

DNR Suggested Methodology for Modeling Restricted Hours of Operation

Construction permit applicants frequently request (or are asked) to implement operating hour restrictions on one or more sources at a facility. This document addresses how to characterize emission sources with restricted hours of operation in an air dispersion modeling analysis for both daily and annual operating restrictions. Several options are available and the option selected will depend on the needs of the facility and on how much flexibility the facility wishes to retain in their construction permits. Note that any operating restrictions used in the modeling analyses will be reflected in the corresponding construction permits.

Special Conditions for Modeling of PM_{2.5}

Meteorological Data - The determination of a facility's compliance with the National Ambient Air Quality Standards (NAAQS) typically requires the use of 5 years of meteorological data. Depending on the form of the NAAQS, either 5 individual years are modeled, with results obtained for each year, or all 5 years are concatenated (combined or linked together) to obtain one set of results for the entire 5 year period as is the case for both annual and 24-hour PM_{2.5}.

However, it should be noted that there is an exception to using a concatenated data set when determining compliance with the annual PM_{2.5} NAAQS *and* there is an annual limitation on operating hours for the source(s) in which averaging times of month or 24-hours are used. **This exception only applies to the use of Option 3, Long-Term Averaging Periods for modeling of annual PM_{2.5}.** While a concatenated data set may be used (since, in this case, it will yield a conservative result), individual year meteorological data sets need to be used to determine the average over 5 years. AERMOD will not yield 5-year average monthly or 24-hour concentration values using a concatenated data set, but will instead yield the highest monthly or 24-hour concentration values ordered by rank as determined by the RECTABLE and MAXTABLE keywords.

Background Data – Throughout Options 3 and 4 below, the equations listed refer to the addition of a background concentration (“+ background”). This “+ background” refers to the single default background concentrations referenced on the DNR website. However, daily PM_{2.5} background data is provided by the DNR on the website for use in the “paired-sums” approach (pairing daily PM_{2.5} background concentration with each model predicted concentration) when modeling 24-hour PM_{2.5}. Please note, the single default background concentration should always be used when modeling annual PM_{2.5}.

If the construction permit applicant chooses to use the daily PM_{2.5} background data files for modeling 24-hour PM_{2.5} and wishes to implement operating restrictions on one or more sources at their facility, the DNR recommends the use of Option 5 only in this situation. The use of the “paired-sums” approach for 24-hour PM_{2.5} is not appropriate with the use of Option 3 and 4. Applying the equations in Option 3 and 4 to ratio the model predicted concentrations would result in the background concentrations being inappropriately ratioed as well when the paired-sums approach is used. Option 5, however, avoids this issue by inputting the operating restriction(s) into the modeling program where it can be incorporated into the predicted concentration separate from being paired with the daily background value.

Option 1 – Continuous Hours of Operation

There are situations where a facility may elect to have an operating limit to remain a minor facility or to avoid triggering a Prevention of Significant Deterioration (PSD) review. As a conservative

estimate, the modeling analysis can be conducted with the default averaging periods applicable to the pollutants being evaluated. Provided that the modeling results in predicted concentrations below the NAAQS, then no operating hour restrictions are required for modeling purposes.

Option 2 – Specific Hours of Operation

If the applicant knows that a source or sources will only operate during specific times of the day or the year, then the model can be set up so that any combination of sources, or the entire facility, will only operate during those specific times (i.e. 6 AM to 6 PM, Dec. 1st to Feb. 29th). In order to accomplish this, select all applicable averaging periods for the pollutant(s) being modeled, and utilize the emission scaling factors ("EMISFACT" keyword in the SO pathway) for each source for which the restriction(s) will apply.

There are several different types of scaling factors that can be used:

SEASON:	Emission rates vary seasonally
MONTH:	Emission rates vary monthly
HROFDY:	Emission rates vary by hour of the day
SEASHR:	Emission rates vary by season and hour of day
SHRDOW:	Emission rates vary by season, hour of day and day of week (M-F, Sat, Sun)
SHRDOW7:	Emission rates vary by season, hour of day and the seven days of the week
MHRDOW:	Emission rates vary by month, hour of day and day of week (M-F, Sat, Sun)
MHRDOW7:	Emission rates vary by month, hour of day and the seven days of the week

The scaling factors appear in the input file as a series of digits following a descriptive keyword (as shown above). The first digit always represents the first block of time during the period. For example, the 1st digit in the "hour of day" scaling factor represents the hour block ending at 1 a.m., and the 24th (last) digit represents the hour block ending at midnight. In the "season" scaling factor, winter represents December, January and February, spring represents March April and May, summer represents June, July and August, and fall represents September, October and November.

To apply an operating restriction using the scaling factors, the hourly emission rate from the source is turned on and off by multiplying them by one (on) or zero (off). A scaling factor of "1" should be placed in the time periods in which the source will operate, and a scaling factor of "0" should be placed in the time periods in which the source will not operate. For hourly scaling factors (HROFDY, SHRDOW, SHRDOW7, MHRDOW and MHRDOW7), a value between zero and one may be used to denote that the source will only operate for a portion of the hour (i.e. "0.5" would be used for half an hour of operation).

Note that the construction permit will include a condition that specifies the start and end time of the operation period for each source for which the scaling factors were used in the modeling analysis. This permitting requirement can be found in Appendix W of 40 CFR Part 51.

Example

An applicant wishes to limit a new paint booth to only operate during the first 8-hour shift of each day (8:30 a.m. to 4:30 p.m.). The "hour of day" scaling factor should appear as follows (note that the scaling factors may be carried to a separate line in the input file):

SO	EMISFACT	PAINTBTH	HROFDY	0	0	0	0	0	0	0	0	0.5	1	1	1
SO	EMISFACT	PAINTBTH	HROFDY	1	1	1	1	0.5	0	0	0	0	0	0	0

Option 3 – Operation During Any Period of the Day or Year

Not all facilities can restrict the operations of one or more sources to a specified time period, as discussed in Option 2. Option 3 applies to facilities with operating time period restrictions that do not specify a specific start or end time. As such, it provides a method to calculate impacts without averaging modeled emissions across non-operating time periods, which is prohibited in Appendix W of 40 CFR Part 51. Option 3, while more labor intensive for the modeler, provides the facility with more operating flexibility than does Option 2. The method for conducting such an analysis is different for short and long-term averaging periods. These methods are described below.

NOTE: The methods described below for determining the short-term NAAQS impact are applied to ranked standards using individual years of meteorological data as well as to probabilistic standards like the 24-hour PM₁₀ NAAQS or PM_{2.5} NAAQS where multiple years are evaluated in the model.

Short-Term Averaging Periods (Daily Hours Operating Restrictions)

For short-term averaging periods in Option 3, model averaging times should be selected that equal the requested operating time period length (i.e. if the applicant requests a limit of 12 hours per day, select the 12-hour averaging period in the model). If the requested operating time period does not match a selectable model averaging period, the two averaging periods that occur as close as possible to either side of the requested daily operating time period should be selected (i.e. if the applicant requests a limit of 16 hours per day, select the 12-hour and 24-hour averaging periods).

There are three separate methods to evaluate this option, with increasing levels of sophistication. The method used to calculate the result depends on whether or not the operating restriction matches a model-selectable averaging period, and also whether or not all sources will be restricted to a single operating restriction, or if there will be multiple operating restrictions.

Option 3a – Operating period equals a model-selectable averaging period

Facility-Wide Limit Scenario

Suppose that an entire facility will be restricted to operating during any 12-hour period of the day in a NAAQS analysis. The facility's emissions would be modeled with a "12" for the parameter of the "AVERTIME" keyword on the CO pathway. The resulting highest-second-highest (H2H) 12-hour impact is then ratioed to an equivalent H2H 24-hour impact using the following equation:

$$\left(\frac{12}{24}\right) 12hr_{H2H} + \text{background} = 24hr \text{ NAAQS impact}$$

Similarly, when evaluating PM₁₀ or PM_{2.5} concentrations over 5 years of meteorological data, the 12-hour impact is ratioed to an equivalent 24-hour impact using the highest-sixth-high (H6H) or highest-eighth-high (H8H) value, respectively.

When evaluating for significant impact, the H1H value is used:

$$\left(\frac{12}{24}\right)12\text{hr}_{H1H} = 24\text{hr significance impact}$$

Multiple Limits Scenario

Suppose that a facility has some sources that may be allowed to operate 24 hours per day while other sources may be limited to some time period less than 24 hours. In these instances, source grouping can be used to produce impacts for the “24-hour sources” and the “less than 24-hour sources”. As an example, the “24-hour sources” are identified as source group A and the “less than 24-hour sources” are identified as source group B. Using 12 hours of operation as the operating period for the “less than 24-hour sources”, the resulting H2H 24-hour impact from group A and the highest-*first*-high (H1H) 12-hour impact from group B are then ratioed to an equivalent total H2H 24-hour impact as follows:

$$\left(\frac{24}{24}\right)24\text{hr A}_{H2H} + \left(\frac{12}{24}\right)12\text{hr B}_{H1H} + \text{background} = 24\text{hr NAAQS impact}$$

Note four things; first, that the two impacts may, and generally will, occur at a different receptor and a different time; second, 24-hour A impact in the above equation is a 24-hour impact and therefore does not change when ratioed; third, this methodology averages the predicted impacts, *and not the emissions*, across non-operating periods; and fourth, that the H1H 12-hour value is used instead of the H2H in this case. The reason for this is that the analysis must not omit the possibility that the impacts from group A and group B could occur at the same time and place. In other words, if the H2H value were to be used instead, it would be possible that the impact from group B at the worse case receptor would be missed (i.e., the H1H impact). Thus, for coincident impacts, the facility’s H2H impact at the worst case receptor is the sum of the (ratioed) H2H value from group A and the (ratioed) H1H value from group B.

Similarly, when evaluating PM₁₀ or PM_{2.5} concentrations over 5 years of meteorological data, the group A impact uses the ratioed highest-sixth-high (H6H) or highest-eighth-high (H8H) value, respectively.

When evaluating for significant impact, always use the H1H value:

$$\left(\frac{24}{24}\right)24\text{hr A}_{H1H} + \left(\frac{12}{24}\right)12\text{hr B}_{H1H} = 24\text{hr significance impact}$$

Option 3b – Operating period does not equal a model-selectable averaging period

Some facilities may have sources that need operating period length restrictions that do not equal an averaging period that can be selected in the model. A 16-hour per day restriction is an example. In these cases, the averaging periods on either side of the requested operating period length should be modeled. The resulting impacts would then be weighted and added together, and then ratioed to a 24-hour averaging period.

Facility-Wide Limit Scenario

Suppose the facility source will be limited to operating a maximum of 16 hours during a 24-hour period. Select "12" and "24" for the parameter of the "AVERTIME" keyword on the CO pathway. The resulting H2H 12-hour and H2H 24-hour modeled impacts are then weighted, combined, and ratioed to a 24-hour averaging period using the following equation:

$$\left(\frac{16}{24}\right)\left[\left(\frac{2}{3}\right)12\text{hr}_{H2H} + \left(\frac{1}{3}\right)24\text{hr}_{H2H}\right] + \text{background} = 24\text{hr NAAQS impact}$$

The 12-hour impact is given proportionately more weight in the above equation since it is closer to the desired 16-hour operating period than the 24-hour impact.

Similarly, when evaluating PM₁₀ or PM_{2.5} concentrations over 5 years of meteorological data, the 12-hour and 24-hour impacts use the highest-sixth-high (H6H) or highest-eighth-high (H8H) values, respectively.

When evaluating for significant impact, the H1H value is used:

$$\left(\frac{16}{24}\right)\left[\left(\frac{2}{3}\right)12\text{hr}_{H1H} + \left(\frac{1}{3}\right)24\text{hr}_{H1H}\right] = 24\text{hr significance impact}$$

The weighted average is calculated using the following generalized equation:

$$\left(\frac{|AP_L - AP_R|}{AP_L - AP_S}\right)(AP_S \text{ hr impact}) + \left(\frac{|AP_S - AP_R|}{AP_L - AP_S}\right)(AP_L \text{ hr impact})$$

...where AP_L is the larger averaging period in hours, AP_S is the smaller averaging period, and AP_R is the averaging period for which the restriction will apply (in the above example these are 24 hours, 12 hours and 16 hours respectively).

Multiple Limits Scenario

Suppose that a facility will have several sources that will operate 24 hours per day and several that will operate for only 16 hours per day. The sources that will operate for 24 hours per day can be grouped in a "24-hour source group", identified as A for this example, and the sources that will only operate 16 hours per day can be grouped together in a "16-hour source group", identified as "B" for this example. Select "12" and "24" for the parameter of the "AVERTIME" keyword on the CO pathway. The resulting impacts for each averaging period and source group can then be combined as demonstrated in the equation below:

$$\left(\frac{24}{24}\right)24\text{hr}_A_{H2H} + \left(\frac{16}{24}\right)\left[\left(\frac{2}{3}\right)12\text{hr}_B_{H1H} + \left(\frac{1}{3}\right)24\text{hr}_B_{H1H}\right] + \text{background} = 24\text{hr NAAQS impact}$$

Similarly, when evaluating PM₁₀ or PM_{2.5} concentrations over 5 years of meteorological data, the group A impact uses the ratioed highest-sixth-high (H6H) or highest-eighth-high (H8H) value, respectively.

When evaluating for significant impact, always use the H1H value:

$$\left(\frac{24}{24}\right)24\text{hr}_A_{H1H} + \left(\frac{16}{24}\right)\left[\left(\frac{2}{3}\right)12\text{hr}_B_{H1H} + \left(\frac{1}{3}\right)24\text{hr}_B_{H1H}\right] = 24\text{hr significance impact}$$

Option 3c – Spatial and Temporal Considerations

Implied in the above equations is the assumption that the 12-hour and 24-hour impacts for a source or source groups occur at the same receptor and on the same day. In practice, this is rarely the case due to differences in emission point locations and release parameters. If the above methodology fails to demonstrate compliance with the applicable 24-hour NAAQS, then additional refinement of the results is necessary.

As a first step, the applicable impacts for the source or source groups can be added together on a like-receptor basis, ignoring whether or not the impacts occurred on the same day. This can be accomplished by using model output plot files imported into a spreadsheet program.

Plot Files:

Lists the user-defined concentration at every receptor for a single source group. For example, a plot file could be generated with the H2H 24-hour concentration at each receptor (only one concentration is reported per receptor). Multiple plot files can be used to determine the spatial interaction of two or more source groups. Plot files can also be used to screen out receptors before going to an additional level of detail with a post file.

If this does not resolve all predicted exceedances, then the receptors where exceedances are still predicted to occur can be rerun in the model to generate a post file. The post file can then be imported into a spreadsheet program where the sources and source groups can be combined on a like-receptor and like-time basis.

Post Files:

Lists every concentration at every receptor for a given averaging period and source group. For example, a post file could be generated that lists all 365 24-hour concentrations that were calculated for all 100 receptors in a modeling analysis. Multiple post files can be used to determine the spatial and temporal interaction of two or more source groups.

Special note on post files: while they are the most powerful form of output, their level of detail inherently limits their usefulness. The output from these files is generally imported into Excel. Excel has a limit of 1,048,576 rows. This effectively limits the size of a modeling analysis to 2864 receptors for 24-hour output to a post file ($366 * 2864 = 1,048,224$ rows), and as little as 119 receptors for 1-hour output ($8784 * 119 = 1,045,296$ rows).

If these additional refinements to Option 3 do not mitigate the predicted exceedances, then additional options, such as emission controls, stack changes, operational changes, or additional operating restrictions, will need to be considered to demonstrate modeled attainment with the NAAQS.

Long-Term Averaging Periods (Annual Hours Operating Restrictions)

If annual hours limitations are to be implemented without regard to season or month, and the annual hours are greater than 364, the annual hours of operation is divided by 730 hours, and the result rounded to the nearest integer. Monthly averaging periods will then be modeled and the predicted concentrations from the highest months will be averaged. The number of months to include in the average is given by the integer from the previous calculation. The average predicted monthly concentration is then multiplied by the number of hours/year of operation to which the emission unit will be limited and divided by 8760 hours. The result is the annual average concentration. This procedure should be performed for each of the five years of the meteorological data set.

Suppose that an entire facility will be limited to operating a maximum of 2000 hours during a year. Dividing 2000 by 730 equals 2.7, which when rounded to the nearest integer equals 3. Select "Month" as a parameter of the "AVERTIME" keyword on the CO pathway, and then select "MONTH" and "3" as the parameters for the "MAXTABLE" keyword on the OU pathway. The resulting three highest modeled impacts are then averaged, and ratioed to an annual averaging period using the following equation:

$$\left[\left(\frac{2000}{8760} \right) \left(\frac{\text{Month}_{1H} + \text{Month}_{2H} + \text{Month}_{3H}}{3} \right) \right] + \text{background} = \text{Annual NAAQS impact}$$

This same equation can be used for evaluating the NAAQS as well as significance because the Monthly averages are the highest values.

If the annual number of hours to which the emission unit is to be limited is less than 365, the same procedure is used, replacing 730 hours with 24 hours and using the highest 24-hour averages rather than monthly averages.

Suppose that an entire facility will be limited to operating a maximum of 150 hours during a year. Dividing 150 by 24 equals 6.25, which when rounded to the nearest integer equals 6. Select "24" as a parameter of the "AVERTIME" keyword on the CO pathway, and then select "24" and "6" as the parameters for the "MAXTABLE" keyword on the OU pathway. The resulting six highest modeled impacts are then averaged, and ratioed to an annual averaging period using the following equation:

$$\left[\left(\frac{150}{8760} \right) \left(\frac{24\text{hr}_{1H} + 24\text{hr}_{2H} + 24\text{hr}_{3H} + 24\text{hr}_{4H} + 24\text{hr}_{5H} + 24\text{hr}_{6H}}{6} \right) \right] + \text{background} = \text{Annual NAAQS impact}$$

A similar method can be used in cases where only a portion of the sources at a facility will have annual hours operating restrictions.

Suppose that a generator at a facility will be limited to operating a maximum of 1500 hours during a year, but the remainder of the sources at the facility will not be limited in their hours of operation. Dividing 1500 by 730 equals 2.05, which when rounded to the nearest integer equals 2. Select "Month" and "Annual" as parameters of the "AVERTIME" keyword on the CO pathway, and then select "MONTH" and "2" as the parameters for the "MAXTABLE" keyword on the OU pathway. Divide the facility into two source groups: the first including only the generator (A), and the second including the remainder of the facility (B). The resulting two highest modeled impacts from the A source group are then averaged, and ratioed to an annual averaging period and then added to the annual average from the remainder of the facility using the following equation:

$$\left[\left(\frac{1500}{8760} \right) \left(\frac{\text{Month A}_{1H} + \text{Month A}_{2H}}{2} \right) \right] + \text{Annual B} + \text{background} = \text{Annual NAAQS impact}$$

Option 4 – Any Period During a Specific Time of Day or Year

In some cases it may be beneficial to blend options 2 and 3. For instance, a facility operates 16 hours per day (8 AM – 12 PM), and never operates between midnight and 8 AM. The best way to account for this is to use scaling factors by setting the HROFDY scaling factor for all sources at the facility to 8 AM – 12 PM (see Option 2). Now assume that there is a source at this facility that will only operate for 2 hours each 16-hour day, but not necessarily on a set schedule. The facility is already restricted to operating between 8 AM and midnight, but this particular source does not need that much flexibility, so Option 3 can be used at the same time. Include the sources that will operate, *with scaling factors applied*, 24 hours per day in one source group (A), and include the source that will only operate for 2 hours per day in its own source group (B). Then include both

the 2-hour (H1H) and 24-hour (H2H) averaging periods in the modeling analysis. After the model has executed it will return concentrations that account for both -- the limited operation of the 2-hour source (represented in the 2-hour averaging period output for the 2-hour source's source group) and the entire facility's lack of operation from midnight to 8am (represented in the 24-hour averaging period output for the other sources, with scaling factors applied). Now the same equations from Option 3 can be applied to determine the final result.

$$\left(\frac{24}{24}\right)24\text{hr A}_{H2H} + \left(\frac{2}{24}\right)2\text{hr B}_{H1H} + \text{background} = 24\text{hr NAAQS impact}$$

Similarly, when evaluating PM₁₀ or PM_{2.5} concentrations over 5 years of meteorological data, the group A impact uses the highest-sixth-high (H6H) or highest-eighth-high (H8H) value, respectively.

When evaluating for significant impact, the H1H value is used:

$$\left(\frac{24}{24}\right)24\text{hr A}_{H1H} + \left(\frac{2}{24}\right)2\text{hr B}_{H1H} = 24\text{hr significance impact}$$

There are two rules that must be followed when using this methodology:

- 1) The block of time included in the scaling factors must be evenly divisible by each averaging period used in the analysis (if the scaling factors include a 16-hour period, then 1, 2, 4 and 8-hour averaging periods may be used, but not 3, 6 or 12-hour averaging periods).
- 2) No block average may overlap the beginning or end of the period of time included in the scaling factors (if the scaling factors are from 8 AM to midnight, then 1, 2, 4 and 8-hour averaging periods may be used, but not 3, 6 or 12-hour averaging periods).

The reason for these rules is to avoid an instance in which only part of a block average is calculated. If 6-hour averages were used in the above example, the 6 AM - noon block would include two hours with zero concentration (hour 6 and 7, which are both outside of the 8 AM - midnight time period included in the scaling factors), resulting in reduced average concentrations for that block. This limitation is the result of the fact that the NAAQS and the models are designed around block averages instead of running averages.

Option 5 – A Hybrid Method for Daily Operating Hours

There is also a method that combines the elements of Option 2 (specific hours of daily operation) and Option 3 (any period of operation during the day) to provide a less conservative method for modeling an “any time of day” style operating restriction. By appropriate source grouping, the various combinations of possible operating times can be combined and the worst-case result evaluated.

Example:

There are three groups of sources: one group may operate 8 hours/day, another group 12 hours/day, and a third group that operates continuously.

For the 8 hr/day group, three possible time blocks are chosen: midnight - 8 am, 8 am - 4 pm, and 4 pm – midnight. Thus for the 8-hr sources there will be three of each source in the model, each of the three collocated with the same input parameters, except their emission factors (see Option 2 above) will reflect their period of operation during the day. For the 12 hr/day group, two possible time

blocks are chosen: midnight - noon, and noon - midnight. For each of the 12-hr sources there will be two sources in the model, differentiated only by their respective emission factors. Each continuously operating source is added as normal.

Then source groups are created for each possible combination of 8, 12, and 24-hr groups of sources. In this case there are six possible combinations:

SRCGROUP A: 8-hr A, 12-hr A, 24-hr
SRCGROUP B: 8-hr A, 12-hr B, 24-hr
SRCGROUP C: 8-hr B, 12-hr A, 24-hr
SRCGROUP D: 8-hr B, 12-hr B, 24-hr
SRCGROUP E: 8-hr C, 12-hr A, 24-hr
SRCGROUP F: 8-hr C, 12-hr B, 24-hr

The combination with the highest predicted results is then evaluated for compliance. This is a somewhat less conservative method than the “any period of the day” method used in Option 3, but with built-in flexibility similar to Option 3. Thus, in some cases, this hybrid method may be an option that makes it possible to achieve compliance when it is not possible using the conventional method of Option 3. The disadvantages are that, since sources are replicated, the model setup and run times are increased. It may also be unwieldy if there are many operating restrictions at the facility, or if the operating restrictions are of shorter time periods (thus requiring more time blocks, and combinations thereof).

Note that the time blocks have great flexibility since each source with a daily restriction is given its own emission factors. Time blocks can be of any integral number of hours evenly divisible into 24 (the allowable time blocks are the same as the available averaging periods in the model: 1, 2, 3, 4, 6, 8, 12 and 24 hours).