Exhibit No.:	
Issues:	Weather Normalization
Witness:	Curt Wells
Sponsoring Party:	MO PSC Staff
Type of Exhibit:	Rebuttal Testimony
Case No.:	GR-2006-0422
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MISSOURI PUBLIC SERVICE COMMISSION

UTILITY OPERATIONS DIVISION

REBUTTAL TESTIMONY

OF

CURT WELLS

MISSOURI GAS ENERGY

CASE NO. GR-2006-0422

Jefferson City, Missouri
November 2006

BEFORE THE PUBLIC SERVICE COMMISSION

OF THE STATE OF MISSOURI

In the matter of Missouri Gas Energy's Tariff Sheets Designed to Increase Rates for Gas Service in the Company's Missouri Service Area	))))	Case No. GR-2006-0422

AFFIDAVIT OF CURT WELLS

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

Curt Wells, of lawful age, on his oath states: that he has participated in the preparation of the following Rebuttal Testimony in question and answer form, consisting of 6 pages of Rebuttal Testimony to be presented in the above case, that the answers in the following Rebuttal 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.

Curt Wells

Subscribed and sworn to before me this 17th day of November, 2006.

NOTARY PUBLIC NOTARY SEAL STATE OF MISSOURI

SUSAN L. SUNDERMEYER
My Commission Expires
September 21, 2010
Callaway County
Commission #06942086

Susan L Sundermeyer
Notary Public

My commission expires 9-21-10

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REBUTTAL TESTIMONY

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CURT WELLS

MISSOURI GAS ENERGY

CASE NO. GR-2006-0422

Q. Please state your name and business address.

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

Q. Are you the same Curt Wells who has submitted direct testimony in this case?

A. Yes, I am.

Q. What is the purpose of your rebuttal testimony?

A. I will address the written direct testimony of Missouri Gas Energy (MGE or Company) witness Russell A. Feingold regarding the calculation of a normal for heating degree days (HDDs) for the MGE districts in Missouri.

EXECUTIVE SUMMARY

Q. Please summarize your rebuttal testimony.

A. The 10-year period for a normal proposed by MGE is inconsistent with international meteorological convention, Commission rulings, and the purpose of adjusting volumes to normal HDDs in Missouri PSC rate cases. The 30-year period used by Staff is consistent with all of these and Staff policy when calculating normal weather variables.

RATIONALE FOR THE NOAA THREE DECADE PERIOD FOR A NORMAL

Q. What time frame did MGE use in constructing a weather normal?

A. In Section 2. WEATHER NORMAL of Mr. Feingold's pre-filed direct testimony, he states: "The Company is proposing to use a 10-year Heating Degree Days ("HDD") average to normalize its natural gas volumes for rate case purposes." (Feingold direct testimony, page 6, lines 10 and 11.)

Q. Does Staff agree with the use of 10-years of data to calculate normal weather?

A. No, it does not. Staff recommends use of the National Oceanic and Atmospheric Association (NOAA) three decade time period to calculate normal weather. International convention has established that three-decade periods are appropriately long and uniform time frames for the calculations of a normal. The current thirty year period used by NOAA is January 1, 1971, through December 31, 2000.

Q. Each of the time frames considered by Mr. Feingold in his testimony end in 2005, as opposed to the current NOAA period which ends in 2000. Why is this not appropriate?

A. NOAA recalculates a 30-year normal at the end of each decade as a way of dealing with changes in measurement conditions and changes in the climate itself. Its goal is to have a stable normal for a weather variable while reflecting changes in weather patterns. In computing normal temperatures, NOAA processes and screens the data to correct for "any inconsistencies in observational practices (e.g., changes in station location, instrumentation, time of observation, etc.) and be serially complete (i.e. no missing values)." (Schedule CW-1, U.S Climate Normals 1971-2000, Products Data) If Mr. Feingold's proposal to use the most recent ten-year period is used, the last five years – *one half* – of his normal period has not gone through this correction process.

This process takes significant time and resources, and so NOAA only performs it at ten-year intervals. Updating every decade is a compromise that provides a database for a weather variable that is accurate, stable for ten years, and updated each decade for long-term changes in weather patterns.

Q. Is there other support for using the NOAA time period?

A. Yes. The use of this time period is based on testimony submitted on behalf of Staff by then Missouri State Climatologist, Dr. Wayne Decker in Case No. GR-92-165. (Schedule CW-2). On page 6, beginning with line 22, Dr. Decker gives his recommendation for the 30 year time period for defining normal heating degree days:

> Q. What would you recommend the Commission use for the "base period" in defining degree day normals for St. Louis?
>
> A. I would recommend that the most recent thirty-year period with a recalculation every decade be used for the following reasons:
>
> (1) it would not allow events which have occurred nearly a century ago to be equally weighted with more recent events in the calculation of normals;
>
> (2) it would allow for an adjustment for changes in climate, both natural and anthropogenic;
>
> (3) this procedure would bring the techniques used in Missouri in line with those used by the National Weather Service and other States;
>
> (4) the thirty-year period is long enough to produce statistics that are stable without major variations from decade to decade;
>
> (5) during the most recent thirty-year period (1961-1990), the observations at Lambert Field have been taken from the same site using the same type of weather instruments.

This recommendation was reaffirmed in Case No. GR-99-315 by then Missouri State Climatologist Steve Qi Hu, PhD, in his direct testimony (Schedule CW-3) beginning on page 7 line 17:

> Q. What should be a time period for developing meaningful climate normals?

> A. In describing climate "normals" the WMO (World Meteorological Organization) requires the use of 30-year temperature and precipitation data. This standard is accepted by the U.S. National Weather Service. One of the reasons for using such a time period in defining climate conditions is that climate has its natural variabilities. These variabilities are shown, in part, by oscillatory variations of temperature and precipitation at various time periods. For example, there have been many studies showing significant interannual and interdecadal temperature variations in the U.S. To minimize the impacts of these fluctuations on averaged climate conditions WMO recommends to use [*sic*] 30-year data in calculation of the normal of the surface air temperature.

COMMISSION DECISIONS

Q. Has the Commission ruled previously on the length of the period for calculating a normal for a weather variable?

A. Yes. In an MGE rate case, Case No. GR-96-285, the Commission decided on this issue in its Report and Order, issued January 22, 1997. At Page 18 of that Report and Order, the Commission states:

> The Commission finds that NOAA's 30-year normals is [*sic*.] the more appropriate benchmark. The 10-year moving average would needlessly cause frequent rate changes based on the introduction of new data every year. If one takes MGE's argument to its logical extreme, the Commission would use the most recent year's experience in MGE's service territory and re-set rates each year. This could lead to serious financial problems for MGE if its rates were set after a record-setting cold year. In addition, the data upon which Staff's recommendation is based has gone through the processes established by NOAA to ensure the best data possible. This safeguard is not present in MGE's approach. (Missouri Public Service Commission, Case No. GR-96-285, Report and Order, Issue Date January 22, 1997, Effective Date February 1, 1997, Page 18.)

STAFF USE OF NORMALS

Q. Mr. Feingold states that the 10-year period proposed by MGE "will result in improved forecasting for normalizing MGE's gas volumes. This means that the annual gas volumes established in the Company's current rate case would better reflect the expected normal weather conditions during the period in which its base rates will be in effect." (Feingold direct, page 7, lines 3-6.). He further states "The goal of our analysis was to determine the best predictor of future HDD levels for purposes of 'normalizing' actual natural gas consumption during the test year and for the upcoming time frame when the Company's new rates are expected to be in effect." (Feingold direct, page 7, lines 12 -15.) Why is this approach not relevant?

A. Gas rates in Missouri are set using test year data. Staff does not attempt to predict weather. Rather, utility sales data from a test year are adjusted for departures from what usage would have been if weather were normal, in order to calculate a revenue requirement and a set of rates for a year where normal weather would have been experienced. Shortening the period used to calculate normal weather reduces the stability of the normal. A 10-year period is too short for determining a normal because it is unstable. This instability is due to the continual updating as each year's data become available, i.e., removal of one year's data and replacing it with another year, can significantly change the calculated normal since each year's data constitutes one tenth of the total data. Schedule CW-4, comparing Mr. Feingold's ten-year moving average to the 30-year NOAA normal for Springfield illustrates the instability of this average.

Mr. Feingold states that "the ability of the 30-year averages to track the actual variation in HDD over time is 'dampened' because of the greater number of years included in the averages." To the contrary, Staff believes this "dampening" provides the stability necessary for a normal and prevents the chasing of short-term variations. As an example, Schedule CW-5 depicts HDD difference from the NOAA 30-year normal for Springfield. It shows that, in general, groups of warm years are followed by groups of cold years, and the converse. Unfortunately, it's not possible to predict when these changes will occur. Because of the unpredictability of these groupings, the normal of the shorter period proposed by Mr. Feingold is more susceptible to these changes, making it less stable, and thus less appropriate for use as a normal.

CONCLUSIONS

Q. What are your conclusions?

A. The 30-year period used by Staff is consistent with international meteorological convention, Commission rulings, and the purpose of adjusting volumes to normal HDDs in Missouri PSC rate cases. The 10-year period for a normal proposed by MGE is not.

Q. Does this conclude your rebuttal testimony?

A. Yes, it does.

U.S. Climate Normals 1971-2000, Products

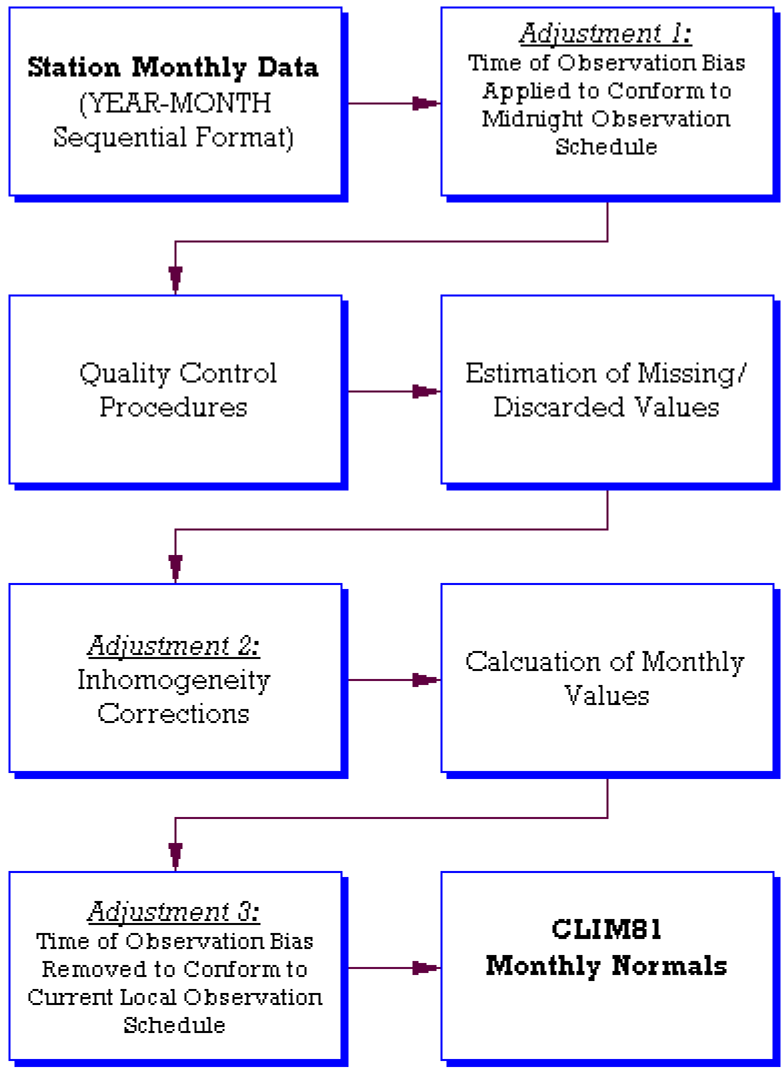
Computational Procedures

A. Adjustments to the Data

A climate normal is defined, by convention, as the arithmetic mean of a climatological element computed over three consecutive decades (WMO, 1989). Ideally, the data record for such a 30-year period should be free of any inconsistencies in observational practices (e.g., changes in station location, instrumentation, time of observation, etc.) and be serially complete (i.e. no missing values). When present, inconsistencies can lead to a non-climatic bias in one period of a station's record relative to another. In that case, the data record is said to be "inhomogeneous". Since records are frequently characterized by data inhomogeneities, statistical methods have been developed to identify and account for these data inhomogeneities. In the application of these methods, adjustments are made so that earlier periods in the data record more closely conform to the most recent period. Likewise, techniques have been developed to estimate values for missing observations. After such adjustments are made, the climate record is said to be "homogeneous" and serially complete. The climate normal can then be calculated simply as the average of the 30 values for each month observed over a normals period like 1971 to 2000. By using appropriately adjusted data records, where necessary, the 30-year mean value will more closely reflect the actual average climatic conditions at all stations.

The methodology used to address inhomogeneity and missing data value problems stations is described in Figure 2. As with all automated quality control and statistical adjustment techniques, only those data errors and inhomogeneities falling outside defined statistical limits can be identified and appropriately addressed. In addition, even the best procedures can occasionally apply corrections where none are required or misidentify the exact year of a discontinuity. In the 1971-2000 monthly normals calculations, the sequential year-month data were adjusted to conform to a common midnight-to-midnight observation schedule. This is necessary since changes in observation time also can lead to non-climatic biases in a station's record. The data were then quality controlled to identify suspect observations and missing or erroneous values were estimated. Finally, the serially complete data series were adjusted for non-climatic inhomogeneities. In the 1971-2000 normals, all stations were processed through the same procedures, whereas in the 1961-1990 normals only NWS First Order stations were evaluated for inhomogeneities. Each of the steps in the data processing procedures used in the 1971-2000 normals calculations is described briefly below.

Figure 2
CLIM81 Processing Steps (Temperature)



In order to effectively compare records among various stations, the time of observation bias, if present, must be removed. While the practice at all NWS First Order stations is to use the calendar day (midnight recording time) for daily summaries, Cooperative Network Station observers record observations once per day summarizing the preceding 24-hour period ending generally in the local morning or evening hours. Observations based on observation times other than midnight can exhibit a bias relative to those based on a midnight observation time (see e.g., Baker, 1975). Moreover, observation times at any one station may change during a station's history resulting in a potential inhomogeneity at that station. To produce records that reflect a consistent observational schedule, the technique developed by Karl et al. (1986) was used to adjust the monthly maximum and minimum temperature observations to conform to observations recorded on a midnight-to-midnight schedule.

However, no time of observation bias adjustments were applied to stations in Alaska, Hawaii, or the U.S. possessions since no model for adjustment presently exists for these regions.

All monthly temperature averages and precipitation totals were cross-checked against archived daily observations to ensure internal consistency. In addition, each monthly observation was evaluated using an adaptation of the quality control procedures described by Peterson et al.(1998). In this approach, observations at each station are expressed as a departure from the long-term monthly mean. Then, monthly anomalies at a candidate station are compared with the anomalies observed at neighboring stations. Where anomalies at the candidate disagree substantially with those of its neighbors, the observations at the candidate are flagged as suspect and an estimate for the candidate is calculated from neighboring observations (see below). If the original observation and the estimate differ by a wide margin (standardized using the observed frequency distribution at the station), the original is discarded in favor of the estimate. Very few observations were eliminated based on the quality control evaluation.

To produce a serially complete data set, missing or discarded temperature and precipitation observations were replaced using the observed relationship between a candidate's monthly observations and those of up to 20 neighboring stations whose observations exhibited the highest correlation with those at the candidate site. Monthly estimates are calculated using the climatological relationship between candidate and neighbor as well as a weighting function based on the neighbor's correlation with the candidate. For temperature estimates, neighboring stations were drawn from the pool of stations found in the U.S. Historical Climatology Network (USHCN; Karl et al. 1990) whereas for precipitation estimates, all available stations were potentially used as neighbors in order to maximize station density for estimating the more spatially variable precipitation values.

Peterson and Easterling (1994) and Easterling and Peterson (1995) outline the method that was used to adjust for temperature inhomogeneities. This technique involves comparing the record of the candidate station with a reference series generated from neighboring data. The reference series is reconstructed using a weighted average of first difference observations (the difference from one year to the next) for neighboring stations with the highest correlation with the candidate. The underlying assumption behind this methodology is that temperatures over a region have similar tendencies in variation. For example, a cold winter followed by a warm winter usually occurs simultaneously for a candidate and its neighbors. If this assumption is violated, the potential discontinuity is evaluated for statistical significance. Where significant discontinuities are detected, the difference in average annual temperatures before and after the inhomogeneity is applied to adjust the mean of the earlier block with the mean of the latter block of data. Such an evaluation requires a minimum of five years between discontinuities. Consequently, if multiple changes occur within five years or if a change occurs very near the end of the normals period (e.g. after 1995), the discontinuity may not be detectable using this methodology.

The methodology employed to generate the 1971-2000 normals is not the same as in previous normals calculations. For example, in the calculation of the previous normals no attempt was made to adjust Cooperative Network observer data records for inhomogeneities other than those associated with the time of observation bias. Therefore, serial year-monthly data for overlapping periods between normals (e.g., for the 20 years in common between the 1961-90 and 1971-2000 normals) will not necessarily be identical.

The following white paper (United States Climate Normals, 1971-2000: Inhomogeneity Adjustment Methodology) [PDF] is available regarding procedures for adjusting station data to account for inhomogeneities due to changes in station locations, instrumentation, time of observation, surrounding environment, observing practice, sensor drift, etc. The purpose of such adjustments is to produce a time series and normals statistics that are representative of the observing practices as of the end of the normals period (December 2000), since these are the conditions under which future observations will likely be compared.

B. Element Computations

The monthly normals for maximum and minimum temperature and precipitation are computed simply by averaging the appropriate 30 values from the 1971-2000 record. The monthly average temperature normals are computed by averaging the corresponding maximum and minimum normals. The annual temperature normals were calculated by taking the average of the 12 monthly normals. The annual precipitation normals were calculated by adding the 12 monthly normals. Note that monthly precipitation totals less than 0.005 inch are shown as zero, and that precipitation includes rain and the liquid equivalent of frozen and freezing precipitation (*e.g.*, snow, sleet, freezing rain, and hail).

Exhibit No.:
Issues: Weather Normalization
Witness: Wayne L. Decker
Type of Exhibit: Direct
Sponsoring Party: MoPSC Staff
Case No.: GR-92-165

MISSOURI PUBLIC SERVICE COMMISSION

LACLEDE GAS COMPANY

Case No. GR-92-165

DIRECT TESTIMONY

OF

WAYNE L. DECKER

Jefferson City, Missouri

July, 1992

Exhibit No. 3
Date 8/13/92 Case No. GR-92-165
Reporter GM

DIRECT TESTIMONY

OF

WAYNE L. DECKER

LACLEDE GAS COMPANY

CASE NO. GR-92-165

Q. What is your name and address?

A. I am Wayne L. Decker. I live at 1007 Hulen Drive, Columbia, Missouri 65203.

Q. What is your professional position?

A. I serve the University of Missouri-Columbia as a Professor of Atmospheric Science. I have also been designated as the State Climatologist for Missouri.

Q. How long have you been employed by the University of Missouri?

A. I came to the University of Missouri an Assistant Professor in September 1949. I was designated as the State Climatologist when the National Weather Service phased-out their program of service to the States in the late 1960's.

Q. Where were you employed prior to your appointment at the University of Missouri?

A. I worked as a climatologist for the National Weather Service (called at that time the U. S. Weather Bureau) and served in World War II as a meteorologist with the U. S. Navy in the Pacific theater.

Q. What has been your formal education?

A. My undergraduate education was at Central College in Pella, Iowa with a major in Chemistry. I received post-graduate training in Meteorology at UCLA in 1943-44. I hold MS and Ph.D degrees from Iowa State University in Climatology.

Q. Do you have any other professional qualifications?

A. Yes. To save time, I have attached a copy of relevant biographical information as Schedule 1.

Q. What does the field of Climatology cover?

A. Climatology is the study of the variations in climate, both spatial and temporal, and documentation of the effects of these variations on man. Climatology involves the use of statistical procedures for determining the risks of climatic events from a probability point of view. The climatologist must asses the effects of discontinuities in the climatic records due to natural causes, changes in observational procedures, and effects of man on the environment. The climatologist interprets the historical observational series in terms of the effects of climate on human food supply and health, weather sensitive operations and economic growth and development.

Q. Does climatology provide information of value to the assessment of heating demands?

A. Yes. For many years the utility companies, consumers, and the State Commissions regulating the supply of fuel and power have used climatic records as a basis for setting rates and anticipating energy needs. The climatologist can provide valuable assistance with the interpretation of the historical climatic records.

Q. Does it make a difference where the weather observations are taken for describing the climatic characteristics of a city or region?

A. Yes, when one interprets climate data over an extended period it is very important to review the history of the weather station locations and the type of instrumentation used. Attached to this testimony as Schedule 2 is a summary prepared by the National Oceanic and Atmospheric Administration (NOAA) of the downtown and Lambert Field locations where weather observations have been taken and the instrumentation used in St. Louis.

Q. Is it a standard practice for climatologists to refer to such a NOAA summary when reviewing historical weather station locations and instrumentation?

A. Yes. In this instance, I reviewed Schedule 2 in the course of preparing this testimony.

Q. According to the data contained in Schedule 2, have the weather records at St. Louis been taken at the same location throughout the time of record keeping?

A. No, the records were first taken at a location in the center of the downtown area of St. Louis. Later, with the establishment of the airport (Lambert Field) these responsibilities were transferred to the airport location.

The downtown temperature observations were taken at roof-top, about 200 feet above the street from 1903 onward until the closing of the observing station in 1968. Prior to 1903, the roof-top station was located about 100 feet above the street.

Unless one carefully reviews the station location descriptions, it would appear that the Lambert Field Station did not experience much of a change since it was established in 1929. There are, however, two changes in the location of the instruments at Lambert Field requiring analysis.

Q. What are these changes?

A. In November 1943 the site of the temperature measurement at Lambert Field was moved from a position away from the building (in an instrument shelter at five feet above the ground) to a roof-top location on the second floor of the Administration Building. This position allowed the dark roofing and the vents from the first floor to provide a less than ideal location for documenting the climate of the area. I have reviewed the degree day values reported for Lambert Field for this period (1943 through September 1957) and these records show the period as one with low heating degree day totals. The average degree days from the period extending from the 1943-44 season through the 1956-57 season is some 6% lower than the mean of 4838 calculated for the period currently used by the Public Service Commission. It is very likely that the warmer temperatures were, at least in part, due to heat added by the roof exposure.

On April 18, 1958, the site of measurement at Lambert Field was moved to a position between the runways and over grass. This move may have resulted in a cooler environment than when the instruments were located close to or on buildings.

Q. Have the weather records always been derived from the same type of weather instruments in St. Louis?

A. For most of the period since the late 1890's the temperature records have come from liquid in glass thermometers (mercury or alcohol in glass). These thermometers were shaded from the sun and protected from the earth's radiation by a louvered box mounted about five feet above the ground or roof top.

However, when the instruments were moved to the runway location at Lambert Field in April 1958, the system of measuring temperatures employed by the National Weather Service in St. Louis was changed. This change consisted of discontinuing the use of liquid thermometers mounted in the white instrument shelter in favor of electrical thermometers exposed in a reflective cylinder over the grass areas between the runways. The observations from these instruments are recorded on indicators in the National Weather Service Office. This new system was installed at all airport observing stations of the National Weather Service at about this same time. Since the instruments were located away from the buildings and the paved tarmac, the temperatures are typically cooler than those previously reported from exposures near the buildings. This system has continued in use for the past three decades. It can be noted that the heating degree days in recent years (since 1960) are markedly higher, suggesting that the new location provides a sampling of temperatures for a slightly cooler climate for the Lambert Field area. Even when one includes the degree day totals for the warmer most recent decade (1981-82 through 1990-91) the thirty-two year average (1958-59 through 1990-91) is very close to the value suggested by the Commission as the long-time average.

Q. For describing the climatic characteristics does the climatologist usually use the entire period of record available for a particular station?

A. Climatologists tend to use a subset of the entire period of record for describing the characteristics of the climate of a city or region. The length of record for this subset should be long enough to represent the climate of the region in a manner that reduces the changes of a short sequence of cool or warm years influencing the climatic statistics. Clearly the period should be long enough to be "representative" of the climate of the region, but not be so long that it measures a condition that has already past and no longer valid for the climatological time series. This problem of defining a base period for the "normal" climate has plagued climatologists for many years. The World Meteorological Organization (a UN agency which coordinates national programs in meteorology and climatology) and the National Weather Service in the U. S. have adopted the policy of using the most recent thirty-year period as the average for comparison purposes. Under their policy, the average is "rolled over" at the beginning of each decade. The newly established "normals" are then used for the next ten years.

Q. Is using the "thirty year normals" better than using the entire record available for St. Louis?

A. The climate of any region is dynamic in the sense that there is a constant change. Some of these changes appear to be random while others are systematic. The "rolled over average" is used for the normals to minimize the systemic errors.

One source of the systemic error is the change in the type of instruments used to measure temperature and the exposure of these instruments. It appears obvious that if a different procedure was previously used for measuring temperature than is used today that the older records should not be included in the base period which defines the climatic normals.

Another systemic error in temperature is the changes associated with the growth of the city of St. Louis. The "urban heat island" is a well documented phenomenon which notes that the urban temperatures are warmer than the nearby rural temperatures, particularly at night. This temperature difference is related to size of the city (area and population). The center of warming and the extent of warming depends on the configuration of the city. In the case of St. Louis, there has been some documentation of the urban effect from detailed studies in the 1960's. It appears that the center of development in St. Louis has been away from the Mississippi River, and the urbanization of the area around Lambert Field is apparent. The opportunity for an urban climate change in the Lambert Field weather records, although not documented, is certainly present.

Q. What would you recommend the Commission use for the "base period" in defining degree day normals for St. Louis?

A. I would recommend that the most recent thirty-year period with a recalculation every decade be used for the following reasons:

(1) it would not allow events which have occurred nearly a century ago to be equally weighted with more recent events in the calculation of the normals;

(2) it would allow for an adjustment for changes in climate, both natural or anthropogenic;

(3) this procedure would bring the techniques used in Missouri in line with those used by the National Weather Service and other States;

(4) the thirty-year period is long enough to produce statistics that are stable without major variations from decade to decade;

(5) during the most recent thirty-year period (1961-1990), the observations at Lambert Field have been taken from the same site using the same type of weather instruments.

Q. Does that conclude your testimony?

A. Yes.

DIRECT TESTIMONY

OF

STEVE QI HU

LACLEDE GAS COMPANY

CASE NO. GR-99-315

Q. Please state your name and business address.

A. My name is "Steve" Qi Hu, and my business address is 237 L.W. Chase Hall, University of Nebraska-Lincoln, Lincoln, Nebraska 68583-0728.

Q. What is your present position?

A. I am a climatologist and an Assistant Professor of Atmospheric Science at the School of Natural Resource Sciences of the University of Nebraska-Lincoln.

Q. How long have you held your position and briefly describe your responsibilities?

A. I was appointed to my present position in February 1999. My responsibilities at this position include research, extension service and teaching. In research, I am developing and improving our understanding of the regional climate variations and climate impacts on regional agriculture and the regional economy. In extension service, I am responsible for disseminating the most recent research results in climate and climate variations to the general public of Nebraska and neighboring states including Missouri. In teaching, I am currently teaching the Agricultural Climatology course.

Q. Do you have any previous work record in the State of Missouri?

A. Yes. I was a Research Assistant Professor of Atmospheric Science at the University of Missouri-Columbia, and served as the Missouri State Climatologist and Director of the Missouri Climate Center for the time period July 1995 through January 1999.

Q. Could you briefly describe your responsibilities at that position?

A. I was developing research programs aimed at understanding the regional climate variations and climate impacts on regional agriculture. In service as the State Climatologist, I was responsible for archiving, maintaining, and disseminating weather and climate data to the general public of Missouri. I was also responsible for providing expert interpretations of weather and climate data to data users.

Q. What is your educational background?

A. I obtained my M.S. and Ph.D. degrees in Atmospheric Sciences from Colorado State University in 1986 and 1992, respectively. I had my post-doctoral training at the State University of New York-Albany from 1992 through 1994. Prior to my M.S. degree, I obtained my B.S. degree in Meteorology from Lanzhou University in China in 1982.

Q. Will you briefly describe your experience as a Climatologist?

A. My research in regional climate variations has produced many refereed publications and numerous conference presentations. I have used various methods in analyzing climatic data and understanding regional climate variations.

Q. What is the purpose of your testimony?

A. I will explain the necessity for adjusting the station temperatures and a procedure I used in correcting the Saint Louis Lambert International Airport station temperature time series for the time period 1961-1998.

Q. What kind of weather station is at the Saint Louis Lambert International Airport?

A. The Saint Louis Lambert International Airport station is a first-order weather station of the U.S. National Weather Service and is operated by properly trained professionals.

Q. Why do you need to adjust the observed temperature?

A. Adjustments of observed air temperature from an individual weather station are needed to remove potential errors and biases in the temperature data.

Q. What possible errors could exist in the observed temperature values?

A. The errors in observed temperature data may be categorized into two groups. 1) The error resulting from observer's human error. This kind of error enters the data when, for example, observers read incorrectly the scales of a thermometer or take the observation at a time different from the specified observation time. 2) The error resulting from malfunctioning thermometers falls into the second category.

Q. How do you find these errors and how do you correct them?

A. These errors are identified at the National Climatic Data Center at Asheville, North Carolina, after the data are reported to the center. The data are checked using a developed quality control method. Erroneous data is flagged and then an estimated value is assigned to replace the erroneous data. The estimated value can be derived using different methods.

Q. What are potential biases in the observed temperature data?

A. There are two sources producing biases in the observed temperature data. 1) The sensor bias. This is a bias due to systematic overestimate or underestimate of the temperature by a thermometer. This kind of bias may be introduced to the data due to drifting of aging sensors. 2) The bias resulting from physical environment change of the weather station. These include station location changes and the surrounding environment change as consequences of economic development, e.g., the new buildings and parking areas, and natural change such as maturing trees. These changes alter the environment of the station and, hence, the averaged thermal condition the station measures.

Q. What kind of biases have you found in the Saint Louis Lambert International Airport weather station data, and what may have caused them?

A. I found that the station location change and consequent exposure changes have caused systematic biases in the station temperature data. My investigation of the station history of the Saint Louis Lambert International Airport station has disclosed that the station location changed four times during the 38-year period of 1961-1998. These occurred in November 1979, January 1985, February 1988, and June 1996. My analysis revealed that two of the four location changes, i.e., the ones in 1979 and 1988, caused systematic warming biases to the station temperature data and the change in 1996 resulted in a reversal of this warming bias.

Q. Why was a warming bias introduced to the data by the location changes in November 1979 and February 1988?

A. The warming bias was introduced to the data because each of those two location changes brought the station to a less open area. For example, in November 1979 the thermometer was moved from a relatively open field to a new location very close to a building with an improved parking area. The building and parking lot pavement absorb solar radiation and emit long-wave radiation to warm the environment during the day. The building also emits more heat during night. The thermal effect of the building and the parking lot added a warming bias to the temperature data of the station. In June 1996, the station was moved back to the airfield, where the thermal effects of the building and the parking lot would no longer impact the temperature readings.

Q. What procedures have you used to correct the bias in the temperature data?

A. The procedures include the following: 1) identify the dates of the station location change by reviewing the station history files and interviewing the observers during visits to the station; 2) identify reference weather stations for which normals are published and which did not experience location changes during the time when the Saint Louis Lambert International Airport station was moved; 3) compare the temperature series of the Saint Louis Lambert International Airport station and the reference stations over the period covering the time of the station location change, and identify any bias introduced to the Saint Louis Lambert International Airport station temperature record from the station's location change; and 4) calculate the correction value and apply it to the daily temperature series of the Saint Louis Lambert International Airport station to remove the bias.

Q. What was the application of these procedures to correct for the location changes at the St. Louis Lambert International Airport?

A. For the November 1979 and February 1988 changes, the reference stations chosen were at Elsberry, MO and Unionville, MO. Five years of monthly maximum and monthly minimum temperatures were used to calculate the changes that had occurred at the St. Louis Lambert International Airport. For the June 1996 change, five years of consistent daily temperature series were available from the Elsberry, MO and Jerseyville, IL weather stations. These data were used to calculate the changes that occurred at the St. Louis Lambert International Airport weather station when the station was moved back to the airfield and the ASOS was commissioned. Further details of the procedures and data used are provided in my work papers.

Q. What are the differences between the uncorrected and corrected temperature data?

A. The warming bias resulting from the November 1979 location change is 0.700°F. There was no bias added to the station temperature from the location change in January 1985. My analysis revealed that the uncorrected temperature was warmer by 0.783°F as a result of the station being moved to a location close to a building and a parking area in February 1988. The station location change in June 1996 was from a site close to a building and a parking area to an open area (see Figure 2 on Schedule 1-8). This location change was accompanied with the observation system change from the conventional unit to the ASOS (Automated Surface Observation System). This change in location resulted in a reversal of the warming bias of –1.875°F. The net effect for the three changes is that the post June 1996 temperatures will read 0.392°F cooler than temperatures read prior to November 1979. This is within the ASOS cooling bias of 0.5°F found by climatologist Thomas McKee ["Climate Data Continuity Project Ends:" Silver Spring, MD 20910, ASOS Program Office Wx23, 8455 Coleville Rd., Suite 705].

Q. How could these differences be affecting the calculated heating degree days and cooling degree days using the uncorrected Saint Louis Lambert International Airport temperature data?

A. Because the heating degree days are defined as the summation of the differences of the actual temperature below a reference temperature, e.g., 65°F, in each hour during each day and over a one year period, a warming bias in observed temperature will lower the difference between the reference and the observed temperatures and, hence, reduce the total number of heating degree days in a year. The opposite effect will occur for cooling degree days. In this case, the warming bias in the Saint Louis Lambert International Airport station temperature data can cause a decrease in the number of heating degree days and an increase in cooling degree days recorded at the station.

Q. Did you provide these corrections for the Saint Louis Lambert International Airport station to Mr. Dennis Patterson for use in calculating normal heating degree days?

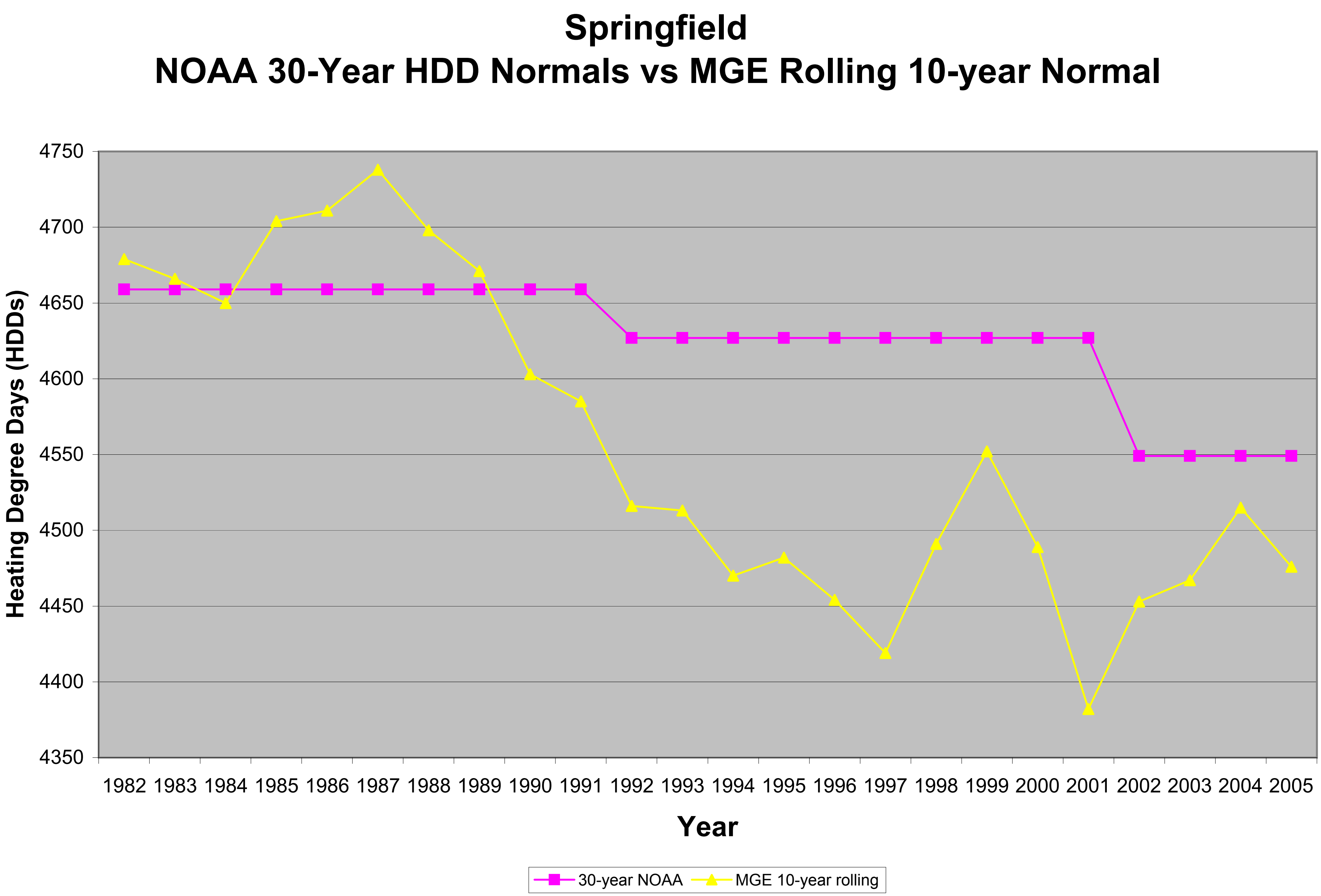
A. Yes, Mr. Patterson used these corrections in his calculation of normal heating degree days for the Saint Louis Lambert International Airport station.

Q. What should be a time period for developing meaningful climate normals?

A. In describing climate "normals" the WMO (World Meteorological Organization) requires the use of 30-year temperature and precipitation data. This standard is accepted by the U.S. National Weather Service. One of the reasons for using such a time period in defining climate conditions is that climate has its natural variabilities. These variabilities are shown, in part, by oscillatory variations of temperature and precipitation at various time periods. For example, there have been many studies showing significant interannual and interdecadal temperature variations in the U.S. To minimize the impacts of these fluctuations on averaged climate conditions WMO recommends to use 30-year data in calculation of the normal of the surface air temperature.

Q. Does this conclude your direct testimony?

A. Yes it does.



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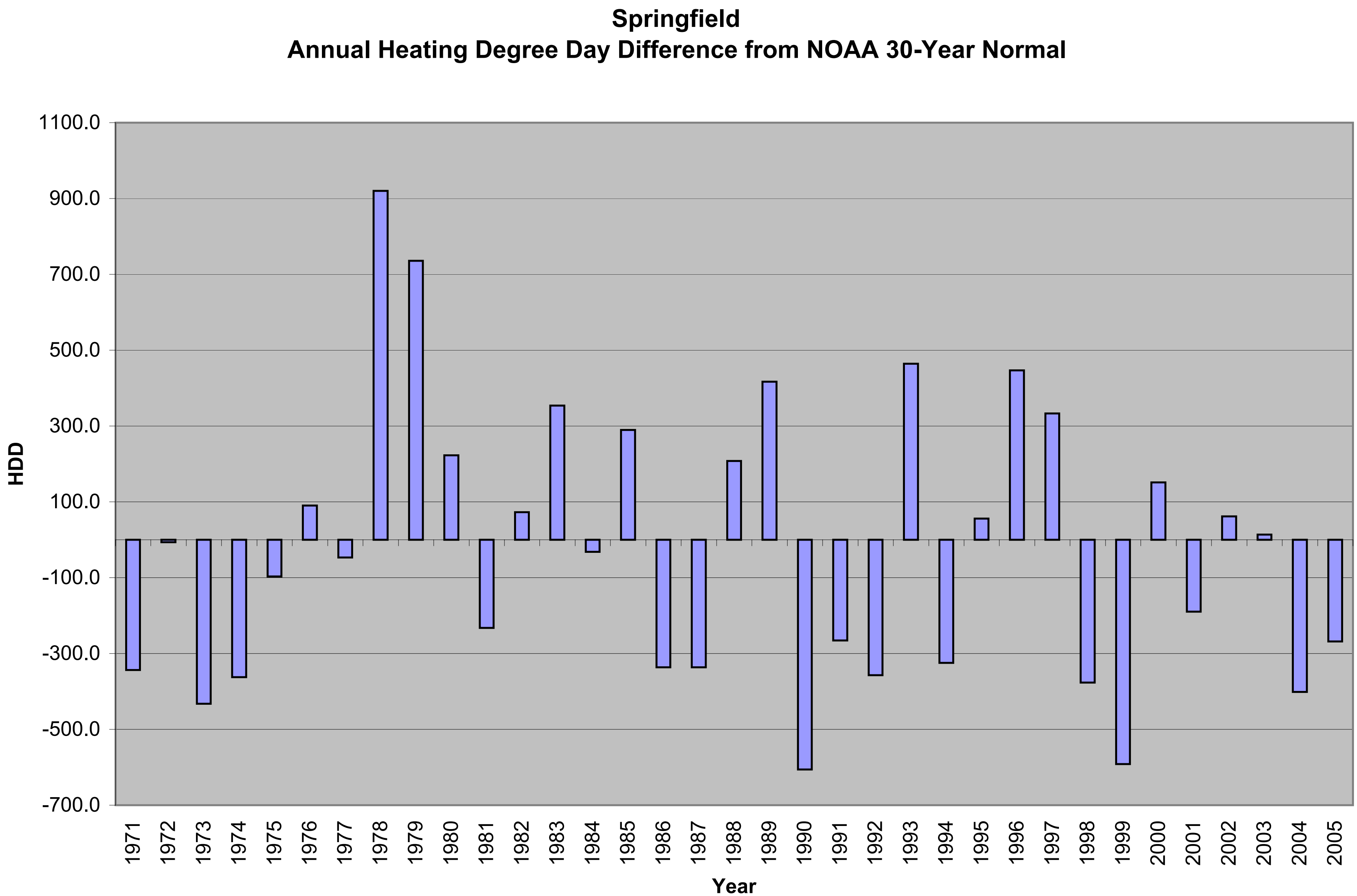
Springfield
Annual Heating Degree Day Difference from NOAA 30-Year Normal
HDD
1100.0
900.0
700.0
500.0
300.0
100.0
-100.0
-300.0
-500.0
-700.0
1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Year