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"ARE DEGREE DAYS OBSOLETE FOR GAS FORECASTING?" Document 2

by

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Introduction

Columbia Gas Distribution Companies (CDC) serves about 1,515,000 residential and 135,000 commercial customers in a six-state area. Eighty-five percent of these customers are located in Ohio (1,067,000) and Pennsylvania (335,000) and the remaining fifteen percent are located in Kentucky, New York, Virginia and Maryland. Approximately ninety-seven percent of these customers use gas for space heating which accounts for over seventy percent of their total gas consumption. Given the magnitude of CDC's heating sales, we are acutely interested in the impact winter weather has on our business. In fact, weather is intertwined with almost every facet of the business from distribution piping design to bi-monthly estimated bills, gas supply contract adherence, sales forecasts, cash flow projections, and rate case filings.

This paper will describe an experimental approach to determining the effect of weather on "weather sensitive" sales which we call the TRUTEMP method and compare this method with the traditional degree day method when measuring weather sensitive usage conservation levels among our residential customers. Other potential applications, such as price elasticity, weather normalization techniques, bi-monthly estimated billing procedures, and peak day weather sensitive gas requirements are also briefly discussed.

The author charges that the 65°F based degree day concept is flawed and obsolete and getting more so with each passing year. Further, the degree day method can transmit biased signals to gas requirements planners and market analysts which can lead to poor forecasts of weather sensitive gas requirements. On the other hand, we contend that the TRUTEMP method is based on thermodynamic principles, tracks changes in building construction quality and occupant habits, is more accurate for daily, monthly and seasonal weather sensitive gas requirements analysis and projections, and provides more comprehensive information on weather sensitive gas usage trends.

Background

The 65°F based degree day for energy consumption analysis and forecasting has been in use for many years. As early as 1915, Eugene D. Milener, a Baltimore gas company engineer, found that the gas consumption of the house-heating plants in that city was proportional to the number of degrees difference between the outside temperature and 64°F (Ref. 1). Later studies indicated that the use of a 65°F base temperature rather than 64°F improved the relationship. As a result, the 65°F figure was put into use and given the name of degree day.

Studies made by the American Gas Association up to 1932 and by the National District Heating Association in 1932 also indicated the 65°F base (Ref. 2) Thus from its beginning, the degree day has had field study support for proportionality between residential fuel use and a 65°F temperature basis.

However, since those earlier days, residential building thermal integrity has increased dramatically through the use of ceiling and wall insulation, storm windows, tighter doors, caulking, etc., which helps retard the escape of heat to the outdoors. Additionally, there is much more supplemental heat, or heat gain, in residences today than in 1932. For example, the Edison Electric Institute reports show average residential electric usage of 675 KWH per month in 1973 versus 46 KWH in 1930, a thirteenfold increase (Ref. 3). Much of this increased electric consumption (2.1 MMBtu per month) is liberated directly into the heated space by the lights and appliances which helps to heat the home and offsets the need for an equal mount of energy from the furnace. This combination of more heat gain and improved thermal integrity lowers the outside temperature point at which the gas furnace is required in order to maintain the thermostat setting. The outside temperature at which this point is reached is called the balance point temperature and is assumed to be 65°F using the traditional degree day method. Lower thermostat settings also directly affect the balance point temperature, i.e., for each degree of permanent thermostat setback, the balance point temperature is lowered one degree (Ref. 4). Given higher energy prices and lower thermostat settings since the 1973 oil embargo, along with improved thermal integrity and higher internal heat gains strongly suggests that the 1932 degree day basis is no longer valid for gas heating usage analysis and forecasting.

Degree Day Method

Figure A illustrates the traditional degree day method of relating weather sensitive gas usage to outside temperature. For each degree that the outside temperature falls below 65°F there is one "degree day." Given this assumed relationship, it is only necessary to know the actual weather sensitive gas usage at any one temperature or the equivalent number of degree days for a home or a group of homes to extrapolate gas usage at any other outside temperature. For example, Figure B depicts a hypothetical sample of 100 homes that consume 40,000 scf (400 scf per home on average) of weather sensitive gas on a day that has 20 degree days (45°F average daily temperature). We would say that this group of homes averages 20 scf per degree day of weather sensitive gas usage (40,000/[100*20]). This 20 scf per degree day is exhibited by the slope of the line, i.e., for each degree day or degree F change in weather, there is a 20 scf per customer change in weather sensitive gas usage. Further, we would assume that at 40 degree days, these homes would consume twice as much weather sensitive gas due to proportionality (40*20*100 = 80,000 scf).

TRUTEMP Method

The TRUTEMP method does not assume a balance point temperature of 65°F or a proportionality of weather sensitive gas usage to that 65°F basis. Instead the methods seeks to determine the true balance point temperature (hence the name TRUTEMP) as well as the actual slope of the usage line, i.e., scfd/customer per degree of outside temperature change from the gas consumption data at hand. The results coming from the TRUTEMP analysis can be surprisingly different than those from degree day analysis.

Going back to our hypothetical 100 customer example shown in Figure B, let's say we collected some additional data as shown in Table 1. The non-weather sensitive gas usage is determined during warm periods when no heating gas is used and is assumed to be constant (there could be some variation in the real world due to vacations, seasonal bathing habits, laundry frequency, etc.). Figure C graphically depicts this data. Notice that the actual balance point temperature seems to be lower than 65°F. For direct comparison with the previous Figure B, we can simply eliminate the non-weather sensitive usage and plot Figure D. If we were to perform a linear regression on this hypothetical weather sensitive gas usage data for periods 3 through 8 in Table 1 we would get the linear equation: scfd/cust. = 1525 - 25*ADT where ADT is average daily temperature. The slope of the line is 25 scfd/customer per degree F and 1525 is the weather sensitive gas usage at zero degrees F. We can solve for the balance point temperature by setting scfd/cust. = 0 and solving for ADT. This yields a 61°F balance point temperature. In this example we have a perfect correlation between weather sensitive scfd/cust. and average daily temperature and every measured point falls exactly on the regression line. If we go back to Table 1, however, and divide the weather sensitive scfd/cust. by the implied degree days we would get a different scfd/cust. per degree day for each period ranging from a low of 15 in period 3 to a high of 22.5 in period 6 as shown in the last column. The various degree day usage factors represent the slope of lines passing from 65°F at zero usage through each of the actual values plotted on Figure D. This is illustrated in Figure E and points up the normalization errors that can result from the traditional degree day method. For example, period 1 would indicate a 975 scfd/cust. weather sensitive usage at zero degrees F while period 6 would indicate 1462.5 scfd/cust. at zero degrees F whereas the actual usage is 1525 scfd/cust. It is interesting to note that if you were to perform a linear regression on the weather sensitive scfd/cust. versus degree days for the periods 3 through 8 we would get the equation: scfd/cust. = -100 + 25*DD. Upon inspection, this equation implies that when there are zero degree days the weather sensitive gas usage equals minus 100 scfd per customer, an impossibility! However, if we set scfd/cust. equal to zero and solve for DD we will get DD equal to 4 which is equivalent to the 61°F balance point temperature we got with the TRUTEMP method. The bottom line of all this discussion is that if the actual balance point temperature is not the same as the assumed degree day based 65°F, serious normalization and peak day usage errors can result from the degree day accounting method of dividing usage by degree days and extrapolating that value to some other weather condition.

A note of caution is in order on weather sensitive scfd/cust. versus average daily temperature or degree day regressions. Only include those periods when the average temperature is somewhat below the balance point temperature or the data points will be biased somewhat by non-weather sensitive usage. For example, in our operating area, when using monthly data, we can use the eight billing months of October through May (which includes over 98 percent of the yearly weather sensitive volumes). July and August are essentially non-weather sensitive usage months while the June and September billing months have days where the average daily temperature is too high to indicate weather sensitive usage but some furnaces click on for a few hours during the colder early morning hours which can bias the data.

Conservation Comparison

The author has applied the TRUTEMP method to the CDC residential market for the period 1972 through the summer of 1984 using company billing data and then compared the results to the degree day method of measuring weather sensitive usage conservation. As the term "conservation" is applied here, we mean the total change in weather sensitive usage per unit of temperature between time periods. This would include not only the effects of added insulation, caulking, storm windows, etc. and thermostat lowering or setbacks in existing homes but also the effects of replacement furnaces in existing homes as well as the gradual mixing in of new homes with more efficient furnaces and better thermal integrity. While this may not fit the pure definition of conservation, the comparison between the two methods is valid and informative as to distortions arising from the degree day method. One could track other definitions of conservation, such as the effect of insulation, etc. in existing homes, where the data exists for such a study.

Figure F illustrates the variability of residential weather sensitive usage per degree day across one heating season compared to the "season average" number used for conservation analysis purposes. The "season average" is determined by dividing the total season's weather sensitive usage by the total degree days and the number of heating customers. Figure F plots weather sensitive scf per heating customer per degree day for each of the eight months of October 1982 through May 1983. While this plot is for an abnormally warm winter, it is very similar in appearance to plots of other winters including the very cold 1976-77 winter. The point of this graph is that all degree days are not created equal and while we, for conservation analysis purposes, treat weather sensitive usage on a degree day basis as a monthly or seasonal constant number and assume that it is indifferent to the severity of weather, it actually is widely variable across a heating season and is sensitive to the severity of the weather. Figure G indicates the monthly errors that result from using the "season average" to project monthly weather sensitive volumes. Using this traditional degree day method to calculate the year-to-year change in the season average weather sensitive scf per heating customer per degree day, or "conservation" as we call it, results in the Figure H plot. The three highest weather sensitive conservation seasons were October 1973-May 1974 (the oil embargo) at 5.0 percent, October 1975- May 1976 at 4.9 percent and October 1982-May 1983 at 7.1 percent. Notice that, using the degree day method, the cold winter of October 1976-May 1977 only shows 3.7 percent conservation even though there were factory and school closings, public pleas to conserve and threats of outages. Later we will see that weather sensitive conservation was actually much greater during this period. Notice also the large apparent reversal of conservation during the winter of 1983-84. We will see that the degree day method has exaggerated the real level of conservation due to the relative severity of the weather.

Turning now to the TRUTEMP method of calculating heating usage and conservation, Figure I illustrates an excellent fit for residential weather sensitive usage versus average daily temperature for the same winter that Figure F was based. Statistical measures are extremely significant with $\bar{R}^2$ = .997 (99.7 percent of the variation in weather sensitive scf per heating customer per day is explained by average daily dry bulb temperature) and other statistical measures well beyond the upper limits of probability shown in many textbooks. Figure I is for the abnormally warm heating season of October 1982-May 1983, but other heating seasons plot as well. For example, the abnormally cold season of October 1976-May 1977 is shown in Figure J and has an $\bar{R}^2$ of .998. Controlled field research programs on homes with sub-meters installed on the furnace fuel line give the same consistent high quality results.

Figure K is included to illustrate graphically how conservation is measured by the TRUTEMP method from one period to another. The upper line is for the heating season 1976-77 (from Figure J) and the lower line is for 1982-83 (from Figure I). At the normal average temperature for the season (41.7°F), the difference in the weather sensitive scf per customer per day is the period's conservation for planning purposes. For a ten percent colder than normal heating season, one would use the lower corresponding average temperature to calculate conservation. If the balance point temperature for the two periods is identical, the difference in slope of the two lines would represent conservation.

Figure L indicates the monthly errors in weather sensitive usage which would result from use of the TRUTEMP method for the October 1982-May 1983 season. Figure M compares these monthly errors between the two calculation methods with the degree day method (from Figure G) and the TRUTEMP method (from Figure L). In every month the TRUTEMP method provides greater accuracy.

Using TRUTEMP to calculate the year-to-year change in weather sensitive usage or "weather sensitive conservation" is depicted in Figure N for the heating seasons of October through May for 1973-74 through 1983-84. Notice that the severe winter season of October 1976-May 1977 now exhibits the same level of conservation as does 1982-83. Notice also that the 1983-84 winter season now indicates only a slight reversal in weather sensitive conservation.

Figure O compares heating season conservation for the eleven-year period of 1973-74 to 1983-84 as measured by the traditional degree day method (from Figure H) and the TRUTEMP method (from Figure N). Most of the years show fairly close agreement with notable exceptions in the heating seasons ending in May 1977, May 1983, and May 1984. Why is this so? You may recall that Figure E illustrated the effect weather severity has on apparent heating conservation as measured by the degree day method. The warmer the weather and lower the zero heat input temperature, the lower the slope of the line (greater conservation) connecting this temperature to the 65°F base temperature and vice-versa. The heating season of 1976-77 was much colder than the previous year, the heating season of 1982-83 was much warmer than the previous year and the heating season of 1983-84 was much colder than the previous year. Therefore, using the arguments put foward above, the degree day method would understate conservation in 1976-77 and overstate it in 1982-83 and understate it again in 1983-84 simply due to relative weather severity from one heating season to the next. Figure P does an excellent job of illustrating this point.

The upper bar graph plots the difference in conservation as measured by the two methods. When the bars are above the zero line, conservation is being overstated by the degree day method and, when the bars are below the zero line, conservation is being understated. Now, compare this upper plot to the lower plot which simply depicts the change in average seasonal temperature from one winter season to the next, warmer above the zero line and colder below. There is an 87 percent positive correlation between these two plots! The degree day method is falsely influenced by the relative change in weather when the balance point temperature is not 65°F.

Table 2 tabulates the CDC residential data by heating season. Weather, prices and conservation data are shown for the two methods. We can also solve the TRUTEMP regression equations for any temperature and divide the resulting daily scf per customer by 24 hours to get average hourly input ratings at that temperature. The data illustrates that if we assume that the bulk of weather sensitive usage at zero degrees F is furnace input and we have an average furnace size in the 100,000 BTUH range, we were oversized by a factor of two in 1984 at zero degrees F! We can also solve for the percent conservation due to a one degree thermostat setback by dividing the regression line slope by the usage at normal winter temperature. For the data shown, this value varied between 4.4 to 4.8% reduction in weather sensitive usage per degree of setback. Over the twelve-year period, a maximum of 20 percent of the total conservation was due to shifts in the balance point temperature (primarily thermostat setback which is reversible) and at least 80 percent was due to reduced TRUTEMP line slopes (thermal integrity and equipment efficiency improvements which are not reversible as prices decline). Preliminary winter season 1984-85 data analysis indicates some increase in the balance point temperature compared to the prior winter as prices declined.

In terms of price elasticity over the twelve-year period, the CDC weather sensitive arc elasticity was -.372 in deflated dollar terms. A log-log regression of deflated dollar price vs. use per customer indicates a short-term price elasticity of -.335 with an $\bar{R}^2$ of .992 for the regression line. Inasmuch as the bulk of conservation over the last twelve years is not reversible, can we expect the price elasticity values of the past to be valid when gas prices decline?

Notice, from Table 2, that the degree day method and TRUTEMP are in close agreement as to the total twelve-year reduction in weather sensitive use per customer at 28.1 percent and 29.8 percent, respectively. This is because the year-to-year variations in weather (which distort the annual degree day based conservation figures) are averaged out over a several year period.

Estimated Billing Procedure

CDC read their residential and low pressure commercial meters on a bi-monthly basis. These customers are divided into "odd" and "even" month meter reading books and are further divided into twenty-one billing units to facilitate meter reader schedules, billing, receipts, etc. The customers receive a bill each month based on an "actual" meter reading or an "estimated" consumption. In truth, while the total consumption for the two-month period is accurately based on actual meter readings, the "actual" monthly bill is really the difference between last month's "estimated" consumption and the two month's total consumption. So, in a sense, all monthly low pressure bills are estimated.

CDC uses a degree day based estimated billing concept which has served its purpose well over the years. From time to time it has been necessary to "discount" the number of monthly degree days on a monthly basis in the estimating procedure to maintain accuracy standards. This "discounting," in a sense, is an attempt to track balance point temperatures as they fall below 65°F.

In order to check the accuracy of the estimating procedure and to investigate possible alternate procedures, CDC set up a pilot program to read a sample of meters on a monthly basis. Three locations (Binghamton, New York, Lexington, Kentucky, Zanesville, Ohio) were chosen and three hundred meters in each location were read on a monthly basis from November 1984 through June 1985. A couple of alternate approaches are being checked against the present estimating procedure, one being a TRUTEMP approach and one that seeks to optimize the $\bar{R}^2$ of the data points across a range of degree day basis temperatures between 50°F and 70°F. At this time the analysis has not been completed and no final determinations have been made. However, the need for discounting monthly degree days in the present estimating procedure and some of the preliminary research findings strongly suggest that something better than the 65°F degree day based procedure is needed.

Conclusion

Weather affects almost every facet of the gas business from the wellhead to planning and analysis. The author has endeavored to illustrate that the traditional degree day approach can lead to biased planning and analysis trends and results. Moreover, to the extent that the thermal integrity and efficiency of homes continues to advance with improved technology, the bias of the degree day methodology will worsen. What is needed is a method that dynamically tracks these advances and accurately considers them for planning purposes. TRUTEMP addresses these considerations and is proposed as a method of dynamically evaluating conservation levels, peak day gas requirements, gas usage elasticity, and estimated billing.

ACKNOWLEDGEMENT

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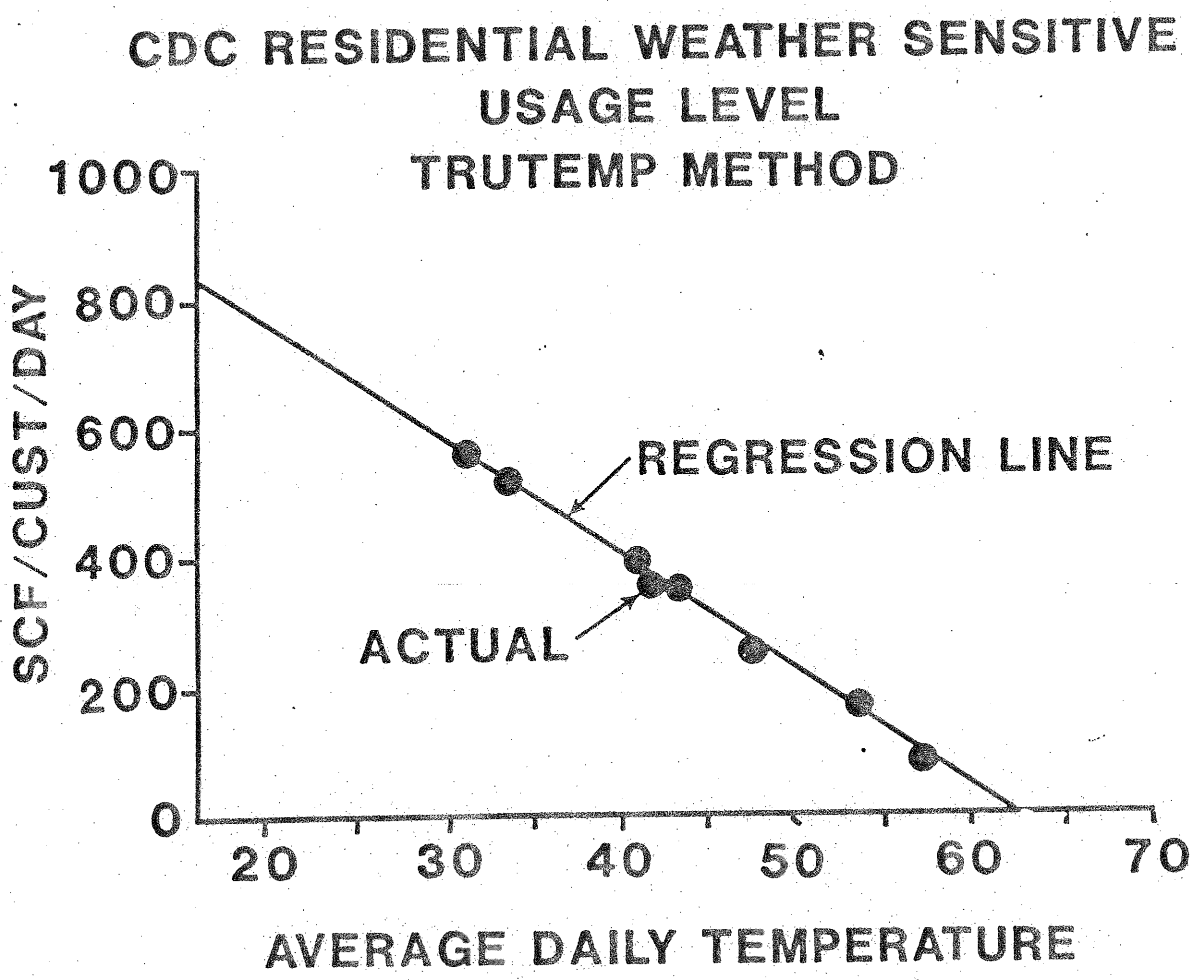

OCT. 1982 THRU MAY 1983

FIGURE I

CDC RESIDENTIAL WEATHER SENSITIVE USAGE LEVEL

ERROR CHART-DEGREE DAY METHOD

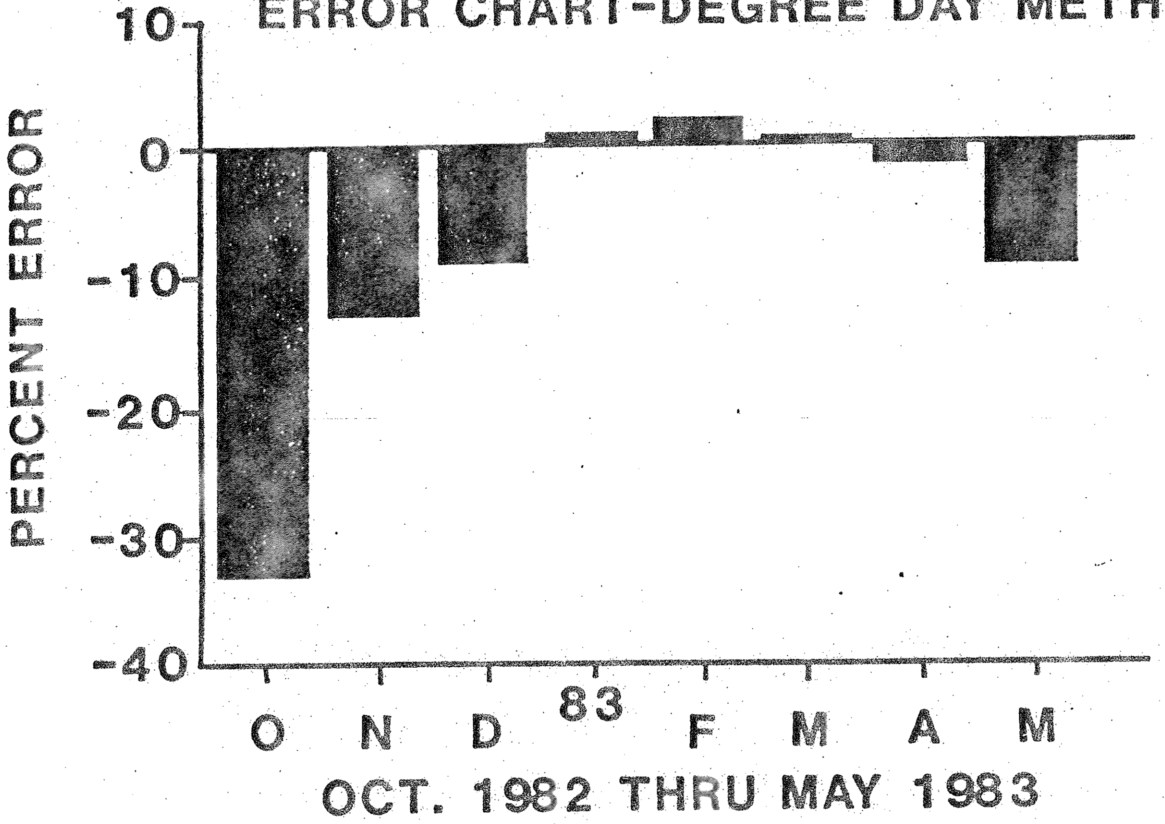

FIGURE G

CDC RESIDENTIAL WEATHER SENSITIVE USAGE LEVEL

TRUTEMP METHOD

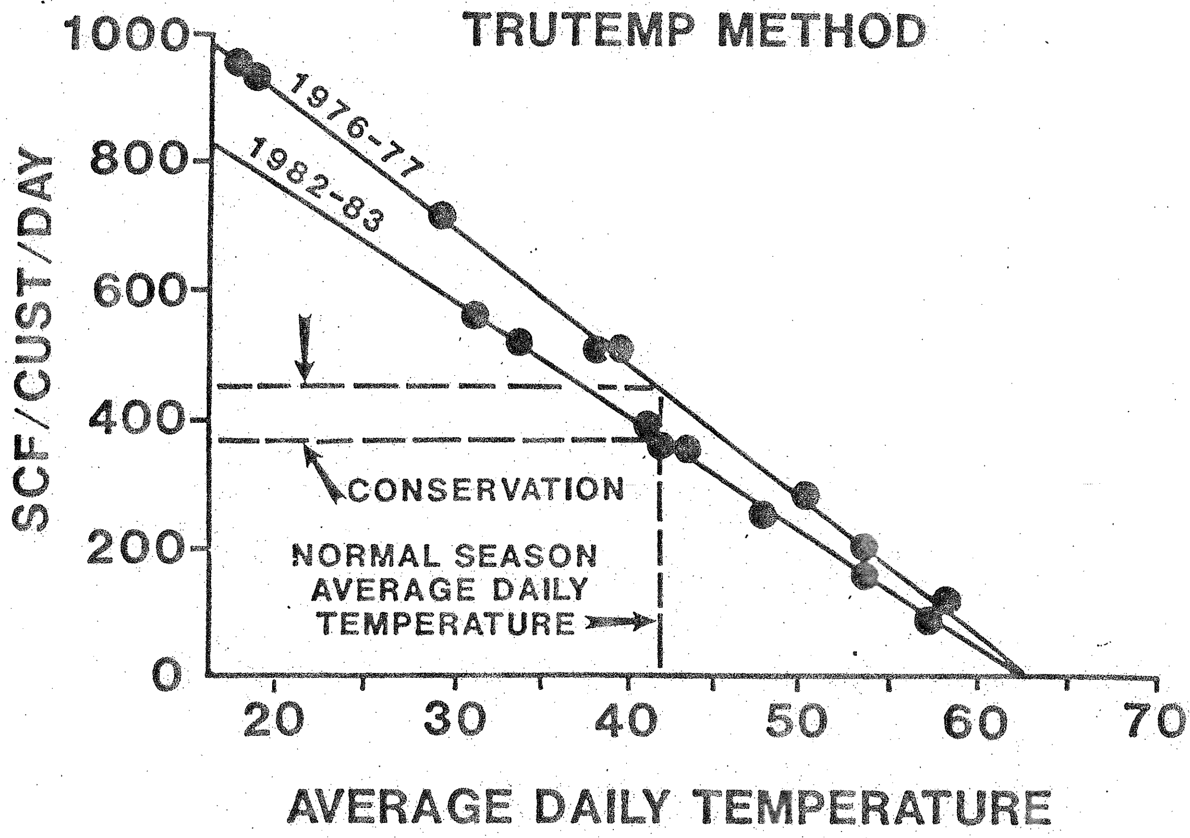

FIGURE K