Exhibit No.:
Issue: Weather Normalized Sales
Witness: Dennis Patterson
Sponsoring Party: Missouri PSC Staff
Type of Exhibit: Direct Testimony
Case No.: GR-2000-512

MISSOURI PUBLIC SERVICE COMMISSION

UTILITY OPERATIONS DIVISION

DIRECT TESTIMONY

OF

DENNIS PATTERSON

UNION ELECTRIC COMPANY

D/B/A AMERENUE

CASE NO. GR-2000-512

Exhibit No. 1
Date 10-11-00 Case No. GR-2000-512
Reporter KF

JEFFERSON CITY, MISSOURI
AUGUST 2000

DIRECT TESTIMONY

OF

DENNIS PATTERSON

UNION ELECTRIC

d/b/a AmerenUE

CASE NO. GR-2000-512

Q. Please state your name and business address.

A. My name is Dennis Patterson and my business address is Missouri Public Service Commission, P. O. Box 360, Jefferson City, Missouri, 65102.

Q. What is your present position with the Missouri Public Service Commission (Commission)?

A. I am a Regulatory Economist in the Electric Department of the Utility Operations Division.

Q. Please review your educational background and work experience.

A. I was trained as an officer and aviator in the U.S. Army. I studied economics, math, sciences and languages, receiving a B.A. in Latin American Studies (University of Missouri, 1983) and an M.S. in Agricultural Economics (University of Missouri, 1989). I joined the Staff of the Commission in April, 1986. I established the Staff's centralized weather database, and have continued to maintain and improve it by employing official weather data and accepted methods of calculating normals. I have been employed by the Commission, the Missouri Army National Guard, the University of Missouri, U.S. Army Reserves, and the U.S. Army.

Q. What is the purpose of your testimony?

A. I will explain my calculations of actual and normal heating degree-day (HDD) variables, which I furnished to Staff witness James Gray.

Q. What are HDD?

A. HDD are a weather measure that was devised to explain the pattern of natural gas used for residential heating. HDD are used to calculate the increased amount of natural gas that would be used in the next 24 hours if the average temperature were to be 1 degree colder than the previous daily average.

Q. How are HDD calculated?

A. HDD are calculated from mean daily temperature (MDT), where MDT is the average of the day's maximum and minimum temperatures (TMAX and TMIN). HDD for the day are calculated as the number of degrees MDT is below 65 degrees Fahrenheit (F), and are set equal to zero when MDT is above 65 F. The data containing TMAX and TMIN are acquired from the National Oceanic and Atmospheric Administration (NOAA). They were acquired for the test year (July, 1998 through June, 1999), and for the current NOAA normals period (January, 1961 through December, 1990).

Q. How were actual daily HDD calculated for the test year?

A. Actual daily HDD are calculated from reported TMAX and TMIN during the test year.

Q. How were normal HDD calculated for the current normals period?

A. The methods which I applied to produce daily HDD normals are described in Schedule 1, attached to my direct testimony. This method complies with provisions of the Commission's Report and Order in Missouri Gas Energy rate Case No. GR-95-285, in which it adopted NOAA's thirty-year HDD normals as a measure of normal weather. NOAA's thirty-year normals were based on temperatures that have been adjusted for exposure changes, such as the difference in temperatures between the current location and a former one. Since HDD are calculated from TMAX and TMIN, I adjusted daily TMAX and TMIN over the thirty years of 1961 through 1990 to match NOAA's series of adjusted monthly TMAX and TMIN, and used this series to calculate daily normal HDD.

Q. Which weather stations did you select?

A. I selected Cape Girardeau FAA Airport (Cape Girardeau) for the Southeast district, and Columbia Regional Airport (Columbia) for the Regional West district.

Q. What types of weather stations are maintained at Columbia and Cape Girardeau?

A. Both Columbia and Cape Girardeau are first-order stations.

Q. What are first-order weather stations?

A. First-order weather stations are usually located at regional or municipal airports, where the weather instruments are continuously monitored by professional observers. The instruments record daily TMAX and TMIN, with hourly observations of precipitation, temperature, dew point, wind and other weather elements. In contrast, cooperative weather stations are usually manned by trained volunteers who record daily observations of TMAX, TMIN and rainfall.

Q. Were the reported daily temperatures complete for both Columbia and Cape Girardeau?

A. No. Observations of daily TMAX and TMIN were missing from the climatological data for Cape Girardeau for every day between March 1, 1997 and February 28, 1999. The daily TMAX and TMIN are the extreme maximum and minimum temperature readings during 24 hours, without regard to time of occurrence. These are preferred for calculating HDD, and should be used consistently wherever possible.

Q. How did you replace the missing data?

A. I filled these dates using the highest and lowest of the official 24 hourly temperatures that were also reported each day for Cape Girardeau. These observations are read on a fixed schedule, and hence may miss the extreme temperatures for a day. As a result, the MDT calculated from the highest and lowest hourly temperatures will usually be different than the MDT calculated with TMAX and TMIN.

Q. Were these the only missing values?

A. No. In addition, both stations have had occasional short periods of missing days since 1961. The treatment of these missing values is discussed at Schedule 1.

Q. Which HDD variables did you calculate for the present rate case?

A. I calculated the actual and normal daily HDD quantities that could be used to explain the difference between the Company's sales given actual test year weather, and the Company's sales given normal test year weather. I also calculated the daily HDD quantities that

could be used to explain the difference between the Company's peak day demands given actual weather on the coldest day of the test year, and the peak day demands given normal weather on the coldest day of the test year. For presentation and to enable crosschecking, I also performed this calculation for the coldest day of every month in the test year. Calendar month summaries of actual and normal HDD and MDT for the test year are presented for Cape Girardeau at Schedule 2-1. Summaries for Columbia are presented at Schedule 2-2.

Q. How did you calculate daily HDD for the actual and normal test years?

A. Following the definition of HDD set forth above, I calculated daily heating degree-days (HDD) below the base MDT of 65 F, for every day of the test year. I then calculated HDD for each day of the 1961-1990 historical period by the same method, using MDT based on NOAA's adjusted daily TMAX and TMIN values. From these 1961-1990 HDD, I calculated daily normal HDD for each day of the 365-day normal year, by averaging HDD chronologically for each day over the thirty-year period, i.e., over 30 observations of January 1, 30 observations of January 2, and so on.

Q. How did you calculate actual and normal HDD for the test year's coldest day?

A. The actual HDD value for the test year's coldest day was selected from the weather data for the test year. The normal HDD value for the normal year's coldest day was calculated as the average over the coldest day of each of the thirty years in the 1961-1990 normals period, where daily HDD during the normals period were calculated from adjusted TMAX and TMIN as discussed above.

Q. Why did you elect to calculate peak day normal HDD in this manner?

A. The peak day normal was calculated this way because coldest day from each year could occur in any month. Because the weather was severe on January 1 in some years, and mild in others, the average for January 1 would not be appropriate. Similarly, because the coldest day occurred in January in some years, December in others, and in November, February and March in still others, the average of the coldest January day would also be inappropriate for the calculation of peak day normal HDD.

Q. How did you calculate actual and normal HDD for the coldest day of each month in the test year?

A. The peak day normal HDD just described was calculated as the thirty-year HDD average for the coldest day of each of the thirty heating years in the normals period. I also calculated HDD normals for the second coldest day, the third coldest day, and so on through the warmest day of the thirty heating years in the normals period. I then added the results to the peak day normal HDD. The whole was then sorted in descending HDD order, thus forming the series of ranked daily normal HDD. By the matching process described in Schedule 1, the daily normal peak day HDD for the coldest day for each month was selected from these results.

Q. Why did you select monthly peak day HDD from ranked daily normal HDD?

A. As discussed above, chronological averages linked to particular days or months tend to underestimate the proper values for peak day normal HDD, both for the test year and for

calendar months within the test year. The method explained in Schedule 1 reduces the tendency to underestimate peak day HDD.

Q. What were the daily normal peak day HDD for the test year and each of the twelve calendar months?

A. Summaries of actual and normal peak day HDD are presented for Cape Girardeau and Columbia at Schedules 2-1 and 2-2.

Q. Does this conclude your direct testimony?

A. Yes, it does.

BEFORE THE PUBLIC SERVICE COMMISSION

OF THE STATE OF MISSOURI

In The Matter Of Union Electric Company, d/b/a AmerenUE, For Authority To File Tariffs Increasing Rates For Gas Service Provided To Customers In The Company's Missouri Service Area	)))))	Case No. GR-2000-512

AFFIDAVIT OF DENNIS PATTERSON

STATE OF MISSOURI)
) **ss**
COUNTY OF COLE)

Dennis Patterson, of lawful age, on his oath states: that he has participated in the preparation of the foregoing written testimony in question and answer form, consisting of 7 pages of testimony to be presented in the above case, that the answers in the attached written testimony were given by him; that he has knowledge of the matters set forth in such answers; and that such matters are true to the best of his knowledge and belief.

Dennis Patterson

Subscribed and sworn to before me this 7th day of August, 2000.

Notary Public

My commission expires_____

SHARON S WILES
NOTARY PUBLIC STATE OF MISSOURI
COLE COUNTY
MY COMMISSION EXP. AUG. 23,2002

SCHEDULE 1.

METHOD FOR CALCULATING DAILY NORMAL TEMPERATURES FOR GAS AND ELECTRIC UTILITIES

OBJECTIVE. To derive normal temperatures, heating degree-days (HDD) for each day of the test year, that equate to the official thirty-year normal daily maximum and daily minimum temperatures (TMAX and TMIN) that are published by the National Oceanographic and Atmospheric Administration (NOAA).

METHOD. To adjust actual daily maximum and minimum temperature values for NOAA's normals period so that the monthly averages of the adjusted daily temperature values are equal to the adjusted monthly average temperatures that NOAA uses to calculate the monthly station normals.

REFERENCES. The contents of this schedule are based on the narrative portion of the most recent NOAA normals publication. (**Climatography of The United States No. 81, Monthly Station Normals of Temperature, Precipitation and Cooling and Heating Degree Days, 1961-90, MISSOURI. James R. Owenby and D. S. Ezell, January, 1992. U.S. DEPARTMENT OF COMMERCE, National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina**) (Monthly Station Normals). The data sets containing the adjusted monthly average TMAX and TMIN that NOAA uses to calculate the Monthly Station Normals are published as a data tape and a companion station name tape (**TD-9641: 1961-90 SEQUENTIAL TEMPERATURE AND PRECIPITATION; TD-9641: 1961-90 NORMALS NAME TAPE**) (monthly sequentials and normals name tape). The documentation that is packaged with the monthly sequentials includes (and cites extensively from) the narrative portion of NOAA's Monthly Station Normals.

DEFINITIONS.

A. **Normals, the NOAA Normals Period, and Publication of NOAA Normals.** A normal is simply an average over a long period of time. For example, the thirty-year normal for annual TMAX is simply the average of thirty observations of average annual TMAX. The NOAA thirty-year normals period is defined as the most recent three full decades. As of 1999, the most recent three decades are the years 1961 through 1990. The 1961-1990 Monthly Station Normals were published in 1992.

B. **Cooling Years and Heating Years.** The calendar year is used as the basis for calculating normals for the cooling year, because the entire cooling season is included in the calendar year. For the same reason, a 12-month year that begins on July 1 and ends the following June 30 is used as the basis for calculating normals for the heating year. The 12-month heating year is preferable statistically because calendar years often contain parts of one extreme winter and one mild one. As a result, a sample of thirty calendar years generally exhibits a larger minimum 12-month total HDD and a smaller maximum 12-month total HDD than the correct ones that would be calculated from a sample of thirty 12-month heating years.

C. **Quantities Derived from TMAX and TMIN.**

1. **Mean Daily Temperature (MDT).** The day's MDT is defined as the simple average of the day's TMAX and TMIN. To prevent bias, daily MDT values should not be rounded in the calculation of monthly normals.

2. **HDD.** HDD for the day are derived from the day's MDT as follows: if MDT is less than 65 F, then MDT is subtracted from 65 and the day's HDD are set equal to the remainder; otherwise HDD are set equal to zero. Also to prevent bias, daily HDD should not be rounded in the calculation of monthly normals.

D. **Measurement Conditions and Exposure Change Adjustments.** When measurement conditions change at a NOAA weather station, an exposure change is said to occur. When official thirty-year normal TMAX and TMIN are calculated for the twelve calendar months, exposure changes over the thirty-year normals period are taken into account with exposure change adjustments. For example, the official weather station at Columbia was moved some 13.5 miles in distance and 100 feet in elevation in October, 1969, from the former Municipal Airport to the current Regional Airport location. In order to calculate normal monthly TMAX and TMIN that were consistent with the location after 1969, it was first necessary to calculate adjustments for monthly average TMAX and TMIN for all months prior to the month of the move in 1969, by referring to the differences between Cosmopolitan Airport temperatures and those at surrounding stations. This change, among others, is noted as occurring on 15 October 1969, in the weather station history for Columbia Regional Airport (**1999 LOCAL CLIMATOLOGICAL DATA, Annual Summary With Comparative Data, Columbia, Missouri (COU), National Climatic Data Center, 151 Patton Avenue, Rm 120, Asheville, NC 28801-5001**). Exposure changes for NOAA normals stations are also documented in the 1961-90 Normals Name Tape cited above.

HISTORY: Because the NOAA Monthly Station Normals are based on weather data that has been adjusted for exposure changes, the Public Service Commission found that these normals should serve as a benchmark for the weather normalization of annual sales for

regulated Missouri utilities (Report and Order, Missouri Gas Energy rate case, Case No. 96-285).

CONDITIONS: The method described below applies for those weather stations where no significant exposure changes have occurred or been discovered since the most recent NOAA normals were published. If such exposure changes have occurred, and if their effects are significant, then the method should be revised to account for the additional information.

NEED FOR DAILY NORMALS: Because utility customer meters are read on staggered schedules, utility rate analysis must look at the differences between actual daily temperatures or degree-days and normal ones on each day in a test year. However, the NOAA normals products don't include daily HDD normals with the characteristics that are needed for the analysis of natural gas sales data. It is therefore necessary to calculate daily normals of HDD that do possess the necessary characteristics. However, in keeping with the Commission's findings, the analysis must also insure that these daily normals equate with NOAA monthly normal TMAX and TMIN.

TYPES OF DAILY NORMALS THAT ARE NEEDED: Natural gas and electricity sales are sensitive to changes in temperature, but respond differently. Temperature and degree-day normals must be distributed among the days in a test year in the manner that best suits these responses. In particular, natural gas usage responds uniformly to temperature changes below a certain base temperature. The thirty-year averages of adjusted HDD for the heating year that extends from July 1, and continues from July 2, and so on through June 30, would be suitable for this type of response. The Staff accordingly calculates daily HDD normals from thirty of these heating years. As of 1999, these heating years run from July 1 of 1961 through June 30 of 1991.

NOAA'S CALCULATION OF MONTHLY NORMAL TMAX AND TMIN. NOAA climatologists tabulate 30 years of actual monthly average TMAX and TMIN for each weather station from the actual daily observations. The resulting 360 monthly observations are adjusted for exposure changes, to make them consistent with the most recent measurement conditions. NOAA publishes the resulting data set of adjusted monthly average TMAX and TMIN in **Monthly Sequential Temperatures and Precipitation** (monthly sequentials). The monthly sequentials provide the benchmark for calculating adjusted daily MDT and HDD for the historical heating years from which the daily normals are calculated.

PROCEDURE FOR CALCULATING DAILY NORMAL TMAX, TMIN, MDT AND HDD. The daily normals can be calculated in three steps: tabulation of the historical data, adjustment of the historical data, and calculation of daily normals. Daily normals may be

calculated (a) by calendar day, (b) for the annual peak day, and (c) for monthly peak days.

A. **Tabulation of Daily Actual Temperatures.** This involves data retrieval and filling in missing values.

   1. **Retrieve Daily Maximum and Minimum Temperature Data.** The data for the desired weather station are retrieved electronically via the Internet from the archives at the Midwestern Climate Center at Champaign, IL. Since there are usually a few periods of missing temperature readings during the normals period, actual daily temperatures from three alternate weather stations are also retrieved. For first-order stations, where there are extended periods of missing data during the test year, hourly readings are also retrieved for those days.

   2. **Fill Missing Observations.** Missing observations are handled differently depending on whether they are sparse or grouped, whether they occur during the normals period or during the test year, and whether the desired station is a cooperative station or a first-order station.

      a. **Groups of missing values during the test year.** During the test year, groups of missing daily actual TMAX and TMIN are filled (where possible) with the highest and lowest reported hourly temperatures from that station. This method is the best available for approximating both the daily temperature levels and the day-to-day temperature patterns of TMAX and TMIN. For cooperative stations that do not report hourly temperatures, and for first-order stations whose hourlies were not reported for the period of missing daily TMAX and TMIN, it will be necessary to use substitutions from nearby stations (below).

      b. **Groups of missing daily values during the normals period.** For convenience, groups of missing daily temperatures are usually filled with averages of daily TMAX and TMIN from three nearby stations during the thirty-year normals period. NOAA normals serve as the benchmark for the average temperature level for a month, while the daily temperatures from nearby stations provide an approximation of the proper day-to-day temperature patterns. NOAA employs this method of substitution when the normals of monthly TMAX and TMIN are developed.

      c. **Occasional singles and pairs of missing daily values.** During the normals period and during the test year, an isolated missing value (or a pair if there are two in a row) is usually filled with an interpolation(s) between its value for the day before and the one for the day after. This method has little effect on the temperature level and day-to-day patterns.

B. **Adjustment of Daily Actual TMAX and TMIN.** This involves calculating a set of temperature averages, subtracting them from a set of benchmarks to calculate

adjustments, applying those adjustments to the daily actual temperatures that underlie the original temperature averages, minimizing rounding errors, and performing checks and balances.

1. **Calculation of Monthly Averages**. For every year and month in the thirty-year normals period, calculate the averages of daily actual TMAX and TMIN. This yields a data set of 360 monthly averages for each.

2. **Calculation of Adjustments**. Subtract the monthly average daily actual TMAX and TMIN from the adjusted monthly average TMAX and TMIN in the monthly sequentials. This yields a data set of 360 adjustments each for TMAX and TMIN. These adjustments necessarily include small fractions of a degree that must not be discarded through rounding.

3. **Adjustment of Daily Actual TMAX and TMIN.** For every day in each year and month of the thirty-year normals period, add the corresponding TMAX adjustment to the daily actual TMAX. Do likewise for daily actual TMIN. This yields a data set of 10,957 observations of adjusted daily TMAX and TMIN for the 1961-1990 thirty-year normals period. The adjusted daily data must then be rounded to the nearest 0.5 degrees for display, but in such a way that no bias is introduced.

4. **Rounding Error.** In the adjustment calculations, simple rounding of every adjusted daily TMAX and TMIN value to the nearest 0.5 degrees would obviously lead to small errors in the new monthly averages of adjusted daily TMAX and TMIN. However, when adjusted MDT and HDD are calculated from the adjusted daily TMAX and TMIN, such simple rounding would lead to cumulative rounding errors of several HDD per month. To prevent this, both positive and negative fractions that are smaller than 0.5 degrees F in adjusted TMAX and TMIN are carried forward and added to the next day's adjusted readings, after which the process is repeated. This accomplishes the desired rounding at the daily level without disturbing the benchmarked monthly averages of adjusted daily TMAX, TMIN, and their daily average, MDT. This technique also prevents cumulative error when monthly totals of adjusted daily HDD are eventually calculated from adjusted daily MDT.

5. **Perform Checks and Balances.** For every month and year in the thirty-year normals period, calculate monthly averages of adjusted daily TMAX and TMIN. This yields 360 averages each for adjusted TMAX and TMIN, which must equal the 360 observations of adjusted average TMAX and TMIN from NOAA's monthly sequentials.

C. **Calculate HDD daily normals products.** Three HDD normals products are needed for setting natural gas rates. The first product is daily normal HDD for the 365 calendar days, which includes the 30-year average HDD for July 1, and

corresponding 30-year averages for July 2 through June 30. This product is used to calculate the difference between actual and normal test year sales.

The second HDD normals product is the 30-year normal HDD that could be expected to occur on the coldest day of the normal year. This product is used to estimate the peak day natural gas demands. Because the year's coldest day has occurred in the months of November through March, it is important that the year's greatest HDD be selected. Simply selecting the greatest HDD from the month that is normally coldest and taking the average over thirty years yields a normal that is too small, which would lead to an underestimate of normal peak day demands.

The third product is the 30-year normal HDD that could be expected to occur on the coldest day of each of the 12 months. This product is also used to estimate peak day demands. Once again, since the year's coldest days have historically occurred more or less at random over the winter months, the simple averages of the historical coldest day HDD from each of the 12 months yields estimates of normal peak day HDD that are too small for the cold winter months. To prevent these errors, the Staff has developed a method to select 12 monthly normal peak day HDD values that do not lead to underestimates of monthly normal peak day natural gas demands.

The three daily normal HDD products are calculated below.

1. **Calculate 30-year daily normal HDD for 365 calendar days.** This involves calculating "adjusted daily" MDT and HDD from adjusted daily TMAX and TMIN, calculating 365 averages by month and day, rounding the results as desired, and performing the checks and balances to insure accuracy at this level.

    a. **Calculate Adjusted Daily MDT and HDD From Adjusted Daily TMAX and TMIN.** This is done for the all the 10,957days in the thirty-year normals period. First, calculate MDT as the average of TMAX and TMIN. Then, where MDT is less than 65 degrees, calculate HDD as 65 degrees minus MDT. Otherwise, set HDD equal to zero.

    b. **Calculate Daily Normal TMAX, TMIN, MDT and HDD by Month and Day from Adjusted Daily Data.** First, perform the necessary operations for dealing with the leap day for each variable. For example, in the HDD leap year, re-designate the nominal months and days from February 29 through June 29 as March 1 through June 30. Discard the extra June 30, as it has no HDD. It is now possible to calculate 365 averages from 30 observations for January 1, 30 observations for January 2, ... February 28, March 1, ... and December 31.

c. **Rounding.** NOAA's test-year temperatures are recorded as whole degrees. By the Staff's method, test-year HDD are calculated to the nearest 0.5 degree-days. Accordingly, the daily normal temperatures and degree-days are usually rounded to these levels, but without disturbing monthly averages and totals. This is accomplished by using the methods discussed in the adjustment of daily actual temperatures above. This kind of rounding eases calculations and crosschecks, and makes it easier to display the daily normals. It is also usual to round daily normal HDD to whole HDD with the same procedure, for the weather normalization of sales in natural gas.

d. **Checks and balances.** At this point, monthly and annual averages of daily normal TMAX, TMIN and MDT are calculated to the nearest .01 degree F, while monthly and annual totals of daily normal HDD are also calculated. The monthly and annual quantities are then compared with NOAA monthly station normals.

   In this comparison, the monthly averages of daily normal TMAX, TMIN and MDT should agree with the NOAA monthly station normals within a rounding tolerance of about .05 degrees. The differences in the comparison of annual temperatures may exceed the monthly differences. This occurs because the NOAA annual temperature normals are calculated as simple averages of the twelve monthly normals, without considering the number of days in the month.

2. **Calculate daily normal HDD for the peak day.** Select the coldest day from each year in a normals period of thirty heating years that begin July 1 and end June 30. Calculate the average of HDD over these thirty heating year peak days. This yields the peak day normal HDD.

3. **Calculate daily normal HDD for the peak day of the 12 calendar months.** These 12 peak day values are selected from 366 ranked daily normals by a method developed by the Staff. The ranked daily normals are a natural extension of the peak day normal HDD. They include the average HDD for the thirty peak (coldest) days, the thirty second coldest days, and so on through the thirty warmest days. The ranked daily normal HDD are calculated from the adjusted daily HDD that were developed above. However, the ranked daily normals are calculated by first arranging the adjusted daily data by year, and then in descending order of MDT, rather than arranging them by months and days within years. However, month and day are assigned to these results afterward so that the monthly normal peak day HDD may be selected. The monthly peak day normal HDD are calculated in the following sequence:

a. **Calculate Adjusted Daily MDT and HDD from Adjusted Daily TMAX and TMIN.** This step is unchanged from the calculation of normals by month and day.

b. **Calculate Daily Normal TMAX, TMIN, MDT and HDD by Rank Order from Adjusted Daily Data.** The adjusted daily data are first arranged by year, and then in descending order of MDT within each year. For leap years, the occurrences of February 29 are set aside temporarily. The daily averages of TMAX, TMIN, MDT and HDD are then calculated over all the years in the normals period for the warmest MDT day, the second warmest MDT day, and so on through the coldest MDT day. The averages for February 29 are calculated separately. At this point, the results consist of 365 ranked daily normals of temperature and degree-days, all sorted in descending MDT order, plus a single observation containing the averages for February 29 that has been set aside.

c. **Rounding.** For accuracy, there should be no rounding during the intermediate steps in the calculation of the ranked daily normals. For convenience, the ranked daily normal TMAX, TMIN and HDD may be rounded by a procedure similar to the one used above.

d. **Assign a calendar month and day to the ranked daily normal HDD.** The assignment of month and day to the ranked daily normals allows them to be tabulated logically, gives information about the severity and usual dates of occurrence of extreme weather, and assists the analyst when the checks and balances are calculated. For this purpose, the 365 adjusted daily normals that were calculated previously by month and day are sorted in descending MDT order, while retaining the month and day that went with each. Then all of these normals are discarded, which leaves a sequence containing only the months and days themselves. The months and days may then be matched directly to the 365 ranked daily normals, which have already been sorted in the corresponding MDT order. The February 29 "ranked" daily normals have simply kept the original month and day, and may now be returned to the data set. However, the ranked normals for this month and day must be used with the proper weighting, because a normal year has only 25 percent of a leap year day on the average.

e. **Select 12 monthly normal peak day HDD.** After the assignment of month and day has been made, select the day with the greatest ranked normal HDD from each month. These HDD values are the monthly peak day HDD.

f. **Checks and Balances.** Ranks, averages and totals from the ranked normals should be crosschecked for accuracy and reasonableness. The assigned months and days are useful for these crosschecks.

1. Ranks. The results from the ranking should yield the same maximums and minimums of TMAX, TMIN, MDT as the averages over the thirty heating year peak days in the normals period. The maximum ranked normal HDD should equal the heating year peak day normal HDD that was previously calculated.

2. Maximum monthly peak day HDD. The maximum of the 12 monthly peak day HDD should also equal the heating year peak day normal HDD that was previously calculated.

3. Averages and totals. Monthly average temperatures and total degree-days may also be calculated from the ranked daily normals, as well as the annual averages and totals. If February 29 normals are included in the calculations with a weight corresponding to the number of leap years in the normals period, then the average of the annual averages and average of the annual totals will correspond exactly to those obtained from the normals that were calculated by month and day. However, when comparing averages of the monthly totals, more ranked normal HDD will be distributed among the months of December, January and February, and fewer among the remaining months. Monthly averages of ranked daily normal TMAX, TMIN and MDT will be reduced in the winter months, but increased in the remaining months. If these conditions are not met, the calculations should be re-examined for errors.

CAPE GIRARDEAU FAA AIRPORT, MISSOURI, MONTHLY SUMMARY STATISTICS
ACTUAL HEATING DEGREE DAYS (HDD) AND NORMAL HEATING DEGREE DAYS (NHDD)
FOR 12 CALENDAR MONTHS BEGINNING 1 JULY 1998 AND ENDING 30 JUNE 1999

		TOTAL HDD BY MONTH			PEAK DAY HDD		
YEAR	MONTH	OBSERVED TOTALS HDD	NORMAL TOTALS NHDD	**ADJUSTMENT, ACTUAL TO NORMAL**	OBSERVED COLDEST DAY HDD	NORMAL COLDEST DAY NHDD	**ADJUSTMENT, ACTUAL TO NORMAL**
1998	7	0	0	**0**	0.00	0.00	**0.00**
1998	8	0	0	**0**	0.00	0.02	**0.02**
1998	9	0	27	**27**	0.00	8.95	**8.95**
1998	10	205	234	**29**	20.00	20.94	**0.94**
1998	11	460	531	**71**	26.00	34.68	**8.68**
1998	12	792	890	**98**	46.00	48.97	**2.97**
1999	1	891	1032	**141**	**52.00**	**57.17**	**5.17**
1999	2	591	804	**213**	35.00	51.84	**16.84**
1999	3	694	559	**(135)**	37.50	35.83	**(1.67)**
1999	4	173	227	**54**	22.00	23.06	**1.06**
1999	5	36	82	**46**	6.00	11.06	**5.06**
1999	6	0	0	**0**	0.00	0.62	**0.62**
12 MONTHS		3842	4386	**544**	**52.00**	**57.17**	**5.17**

CAPE GIRARDEAU FAA AIRPORT, MISSOURI, MONTHLY SUMMARY STATISTICS
MEAN DAILY TEMPERATURE (MDT) AND NORMAL MEAN DAILY TEMPERATURE (NMDT)
FOR 12 CALENDAR MONTHS BEGINNING 1 JULY 1998 AND ENDING 30 JUNE 1999

		AVERAGE MDT BY MONTH			PEAK DAY MDT		
YEAR	MONTH	OBSERVED AVERAGE MDT	NORMAL AVERAGE NMDT	**ADJUSTMENT, ACTUAL TO NORMAL**	OBSERVED COLDEST DAY MDT	NORMAL COLDEST DAY NMDT	**ADJUSTMENT, ACTUAL TO NORMAL**
1998	7	78.0	79.6	**1.5**	69.00	69.70	**0.70**
1998	8	76.1	77.1	**1.0**	73.00	66.95	**(6.05)**
1998	9	73.1	70.0	**(3.1)**	65.00	56.05	**(8.95)**
1998	10	59.5	58.5	**(1.0)**	45.00	44.06	**(0.94)**
1998	11	49.7	47.3	**(2.4)**	39.00	30.32	**(8.68)**
1998	12	39.5	28.8	**(10.7)**	19.00	16.03	**(2.97)**
1999	1	36.3	31.7	**(4.6)**	**13.00**	**7.83**	**(5.17)**
1999	2	43.9	28.6	**(15.3)**	30.00	13.16	**(16.84)**
1999	3	42.6	47.2	**4.6**	27.50	29.17	**1.67**
1999	4	59.9	58.3	**(1.6)**	43.00	41.94	**(1.06)**
1999	5	66.3	67.5	**1.2**	59.00	53.94	**(5.06)**
1999	6	75.3	76.1	**0.8**	65.00	64.92	**(0.08)**
12 MONTHS		58.5	57.2	**(1.3)**	**13.00**	**7.83**	**(5.17)**

COLUMBIA REGIONAL AIRPORT, MISSOURI, MONTHLY SUMMARY STATISTICS
ACTUAL HEATING DEGREE DAYS (HDD) AND NORMAL HEATING DEGREE DAYS (NHDD)
FOR 12 CALENDAR MONTHS BEGINNING 1 JULY 1998 AND ENDING 30 JUNE 1999

		TOTAL HDD BY MONTH			PEAK DAY HDD		
YEAR	MONTH	OBSERVED TOTALS HDD	NORMAL TOTALS NHDD	**ADJUSTMENT, ACTUAL TO NORMAL**	OBSERVED COLDEST DAY HDD	NORMAL COLDEST DAY NHDD	**ADJUSTMENT, ACTUAL TO NORMAL**
1998	7	0	0	**0**	0.00	0.17	**0.17**
1998	8	0	0	**0**	0.00	0.89	**0.89**
1998	9	7	52	**45**	3.00	11.52	**8.52**
1998	10	242	285	**43**	17.00	23.88	**6.88**
1998	11	501	627	**126**	27.50	38.60	**11.10**
1998	12	926	1029	**103**	55.00	56.89	**1.89**
1999	1	1138	1159	**21**	**65.50**	**64.53**	**(0.97)**
1999	2	657	921	**264**	36.50	58.76	**22.26**
1999	3	727	676	**(51)**	34.00	40.91	**6.91**
1999	4	276	316	**40**	26.50	26.75	**0.25**
1999	5	82	137	**55**	8.50	14.22	**5.72**
1999	6	19	10	**(9)**	8.50	3.63	**(4.87)**
12 MONTHS		4575	5212	**637**	**65.50**	**64.53**	**(0.97)**

COLUMBIA REGIONAL AIRPORT, MISSOURI, MONTHLY SUMMARY STATISTICS
MEAN DAILY TEMPERATURE (MDT) AND NORMAL MEAN DAILY TEMPERATURE (NMDT)
FOR 12 CALENDAR MONTHS BEGINNING 1 JULY 1998 AND ENDING 30 JUNE 1999

		AVERAGE MDT BY MONTH			PEAK DAY MDT		
YEAR	MONTH	OBSERVED AVERAGE MDT	NORMAL AVERAGE NMDT	**ADJUSTMENT, ACTUAL TO NORMAL**	OBSERVED COLDEST DAY MDT	NORMAL COLDEST DAY NMDT	**ADJUSTMENT, ACTUAL TO NORMAL**
1998	7	76.9	77.4	**0.5**	66.50	66.94	**0.44**
1998	8	77.0	75.2	**(1.7)**	71.50	64.41	**(7.09)**
1998	9	72.5	67.9	**(4.6)**	62.00	53.22	**(8.78)**
1998	10	57.7	56.5	**(1.1)**	48.00	41.12	**(6.88)**
1998	11	48.3	44.1	**(4.2)**	37.50	26.40	**(11.10)**
1998	12	35.2	33.3	**(1.9)**	10.00	8.11	**(1.89)**
1999	1	28.3	27.4	**(0.9)**	**-0.50**	**0.47**	**0.97**
1999	2	41.5	32.6	**(9.0)**	28.50	6.24	**(22.26)**
1999	3	41.6	43.4	**1.8**	31.00	24.09	**(6.91)**
1999	4	56.4	55.0	**(1.4)**	38.50	38.25	**(0.25)**
1999	5	63.6	64.0	**0.4**	56.50	50.78	**(5.72)**
1999	6	72.2	72.2	**0.1**	56.50	61.37	**4.87**
12 MONTHS		56.0	54.0	**(2.0)**	**-0.50**	**0.47**	**0.97**