MISSOURI PUBLIC SERVICE COMMISSION

STATE OF MISSOURI

In the matter of the Application of Union Electric Company for an order authorizing: (1) certain merger transactions involving Union Electric Company; (2) the transfer of certain Assets, Real Estate, Leased Property, Easements and Contractual Agreements to Central Illinois Public Service Company; and (3) in connection therewith, certain other related transactions.	)	Case No. EM-96-149

AFFIDAVIT OF ALLEN DUTCHER

STATE OF MISSOURI)
) SS.
CITY OF ST. LOUIS)

Allen Dutcher, being first duly sworn on his oath, states:

1. My name is Allen Dutcher. I work in the City of Lincoln, Nebraska, and I am the Nebraska State Climatologist and Operations Climatologist for the High Plains Climate Center at the University of Nebraska.

2. Attached hereto and made a part hereof for all purposes is my Rebuttal Testimony consisting of pages 1 through 16, ~~with Appendix A and including Schedules 1 - ___~~, all of which testimony has been prepared in written form for introduction into evidence in Missouri Public Service Commission Case No. EM-96-149 on behalf of Union Electric Company.

3. I hereby swear and affirm that my answers contained in the attached testimony to the questions therein propounded are true and correct.

Affiant

Subscribed and sworn to before me this 31st day of March 1999.

Notary Public

DEBBY ANZALONE
Notary Public - Notary Seal
STATE OF MISSOURI
St. Louis County
My Commission Expires: April 18, 2002

REBUTTAL TESTIMONY
OF
ALLEN DUTCHER

UNION ELECTRIC COMPANY
CASE NO. EM-96-149

Q. Please state your name and business address.

A. My name is Allen Dutcher and I am employed by the University of Nebraska in Lincoln, Nebraska. My business address is High Plains Climate Center, 15 L.W. Chase Hall, University of Nebraska, Lincoln, Nebraska, 68583-0728.

Q. What is your present position?

A. I am the Nebraska State Climatologist and Operations Climatologist for the High Plains Climate Center.

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

A. I became the acting State Climatologist in November 1990, and the official State Climatologist in January of 1991. Since becoming the official State Climatologist in 1991, I have had the opportunity to work on a variety of projects including developing quality control routines for real-time electronic climate data retrieval, the continued development of the Automated Weather Data Network maintained by the High Plains Climate Center, development of an Internet climate data delivery system, modeling soil moisture conditions throughout the central High Plains, assisting in the development of evapotranspiration (water use) budgets for a variety of agricultural crops, and investigating climatic conditions that have the potential to impact crop yields up to 12 months prior to harvest.

Q. Briefly describe your experience with the High Plains Climate Center?

A.. As an Operations Climatologist, I am responsible for providing climatic data analysis for the High Plains Climate Center ("HPCC"). My duties include acquiring climatic data from various monitoring networks located within the HPCC service region (CO, KS, NE, ND, SD, WY), disseminating climatic data to the general public, instituting quality control techniques to guarantee climatic data accuracy, and developing climatic data products for dissemination to the general public.

Q. What other climatology positions have you held?

A. I have served as the president of the American Association of State Climatologists, I am an active member of the Governor's Climate Assessment and Response Committee, and I presently serve as an advisory member and contributor to CropWatch, which is an interdisciplinary publication addressing environmental factors that impact crop yields.

Q. What particular expertise do you have that is relevant to this matter before the Commission?

A. To my knowledge, I pioneered the application of an engineering technique called "double mass analysis" to isolate variations in recorded temperature caused by the change in sensors, and to identify and rationalize the bias inherent in such changes. Significantly, both the Staff and the Company used my pioneering application to determine the appropriate adjustment in this case. I will be presenting further applications of this technique to the climatology community at our annual conference to be held later this summer. In simple terms, a double mass analysis compares, over time, the temperature

readings at the station in question with the temperature readings at surrounding stations. The goal is to isolate any change in the way the station in question is monitoring the environment.

Q. What is the purpose of your testimony?

A. I will address the proper method for measuring the change in the recording of surface air temperatures at Lambert Airport that resulted from the commissioning of the Automated Surface Observation System ("ASOS") on May 15, 1996. I have examined the careful analysis of the Ameren Corporate Planning Department for adjusting the temperature data recorded at Lambert since May 1996. I have concluded that the Ameren analysis is fully consistent with established procedures and practices within the climatology community, and it accurately measures the change that resulted from the commissioning of ASOS.

I have also considered the novel suggestion of the Missouri Public Service Commission Staff that Ameren realign the reams of historical data maintained from January 1, 1961 through May 15, 1996. As an initial matter, the massive task proposed by the Staff is a practical impossibility. There are countless variables -- moisture, wind, sunlight, proximity to buildings or other man-made objects, advances in technology, movements in the physical location of temperature-reading sensors, time of observation changes, observer changes, heat island effects due to industrialization, warming trends that track population shifts, etc. -- that affect the reliability over time of temperature readings at any given weather station. It is essential to note that *documents reflecting the manifold changes at weather stations are often incomplete, especially at "second-order stations" or "cooperative observer sites," and, to a certain degree, such records simply do not exist.*

Even if such records existed, and even if one diligently tried to account for the staggering number of variables that affect temperature readings, the fact is that temperature

measurements in the real world -- as opposed to a laboratory -- *necessarily* defy precision. For example, a laboratory analysis conducted by the National Weather Service found that the ASOS thermometer had a maximum error of +/- .9 ° F.

To realign nearly four decades of weather history would involve the analysis of literally thousands of pages of meteorological data. In addition, one would need to conduct in-person tours of each weather station site, interview all the personnel there, past and present, who have actively been involved in climate data acquisition, and inspect an array of historical records. This would be necessary, at a minimum, to determine how many sensor changes and/or physical station moves occurred at each weather station site, because all of this information may not be recorded and collected at a central location. In addition, one would need to analyze city records for the past four decades to gauge urban development throughout the St. Louis metropolitan area. This would be necessary, again at a minimum, to account for changes in the physical location immediately surrounding the stations, as well as to reflect additional heat generated by the city as a whole. At best, one could only hope to come up with a confident estimate of the annual heat island increase due to urban expansion.

I have reviewed the Staff's analysis, and I have concluded that it falls far short of what would be necessary, assuming it were possible, to re-write nearly four decades of weather history. The Staff's analysis is, in point of fact, riddled with fundamental, glaring flaws. To take just one example, the Staff purports to compare temperatures taken at Lambert Airport to temperatures taken at two other stations for the period 1960-1996. *But one of the comparison stations did not even exist until 1975.* These and other errors suggest a remarkable -- and profoundly unscientific -- inattention to detail. Purporting to cleanse the

historical records of errors, the Staff has injected its own errors and biases into those records. The Staff's analysis is, in short, totally unreliable.

Q. Describe the new temperature recording system installed at Lambert Airport in June 1996.

A. On May 15, 1996, the device for recording official temperature at the National Weather Service St. Louis site switched to the ASOS at Lambert Airport. The implementation of ASOS resulted in both a physical station move and a temperature sensor upgrade. The new sensors have undergone extensive environmental tests to insure accuracy, and they also have better enclosures around them that increase the ventilation required to obtain more accurate temperature readings. The physical move associated with the implementation of ASOS at Lambert Airport is significant. The new location is in close proximity to airfield runways. The old location was near office buildings, which can have the effect of reducing airflow, and parking lots, which can radiate heat. The distance between the old and new sites is about one mile.

Q. Is there a side by side comparison of the temperature data recorded by the old temperature recording device versus the new temperature recording device?

A. Prior to the commissioning of any ASOS site, a one- to two-year test period is conducted by National Weather Service personnel to assess the accuracy of the new system and to train personnel on general maintenance procedures associated with the system. NWS personnel were to compile records generated by both the old and new monitoring systems during this pre-commission period. This data was not archived by the NWS in the ordinary course of business. Moreover, the National Climatic Data Center (NCDC), which is ordinarily assigned the task of maintaining climatic databases, does not have the St. Louis

ASOS pre-commission data in its archives. I am confident that if this data is ever located, it will demonstrate that the Ameren analysis was far more accurate than the Staff's analysis.

Q. Absent a side by side comparison, how can temperature differences between old and new temperature recording systems at Lambert be quantified?

A. As I described earlier, the double mass analysis can be used for this purpose -- and indeed has been used by both parties before the Commission. When using double mass analysis, one calculates the daily differences between the site of interest and appropriate comparison sites. These differences are accumulated over time and plotted against the passage of time. If there is no change in the manner in which the station in question has monitored the environment, a linear function (straight line) will appear over time. If a change has occurred, then the plot will reflect this by a change in the slope of the line.

By calculating the change in the slope of the line after the introduction of a new monitoring system, a daily rate of change or bias can be calculated. It is then necessary to determine how to account for this bias. This analysis will capture both the bias introduced by the change in sensors at Lambert and the bias introduced by the change in sites, although it will not determine how much of the bias is attributable to each of these changes (and this information is, in any event, not really needed).

Q. Describe your experience in using the double mass technique to quantify the temperature bias between different temperature recording stations.

A. I have previously used the double mass technique to isolate the impact that the installation of an ASOS had at the Lincoln Municipal Airport for Lincoln Electric Systems. My analysis revealed a 1.9°F cooling bias that resulted from the introduction of ASOS and a

physical station move. Lincoln Electric adopted my analysis and incorporated it into its weather normalization model.

Q. Have you reviewed the analysis of the ASOS temperature change at Lambert Airport performed by the Ameren Corporate Planning Department?

A. Yes, I have.

Q. Please describe the method of analysis that Ameren conducted.

A. Ameren selected six sites within a forty mile radius of the Lambert Station. Their engineers then focused on the time period March 1996 through August 1997. Ameren wisely removed certain data that, upon inspection, were revealed to be outside the upper and lower limits of acceptability -- that is, statistical outliers. For example, if all the sites in the St. Louis area reported a temperature of 60°, and one site reported a temperature of 80°, Ameren removed that erroneous reading. In the jargon of our field, Ameren put the data through a "statistical quality control check." Whenever possible, climatologists perform such a check to ensure, as far as possible, the reliability of their data.

In the course of conducting its careful analysis, Ameren's engineers interviewed personnel at weather stations. This proved to be invaluable in ferreting out potentially unreliable data. In fact, the Company was able to relay information to me about station moves and upgrades that I did not find in station history documentation. At the St. Louis WSFO cooperative station, Ameren's engineers learned that the sensor technology had been updated and its physical location had been moved from the Busch Wildlife Center to the Missouri Research Park. Ameren's engineers prudently concluded that the St. Louis WSFO was thus an inappropriate comparison station due to the location move, the sensor upgrade and the environment change.

Ameren then conducted a double mass analysis, comparing the reliable temperature readings at the six comparison sites it had selected to the readings at the Lambert site for the relevant time period. For example, against the St. Louis Science Center station, the Lambert Airport station changed by 2.2. degrees. Ameren's engineers averaged the six figures and arrived at a figure of 2.0°

Q. Did you review Ameren's analysis?

A. Yes, I reviewed it with great care.

Q. Please describe your review.

A. I have inspected Ameren's EXCEL spreadsheet file containing their analysis data and resultant plots and have determined that they used the same data that I did in my independent study for Alton, St. Louis Science Center, St. Charles, and St. Charles 7 SW. I extracted the data from Ameren's spreadsheet and compared it to my data and it matched perfectly for maximum and minimum temperatures.

Q. What is your opinion as to the reasonableness of this analysis?

A. Ameren's engineers did admirable work, completely consistent with the highest standards of my discipline. Ameren's engineers used the appropriate data; and they correctly employed the double mass analysis. I am confident that their results are accurate.

Q. The Missouri Public Service Commission Staff has suggested that the historical temperature data taken at Lambert from January 1, 1961 through May 15, 1996 should be adjusted to make it consistent with current readings taken after the ASOS commissioning. Have you reviewed the analysis of the Missouri Public Service Commission Staff?

A. Yes, I have.

Q. Please comment on the Staff's attempt to realign nearly four decades of weather data.

A. As I stated earlier, I reject the premise that it is possible to accurately realign weather history to reflect current conditions. Besides correcting for station moves, sensor changes, and observation changes, one must attempt to adjust for the growth of the St. Louis metropolitan area. As a city grows it generates additional heat that is captured within the climate records. It is impossible to fully determine what the annual rate of increase for the St. Louis heat island effect has been over the last 38 years. By rewriting weather history, one must completely alter the climate data that has already been reviewed and filtered through a statistical quality control check by the National Climatic Data Center, and thereby deemed "official." In effect, the Staff is purporting to create a new data set by changing more than thirty years of historical data. And if any station move, sensor change, or observation shift occurs in the future, the new data set must also be adjusted once again to reflect current conditions.

A simple question might be posed to those who now purport to undertake the task of realigning weather history: If the idea of altering historical weather data is appropriate, why was this not done when the Lambert Airport station was moved during the late 1970s, and twice during the 1980s? Of course, the answer is simple. No one thought it was, as a practical matter, *possible* to undertake this task. Accordingly, I reject the Staff's quixotic attempt to make corrections to the entire historical data base for Lambert Airport. Rather, Ameren should simply, as it has, incorporate the bias introduced by the commissioning of ASOS into their models on a prospective basis.

Q: Is your point simply that it would be a lot of work to re-write nearly four decades of weather history?

That's only part of the problem. The threshold, and certainly insurmountable, problem is that *most of the data needed to align nearly four decades of weather history simply does not exist*. This point cannot be emphasized enough. The Staff is purporting to make incredibly precise changes (in hundredths of degrees) to recorded temperature readings as long ago as 1961. But in many cases, the data needed to make such adjustments (*e.g.*, records relating to changes in sensor technology and location) are not archived. Thus, there is no way even to begin the monumental task allegedly undertaken by the Staff.

So, to be very clear: My problem with the Staff's analysis, at a fundamental level, is two-fold. First, all of the data needed to re-write nearly four decades of weather history does not exist. Second, even if all such records existed, which they emphatically do not, it would be humanly impossible to sift through that mountain of data and make the precise adjustments proposed by the Staff. It is, in short, no more possible to rewrite weather history than it is to re-write history of any kind.

Q. How does the scientific climatology community view changing historical climate data?

A. The climatology community rejects the novel, and ultimately futile, approach now embraced by the Staff. Scientists -- that is, persons interested in accuracy -- use official temperature records as the source for historical temperatures. If historical climate records are altered, an artificial data base is created which no longer replicates the observations taken at a particular site. The approach now suggested by the Staff would require continual adjustments to historical climate records to account for the myriad of variables that impact temperature

readings over time (technology changes, sensor moves, shifts in demography, creation of man-made heat islands, *etc.*). Due to limitations in the precision of temperature readings, it is, however, impossible to make tiny adjustments in temperature readings -- and to attempt to do so is simply to inject a new, and possibly grave, source of error into the historical record. Indeed, after each successive adjustment, there is an increase in the potential that the new climatic data is equally far removed from the original measurements taken at the observation site, and from a "true" reading of what the temperature "actually" was decades ago.

By using a double mass technique, the historic climatic data base is maintained, while only the most recent event requires a correction term applied to it. If a sensor change or station move should occur at Lambert Airport in the future, one only needs to determine the effect of the most recent move and make the proper adjustments to all climate records since the inception of the move. All climate records up to the most recent move can be maintained in their original form.

Q. But what is your response to Dennis Patterson's claim that the Staff's adjustments simply follow the methodology of the National Oceanographic and Atmospheric Administration (NOAA) (p.5, lines 5-7)?

A. Most obviously, NOAA does not adjust historical climate data, as the Staff has attempted to do. Secondly, the Staff's analysis relies on estimated data to fill in the gaps caused by the inevitably missing data. NOAA, in contrast, does not use any estimated data in calculating monthly normals. The original NOAA methodology for the calculation of normals was co-authored by the current Director of the NCDC in an article published in 1987, which makes this point very clear. *See* Karl and Williams, *An Approach to Adjusting Climatological Time Series for Discontinuous Inhomogeneities*, 26 Journal of Climate and

Applied Meteorology 1744, 1755 (Dec. 1987)("[M]issing data in the original series were estimated, but *not used in the adjustment scheme*.")(emphasis added).

Q. In your review of the Staff's analysis, did the Staff properly undertake the method it set for itself?

A. No. Remarkably, the Staff purports to undertake a novel methodology that would require an intense and meticulous review of reams of data, some of which may not even exist -- and then the analysis actually produced by the Staff does not undertake such a review, but rather is rife with obvious flaws and oversights.

Q. What are the flaws that you found in the Staff's analysis?

A. There are at least three very basic, and very fundamental flaws, with the Staff's analysis.

First, the Staff purports to compare the temperature readings at Lambert Airport against two other stations, St. Charles 7 SSW and the St. Louis WSFO, for the time period 1961-1996. But the St. Charles 7 SSW station did not even exist until 1975, and the St. Louis WSFO station was discontinued in 1995, *before the installation of the ASOS*. One need not be a scientist to understand that something that does not exist cannot be a point of comparison. How this elementary point escaped the Staff is, frankly, difficult to fathom.

(Interestingly, it seems that the Staff made no effort whatsoever to review the data from 1961 to 1977 (which it nonetheless claims was consistent with the post-ASOS period, *i.e.* that there was no bias difference between the 1961-1978 time period and the post-ASOS period). I, however, took the time to evaluate this unsubstantiated assumption. I conducted a double mass analysis between Lambert and St. Charles, determining that the average daily bias for the 1961-1978 time period was *not* consistent with the post-ASOS period. In fact,

my analysis indicated at least five distinct slope changes *within* the 1961-1978 time period. The last of these five distinct slope changes occurred in 1972. The subsequent 1972-1978 time period had an average daily minimum temperature bias that was .9°F cooler than the post-ASOS period. In addition, the average daily maximum temperature bias for the 1972-1978 time period was 1.18°F warmer than the post-ASOS period.)

Second, the two stations used by the Staff are what are called "cooperative stations." The personnel at such sites are typically not trained professionals. When meteorologists employ data from cooperatives, it should be basic procedure to filter that data through a statistical quality control check. Readings flagged as statistical outliers are thereby discarded. It is vital to conduct a statistical control check, especially when one is using only *two* comparison sites. (Recall that each of these two stations, at various times, were not even in existence. Recall also that Ameren used *six* comparison stations.) But the Staff apparently simply took as a given all the data from the cooperatives observer sites, *and made (from what I can tell) no effort whatsoever to remove erroneous data.* When the double mass analysis is *correctly* applied, erroneous data is assigned a value of zero, and then removed so that there is no impact on the statistical derivation of slopes and slope changes.

Third, the time of observation at one of the stations selected by the Staff as a comparison point -- the WSFO station -- shifted over time. Time of observation shifts can impact the measurement of daily maximum and minimum temperatures. The Staff attempted to account for this change in observation time by developing its own time of observation bias by using 38-years of temperature data. It is unclear to me why a 38-year period was chosen when NCDC has already calculated the time of observation bias corrections for most cooperative observer sites across the United States based upon the thirty-year 1961-90 normal

period. These bias corrections were developed to adjust cooperative observer sites to a uniform midnight observation time. By doing this, cooperative stations can be compared to first-order NWS sites that recorded daily maximum and minimum temperatures on a midnight observation schedule. Since the station of concern between parties is located at Lambert Airport and reports daily observations on a midnight schedule, there is no plausible rationale for adjusting this data to a cooperative station observation time.

These are three errors that jump off the page and inevitably call into question the entire analysis undertaken by the Staff. By no means, however, is this intended as an exhaustive list. The slap-dash character of the Staff's analysis suggests countless other lapses. For example, it does not appear that the Staff troubled to actually visit the two stations it used as comparisons sites. Had it done so, it would have learned, as Ameren did, that there was a significant change in the physical location of the sensors at the WSFO cooperative station. In addition, temperature readings at the St. Charles 7 SSW station taken by a liquid and glass minimum thermometer were updated to an MMTS system. (When a station used as a comparison site employs new sensor technology, that changes the double mass output, and must be accounted for in any analysis.) Had the Staff learned of these critically important facts, it would then have been required to adjust the data from those stations accordingly. But the Staff did not undertake its analysis in the manner of careful scientists. Rather, it seems to have known the answer it wanted, and it was prepared to take short-cuts to get there.

Q. In light of these flaws, what is the reliability of the results of the Staff's analysis?

A. From a scientific perspective, the Staff's analysis is worthless.

Q: The Staff has retained Dr. Steven Qi Hu as an expert in this case. Have you reviewed the testimony he last submitted?

A: Yes, I have.

Q: Are you the "Dutcher" referred to in Schedule 1-2 of Dr. Hu's testimony?

A: Yes, I am. Dr. Hu states on that Schedule that he is applying the double mass analysis. As I stated earlier, I developed the application of that method of analysis to the measurement of variations in recorded temperature.

Q: In his testimony, Dr. Hu notes that there have been four location changes at Lambert Airport in the past 38 years -- 1978, 1985, 1988, and 1996. He states that "two of the four location changes, . . . 1978 and 1988, caused systematic warning biases." (p.4, line 21) With regard to the ASOS change, Dr. Hu writes, "I found no bias from the location change in June [sic] 1996." (p.6, lines 10-11) Please comment on Dr. Hu's testimony.

A: My initial reaction was one of total puzzlement. In the climatology community, there is no question -- no question whatsoever -- that ASOS introduces a cooling bias. Dr. Thomas McKee of Colorado State University, perhaps the foremost expert on ASOS temperature discrepancies in the country, conducted a study of over 140 stations in the United States. He concluded that the *average* cooling bias was 1.3°. As I mentioned earlier, my analysis of the commissioning of ASOS at the Lincoln Airport found a 1.9° cooling bias. When ASOS replaced the old observation devices at Lambert Airport, the station location was moved away from a cluster of buildings near an asphalt parking lot, and to a grassy area located at the center of runways. This location change itself could be expected to produce a cooling bias. Thus, Dr. Hu's suggestion that no cooling bias resulted from the

commissioning of ASOS in May 1996, together with the station location change, is indisputably wrong.

Q. Does that complete your testimony?

A. Yes, it does.