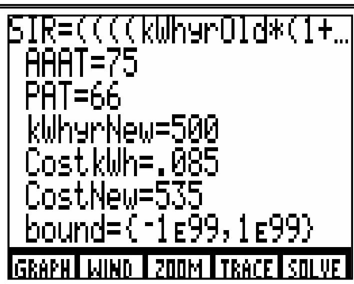
Nugget-76

temperature, in Fahrenheit degrees, around the refrigerator over a year.

PAT = the Present Ambient Temperature, in Fahrenheit degrees. This is the temperature while the metering is taking place. If this temperature is greater than the AAAT, the metered reading must be adjusted downward for a more accurate annual kWh/yr estimate. If this temperature is lower than the AAAT, the metered reading must be adjusted upward. The "AREFR' equation makes this adjustment automatically. Note: If you want to negate the impact of the temperatures — AAAT and PAT — set each equal to 70.

See next panel

Nugget-77



(The screen has been scrolled up two lines).

kWhyrNew = the estimated kWh/yr consumption of the replacement refrigerator.

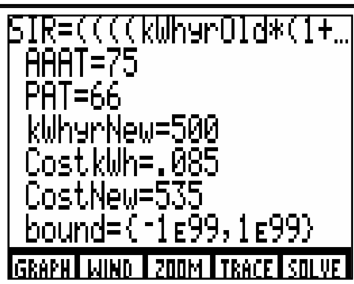
CostkWh = the cost of delivered electricity per kWh.

CostNew = the cost of replacing the old refrigerator. This price should include the refrigerator cost, any delivery charge, and any disposal charge for the old refrigerator.

LIF = the discounted expected life (15 years) of the refrigerator. This is a

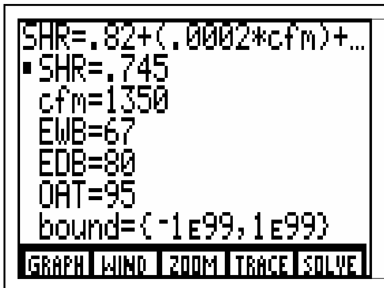
See next panel

Nugget-78



value you can adjust in the calculator memory. Notice it does not show up in the screen displays at the left. See the Texas Instruments TI-86 instruction manual, pages 58 - 61 for help. "LIF" is fifteen years discounted by a specific Department of Energy (DOE) rate. From April 1, 2004 to March 31, 2005 the U.S. average "LIF" value published by the DOE was 11.49 (the SIR values in panels Nugget-75 and 76 are calculated with this value). The value for "LIF" must be adjusted annually for your area. See "Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis - April 2004" at <u>http://www.eere.energy.gov/femp/pdfs/ashb04.pdf.</u>

Nugget-79

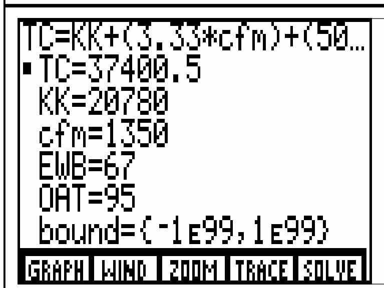


<u>ARISR (sensible to total capacity ratio of air-to-air cooling equipment)</u>

SHR = sensible to total capacity ratio.
cfm = cubic feet per minute flowing through refrigerant coil.
EWB = entering wet-bulb temperature, °F.
EDB = entering dry-bulb temperature, °F.
OAT = outdoor dry-bulb temperature, °F.

- Comment: See *Residential Equipment Selection: Manual S*, by Air Conditioning Contractors of America (ACCA), pages A3-1 through A3-2.

Nugget-80



<u>ARITC (total capacity of air-to-air cooling equipment)</u>

TC = total capacity of air-to-air cooling equipment.
KK = a constant, for generic cooling equipment, use 20780.
cfm = cubic feet per minute flowing through refrigerant coil.
EWB = entering wet-bulb temperature, °F.
OAT = outdoor dry-bulb temperature, °F.

- Comment: See *Residential Equipment Selection: Manual S*, by Air Conditioning Contractors of America (ACCA), pages A3-1 through A3-2.

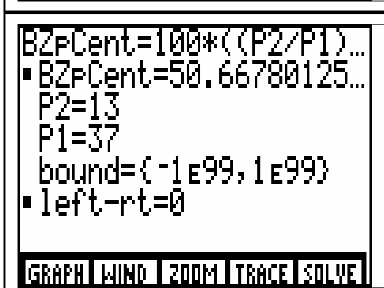
Nugget-81

<u>ARVAL (determine R-value with non-contact thermometer)</u>

RvalU = calculated R-value of surface using non-contact thermometer.
WALLiT = Indoor wall temperature, °F.
WALLoT = Outdoor wall temperature, °F.
AIRiT = Indoor air temperature, °F.

- Comment: This equation is useful with non-contact thermometers such as the Raytek® Raynger. Be careful of the effect of the sun and other sources of radiant heat. Also, be aware of thermal time lags.

Nugget-82

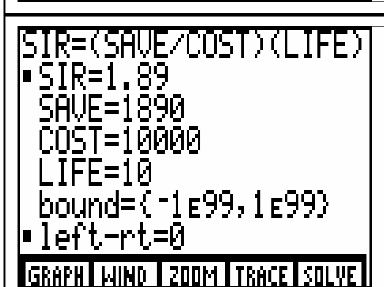


<u>ASERP (building-to-zone percentage of zone-to-outdoor leakage rate)</u>

BZpCent = building-to-zone percentage of zone-to-outdoor leakage rate (also building-to-duct as percentage of duct-to-outdoor leakage).
P2 = zone-to-outside (duct-to-outside) pressure difference, Pascals.
P1 = building-to-zone (building-to-duct) pressure difference, Pascals

- Comment: The example values indicate that the building-to-zone leakage is about 50% of the zone-to-outside leakage.

Nugget-83

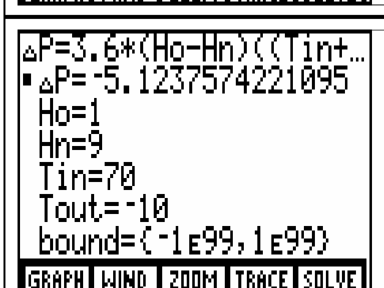


<u>ASIR (simple savings-to-investment ratio)</u>

SIR = simple savings-to-investment ratio.
SAVE = First-year savings due to energy-saving measure, dollars.
COST = Cost of energy-saving measure, dollars.
LIFE = Expected life of energy-saving measure, years.

- Comment: If the SIR is less than one, the energy-saving measure is not worth implementing; if it is more than one, it is worth implementing. The higher the "SIR," the better.

Nugget-84

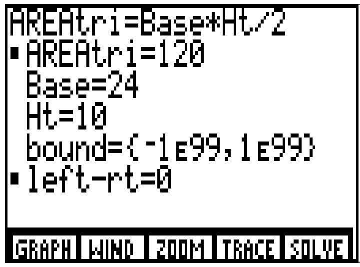


<u>ASTAK (building stack pressure at given height)</u>

ΔP = building stack pressure at a given height.
Ho = height at observation measurement, ft.
Hn = height of neutral pressure level, ft. **Tin =** temperature indoors, °F.
Tout = temperature outdoors, °F. For below zero temps., use "(-)" key.

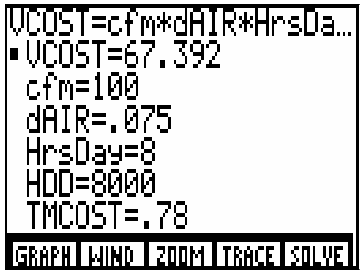
- Comment: This equation <u>estimates</u> ΔP. The neutral pressure level is usually above mid-height for residential buildings. For tall buildings, it is from 0.3 to 0.7 of total building height. See *ASHRAE Fundamentals Handbook.*

Nugget-85



<u>**ATRIa** (area of a triangle)</u>
AREAtri = area of a triangle, such as a gable end.
Base = the base dimension of the triangle.
Ht = the height of the triangle.

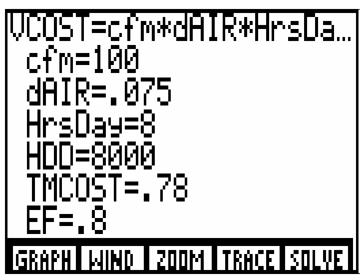
Nugget-86



<u>**AVNT1** (space heating energy consumption for ventilation)</u>
VCOST = annual cost of space heating energy for ventilation. **cfm =** actual cubic feet per minute of exhaust fan(s). **dAIR =** density of air (at sea level 0.075 pounds/cubic foot) See air density correction factors on page 106.
HrsDay = hours of average daily running time of exhaust fan(s).
HDD = heating degree days, base 65°F.
TMCOST = therm cost of space heating fuel. Use Equation Nugget "AFUEL" to determine this value.

See next panel

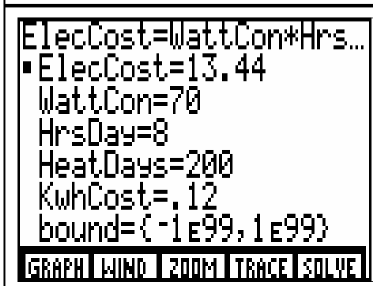
Nugget-87



AVNT1, continued. (The screen has been scrolled up one line).
EF = <u>seasonal</u> efficiency of the space heating unit. Include losses from distribution system. Note: seasonal efficiency is always less than steady-state efficiency (that which is calculated with a flue-gas analysis tester).

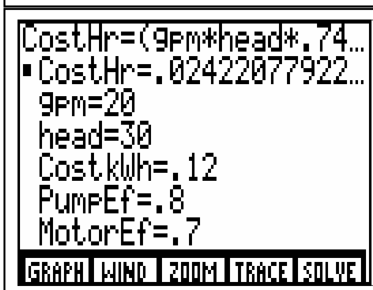
- Comment: This equation assumes that all make-up air for the exhaust ventilation flows directly from the outside. The value of "VCOST" is the energy required to heat the make-up air that replaces the exhausted ventilation air.

Nugget-88



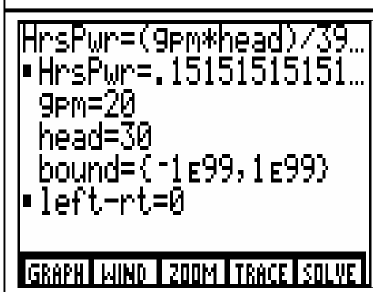
<u>**AVNT2** (annual electrical consumption for ventilation)</u>
ElecCost = annual electrical cost to operate an exhaust fan.
WattCon = power consumption of fan, in Watts.
HrsDay = hours of average daily running time of exhaust fan(s).
HeatDay = heating days per year. A heating day is any day having an average outdoor temperature less that 65°F.
KwhCost = cost of electricity, per kWh.

Nugget-89



<u>**AWATC** (cost to operate a water pump)</u>
CostHr = Cost per hour to operate a water pump.
gpm = gallons per minute moved by the pump.
head = the head in feet.
CostkWh = cost of electricity in kWh.
PumpEf = pump efficiency as a decimal.
MotorEf = pump motor efficiency as a decimal.

Nugget-90



<u>**AWATP** (horsepower needed to pump water)</u>
HrsPwr = horse power of pump and motor required to pump water.
gpm = gallons per minute moved by the pump.
head = the head in feet.

•Press the **EXIT** key to exit the SOLVER feature.

SUPPORT INFORMATION

HEATING DEGREE DAY$_{65}$ CORRECTION FACTORS, C_D

QUALITY OF CONSTRUCTION AND RELATIVE USE OF ELECTRICAL APPLIANCES	NUMBER OF DEGREE DAYS (65°F)								
	1000	2000	3000	4000	5000	6000	7000	8000	9000
Well-Constructed House. Large quantities of insulation, tight fit on doors and windows, well sealed openings. Large use of electrical appliances. Large availability of solar energy at the house.	0.48	0.45	0.42	0.39	0.36	0.37	0.38	0.39	0.40
House of Average Construction. Average quantities of insulation, average fit on doors and windows, partially sealed openings. Average availability of solar energy at the house. Average use of electrical appliances.	0.80	0.76	0.70	0.65	0.60	0.61	0.62	0.69	0.67
Poorly Constructed House. Small quantities of insulation, poor fit on doors and windows, unsealed openings. Small use of electrical appliances. Small availability of solar energy at the house.	1.12	1.04	0.98	0.90	0.82	0.85	0.88	0.90	0.92

Source: ASHRAE

AIR DENSITY CORRECTION FACTORS

Altitude (ft)		Sea Level	1000	2000	3000	4000	5000	6000	7000	8000	9000	10,000
Barometer	(in.Hg)	29.92	28.86	27.82	26.82	25.84	24.90	23.98	23.09	22.22	21.39	20.58
	(in.w.g.)	407.5	392.8	378.6	365.0	351.7	338.9	326.4	314.3	302.1	291.1	280.1
Air Temp.	-40°	1.26	1.22	1.17	1.13	1.09	1.05	1.01	0.97	0.93	0.90	0.87
°F	0°	1.15	1.11	1.07	1.03	0.99	0.95	0.91	0.89	0.85	0.82	0.79
	40°	1.06	1.02	0.99	0.95	0.92	0.88	0.85	0.82	0.79	0.76	0.73
	70°	1.00	0.96	0.93	0.89	0.86	0.83	0.80	0.77	0.74	0.71	0.69
	100°	0.95	0.92	0.88	0.85	0.81	0.78	0.75	0.73	0.70	0.68	0.65
	150°	0.87	0.84	0.81	0.78	0.75	0.72	0.69	0.67	0.65	0.62	0.60
	200°	0.80	0.77	0.74	0.71	0.69	0.66	0.64	0.62	0.60	0.57	0.55
	250°	0.75	0.72	0.70	0.67	0.64	0.62	0.60	0.58	0.56	0.58	0.51
	300°	0.70	0.67	0.65	0.62	0.60	0.58	0.56	0.54	0.52	0.50	0.48
	350°	0.65	0.62	0.60	0.58	0.56	0.54	0.52	0.51	0.49	0.47	0.45
	400°	0.62	0.60	0.57	0.55	0.53	0.51	0.49	0.48	0.46	0.44	0.42
	450°	0.58	0.56	0.54	0.52	0.50	0.48	0.46	0.45	0.43	0.42	0.40
	500°	0.55	0.53	0.51	0.49	0.47	0.45	0.44	0.43	0.41	0.39	0.38
	550°	0.53	0.51	0.49	0.47	0.45	0.44	0.42	0.41	0.39	0.38	0.36
	600°	0.50	0.48	0.46	0.45	0.43	0.41	0.40	0.39	0.37	0.35	0.34
	700°	0.46	0.44	0.43	0.41	0.39	0.38	0.37	0.35	0.34	0.33	0.32
	800°	0.42	0.40	0.39	0.37	0.36	0.35	0.33	0.32	0.31	0.30	0.29
	900°	0.39	0.37	0.36	0.35	0.33	0.32	0.31	0.30	0.29	0.28	0.27
	1000°	0.36	0.35	0.33	0.32	0.31	0.30	0.29	0.28	0.27	0.26	0.25

Standard Air Density, Sea Level, 70°F - 0.075 lb/cu ft at 29.92 in. Hg

Source: *HVAC Systems Duct Design*, SMACNA, 1981.

Air density, $d = 1.325\ (Pa/(460+T))$

where: Pa = barometric pressure, in Hg

T = temperature, °F

Multiply standard air density at Sea level of 0.075 by the correction factors in the table to get your air density.

The Equation Nuggets with Labels

1. ABMI (Body Mass Index)
   × BMI=(Wt*704)/Ht^2
2. ACFM (pressure created by exhaust devices)
   × cfm=(CFM50/50^.65)(¾P^.65)
3. ACFM1 (determination of vent fan size when house is "too tight")
   × VentFan=ð(((Btl/LBLn)^2)-((CFM50/LBLn)^2))
4. ACFMd (depressurization blower door result temperature adjusted)
   × CFMadDp=CFMnom*((Tout+459.7)/(Tin+459.7))^.5
5. ACFMp (pressurization blower door result temperature adjusted)
   × CFMadPr=CFMnom*((Tin+459.7)/(Tout+459.7))^.5

---

6. ACH50 (air changes per hour at 50 Pascals building pressure from CMF_{50})
   × ACH5o=CFM50*60/(FT2*CG)
7. ACHIL (equivalent wind chill temperature, 2001 version)
   × WCHILL=35.74+(0.6215*Tout)-(35.75*(SPEED^0.16))+(0.4275*Tout*(SPEED^0.16))
8. ACHN (building air change per hour at natural pressure)
   × ACH=CFM50*60/(LBLn*FT2*CG)
9. ACIRa (area of a circle)
   × AREAcir=.78539(dia^2)
10. ACIRc (circumference of a circle)
    × CIRcir=3.14159dia

---

11. ACLG1 (annual cooling cost of air leakage)
    × ALCcost=((.026*CDD*KWHcost*CFM50)/(LBLn*SEER))
12. ACLG2 (cooling cost-effectiveness guideline for air sealing)
    × SAV100C=((.026*100*CDD*KWHcost)/(LBLn*SEER))*PBper
13. ACO2O (air-free carbon monoxide from as-measured carbon monoxide and carbon dioxide for a number 2 oil appliance)
    × COairFre=COppm(15.3/CO2)
14. ACOAR (air-free carbon monoxide from as-measured carbon monoxide and oxygen percentage in flue gas, any fuel)
    × COairFre=COppm(20.9/(20.9-Oxy2))
15. ACOLP (air-free carbon monoxide from as-measured carbon monoxide and carbon dioxide for a liquefied propane, LP, appliance)
    × COairFre=COppm(14/CO2)

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16. ACONG (air-free carbon monoxide from as-measured carbon monoxide and carbon dioxide for a natural gas appliance)
    × COairFre=COppm(12.2/CO2)
17. ACORM (for determining the carbon monoxide concentrations in a room from an unvented natural gas or propane appliance, such as a gas range/oven)
    × COppm=((COairFre*Vg*Gr)(1-(1/(2.713^(Nach*t)))))/(Nach*v)
18. ADEWP (dewpoint temperature determination)
    × DewPt=1.8*((ú4111/(ln (HuRa*101325/(HuRa+.62198))-23.7093)+35.45)-273)+32
19. ADUCT (round duct diameter to rectangular)
    × DuctDia=1.3((s1*s2)^.625)/(s1+s2)^.25)
20. AELA (effective leakage area from CFM_4)
    × ELAin2=.2835*CFM4

The Equation Nuggets with Labels
(continued)

21. AEQLA (equivalent leakage area from CFM_{10})
× `EQLAin=.2939*CFM10`

22. AFCOM (payments on loan, interest, principle, periods)
× `PI=PRIN(i(1+i)^per)/(((1+i)^per)-1)`

23. AFUEL (per therm cost of fuel)
× `TMCOST=(UTCOST*100000)/(BTUUNIT*EF)`

24. AH2O (annual domestic water heating energy consumption)
× `H2Oerg=GALyr*(Tout-Tin)*8.33/(EF*BTUUNIT)`

25. AHET1 (annual space heating cost)
× `FUELCOST=DHL*HDD*CD*24(UTCOST/(BTUUNIT*EF))/¾T`

---

26. AHET2 (savings from heating system efficiency improvements)
× `SAVE=QUAN*((E2-E1)/E2)*OSF`

27. AHET3 (annual heating costs of air leakage)
× `ALHcost=(26*HDD*(UTCOST/BTUUNIT)*CFM50/(LBLn*EF)).6`

28. AHET4 (heating cost-effectiveness guideline for air sealing)
× `SAV100H=(26*100*HDD*(UTCOST/BTUUNIT)/(LBLn*EF)).6*PBper`

29. AHET5 (transmission heat transfer through a surface)
× `BTU=Area*HDD*24*U`

30. AHET6 (air leakage heat loss per year)
× `BTU=FT2*CG*ACH*.0182*HDD*24`

---

31. AHET7 (analysis for heating system replacement)
× `SIR=((LIFE*OSF*FUELCOST)/COST)((E2-E1)/E2)`

32. AHI (heat index or apparent temperature)
× `HI=(ú42.379)+(2.04901523(Tout))+(10.14333127(RH))-(.22475541 (Tout)(RH))-(6.83783(10^ú3)(Tout^2))-(5.481717(10^ú2)(RH^2))+ (1.22874(10^ú3)(Tout^2)(RH))+(8.5282(10^ú4)(Tout)(RH^2))-(1.99 (10^ú6)(Tout^2)(RH^2))`

33. AHRAT (humidity ratio)
× `HuRa=.62198*RH*.01/((e^(ú23.7093+(4111/((.5555*(Tin-32)+273)- 35.45)))*101325)-RH*.01)`

34. AIREQ (building air flow rate, air equation)
× `Q=HC*¾P^Fx`

35. AIRSF (air speed in units of feet per minute)
× `AirSpd=255.9ðVelPr`

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36. AIRSP (air speed in units of miles per hour)
× `AirSpd=2.91ðVelPr`

37. AMLR (Minneapolis leakage ratio)
× `Mlr=CFM50/AGSarea`

38. APYTH (Pythagorean theorem)
× `HYP^2=s1^2+s2^2`

39. AREFR (Savings-to-Investment Ratio for refrigerator replacement)
× `SIR=((((kWhyrOld*(1+((AAAT-PAT)*.025)))-(kWhyrNew*(1+((AAAT-70) *.025))))*CostkWh)*LIF)/CostNew`

40. ARISR (sensible to total capacity ratio of air-to-air cooling equipment)
× `SHR=.82+(.0002*cfm)+(ú.0475*EWB)+(.0325*EDB)+(.0025*OAT)`

The Equation Nuggets with Labels
(continued)

41. ARITC (total capacity of air-to-air cooling equipment)
 × `TC=KK+(3.33*cfm)+(500*EWB)+(ú225*OAT)`
42. ARVAL (determine R-value with non-contact thermometer)
 × `RvalU=(WALLiT-WALLoT)/(1.4(AIRiT-WALLiT))`
43. ASERP (building-to-zone percentage of zone-to-outdoor leakage rate)
 × `BZpCent=100*((P2/P1)^.65`
44. ASIR (simple savings-to-investment ratio)
 × `SIR=(SAVE/COST)(LIFE)`
45. ASTAK (building stack pressure at given height)
 × `¾P=3.6*(Ho-Hn)((Tin+459.67)-(Tout+459.67))/(Tout+459.67)`

---

46. ATRIa (area of a triangle)
 × `AREAtri=Base*Ht/2`
47. AVNT1 (space heating energy consumption for ventilation)
 × `VCOST=cfm*dAIR*HrsDay*.24*HDD*TMCOST(.0006/EF)`
48. AVNT2 (annual electrical consumption for ventilation)
 × `ElecCost=WattCon*HrsDay*HeatDays*KwhCost*.001`
49. AWATC (cost to operate a water pump)
 × `CostHr=(gpm*head*.746*CostkWh)/(3960*PumpEf*MotorEf)`
50. AWATP (horsepower needed to pump water)
 × `HrsPwr=(gpm*head)/3960`

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Instructions
for

Financial Functions
A Program from Texas Intruments

Introduction

Financial Functions is a shareware program available from the Texas Instruments internet site, www.ti.com. This assembly language program is free of charge at this internet site, as are the included instructions written by Texas Instruments staff. This software has been loaded into your TI-86 graphing calculator for your convenience. You have not been charged for this financial software.

Please notice that you must access Financial Functions by pressing the **2nd** and **MATH** keys, not by pressing **PRGM** for programs (note that on the **PRGM** **"**NAMES" menu, "Financ" and "finexe" are listed as menu items, but you cannot access these functions from this menu, you must use the **MATH** key to access the Financial Functions).

This is very important!

If you are familiar with the SOLVER function of the TI-86 where the Equation Nuggets are stored, you will realize that the Financial Functions work very much like the SOLVER function—you may solve for any one of the variables by entering values for the other variables. In the case of the Financial Functions, you will at times be required to enter a "0" rather than a number greater or less than zero.

To make use of the Financial Functions, follow the instructions on the following pages. We have included the Texas Instrument's Table of Contents for these instructions. The page numbers referenced in the Table of Contents on the next page are found on the upper right corner of each page.