



MEMORANDUM

To: Chris Beekman (Ohio Environmental Protection Agency)
CC: Gary Bramble (AES), George Schewe (Trinity)
From: Brian Otten (Trinity)
Date: 18 September 2015
RE: Modeling Memorandum #1 – AES (DP&L) CEMS Data Processing for SO₂ NAAQS Designation Modeling for the Data Requirements Rule

Dayton Power & Light Company (referred to as DP&L herein) now part of AES Corporation (AES) in association with our air quality contractor, Trinity Consultants (Trinity), submits this supplemental information regarding the generation of hourly emissions for the air quality analysis to be performed with respect to DP&L's Stuart and Killen Stations and surrounding area. This work was undertaken in support of the Ohio Environmental Protection Agency (Ohio EPA) who is responding to the mandate for designating areas in Ohio under the final Data Requirements Rule¹ (DRR). The DRR presented a specific schedule for implementation and methods to model or monitor areas and facilities to allow the designation of all areas currently unclassified with respect to the 2010 1-hour SO₂ NAAQS. Part of that work on the part of OEPA is to use Continuous Emissions Monitoring System (CEMS) data to characterize actual emissions from 2012-2014 for sources subject to review. Stuart and Killen Stations are included in that consideration.

Specifically, to that end, DP&L has compiled the CEMS data for these years and has provided previously an hourly electronic file of emissions for each unit for 2012-2014². Some data hours and periods were missing for any number of reasons. For these missing hour(s) of measurement data, the values just before and just after the missing value (s) were used to interpolate an appropriate substitution value or a binning technique (explained below) was used. In this memorandum DP&L is submitting supplemental information to further explain the approach used to derive, fill, and report hour-by-hour modeled SO₂ emission rates for Stuart and Killen Stations. As specified by OEPA, these methods did not rely on the Part 75 methods. The methodology used was based, rather on the continuous emissions monitoring systems (CEMS) in place at each stack and boiler and the corresponding operating parameter monitoring data collected during the selected 3-year modeling period of January 1, 2012 through December 31, 2014. This approach is consistent with the guidance provided by the U.S. EPA in the modeling Technical Assistance Document³ which states that "the use of temporally varying actual emissions" are recommended for use in designation modeling. Each DP&L station is addressed below with similar techniques but with more robust treatment of Stuart due to more units and stacks.

¹ *Data Requirements Rule for the 2010 1-Hour Sulfur Dioxide (SO₂) Primary National Ambient Air Quality Standard (NAAQS)*, U.S. Environmental Protection Agency, signed by Administrator Gina McCarthy, August 10, 2015. Official version will be published in the Federal Register in the Fall 2015 at Regulations.gov (<http://www.regulations.gov>) in Docket No. EPA-HQ-OAR-2013-0711.

² 2015-0828 Stuart Emission files to OEPA.zip; Killen_CEMS_Data_Sub_Methodology_2015-0819.pdf; Killen_CEMS_Emission_Calculations_2015-0821.xlsx; Killen_Hourly_Emissions.hrl

³ *SO₂ NAAQS Designations Modeling Technical Assistance Document, Draft, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, December 2013.*

Killen Station has one unit and one stack. The single unit in operation at Killen Station (Unit 2) exhausts through the single stack at the facility. Thus, the treatment of Killen Station hourly emissions and related parameters was straightforward in terms of substitution and assignment to one stack. (No figure given herein for Killen).

Stuart Station, on the other hand, has four units each serviced by a flue in the combined main stack and an individual bypass dry stack per unit. Each unit at Stuart Station exhausts through a distinct stack during bypass operation. However, during normal operation, each boiler's exhaust is routed to a single stack (the wet stack) with four flues, each boiler having a distinct flue. This stack configuration is further illustrated in Figure 1 below. Due to the proximity of the normal operation flues (wet stack) to each other (less than one flue diameter apart in each case), their associated plumes will likely combine near the stack tip and an enhanced buoyancy plume will form. As such, additional calculations for plume combination are also used to define stack emissions and flows for a series of potential various configurations of "combined stacks" (one flue, two flues, three flues or four flues operating in a given hour). "Combined flues" in this wet stack are identified in the model and represent either two units in operation, three units in operation, or four units in operation with their equivalent diameters, flows, and emissions calculated with respect to the number in operation. These combined stacks are all located in the same location; the center point of the four flues.

Figure 1. Stuart Station Stack Configuration



DP&L has relied on CEMS data from Stuart and Killen Station directly with no alterations or refinements (apart from the applied substitution methodology for invalid or missing data). Specific details regarding the derivation

of the modeled hour-by-hour SO₂ emission rates for Stuart and Killen Station are presented in the following subsections with explicit references to the associated hourly emissions derivation spreadsheets submitted to the Ohio EPA on August 21, 2015 for Killen⁴ and August 28, 2015⁵ for Stuart.

DERIVATION OF MODELED EMISSION RATES

The CEMS data handling and acquisition system (DHAS) for each unit at Stuart and Killen Stations produces hourly average SO₂ emission rates (example - refer to column F of the *Unit 1 Wet* tab in the hourly emissions spreadsheet⁶) based on the measured SO₂ concentration and flow rate in the stack exhaust. Data can either be 1) valid, 2) missing, offline, or partially offline or 3) invalid. Valid hours are taken at face value in terms of the hourly emissions and flow rate. The following discussion focuses on Unit 1 at Stuart but the same discussion applies equally as well for Units 2, 3, and 4 at Stuart, and Unit 2 at Killen.

Valid: A total of the 26,304 hourly CEMS data points were collected over the 3-year period per unit at each station. For the example unit herein, these data include an hourly SO₂ emission rate data set for Unit 1 which has only 109 hours that were flagged by the DAHS as invalid and which would require substitution. Additional hours were flagged as missing, scrubber offline, or scrubber partially offline. Hence, “valid” data points (generally greater than 90% of the total) make up the remainder of the CEMS hourly emissions and stack parameters after discounting these invalid or missing values.

Missing, offline, or partially offline: these hours are flagged separately (refer to values of “1” in Column Q of the *Unit 1 Wet* tab in the hourly emissions spreadsheet) and are not the same as invalid data. These flags represent hours in which the DAHS indicated the hour as missing, offline, or partially offline due to an insufficient amount of valid data recorded for that hour. However, because a recorded data point exists for a large majority of these flagged hours, DP&L determined that these values are likely more representative of the actual boiler operations for a given hour than a substituted value and as such were generally included in the hourly emissions. One exception to that procedure is noted below for June 16, 2013.

Invalid: this type of data for an hour is the third type of data which was noted. These hours of data are flagged by the DAHS for each hour where an invalid reading was taken (refer to TRUE values in column G of the *Unit 1 Wet* tab in the hourly emissions spreadsheet). Invalid data periods are required to be filled with estimated SO₂ emission rates because actual emissions were potentially occurring during these events. Measurements were being taken during these hours but the CEMS may have been malfunctioning and thus, the emissions were not being measured and recorded properly for these hours. A comprehensive review of the hourly SO₂ emissions datasets for invalid hours for each unit generated by the DAHS, indicates two circumstances which require unique, data-substitution techniques. For periods of invalid data less than or equal to eight hours, a linear interpolation technique between valid hours was used. For periods of invalid data greater than eight hours, a binning technique was used. Each is described below.

Interpolation: Given the limited number and duration of invalid data periods of eight hours or less (approximately 50 hours of the Unit 1 Wet Stack emissions data set), DP&L chose a linear interpolation filling technique using the two good data points surrounding the invalid data period, rather than a more complex technique involving emission factors or use of peak values from a representative range of boiler operating

⁴ Killen_CEMS_Emission_Calculations_2015-0821.xlsx

⁵ STU_Unit1_CEMS_Emission_Calculations_2015-0828.xlsx

⁶ STU_Unit1_CEMS_Emission_Calculations_2015-0828.xlsx

conditions. This interpolation technique was performed using the FORECAST function in Microsoft® Excel. The first required field to execute this function is an invalid data period count (refer to column J of the *Unit 1 Wet* tab in the hourly emissions spreadsheet) that starts at 1 for the first invalid hour from an event and continues counting until a valid data point is encountered. The sequential integer list of invalid hours for each event defines the number of data points for which an interpolation calculation is required. For example, if three sequential data points were missing, the counter sets the first missing hour to 1, the second missing hour to 2, and the third missing hour to 3. The next field required for this function is the last good hour before the invalid data period starts and the first good hour after the invalid data period ceases. These SO₂ emission rates define the starting point and end point for the linear interpolation (refer to columns K & L of the *Unit 1 Wet* tab in the hourly emissions spreadsheet respectively). The final field required for the function is the range of invalid hours where a 0 flag is assigned to the position of the last good hour and to the next good value hour after the invalid period (see “Count Invalid Data Period Duration in Table 1). Table 1 provides an example of how the FORECAST function is applied to perform linear interpolation where “blue text” indicates data directly from the CEMS DAHS, “black text” indicates a calculated value, “green highlights” indicate a good data hour, and “orange highlights” indicate an invalid hour requiring substitution.

Table 1. Example of Invalid SO₂ Emissions Interpolation Technique

| Date | Unit 1 Stack Flowrate (Standard ft ³ /hr) | Unit 1 Flowrate Invalid Data Flag | Unit 1 Power Output (MW) | Unit 1 SO ₂ Emissions (lb/hr) | Unit 1 SO ₂ Emissions Invalid Data Flag | Interpolation Procedure | | | | | Unit 1 SO ₂ Emissions (lb/hr) |
|---------------|--|-----------------------------------|--------------------------|--|--|--|--------------------|----------------|--------------------|----------------|--|
| | | | | | | Count Invalid Data Period Duration (hrs) | Forecast Initial Y | Forecast End Y | Forecast Initial X | Forecast End X | |
| 02/26/2012 04 | 88,495,889 | FALSE | 600.3 | 83.7 | FALSE | 0 | 354.2 | 83.7 | 0 | 1 | 83.7 |
| 02/26/2012 05 | 87,503,137 | FALSE | 589.1 | 276 | TRUE | 1 | 83.7 | 479.4 | 0 | 3 | 215.6 |
| 02/26/2012 06 | 89,844,623 | FALSE | 604.1 | 283.4 | TRUE | 2 | 83.7 | 479.4 | 0 | 3 | 347.5 |
| 02/26/2012 07 | 89,697,189 | FALSE | 608.9 | 479.4 | FALSE | 0 | 83.7 | 479.4 | 0 | 1 | 479.4 |

In Table 1 the invalid data flag built into the DAHS indicates a 2-hour block of missing data occurred from 2/26/12 5:00AM until 2/26/12 at 7:00AM. The last good reading before the invalid data period starts (83.7 lb/hr) and the first good reading after the invalid ends (479.4 lb/hr) defines the bounds for the SO₂ emission rate interpolation (i.e., range of “Y” values). The starting “X” value for the interpolation is always set to the last good value hour (with a flag 0) and the ending “X” value is set to the next good value hour (one hour past the duration of the event (2 in this case). With these inputs, the results of the FORECAST function creates a smooth line of 2 data points connecting the last good hour before the event to the first good hour after the event. An identical approach was applied to all invalid hours in the SO₂ emissions data set.

Binning: In a small number of instances (approximately 59 hours of the Unit 1 Wet Stack emissions data set) the invalid data period will exceed eight hours in duration. Because boiler operation can vary somewhat significantly across this timeframe, DP&L elected to incorporate an additional substitution methodology henceforth referred to as “binning”. The binning procedure creates a table of values (Table 2), which represents the average CEMS data (emissions, flowrate, or temperature) over a certain range of power output(MW bin). Temperature specifically is limited to a subset of values for these binning averages since the parameter was not being recorded for the full three year dataset. These binned values are calculated on the basis of valid measured CEMS data for every hour, however binned values are only used as substituted values if the invalid data period exceeds eight hours in duration as indicated in Table 3.

In summary, data is substituted with one of three datasets: the original recorded data, the interpolated dataset, or the binned dataset. If the invalid hour is identified as missing/partially offline/offline, then the recorded data is used as the substituted value. This was true for all applicable periods of time except the June 16, 2013, hours 13:00-16:00 where the substitution had been made using 40 CFR Part 75 methods which resulted in extremely high hourly emissions. Given that hourly data were available, these data were thought to better represent these hours rather than the maximum, pre-invalid hour values.

Otherwise, the interpolated data set is used for substitution during invalid data periods fewer than or equal to 8 hours in duration and the binned data set is used for substitution during invalid data periods longer than 8 hours in duration. This selection procedure is outlined in Table 4 with recorded data selection highlighted green, the interpolation dataset selection highlighted as blue, and the binned dataset selection highlighted as yellow.

Table 2. Example of Averaging Bins for SO₂ Emissions Binning Technique

| MW Bin Start | MW Bin End | Average SO₂ Emission Rate (lb/hr) | Average Temperature (F) | Average Flowrate (scfh) |
|---------------------|-------------------|---|--------------------------------|--------------------------------|
| 0 | 50 | 66.3 | 94.5 | 46,799,318 |
| 50 | 100 | 116.9 | 92.4 | 50,162,343 |
| 100 | 150 | 272.6 | 105.6 | 46,915,507 |
| 150 | 200 | 208.4 | 111.5 | 48,789,671 |
| 200 | 250 | 266.9 | 106.8 | 52,052,802 |
| 250 | 300 | 471.4 | 114.4 | 57,822,976 |
| 300 | 350 | 410.5 | 120.3 | 65,293,304 |
| 350 | 400 | 500.7 | 123.2 | 71,214,416 |
| 400 | 450 | 543.7 | 123.7 | 78,698,904 |
| 450 | 500 | 611.3 | 125.4 | 83,028,791 |
| 500 | 550 | 704.1 | 124.2 | 89,163,333 |
| 550 | 600 | 649.2 | 126.1 | 91,946,525 |
| 600 | 650 | 756.7 | 123.4 | 93,417,148 |

Table 3. Example of Invalid SO₂ Emissions Binning Technique

| Date | Unit 1 Stack Flowrate (Standard ft ³ /hr) | Unit 1 Flowrate Invalid Data Flag | Unit 1 Power Output (MW) | Unit 1 SO ₂ Emissions (lb/hr) | Unit 1 SO ₂ Emissions Invalid Data Flag | Count Invalid Data Period Duration (hrs) | Binned DataSet |
|---------------|--|-----------------------------------|--------------------------|--|--|--|--|
| | | | | | | | Unit 1 SO ₂ Emissions (lb/hr) |
| 12/05/2013 13 | 37,357,519 | FALSE | 224.4 | 427.3 | TRUE | 1 | 266.9 |
| 12/05/2013 14 | 21,637,685 | FALSE | 224.8 | 247.5 | TRUE | 2 | 266.9 |
| 12/05/2013 15 | 86,059,234 | FALSE | 225.1 | 984.3 | TRUE | 3 | 266.9 |
| 12/05/2013 16 | 82,207,683 | FALSE | 278.8 | 940.2 | TRUE | 4 | 471.4 |
| 12/05/2013 17 | 85,400,274 | FALSE | 445.9 | 976.8 | TRUE | 5 | 543.7 |
| 12/05/2013 18 | 88,931,374 | FALSE | 540.6 | 1017.1 | TRUE | 6 | 704.1 |
| 12/05/2013 19 | 88,870,277 | FALSE | 548.2 | 1016.4 | TRUE | 7 | 704.1 |
| 12/05/2013 20 | 89,012,377 | FALSE | 551.8 | 1018.1 | TRUE | 8 | 649.2 |
| 12/05/2013 21 | 88,818,676 | FALSE | 548.9 | 1015.9 | TRUE | 9 | 704.1 |
| 12/05/2013 22 | 89,293,816 | FALSE | 550.3 | 1021.3 | TRUE | 10 | 649.2 |
| 12/05/2013 23 | 89,174,287 | FALSE | 549.2 | 1019.9 | TRUE | 11 | 704.1 |
| 12/06/2013 00 | 88,530,457 | FALSE | 547.6 | 1012.6 | TRUE | 12 | 704.1 |
| 12/06/2013 01 | 86,374,655 | FALSE | 525.7 | 987.9 | TRUE | 13 | 704.1 |
| 12/06/2013 02 | 89,502,517 | FALSE | 550.3 | 1023.7 | TRUE | 14 | 649.2 |
| 12/06/2013 03 | 89,443,351 | FALSE | 548.5 | 1023 | TRUE | 15 | 704.1 |
| 12/06/2013 04 | 91,532,141 | FALSE | 567.4 | 1046.9 | TRUE | 16 | 649.2 |

Table 4. Example of Invalid SO₂ Emissions Substitution Dataset Selection

| Date | Unit 1 SO ₂ Emissions (lb/hr) | Unit 1 SO ₂ Emissions Invalid Data Flag | Interpolation DataSet | Binned DataSet | Unit 1 SO ₂ Emissions (lb/hr) | Unit 1 SO ₂ Emissions (lb/hr) | Missing or Offline Due to Few Data Points for That Hour | Final Substituted SO ₂ Emissions Data Set (lb/hr) |
|---------------|--|--|--|--|--|--|---|--|
| | | | Count Invalid Data Period Duration (hrs) | Unit 1 SO ₂ Emissions (lb/hr) | | | | Final Substituted SO ₂ Emissions Data Set (lb/hr) |
| 03/07/2012 05 | 642 | TRUE | 1 | 629.5 | 704.1 | 0 | 629.5 | |
| -- | -- | TRUE | -- | -- | -- | -- | -- | |
| 05/12/2012 05 | 445.2 | TRUE | 1 | 452.2 | 611.3 | 0 | 611.3 | |
| 05/12/2012 06 | 465 | TRUE | 2 | 457.2 | 611.3 | 0 | 611.3 | |
| 05/12/2012 07 | 510.2 | TRUE | 3 | 462.3 | 649.2 | 0 | 649.2 | |
| 05/12/2012 08 | 488.2 | TRUE | 4 | 467.3 | 649.2 | 0 | 649.2 | |
| 05/12/2012 09 | 487 | TRUE | 5 | 472.3 | 649.2 | 0 | 649.2 | |
| 05/12/2012 10 | 492.2 | TRUE | 6 | 477.3 | 649.2 | 0 | 649.2 | |
| 05/12/2012 11 | 491.3 | TRUE | 7 | 482.3 | 649.2 | 0 | 649.2 | |
| 05/12/2012 12 | 491.5 | TRUE | 8 | 487.4 | 649.2 | 0 | 649.2 | |
| 05/12/2012 13 | 494.8 | TRUE | 9 | 492.4 | 649.2 | 0 | 649.2 | |
| -- | -- | TRUE | -- | -- | -- | -- | -- | |
| 05/31/2012 05 | 398.1 | TRUE | 1 | 397.0 | 611.3 | 0 | 397.0 | |
| -- | -- | TRUE | -- | -- | -- | -- | -- | |
| 06/04/2012 17 | 862.9 | TRUE | 1 | 439.4 | 649.2 | 1 | 862.9 | |
| 06/04/2012 18 | 860.5 | TRUE | 2 | 433.8 | 649.2 | 1 | 860.5 | |
| 06/04/2012 19 | 854.2 | TRUE | 3 | 428.3 | 649.2 | 1 | 854.2 | |

Flowrates and Temperatures: An identical substitution methodology is applied to the flowrates during normal operating conditions (wet stacks at Stuart). However, because limited temperature data was available, the temperature data is exclusively composed of binned values for this modeling analysis for all wet stacks at Stuart Station. Additionally, this same methodology is applied to the Killen station CEMS data with one minor alteration. Killen flowrate and emissions are sometimes recorded as negative values by the DAHS. Because these values are invalid data points and the negative data only occur when the stack is not in operation, these values are substituted with a value of zero in the final emissions dataset.

The Stuart bypass stack CEMS data is also substituted with an identical methodology, apart from two additional conditions to account for the relatively high emission rates exhibited by the bypass stacks during operation and the sometimes limited duration of stack operation. The first condition was to check prior to an hour being substituted with a binned value to determine whether the stack was in operation for that hour (refer to column H of the *Unit 1 Wet* tab in the hourly emissions spreadsheet). Because historically the binned bypass emissions are somewhat significant, this condition is necessary to ensure the substitution is appropriate for the data period (i.e. the stack was actually operating for the hours being substituted). A second condition is added prior to the interpolation dataset being selected for substitution at the bypass stacks. Because the bypass stacks could potentially be operated for a duration of fewer than 8 hours (in other words were not operating at all prior to operating), the interpolated dataset will mistakenly indicate the interpolated emissions/flowrate during those hours should be zero (as indicated in Table 5 below). If this circumstance occurs in the CEMS data, then interpolated emissions will not be selected as the substitution for the final data set, but rather the binned values will be selected for substitution (also indicated in Table 5 below). An identical methodology is also applied to the flowrate and temperature for all Stuart bypass CEMS data.

Table 5. Example of Invalid SO₂ Emissions Binned Dataset Selection

| Date/Hour | Unit 1 SO ₂ Emissions (lb/hr) | Unit 1 SO ₂ Emissions Invalid Data Flag | Operating Duration (min) | Count Invalid Data Period (hrs) | Interpolation Procedure | | | | Unit 1 SO ₂ Emissions (lb/hr) | Binned DataSet Unit 1 SO ₂ Emissions (lb/hr) | Final Substituted SO ₂ Emissions Data Set (lb/hr) |
|---------------|--|--|--------------------------|---------------------------------|-------------------------|----------------|--------------------|----------------|--|---|--|
| | | | | | Forecast Initial Y | Forecast End Y | Forecast Initial X | Forecast End X | | | |
| 01/09/2012 17 | 0 | FALSE | 0 | 0 | 49.3 | 0 | 0 | 1 | 0 | 3,016 | 0 |
| 01/09/2012 18 | 10,286 | TRUE | 48 | 1 | 0 | 0 | 0 | 6 | 0 | 3,016 | 3,016 |
| 01/09/2012 19 | 10,303 | TRUE | 60 | 2 | 0 | 0 | 0 | 6 | 0 | 3,016 | 3,016 |
| 01/09/2012 20 | 10,314 | TRUE | 60 | 3 | 0 | 0 | 0 | 6 | 0 | 3,016 | 3,016 |
| 01/09/2012 21 | 10,345 | TRUE | 60 | 4 | 0 | 0 | 0 | 6 | 0 | 3,016 | 3,016 |
| 01/09/2012 22 | 8,644 | TRUE | 31 | 5 | 0 | 0 | 0 | 6 | 0 | 3,016 | 3,016 |
| 01/09/2012 23 | 0 | FALSE | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3,016 | 0 |

This concludes the conditions under which the CEMS data substitution for DP&L Stuart and Killen stations is applied. These conditions are further summarized in a series of flowcharts previously relayed to Ohio EPA on August 28th and August 21st for Stuart and Killen stations, respectively. Additional clarification can be provided upon request from Ohio EPA or through written/verbal communications with Trinity Consultants.