Instructions
for
Multi-Point Blower Door
and
Duct Blower Testing
(Power Regression Analysis)

INTRODUCTION

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

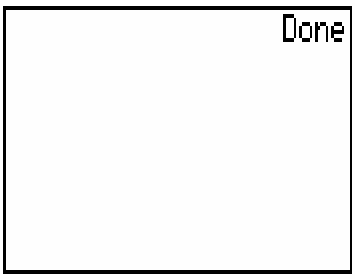
Multi-point duct blower analysis can also be performed.

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

PROGRAM OPERATION

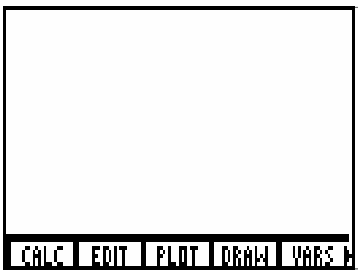
Follow the instructions beginning on page 85. Pictures of the TI-86 screens appear on the left side of pages 85 through 88 with explanations to the right of each picture.

Regress-1



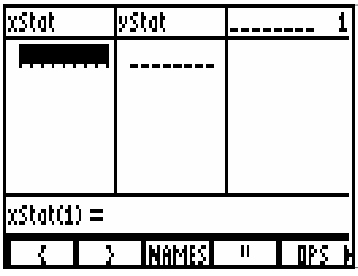
- When you turn your TI-86 calculator on, it is likely that the display will look liked this.
- This routine explained here is used for multi-point blower door or duct blower testing. Multi-point means that CFM flow readings are taken at different pressures, usually at least six different house pressures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

Regress-2



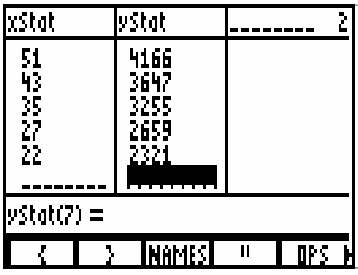
- You will see this menu on the screen.
- "CALC," **F1,** for calculating regressions.
- "EDIT," **F2,** for editing and entering data.
- "PLOT," **F3**, for plotting functions.
- "DRAW," **F4**, for graphing regression lines and scatter plot diagrams.
- "VARS," **F5,** lists all the statistical tests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

Regress-3



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

Regress-4



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

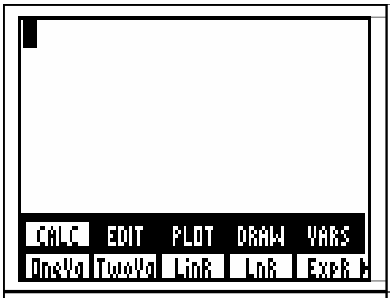
Regress-5

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

Regress-6

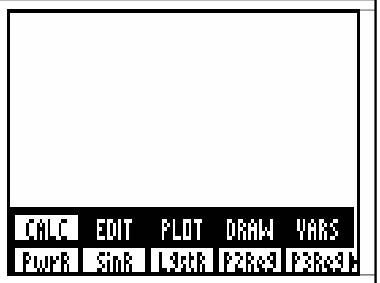
- OK, here we go. Press the **2nd** key and then the **STAT** key.
- You will see the **STAT** menu screen, as at the left.
- Press **F1** for "CALC" to the we can perform the regression analysis on the data pairs that we entered at panel "Regress-4." The data we entered is still there, if you want to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

Regress-7



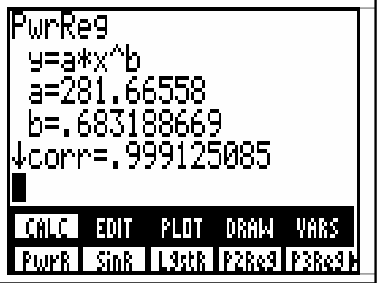
- Press **F1** for "CALC." Notice that the primary menu moves up and a secondary menu is displayed for "CALC" (notice that "CALC" is highlighted).
- At the right-most menu item, **F5** "ExpR" there an arrow pointing to the right indicating that there are more menu items. Press the **MORE** key to go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

Regress-8



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

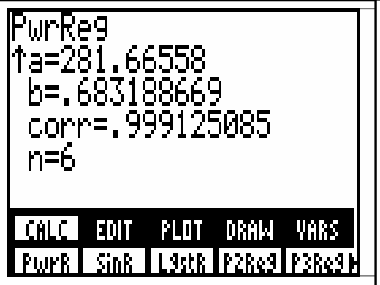
Regress-9



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

[continued on next panel]

Regress-10



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

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

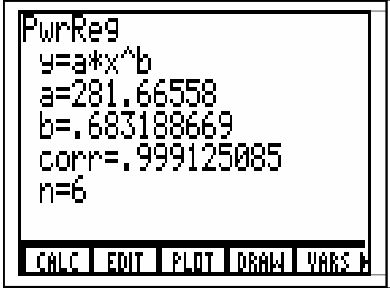
[continued on next panel]

Regress-11

[intentionally left blank]

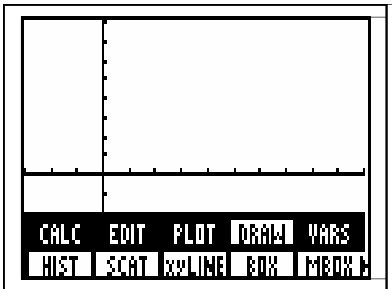
- "corr=.999125085" is the correlation coefficient. This number should be 0.99 or greater. If it is less than 0.99, do the blower door testing again. A value of less than 0.99 indicates a bad fit of the data pairs to the house leakage curve. Windy conditions often cause a correlation coefficient value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

Regress-12



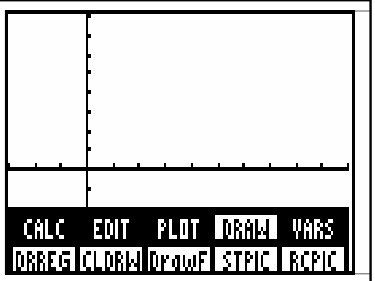
- Press **EXIT** one time. This will hide the secondary "CALC" menu sets.
- If you need to correct the data pairs or enter new ones for a different house, press **F2** for "EDIT" (see panels "Regress-4" through "Regress-6").
- Now, let's see what else we can do with our data pairs.
- Press **F4**, "DRAW"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

Regress-13



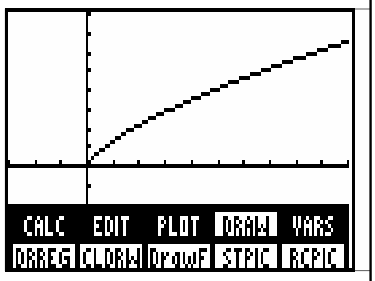
- You will see the screen at the left. Notice the secondary "DRAW" menu ("DRAW" is highlighted).
- **F2**, "SCAT" draws a scatter diagram of the data pairs. Try it.
- **F3**, "xyLINE" connects the data pairs with a line. Try it.
- Notice that there is a right-pointing arrow in the right-most sub-menu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

Regress-14



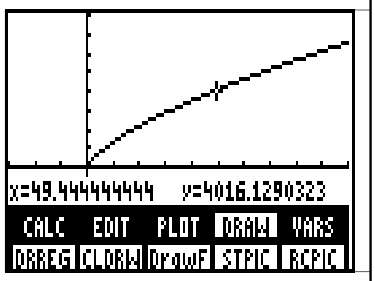
- The secondary menu set has now changed.
- The two items that are useful to use in the secondary menu are **F1,** "DRREG" (draw regression line) and **F2**, "CLDRW" (clear drawing).
- The parameters of the graphing functions of the TI-86 are set so that the regression drawing—the house leakage curve—will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

Regress-15



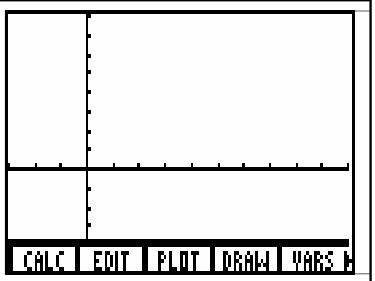
- Within a few seconds you will notice that the house leakage curve appears on the screen. The vertical axis, y, represents CFM flow, the horizontal axis, x, represents ΔP.
- The "DRAW" features use the most recent blower door test data entered.
- If you want to watch the line drawing again, press **F2**,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

Regress-16



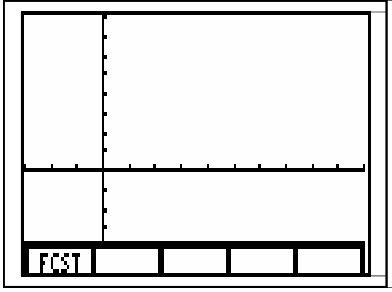
- Now for some more fun, press the up cursor key. You will notice the crosshair cursor moving upward and the x (ΔP) and y (CFM flow) coordinates appear above the menu bars. Tracing the leakage curve with the cursor characterizes the house for which you have entered data.
- When you are finished with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

Regress-17



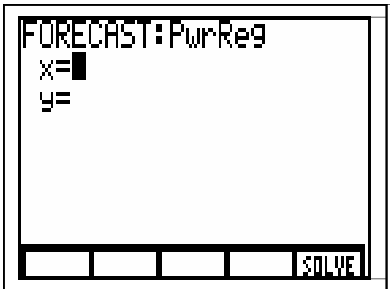
- Now you will see the primary "STAT" menu and the x and y coordinates on the screen.
- Notice that there is another menu set indicated by the right-pointing arrow in the right-most menu cell.
- Press the **MORE** key once to move to the next menu set.

Regress-18



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

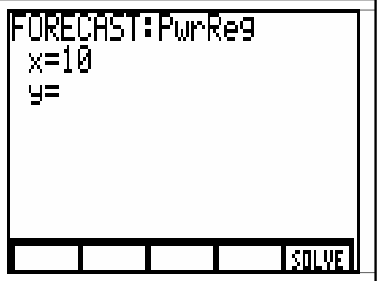
Regress-19



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

This is very important!

Regress-20

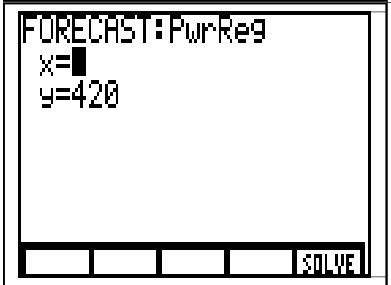


- Let's try an example.
- At "x" enter the building pressure for which you want a CFM flow. For our example, enter "10" Pascals of building pressure.
- Press **ENTER** or the down arrow once to move the cursor to the y position. Remember, y is the CFM for at the corresponding ΔP entered at "x=".

Regress-21

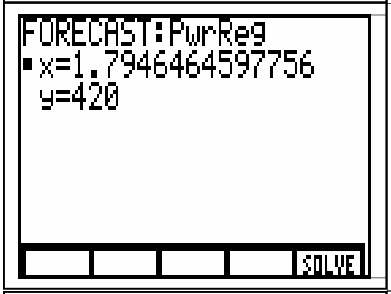
- Press **F5**, "SOLVE," for the answer or "1358." In other words, the CFM_{10} of this house is 1358.
- This can now be plugged into the Equation Nugget "AEQLA" (see panel Nugget-53 on page 99) to find the equivalent leakage area (EqLA) of this house.
- You can also find the CFM_4 for this house with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

Regress-22



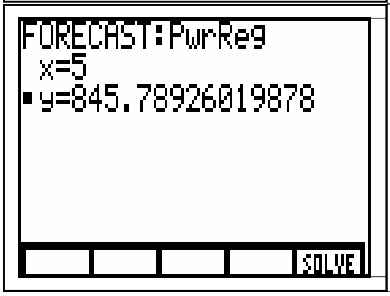
- Now let's try something else that is useful to know.
- Let's assume that this house has a total actual exhaust rate from all the exhaust appliances (kitchen fans, bathroom fans, vented dryer, etc.) of 420 CFM. Because the forecast function finds points on the house leakage curve, if we know the value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

Regress-23



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

Regress-24



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