ZipTest Pro

Building Diagnostics Software

for

Texas Instruments TI-86 Calculator

Specifications

and

Instructions

ZipTest Pro

Building Diagnostics Software

for

Texas Instruments TI-86 Calculator

Specifications and Instructions

WxWare Diagnostics
Building Analysis Tools

WxWare Diagnostics is a division of
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SOFTWARE LICENSE AGREEMENT AND LIMITED WARRANTY

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WxWare Diagnostics
220 Meadow Road
Topsham, ME 04086
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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 software, please read the *TI-86 Graphing Calculator Guidebook* and this ZipTest Pro
instruction book.

WARNING!

Do not press "2nd" (light orange in color), "MEM" and then "DELET" (Delete). Doing so might delete an entire program, equation, list, string, etc.

Do not add an equation to the "SOLVER" feature of the TI-86 calculator before making sure that you do not to use a variable name that has already been assigned to a string, list or constant. If you make this mistake, it will alter the program operation. Check the "VARS" listing in the calculator first. Read the TI-86 manual for more information.

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	207-725-6723
220 Meadow Road	Fax: 207-725-7818
Topsham, Maine 04086	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.

SOFTWARE TRAINING

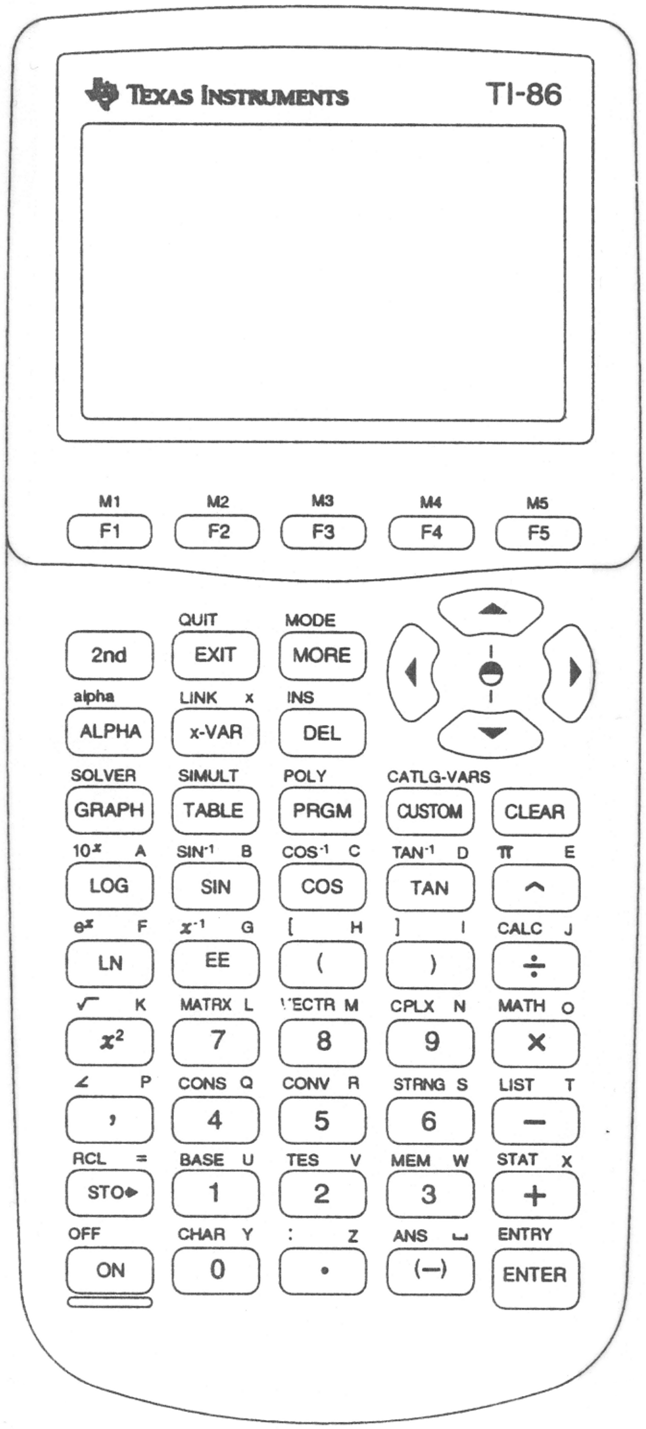
Training for the use of ZipTest Pro software is available for groups. Contact Rick Karg for information.

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*

Texas Instruments
TI-86 Graphing Calculator/Computer



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Instructions
for

Building Tightness Limit Calculations for Acceptable Indoor Air Quality

[Program "BTL1"]

February, 1999 (V2.0)

Introduction

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

BTL Calculation Procedure for Determining CFM_{50} Minimum

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

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

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

The calculations included here take into account:

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

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

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

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

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

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

This calculation procedure determines:

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

The user inputs required are:

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

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

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

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

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

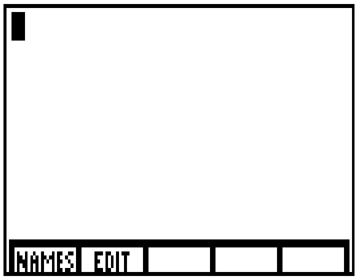
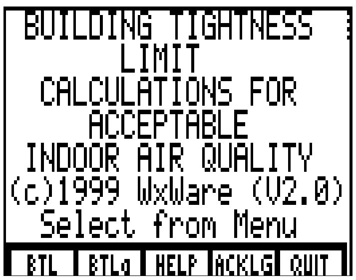
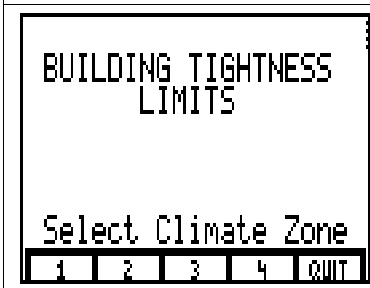
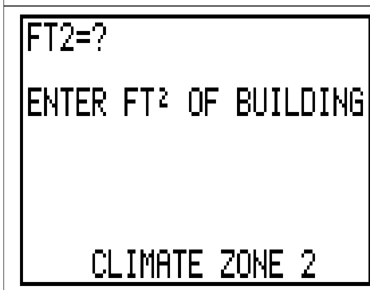
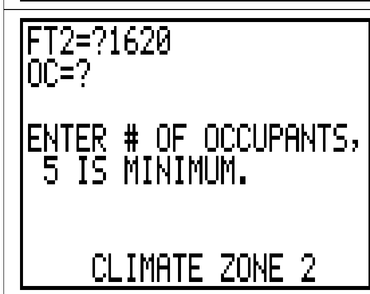
Of the calculated values in this procedure, the Minimum Target Effective Leakage Area ("Target ELAmin" on the calculator screen) and Minimum Target CFM ("Target CFMmin" on the calculator screen) are the most reliable as a target values because they do not require the flow exponent (slope of the building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

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

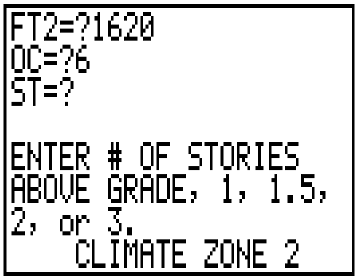
If a dwelling is tighter than the ASHRAE 62-1989 guidelines, the ventilation necessary ("Vent CFM Needed") to bring the dwelling into compliance with the ASHRAE 62-1989 guidelines is displayed as number 8 on the screen of calculated values and the "All Data" screen. The determination of the required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

Acknowledgements

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

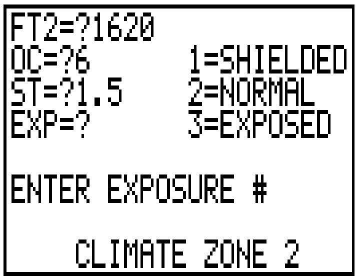
BTL1-1		Turn the TI-86 calculator on. Press **PRGM** (Programs). You will see this menu on the screen. Press **F1** for **NAMES.** **NOTE: It is best never to press EDIT, F2.** You will see the menu and sub-menu displayed in Panel BTL1-2."
BTL1-2		Press **F1, F2, F3, F4**, or **F5** for the program "BTL1." The menu key for this program will depend upon the number of programs loaded in the memory of you TI-86 calculator. For the screen at the left, four usable programs are loaded onto the calculator, "BTL1" (**F1**), "BTUDD" (**F2**), "DTL" (**F3**) and "Press" (**F5**). "Financ" is not usable (nor is "finexe" on the next menu set). "BTL1" will appear at the cursor location. Press **ENTER**. **Note: The exact name of the program must appear at the**
BTL1-3		You will see this menu on the screen. This is the main menu screen. **F1, "**BTL" to starts the Building Tightness Limits program. **F3, "**HELP" lists instructions for this screen. **F2, "**BTLa" starts the revised Building Tightness Limits program. **F4, "**ACKLG " (Acknowledgments) selection lists the author of the program, etc. **F5, "**QUIT" selection allows you to exit the program. Always exit the program by selecting **F5** from this menu; the decimal place is thereby set to
BTL1-4		Select **F1, "**BTL," to start the Building Tightness Limits program. You will see this menu on the screen. You are asked to select your climate zone. Refer to the map of North America on page 15 for your appropriate climate zone number. Note: If you select **F5, "**QUIT," you will exit the program. **DONE** will appear in the upper right corner of the screen If you want to re-enter the program, press **ENTER** or press **PRGM.**
BTL1-5		The climate zone you selected appears at the bottom of the screen. Enter the heated square footage of the house. The value you enter will be displayed after the "**?**" This value is used to determine whether the building tightness limit is calculated using 15 cfm/person or 0.35 air changes per hour. If the square footage is greater than the number of occupants multiplied by 322 ft^2, 0.35 air changes per hour is used rather than 15 cfm per person.
BTL1-6		Enter the number of occupants—by design. It is common to count the number of bedrooms and multiply by two to determine the number of occupants for this procedure. *Five is the minimum number of occupants that may be entered.* Please refer to "Building Tightness Guidelines: When Is a House Too Tight?" by George Tsongas, *Home Energy,* March/April, 1993, pp. 18-24, for discussion and guidance. Enter "6," for example, and press **ENTER**.

BTL1-7



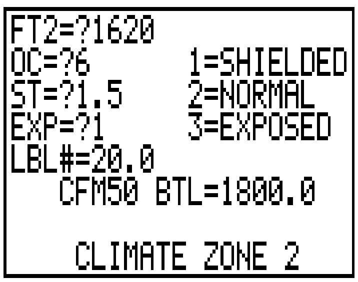
You are prompted to enter the number of exposed stories of the house. Basements below grade generally should not be included in the number of stories. The value you enter will be displayed after the "**?**"
Enter "1.5" stories, for example, and press **ENTER**.

BTL1-8



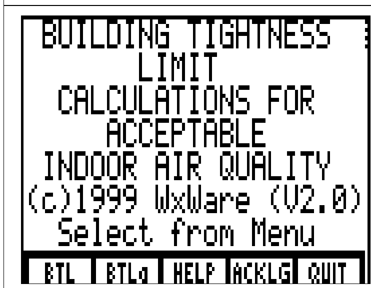
You are prompted to enter the appropriate exposure number for the house The value you enter will be displayed after the "**?**"
Enter "1," for example, and press **ENTER**.
The "EXP" or exposure value should be entered with care. "SHIELDED" is for buildings with significant blockage to the wind (trees or other buildings), "NORMAL" signifies buildings in a typical suburban setting (obstructions to the wind around building, but not dense), "EXPOSED" is for buildings with very

BTL1-9



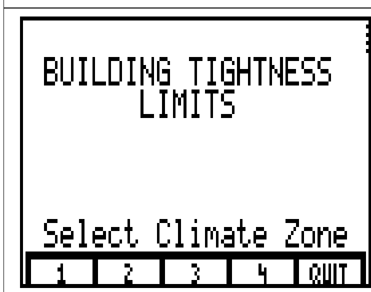
"CFM50 BTL=1800.0" is displayed. This is the Building Tightness Limit (BTL) for this example house, i.e., at a blower door depressurization of 50 Pascals, the CFM_{50} minimum value is 1800.
Notice that all the values you entered are displayed on the screen, including the climate zone and the "LBL #" value (if CFM_{50} is divided by the LBL#, the approximate $CFM_{natural}$ results). This example has been calculated using 15 cfm per person.

BTL1-10



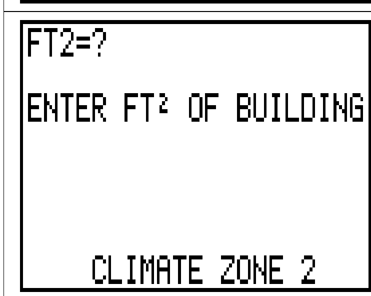
Now enter values for a demonstration of a calculation for a house that exceeds the size limitations for the use of 15 cfm/person calculation procedure. Instead, the calculation for this example will use 0.35 air changes per hour.
Press **F1, BTL**. to begin the demonstration.

BTL1-11



You are asked to select your climate zone. Refer to the map of North America on page 15 for the appropriate climate zone number.
If you select **F5, "**QUIT," you will return to the main menu screen.
Select **F2** for Climate Zone 2.

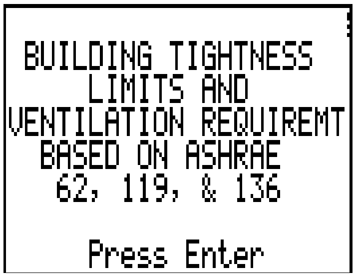
BTL1-12



The climate zone you selected appears at the bottom of the screen.
Enter the heated square footage of the house. The value you enter will be displayed after the "**?**" This value is used to determine whether the building tightness limit is calculated using 15 cfm/person or 0.35 air changes per hour. If the square footage is greater than the number of people multiplied by 322 ft^2, 0.35 air changes per hour is used rather than 15 cfm per person.
As a demonstration, enter "2200 ft^2" and press **ENTER**.

BTL1-13	FT2=?2200 OC=? ENTER # OF OCCUPANTS, 5 IS MINIMUM. CLIMATE ZONE 2	Enter the number of occupants—by design. You may count the number of bedrooms and multiply by two, using five as a minimum product, to determine the number of occupants for this procedure. Enter "6" for this demonstration and press **ENTER**.
BTL1-14	FT2=?2200 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 and press **ENTER**.
BTL1-15	FT2=?2200 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 "**?**" 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	FT2=?2200 OC=?6 1=SHIELDED ST=?1.5 2=NORMAL EXP=?1.5 3=EXPOSED CG=? ENTER AVERAGE CEILING HT FOR CALCULATION OF OCCUPIED VOLUME.	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	FT2=?2200 OC=?6 1=SHIELDED ST=?1.5 2=NORMAL EXP=?2 3=EXPOSED CG=?8 LBL#=16.7 CFM50 BTL=1714.4 CLIMATE ZONE 2	"CFM50 BTL=1714.4" is displayed. This is the Building Tightness Limit (BTL) for this demonstration house; at a blower door depressurization of 50 Pascals the CFM_{50} minimum value for acceptable air quality is 1714.4. Notice that all the values you entered are displayed on the screen, including the climate zone and the LBL "N" number. This example has been calculated using 0.35 air changes per hour rather than 15 cfm per person. Press **ENTER**
BTL-18	BUILDING TIGHTNESS LIMIT CALCULATIONS FOR ACCEPTABLE INDOOR AIR QUALITY (c)1999 WxWare (V2.0) Select from Menu BTL BTLa HELP ACKLG QUIT	You will see the at the left screen displayed. Select **F2, BTLa**. Now we will look at the next calculation procedure which is a more accurate method of determining building tightness and required ventilation for tight buildings.

BTL1-19

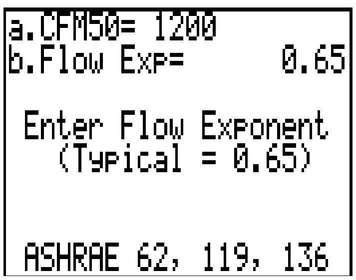


For an explanation of this procedure, refer to "**BTLa Calculation Procedure based on ASHRAE 62, 119, and 136**" on page 3 of this instruction manual.
Press **ENTER** to proceed to the next screen.

BTL1-20

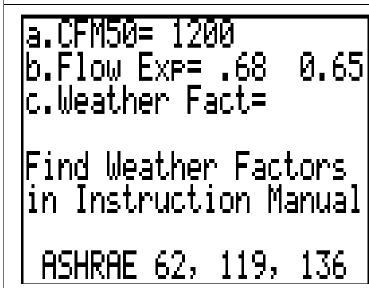
Enter "a.CFM50" of the building, whether it was measured by a single-point or multi-point blower door test.
Notice that "CFM50" on the display is preceded by the letter "a." This is the case for all the input values required for this procedure.
Notice that "ASHRAE 62, 119, 136" is at the bottom of the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

BTL1-21



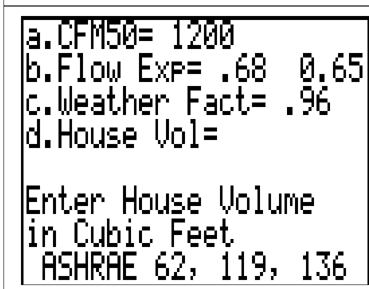
The next prompt, "b.Flow Exp," requires you to enter the flow exponent for the building (the slope of the air-leakage curve of the building). If you have performed a single-point blower door test on the building, enter ".65," the typical value of the flow exponent (displayed to the right on the screen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

BTL1-22



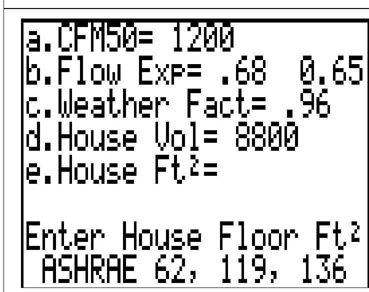
Enter the weather factor, "c.Weather Fact." These values are listed in this instruction manual on pages 16 through 18 for locations in Canada and the United States, designated as "W." These factors are used to estimate the natural air leakage for the purpose of determining the CFM ratings of added exhaust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

BTL1-23



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

BTL1-24



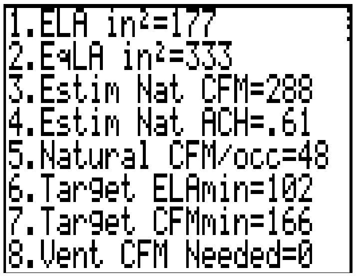
Enter the square footage of building floor area, "e.House Ft^2." If you included the basement in the volume figure, include the basement here also.
For this example, enter "1100" and press **ENTER** .

BTL1-25	a.CFM50= 1200 b.Flow Exp= .68 0.65 c.Weather Fact= .96 d.House Vol= 8800 e.House Ft²= 1100 f.Bldg Ht, ft= ASHRAE 62, 119, 136	Enter the building height above grade in units of feet, "f.Bldg Ht, ft." For buildings with uneven above grade heights—walk-out basements, one and one-half story buildings—use the average height of the building. For this example enter "8" and press **ENTER** Notice that "ASHRAE 62,119, 136" remains at the bottom of the screen as a reminder of the methodology on which you are working.
BTL1-26	a.CFM50= 1200 b.Flow Exp= .68 0.65 c.Weather Fact= .96 d.House Vol= 8800 e.House Ft²= 1100 f.Bldg Ht, ft= 8 g.Story Ht, ft= ASHRAE 62, 119, 136	Enter the average height of one story of the building, "g.Story Ht, ft." This value and the "Bldg Ht" from the previous entry (see Panel BTL1-37) determines the number of stories in the building. The resulting value (the number of stories) should not exceed three. For this example, enter "8" and press **ENTER**
BTL1-27	a.CFM50= 1200 b.Flow Exp= .68 0.65 c.Weather Fact= .96 d.House Vol= 8800 e.House Ft²= 1100 f.Bldg Ht, ft= 8 g.Story Ht, ft= 8 h.Occupant Count= ▮	Enter the "h.Occupant Count" as the next and final input value for this procedure. Enter the number of occupants or the number of bedrooms plus one, whichever is larger. This value is used to determine the ventilation requirements for the dwelling. The greater the number of occupants or bedrooms, the greater the amount of fresh are required for acceptable indoor air quality. For the example, enter "5"
BTL1-28	a.CFM50= 1200 b.Flow Exp= .68 0.65 c.Weather Fact= .96 d.House Vol= 8800 e.House Ft²= 1100 f.Bldg Ht, ft= 8 g.Story Ht, ft= 8 h.Occupant Count= 5	Review the input values you have entered before you press **ENTER**. Now, press **ENTER** and move on to the next screen which displays all the output values for the example problem. Note that all the input values are lettered (a. through h), and that on the next screen (Panel BTL1-29), all the output values are numbered (1. through 8.). Press **ENTER** to move to the next screen.
BTL1-29	1.ELA in²=61 2.EqLA in²=118 3.Estim Nat CFM=54 4.Estim Nat ACH=.37 5.Natural CFM/occ=11 6.Target ELAmin=84 7.Target CFMmin=75 8.Vent CFM Needed=52	On this screen, all the outputs are displayed except number 9. "1.ELA in^2" is equal to "61" for the example. ELA (Effective Leakage Area) was developed at Lawrence Berkeley Laboratory (LBL) and is used in their air leakage model. The ELA is defined as the area of a special nozzle-shaped hole (similar to the inlet of your blower door fan) that would leak the same amount of air as the building does at a pressure of 4 Pascals. In the Solver section of the TI-86, the Equation Nugget with the name "AELA" can be used to calculate ELA if you know the CFM_4 of the building. [continued on next panel]
BTL1-30	1.ELA in²=61 2.EqLA in²=118 3.Estim Nat CFM=54 4.Estim Nat ACH=.37 5.Natural CFM/occ=11 6.Target ELAmin=84 7.Target CFMmin=75 8.Vent CFM Needed=52	"2.EqLA in^2" is equal to "118" for the example. EqLA (Equivalent Leakage Area) is defined by researchers at the Canadian National Research Council as the area of a sharp-edged orifice that would leak the same amount of air as the building does at a pressure of 10 Pascals. In the Solver section of the TI-86, the Equation Nugget with the name "AEQLA" can be used to calculate EqLA if you know the CFM_{10} of the building. Typically, EqLA more closely approximates the physical characteristics of building airtightness than ELA. [continued on next panel]

BTL1-31	1.ELA in²=61 2.EqLA in²=118 3.Estim Nat CFM=54 4.Estim Nat ACH=.37 5.Natural CFM/occ=11 6.Target ELAmin=84 7.Target CFMmin=75 8.Vent CFM Needed=52	"3.Estim Nat CFM" (estimated natural CFM) is equal to 54 for the example. This calculated value is based on ELA, the Weather Factor (see Panel BTL1-34) and the dimensions of the building. It is the cubic feet per minute of air leakage based on natural forces such as wind pressure and differences in air density. "4. Estim Nat ACH" is equal to 0.37 for the example. This is merely the "Estim Nat CFM" multiplied by 60 minutes per hour and divided by the building volume in units of cubit feet. [continued on next panel]
BTL1-32	1.ELA in²=61 2.EqLA in²=118 3.Estim Nat CFM=54 4.Estim Nat ACH=.37 5.Natural CFM/occ=11 6.Target ELAmin=84 7.Target CFMmin=75 8.Vent CFM Needed=52	"5.Natural CFM/occ" (estimated natural CFM per occupant) is number 3, estimated natural CFM, divided by the "Occupant Count" (see Panel BTL1-27). In order to comply with ASHRAE 62-1989, this value must be at least 15 (15 CFM per person). If this value is less than 15, "8.Vent CFM Needed" (ventilation CFM needed to comply with ASHRAE 62-1989) will be a value greater than zero. Notice that for the example, outputs in the screen panel at the left that the CFM per occupant is 11 and "8.Vent CFM Needed" is equal to 52. [continued on next panel]
BTL1-33	1.ELA in²=61 2.EqLA in²=118 3.Estim Nat CFM=54 4.Estim Nat ACH=.37 5.Natural CFM/occ=11 6.Target ELAmin=84 7.Target CFMmin=75 8.Vent CFM Needed=52	"6.Target ELAmin" (target ELA minimum) is the minimum effective leakage area of the building that will satisfy ASHRAE 62-1989. If the building is made tighter than this, mechanical ventilation must be added to comply with ASHRAE 62-1989. This value is based on 0.35 air changes per hour or 15 CFM per person, whichever is larger. Notice in this example that the actual ELA, line 1, is 61 in^2 and the target ELA minimum, line 6, is 84in^2, thus the building is tighter than ASHRAE 62-1989. Mechanical ventilation must be added. [continued on next panel]
BTL1-34	1.ELA in²=61 2.EqLA in²=118 3.Estim Nat CFM=54 4.Estim Nat ACH=.37 5.Natural CFM/occ=11 6.Target ELAmin=84 7.Target CFMmin=75 8.Vent CFM Needed=52	"7.Target CFMmin" (target CFM minimum) is the minimum natural CFM that will satisfy ASHRAE 62-1989. This value is based on 0.35 air changes per hour or 15 CFM per person, whichever is larger. As with the ELA values for this example, the actual CFM, line 3, is less than the 75 CFM (line 7) required to comply with ASHRAE 62-1989, thus ventilation must be added. "8 Vent CFM Needed" (ventilation CFM needed) is the CFM of mechanical ventilation required to bring the below-compliance building into compliance with ASHRAE 62-1989. [continued on next panel]
BTL1-35	[intentionally left blank]	This value is calculated with a variation of equation 45 on page 25.21 in *1997 ASHRAE Fundamentals Handbook.* In the example problem, the amount of actual ventilation needed is 52 CFM. Notice that this value is significantly more than line 3 subtracted from line 7. **Note: Because estimated air leakage is based on blower door tests that may vary by as much as a factor of 2 from actual air leakage rates, ventilation guidelines should be used with caution.** [continued on next panel]
BTL1-36	[intentionally left blank]	**Note: Compliance with ASHRAE 62-1989 and the procedures of this ZipTest software do not guarantee that a moisture or indoor air quality problem will not develop. A healthy rate of ventilation may be more or less than the suggested estimate calculated here. Be cautions and use common sense.** Now, press ENTER to move to the "ALL DATA" screen

BTL1-37	a)1200 1)61 All b).68 2)118 Data c).96 3)54 d)8800 4).37 e)1100 5)11 f)8.0 6)84 g)8.0 7)75 h)5 8)52 9)1537	The "All Data" display lists all the your inputs and outputs for a calculation. This is presented as a summary for your convenience. The letters and numbers correspond with the line letters (inputs) and numbers (outputs) on the two previous calculator displays. a) CFM$_{50}$ from blower door test (see Panel BTL1-20). b) Flow exponent from blower door test or 0.65 (see Panel BTL1-21). c) Weather factor from pages 16 through 18 (see Panel BTL1-22).
BTL1-38	a)1200 1)61 All b).68 2)118 Data c).96 3)54 d)8800 4).37 e)1100 5)11 f)8.0 6)84 g)8.0 7)75 h)5 8)52 9)1537	e) House square footage (see Panel BTL1-24). f) Building height (see Panel BTL1-25). g) Story height (see Panel BTL1-26). h) Occupant count (see Panel BTL1-27). 1) Actual ELA (effective leakage area) (see Panel BTL1-29). 2) Actual EqLA (equivalent leakage area) (see Panel BTL1-30) 3) Estimated actual natural CFM (see Panel BTL1-31).
BTL1-39	a)1200 1)61 All b).68 2)118 Data c).96 3)54 d)8800 4).37 e)1100 5)11 f)8.0 6)84 g)8.0 7)75 h)5 8)52 9)1537	5) Estimated actual natural CFM per occupant (see Panel BTL1-32). 6) Target minimum ELA for compliance (see Panel BTL1-33). 7) Target minimum CFM for compliance (see Panel BTL1-34). 8) Mechanical ventilation CFM needed for compliance(see Panels BTL1-34 & 35). 9) Target minimum CFM$_{50}$ value. This is the only place this output appears. This is meant to minimize the importance of this value because it is problematic to use it as a house tightening target (see page 4). If you must
BTL1-40	BUILDING TIGHTNESS LIMIT CALCULATIONS FOR ACCEPTABLE INDOOR AIR QUALITY (c)1999 WxWare (V2.0) Select from Menu BTL BTLa HELP ACKLG QUIT	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	a.CFM50= 3230 b.Flow Exp= .65 0.65 c.Weather Fact= .96 d.House Vol= 28500 e.House Ft^2= 2400 f.Bldg Ht, ft= 16 g.Story Ht, ft= 8 h.Occupant Count= 6	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	1.ELA in^2=177 2.EqLA in^2=333 3.Estim Nat CFM=288 4.Estim Nat ACH=.61 5.Natural CFM/occ=48 6.Target ELAmin=102 7.Target CFMmin=166 8.Vent CFM Needed=0	All the outputs, except target minimum CFM$_{50}$ are listed on the output display. Notice that no mechanical ventilation (line 8) is called for. The natural CFM per occupant, line 5, exceeds the ASHRAE 62-1989 minimum of 15 and the estimated natural ACH , line 4, exceeds the minimum 0.35. The actual ELA, line 1, exceeds the target minimum ELA on line 6. This house can be significantly tightened before the ASHRAE 62-1989 minimum values are reached. [continued on next panel]

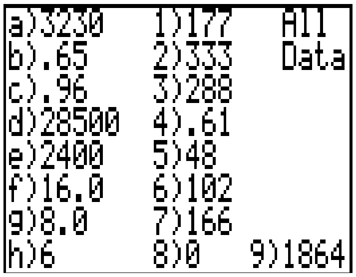
BTL1-43



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

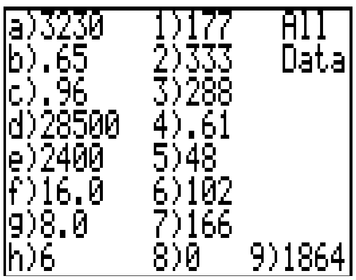
Press to move to the "All Data" display.

BTL1-44



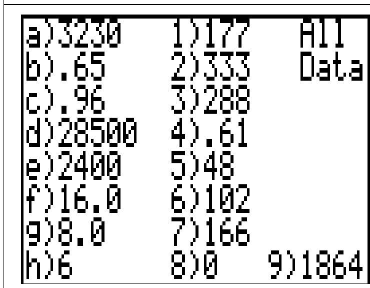
a) CFM50 from blower door test (see Panel BTL1-20).
b) Flow exponent from blower door test (see Panel BTL1-21).
c) Weather factor from pages 16 through 18 (see Panel BTL1-22).
d) House volume (see Panel BTL1-23).
e) House square footage (see Panel BTL1-24).
f) Building height (see Panel BTL1-25).
g)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

BTL1-45



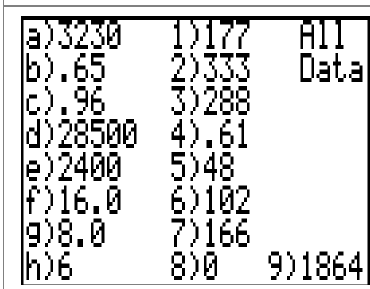
2) Actual EqLA (equivalent leakage area) (see Panel BTL1-30).
3) Estimated actual natural CFM (see Panel BTL1-31).
4) Estimated actual natural ACH (see Panel BTL1-31).
5) Estimated actual natural CFM per occupant (see Panel BTL1-32).
6) Target minimum ELA for compliance (see Panel BTL1-33).
7) Target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

BTL1-46



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

BTL1-47



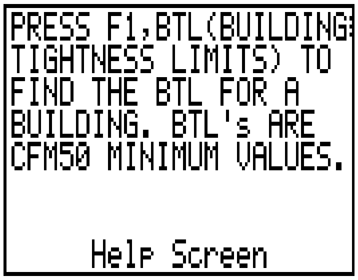
The TI-86 does not allow storage of this "All Data" display out in the field unless you have the Graph Link cable and software and a portable PC or Mac computer in the field. You cannot store the display in the TI-86 for recall and printing later. You can, of course, re-enter the input data back at your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

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

BTL1-48

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

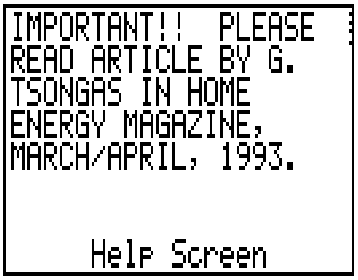
BTL1-49



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

Press **ENTER**.

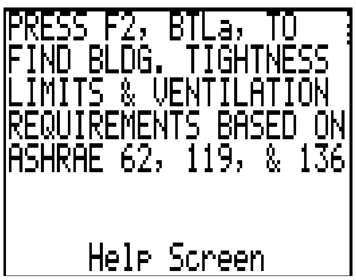
BTL1-50



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

Press **ENTER**.

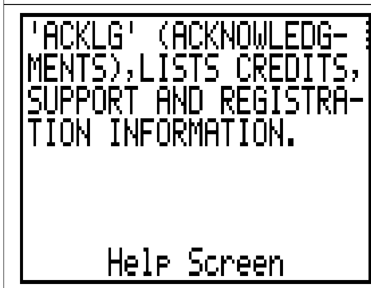
BTL1-51



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

Press **ENTER**.

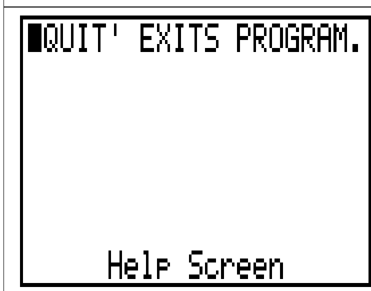
BTL1-52



You will see the screen at the left displayed.

Press **ENTER**.

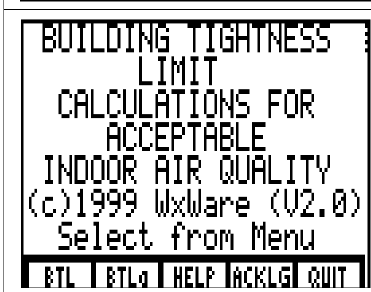
BTL1-53



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

Press **ENTER**.

BTL1-54

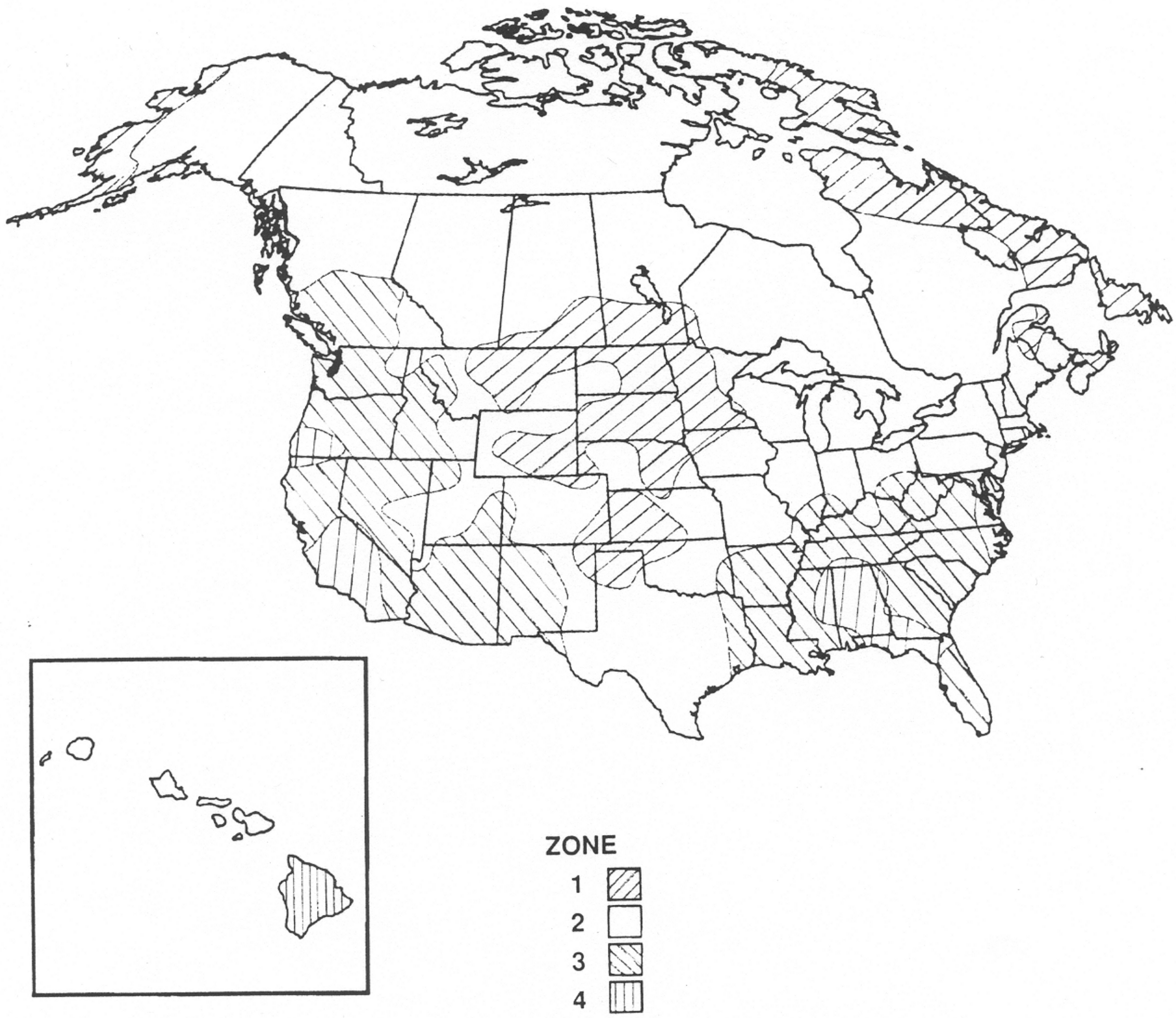


Select **F4,** "ACKLG," (acknowledgments).

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

BUILDING TIGHTNESS LIMITS CLIMATE ZONE MAP

(For use with BTL method)



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Instructions
for

Energy Index Calculations
in units of Btu/Ft^2,DD
[Program "BTUDD"]

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 before BTU/FT^2,DD is calculated. See the instructions 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, 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.

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").

$$Q = \frac{gal/yr \times (T_{out} - T_{in}) \times 8.33\ lbs/gal \times 1\ Btu/lb,^{0}F}{Eff \times C}$$

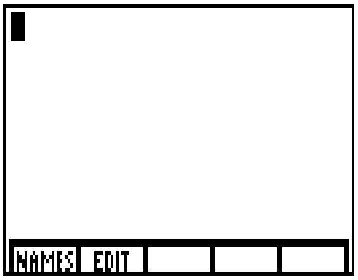
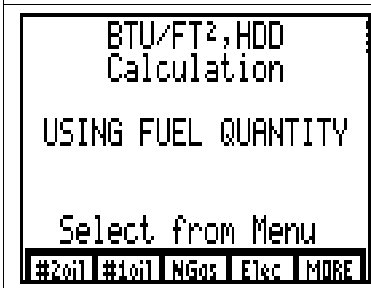
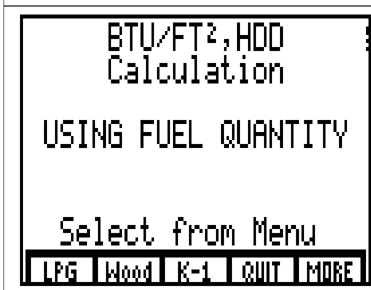
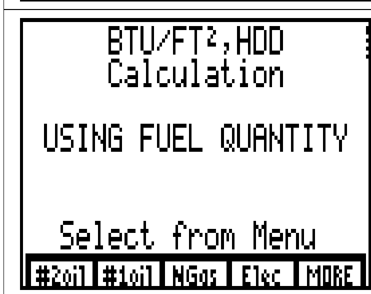
where:

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.
8.33 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.

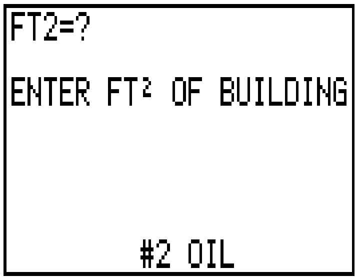
Gallons of hot water use per day in North America averages about 62 gallons per household. Two adults in a household use from 30 to 60 gallons per day. A household with two adults and two children might have an average daily use as high as 90 gallons per day. Households with very young children often 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.

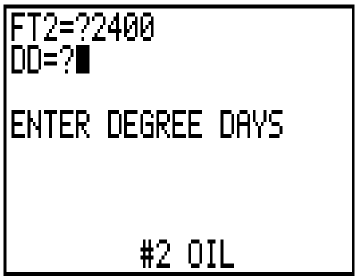
BTUDD-1		Turn the TI-86 calculator on. Press **PRGM** (Programs). You will see this menu on the screen. Press **F1** for "NAMES." **NOTE: It is best never to press EDIT, F2.**
BTUDD-2		You will see this menu on the screen. Press **F1, F2, F3, F4**, or **F5** for the program "BTUDD." The menu key for this program will depend upon the number of programs loaded into the memory of your TI-86 calculator. (Note: Some BTU/FT^2/DD programs have been customized for various areas of North America and are designated by different names). "BTUDD" will appear at the cursor location. Press **ENTER**. Note: The exact name of the program must appear at the
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.
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



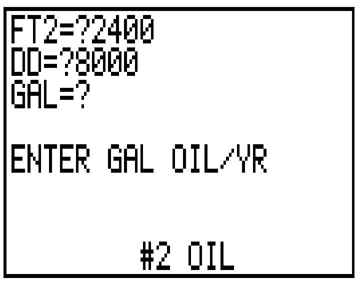
You will see the screen at the left displayed .
You are asked to “ENTER FT^2 OF BUILDING.” Enter the square feet of the *occupied* area of the building. When you enter the square footage, the value will be displayed after the **“?”**
Notice that “#2 OIL” is displayed at the bottom of the screen as a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

BTUDD-8



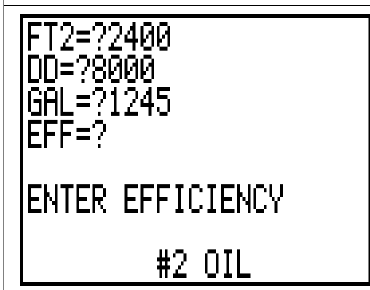
You are asked to **ENTER DEGREE DAYS**. Enter the heating degree days, base 65°F, for the location of the building. When you enter the heating degree days, the value will be displayed after the “**?**”
Press **ENTER**.

BTUDD-9



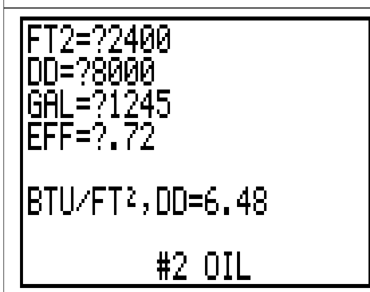
You are asked to **ENTER GAL OIL/YR**. Enter the gallons of #2 oil used in one year for space heating only. If your fuel use figure includes fuel for domestic hot water, subtract this amount from the total to get space heating fuel quantity (see page 20 for instructions). When you enter the gallons of oil used, the value will be displayed after the “**?**”
Press **ENTER**

BTUDD-10



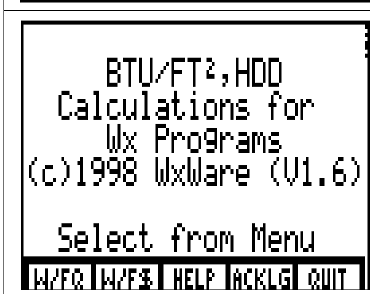
You are asked to “ENTER EFFICIENCY.” Enter the estimated <u>seasonal efficiency</u> for the oil heating system. When you enter the seasonal efficiency, the value will be displayed after the “**?**” Enter the efficiency as a decimal.
Note: If you enter “1.00,” your answer will be a BTU/FT^2, DD *input* value. If you enter a decimal efficiency number, i.e.,” 0.72,” your answer will be a BTU/FT^2, DD *output* value.
Press **ENTER**.

BTUDD-11



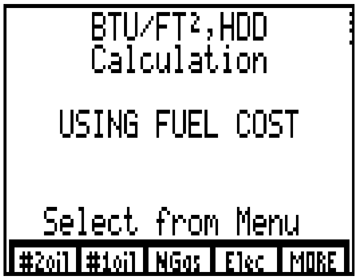
Notice the answer is displayed on the screen after **BTU/FT2, DD=**
All of the values you entered are displayed on the screen.
Enter the BTU/FT^2, DD on your audit form, if required.
Each of the other fuels—#1oil, NGas, Elec, LPG, Wood, and K-1—work in the same manner when you select **F1**, “W/FQ” from the main menu.
Press **ENTER** to return to main menu.

BTUDD-12



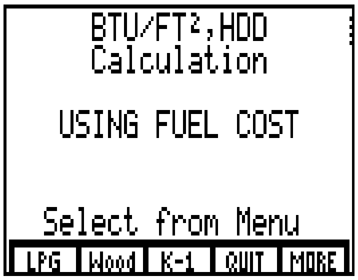
Your will see the screen at the left displayed , the main menu screen.
As another demonstration, select **F2,** **“**W/F$” (with fuel dollars), the selection for finding BTU/FT^2, DD if you know the annual dollars spent for a fuel type.
Do not use this routine unless you must. Using “W/FQ” is more accurate because one less variable—fuel cost per unit—is required.

BTUDD-13



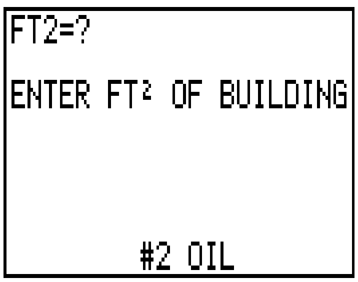
You will see this menu on the screen.
F1 is for "#2 oil," **F2** for "#1 oil," **F3** for "NGas" (natural gas), **F4** for "Elec" (electric) heat.
Select **F5**, "MORE," for more choices of space-heating fuels.

BTUDD-14



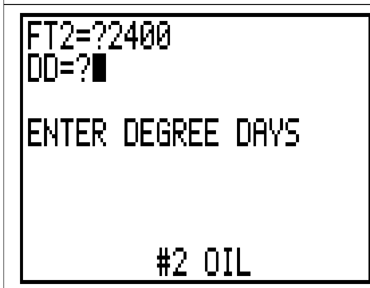
F1 is for "LPG," **F2** for "Wood," **F3** for "K-1," **F4** for "QUIT," or **F5** for "MORE" (this will return you to the previous menu screen).
If you select **F4, "**QUIT," you will return to the main menu screen.
Select **F5, "**MORE," and then select **F1, "**#2oil," for #2 Oil.

BTUDD-15



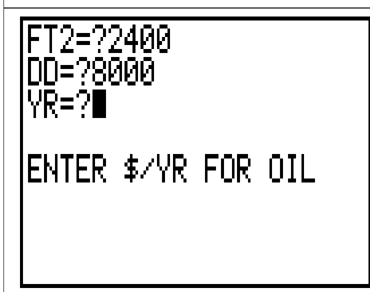
You are asked to "ENTER FT^2 OF BUILDING." Enter the square feet of the *occupied* area of the building. When you enter the square footage, the value will be displayed after the "**?**"
Notice that "#2 OIL" is displayed at the bottom of the screen as a reminder of your fuel selection.
Press **ENTER**.

BTUDD-16



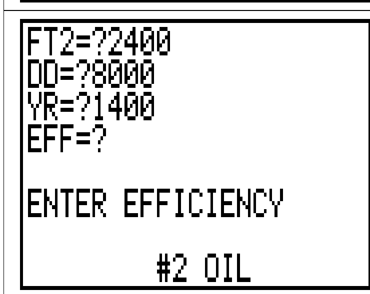
You are asked to "ENTER DEGREE DAYS." Enter the heating degree days, base 65°F, for the location of the building. When you enter the heating degree days, the value will be displayed after the "**?**"
Press **ENTER**.

BTUDD-17



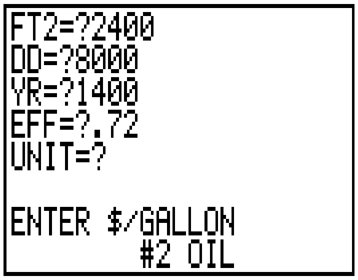
Enter the cost in one heating season for #2 oil used for space heating. If your fuel cost figure includes fuel for domestic hot water, subtract this amount from the total to get space heating fuel dollars. When you enter the seasonal cost for oil, the value will be displayed at the "**?**"
Press **ENTER**.

BTUDD-18



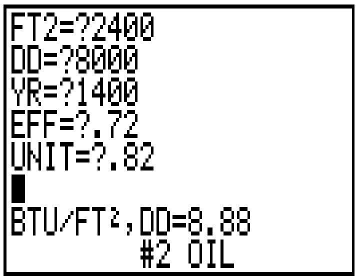
You are asked to "ENTER EFFICIENCY." Enter the estimated *seasonal efficiency* for the oil heating system. When you enter the seasonal efficiency, the value will be displayed after the "**?**" Enter the efficiency as a decimal. Note: If you enter "1.00," your answer will be a BTU/FT^2, DD *input* value. If you enter a decimal efficiency number, i.e.," 0.72," your answer will be a BTU/FT^2, 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

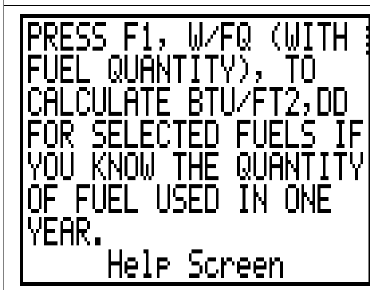


Notice the answer is displayed on the screen after "BTU/FT^2, DD="
All of the values you entered are displayed on the screen.
Enter the BTU/FT^2, DD on your form, if required.
Each of the other fuels—#1oil, NGas, Elec, LPG, Wood, and K-1—work in the same manner when you select **F2**, "W/F$," from the main menu.
Press **ENTER** to return to main menu.

BTUDD-21

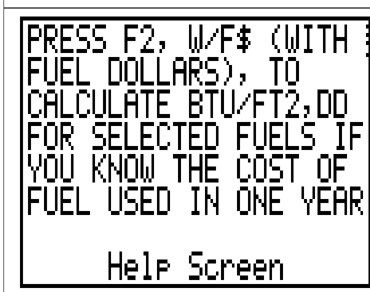
From the main menu, select **F3, "**HELP."
You will see the screen at the left displayed.
Press **ENTER**.

BTUDD-22



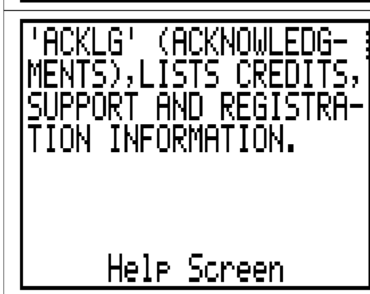
You will see the screen at the left displayed.
Press **ENTER**.

BTUDD-23



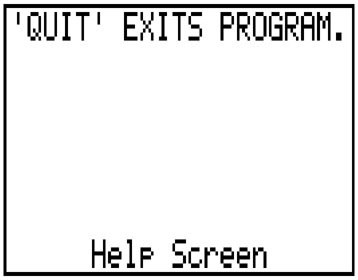
You will see the screen at the left displayed.
Press **ENTER**.

BTUDD-24



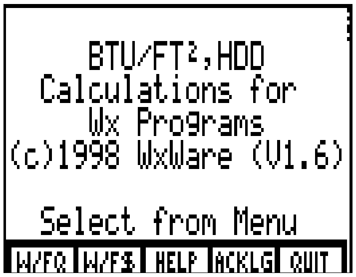
You will see the screen at the left displayed.
Press **ENTER.**

BTUDD-25



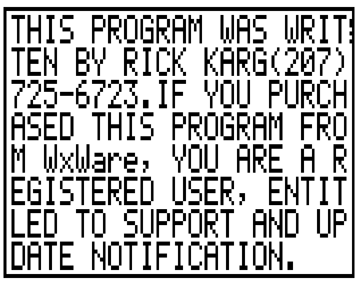
You will see the screen at the left displayed.
Press **ENTER**.
Note: If you make a mistake while entering data before you press **ENTER**, use the arrow buttons to move the cursor over the erroneous entry and type the correct entry. If you notice you have made a mistake after you have pressed **ENTER**, 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**.

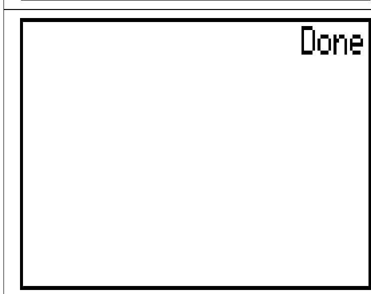
BTUDD-28

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.

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)

February, 1999 (V1.0)

Combustion Venting Safety: Depressurization Tightness Limits (DTL) Program

This program, DTL (Depressurization Tightness Limits), includes three calculation procedures; CFM_{50}, CFM and P. The primary purpose of this program is to allow you to determine if natural draft 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:

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

where:

CFM = total cubic feet per minute flow rate of actual mechanical exhaust from building;
CFM50 = the tested blower door CFM_{50} of the building;
P = 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 P. Solving for CFM_{50} is the most often used routine. To solve for CFM50 you must choose the P target value to use. Many energy auditing and weatherization programs select a P = -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.

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 consort 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 natural 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.

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.

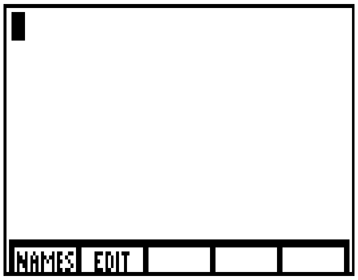
A gas-fired range/oven, or other unvented combustion appliance, is not affected by negative pressures in a house because it is not vented—or coupled—to the outdoors, so the indoor-outdoor pressure difference is irrelevant.

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 P 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 P.

Finally, you can solve for P 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 P in Pascals. This routine helps you determine if the combustion appliances are in danger 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 54 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

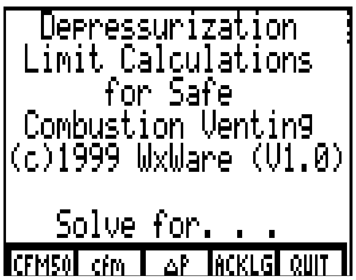


Turn the TI-86 calculator on.
Press **PRGM** (Programs).
You will see this menu on the screen.
Press **F1** for “NAMES.”
NOTE: It is best never to press “EDIT,” **F2.**

DTL-2

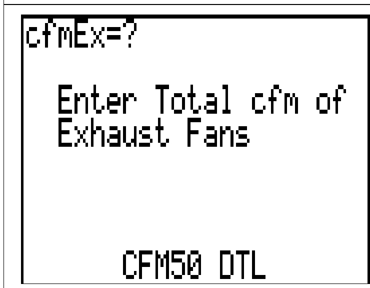
You will see this menu and sub-menu on the screen.
Press **F1, F2, F3, F4**, or **F5** for the program **DTL**. The menu key for this program will depend upon the number of programs loaded in the memory of you TI-86 calculator.
“DTL” will appear at the cursor location.
Press **ENTER**. **Note: The exact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

DTL-3



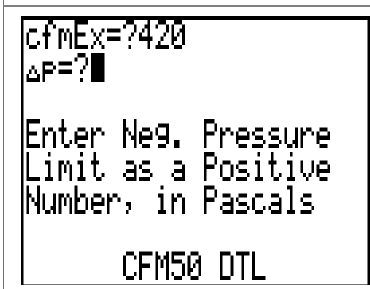
You will see this menu on the screen. This is the main menu screen.
Select **F1,** “CFM50,” to solve for CFM_{50} depressurization tightness limit.
Select **F2,** “cfm,” to solve for cfm exhaust limit of house exhaust appliances.
Select **F3,** “ P,” to solve for resulting P from existing CFM_{50} and 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

DTL-4



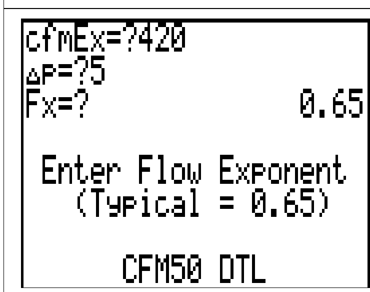
Select **F1,** “CFM50,” to solve for CFM_{50} depressurization tightness limit.
You will see this menu on the screen.
Enter the actual, total cfm exhaust rate of all the exhaust appliances in the house. You may include appliances that are not yet installed, such as a dryer
For this example, assume the 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.

DTL-5



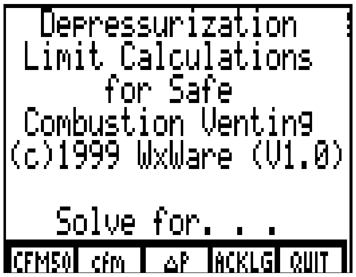
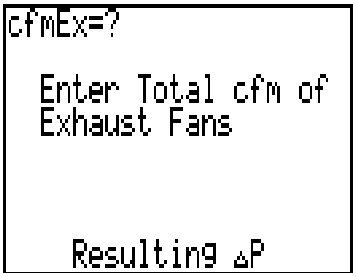
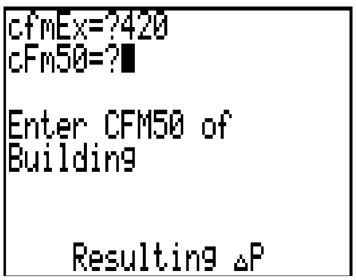
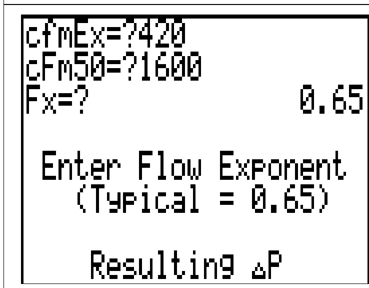
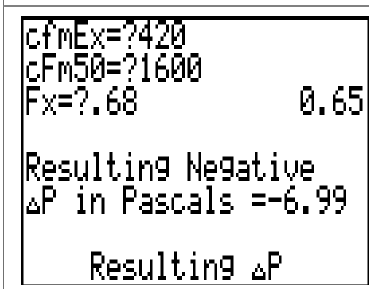
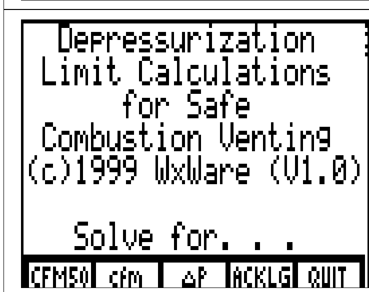
Now you must enter the target P in units of Pascals. This is the difference between the indoor and outdoor pressure allowable. You must choose this value for the safe operation of the natural draft combustion appliances. Most auditors for weatherization programs use a P = -5 Pascals, plus or minus one.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

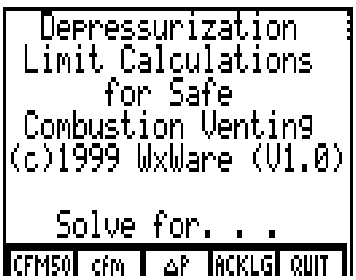
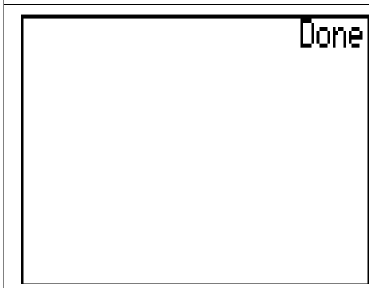
DTL-6



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.

DTL-7	cfmEx=?420 ΔP=?5 Fx=?.65 0.65 CFM50 DTL = 1876 CFM50 DTL	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 P = -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	Depressurization Limit Calculations for Safe Combustion Venting (c)1999 WxWare (V1.0) Solve for. . . CFM50 | cfm | ΔP | ACKLG | QUIT	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	cFm50=? Enter CFM50 of Building cfm Exhaust Limit	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	cFm50=?1540 ΔP=? Enter Neg. Pressure Limit as a Positive Number, in Pascals cfm Exhaust Limit	Now you must enter the target P 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 natural draft combustion appliances. Most auditor for weatherization programs use a P = -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.
DTL-11	cFm50=?1540 ΔP=?5 Fx=? 0.65 Enter Flow Exponent (Typical = 0.65) cfm Exaust Limit	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	cFm50=?1540 ΔP=?5 Fx=?.65 0.65 Exhaust Limit in cfm = 345 cfm Exaust Limit	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 P = -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 “ P” routine. This allows you to solve for the resulting P, the difference in Pascals of pressure between the indoors and outdoors of the house. You can quickly determine whether the natural draft 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 P.”
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 P” answer of -7.0 is displayed. Notice that the input values are displayed along with the output. This resulting P” 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 two acknowledgements screens. Press **ENTER**.
DTL-20		This is the second of two acknowledgements screens. Press **ENTER**.
DTL-21		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-22		You will now see this display. You have now properly exited from the DTL program.
DTL-23		
DTL-24		

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Instructions for

Pressure Diagnostics

[Program "Press"]

February, 1999 (V2.3)

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} Series Leakage Values (Building/Zone, Zone/Outdoors, Total Path):
   - Hole Method.
   - Door Method.
   - Vent Method.
3) 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.
4) Calculation of Minneapolis Duct Blaster® Flow Rates, both older (serial numbers from 0-591) and newer (serial numbers from 592 and up) models.

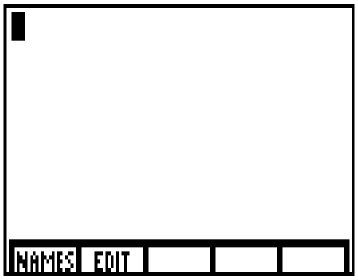
For more information about these test procedures, consult the following documents:

- *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 37. Pictures of the TI-86 screens appear on the left side of pages 37 through 52 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®, Model 3.
“BLD P,” **F2,** is for the calculation of Building Series Leakage Testing. This routine includes the hole, door, and vent methods.
“HELP,” **F3,** lists instructions for this screen.
“MORE,” **F4,** moves you to the next menu screen.

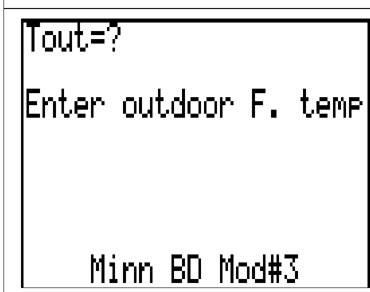
Press- 4

Select “MORE,” **F4** and you will see this menu on the screen.
“BLSTR,” **F1**, calculates Minneapolis Duct Blaster® Flow Rates.
“DUC P,” **F2**, is for the calculation of Duct Series Leakage Testing.
“HELP,” **F3**, lists instructions for this screen.
“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®, Model 3.
Note: This calculation procedure does not work for the Minneapolis Blower Door®, Model 2.

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 prompt instruction on the screen below the prompt line.
Notice that “Minn BD Mod#3” is at the bottom of the screen as a reminder

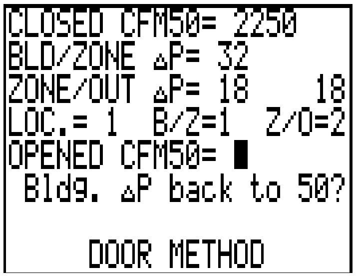
Press-7	Tout=?10 Tin=? Enter indoor F. temp Minn BD Mod#3	Enter "Tin," the indoor temperature (F^0). If the temperature is different indoors than it is outdoors, the blower door CFM_{50} value will be influenced because of the different air densities. The magnitude of the difference is dependent on the degree of temperature difference. Enter "70" and press **ENTER**.
Press-8	Tout=?10 Tin=?70 Test=? Enter Test Type: Depressurization = 1 Pressurization = 2 Minn BD Mod#3	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. If the CFM_{50} results were not temperature-corrected, this question would not be necessary. See panel explanation "Press-7" just above for a brief explanation. Enter "1" and then press **ENTER.**
Press-9	BLD∆P=? Enter ACTUAL Bldg. to Outdoor ∆P in Pascals Depressurization Test	Enter "BLD P," 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. This 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.
Press-10	BLD∆P=?35 FAN∆P=? Enter Fan ∆P in Pascals Depressurization Test	"FAN P," 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.
Press-11	BLD∆P=?35 0=OPEN FAN∆P=?100 1=A-RING CONFIG=? 2=B-RING 3=C-RING Enter Ring Config. Depressurization Test	"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" will always be "0." Press **ENTER.**
Press-12	BLD∆P=?35 0=OPEN FAN∆P=?100 1=A-RING CONFIG=?0 2=B-RING 3=C-RING Tin = 70 Tout = 10 FANFLO ---> 4501 CFM50 ----> 5675 Depressurization Test	The Fan Flow and the CFM_{50} answers are displayed along with all the data you entered. The "FANFLO" of 4501 is the CFM_{35}. 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- 13	Would You Like to Determine ELA, EqLA, Target CFM, Vent. Required, etc? If so, please use the BTL1/BTLa Program Press Enter to Return	After pressing **ENTER** you will see this display. This is a reminder that another program included in the ZipTest Two 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," (**F2** menu item) routine. When you press **ENTER**, you will be returned to the home screen of the pressure diagnostics program, "Press."
Press- 14	1.ELA in²=61 2.EqLA in²=118 3.Estim Nat CFM=54 4.Estim Nat ACH=.37 5.Natural CFM/occ=11 6.Target ELAmin=84 7.Target CFMmin=75 8.Vent CFM Needed=52	***[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). 2. EqLA, Equivalent Leakage Area in square inches. (see panel BTL1-30). 3. Estimated Natural CFM (see panel BTL1- 31). 4. Estimated Natural ACH (see panel BTL1- 31). 5. Natural CFM/occ (see panel BTL1- 32). [continued next panel]
Press- 15	a)1200 1)61 All b).68 2)118 Data c).96 3)54 d)8800 4).37 e)1100 5)11 f)8.0 6)84 g)8.0 7)75 h)5 8)52 9)1537	***[Please Note: this panel does not follow the above Panel Press-13, it is a sample from the BTL1 program/BTLa routine]*** 6. Target ELA minimum (see panel BTL1- 33). 7. Target CFM minimum (see panel BTL1- 34). 8. Ventilation CFM needed (see panels BTL1- 34 & 35). 9) Target minimum CFM_{50} value (see panel BTL1- 39). ***End of sample screens from the "BTL1" program/"BTLa" routine. . .***
Press- 16	CALCULATIONS FOR DUCT BLASTER, BLOWER DOOR & SERIES LEAKAGE TESTING (c)1999 WxWare (V2.3) Select from Menu Mbd3 BLDΔP HELP MORE QUIT	Back to the home screen of the pressure diagnostics program, "Press." Now select, "BLD P," **F2** for "Building Series Leakage Tests."
Press- 17	BUILDING SERIES-LEAKAGE TESTS Select from Menu HOLE DOOR VENT QUIT	You will see the Building Series-Leakage Tests 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	BLD/ZONE ΔP1= HOLE METHOD	You will see this screen, prompting for building/zone P1. The building should be at 50 Pascals of pressure while the building/zone P1 is measured. **Note: If you are not able to obtain a building pressure difference of 50 Pascals, this procedure will not 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.

Press- 19	BLD/ZONE ΔP1= 35 ZONE/OUT ΔP1= 15 HOLE METHOD	Enter "35" as the "BLD/ZONE P1." Press **ENTER**. Now you are prompted to enter the "Zone/Out P1."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 P1." "BLD/ZONE P1" plus "ZONE/OUT P1" should equal 50, plus or minus 2.
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 P1 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 (after-hole) building to zone pressure, "BLD/ZONE P2." **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 P2 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.
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 (after-hole) zone to outdoor pressure, "ZONE/OUT P2." Notice that to the right of "ZONE/OUT P2" the suggested pressure is displayed. Your measured "ZONE/OUT P2" 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. Refer to Panel Press-29 for the input labels. 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**.

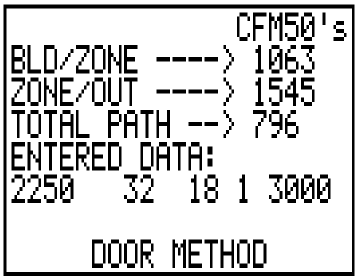
Press- 25	CALCULATIONS FOR DUCT BLASTER, BLOWER DOOR & SERIES LEAKAGE TESTING (c)1999 WxWare (V2.3) Select from Menu Mbd3 | BLD∆P | HELP | MORE | QUIT	The main menu is displayed. Press “BLD P,” **F2**, for Building Series Leakage Tests.
Press- 26	BUILDING SERIES-LEAKAGE TESTS Select from Menu HOLE | DOOR | VENT | | QUIT	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	CLOSED CFM50= DOOR METHOD	Enter the Closed 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	CLOSED CFM50= 2250 BLD/ZONE ∆P= DOOR METHOD	Measure the building-to-zone pressure, “BLD/ZONE P.” Enter “32” and press **ENTER**.
Press- 29	CLOSED CFM50= 2250 BLD/ZONE ∆P= 32 ZONE/OUT ∆P= 18 DOOR METHOD	Measure the zone-to-outdoors pressure, “ZONE/OUT P.” Notice that the suggested “ZONE/OUT P” pressure is displayed at the right. Your measured “ZONE/OUT P” should be within 2 Pascals of this displayed number. Enter “18” and press **ENTER**.
Press- 30	CLOSED CFM50= 2250 BLD/ZONE ∆P= 32 ZONE/OUT ∆P= 18 18 LOC.= B/Z=1 Z/O=2 INDICATE LOCATION OF OPENED DOOR DOOR METHOD	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 P of 32 Pascals. Enter “1” and press **ENTER**.

Press- 31



Now enter the opened CFM_{50}.
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 .

Press- 32

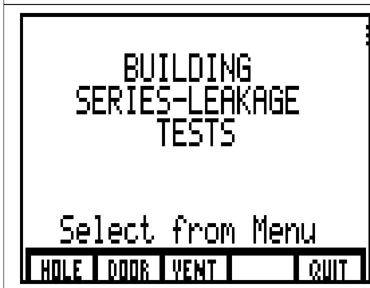


The CFM_{50} "BLD/ZONE, ZONE/OUT," and "TOTAL PATH" values are displayed.
Notice that the "ENTERED DATA" is displayed in the order in which it was entered. See panel "Press-37" for the order of entry.
Dividing the BLD/ZONE CFM_{50} by 10 yields the approximate square inches of leakage between the building 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/

Press- 33

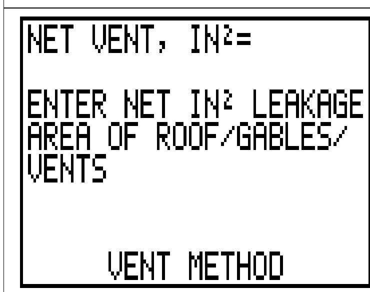
The main menu is displayed.
Press "BLD P," **F2**, for Building Series Leakage Tests.

Press- 34



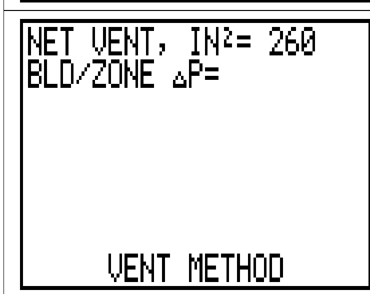
Press "VENT," **F3**, for the Vent Method.
For this test, the openings in the attic are measured or estimated. The building-to-zone and the zone-to-the outdoor pressures are measured. This method is weak because of the difficulty of measuring the openings in most attics (zone to outdoors). However, this 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



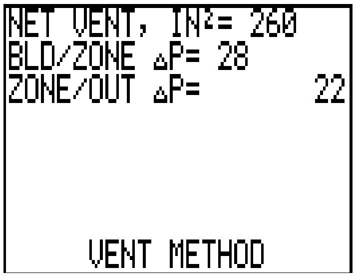
"Enter net square inches of leakage area of roof/gables/vents. This is often difficult to measure or estimate. Do the best you can.
For the example, enter "260" and press **ENTER**.

Press- 36



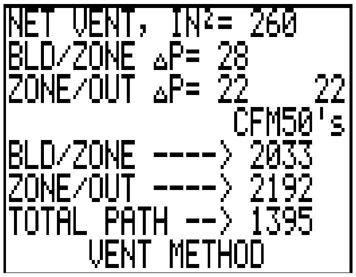
With the building to outside pressure at 50 Pascals, measure the building to zone pressure difference. This pressure should be close to 50 Pascals.
For the example, enter "28" and press **ENTER**.

Press- 37



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

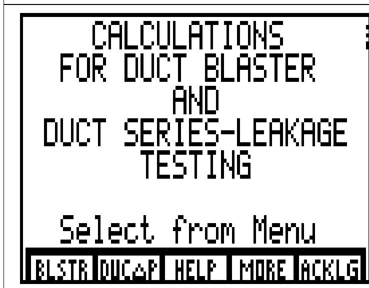


The CFM_{50} values are displayed for building-to-zone, zone-to-outdoors, and total path.
The Total Path value for the vent method, the hole method, and the door method will always be less than the building-to-zone or the zone-to-outdoor CFM_{50} values. The Total Path figure includes the combined air-flow resistance of the building-to-zone barrier and the zone-to-outdoor barrier.
This ends the Building Series Leakage examples.

Press- 39

You will see the main screen displayed.
Press "MORE," **F4**, to move to the other primary menu.

Press- 40

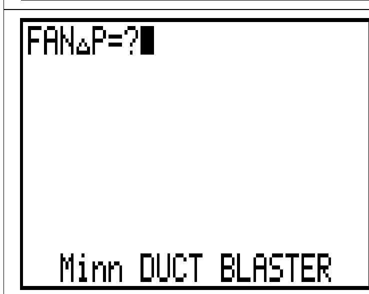


Press "BLSTR," **F1**, for Minneapolis Duct Blaster® Flow Rate calculations.
The Duct Blaster is a calibrated air flow measurement system used to test the airtightness of forced air distribution systems. See the *Minneapolis Duct Blaster® Operation Manual* for discussion of proper use of the Duct Blaster®. 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.

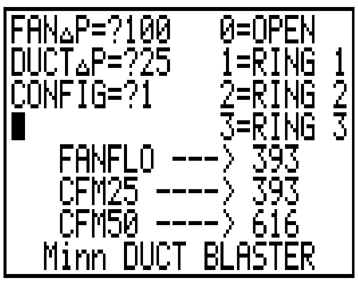
Press- 41

As of March 1995, The Energy Conservatory (TEC) began producing a duct blaster with a different calibration than the original. The WxWare ZipTest software can calculate flow rates for both types.
Serial numbers 0 - 591 are designated in the ZipTest 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, press **ENTER** to move to the next screen.

Press- 42



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

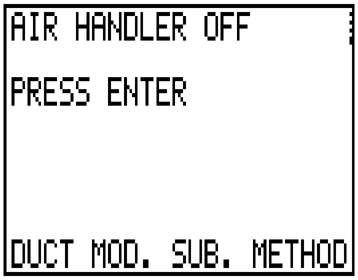
Press- 43		Now enter the duct pressure. The reference pressures for testing usually are 25 Pascals, 50 Pascals, or the average actual operating pressure of the duct system. If you are not able to reach 25 Pascals, enter the value that was reached. The program will calculate the CFM_{25} from the data that you provide. (The program assumes the flow exponent, n=0.65). Enter “25” and press **ENTER.**
Press- 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. 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). The last two methods are experimental at this time (Feb. 1995)

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 P2,” the building to duct pressure after the hole is made. For the example “27.” Measure and enter the “DUC/OUT P2,” the duct to outdoors pressure after the hole is made. For the example “23.”
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 & SERIES LEAKAGE TESTING (c)1999 WxWare (V2.3) Select from Menu MbΔ3 BLDΔP 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 “DUC P,” **F2**, for the Duct Series Leakage menu.

Press- 55

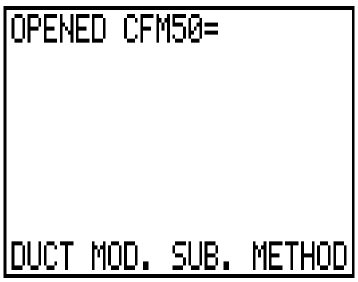
The Duct Series Leakage menu is displayed.
Press "MODSB," **F2**, for the Duct Modified Subtraction Method calculation.
The method works best when the duct leakage is less than 200 CFM_{50}

Press- 56



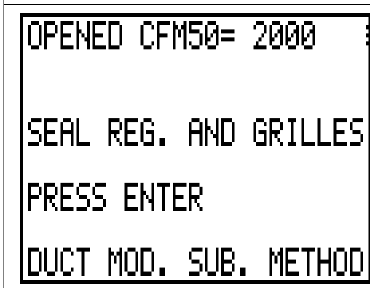
Air handler should be off.
Press **ENTER**.

Press- 57



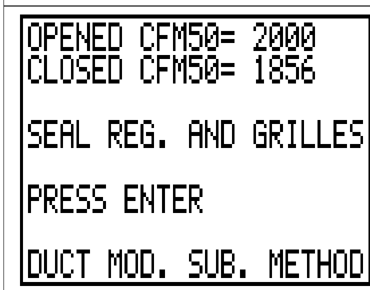
With the blower door, measure the CFM_{50} with the duct system open to the building, i.e. not taped or sealed.
For the example, enter "2000" and press **ENTER.**

Press- 58



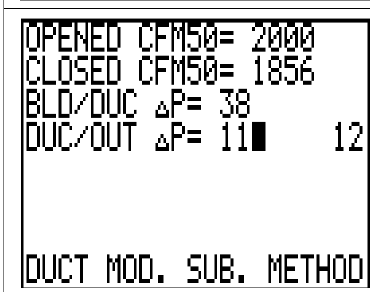
Now seal registers and grilles and measure the CFM_{50} with the blower door.
Press **ENTER.**

Press- 59



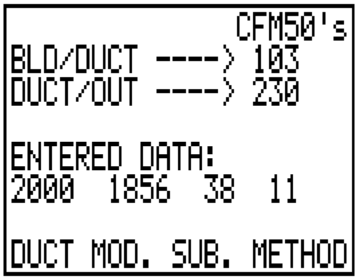
Now enter the Closed CFM50 (registers and grilles sealed). For the example enter "1856."
Press **ENTER**.

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

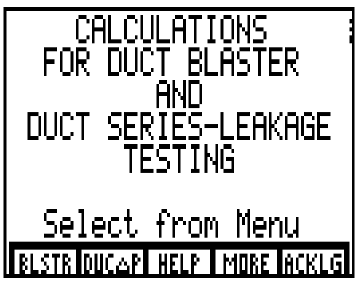


The CFM_{50} values for the building-to-duct and the duct-to-the outdoor are displayed.
Notice that the “ENTERED DATA” is displayed in the order in which it was entered. Refer to Panels Press-59 and Press-60 for the input labels.
Press **ENTER**.

Press- 62

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

Press- 63

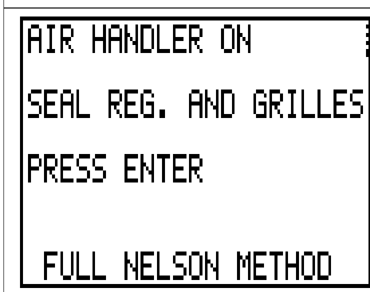


Press “DUC P,” **F2** for Duct Series Leakage Tests.

Press- 64

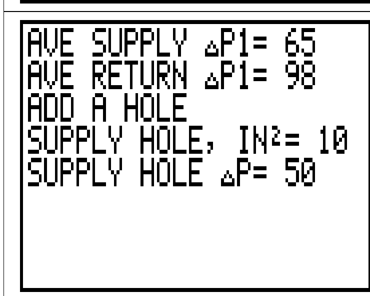
Press “NELSN,” **F3,** for an example of the Full-Nelson Method.
This method is still experimental. Act accordingly with the results. This method provides insight into the relative leakiness of the return and supply sides of the duct system in terms of CFM_{50}.

Press- 65



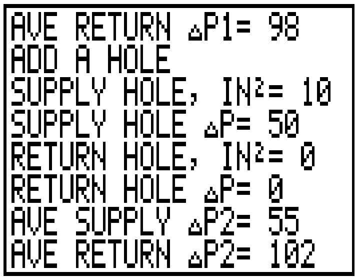
Instructions for Full-Nelson Method are displayed.
Note that high pressures may be created in the duct system. These pressures could damage the duct system.
Press **ENTER.**

Press- 66



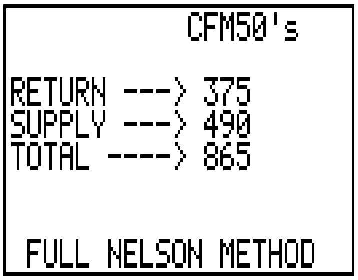
Enter the average supply duct pressure, for the example, “65” Pascals.
Enter the average return duct pressure, for the example, “98” Pascals.
Add a hole to either the supply side or the return side.
Enter the Supply Hole size, for the example, “10” square inches.
Enter the Supply Hole Pressure Difference,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

Press- 67



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   P2" after the hole is made. For the example enter "55."
Enter the average return pressure, "AVE RETURN   P2" after the hole is

Press- 68



The return duct CFM_{50}, supply duct CFM_{50}, and the total CFM_{50} are displayed.
Press **ENTER**.

Press- 69

Back to the main menu.
Press "MORE," **F4**, for one last example.

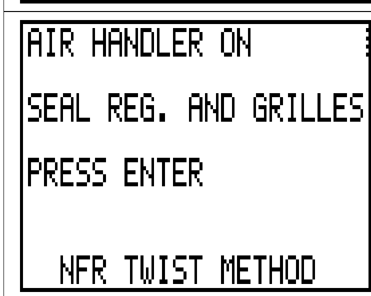
Press- 70

The other primary menu is displayed.
Press "DUC P," **F2**, for Duct Series Leakage Tests.

Press- 71

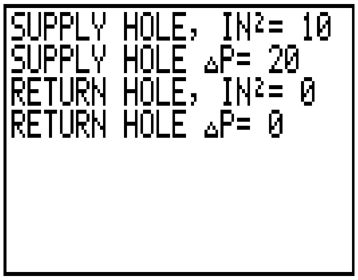
Press "TWIST," **F4,** for an example of the Nelson-with-NFR-Twist Method (NFR is Natural Florida Retrofit).
This method is still experimental. Act accordingly with the results.
Note: If you make a mistake while entering data before you press ENTER, use the arrow buttons to move the cursor over the erroneous 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



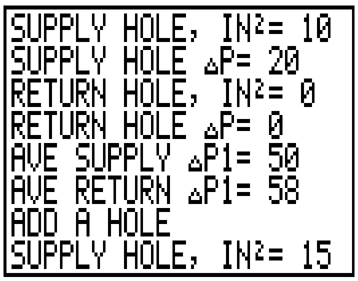
Instructions for the Nelson-with-NFR-Twist Method are displayed.
Note that high pressures may be created in the duct system. These pressure could damage the duct system.
This method is similar to the Full-Nelson method, except a hole is added to relieve pressure in the ducts.
Press **ENTER.**

Press- 73



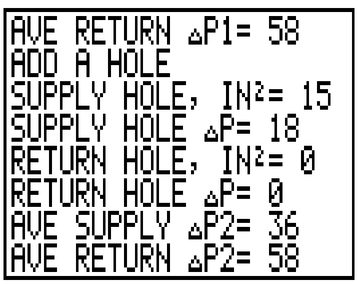
Enter the initial added supply hole. For the example, enter "10" square inches.
Enter the pressure across the supply hole. For the example, enter "20."
Enter the return hole. In the example, a return hole is not added, so enter "0."
Enter the return hole pressure difference. If no return hole is added,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

Press- 74



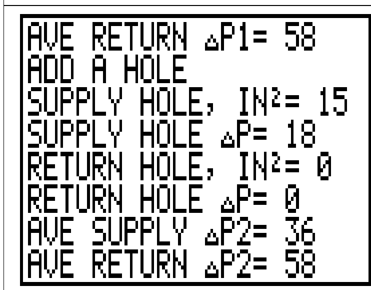
Enter the average supply pressure difference, "AVE SUPPLY P1" for the example is "50."
Enter the average return pressure difference, "AVE RETURN P1" for the example is "58."
Add a hole to either or both sides of the duct system. For the example a supply hole is added, "15." Note that the supply hole went from the initial 20 square inches to 15 square inches. Use the actual hole size, not the change

Press- 75



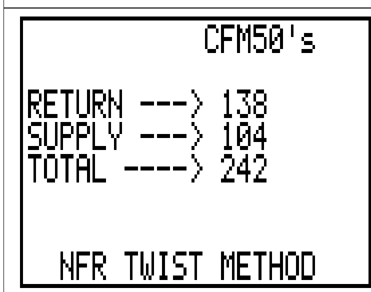
(The screen has been scrolled up five lines).
Enter the pressure across the supply hole, "SUPPLY HOLE P." For the example enter "18."
Enter the return hole size. For the example, enter "0."
Enter the return hole pressure difference. If no hole is made, the return hole pressure difference is "0."

Press- 76



Enter the average supply pressure difference after the second hole is added, "AVE SUPPLY P2." For our example this is "36."
Enter the average return pressure difference after the second hole is added, "AVE RETURN P2." For our example this is "58."
Press **ENTER**.

Press- 77

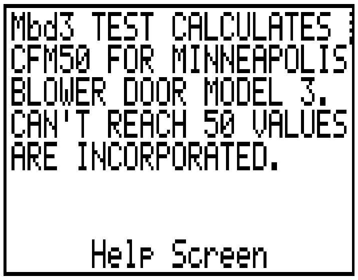


The return duct CFM_{50}, supply duct CFM_{50}, and the total CFM_{50} are displayed.
This ends the Duct Series Leakage Test examples.
Press **ENTER**.

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.

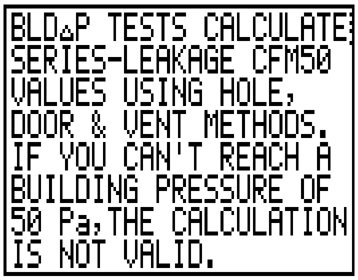
Press- 79



The “Mbd3,” **F1**, menu item.

Press **ENTER**.

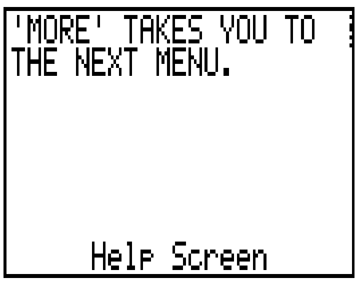
Press- 80



The “BLD P,” **F2**, menu item.

Press **ENTER.**

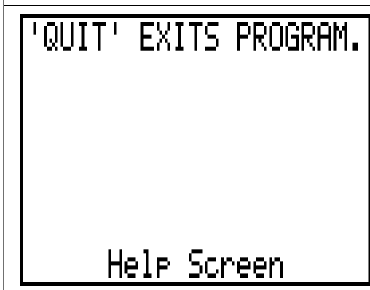
Press- 81



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.

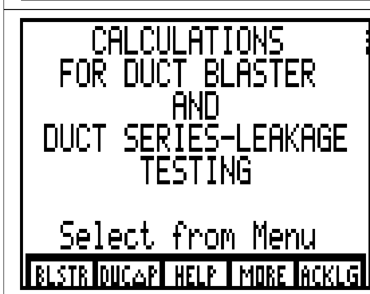
Press **ENTER.**

Press- 83

And, back to the main menu screen.

Press “MORE,” **F4,** for the other primary menu screen.

Press- 84



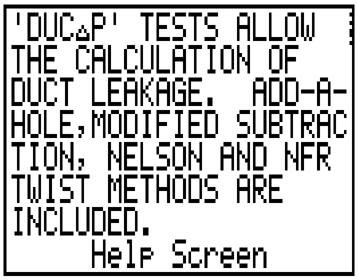
There is a “HELP,” **F3**, button on this menu also.

Go ahead, press it.

Press- 85

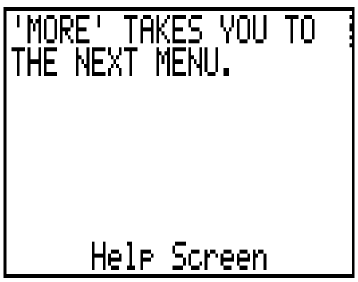
The “BLSTR,” **F1**, menu item.
Press **ENTER**.

Press- 86



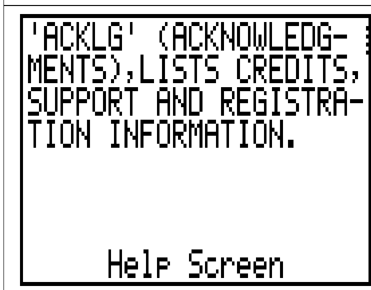
The “DUC P,” **F2**, menu item.
Press **ENTER**.

Press- 87



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

Press- 88

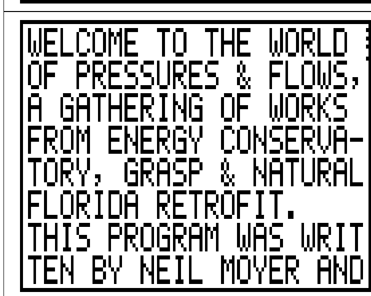


The “ACKLG,” **F4,** menu item.
Press **Enter.**

Press- 89

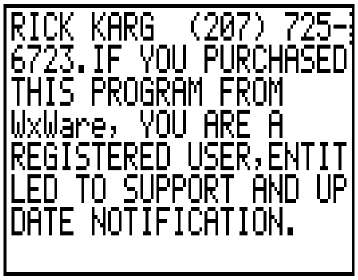
Now we are back to one of the primary screens.
Press “ACKLG,” **F5**. This is the acknowledgments section.

Press- 90



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

Press- 91



This is the second acknowledgments screen.
Press **ENTER**.

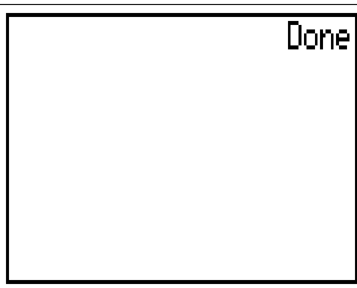
Press- 92

This is the third acknowledgments screen.
Press **ENTER.**

Press- 93

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



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

Press- 96

Instructions
for

Multi-Point Blower Door
and
Duct Analyzer Testing

(Power Regression Analysis)

INTRODUCTION

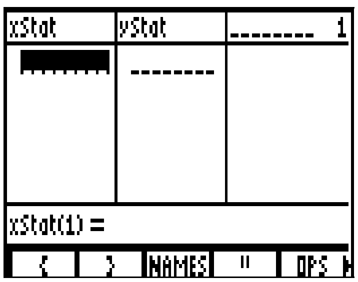
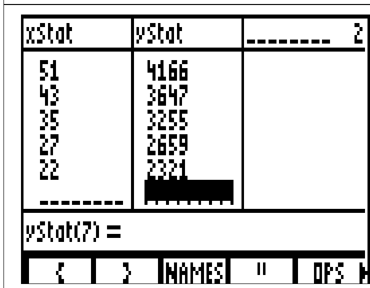
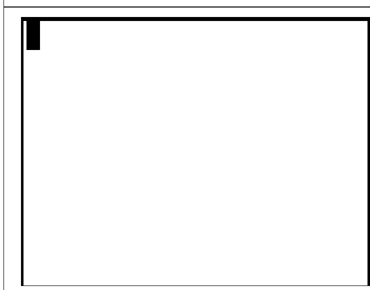
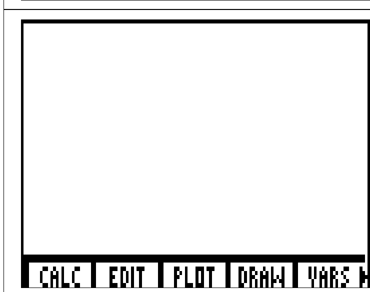
Using the "STAT" (statistics) feature of the calculator allows you to perform multi-point blower door power regression analysis. This feature calculates the regression equation, the house constant, the flow exponent, the correlation coefficient, solves for any house pressure or CFM, draws a scatter plot 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 analyzer power regression analysis can also be performed.

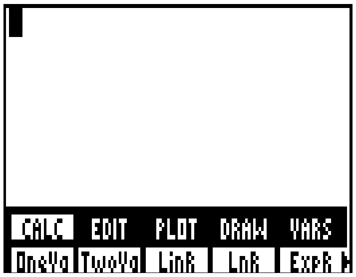
Read the Chapters 11 and 14 in the Texas Instruments *TI-86 Graphing Calculator Guidebook* for more information about these features.

PROGRAM OPERATION

Follow the instructions beginning on page 55. Pictures of the TI-86 screens appear on the left side of pages 55 through 58 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 is used for multi-point blower door or duct analysis testing. Multi-point means that CFM flow readings are taken at different pressures, usually at least six data pairs 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
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, P, usually between the indoors and outdoors. The second column "yStat will be used to signify blower door or duct analyzer
Regress-4		Place the cursor one 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 P of 51. Press **ENTER**. Continue to 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
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
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

Regress-7

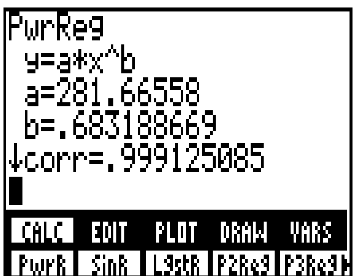


Press **F1** for "CALC." Notice that the primary menu moves up and a secondary menu is displayed for "CALC" (notice that "CALC" is highlighted).
At the right-most menu item, **F5** "ExpR" there an arrow pointing to the right indicating that there are more menu items. Press the **MORE** key to go to the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

Regress-8

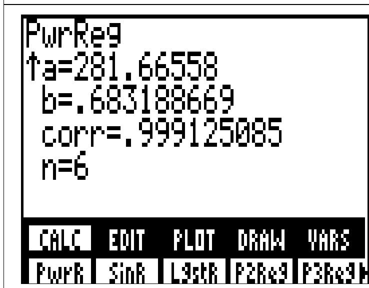
We <u>must</u> perform a power regression analysis on the data pairs. This is because a power regression fits the model of our flow equation:
CFM = HC x P^{Fx} where CFM = cubic feet per minute flow rate; HC = the house constant (the flow rate when P = 1); P = the pressure difference between the indoors 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,

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 P = 1.
"b=.683188669" is the flow exponent (see panel "Regress-8"). If we performed

Regress-10



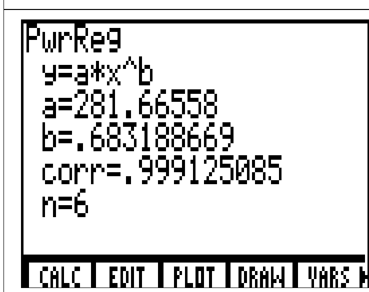
that the average flow exponent would be 0.65, so we assume an 0.65 flow exponent when we do a single-point blower door test. But when we do a multi-point test, the power regression analysis determines the specific exponent for the house. As we weatherize a house, the flow exponent changes because we alter 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 next panel]

Regress-11

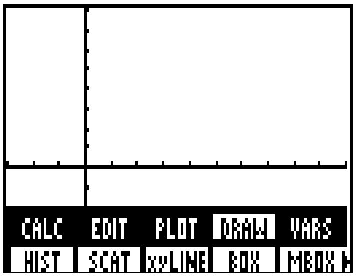
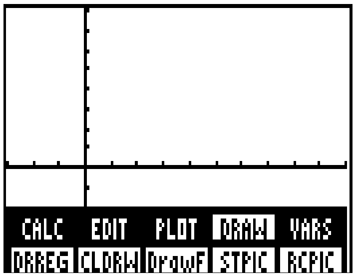
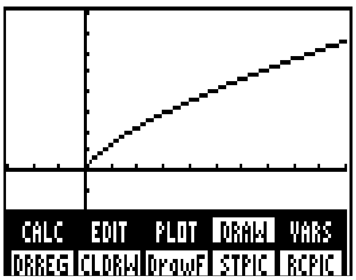
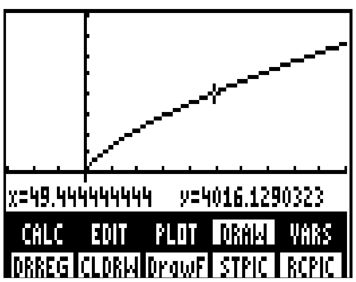
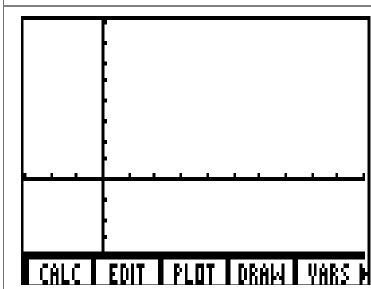
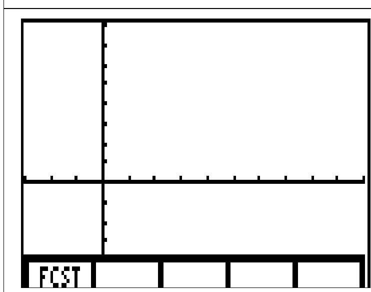
[intentionally left blank]

"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. This indicates a bad fit of the data pairs to a straight house leakage curve (regression line). 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 blaster multi-point test.

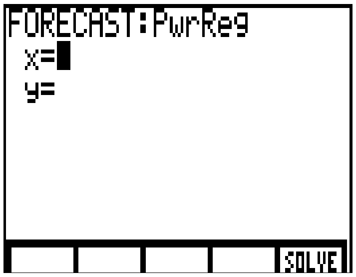
Regress-12



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.

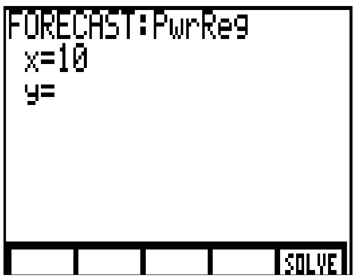
Regress-13		You will see the screen at the left. Notice the secondary “DRAW” menu (“DRAW” is highlighted). **F2**, “SCAT” draws a scatter diagram of the data pairs. Try it. **F3**, “xyLINE” connects the data pairs with a line. Try it. Notice that there is a right-pointing arrow in the right-most sub-menu 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 power regression line—our house leakage curve—is appearing on the screen. The vertical axis, y, represents CFM flow, the horizontal axis, x, represents P. 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 users have become addicted to this action, so be cautions, don’t overdo it!
Regress-16		Now for some more fun, press the up cursor key. You will notice the crosshair cursor moving upward and the x (P) 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 regression line—house leakage curve. If we enter any value for x (P), 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 (P). This allows us to find CFM_4 for effective leakage area (ELA), CFM_{10} for equivalent leakage area (EqLA), or CFM_{50}

Regress-19



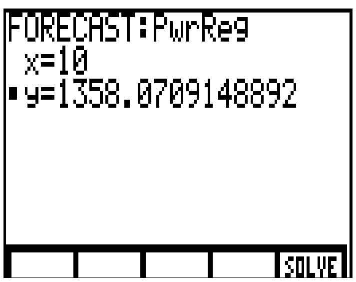
Notice the menu structure changes. This is the forecast function. It utilizes the most recent blower door data pairs entered. **Note: You must do a power regression calculation ("CALC" and then "PwrR") before you can forecast with the entered data.**
The only menu item is at **F5**, "SOLVE." When you press **F5**, "SOLVE," the forecast feature will solve for x (P) 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.

Regress-20



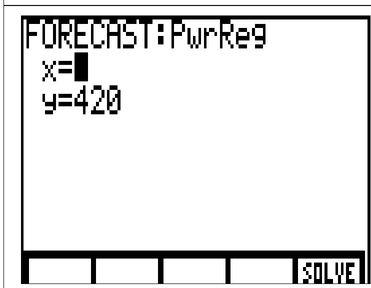
Let's try and example.
At "x" enter the building pressure for which you want a CFM flow. For our example, enter "10" Pascals of building pressure.
Press **ENTER** or the down arrow once to move the cursor to the y position.
Remember, y is the CFM for at the corresponding P entered at "x=".

Regress-21



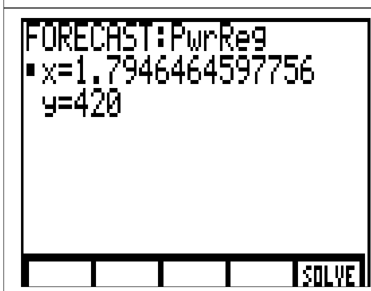
Press **F5**, "SOLVE," for the answer or "1358." In other words, the CFM_{10} of this house is 1358.
This can now be plugged into the Equation Nugget "AEQLA" (see panel Nugget-53 on page 69) to find the equivalent leakage area (EqLA) of this house.
You can also find the CFM_4 for this house with this forecast function. The CFM_4 is needed to find the effective leakage area (ELA) (see panel Nugget-

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 (regression line), 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 P.
Enter "420" at "y=" and then move the cursor up to the "x=" line. If you want

Regress-23



Press **F5,** "SOLVE," to solve for the corresponding x value, P.
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 P, 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

Regress-24

The maximum P 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.
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, the DTL will be reduced. Press **EXIT** to leave "STAT."

Instructions
for

Equation Nuggets

February, 1999 (V3.0)

INTRODUCTION

The fifty equations loaded into the SOLVER equation section were selected for their relevance to building diagnostics in both the residential and commercial area. Each of the equations is explained in this document. There are two lists of the equations at the end of this section, one list is a printout of the equations by name, exactly as they are entered in the calculator. The other is a list describing the uses of each equation. This is a handy list to carry with you.

The powerful SOLVER equation feature of the TI-86 calculator allows you to solve for any 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, and find the limits of your variable values.

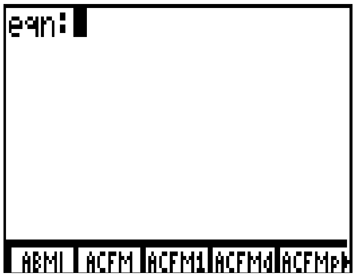
An extremely useful feature of the TI-86 calculator is that variable values from one equation or program are automatically saved to memory until the value is changed by a new value keyed in by the user. A few examples for clarity: If you wish to calculate the dew point temperature of the air in a building, 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 series leakage testing 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

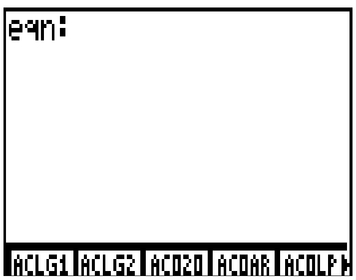


Activate the TI-86 be pressing the **ON** button.
Press the light orange **2nd** button, and then press the **SOLVER** button (this is the second function of the **GRAPH** button).
You will see the screen at the left. The menu of equations available to you are displayed at the bottom of the screen. The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

Nugget-2

The second set of five SOLVER equation names is displayed.
For a quick overview of all fifty equations, refer to the equations lists on pages 77 and 78.
Press the **MORE** button.

Nugget-3



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

Nugget-4

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

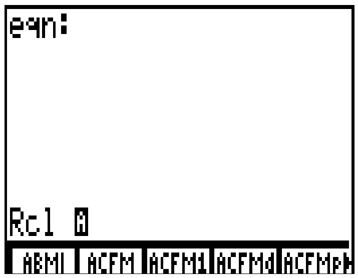
Nugget-5

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

Nugget-6

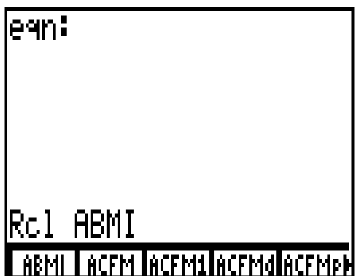
The sixth set of five SOLVER equation names is displayed.
Press the **MORE** button until you have gone through all the equations—fifty—that begin with "A." Equations after this (that do not begin with "A") are not intended for your use here.
You can freely move through this list of SOLVER equations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

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 just above the equation menu.

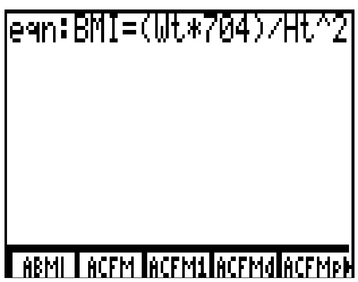
Nugget-8



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

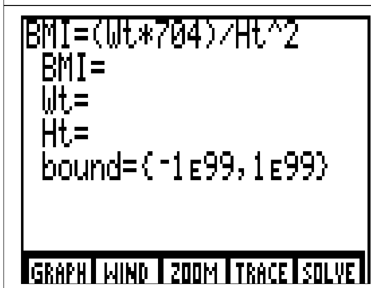
ABMI is the body mass index equation. It has nothing to do with building diagnostics; it will show you whether you are a healthy weight (BMI less than 25), overweight (BMI from 25 to 30), or obese (BMI above 30). It is

Nugget-9



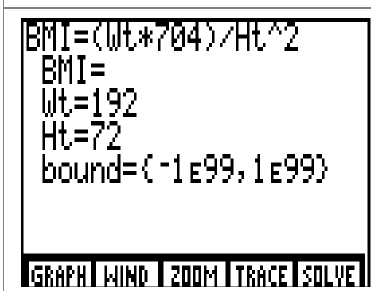
The “ABMI” equation is now loaded into the SOLVER feature of the calculator; the SOLVER working area.
This powerful feature allows you to solve for any variable in the equation if you enter values for all the other variables (there is no need to rewrite the equation to do this).
Notice that the equation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

Nugget-10



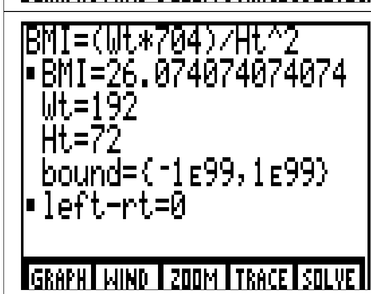
Press the down arrow button once or the **ENTER** button.
The three variables for this equation—BMI, Wt, and Ht—are listed.
Ignore the “bound” line of information.
Notice that the menu changed at the bottom of the screen when you pressed **ENTER** or the down arrow button once. Of these displayed menu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

Nugget-11



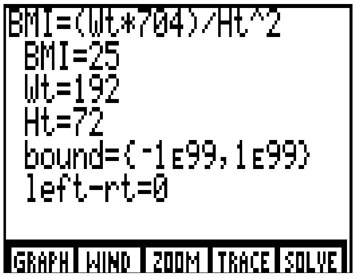
Let’s assume you weigh 192 pounds and you are six feet tall (72 inches).
Let’s find your body mass index to determine if you are a healthy weight.
Enter 192 on the “Wt” (weight) line. This should be in units of pounds. Move the cursor to the proper line with the cursor arrow keys on the TI-86.
Enter 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

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

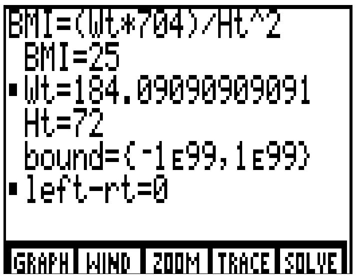


Enter 25 on the “BMI” line.

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

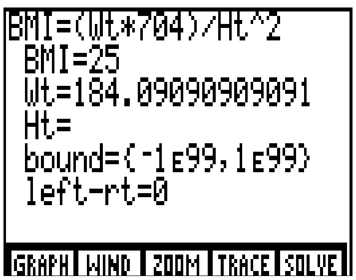


You see that you must get your weight down to 184 pounds for a body mass index of 25.

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!

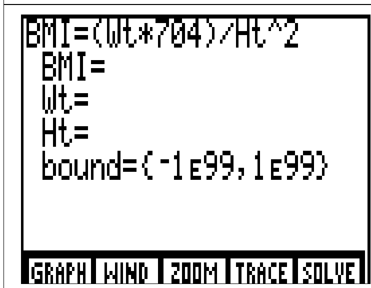
Notice the small black square to the left of “Wt,” indicating the last variable

Nugget-15



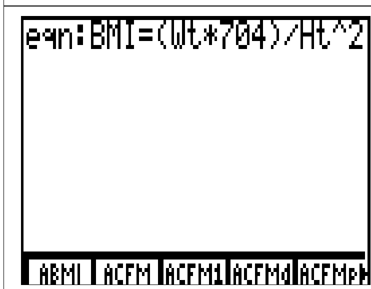
It is recommended that you delete the values for each variable before you move on to another Equation Nugget. This frees memory in the calculator. Place the cursor on the “Ht” line and then press the **CLEAR** key. The value for the “Ht” variable will be deleted.

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.

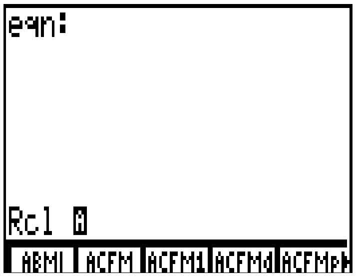
It is very important to delete one Equation Nugget from the working area of the SOLVER function before you load another one into the working area. One equation loaded over another can result in the mixing of the equation variables, yielding strange and meaningless answers.

So, with the cursor on the top line, press **CLEAR**.

Nugget-18

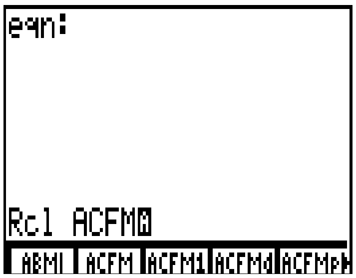
Now the calculator is ready to load another Equation Nugget in the working area of SOLVER.

Nugget-19



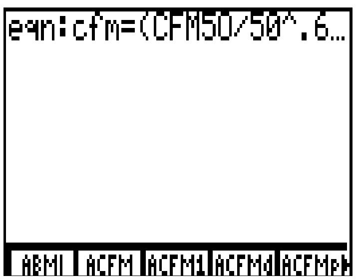
Let's try the next Equation Nugget.
Press the orange **2nd** key and then the **RCL** key. You will see the "Rcl" (recall) at the bottom left of the display, as on the example display at the left.
Press F2 for "ACFM."

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

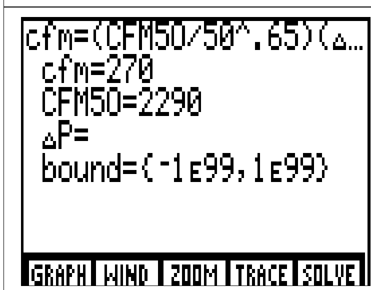


ACFM (pressure created by exhaust devices).
cfm = cubic feet per minute of exhaust appliances.
CFM50 = blower door test results at 50 Pascals pressure.
P = pressure difference between indoors and outdoors created by operation of exhaust fans (shown as positive number, but actually is negative).
Press the down arrow button once or the **ENTER** button.

Nugget-22

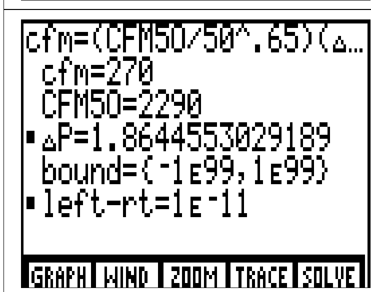
The three variables for this equation—cfm, CFM50, and P—are listed.
Ignore the "bound" line of information.
Notice that the menu changed at the bottom of the screen when you pressed **ENTER** or the down arrow button once. Of these displayed menu features, "SOLVE" is the one you will use the most. For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

Nugget-23



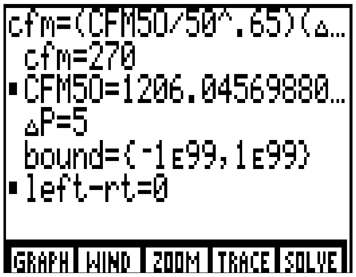
Let's assume a 1500 square foot building with a CFM_{50} of 2290 has a kitchen vent fan (100 cfm) and a bathroom vent fan (50 cfm). Will venting the existing unvented dryer cause excessive negative pressure in the house? We can't actually test for this until the dryer is vented. This equation can help. 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.

Nugget-24



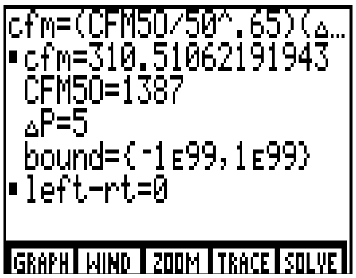
Move from line to line by using the arrow buttons or **ENTER**.
If you make a mistake, just type over it or position the cursor over the mistake and press the **DEL** (delete) button.
Move the cursor to the " P" line.
With the cursor on the " P" line, press **F5**, "SOLVE."
The house pressure created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

Nugget-25



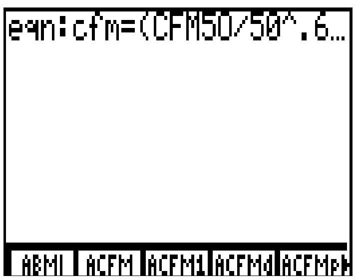
You may solve for any of the three variables in this equation.
Notice that a small, square bullet is displayed to the left of the variable for which you last solved.
Another example: Suppose we assume that -5 Pascals is the highest negative pressure this building can tolerate without backdrafting problems.
Enter 5 on the “ P” line (no need to enter a negative sign).
Move the cursor to the CFM50 line and press “SOLVE,” **F5.** We have found

Nugget-26



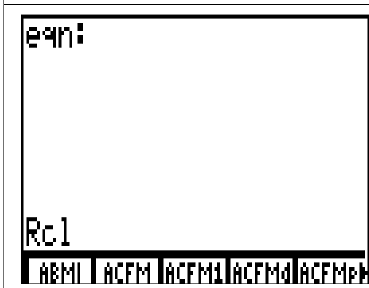
Another example: Let’s assume the Building Tightness Limit (BTL) for this house is 1387 CFM_{50} (this can be calculated with the BTL program loaded in your TI-86 calculator). Enter “1387” on the “CFM50” line.
We want to find the maximum cfm we can exhaust from this building without creating more than -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.

Nugget-27



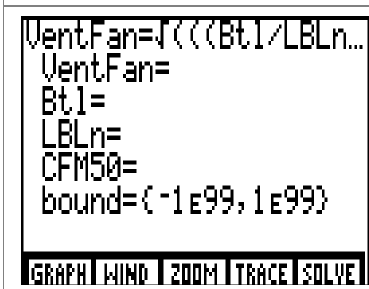
Move the cursor up to the top line, the equation line. You may change the equation for your use, but your changes will be temporary. You cannot change the equation in the memory, so the next time you call it up, it will not reflect your changes.
NOTE: Before calling another equation up, locate the cursor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

Nugget-28



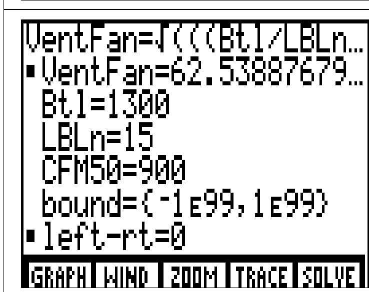
The equation is cleared.
To call another equation, press the light orange **2nd** button, and then press the RCL button (this is the second function of the **STO>** button).
Your screen will look like the picture at the left.
When you press one of the menu buttons at the bottom of the screen, the SOLVER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

Nugget-29



The next Equation Nugget is “ACFM1.”
ACFM1 (determination of vent fan size when house is “too tight”).
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 Pro software).
LBLn = Lawrence Berkeley Lab. correlation number as determined by the same program referenced just above.
CFM50 = actual blower door test result at 50 Pascals of pressure.

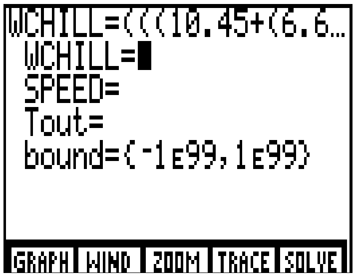
Nugget-30



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	CFMadDp=CFMnom*((Tou… CFMadDp=▮ CFMnom= Tout= Tin= bound={-1E99,1E99} GRAPH WIND ZOOM TRACE SOLVE	**ACFMd** (depressurization blower door result temperature adusted). **CFMadDp =** blower door CFM temperature adjusted for depressurization test. **CFMnom =** nominal blower door reading before adjustment. **Tout =** temperature indoors, ^{0}F. **Tin =** temperature outdoors, ^{0}F.
Nugget-32	CFMadDp=CFMnom*((Tou… ▪CFMadDp=2027.071829… CFMnom=2200 Tout=-10 Tin=70 bound={-1E99,1E99} ▪left-rt=0 GRAPH WIND ZOOM TRACE SOLVE	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	CFMadPr=CFMnom*((Tin… CFMadPr= CFMnom= Tin= Tout= bound={-1E99,1E99} GRAPH WIND ZOOM TRACE SOLVE	**ACFMp** (pressurization blower door result temperature adusted). **CFMadPr =** blower door CFM temperature adjusted for pressurization test. **CFMnom =** nominal blower door reading before adjustment. **Tout =** temperature indoors, ^{0}F. **Tin =** temperature outdoors, ^{0}F.
Nugget-34	CFMadPr=CFMnom*((Tin… ▪CFMadPr=2387.680560… CFMnom=2200 Tin=70 Tout=-10 bound={-1E99,1E99} ▪left-rt=0 GRAPH WIND ZOOM TRACE SOLVE	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.
Nugget-35	ACH5o=CFM50*60/(FT2*… ACH5o=▮ CFM50= FT2= CG= bound={-1E99,1E99} GRAPH WIND ZOOM TRACE SOLVE	**ACH50** (air changes per hour at 50 Pascals building pressure from CMF_{50}). **ACH5o =** is air changes per hour at 50 Pascals of building pressure. **CFM50 = i**s 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	ACH5o=CFM50*60/(FT2*… ▪ACH5o=13.75 CFM50=2200 FT2=1200 CG=8 bound={-1E99,1E99} ▪left-rt=0 GRAPH WIND ZOOM TRACE SOLVE	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 ACH50 value is 13.75. This is the Air Change per Hour at 50 Pascals of pressure difference between the indoors and outdoors.

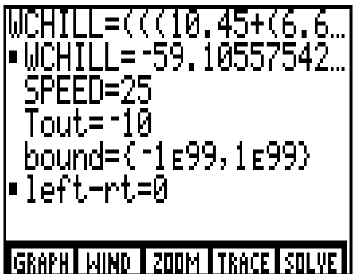
Nugget-37



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

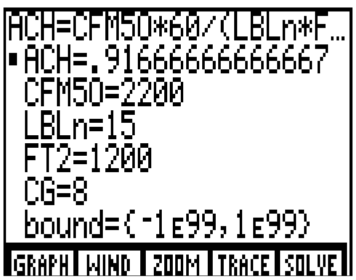
This is the wind chill temperature spoken of by weather forecasters.

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.

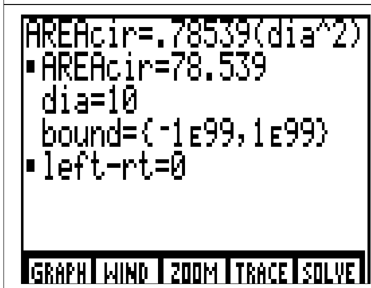
Nugget-39



ACHN (building air change per hour at natural pressure).
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.
FT2 = square footage of the house.
CG = ceiling height (FT2 x CG = volume).

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

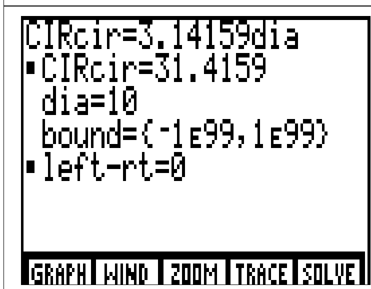
Nugget-40



ACIRa (area of a circle).
AREAcir = the area of the circle.
dia = diameter of circle.

Work out the example at the left. The units for the area of the circle will always be the square of the units for the diameter, e.g., a circle with a diameter of 10 feet had an area of 78.5 ft^2.

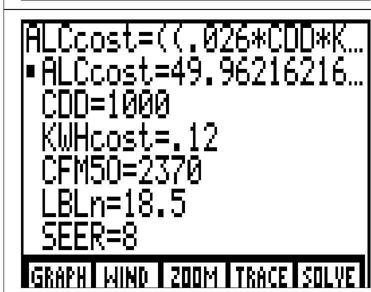
Nugget-41



ACIRc (circumference of a circle).
CIRcir = the circumference of the circle.
dia = diameter of circle.

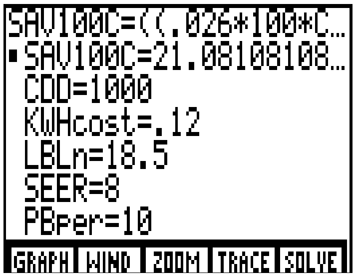
Work out the example at the left.

Nugget-42



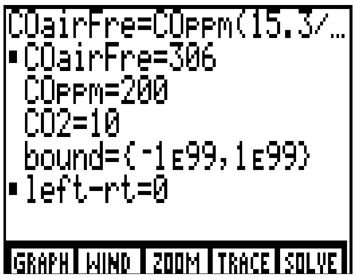
ACLG1 (annual cooling cost of air leakage).
ALCcost = annual cooling cost in dollars.
CDD = cooling degree days.
KWHcost = kiloWatt hour cost of electricity.
CFM50 = CFM_{50} from the blower door test
LBLn = Lawrence Berkeley Lab. correlation factor. This number is displayed by the Building Tightness Limits "BTL1" program, "BTL" routine.
SEER = seasonal energy efficiency ratio for cooling equipment.

Nugget-43



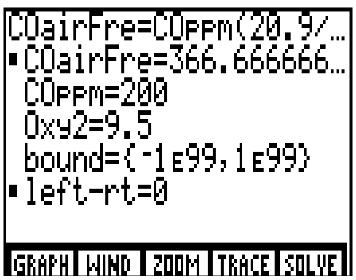
ACLG2 (cooling cost-effectiveness guideline for air sealing).
SAV100C = cooling cost-effectiveness guideline per 100 CFM_{50} reduction.
CDD = cooling degree days.
KWHcost = kiloWatt hour cost of electricity.
LBLn = Lawrence Berkeley Lab. correlation factor. This number is displayed by the Building Tightness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

Nugget-44



ACO2O (air-free carbon monoxide from as-measured carbon monoxide and carbon dioxide for a number 2 oil appliance).
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

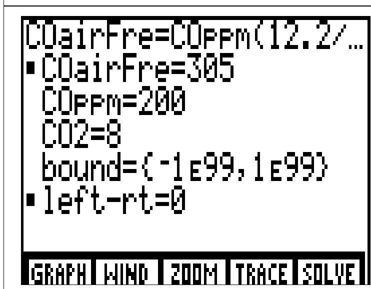


ACOAR (air-free carbon monoxide from as-measured carbon monoxide and oxygen percentage in flue gas, any fuel).
COairFre = air-free carbon monoxide in units of parts per million (ppm).
COppm = as-measured carbon monoxide in units of ppm.
Oxy2 = percentage of oxygen in measured air sample (enter 9.5% as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

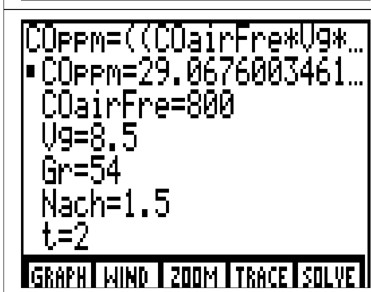
ACOLP (air-free carbon monoxide from as-measured carbon monoxide and carbon dioxide for a liquified propane, LP, appliance).
COairFre = air-free carbon monoxide in units of parts per million (ppm).
COppm = as-measured carbon monoxide in units of ppm.
CO2 = percentage carbon monoxide in flue gas (as a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

Nugget-47



ACONG (air-free carbon monoxide from as-measured carbon monoxide and carbon dioxide for a natural gas appliance).
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).

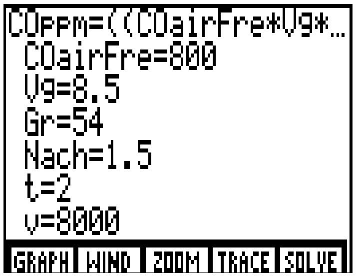
Nugget-48



ACORM (for determining the carbon monoxide concentrations in a room from an unvented natural gas or propane appliance, such as a gas range/oven).
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 $\dfrac{\text{input rate (Btu/hr)}}{\text{heat value of fuel (Btu/ft}^3\text{)}}$

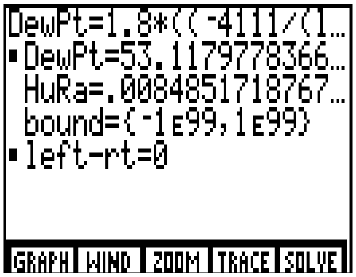
See next panel

Nugget-49



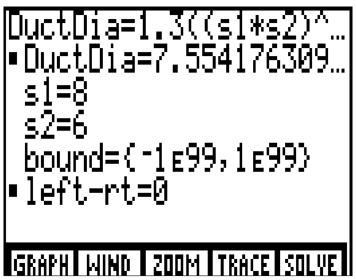
ACORM continued. (display is scrolled one line from panel "Nugget-48" at the bottom of the previous page).
Nach = natural air changes per hour of room or of house.
t = time interval, in hours.
v = volume of room or of house, in ft^3.

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.

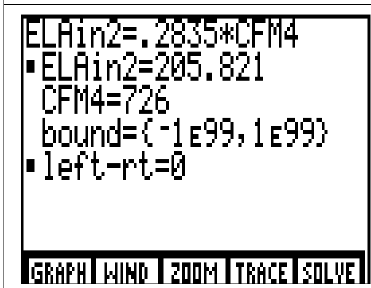
Nugget-51



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.

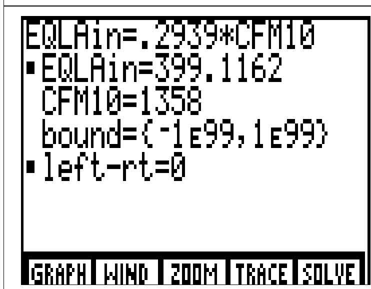
Remember, you can enter any two variables here and solve for the third. This is a very useful equation for ductwork design, installation, and retrofit.

Nugget-52



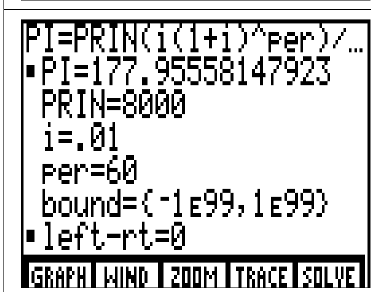
AELA (effective leakage area from CFM_4).
ELAin2 = Effective Leakage Area, in^2 (Lawrence Berkeley Labs).
CFM4 = CFM at 4 Pascals of building pressure. This value can be calculated using a multi-point blower door test. You must know the house constant and the "Fx" number (flow exponent). This is explained later in this instruction document and can be calculated with a blower door and the TI-86 calculator. The SOLVER equation "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 (National Research Coun. of Canada).
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.

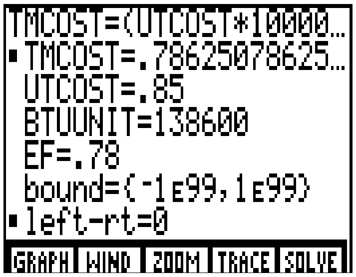
Nugget-54



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.

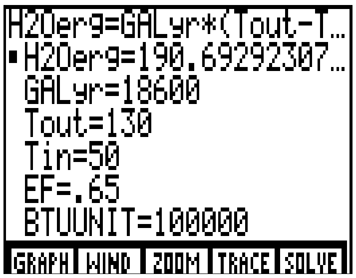
Remember, you can solve for any of these variables by entering the others.

Nugget-55



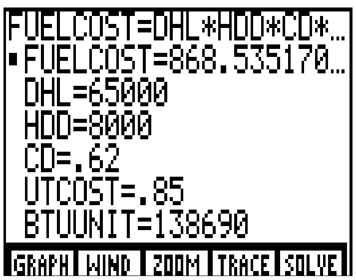
AFUEL (per therm cost of fuel).
TMCOST = per unit cost of fuel, in dollars and cents.
UTCOST = per unit cost of fuel under consideration, in dollars and cents.
BTUUNIT = British thermal units (BTU) per unit of fuel under consideration, input value.
EF = <u>seasonal</u> efficiency of the space heating 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



AH2O (annual domestic water heating energy consumption).
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



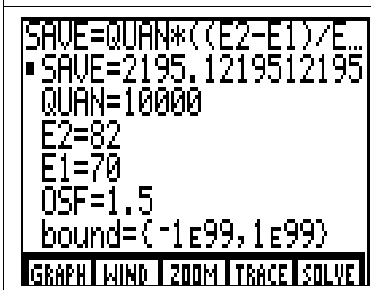
AHET1 (annual space heating cost).
FUELCOST = annual space heating fuel cost, in dollars.
DHL = calculated design heat load of building, in Btu/hr. Use an acceptable method of calculation.
HDD = heating degree days, base 65°F.
CD = empirical correction factor for HDD_{65}. Refer to page xx of this document 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

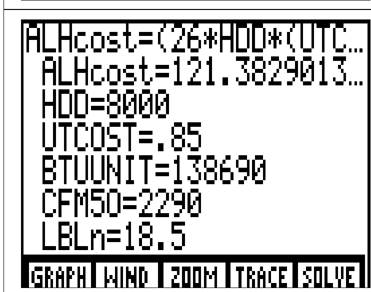
AHET1 continued. (The screen has been scrolled up two lines)
BTUUNIT = input value per unit of fuel, e.g., per gallon of oil.
EF = <u>Seasonal</u> efficiency of the space heating unit. Include losses from distribution system. Note: seasonal efficiency is always less than steady-state efficiency (that which is calculated with a flue-gas analysis tester).
T = 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



AHET2 (savings from heating system efficiency improvements).
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.

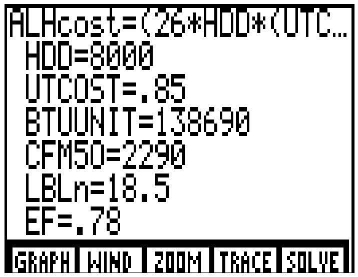
Nugget-60



AHET3 (annual heating costs of air leakage).
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.

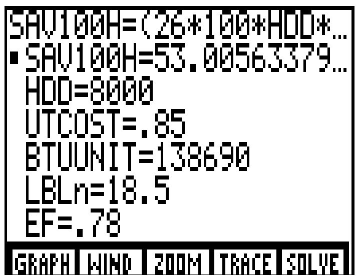
See next panel

Nugget-61



AHET3, continued. (The screen has been scrolled up one line).
EFF = Seasonal 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 calculated with a flue-gas analysis tester).

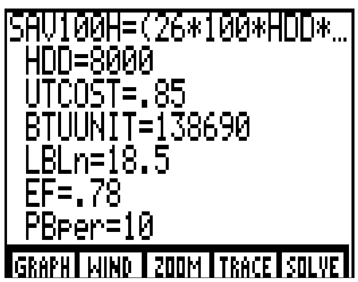
Nugget-62



AHET4 (heating cost-effectiveness guideline for air sealing).
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.

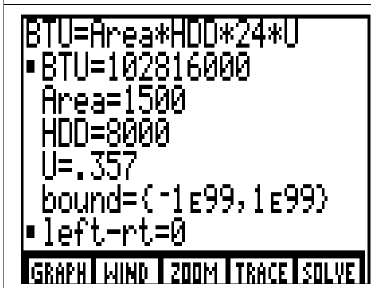
(See next panel).

Nugget-63



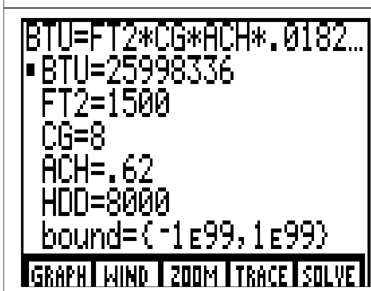
AHET4 continued. (The screen has been scrolled up one line).
EF = Seasonal efficiency of the space heating unit. Include losses from distribution system. Note: seasonal efficiency is always less than steady-state efficiency (that which is calculated with a flue-gas analysis tester).
PBper = Reasonable 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.

Nugget-64



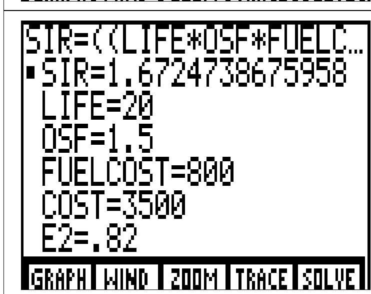
AHET5 (transmission heat transfer through a surface).
BTU = transmission heat loss per year through a surface area (Btu/yr).
Area = surface area in square feet.
HDD = heating degree days, base 65°F.
U = thermal transmittance, U-factor. The inverse of R-value.
Comment: Use this equation to calculate Btu/hr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

Nugget-65



AHET6 (air leakage heat loss per year).
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 SOLVER 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.”

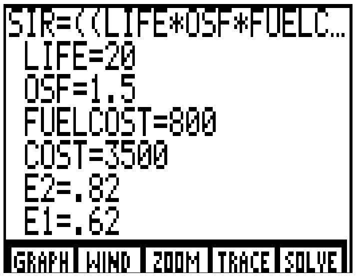
Nugget-66



AHET7 (analysis for heating system replacement).
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.

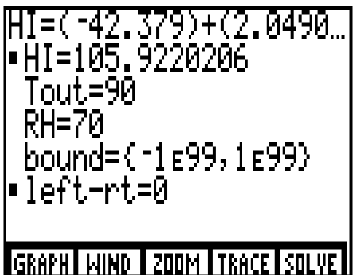
(continued on next panel)

Nugget-67



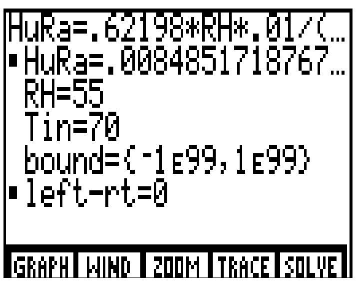
AHET7, continued. (The screen has been scrolled up one line).
FUELCOST = annual space heating cost **before** upgrade or replacement.
COST = total cost of upgrading or replacing heating system, dollars.
E2 = steady-state efficiency **after** upgrade or replacement.
E1 = steady-state efficiency **before**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

Nugget-68



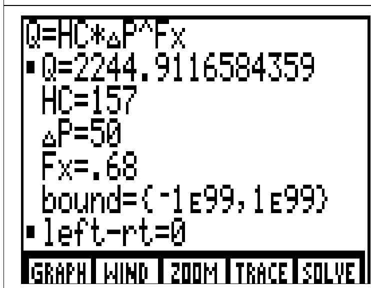
AHI (heat index or apparent temperature).
HI = heat index or apparent temperature, used by weather reporters during hot and humid weather.
Tout = temperature outdoors, ^{0}F.
RH = relative humidity, as a percentage (enter 70% as 70, not as 0.70).

Nugget-69



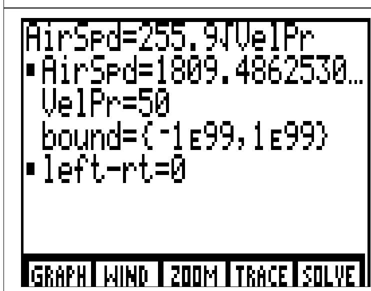
AHRAT (humidity ratio).
HuRa = humidity ratio, the mass of mater vapor to the mass of dry air.
RH = relative humidity. Measure this with a good sling psychrometer or digital humidity gauge (inexpensive devices might give inaccurate readings).
Tin = Temperature, °F. This may be indoor or outdoor temperature.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

Nugget-70



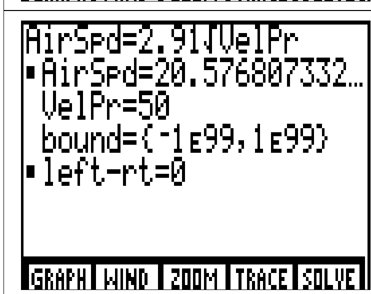
AIREQ (building air flow rate, air equation).
Q = building air leakage flow rate.
HC = house constant. This value can be calculated using a multi-point blower door test (the TI-86 can perform this test).
P = building pressure, Pascals.
Fx = building flow exponent. This also can be determined with a multi-point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

Nugget-71



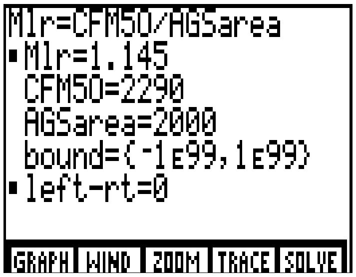
AIRSF (air speed in units of feet per minute).
AirSpd = air speed in units of feet per minute.
VelPr = velocity pressure, in Pascals
Comment: This equation is for sea-level air density. This equation will give the pressure against the side of a building, in Pascals, if the wind speed at the side of the 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."

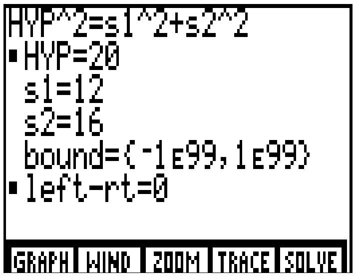
Nugget-73



AMLR (Minneapolis leakage ratio).
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 infiltration 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.

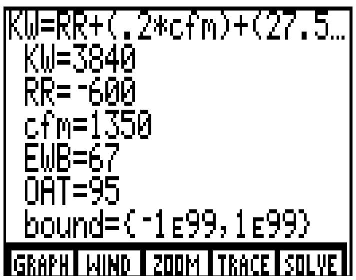
Nugget-74



APYTH (Pythagorean theorem).
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 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 evenly. This is Leslie's favorite equation.

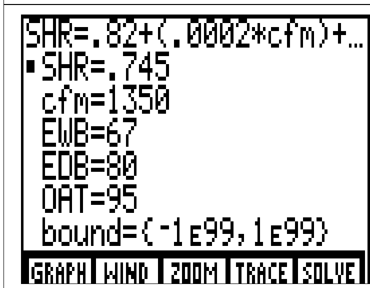
Nugget-75



ARIKW (power requirement of air-to-air cooling equipment).
KW = power requirement of air-to-air cooling equipment.
RR = a constant, for generic cooling equipment, use -600.
cfm = cubic feet per minute flowing through refrigerant coil.
EWB = entering wet-bulb temperature, ^{O}F.
OAT = outdoor dry-bulb temperature, ^{O}F.

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

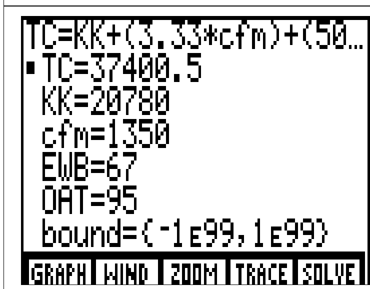
Nugget-76



ARISR (sensible to total capacity ratio of air-to-air cooling equipment).
SHR = sensible to total capacity ratio
cfm = cubic feet per minute flowing through refrigerant coil.
EWB = entering wet-bulb temperature, ^{O}F.
EDB = entering dry-bulb temperature, ^{O}F.
OAT = outdoor dry-bulb temperature, ^{O}F.

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

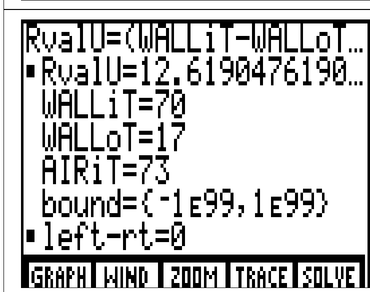
Nugget-77



ARITC (total capacity of air-to-air cooling equipment).
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, ^{O}F.
OAT = outdoor dry-bulb temperature, ^{O}F.

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

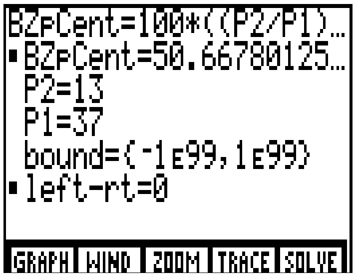
Nugget-78



ARVAL (determine R-value with non-contact thermometer).
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-79

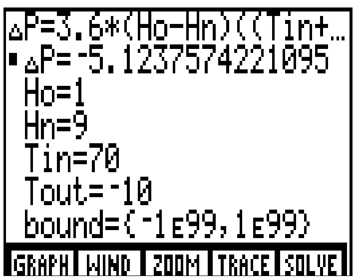


ASERP (bldg.-to-zone percentage of zone-to-outdoor leakage rate).
BZpCent = building-to-zone percentage of zone-to-outdoor leakage rate (also bldg.-to-duct as percentage of duct-to-outdoor leakage).
P2 = zone-to-outside (duct-to-outside) pressure difference, Pascals.
P1 = building-to-zone (building-to-duct) pressure difference, Pascals
Comment: The example values indicate that the building-to-zone leakage is about 50% of the zone-to-outside leakage.

Nugget-80

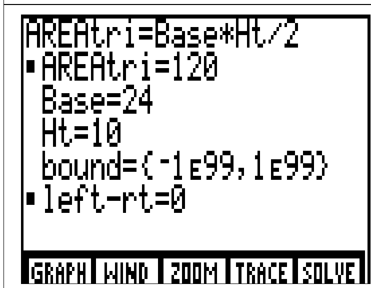
ASIR (simple savings-to-investment ratio).
SIR = simple savings-to-investment ratio.
SAVE = First-year savings due to energy-saving measure, dollars.
COST = Cost of energy-saving measure, dollars.
LIFE = Expected life of energy-saving measure, years.
Comment: If the SIR is less than one, the energy-saving measure is not worth implementing; if it is more than one, it is worth implementing. The higher the "SIR," the better.

Nugget-81



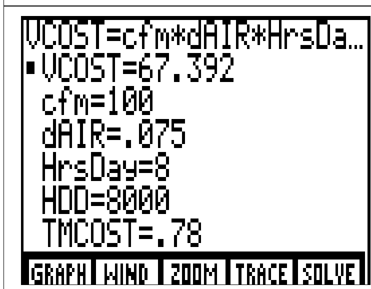
ASTAK (building stack pressure at given height).
P = building stack pressure at a given height.
Ho = height at observation measurement, ft.
Hn = height of neutral pressure level, ft. **Tin =** temperature indoors, °F.
Tout = temperature outdoors, °F. For below zero temps., use "(-)" key.
Comment: This equation estimates P. 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-82



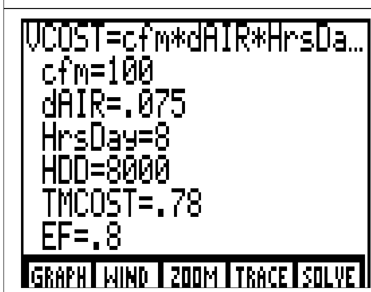
ATRIa (area of a triangle).
AREAtri = area of a triangle, such as a gable end. The mathematical units used for the base and the height of the triangle are merely squared for the area of the triangle. For the example at the left, a base of 24 feet and a height of 10 feet yields an area of 120 square feet.
Base = the base dimension of the triangle.
Ht = the height of the triangle.

Nugget-83



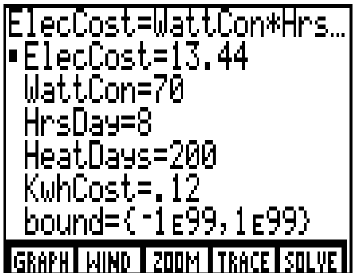
AVNT1 (space heating energy consumption for ventilation).
VCOST = annual cost of space heating energy for ventilation. **cfm =** actual cubic feet per minute of exhaust fan(s). **dAIR =** density of air (at sea level 0.075 pounds/cubic foot) See air density correction factors on page 76.
HrsDay = hours 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. (continued in next panel)

Nugget-84



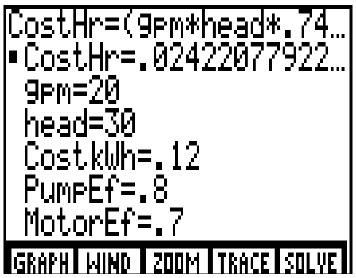
AVNT1 4, continued. (The screen has been scrolled up one line).
EF = seasonal efficiency of the space heating unit. Include losses from distribution system. Note: seasonal efficiency is always less than steady-state efficiency (that which is calculated with a flue-gas analysis tester).
Comment: This 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-85



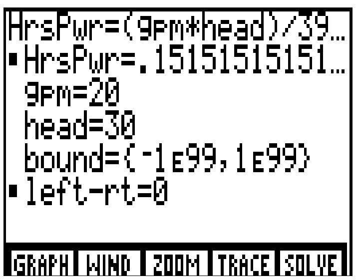
AVNT2 (annual electrical consumption for ventilation).
ElecCost = annual electrical cost to operate an exhaust fan.
WattCon = power consumption of fan, in Watts.
HrsDay = hours of average daily running time of exhaust fan(s).
HeatDay = heating days per year. A heating day is any day having an average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

Nugget-86



AWATC (cost to operate a water pump).
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.

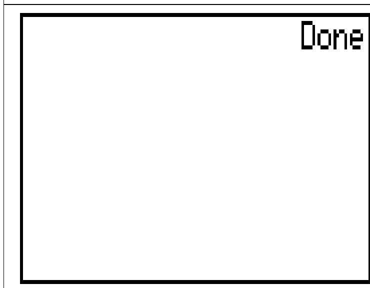
Nugget-87



AWATP (horsepower to pump water).
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.

Nugget-88



This ends the SOLVER equation section of the instructions. Read Chapter 15 in the *TI-86 Graphing Calculator Guidebook* for more instruction regarding the SOLVER features of the calculator.

Nugget-89

Nugget-90

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

The Equation Nuggets as They Appear in the TI-86 Calculator

ABMI	BMI=(Wt*704)/Ht^2
ACFM	cfm=(CFM5O/50^.65)(ΔP^.65)
ACFM1	VentFan=√(((Btl/LBLn)^2)-((CFM50/LBLn)^2))
ACFMd	CFMadDp=CFMnom*((Tout+459.7)/(Tin+459.7))^.5
ACFMp	CFMadPr=CFMnom*((Tin+459.7)/(Tout+459.7))^.5
ACH5O	ACH5o=CFM5O*60/(FT2*CG)
ACHIL	WCHILL=(((10.45+(6.686112*√SPEED)-(.447041*SPEED))/22.034)*(Tout-91.4))+91.4
ACHN	ACH=CFM5O*60/(LBLn*FT2*CG)
ACIRa	AREAcir=.78539(dia^2)
ACIRc	CIRcir=3.14159dia
ACLG1	ALCcost=((.026*CDD*KWHcost*CFM5O)/(LBLn*SEER))
ACLG2	SAV100C=((.026*100*CDD*KWHcost)/(LBLn*SEER))*PBper
ACO2O	COairFre=COppm(15.3/CO2)
ACOAR	COairFre=COppm(20.9/(20.9-Oxy2))
ACOLP	COairFre=COppm(14/CO2)
ACONG	COairFre=COppm(12.2/CO2)
ACORM	COppm=((COairFre*Vg*Gr)(1-(1/(2.713^(Nach*t)))))/(Nach*v)
ADEWP	DewPt=1.8*((-4111/(ln (HuRa*101325/(HuRa+.62198))-23.7093)+35.45)-273)+32
ADUCT	DuctDia=1.3((s1*s2)^.625)/(s1+s2)^.25)
AELA	ELAin2=.2835*CFM4
AEQLA	EQLAin=.2939*CFM10
AFCOM	PI=PRIN(i(1+i)^per)/(((1+i)^per)-1)
AFUEL	TMCOST=(UTCOST*100000)/(BTUUNIT*EF)
AH2O	H2Oerg=GALyr*(Tout-Tin)*8.33/(EF*BTUUNIT)
AHET1	FUELCOST=DHL*HDD*CD*24(UTCOST/(BTUUNIT*EF))/ΔT
AHET2	SAVE=QUAN*((E2-E1)/E2)*OSF

The Equation Nuggets as They Appear in the TI-86 Calculator

AHET3	ALHcost=(26*HDD*(UTCOST/BTUUNIT)*CFM5O/(LBLn*EF)).6
AHET4	SAV100H=(26*100*HDD*(UTCOST/BTUUNIT)/(LBLn*EF)).6*PBper
AHET5	BTU=Area*HDD*24*U
AHET6	BTU=FT2*CG*ACH*.0182*HDD*24
AHET7	SIR=((LIFE*OSF*FUELCOST)/COST)((E2-E1)/E2)
AHI	HI=(-42.379)+(2.04901523(Tout))+(10.14333127(RH))-(.22475541(Tout)(RH)) -(6.83783(10^-3)(Tout^2))-(5.481717(10^-2)(RH^2))+(1.22874(10^-3)(Tout^2)(RH)) +(8.5282(10^-4)(Tout)(RH^2))-(1.99(10^-6)(Tout^2)(RH^2))
AHRAT	HuRa=.62198*RH*.01/((e^(ú23.7093+(4111/((.5555*(Tin-32)+273)-35.45)))*101325)-RH*.01)
AIREQ	Q=HC*ΔP^Fx
AIRSF	AirSpd=255.9 √VelPr
AIRSP	AirSpd=2.91 √VelPr
AMLR	Mlr=CFM5O/AGSarea
APYTH	HYP^2=s1^2+s2^2
ARIKW	KW=RR+(.2*cfm)+(27.5*EWB)+(24.5*OAT)
ARISR	SHR=.82+(.0002*cfm)+(-.0475*EWB)+(.0325*EDB)+(.0025*OAT)
ARITC	TC=KK+(3.33*cfm)+(500*EWB)+(-225*OAT)
ARVAL	RvalU=(WALLiT-WALLoT)/(1.4(AIRiT-WALLiT))
ASERP	BZpCent=100*((P2/P1)^.65
ASIR	SIR=(SAVE/COST)(LIFE)
ASTAK	ΔP=3.6*(Ho-Hn)((Tin+459.67)-(Tout+459.67))/(Tout+459.67)
ATRIa	AREAtri=Base*Ht/2
AVNT1	VCOST=cfm*dAIR*HrsDay*.24*HDD*TMCOST(.0006/EF)
AVNT2	ElecCost=WattCon*HrsDay*HeatDays*KwhCost*.001
AWATC	CostHr=(gpm*head*.746*CostkWh)/(3960*PumpEf*MotorEf)
AWATP	HrsPwr=(gpm*head)/3960

The Equation Nuggets with Labels

1. ABMI (Body Mass Index)
2. ACFM (pressure created by exhaust devices)
3. ACFM1 (determination of vent fan size when house is “too tight”)
4. ACFMd (depressurization blower door result temperature adjusted)
5. ACFMp (pressurization blower door result temperature adjusted)

6. ACH50 (air changes per hour at 50 Pascals building pressure from CMF_{50})
7. ACHIL (equivalent wind chill temperature)
8. ACHN (building air change per hour at natural pressure).
9. ACIRa (area of a circle)
10. ACIRc (circumference of a circle)

11. ACLG1 (annual cooling cost of air leakage)
12. ACLG2 (cooling cost-effectiveness guideline for air sealing)
13. ACO2O (air-free carbon monoxide from as-measured carbon monoxide and carbon dioxide for a number 2 oil appliance)
14. ACOAR (air-free carbon monoxide from as-measured carbon monoxide and oxygen percentage in flue gas, any fuel)
15. ACOLP (air-free carbon monoxide from as-measured carbon monoxide and carbon dioxide for a liquefied propane, LP, appliance)

16. ACONG (air-free carbon monoxide from as-measured carbon monoxide and carbon dioxide for a natural gas appliance)
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)
18. ADEWP (dewpoint temperature determination)
19. ADUCT (round duct diameter to rectangular)
20. AELA (effective leakage area from CFM_4)

21. AEQLA (equivalent leakage area from CFM_{10})
22. AFCOM (payments on loan, interest, principle, periods)
23. AFUEL (per therm cost of fuel)
24. AH2O (annual domestic water heating energy consumption)
25. AHET1 (annual space heating cost)

The Equation Nuggets with Labels
(continued)

26.	AHET2	(savings from heating system efficiency improvements)
27.	AHET3	(annual heating costs of air leakage)
28.	AHET4	(heating cost-effectiveness guideline for air sealing)
29.	AHET5	(transmission heat transfer through a surface)
30.	AHET6	(air leakage heat loss per year)
31.	AHET7	(analysis for heating system replacement)
32.	AHI	(heat index or apparent temperature)
33.	AHRAT	(humidity ratio)
34.	AIREQ	(building air flow rate, air equation)
35.	AIRSF	(air speed in units of feet per minute)
36.	AIRSP	(air speed in units of miles per hour)
37.	AMLR	(Minneapolis leakage ratio)
38.	APYTH	(Pythagorean theorem)
39.	ARIKW	(power requirement of air-to-air cooling equipment)
40.	ARISR	(sensible to total capacity ratio of air-to-air cooling equipment)
41.	ARITC	(total capacity of air-to-air cooling equipment)
42.	ARVAL	(determine R-value with non-contact thermometer)
43.	ASERP	(bldg.-to-zone percentage of zone-to-outdoor leakage rate)
44.	ASIR	(simple savings-to-investment ratio)
45.	ASTAK	(building stack pressure at given height)
46.	ATRIa	(area of a triangle)
47.	AVNT1	(space heating energy consumption for ventilation)
48.	AVNT2	(annual electrical consumption for ventilation)
49.	AWATC	(cost to operate a water pump)
50.	AWATP	(horsepower to pump water)

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 assemble 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).

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.

TI-86 Financial Functions

Loading and Installing Finance Features on Your TI-86

To load the financial features onto your TI-86, you need a computer and the TI-86 Graph Link software and cable. You also need to download the finance program file from the Internet and save it on your computer.

Loading the Finance Features into TI-86 Memory

*When sending a program from your computer to the TI-86, the calculator must **not** be in Receive mode. The Receive mode is used when sending programs or data from one calculator to another.*

1. Start the TI-86 Graph Link on your computer. — (WLink86.exe)
2. Turn on your TI-86 and display the home screen. — [ON] [2nd] [QUIT]
3. Click on the Send button on the TI-86 Graph Link toolbar to display the Send dialog box.

4. Specify the finance program file as the file you want to send. — finance1.86g
5. Send the program to the TI-86. The program and its associated executable file become items on the PRGM NAMES menu.
6. Exit Graph Link

*The executable file associated with the assembly language program (**finexe**) appears on the* PRGM NAMES *menu, but you need not do anything with it.*

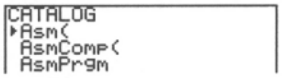
Installing the Finance Features for Use

Use the assembly language program **Finance** to install the finance features directly into the TI-86's built-in functions and menus. After installation, the finance features are available each time you turn on the calculator. You do not need to reinstall them each time. When you run assembly language programs that do not install themselves into the [2nd] [MATH] [MORE] menu, their features are lost when you turn off the calculator.

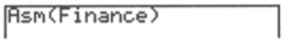
All examples assume that **Finance** is the only assembly language program installed on your TI-86. The position of FIN on the MATH menu may vary, depending on how many other assembly language programs are installed.

For assembly language programs that must be installed, up to three can be installed at a time (although the TI-86 can store as many as permitted by memory). To install a fourth, you must first uninstall (page 3) one of the others.

1. Select **Asm(** from the CATALOG to paste it to a blank line on the home screen. — [2nd] [CATLG-VARS] [F1] [▼] (move ▸ to **Asm(**) [ENTER]



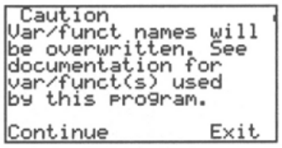
2. Select **Financ** from the PRGM NAMES menu to paste **Finance** to the home screen as an argument. — [PRGM] [F1] (select **Financ**) [)]



The variables that will be overwritten are listed on the FIN FUNC *and* FIN VARS *menus (page 12).*

3. Run the installation program. — [ENTER]

   Caution: If you have values stored to variables used by the finance features, they will be overwritten. To save your values, press [F5] to exit and then store them to different variables. Then repeat this installation.



❹ Continue the installation. (Your version number may differ from the one shown in the example.) [F1]

❺ Display the home screen. [CLEAR]

Displaying the FIN (Finance) Menu [2nd] [MATH] [MORE]

If other assembly language programs are installed, FIN *may be in a menu cell other than* [2nd] [MATH] [MORE] [F2].

When you install the financial program on your TI-86 and activate it, **FIN** becomes the last item on the **MATH** menu.

NUM	PROB	ANGLE	HYP	MISC	▸	INTER	FIN			

FIN: Finance Menu

The FIN Menu [2nd] [MATH] [MORE] [F2]

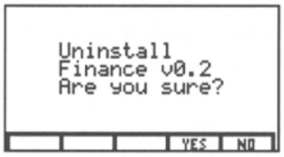
TVM	FUNC	VARS	FORMT	Uninst
TVM Solver	Financial Functions Menu	Finance Variables Menu	Payment Format Editor	Uninstall Instruction

Uninstalling the Finance Features

*When you uninstall the finance features, the finance assembly language programs (**Finance** and **finexec**) remain in memory, but the* FIN *option is removed from the* MATH *menu.*

❶ Display the FIN menu, and then select **Uninst**. [2nd] [MATH] [MORE] [F2] [F5]

❷ If you are sure you want to uninstall, select **Yes** from the confirmation menu. The FIN menu is removed and the home screen is displayed. (Your version number may differ from the one shown in the example.) [F4]



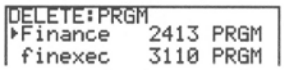
Deleting the Finance Program from TI-86 Memory

Deleting the program does not delete the variables associated with the program.

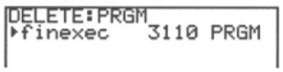
❶ Select **DELET** from the MEM menu. [2nd] [MEM] [F2]

❷ Select **PRGM** from the MEM DELET menu. [MORE] [F5]

❸ Move the selection cursor to **Finance**, and then delete it. [▼] (as needed) [ENTER]



❹ Move the selection cursor to **finexec**, and then delete it. [▼] (as needed) [ENTER]



The TVM (Time-Value-of-Money) Variables

FIN VARS (Finance Variables) Menu [2nd] [MATH] [MORE] [F2] [F3]

TVM	FUNC	VARS	FORMT	Uninst
N	I	PV	PMT	FV

▸

PY	CY			

Prompts that correspond to some TVM variables are shown in parentheses.

N Number of payment periods

I Interest rate (**I%=**)

PV Present value of loan or lease

PMT Payment amount

FV Future value of loan or lease

PY Payments per year (**P/Y=**)

CY Compounding periods per year(**C/Y=**)

- When you enter a value at prompts in the payment format editor (page 4) or the TVM Solver (page 5), the corresponding variable values are updated.
- When you solve for a TVM variable using the TVM Solver, the corresponding variable value is updated.
- When you enter numbers as arguments for a TVM function, the corresponding variable values are *not* updated.
- When you solve for a TVM variable using a TVM function, the corresponding variable value is *not* updated.

Setting the Payment Format

Payment Format Editor [2nd] [MATH] [MORE] [F2] [F4]

TVM	FUNC	VARS	FORMT	Uninst

The payment format settings define the number of payments per year (**P/Y**), the number of compounding periods per year (**C/Y**), and whether the payments are received at the end or beginning of each period (**PMT:END BEGIN**).

You also can change a setting by storing a value to **PY** *or* **CY** *or by executing* **pEnd** *or* **pBegin** *(page 11).*

The payment format editor to the right shows the defaults. To change payments per year or compounding periods per year, enter a new value. To change the payment due setting, move the cursor onto **END** or **BEGIN**, and then press [ENTER].

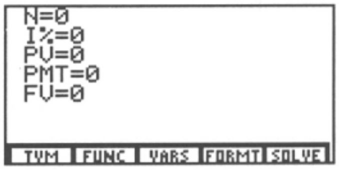
Entering Cash Inflows and Cash Outflows

When using the financial functions, you must enter cash inflows (cash received) as positive numbers and cash outflows (cash paid) as negative numbers. The financial functions follow this convention when computing and displaying answers.

Using the TVM (Time-Value-of-Money) Solver

FIN TVM Solver Menu [2nd] [MATH] [MORE] [F2] [F1]

TVM	FUNC	VARS	FORMT	SOLVE



The TVM Solver displays prompts for the five time-value-of-money (TVM) variables.

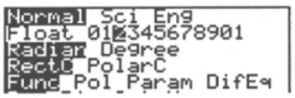
To solve for an unknown variable, enter the four known variable values, move the cursor to the unknown variable prompt, and then select **SOLVE** ([F5]) from the FIN TVM Solver menu. Values displayed on the TVM Solver are stored to corresponding TVM variables.

When the TVM Solver is displayed, **SOLVE** *replaces* **Uninst** *on the* FIN *menu.*

Solving for an Unknown TVM Variable (Payment Amount)

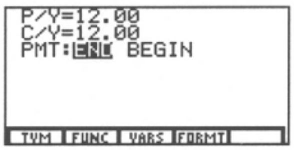
You want to buy a $100,000 house with a 30-year mortgage. If the annual percentage rate (APR) is 18%, what are the monthly payments?

1. Set the fixed-decimal mode to 2 decimal places to display all numbers as dollars and cents. — [2nd] [MODE] [▼] [▶] [▶] [▶] [ENTER]



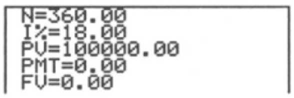
2. Select **FIN** from the MATH menu to display the FIN menu. — [2nd] [MATH] [MORE] [F2]

3. Select **FORMT** from the FIN menu to display the payment format editor. Set 12 payments per year, 12 compounding periods per year, and payments received at the end of each payment period. — [F4] **12** [▼] **12** [▼] [ENTER]

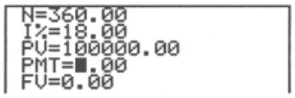


Enter cash inflows as positive numbers and cash outflows as negative numbers.

4. Display the TVM Solver and enter the known values for four TVM variables. The **N** value of 360 was derived from 30 (years) [×] 12 (months). — [F1] **360** [▼] **18** [▼] **100000** [▼] [▼] **0** [ENTER]

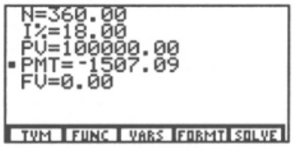


5. Move the cursor to the **PMT** TVM variable. — [▲]



You cannot leave a variable blank. If you do not have a value, set it to zero.

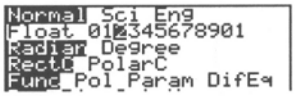
6. Select **SOLVE** to compute the answer. A small square is displayed next to the solution variable. The answer is stored to the corresponding TVM variable. — [F5]



Financing a Car

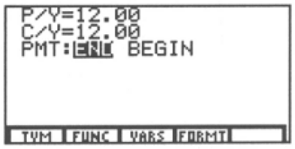
You have found a car you would like to buy. The car costs $9,000. You can afford payments of $250 per month for four years. What annual percentage rate (APR) will make it possible for you to afford the car?

1. Set the fixed-decimal mode to 2 decimal places to display all numbers as dollars and cents.
   [2nd] [MODE] [▼] [▶] [▶] [▶] [ENTER]



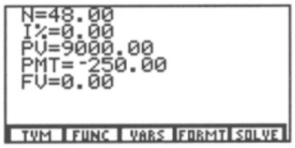
When you change **P/Y**, **C/Y** *changes automatically.*

2. Display the payment format editor. Set payments per year and compounding periods per year to 12. Set payment due at the end of each period.
   [2nd] [MATH] [MORE] [F2] [F4] **12** [▼] [▼] [ENTER]

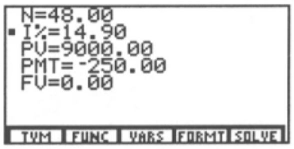


As you enter a value at any TVM Solver prompt, the corresponding TVM variable value is updated.

3. Display the TVM Solver. Enter 48 monthly payments, present value of $9,000, payment amount of ⁻$250 (negation indicates cash outflow), and future value of $0. The **N** value (48) was derived from 4 (years) [×] 12 (months).
   [F1] **48** [▼] [▼] **9000** [▼] [(-)] **250** [▼] **0** [ENTER]



4. Move the cursor to **I%=** (interest rate) and then select **SOLVE** from the TVM Solver menu. A small square is displayed next to the solution. The solution value is stored to the TVM variable **I**.
   [▲] [▲] [▲] [F5]

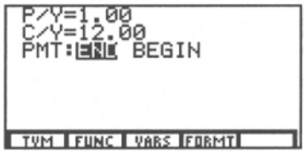


Computing Compound Interest

At what annual interest rate, compounded monthly, will $1,250 accumulate to $2,000 in 7 years?

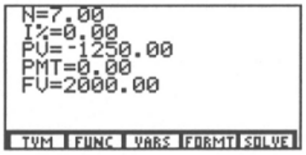
Because there are no payments when you solve compound interest problems, you must set **PMT** *to* **0** *and set* **P/Y** *to* **1**.

1. Display the payment format editor. Set payments per year to 1 and compounding periods per year to 12. Set payment due at the end of each period.
   [2nd] [MATH] [MORE] [F2] [F4] **1** [▼] **12** [▼] [ENTER]

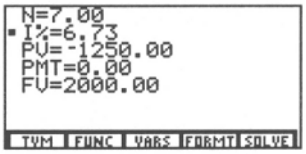


The decimal mode is fixed at **2** *from the previous example.*

2. Display the TVM Solver. Enter 7 annual payments, present value of ⁻$1,250 (negation indicates cash outflow), payment amount of $0, and future value of $2,000.
   [F1] **7** [▼] [▼] [(-)] **1250** [▼] **0** [▼] **2000** [ENTER]



3. Move the cursor to **I%=** (interest rate) and then select **SOLVE** from the TVM Solver menu. A small square is displayed next to the solution. The solution value is stored to the TVM variable **I**.
   [▲] [▲] [▲] [F5]



Using the Financial Functions

Entering Cash Inflows and Cash Outflows

When using the financial functions, you must enter cash inflows (cash received) as positive numbers and cash outflows (cash paid) as negative numbers. The financial functions follow this convention when computing and displaying answers.

FIN FUNC (Financial Functions) Menu [2nd] [MATH] [MORE] [F2]

TVM	FUNC	VARS	FORMT	Uninst
tvmN	tvmI	tvmPV	tvmP	tvmFV

▸

npv	irr	bal	Σprn	Σint

▸

nom	eff	dbd	pBegin	pEnd

Calculating Time-Value-of-Money

The first five items on the FIN FUNC menu are the time-value-of-money (TVM) functions. You can use them to analyze financial instruments, such as annuities, loans, mortgages, leases, and savings, on the home screen or in a program.

All arguments and punctuation inside the [ ] brackets are optional.

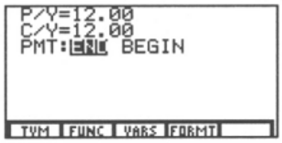
To store a value to a TVM variable, use the TVM Solver or use [STO▸] *and any TVM variable on the* FIN VARS *menu.*

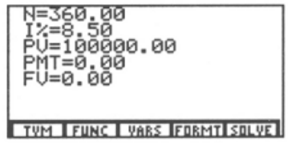
tvmN [(*I%,PV,PMT,FV,P/Y,C/Y*)]	Computes the number of payment periods
tvmI [(*N,PV,PMT,FV,P/Y,C/Y*)]	Computes the annual interest rate
tvmPV [(*N,I%,PMT,FV,P/Y,C/Y*)]	Computes the present value
tvmP [(*N,I%,PV,FV,P/Y,C/Y*)]	Computes the amount of each payment
tvmFV [(*N,I%,PV,PMT,P/Y,C/Y*)]	Computes the future value

Each TVM function takes zero to six arguments. Each argument must be a real number or a TVM variable. The values that you specify as arguments for these functions are not stored to the TVM variables.

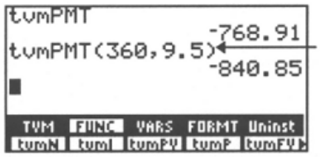
If you enter less than six arguments, you must enter arguments in the order of the syntax, up to the last argument you want to enter. The program substitutes a previously stored TVM variable value for each subsequent unspecified argument. If you enter any arguments with a TVM function, you must place the argument or arguments in parentheses. The following examples show some ways to use the TVM functions.

Assume these values are stored to the TVM variables in the payment format editor and TVM Solver.



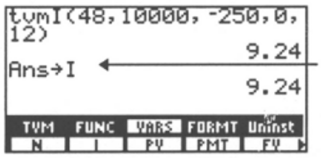


*When you execute a TVM function on the home screen with no specified arguments, the TVM function (**tvmPMT** in the example) uses stored TVM variable values.*



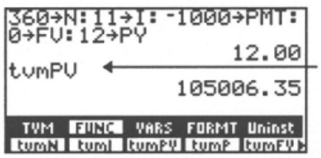
To change an argument without changing the value stored to a TVM variable, enter arguments up to the argument you want to change. In the example, the interest rate is changed to **9.5**.

You can enter arguments directly on the home screen. Remember, neither the answer nor the arguments are stored to the TVM variables.



To store an answer to the appropriate TVM variable, use [STO▶] *and the* FIN VARS *menu.*

If you prefer, you can store values to the TVM variables on the home screen.



*When you execute a TVM function (**tvmPV** in the example), it uses the newly stored TVM variable values.*

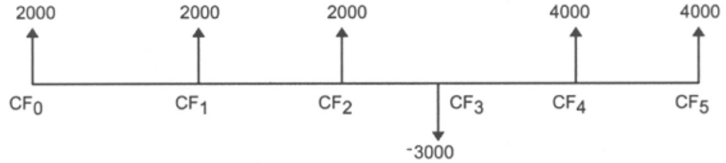
Calculating Cash Flows

The next FIN FUNC menu items are cash flow functions. Use them to analyze the value of money over equal time periods. You can enter unequal cash flows. You can enter cash inflows or outflows.

npv(*interestRate,cashFlow0, cashFlowList*[*,cashFlowFrequency*]**)**	Returns the sum of the present values for the cash inflows and outflows
irr(*cashFlow0,cashFlowList* [*,cashFlowFrequency*]**)**	Returns the interest rate at which the net present value of the cash flows is equal to 0

- *interestRate* is the rate by which to discount the cash flows (the cost of money) over one period.
- *cashFlow0* is the initial cash flow at time 0; it must be a real number.
- *cashFlowList* is a list of cash flow amounts after the initial cash flow *cashFlow0*.
- *cashFlowFrequency* is a list in which each element specifies the frequency of occurrence for a grouped (consecutive) cash flow amount, which is the corresponding element of *cashFlowList*. The default is 1; if you enter values, they must be positive integers <10,000.

The uneven cash flow below is expressed in lists. *cashFlowFrequency* indicates that the first element in *cashFlowList* (**2000**) occurs twice (**2**), the second element (**⁻3000**) occurs once (**1**), and the third element (**4000**) occurs twice (**2**).

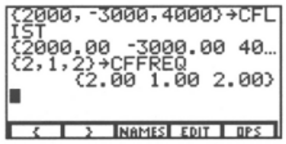


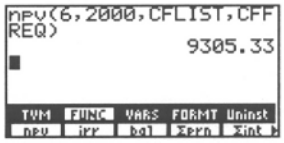
cashFlow0 = **2000**

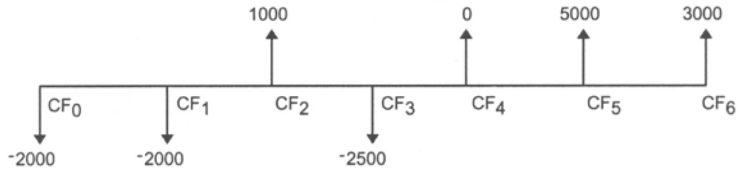
cashFlowList = **{2000,⁻3000,4000}**

cashFlowFrequency = **{2,1,2}**

I% = **6**



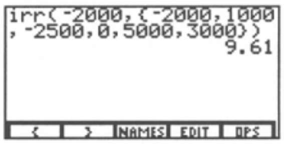




cashFlow0 = **⁻2000**

cashFlowList = **{⁻2000,1000, ⁻2500,0,5000,3000}**

cashFlowFrequency = **N/A**



Calculating Amortization

Items eight, nine, and ten are the amortization functions. Use them to calculate balance, sum of principal, and sum of interest for an amortization schedule.

roundValue specifies the internal precision used to calculate the balance.

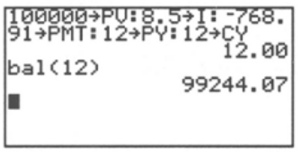
effectiveRate, nominalRate, and compoundingPeriods must be real numbers; compoundingPeriods must be > 0.

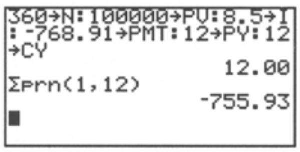
bal(, **ΣPrn(** , *and* **ΣInt(** *use stored values for* I%, **PV**, *and* **PMT**. *You must store values to these variables before computing the principal.*

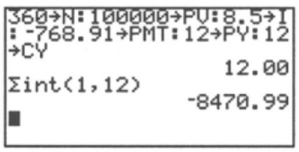
bal(*nPayment*[,*roundValue*]**)** — Computes the balance for an amortization schedule; *nPayment* (the number of the payment at which to calculate a balance) must be a positive integer <10,000

ΣPrn(*paymentA*,*paymentB* [,*roundValue*]**)** — Computes the sum of the principal during a specified period for an amortization schedule; *paymentA* (the starting payment) and *paymentB* (the ending payment in the range) must be positive integers <10,000

ΣInt(*paymentA*,*paymentB* [,*roundValue*]**)** — Computes the sum of the interest during a specified period for an amortization schedule; *paymentA* (the starting payment) and *paymentB* (the ending payment in the range) must be positive integers <10,000







Amortization Example: Calculating an Outstanding Loan Balance

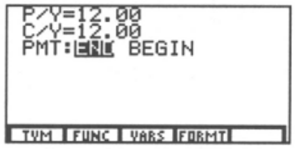
You want to buy a home with a 30-year mortgage at 8 percent annual percentage rate (APR). Monthly payments are \$800. Calculate the outstanding loan balance after each payment and display the results in a graph and in the table.

1. Display the mode screen and set the fixed-decimal setting to **2**, as in dollars and cents. Also, set **Param** graphing mode.

   [2nd] [MODE] [▼] [▶] [▶] [▶] [ENTER] [▼] [▼] [▼] [▶] [▶] [ENTER]

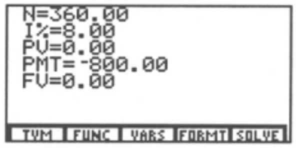
2. Display the payment format editor, and then set payments and compounding periods per year to 12, to be received at the end of each period.

   [2nd] [MATH] [MORE] [F2] [F4] **12** [▼] [▼] [ENTER]



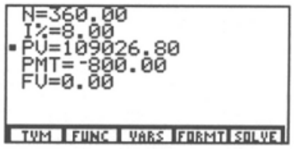
3. Display the TVM Solver, and then enter the known TVM variable values:
   N=360 **PMT=⁻800**
   I=8 **FV=0**

   [F1] **360** [▼] **8** [▼] [▼] [(-)] **800** [▼] **0** [ENTER]



4. Move the cursor to the **PV=** prompt and solve for the present value of the loan. A small square specifies the solution.

   [▲] [▲] [F5]



A stat plot is turned on if it is highlighted with a box.

5. Display the parametric equation editor. Turn off all stat plots.

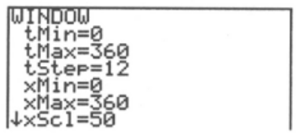
   [GRAPH] [F1] (if a plot is on, press [▲], [▶] to highlight it, and [ENTER]; then [▼])

6. Define **xt1** as **t** and **yt1** as **bal(t)**.

   [F1] [▼] [2nd] [MATH] [MORE] [F2] [F2] [MORE] [F3] [2nd] [F1] [)]

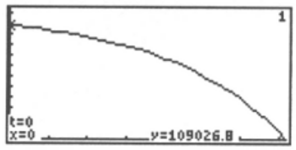
7. Display the window variable editor, and then enter these window variable values as shown.

   [GRAPH] [F2] **0** [▼] **360** [▼] **12** [▼] **0** [▼] **360** [▼] **50** [▼] **0** [▼] **125000** [▼] **10000**



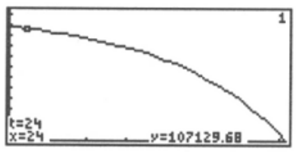
8. Draw the graph and activate the trace cursor. Explore the graph of the outstanding balance over time.

   [F5] [F4] [◀] [▶]



9. Enter a value for **t** to view the balance at a specific time.

   24 [ENTER]

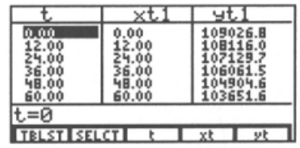


⑩ Display the table setup editor, and then enter these values:
TblStart=0 ΔTbl=12
Indpnt: Auto

[TABLE] [F2]
0 [▼] 12 [▼] [ENTER]

⑪ Display the table of outstanding balances, where **xt1** represents time and **yt1** represents balance at that point in time.

[F1]

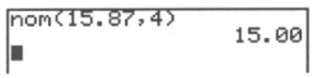


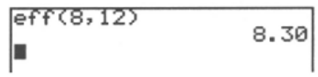
Calculating Interest Conversion

Use the interest conversion functions **nom** and **eff** to convert interest rates from an annual effective rate to a nominal rate (**nom**), or from a nominal rate to an annual effective rate (**eff**).

nom(*effectiveRate,compoundingPeriods***)** Computes the nominal interest rate

eff(*nominalRate,compoundingPeriods***)** Computes the effective interest rate



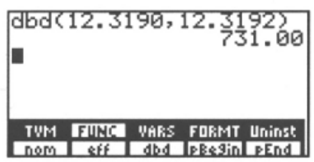


Finding Days Between Dates

Use the date function **dbd** to calculate the number of days between two dates using the actual-day-count method. *dateA* and *dateB* can be numbers or lists of numbers within the range of the dates on the standard calendar.

Dates must fall between the years 1950 and 2049.

dbd(*dateA,dateB***)** Calculates the number of days between dates; enter *dateA* and *dateB* in either of two formats: *MM.DDYY* (for U.S.) or *DDMM.YY* (for Europe)



Defining the Payment Method

pEnd and **pBegin** specify a transaction as an ordinary annuity or an annuity due. Executing either instruction sets the payment method for subsequent financial calculations. The current setting is displayed in the payment format editor (page 4).

On the payment format editor's **PMT:END BEGIN** *line, select* **END** *to set ordinary annuity or select* **BEGIN** *to set annuity due.*

pBegin Specifies an annuity due, where payments occur at the beginning of each payment period (Most leases are in this category.)

pEnd Specifies an ordinary annuity, where payments occur at the end of each payment period (Most loans are in this category; **Pmt_End** is the default.)

Menu Map for Financial Functions

MATH Menu (where FIN is automatically placed) [2nd] [MATH]

NUM	PROB	ANGLE	HYP	MISC	▸	INTER	FIN			

(MATH) FIN (Financial) Menu [2nd] [MATH] [MORE] [F2]

TVM	FUNC	VARS	FORMT	Uninst

FIN TVM (Time-Value-of-Money) Solver Menu [2nd] [MATH] [MORE] [F2] [F1]

TVM	FUNC	VARS	FORMT	SOLVE

FIN FUNC (Financial Functions) Menu [2nd] [MATH] [MORE] [F2] [F2]

TVM	FUNC	VARS	FORMT	Uninst						
tvmN	tvmI	tvmPV	tvmP	tvmFV	▸	npv	irr	bal	Σprn	Σint
					▸	nom	eff	dbd	pBegin	pEnd

FIN VARS (Financial Variables) Menu [2nd] [MATH] [MORE] [F2] [F3]

TVM	FUNC	VARS	FORMT	Uninst						
N	I	PV	PMT	FV	▸	PY	CY			

FIN FORMT (Financial Format) Menu [2nd] [MATH] [MORE] [F2] [F4]

TVM	FUNC	VARS	FORMT	