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ON BEHALF OF THE
MISSOURI PUBLIC SERVICE COMMISSION
UTILITY OPERATIONS DIVISION

DIRECT TESTIMONY

OF

STEVE QI HU, PH.D.

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**Missouri Public
Service Commission**

LACLEDE GAS COMPANY

CASE NO. GR-99-315

Jefferson City, Missouri

June, 1999

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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?

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1 A. Yes. I was a Research Assistant Professor of Atmospheric Science at the
2 University of Missouri-Columbia, and served as the Missouri State Climatologist and
3 Director of the Missouri Climate Center for the time period July 1995 through January
4 1999.

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

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

11 Q. What is your educational background?

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

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

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

21 Q. What is the purpose of your testimony?

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

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

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

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

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

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

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

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

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

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

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

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

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

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

22 A. The warming bias was introduced to the data because each of those two
23 location changes brought the station to a less open area. For example, in November 1979

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1 the thermometer was moved from a relatively open field to a new location very close to a
2 building with an improved parking area. The building and parking lot pavement absorb
3 solar radiation and emit long-wave radiation to warm the environment during the day.
4 The building also emits more heat during night. The thermal effect of the building and
5 the parking lot added a warming bias to the temperature data of the station. In June 1996,
6 the station was moved back to the airfield, where the thermal effects of the building and
7 the parking lot would no longer impact the temperature readings.

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

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

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

22 A. For the November 1979 and February 1988 changes, the reference stations
23 chosen were at Elsberry, MO and Unionville, MO. Five years of monthly maximum and

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1 monthly minimum temperatures were used to calculate the changes that had occurred at
2 the St. Louis Lambert International Airport. For the June 1996 change, five years of
3 consistent daily temperature series were available from the Elsberry, MO and Jerseyville,
4 IL weather stations. These data were used to calculate the changes that occurred at the
5 St. Louis Lambert International Airport weather station when the station was moved back
6 to the airfield and the ASOS was commissioned. Further details of the procedures and
7 data used are provided in my work papers.

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

10 A. The warming bias resulting from the November 1979 location change is
11 0.700°F. There was no bias added to the station temperature from the location change in
12 January 1985. My analysis revealed that the uncorrected temperature was warmer by
13 0.783°F as a result of the station being moved to a location close to a building and a
14 parking area in February 1988. The station location change in June 1996 was from a site
15 close to a building and a parking area to an open area (see Figure 2 on Schedule 1-8).
16 This location change was accompanied with the observation system change from the
17 conventional unit to the ASOS (Automated Surface Observation System). This change in
18 location resulted in a reversal of the warming bias of -1.875°F. The net effect for the
19 three changes is that the post June 1996 temperatures will read 0.392°F cooler than
20 temperatures read prior to November 1979. This is within the ASOS cooling bias of
21 0.5°F found by climatologist Thomas McKee ["Climate Data Continuity Project Ends:"
22 Silver Spring, MD 20910, ASOS Program Office Wx23, 8455 Coleville Rd., Suite 705].

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

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

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

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

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

18 A. In describing climate "normals" the WMO (World Meteorological
19 Organization) requires the use of 30-year temperature and precipitation data. This
20 standard is accepted by the U.S. National Weather Service. One of the reasons for using
21 such a time period in defining climate conditions is that climate has its natural
22 variabilities. These variabilities are shown, in part, by oscillatory variations of
23 temperature and precipitation at various time periods. For example, there have been

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1 many studies showing significant interannual and interdecadal temperature variations in
2 the U.S. To minimize the impacts of these fluctuations on averaged climate conditions
3 WMO recommends to use 30-year data in calculation of the normal of the surface air
4 temperature.

5 Q. Does this conclude your direct testimony?

6 A. Yes it does.