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JOHN K. BRYAN
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June 23, 1981

Mr. Harold R. Denton
Director of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Denton: ULNRC- 456

DOCKET NUMBERS 50-483 AND 50-486
CALLAWAY PLANT, UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

Reference: NRC letter dated May 29, 1981 signed by R. L. Tedesco

The referenced letter requested additional information concerning the Callaway Plant FSAR. Transmitted herewith are responses to questions in the referenced letter. This information will be formally incorporated into the Callaway Plant FSAR in the next revision. This information is hereby incorporated into the Callaway Application.

Very truly yours,

John K. Bryan

NCS/afg

8106290230

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

John K. Bryan, of lawful age, being first duly sworn upon oath says that he is Vice President-Nuclear and an officer of Union Electric Company; that he has read the foregoing document and knows the content thereof; that he has executed the same for and on behalf of said company with full power and authority to do so; and that the facts therein stated are true and correct to the best of his knowledge, information and belief.

By John K. Bryan
John K. Bryan
Vice President
Nuclear

SUBSCRIBED and sworn to before me this 23rd day of June, 1981

Barbara J. Pfaff
BARBARA J. PFAFF
NOTARY PUBLIC, STATE OF MISSOURI
MY COMMISSION EXPIRES APRIL 22, 1985
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ITEM 451.1C: The frequency of lightning strikes is not presented in the discussion of severe weather and extreme meteorological conditions in Section 2.3.1 of the FSAR. Provide seasonal and annual estimates of lightning strikes to safety-related structures at the site considering the "attractive area" of the structures. A suggested reference for this type of analysis is J. L. Marshall, Lightning Protection, 1973. See also Section 2.3.1 of the Wolf Creek FSAR for a discussion of expected lightning strikes to ground as a function of number of thunderstorms.

RESPONSE: The frequency of lightning strikes to an area is related to the number of thunderstorm days in that area. In order to characterize the expected frequency of lightning strikes to the area of the Callaway Plant, data from Columbia, Missouri regarding the average number of thunderstorm days over a 30-year period were used. These data were presented in Table 2.3-1 of the FSAR and are summarized below:

SEASON	THUNDERSTORM DAYS
Winter (January through March)	5
Spring (April through June)	22
Summer (July through September)	22
Fall (October through December)	6
Annual Total	55

The following discussion, which estimates the number of lightning strikes to safety-related structures at the site, was developed following the methodology presented by J. L. Marshall in Lightning Protection, published in 1973. The "attractive area" of the structures was determined for a lightning strike with an electrical current magnitude of 20,000 amperes, which corresponds to the current magnitude of 50 percent of lightning flashes. The attractive area (A) of a structure is:

$$A = LW + 4H (W + L + \pi H)$$

where: L = structure length, meters;
W = structure width, meters; and
H = structure height, meters.

The grouping of safety-related structures that maximizes the attractive area is composed of five structures. These are the reactor building, control building, auxiliary building, diesel generator building, and fuel building. For simplicity, this grouping has been assumed to have the following dimensions:

$$L = 99.1 \text{ m}$$
$$W = 91.4 \text{ m}$$
$$H = 63.4 \text{ m}$$

The assumed dimensions are the maximum linear dimensions of this grouping and, thus, maximize the attractive area of the structures.

These dimensions yield an attractive area of 0.108 km^2. The number of lightning strikes to earth per thunderstorm day per square kilometer (N_E) is given by:

$$N_E = (0.1 + 0.35 \sin x)\ (0.40 \pm 0.20)$$

where: x = the geographic latitude.

Using the approximate plant latitude of 38°47', the value of N_E calculated from the above equation is $N_E = 0.128$. Then, the number of lightning strikes per square kilometer per year is:

$$N_E \times 55 \frac{\text{thunderstorm days}}{\text{year}} = 7.04 \frac{\text{flashes}}{\text{km}^2 \text{ year}}$$

Since the safety-related structures of interest have an attractive area of 0.108 km^2, the probability is that there will be:

$$7.04 \frac{\text{flashes}}{\text{km}^2 \text{ year}} \times 0.108 \text{ km}^2 = 0.76 \frac{\text{flashes}}{\text{year}}$$

or one lightning flash every 1.32 years (480 days).

From the Wolf Creek FSAR, it was seen that the number of flashes to ground per square mile per year is between 0.05 and 0.8 times the number of thunderstorm days per year. For the Callaway Plant area, this is between 3 and 44 lightning strikes per square mile per year, or between 1 and

17 lightning strikes per square kilometer per year. The number previously calculated (7.04 lightning strikes per square kilometer per year) falls within this range.

The seasonal estimate of lightning strikes to safety-related structures considering their attractive area is presented below:

SEASON	FLASHES PER SEASON	NUMBER OF SEASONS FOR ONE FLASH
Winter	0.07	14.5
Spring	0.30	3.3
Summer	0.30	3.3
Fall	0.08	12.1

REFERENCES:

Dames & Moore, 1980, Final safety analysis report, Wolf Creek, for Kansas Gas & Electric Co.

Marshall, J.L., 1973, Lightning protection: John Wiley and Sons.

ITEM 451.2C: The tornado statistics presented in Section 2.3.1.2.6 are based on a regional data base that ended in 1971. Identify any tornados that have occurred in the vicinity of the site since 1971, and provide estimates of the intensity (maximum wind speed) and path area of each. Compare the annual tornado strike probability for this period with strike probabilities determined for previous periods of record (see pages 2.3-6 and 2.3-7).

RESPONSE: The publication Storm Data, published by the National Oceanic and Atmospheric Administration (NOAA), was consulted to obtain information concerning tornado strikes in the vicinity of the site for the period 1972 through 1980. The area comprising this vicinity was assumed to include Callaway County and the seven-county area surrounding Callaway County. The counties investigated are Audrain, Boone, Callaway, Cole, Gasconade, Montgomery, Osage, and Warren counties.

The tornados recorded in these counties are shown below, along with an estimate of the path area of each. No estimate of the maximum wind speed that occurred was available from this source. In order to provide some indication of the intensity of the tornado, an estimate of property and crop damage is included, also obtained from the NOAA publication. The parameters of the design basis tornado for the Callaway Plant, which were obtained from Regulatory Guide 1.76 (1974), are shown in Section 2.3.1.2.6.2 of the FSAR Addendum.

LOCATION (COUNTY)	DATE	PATH LENGTH (km)	PATH WIDTH (m)	ESTIMATED DAMAGE*	
				PROPERTY	CROPS
Boone	09/07/72	0.2	46	4	-
Boone	03/13/73	11.3	46	4	-
Boone	05/26/73	4.8	46	5	-
Callaway	07/20/73	1.6	46	3	?
Cole, Boone and Callaway	05/12/80	40.2	46	4	4
Montgomery	05/12/80	1.6	91	5	2

*Storm damages are placed in nine categories:

1 - Less than $50
2 - $50 to $500
3 - $500 to $5,000
4 - $5,000 to $50,000
5 - $50,000 to $500,000
6 - $500,000 to $5 million
7 - $5 million to $50 million
8 - $50 million to $500 million
9 - $500 million to $5 billion

For this 9-year period, six tornados were recorded. Using the method of Section 2.3.1.2.6.1 and assuming that the eight-county area corresponds to the 1-degree, longitude-latitude square, the annual strike probability (P_S) is computed from the data period 1972 through 1980:

$$P_S = \frac{2.821\ E}{A} = 5.01 \times 10^{-4}$$

This figure is comparable to the strike probability computed using the Pautz (1969) data where $P_S = 7.5 \times 10^{-4}$ and is somewhat less than the value determined by Poultney (1973) where the annual strike probability was found to be 1.21×10^{-3}.

REFERENCES:

Pautz, M.E., 1969, Severe local storm occurrences 1955-1967. Office of Meteorological Operations, Silver Spring, Maryland, ESSA Technical Memo, WBTM FCST 12.

Poultney, N.E., 1973, The tornado season of 1972. Weatherwise, 26, 22-27.

U.S. Department of Commerce, 1972-1980, Storm data. NOAA, Washington, D.C., volumes 14 through 22.

ITEM 451.3C: Describe the procedures used for determining the meteorological conditions which would result in the minimum heat transfer rates (Tables 2.3-13 and 2.3-14) and the greatest evaporation from the retention pond (Table 2.3-15) for design of the ultimate heat sink.

RESPONSE: The following procedures were used to obtain the meteorological data required for the design of the ultimate heat sink. All average and extreme values of meteorological parameters were based on 3-hourly data for Columbia, Missouri, for the 25-year period January 1, 1945 to October 31, 1969. The data were obtained from the U.S. Department of Commerce, National Climatic Center, Asheville, North Caroline, on magnetic tapes in TDF-14 format.

Since many of the calculations are concerned with daily averages of meteorological parameters, an additional data file was compiled consisting of average values of the following meteorological parameters for each calendar day of the data period: cloud cover, wind speed, dry-bulb, wet-bulb, and dew point temperatures, and relative humidity. A separate dew point temperature value was calculated for each 3-hourly observation using dry-bulb and wet-bulb values, and the daily averages for the calculated dew point appear in the daily average data file, together with daily averages for the depression of the wet bulb and the depression of the calculated dew point.

The calculated dew point was used in the data analysis instead of the original dew point, since wet-bulb measurements are generally more reliable than direct measurements of dew point.

Where 30-day average values of a parameter were required, the 30-day periods were obtained by taking each consecutive day as the beginning of a particular 30-day period. For example, after June 1 - 30, the 30-day period of June 2 - July 1 was considered rather than July 1 - 30. The data set of daily average values was used in computing 30-day averages.

In computing averages, a minimum of four 3-hourly average values were considered necessary for a

valid daily average, and 15 valid daily values were used as the minimum for a valid 30-day average.

After the highest 30-day average period for a given parameter was determined, the daily values of the parameter were determined. The daily values of the parameter for the period were obtained by listing the required portion of the data set.

The evaporative heat flux for each day within the summer months of June to September was calculated using the following equation from "An Analytical and Experimental Study of Transient Cooling Pond Behavior" by P.O. Ryan and D.R.F. Harleman, Ralph Parsons Lab, MIT Report No. 161, January 1973:

$$\phi = f(w)\ (e_s - e)$$

where: ϕ = evaporative heat flux (Btu/ft^2/day);

e_s = saturation vapor pressure (mm Hg);

e = actual vapor pressure (mm Hg); and

$f(w) = 70 + 0.7\ w^2$

where w = wind speed (mph).

The period of minimum heat transfer was determined by finding the period of highest equilibrium temperature for the retention pond. The equilibrium temperature, as defined by Ryan and Harleman, is a function of net radiation, wind speed, ambient temperature, and dew point temperature, in accordance with the following equation:

$$T_E = \frac{\phi_r + f(w)\ [\beta T_d + 0.255\ T_a] - 1600}{23 + f(w)\ (\beta + 0.255)}$$

where: T_E = equilibrium temperature toward which the pond tends (°F);

ϕ_r = net radiation term (Btu/ft^2/day);

$= \phi_{sn} + 1.16\text{x}10^{-13}\ (460 + T_a)^6 (1 + 0.17c^2)$;

ϕ_{sn} = net incident solar radiation (Btu/ft^2/day);

$= (1 - 0.71c^2)\ H_o \times 24$;

H_o = average daily absorbed solar radiation for clear sky (Btu/ft^2/day);

= 68.362-40.982 x sin [2π x (DAY/366)+1.739] for 39^o latitude;

DAY = sequential number of the day of the year beginning with 1 for January 1 and ending with 365 or 366 for December 31;

c = average cloud cover (in tenths);

f(w) = wind function (Btu/ft^2/day/mm Hg);

= 70 + 0.70 x ws^2;

The Brady form of f(w) instead of the Lake Hefner form [f(w) = 12.4 x ws^2] in the above reference was used because the latter is physically unrealistic and gives excessive values of T_E for low wind speeds.

ws = wind speed (mph);

β = 0.255 - 0.0085 T* + 0.000204 T*^{2} (mm Hg/^{o}F);

T* = 1/2 (T_s + T_d) (^{o}F);

T_d = dew point (^{o}F);

T_a = ambient temperature (^{o}F); and

T_s = surface temperature of the pond (^{o}F).

The 3-hourly observations for ambient temperature, wet-bulb temperature, cloud cover, and wind speed were averaged to obtain daily values. The dew point temperature was then calculated from the ambient temperature and wet-bulb temperature.

The equilibrium temperature was calculated for each day using the above parameters. An initial value of T_s was assumed and T* and β were calculated. Then, for given values of ϕ_r, T_d,

T_a, and f(w), the value of T_E was calculated. The difference, $(T_E - T_S)/2$, was then used as an improved estimate of the value of T_S and the process was repeated until the difference became less than or equal to 0.5°F. Generally, the equilibrium temperatures are found within 4 to 5 iterations.

The 40 highest daily equilibrium temperatures were found, as well as the 40 highest 30-day equilibrium temperatures. The 30-day equilibrium temperature is the average of a 30-consecutive-day period between June 1 and September 30.

REFERENCE:

Ryan, P.J., and Harleman, D.R.F., 1973, An analytical and experimental study of transient cooling pond behavior. Ralph H. Parsons Laboratory, Department of Civil Engineering, MIT, Report no. 161 (January).

ITEM 451.4C: Table 2.3-37 of the FSAR indicates that moderately stable (Pasquill Type F) and extremely stable (Pasquill Type G) conditions have persisted for 20- and 19-hour periods, respectively, at the Callaway Site during the period May 1973 - May 1975. Persistence of these stability classes for periods greater than 12 hours is very unusual. Discuss the causes of persistent stability conditions for greater than 12 hours for Classes F and G. Identify the synoptic conditions during the observed periods of persistent F and G stability classes for periods greater than 12 hours, and discuss the possibility of instrument malfunction.

RESPONSE: Reanalysis of the two FSAR years 1973-1975 occurred after a portion of the 90-10m delta temperature values, which were misaligned and located in a data file used to calculate stability, were corrected. The results are shown in Table 451.4C-1, and the corresponding instances where F and G stability persisted for a period of greater than 12 hours are presented below. These were:

STABILITY	TIME PERIOD	HOURLY PERSISTENCE
F	05/27/73-1400 to 05/28/73-0900	20
F	07/05/73-1900 to 07/06/73-0700	13
G	10/25/73-2100 to 10/26/73-0900	13
F	12/21/73-2000 to 12/22/73-1000	15
F	02/12/74-1800 to 02/13/74-0700	14
F	11/01/74-1900 to 11/02/74-0800	14

Stability persistence time periods ending on 12/22/73 at 1000 and on 11/02/74 at 0800 occurred in advance of a low pressure system. Prevalent meteorological conditions were cloudy skies with very little surface heating, all of which increased stability of the surrounding air. There was no evidence of instrument malfunction.

Stability persistence time periods ending on 07/06/73 at 0700, 10/26/73 at 0900, and 02/13/74 at 0700 occurred during strong high pressure system passage. Meteorological conditions were clear skies, which promoted radiational cooling and thereby increased stability. Again, there was no evidence of an instrument malfunction.

TABLE 451.4C-1

CALLAWAY GENERATING STATION
REFORM, MISSOURI
UNION ELECTRIC COMPANY
DAMES AND MOORE JOB NO 7677-066-07
DATA PERIOD FROM 5/ 4/73 TO 5/ 4/75
DATE AND TIME OF RUN 06/15/81. 14.34.59.

NUMBER OF HOURS

NUMBER OF CONSECUTIVE HOURS	PASQUILL STABILITY CLASS -A-	-B-	-C-	-D-	-E-	-F-	-G-
2	392	198	292	4999	3778	1656	670
3	251	66	113	4050	2919	1130	486
4	153	22	48	3377	2313	777	354
5	91	6	20	2897	1872	531	250
6	50	0	8	2516	1524	371	168
7	27	0	2	2209	1242	260	110
8	15	0	0	1954	1008	176	71
9	7	0	0	1740	814	114	41
10	2	0	0	1559	641	73	22
11	0	0	0	1413	500	44	10
12	0	0	0	1296	382	25	4
13	0	0	0	1199	279	16	1
14	0	0	0	1112	202	11	0
15	0	0	0	1034	140	7	0
16	0	0	0	964	93	5	0
17	0	0	0	900	63	4	0
18	0	0	0	843	42	3	0
19	0	0	0	792	32	2	0
20	0	0	0	747	25	1	0
21	0	0	0	702	19	0	0
22	0	0	0	659	14	0	0
23	0	0	0	621	11	0	0
24	0	0	0	586	8	0	0
>24	0	0	0	551	5	0	0

671 INVALID HOUR(S).

Finally, the most persistent stability time period of 20 hours occurred between May 27 and May 28, 1973. Although the stability classes determined by the two delta temperature sensors differ, this could be accounted for by the weather system that passed through Missouri over that 2-day period. During that time period, a slow-moving cold front from a deep low pressure system moved through Missouri. A low-level inversion does occur during these episodes and causes fog. Because this slow-moving low pressure system traveled almost directly over Fulton, Missouri, the large spread in delta temperature values was possible. Fog and light rain showers were reported from this system on May 27, 1973 in Springfield, Missouri and Omaha, Nebraska. Although the weather map data only reproduce conditions at one time period on May 27, it is probably safe to assume that fog did occur before the advancing cold front. If this is the case, then a low-level inversion would have occurred and caused the great difference in delta temperature values. The slow movement of the system would have caused a persistent F stability for the 60-10m delta temperature.

REFERENCE: Daily Weather Maps, U.S. Department of Commerce.

Finally, the most persistent stability time period of 20 hours occurred between May 27 and May 28, 1973. Although the stability classes determined by the two delta temperature sensors differ, this could be accounted for by the weather system that passed through Missouri over that 2-day period. During that time period, a slow-moving cold front from a deep low pressure system moved through Missouri. A low-level inversion does occur during these episodes and causes fog. Because this slow-moving low pressure system traveled almost directly over Fulton, Missouri, the large spread in delta temperature values was possible. Fog and light rain showers were reported from this system on May 27, 1973 in Springfield, Missouri and Omaha, Nebraska. Although the weather map data only reproduce conditions at one time period on May 27, it is probably safe to assume that fog did occur before the advancing cold front. If this is the case, then a low-level inversion would have occurred and caused the great difference in delta temperature values. The slow movement of the system would have caused a persistent F stability for the 60-10m delta temperature.

REFERENCE: Daily Weather Maps, U.S. Department of Commerce.

ITEM 451.5C: In the discussion of the potential influence of the plant and its facilities on local meteorology (Section 2.3.2.2), two somewhat different sets of design parameters for the natural draft cooling towers are presented (see pages 2.3-23 and 2.3-31). Clarify the design characteristics for the natural draft cooling towers, particularly for the exit diameter and heat rejection rate.

RESPONSE: The design characteristics for the natural draft cooling towers contain typographical errors on pages 2.3-23 and 2.3-31 of the FSAR. The correct parameters are:

a. Tower height, 555 feet;

b. Diameter of top of tower, 252.7 feet;

c. Heat rejection rate, 8.04×10^9 Btu/hr per tower; and

d. Water flow rate, 568,000 gpm per tower.

The heat rejection rate as listed on page 2.3-23 is incorrect, and the tower exit diameter as listed on page 2.3-31 is incorrect. However, the correct parameters listed above were used in the analysis.

ITEM 451.6C: In the calculation of cooling system impacts, wind speed and wind direction measurements at the 60m level were used to determine conditions representative of the top of the cooling tower (at about 170m above the surface). Discuss the rationale for using measurements from the 60m level when similar measurements were available from the 90m level. Also discuss the validity of use of the wind speed power law described on pages 2.3-25 and 2.3-26 to extrapolate from measurements at 60m to represent conditions at 170m.

RESPONSE: A. Wind Speed and Wind Direction

In the analysis of cooling system impacts, the results of an on-site meteorological monitoring program were utilized. The information available for use in the cooling tower model (TOWER 1 as described in the FSAR) consisted (in part) of the following:

PARAMETER	LEVEL
Wind speed/direction	10 m
Wind speed/direction	60 m
Wind speed/direction	90 m
Temperature	10 m
Dew Point	10 m
ΔT	90/10 m
ΔT	60/10 m

Wind speed and direction measurements were available at three levels, namely, 10, 60, and 90 m AGL. Temperature lapse (ΔT) measurements were available over two intervals, 90-10 and 60-10 m. For the analysis of cooling system impacts, wind speed and direction measurements from the 60 m level were used in conjunction with temperature and dew point measurements at the 10 m level at ΔT measurements over the 90-10 m interval. The rationale for using wind speed and direction measurements from the 60 m level as opposed to the 90 or 10 m levels was based primarily on compatibility with ΔT measurements and data recovery. Inasmuch as the 90-10 m ΔT measurements span essentially the entire surface layer (assumed to be the lowest 100 m of the friction layer), they are ideally suited for the determination of stability in the lowest layers of the atmosphere. In addition to a more favorable

data recovery for the 60 m wind measurements, it was felt that it would be more appropriate to use wind measurements that were bracketed by the temperature lapse measurements rather than to have wind speed and direction measurements at the upper or lower end of the temperature lapse measurement interval. Presumably, this approach will be more representative of average conditions in the layer over which atmospheric stability was calculated.

B. Wind Speed Power Law

In order to extrapolate wind speed measurements at the 60 m level to represent conditions at the top of the cooling tower (170 m), a simple power law was used. The power law as used in TOWER 1 was as follows:

$$U_h = U_o \left(\frac{h}{h_o}\right)^s$$

where: U_h = wind speed at cooling tower height (m/s);

U_o = wind speed at 60 m (m/s);

h = height of cooling tower (170 m);

h_o = height of wind sensor (60 m); and

s = power law exponent

= 0.25 for unstable/neutral conditions

= 0.50 for stable conditions.

The use of the power law is consistent with current theories on the vertical structure of wind speed in the surface layer. This formulation has been used by many investigators such as Frost (1948) and Sutton (1953). Frost estimated that the value of the power law exponent should vary between 0.1 for extremely unstable atmospheric conditions and 0.8 for extremely stable conditions. Inasmuch as the atmosphere rarely exhibits extreme behavior, it is more reasonable to assume values for the exponents that are more representative of typical atmospheric stability conditions. The values used of s=0.25 (unstable/neutral) and s=0.5 (stable) are within the range of values used by these earlier researchers. The results obtained with the predictive model TOWER 1 should be less sensitive to choice of power law

exponent in the power law extrapolation than to the choice of criteria used in the determination of atmospheric stability.

REFERENCES: Frost, R., 1948, Quart. J. Roy. Met. Soc., vol. 74.

Sutton, O.G., 1953, Micrometeorology. McGraw-Hill, New York.

ITEM 451.7C: The discussion of data recovery on page 2.3-49 indicates that data from other levels and intervals were substituted to enhance the data recovery for the primary measurements, i.e., wind speed and wind direction at the 10m level and temperature difference between 10m and 60m. Preliminary analysis of the hour-by-hour meteorological data provided on magnetic tape suggests that about 23% of the primary data for the combined three-year period (5/73 - 5/75 and 3/78 - 3/79) had to be substituted for the primary measurements. Discuss the problems with the data collection program which necessitated such a large fraction of substituted data, and indicate what modifications will be made to the operational program to enhance data recovery of the primary meteorological measurements. Also discuss the difficulties in measuring precipitation at the site which necessitated use of precipitation data from Columbia, and indicate the real-time representativeness of Columbia precipitation data for use at the Callaway site.

RESPONSE: The Union Electric Company's meteorological monitoring system consists of Climet wind systems located at the 10-, 60-, and 90-meter (m) levels; Climet delta temperature systems that measure temperature differences between the 10- and 60-m levels and also the 10- and 90-m levels; an EG&G cooled mirror dew point system at 10 m; a back-up Climet lithium chloride (LiCl) dew point system at 10 m; a Climet temperature sensor at 10 m; and a Climet weighing bucket rain gauge at 2 m.

All data as of March 1978 are recorded on Esterline Angus (EA) analog recorders. The sequential multipoint recorder, EA Model E1124E, records the reference temperature, LiCl dew point, and both delta temperatures. (In Phase I of this study, the multipoint also recorded the 90-m dew point.) Three EA E1102S side-by-side dual-pen analog recorders record the wind speed and wind direction at all three tower levels. The EG&G cooled mirror dew point is also recorded on a separate EA L1101S analog recorder. The weighing bucket rain gauge records precipitation on an EA 6016 analog recorder. Before March 1978, digital data were available to augment the analog data, but with the beginning of the last FSAR data

collection year, this digital data system was judged unsuitable as a back-up system and, therefore, was not used in the final FSAR year.

The Union Electric 3-year data collection effort has been noteworthy because of the problems that the instruments and recorders have had. The dual-pen recorders that record wind speed and wind direction have capillary inking pens. The pens have had a tendency to accumulate ink at the tip; the ink dries, blocking ink flow and preventing data from being recorded on the analog charts. This occurrence does not take place at all recorders concurrently, and if it does happen at the 10-m primary data level, data from either the 60- or 90-m wind sensors are substituted after the data are adjusted to height.

The multipoint recorder has had numerous break-downs over the 3-year period. Another multipoint recorder is used if the original recorder is not repairable at the site. The original recorder is placed on line after being repaired by the manufacturer.

The EG&G cooled mirror dew point, like the multipoint recorder, has been sent back to the manufacturer a number of times for repairs because of failures within the dew point system. In the event of the EG&G dew point failure, the LiCl dew point data are substituted until the EG&G dew point is back on line.

The 60-10m delta temperature displayed inter-mittent problems in the first 2 years of data collection. This problem appeared during periods of high humidity. Numerous tests were performed on the 60-10m delta temperature system to no avail. Finally, the problem was traced to a small crack in the tower cabling from the 60-m level. All tower cabling was replaced and the problem ceased. When the 60-10m data did appear suspect, it was invalidated and 90-10m delta temperature data substituted.

In addition to instrument and recorder problems, the Union Electric meteorological tower has been hit by lightning, ice storms, and freezing drizzle. Lightning has struck the tower at least three times, knocking out all instrumentation. Freezing drizzle and ice storms have frozen

the wind sensors and stopped the sensors from functioning normally. In March 1981, heaters were installed on all three levels of wind sensors to prevent this icing problem.

The combination of recorder malfunctions, sensor malfunctions, and acts of God have worked together, yielding reduced data recovery rates at the 10-m primary level. Procedures have been implemented to increase the data recovery for all parameters. These procedures consist mainly of intensified inspection of the monitoring system operating parameters by Union Electric personnel performing site checks in order to more quickly identify potential problems and respond with remedial measures. It is expected that this increased attention to system operation, along with the new tower cabling and sensor heaters (where appropriate), will increase the valid data recovery of the meteorological monitoring system. As can be seen in the response to Item 451.8C, data recovery of meteorological parameters has been generally above the 90 percent rate of recovery specified for most such parameters.

Instrument operating difficulties were experienced with the precipitation gauge at the Callaway site. Since precipitation events can produce significant quantities of precipitation during short periods of time, even short periods of instrument outage can result in serious distortion of the data base. The Columbia National Weather Service is within 40 km (25 miles) of the Callaway site, and there are no intervening topographic features to suggest the two locations would have different precipitation climatologies. Therefore, it was decided that the Columbia precipitation data were probably more representative of the Callaway site than the short-term data available from the on-site sensor. Considering the seasonal and annual anomalies that can occur in precipitation data, the Columbia period of record is almost certainly more representative of the Callaway site than any 2- or 3-year period measured on site.

More emphasis has been placed on the careful operation of the on-site precipitation sensor since March 1979. Except for a 3-month period in 1980, it has been operating at better than 90 percent data recovery. During that 3-month period, an evaporation study was conducted at the

UHS retention pond that included the measurement of precipitation that can be substituted for missing data during that period. Also, the primary precipitation sensor at the on-site tower is being replaced to provide a more accurate, reliable data base. The replacement sensor will use the tipping bucket method of measurement. This method is considered superior, with respect to accuracy, reliability, and resolution, to the presently used method of determining precipitation, which is a weighing bucket.

Although it is recognized that in real time, precipitation data from Columbia may be skewed or differ from that of the Callaway site, such as if a rainstorm should arrive at the two locations at different times or if it should arrive at one and not the other, it is expected that the Columbia data will be comparable to conditions at the Callaway site. Although the data since March 1979 have not been recovered from the strip chart recordings, they are available for making a real-time comparison between Columbia and Callaway or a longer-term comparison when a sufficiently large data base is available to average out seasonal and annual anomalies.

ITEM 451.8C: Describe the status of the on-site meteorological measurements program since March 1979.

RESPONSE: Since March 1979, the on-site meteorological monitoring program has continued to operate. The instruments are checked three times per week by Union Electric-Nuclear Operations and calibrated quarterly by Dames & Moore. The data are recorded on analog recorders. The strip chart records are reviewed to verify that the data are acceptable and then archived at the Dames & Moore office in the Chicago area. Estimated percentage data recovery rates for each parameter are as follows:

PARAMETER	04/79 to 12/79	01/80 to 12/80	01/81 to 02/81
Wind Speed, 10m	90	92	94
Wind Speed, 60m	91	94	98
Wind Speed, 90m	90	92	98
Wind Direction, 10m	89	93	85
Wind Direction, 60m	88	96	98
Wind Direction, 90m	83	91	97
Temperature, 10m	93	94	100
Delta Temperature, 60-10m	93	94	100
Delta Temperature, 90-10m	93	90	100
LiCl Dew Point, 10m	91	94	100
Cooled Mirror Dew Point, 10m	32	58	98
Precipitation, 1m	94	74	92

ITEM 451.9C: Tables 2.3-66, 2.3-67, and 2.3-68 present terrain/recirculation correction factors to be applied to a straight-line Gaussian dispersion model to better characterize temporal variations in meteorological conditions. These correction factors were estimated based on the results of a variable-trajectory puff advection model using one year of hour-by-hour meteorological data from the Callaway site. Substantial reductions (up to a factor of 100 lower than the straight-line model) are suggested for distances approaching 50 miles. Discuss the reasonableness and appropriateness of correction factors for receptors at distances greater than about 5 miles from the source developed by use of a variable-trajectory model with only a single source of meteorological data as input. Also discuss the use of site-specific wind speed profiles for this analysis when standard wind speed profiles are assumed for data substitution and cooling tower impact assessments.

RESPONSE: Dames & Moore's variable-trajectory puff advection model, PUFF, was used, along with a straight-line model, in the derivation of terrain/recirculation correction factors (TCFs). PUFF tracks the advection and dispersion of up to 500 Gaussian puffs across the study area. New puffs are emitted continuously at 20-minute intervals throughout the year. Puffs are discarded when they leave the study area, or when they have become so attenuated that they no longer have a significant impact at any receptor location. The criterion for discarding an attenuated puff is comparison of the puff center χ/Q to a user-specified cutoff χ/Q value. In the original analysis, this cutoff was inadvertently set to an inappropriately high value. The result was that puffs were discarded too quickly, before they could reach the more distant receptor locations.

The PUFF model analysis has been repeated for ground-level release using a more appropriate χ/Q cutoff value. Revised TCFs are presented in Table 451.9C-1 for the 10 receptor ring distances used in the PUFF analysis. As this table indicates, the strong systematic underprediction of PUFF model results in relation to straight-line model results for large source-receptor distances is no longer present.

TABLE 451.9C-1

TERRAIN/RECIRCULATION CORRECTION FACTORS AT TEN STANDARD DISTANCES
GROUND-LEVEL RELEASE
BASED ON MAY 4, 1974 TO MAY 4, 1975 DATA

DISTANCE (MILES)	SECTOR NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
.25	.99	.87	1.05	.77	.91	.90	.98	1.01	.89	1.03	.99	1.14	1.07	1.02	.95	.99
.75	1.04	.92	.98	.87	.91	.95	.99	.94	.93	.92	1.10	1.13	1.13	.95	.94	1.06
1.50	1.13	1.00	1.01	.93	.96	1.0[illegible]	1.00	.89	.98	.93	1.08	1.01	1.05	1.00	.89	1.00
2.50	1.11	.91	.93	.80	.91	.91	1.01	.95	.99	.99	1.16	.94	1.10	.96	.93	1.03
3.50	.99	.79	.83	.75	.99	1.00	.99	.93	.84	.94	1.14	1.03	1.05	.95	.87	.97
5.00	.92	.72	.77	.74	.92	.93	1.04	.98	.80	.93	1.04	.91	1.03	.94	.77	.93
10.00	.95	.75	.80	.74	.80	.78	.96	.62	.78	.60	.88	.94	.81	.92	.85	.79
20.00	.91	.64	1.01	.65	.72	.61	.73	.61	.52	.51	.65	.74	.82	.88	.81	.81
35.00	.70	.58	.91	.45	.53	.47	.65	.37	.34	.32	.39	.55	.82	.74	.71	.77
50.00	.56	.48	.50	.28	.42	.28	.46	.41	.32	.27	.30	.48	.64	.51	.49	.65

The mild overall decrease in TCF values at large downwind distances may be attributed to plume meander, accounted for in PUFF but not in the straight-line model. With wind directions varying hourly, plume elements in PUFF actually cover a greater distance before arriving at a given receptor than is assumed in the straight-line model. They are, therefore, somewhat more attenuated on arrival at the receptor than the straight-line model algorithm would indicate.

The revised PUFF model analysis utilized standard vertical wind speed profiles, rather than the site-specific profiles employed in the original PUFF analysis. Although the site-specific profiles may more accurately reflect actual conditions at the plant site, the standard profiles were chosen in order to ensure consistency with other portions of the final safety analysis.

Revised TCFs will be computed for the mixed-mode case as well as the ground-level case. The revised TCFs will be logarithmically interpolated to provide TCFs for all downwind distances of interest. This complete set of TCFs will then be applied to all straight-line model results presented in the FSAR.

Use of a single meteorological station as the data source for the PUFF analysis is justified by the absence of severe terrain within the region of interest and by the fact that only long-term average relative concentrations are evaluated. Absence of severe terrain implies that deviations from straight-line flow that do occur are not strongly systematic. Effects of random plume meander and mesoscale recirculation on annual average χ/Q values are adequately represented via PUFF simulations with single-station on-site meteorological input.