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**Trip Length Activity Factors for Running Loss and
Exhaust Running Emissions**

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1.0 INTRODUCTION

MOBILE6 will compute and report (as a user option) hourly emission factors for start, running, and evaporative emissions. These will be in addition to the standard daily emission estimates which are currently calculated by MOBILE5. The hourly emission factors will allow the MOBILE6 model to provide more precise output that accounts for the time of day that vehicle emissions occur. The temporal distribution of emissions is an important factor in the formation of diurnal evaporative and start emissions.

The hourly emission estimates require considerable vehicle activity information and analysis. The term "activity" refers to the vehicle's operating mode such as running, idling, parked (soaking), etc. The specific activity information includes soak durations, time of soak, trip lengths, time of trip, and other information. This document (M6.FLT.005) discusses the issue of vehicle run time as it pertains to running loss emissions and exhaust emissions. Other activity estimates needed to develop daily emission factors for hot soak, diurnal, start or resting loss emissions will be documented in other MOBILE6 documents listed with the report numbers "M6.FLT.XXX."

2.0 DATA SOURCES USED

The primary data source for this analysis is an EPA instrumented vehicle study conducted in Baltimore and Spokane. In these studies, instrumentation to monitor vehicle usage was installed with the motorists' permission on 168 randomly selected vehicles while they were tested at an Inspection / Maintenance (I/M) station. The motorists returned one or two weeks later to have the instrumentation removed. Information from more than 8,500 vehicle-trips was recorded. The raw data collected from the study were processed by the Radian Corporation under EPA contract to create a "trip characteristics" file. This processed file was used to develop the hourly soak time distributions. For more details regarding the instrumented vehicle study and the data processing, please refer to the document "Travel Trip Characteristics Analysis" Final Report under EPA Contract 68-C1-0079 WA 2-05 with Sierra Research.

3.0 METHODOLOGY FOR RUNNING LOSS EMISSION ACTIVITY

This section describes the basic methodology to develop the trip length activity estimates used to calculate running loss emissions. The process consisted of several steps. These are discussed below.

3.1 Definitions

3.1.1 Running Loss Emissions

Running loss emissions are evaporative emissions which have escaped from a vehicle while the engine is operating. These emissions may appear from numerous locations on a vehicle such as the evaporative canister, the fuel inlet, the top of the gas tank, and other spots where the integrity of the evaporative system has broken down or the purge system has become inoperative. Running loss emissions may be an artifact of a particular evaporative system design or the result of poor maintenance. In severe cases the emissions can become quite high as the result of large thermal gradients around a vehicle's fuel and evaporative system. In addition, because of greater heating of the fuel and evaporative system on longer trips, running loss emissions are not constant throughout a trip. Instead, the rate is assumed to continually increase as a function of trip length until it reaches a plateau at a trip length of about 50 to 60 minutes.

3.1.2 Running Loss Trip

For the purpose of activity estimates for running loss emissions, a trip is defined as the duration of time or distance between a vehicle key on and key off (excluding engine stalls, which were removed from the database). Throughout this document the time duration of a trip will be referred to as the "trip time length". The duration of a trip in miles

will be referred to as the “trip distance length”.

3.2 Hourly Intervals

The 24 hour day was divided into 14 different hourly groups. Thirteen of these groups have a duration of one hour. These start at 6:00AM and run through 7:59:59PM. The fourteenth group contains the remaining nighttime hours as one interval. Collapsing these hours into one group was done for three reasons: (1) the emissions contributed during the night have a relatively smaller impact on daily ozone or CO formation than those contributed during the morning or day, (2) there were relatively little data for these time periods, and (3) what data were available produced results which showed very little hour to hour variance. The hourly intervals are shown in Table 1. In addition to their use for the running loss activity estimates presented here, the same hourly group intervals are used in the calculation of activity estimates for start emissions, running emissions, hot soak emissions, resting loss emissions, and diurnal emissions.

Table 1 <u>Hourly Ranges</u>		
Group Name	Hourly Range	Time
6	6 - 7	6 am to 7 am
7	7 - 8	7 am to 8 am
8	8 - 9	8 am to 9 am
9	9 - 10	9 am to 10 am
10	10 - 11	10 am to 11 am
11	11 - 12	11 am to noon
12	12 - 13	noon to 1 pm
13	13 - 14	1 pm to 2 pm
14	14 - 15	2 pm to 3 pm
15	15 - 16	3 pm to 4 pm
16	16 - 17	4 pm to 5 pm
17	17 - 18	5 pm to 6 pm
18	18 - 19	6 pm to 7 pm
24	19 - 24 and 24 - 5	7 pm to 6 am

3.3 Weekday Versus Weekend

For a number of the activity parameters a significant difference existed between the value for the weekday and the value for the weekend. Conceptually this make sense since most motorists have different usage patterns for their vehicles on weekdays than on weekends. Differences may also exist for the various days of the week; however, the database was too small to reliably discern these differences.

The MOBILE6 model will distinguish between weekend and weekday in terms of activity and emissions, and a user input will be required to tell the model which one is to be reported. The default will likely be the “weekday.” Also, since the default MOBILE6 hourly activity estimates are based exclusively on 168 vehicles, and cannot possibility reflect all geographical areas, times, or other variables, the user will have the option of providing running loss activity data into the MOBILE6 model from an external file.

3.4 Trips per Car-Day

The first necessary parameter in the model is the estimate for trips/car-day. Four different estimates were developed. There is one estimate for each combination of car or truck and weekday or weekend. These are average values obtained from the instrumented vehicle database. The values are shown in Table 2a.

Table 2a			
<u>Trips per Car per Day</u>			
<u>Cars</u>		<u>Trucks</u>	
Weekday	Weekend	Weekday	Weekend
7.28	5.41	8.06	5.68

These estimates are based on the instrumented car data, and are subject to revision pending completion of a thorough analysis of national trip data by an EPA contractor. The values could potentially vary considerably from those presented here.

3.5 Daily Trip Distribution by Hourly Group

Table 2b contains distributions of vehicle trips by hourly group. One of the distributions is based on vehicle miles travelled (VMT) of the trips, and the other is based

on the distribution of trip counts. Distance estimates and count-based estimates are provided for each of the fourteen groups, and separate estimates are provided for weekends and weekdays. The trip count distribution is shown for comparison purposes, since it is expected that the MOBILE6 model activity distribution for running losses will be based on trip distances in miles. The distance-based distribution will be used because it is directly proportional to the VMT accumulated during the hourly group. This is important because in the MOBILE6 model running loss emissions are a function of miles, and are presented in units of grams / mile.

Table 2b		
<u>Daily Distribution of Weekday Trips by Hourly Group</u> (in percent)		
Hour	VMT Based	Trip Count Based
6	3.67	1.983
7	7.29	5.461
8	8.18	5.872
9	4.75	4.744
10	4.59	5.217
11	5.40	6.757
12	6.10	8.237
13	7.05	7.352
14	7.97	8.069
15	8.14	9.015
16	8.94	8.603
17	8.19	7.779
18	6.28	6.025
24	13.45	14.887

Significant differences in the VMT based and the trip count based distribution can occur. For example, Table 2b shows that approximately 4.155 percent of the weekday daily trip VMT occurred during the period from 6:00 AM to 6:59:59 AM; however, this VMT represented 1.983 percent of the total daily trips. The data which underlie Table 2b were obtained from the instrumented vehicle database. Each column sums to 100 percent.

Table 2c <u>Daily Distribution of Weekend Trips by Hourly Group</u> (in percent)		
Hour	VMT Based	Trip Count Based
6	0.90	0.905
7	1.70	1.962
8	2.84	3.068
9	4.57	6.590
10	6.20	6.992
11	7.62	7.998
12	8.79	10.312
13	9.98	7.294
14	7.64	8.803
15	9.19	7.294
16	9.04	7.998
17	6.88	7.042
18	6.57	6.087
24	18.07	17.656

3.6 Running Loss Trip Distance Length Distribution by Hourly Group

A distribution of running loss trip distance lengths was developed for each of the 28 hourly group / weekday-weekend groups. The methodology used to analyze the data, and the results of the analysis are presented below. This particular methodology for estimating running loss activity was chosen because it fits the running loss emission values that are available in MOBILE5 (these will not be updated in MOBILE6). The only enhancement for the new model is that these activity parameters will be available for each hourly group and for weekday/weekend categorization (28 groups) rather than just an overall average set which represents all hours and days of the week. The overall set of MOBILE5 running loss activity estimates are shown in Table 2d (the percentages shown in Table 2d add up to 100%). For additional details regarding the MOBILE5 activity

parameters for running losses see the EPA report EPA-AA-AQ-AB-94-01 May 94 entitled “User Guide to MOBILE5.”

TABLE 2d MOBILE5 Running Loss Activities						
Trip Duration Range (min)	0 - 10 minutes	11 - 20 minutes	21 - 30 minutes	31 - 40 minutes	41 - 50 minutes	51+ minutes
Percentage	6.744	18.507	16.775	13.108	8.335	36.531

3.6.1 Methodology

The analysis consisted primarily of categorizing each of the 8,500 vehicle trips in the database into a particular hourly / weekday-weekend group. This was done by examining the day of the week of the trip, and the starting and ending time of each trip. A vehicle trip was classified as a weekday trip if it started on Monday through Friday. It was a weekend trip if it started on Saturday or Sunday.

A vehicle trip was classified into a particular hourly group if any part of the trip duration was in a given hourly group. A given vehicle trip could potentially be classified into one, two, or even three different hourly groups depending on the duration of the trip, and how many group interval boundaries it crossed. This classification could fit two general cases which are best illustrated with an example. (1) If a vehicle trip was from 8:20 AM to 8:40 AM it was classified as a twenty minute trip in Hourly Group 8. (2) If the trip was from 7:51 to 8:15, its contribution had to be split between two hourly groups (7 and 8 hour). Thus, a nine minute trip was assigned to the Hour 7 group, and a nine to twenty-five minute trip was assigned to the Hour 8 group. The nine to twenty-five minute label was assigned to the hour 8 group rather than a fifteen minute label, because the vehicle had been operating for nine minutes prior to the 8th hour, and would nominally have higher running losses than a vehicle which was just starting its trip. This is reflected in the MOBILE6 model because running losses are a function of the duration of the trip.

After labelling each of the trips in the database using the method above, each trip was classified into one of six trip duration categories based on trip duration in minutes (see Table 3). For example, the trip which lasted from 8:20 to 8:40 AM would fall into category #2 and hour 8. The trip which lasted from 7:51 to 8:15 AM would be treated as two trips. The first phase (nine minutes) would fall into the category #1 and hour 7. The second phase would fall into category #3 and hour 8. Category #3 is used because the upper duration of the trip is 25 minutes, and the maximum length of the trip is used to determine

category number. Running loss emissions from trips are also measured in 10 minute intervals, and are keyed to the upper duration of the trip.

Table 3 Trip Duration Categories	
Category Number	Trip Duration Range (in Minutes)
1	0 - 10 minutes
2	11 - 20 minutes
3	21 - 30 minutes
4	31 - 40 minutes
5	41 - 50 minutes
6	51+ minutes

After classifying the trips and phases of trips by hourly / weekday-weekend group, and by category number, the duration in miles of each trip and trip phase was found. In cases where the trip contained only one phase the trip distance in miles was readily available. In cases where two phases were present, the mileage was split according to the length of the trip in time. This assumes that the average speeds in both phases were equal.

After obtaining the mileage for each trip and trip phase, the mileages were summed for each hourly / weekday-weekend group and for each category within a hourly /weekday-weekend group. From the sums, percentages contributions were calculated for each category within a group. Tables 4a and 4b show these percentages for weekdays and weekends.

TABLE 4a and 4b
Mileage (VMT) Distribution by Trip Length (in time)

TABLE 4a							
	Hour	0-10 Min	11-20 Min	21-30 Min	31-40 Min	41-50 Min	51+ Min
Weekday	6	14.89%	22.70%	29.44%	20.76%	12.22%	0.00%
Weekday	7	16.06%	31.05%	40.00%	9.13%	3.75%	0.00%
Weekday	8	14.56%	33.48%	18.37%	18.49%	3.01%	12.10%
Weekday	9	27.40%	32.71%	22.20%	4.75%	0.00%	12.94%
Weekday	10	28.47%	42.99%	17.06%	7.92%	3.56%	0.00%
Weekday	11	32.94%	32.78%	14.96%	7.53%	5.34%	6.47%
Weekday	12	33.41%	39.64%	15.19%	11.76%	0.00%	0.00%
Weekday	13	28.89%	46.80%	13.93%	9.27%	1.10%	0.00%
Weekday	14	27.08%	39.31%	18.29%	3.18%	1.38%	10.76%
Weekday	15	26.79%	41.84%	24.28%	3.90%	2.20%	0.99%
Weekday	16	24.91%	40.78%	18.79%	10.87%	1.76%	2.89%
Weekday	17	21.09%	34.84%	29.41%	9.23%	5.42%	0.00%
Weekday	18	26.80%	32.23%	25.10%	11.98%	3.05%	0.84%
Weekday	24	20.95%	37.26%	24.51%	7.52%	6.37%	3.38%
TABLE 4b							
	Hour	0-10 Min	11-20 Min	21-30 Min	31-40 Min	41-50 Min	51+ Min
Weekend	6	18.98%	60.63%	20.39%	0.00%	0.00%	0.00%
Weekend	7	26.89%	42.40%	30.71%	0.00%	0.00%	0.00%
Weekend	8	20.60%	41.68%	18.82%	0.00%	18.90%	0.00%
Weekend	9	29.83%	38.26%	23.09%	8.82%	0.00%	0.00%
Weekend	10	25.57%	42.08%	16.58%	15.77%	0.00%	0.00%
Weekend	11	27.61%	36.42%	13.25%	10.31%	3.38%	9.03%
Weekend	12	25.85%	35.51%	28.61%	3.54%	6.49%	0.00%
Weekend	13	18.37%	19.41%	22.48%	9.86%	4.32%	25.56%
Weekend	14	23.71%	39.19%	12.26%	14.93%	9.91%	0.00%
Weekend	15	21.16%	25.39%	25.46%	4.07%	0.00%	23.92%
Weekend	16	25.66%	25.90%	12.34%	6.60%	15.03%	14.48%
Weekend	17	24.31%	37.71%	27.30%	3.91%	0.00%	6.76%
Weekend	18	18.01%	38.43%	18.27%	20.83%	4.46%	0.00%
Weekend	24	15.69%	27.42%	15.74%	9.57%	2.58%	28.99%

3.6.2 Results

Tables 4a and 4b show the running loss activity estimates for all 28 groups and 6 categories. Each of the cells in Tables 4a and 4b show the percentage of vehicle miles travelled (VMT) for a given hourly / weekday-weekend group which falls in a given trip duration category. For example, 14.89 percent of the VMT in the 6 AM to 7 AM time interval on a weekday occurs in trips which are 0 to 10 minutes in duration. Also, each of the rows in the tables sums to 100 percent.

3.7 Using the Hourly Running Loss Activities in MOBILE6

3.7.1 Hourly Running Loss Calculation

The average hourly running loss emissions are calculated from four parameters. These are: (1) the six running loss emission values (one value for each trip duration category). These values will not be updated for MOBILE6, and can be found in EPA document AP-42 for MOBILE5. (2) the six trip duration by hourly group running loss activity values shown in Table 4a or 4b. (3) the number of trips per day per vehicle values shown in Table 2a, and (4) the daily distribution of trips by hourly group (shown in Tables 2b and 2c).

MOBILE6 will multiply each of the six running loss emission values with each of the corresponding six running loss activity values. The six products (emissions x activities) are then summed to produce an estimate of running losses on a per trip basis. The calculation is done once for each of the 28 groups, to produce a value for each of the 28 groups. These 28 hourly running loss emission values are per trip estimates, and are the result of an intermediate calculation in the MOBILE6 model.

The second calculation takes the 28 hourly running loss emission values in per trip units, and converts them into average hourly running loss emission values. This is done by multiplying the 28 hourly per trip running loss values by the number of trips per day (shown in Table 2a) and by the appropriate value from the daily distribution of trips by hourly group table (shown in Table 2b or 2c). The daily distribution of trips by hourly group apportions the overall trips per day value into hourly group values.

3.7.2 Daily Running Loss Calculation

An overall daily running loss average is computed by weighting together the average running loss values of the 28 groups. The weighting factors are the daily distribution of trips by hourly group values shown in Tables 2b and 2c. The number of trips per day per vehicle from Table 2a is used to calculate the final daily running loss emissions.

4.0 METHODOLOGY FOR RUNNING EXHAUST EMISSION ACTIVITY

This short section describes the basic methodology to develop the trip length activity estimates used to calculate running exhaust emissions. The process and the results are virtually identical to those shown in the running loss activity estimate sections, and are shown here for completeness.

4.1 Definition

Exhaust running emissions are the emissions which exit a vehicle's tailpipe while the vehicle is operating in a warmed up condition. Excluded from the definition of exhaust running emissions are those emissions which occur during vehicle start (cranking the engine) and warm-up. Standardized test procedures such as the Federal Test Procedure (FTP), and test equipment have been extensively developed to measure exhaust emissions. The exhaust running emissions in the MOBILE6 model are based on such FTP data.

Detailed information on the definition of start emissions, the methodology used to develop the start emission estimates, and the projected MOBILE6 light duty vehicle start emission factors are provided in the EPA reports M6.STE.003 entitled "Determination of Start Emissions as a Function of Mileage and Soak Time for 1981-1993 Model Year Light-Duty Vehicles", and M6.STE.002 entitled "The Determination of Hot Running Emissions from FTP Bag Emissions." Also, detailed information on the determination of running exhaust emission factors for MOBILE6 can be found in EPA report M6.EXH.001 entitled "Determination of Running Emissions as a Function of Mileage for 1981-1993 Model Year Light-Duty Vehicles."

4.2 Activity Estimates

The activity estimates for exhaust running emissions required for the MOBILE6 model are minimal, since we assume exhaust running emissions are not a function of the trip length or the preceding soak period. Thus, the only activity estimates needed to calculate hourly running exhaust emissions in MOBILE6 are the trips per day per vehicle estimates and the daily trip distribution by hourly group. The trips per day per vehicle value is an estimate of overall daily vehicle usage. It is shown in Table 2a. The trip distribution by hourly group allocates the trips per vehicle over all 14 hourly groups. It is shown in Tables 2b and 2c.

COMMENTS

Comments on this report and its proposed use in MOBILE6 should be sent to the attention of the author, and submitted electronically to mobile@epamail.epa.gov, or by fax to (313)741-7939, or by mail to MOBILE6 Review Comments, US EPA Assessment and Modeling Division, 2565 Plymouth Road, Ann Arbor MI 48105. Electronic submission of comments is preferred, since we will make any comments available on our web site. In your comments, please note clearly the document that you are commenting on including the report title and the code number listed. Please be sure to include your name, address, affiliation, and any other pertinent information.