Exhibit No.:
Issue: Weather Normalization
Witness: Jay R. Turner, D.Sc.
Type of Exhibit: Rebuttal Testimony
Sponsoring Party: Laclede Gas Company
Case No.: GR-99-315

LACLEDE GAS COMPANY

GR-99-315

REBUTTAL TESTIMONY

OF

JAY R. TURNER, D.Sc.

REBUTTAL TESTIMONY OF JAY ROBERT TURNER, D.Sc.

Q. Please state your name and business address.

A. My name is Jay Robert Turner, and my business address is 210 Cupples Hall II, Washington University, One Brookings Drive, St. Louis, Missouri, 63130-4899.

Q. What is your current position?

A. I am an Assistant Professor of Chemical Engineering and Engineering & Policy (joint appointment) in the School of Engineering and Applied Science at Washington University in St. Louis.

Q. Please state how long you have held your position and briefly describe your responsibilities.

A. I was appointed to my current position in January 1994. My responsibilities include research and teaching. My research focuses on field measurements including extensive use of weather sensors, analysis of meteorology and other data sets, statistical design of experiments, and characterization of ambient air pollutants. I also conduct laboratory experiments. My teaching focuses on environmental engineering concepts, including but not limited to analytical measurements, data reduction, and statistical analysis. I also conduct research and teach courses in environmental policy

Q. What is your educational and previous professional background?

A. I received B.S. and M.S. degrees in Chemical Engineering in 1987 from UCLA. During my M.S. graduate studies, I was also a research fellow of the Deutscher Akademisher Austauchdienst (DAAD) at the University of Duisburg, Germany. I received a D.Sc. in

Chemical Engineering in 1993 from Washington University. Upon joining the Washington University faculty in January 1994, I took an eight-month leave of absence to work in the Environmental Analysis Division of the Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

Q. What is the purpose of your rebuttal testimony?

A. I will provide testimony rebutting the June 1999 direct testimony of Dr. Steve Qi Hu, Ph.D. (Dr. Hu) and Dennis Patterson filed on behalf of the Commission Staff in Case No. GR-99-315. Specifically, I will address Dr. Hu's proposed adjustments to the St. Louis Lambert International Airport NWS (Lambert Station) temperature data for the purposes of calculating heating degree day values.

Q. What are the adjustments proposed by Staff?

A. According to the direct testimony of Dr. Hu, a number of warming or cooling "biases" have occurred at the Lambert Station over the past twenty years. These "biases" refer to variations in temperature measurements due to a change in temperature sensor type, location or other related factors rather than an actual climatic variation in temperature. According to Dr. Hu there was a warming bias of +0.700 °F in the Lambert temperature data resulting from a November 1979 location change. Dr. Hu found that there was no bias introduced by a January 1985 location change; however, a location change in February 1988 introduced a +0.783°F warming bias. Finally, according to page 6 of Dr. Hu's direct testimony, a June 1996 sensor change and location change resulted in a 1.875°F cooling bias at Lambert Station. To correct for these so called biases, Dr. Hu adjusts the official NOAA observed weather data at Lambert to bring them into line with

what Dr. Hu believes the temperature readings should have been in the absence of such changes.

Q. Do you have any general concerns or comments regarding the adjustments proposed by Dr. Hu and the analyses underlying them?

A. Yes. All of Dr. Hu's adjustments are premised on the assumption that he has correctly identified and measured, through application of a "double mass analysis" warming or cooling biases that supposedly occurred at Lambert Station. I have a number of serious concerns, however, with both the overall appropriateness of the double mass analysis used by Dr. Hu as well as how it was applied to adjust the official NOAA data.

Q. Please describe your concerns.

A. As a preliminary matter, I should note that Dr. Hu has used the double mass analysis technique to adjust the official NOAA data. This technique has never been used, to my knowledge, by NOAA itself to adjust its own data for products provided to the public. NOAA has a documented methodology for quantifying "inhomogeneities" (such as bias arising from stations being moved or sensor types being changed) in station temperature time series. In my opinion, any alternative to the NOAA method should be benchmarked against the NOAA method and used only if demonstrated to be equal or superior in performance.

Q. What is the premise for using a double mass analysis for this application?

A. The double mass analysis uses a reference station to determine whether the temperature variability over time at a target station – Lambert Station in this case – is due to a change in sensor location, sensor type, or surroundings (collectively "exposure changes") and is

thus a bias or is due to the inherent climatic variability. It is generally assumed in such an analysis that the target station and neighboring stations will experience similar climate conditions. As I will discuss in detail later, at the very least, two reference stations must be used to determine whether the presumably non-climatic changes – a bias – indeed occurred at the target station and not the reference station. Temperature data is, by definition, "noisy" data. Many data analysis tools rely upon the power stemming from the size of large data sets to handle such noise. By this I mean the size of the data set is often very important. Relatively small data sets, such as a few years of data, for periods prior to and following the onset of an exposure change can lead to large uncertainties. This can be compounded by seasonal and other climatic variations super-imposed on the "change bias" (a bias caused by an exposure change). Ultimately, these factors can lead to low confidence in the results of such an analysis. Furthermore, the double mass analysis, at least as applied in this case, does not account for seasonal effects. In the absence of a more rigorous analysis, there is no reason to assume, *a priori*, that the change bias is the same for all seasons. Indeed, the NOAA approach for calculating climatic normals does address this issue by addressing inhomogeneities using adjustments that vary on a monthly-specific basis. In summary, absent an analysis showing that seasonal variations in bias do not exist, it is impossible to conclude that the double mass analysis will produce a reasonable adjustment for a particular season. Given that the vast majority of the Company's weather sensitive load occurs in a single season-i.e. the winter period – this lack of seasonal differentiation can only be described as a fundamental flaw in Staff's analysis.

Q. Does your review of the data provided by Staff suggest that double mass analysis would actually produce different results if such result was developed and broken down on a seasonal basis?

A. Yes. I saw significant evidence of such seasonal differences.

Q. Are there additional reasons why it might be inappropriate to utilize a double mass analysis?

A. Yes. It would be inappropriate to use a double mass analysis in those instances where one of the stations is located in an area that is influenced by urbanization during the time period under review.

Q. What do you mean by "the influence of urbanization"?

A. In this context, I mean a situation which leads to gradual increases in temperatures over time in a defined urban area. This is driven by an extensively built environment (such as buildings, structures, and pavement) as well as heat generated by the large numbers of people present, as well as associated transportation effects. To the extent the target station is subject to an urbanization effect, comparisons with reference stations which are not subject to such an effect are questionable at best.

Q. Has there been an urbanization effect at Lambert Station?

A. Yes. While Lambert Station temperature values used to be characteristic of the outlying rural area, they now are much more representative of the overall urban environment. The reference stations selected by Staff in this proceeding are unaffected by urbanization and therefore dissimilar to the Lambert Station in this critical respect. Under such

circumstances, a double mass analysis using such dissimilar stations will produce questionable results.

Q. Are you suggesting that Staff's method for selecting the reference stations used in its double mass analysis was flawed?

A. Yes. It is important to keep several considerations in mind in determining how to properly select reference stations for double mass analysis. Let's say a double mass analysis is used to quantify the change bias between a reference station and the target station. The calculated bias cannot simply be assigned to the target station – even if the station history reflects that there was a change in sensor type or location at the target station – because it is possible that there was also a significant change at the reference station which could account for some – if not all - of the calculated bias. Generally, this issue is resolved by repeating the analysis using a different reference station to see if "consistent" results are obtained. While there are various methods to test for consistency, the obvious approach is to compare the two reference stations to each other using a double mass analysis. Indeed, a well-planned strategy would include such a comparison at the time the reference stations are being screened.

Q. What then should be the first step in identifying suitable reference stations?

A. The first step in identifying suitable reference stations is to define acceptability criteria such as environmental conditions similar to the target station, a robust data series, and a station history with no significant changes in sensor type or location during the period of interest. As Staff has pointed out, however, station histories are often unreliable. The purported 1988 sensor location change at Lambert Station is one such example; this

purported change does not appear in that Station's history record. Furthermore, environmental changes – such as the influence of urbanization which I just described - or sensor drift will not necessarily be detected in qualitative analyses. For this reason, it is crucial to perform a statistical screening analysis between the candidate reference stations to identify any bias at these stations which would nullify their subsequent use to quantify change bias at Lambert. For this analysis, however, Dr. Hu has stated in his recent deposition that he did not perform double mass analysis between the reference stations. Had he done so, he would have found a change bias in 1988 between the Elsberry and Union reference stations which was greater then the change bias between the reference stations and St. Louis Lambert! Thus, at least one of these reference stations is unacceptable.

Q. Are there other factors that suggest Staff selected inappropriate reference stations?

A. Yes. The criteria for consistent behavior extends beyond the two double mass analyses (two references stations versus Lambert) merely yielding the same mean change bias. Another test for consistency is that the nature of the change bias should be the same if the inducing change occurs at the target station. Again using 1988 as merely an example, an inspection of Dr. Hu's workpapers shows that the change bias between the Elsberry and Lambert Stations occurs for the maximum temperature, while between Union and Lambert the change bias occurs for the minimum temperature. I struggle to see how a sensor type or location change at Lambert can cause two such distinctly different effects. Again, this indicates an inconsistent finding which begs for a more careful analysis concerning the suitability of the reference stations. In summary, statistical analyses are

necessary to justify the selection of reference stations. A necessary, but not sufficient, criteria is that there be no change bias between the reference stations. This must be studied on a station-by-station basis, and not by comparing one reference station to the average of a group of candidate reference stations.

Q. Were the reference stations utilized by Dr. Hu, namely Elsberry, MO, Union, MO and Jerseyville, IL visited by the Company to investigate their location, environment and usefulness as reference stations?

A. Yes. Each of Dr. Hu's reference stations were visited and investigated to determine sensor change, sensor location change, sensor calibration, environment, observer readings and related matters. These visitations were made by myself and/or under my direction and supervision.

Q. Please generally describe what was found at the Elsberry, Missouri station?

A. Elsberry was visited on July 15, 1999. Elsberry is approximately 38 linear miles from the Lambert Station. The temperature sensor is located at the United States Department of Agriculture Plant Materials Center. The station observer was interviewed at length, providing valuable insights into the station history. There have been two significant changes over the last 15 years. In 1988, the sensor was changed from a liquid thermometer unit to a digital "MMTS". At the same time, it was moved from a relatively open area to within approximately 12 feet of the station office (a dark brown one-story structure) and a small tree. Over time, this tree gradually grew into a large shade tree , including casting a shadow on the MMTS unit. After eleven years, the station was moved at the request of a NOAA representative over concerns from both the building and

now-large tree. This move of about 27 feet to its current location – which took place within roughly a month prior to my visit in July 1999 – now places the sensor approximately 30 feet from the building but only some 6 feet from a black-top driveway. Regarding the readings taken at the station, the observer reported that readings were taken twice a day – at 8:00 a.m. to record the minimum temperature and at 4:30 p.m. local time to record the maximum temperature. The readings are usually taken by an office secretary. According to the observer, the sensor is infrequently calibrated, at most every 3 to 5 years.

Q. What did the visit to the Union, MO station disclose?

A. The Union, MO station is located approximately 41 linear miles from the St. Louis Lambert station in the backyard of the station observer's residence. The current sensor location is in a grassy area about 20 feet from a garage (which is not used for storing in-use vehicles) with a grass/dirt/gravel driveway. There are a few large trees standing within 50 feet of the sensor. As at Elsberry, according to the Union observer, the sensor was upgraded from a liquid thermometer unit to a digital MMTS unit sometime in the mid-to-late 1980's. At the same time, the sensor was moved to a location immediately adjacent to the observer's residence. After a few months it was moved again over NOAA concerns that the residence's proximity made the sensor's readings unreliable. The Union, MO station temperature is normally read at 6:00 p.m. local time. However, the observer informed me that storms in the area occasionally cause the MMTS unit to malfunction. In this case as well as other times when he believes the MMTS reading to

be unreliable, he will read and record the temperature from the old liquid thermometer which remains in place.

Q. What was found at the Jerseyville, Illinois station?

A. The Jerseyville, Illinois station is approximately 25 linear miles from St. Louis Lambert station. It was inspected on July 8, 1999 and was found to be adjacent to the Jerseyville wastewater treatment plant. The sensor type and location were last changed during the early to mid 1980's. The current sensor is located on a grassy plot a foot or two from an asphalt drive area, which is bordered on the far side by a long warehouse-like building at a distance of approximately 25 feet. The sensor is also approximately 10 - 15 feet from a large water treatment basin at the plant, which is essentially a concrete pool containing water. The water is normally maintained at a temperature of 50°-60° F during the winter. Finally, the sensor is also adjacent to a shade tree and a low building on another side. The station temperature is read between 7:00 and 8:00 a.m., local time. According to the observer, the current sensor has not been calibrated in approximately four years.

Q. Based on the investigation of the three reference stations chosen for Dr. Hu's double mass analysis, did they appear to be free of location or other exposure type changes?

A. No. There were clearly location and sensor type changes at all three stations in the 1980's. At the Union, MO station and the Elsberry, MO station there were other location changes as well in response to buildings or overgrown shade trees, indicative of the sensitivity of the sensors to such conditions. Furthermore, as previously discussed, the Union, MO station observer indicated he substitutes the former liquid thermometer sensor's readings for that of the current sensor at his discretion following storms or when

he otherwise simply believes the current sensor to be providing unreliable readings. The Jerseyville, IL station is adjacent to an open, water treatment basin whose 50°-60° F temperature of its contents could readily affect the sensor reading depending on the direction of the wind on any given day. All of the stations in question are at some distance from the St. Louis Lambert station and are located in basically rural areas. They therefore do not have the urbanized airport setting of the Lambert station. These conditions clearly require the elimination of at least either the Elsberry or Union station from being used as a reference station for the 1988 analysis and raise numerous serious questions about all three stations used by the Staff. These factors should have been considered when the reference stations were selected, but Dr. Hu apparently did not make any investigation of the stations themselves until after the stations were selected in his analysis. In fact he apparently did not inspect these stations until after he had filed his direct testimony with the Commission.

Q. Do you have any other general concerns regarding Staff's selection of reference stations?

A. Yes. To the extent that reference stations have been selected on some valid basis, one would expect some level of continuity in their use over time. It is my understanding, however, that the reference stations used by Staff to adjust Lambert weather data have repeatedly changed over the past several years. In 1996, for example, Staff used no reference station at all, but simply substituted a St. Charles Missouri station for Lambert Station. In the Company's 1998 rate case it used the weather stations at NWS St. Louis WSFO weather station and the St. Charles 7SSW station for its reference stations. In the recent UE case, however, these stations were eventually abandoned in favor of still other

weather stations. In this case, Staff has once again changed its reference stations to the weather stations discussed above. Obviously, this history of continually changing reference stations on an apparently ad hoc basis does not inspire confidence in the methods or criteria used by the Staff to make its reference station selections.

Q. Do you have any other general concerns regarding Dr. Hu's analysis?

A. Yes. Although I was ultimately able to detect numerous, obvious errors and unjustified assumptions throughout Dr. Hu's analysis, I have to note that I found it very difficult to review and verify the remainder of his analysis. I analyzed his working papers and related documents, including responses submitted by Dr. Hu and other Staff members in response to Data Information Requests made by Laclede Gas Company. I also reviewed selected testimony and discovery for Case Nos. GR-98-374 and EM-96-149 in which Dr. Hu had also made adjustments to the St. Louis Lambert Station observed temperature data. However, this analysis was very difficult to conduct. The workpapers provided by Dr. Hu are not completely documented. There is no documentation of the original sources for the data. This is contrary to good analysis practices which dictate that a knowledgeable person should be able to track the data from its original source to the form in which it is ultimately used for statistical analysis.

Q. What are the implications of this?

A. It is necessary for me to *assume* that the temperature data in the working papers of Dr. Hu is correct, as I am still in the process of verifying the data. This is a significant shortcoming given that the analysis compares first-order weather station temperature data to co-operative weather station temperature data. The approach used to reconcile the

fundamental differences between these data sets should be clearly documented in the working papers.

Q. Assuming the temperature data is indeed correct, and that the time of observation bias has been adjusted appropriately, what is your opinion of Dr. Hu's analysis to arrive at the proposed temperature adjustments?

A. As previously indicated, Dr. Hu applied the double mass analysis methodology to generate estimates for bias introduced by temperature sensor and/or location changes at the Lambert Station. Even a*ssuming* use of the double mass analysis is acceptable and that the first order weather station data is comparable to co-op data adjusted for time of observation bias, his application of the method is flawed on numerous accounts and his results cannot be trusted.

Q. Please provide an example of these flaws.

A. The approach for using a double mass analysis to detect and estimate temperature bias begins with a calculation of the accumulated temperature difference between a target station (in this case, Lambert Station) and a reference station. In most cases, Dr. Hu used monthly averages of the daily maximum and minimum temperature to perform separate analyses for the these two parameters. The bias observed for the maximum and minimum temperatures were linearly averaged to obtain the mean bias between the reference station and the target station. This analysis was repeated for the target station and a second reference station, presumably to insure that the observed bias applies to the target station. The month for which the change bias occurs should be the same for both the minimum

and maximum temperature analyses since, in both cases, it is a single event triggering the bias.

Q. Can these required characteristics of an actual bias be confirmed through a review of Staff analysis?

A. No. It is impossible to do so. First, consider the purported bias introduced by a November 1979 station location change at Lambert that compared to the Elsberry Co-Op Station. If the location change occurred in November 1979, the discontinuity in the line generated by the double mass analysis should occur in that month. The slope calculation for the period prior to the location change should stop in October 1979 and the slope calculation for the period following the location change should start in December 1979. A detailed inspection of Dr. Hu's graphs and electronic files submitted as working papers, however shows otherwise. For the maximum temperature analysis, Dr. Hu stopped the pre-change slope calculation in November 1978 (a full year before the station change occurred), and started the post-change calculation in July 1979 (four months before the station change occurred). On the other hand, for the minimum temperature analysis, Dr. Hu stopped the slope calculation in November 1979 for the pre-change period and started the slope calculation in December 1979 for the post-change period. It defies logic that Dr. Hu could assign the discontinuity – presumably caused by a sensor location change - to one time period for the maximum temperature and to an entirely different period for the minimum temperature. Furthermore, Dr. Hu provides no rationale for having a gap of seven months in the maximum temperature analysis for the time he assumed the discontinuity occurred. It should be noted that the analysis dates in

his graph titles are incorrect and cannot be used to determine the time intervals assigned to the pre- and post-location changes.

Q. Did you find any additional problems with this specific November 1979 station change analysis?

A. Yes, I did. An inspection of the plot for the accumulated difference in maximum temperature reveals a series of peaks and valleys. This indicates a seasonal dependence to the accumulated difference. Further inspection of the 1976-1981 period shows the summer months generally have driven the accumulated difference more negative (that is, the temperature at the reference station is less than the temperature at the target station) while the winter months have generally driven the accumulated difference more positive (that is, the temperature at the reference station is greater than the temperature at the target station). In my opinion, the double mass analysis cannot be used to generate a single temperature adjustment to be applied to the data independent of season when the data exhibits such strong seasonal trends.

Q. And what about the minimum temperature analysis for the November 1979 station change as compared to Elsberry?

A. At first glance, one might assume the methodology was almost correct because the month used for the slope change in the double mass analysis is consistent with the presumed month that the station was moved. However, this is not sufficient to guarantee a robust analysis. Even a casual, visual inspection of the graphs for the accumulated difference in minimum temperature reveals a significant problem. Dr. Hu has apparently violated one of the most fundamental principles in applying a linear regression to data. If you simply

connect the first and last points in a time series – in this case the points corresponding to January 1976 and November 1979 for the period prior to the purported 1979 location change – and all the intermediate points fall on the same side of the line, the trend is *not* linear and there is no basis for using a linear regression to calculate a slope. Indeed, this is the case for the minimum temperature data for the November 1979 change which clearly demonstrates that there is a gradual environmental change – or sensor problem such as drift – at either the target or the reference station during this period. At best, this voids the data analysis and at worst it demonstrates an utter lack of understanding of the fundamentals of statistical data analysis.

Q. Do you have any other comments regarding this particular analysis?

A. Yes, in general it should be noted that Dr. Hu did not center his time series data around the presumed date of location and/or sensor change. A sound analysis would: (1) use the same record length on each side of the discontinuity (that is, the same number of months before the change as after the change); and (2) would include a sensitivity analysis of the calculated bias as a function of record length to determine whether the results are stable.

Q. You have discussed the Lambert Station – Elsberry analysis at length. Do you have any comments concerning the 1979 analysis for Lambert Station with Union as the reference station?

A. First, it should be pointed out the reference station utilized by Dr. Hu was Union, MO, and not Unionville, MO as stated in his direct testimony. Assuming that Dr. Hu really meant Union, MO, the double mass analysis for Lambert Station and Union suffers from the problems similar to Elsberry in defining the date of the discontinuity for the purpose

of calculating the change in slope (and thus, the bias). For the maximum temperature analysis, Dr. Hu stopped the pre-change slope calculation in May 1979, and started the post-change calculation in October 1979. For the minimum temperature analysis, he stopped the slope calculation in November 1979 for the pre-change period and started the slope calculation in December 1979 for the post-change period. Again, the erroneous misalignment of the records for the maximum temperature analysis is indicative of a fundamentally flawed analysis. Since errors such as these can have a profound effect on Dr. Hu's calculated biases, these errors alone make the analysis completely unreliable.

Q. Let us turn our attention to the purported February 1988 station location change at Lambert Station. Did you review Dr. Hu's analysis for this event?

A. Yes, I did. Unfortunately this analysis was even more inappropriate. First, Dr. Hu used a six-year time series of monthly data for the 1979 analysis but only a five-year time series for the 1988 analysis. No reason is stated for this change in methodology anywhere in his testimony or workpapers. Also Dr. Hu consistently fails to properly align the discontinuity with the purported date the station was moved (February 1988). Let us first consider the case of Elsberry as the reference station. For the maximum temperature analysis, Dr. Hu stopped the pre-change slope calculation in July 1988, and started the post-change calculation in February 1989. For the minimum temperature analysis, he stopped the slope calculation in May 1988 for the pre-change period and started the slope calculation in June 1988 for the post-change period. These discontinuities are not aligned and, furthermore, do not correspond at all to the purported station location change being in February 1988. Now consider Union. For the maximum temperature analysis, Dr. Hu

stopped the pre-change slope calculation in May 1988, and started the post-change calculation in September 1988. For the minimum temperature analysis, he stopped the slope calculation in May 1988 for the pre-change period and started the slope calculation in June 1988 for the post-change period.

Q. Let us shift gears here. The Staff is proposing a 30-year adjusted temperature database to determine degree days for the 30-year period ended 1990 for Lambert Station for the purpose of weather normalization. What is your opinion of this approach?

A. First, let it be clear that this is not the NOAA 1990 normal. As to the use of 30 years of data to determine normals, there seems to be widespread confusion regarding the intent - and thus proper use - of the NOAA 30-year norm. Its intended use is for the purpose of *comparison*: (1) to assess the deviation of a given event – such as annual HDD for a given year – from a reference period; and (2) to perform synoptic analyses, such as investigating spatial correlation. For some reason, however, the NOAA 30-year norms are assumed by some people to have *predictive* power. This is nonsense. N.B. Guttman of NOAA (Bulletin American Meteorological Society, 1989, pp. 602-607) quotes an earlier study which concluded "Climate normals... are extremely inefficient for the primary use to which they are put; estimating future conditions" and "... the concept of climatic normal should be abandoned in practical climatology." In summary, normals are very useful tools to assess variability. Given a NOAA 30-year HDD normal, one can estimate the *range* of annual HDD which might be observed in the near future. However, it is not a good predictor for actually estimating the HDD value.

Q. So what are the implications for weather normalization?

A. Although Staff has not used a NOAA 30-year normal in this case, the only justification for using the NOAA 30-year norm as the basis for weather normalization is that it can be looked up in a table. There is no scientific nor statistical basis for its use in this application. The arcane notion that the NOAA 30-year norm is a NOAA-"sanctioned" predictor for applications such as near-term HDD estimation must be abandoned in favor of a methodology demonstrating more predictive value.

Q. Does this conclude your testimony?

A. Yes.

BEFORE THE PUBLIC SERVICE COMMISSION

OF THE STATE OF MISSOURI

In the Matter of Laclede Gas Company's)
Tariff to Revise Natural Gas Rate Schedules.) Case No. GR-99-315

AFFIDAVIT

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

Jay R. Turner, of lawful age, being first duly sworn, deposes and states:

1. My name is Jay R. Turner. My business address is 210 Cupples Hall II, One Brookings Drive, St. Louis, Missouri 63130-4899; and I am Assistant Professor of Chemical Engineering and Engineering & Policy in the School of Engineering and Applied Sciences for Washington University in St. Louis.

2. Attached hereto and made part hereof for all purposes is my rebuttal testimony, consisting of pages 1 to 19.

3. I hereby swear and affirm that my answers contained in the attached testimony to the questions therein propounded and correct to the best of my knowledge and belief.

Jay R. Turner

Subscribed and sworn to before me this 5TH day of August, 1999.

PATRICIA P. HICKS
Notary Public — Notary Seal
STATE OF MISSOURI
City of St. Louis
My Commission Expires: June 27, 2002

Patricia P. Hicks