EMFAC Modeling Change Technical Memo

**SUBJECT**: INCLUSION OF EXTENDED IDLE FOR HEAVY-HEAVY-DUTY

DIESELS

**LEAD:** HECTOR MALDONADO

# Summary

Idle emissions for heavy-duty vehicles were introduced to the inventory in EMFAC2000. At that time, EMFAC2000 included only that activity associated with “idle trips” defined as key-on to key-off events with no appreciable distance traveled. This activity is indicative of a truck in queue to either pick up or drop off a shipment. Instrumented truck activity data has shown that considerable amounts of idle occur between trips. We are now proposing to include extended idle events that better reflect activity associated with truck stops, rest areas, and distribution centers.

Staff analyzed the second by second data collected over 2,500 trips taken by eighty-four heavy-heavy duty diesel trucks instrumented to record activity. The current analysis and the proposed change to the inventory is limited to heavy-heavy duty diesels and is consistent with a separate chassis dynamometer cycle development effort. Modifications to the activity of other vehicle classes may follow. The results of this analysis revealed that on average, heavy-heavy-duty diesel trucks idle for over one and a one half hours per day (105.4 minutes). This estimate can be contrasted to the current estimate contained in EMFAC of about 13 minutes per vehicle per day.

The proposed modification to the idle activity estimates for heavy-heavy-duty diesel trucks is predicted to increase the inventory from this segment of the fleet. Statewide, in the year 2002, the proposed change would result in an increase of 1 ton per day for hydrocarbon (HC), 7 tons per day of carbon monoxide (CO), 22 tons per day of oxides of nitrogen (NOx), and 0.6 tons per day of particulate matter (PM). Similar increases are estimated for the year 2010.

# Reason for Change

Since EMFAC2000 became final, we have collected new information regarding truck activity and performed additional analyses. Because both the ARB and the South Coast Air Quality Management District are considering measures to reduce heavy-duty truck idling, staff is seeking to modify the modeling assumptions in EMFAC to include extended idling events.

**Methodology**

EMFAC currently estimates idle using the following equation:

## Idle(gms)=Total Trips\* Percent Idle Trips\*Minutes per Idle Trip\*Grams per Minute

The total number of trips, the percent of trips assumed to be idle trips, and the minutes per idle trip estimates currently used in the model are all derived analyses of previously performed instrumented truck studies.

A trip is defined as an engine on to engine off event. Within the current model, the estimates of idle activity are assumed to vary by gross vehicle weight class (light-heavy, medium-heavy and heavy-heavy) and time of day. The grams per minute idle emission rates are estimated for HC, CO, NOx, PM, and CO2. These estimates are based on emissions tests performed by the University of West Virginia (data provided by Mridul Gautam, Ph.D.) and the Colorado School of Mines (Idle Emissions from Heavy-Duty Diesel and Natural Gas Vehicles at High Altitude, 2000). No modifications to the emission rates are being suggested as a result of this proposed change.

Staff analyzed two instrumented truck studies performed between 1997 and 2000. The first was conducted by Battelle Memorial Institute and is entitled “Heavy Duty Truck Activity Data”, March 1999. The second was performed by Jack Faucett Associates (JFA) and is entitled “Heavy Duty Vehicle Fleet Characterization in the South Coast Air Basin”, September 2001. As a result of the analyses of the data collected in these efforts, staff seeks to update the idle emissions inventory for heavy-heavy duty diesel trucks by revising the number of trips per vehicle per day, the hourly trip distribution, and the minutes per trip spent idling.

The proposed methodology obviates the need to separately account for idle and non-idle trips, therefore the percent of trips assumed to have idle emissions will be adjusted to 100% in EMFAC.

**Idle(gms)=Total Trips\*Minutes per Idle Trip\*Grams per Minute**

# Number of Trips per Day

The second by second records of a total of 84 instrumented heavy-heavy duty diesel powered trucks operated throughout California were analyzed to determine the number of trips taken per vehicle per day. This analysis revealed that the fleet took a total of 2,511 trips over a period of 496 days. Therefore, a fleet-wide average estimate of 5.06 trips per day is suggested to replace the current estimate of 10.33 trips per day.

The proposed estimate is based on an analysis performed on a large data set of trucks and activity. The instrumented vehicles were recruited to be representative of the overall fleet with respect to age, area of operation, gross vehicle weight, fuel type and operating characteristics. The recruitment criteria utilized by Battelle were based on data provided by CALTRANS (VMT contribution by vehicle class) and information extracted from the Truck Inventory and Use Survey (TIUS) performed by the U.S. Census Department (fleet make up by type of operation). Their recruitment plan is explained in detail in chapter two of their report. Jack Faucett Associates used Department of Motor Vehicles (DMV) data to establish fleet makeup by area and age, and truck fleet directories to determine fleet size by operation type. Their methodology is spelled out in section six of their report. The combination of the two studies constitutes the most comprehensive data set available of California heavy-duty truck driving patterns (See Tables 1 and 2).

**Table 1.**

**Heavy-Heavy Duty Diesel Instrumented Truck Fleet**

**Distribution by Vocation**

|  |  |  |  |
| --- | --- | --- | --- |
| Business Type | Trucks | Business Trucks | Trucks |
| Retail Trade | 30 | Building/Construction | 4 |
| For Hire Trans | 22 | Postal/Parcel | 1 |
| Agriculture | 13 | Other | 5 |
| Wholesale Trade | 9 | Total | 84 |

**Table 2.**

**Heavy-Heavy Duty Diesel Instrumented Truck Fleet**

**Activity by Area of Operation**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Air Basin** | **% Trips** | **% VMT** | **Air Basin** | **% Trips** | **% VMT** |
|  |  |  |  |  |  |
| Great Basin | 0.1 | 0.3 | Sacramento Valley | 27.4 | 18.0 |
| Southeast Desert | 0.7 | 1.2 | Salton Sea | 1.6 | 3.0 |
| Mountain Counties | 2.8 | 3.5 | San Diego | 4.9 | 0.9 |
| North Central Coast | 2.3 | 1.6 | San Francisco | 20.8 | 15.6 |
| North Coast | 0.3 | 0.2 | San Joaquin | 18.6 | 23.3 |
| Northeast Plateau | 0.3 | 0.3 | South Coast | 15.9 | 26.5 |
| South Central Coast | 3.1 | 3.6 | Mojave Desert | 1.2 | 2.2 |

# Trip Starts by Time of Day

EMFAC calculates the emissions inventory on an hourly basis. It is therefore necessary to update the hourly “trip distribution” table in order to be consistent with the proposed modification to idle activity. This is done to properly allocate idle emissions throughout the day. The instrumented vehicle data set mentioned earlier was also analyzed to determine what fraction of the 2,511 trips occurred in each hour of the day. Table 3 below contrasts the current and proposed trip distributions for heavy-heavy-duty diesel trucks.

# Total Idle Time

A total of 9.3 million seconds (about 2,580 hours) of data comprising the 2,511 trips were analyzed to determine the fleet average idle time. The total idle time per trip was determined by dividing 3,136,828 seconds of idle by 2,511 trips to derive an average estimate of 20.82 minutes per trip. This can be contrasted to the current estimate of about 4.8 of idle minutes per trip based on a previous analysis of a smaller data set.

**Table 3.**

## Hourly Trip Distribution

|  |  |  |
| --- | --- | --- |
|  | Percent of Trips | |
| **Hour** | **Current** | **Proposed** |
| **12am-1am** | 1.96 | 2.63 |
| **1am-2am** | 2.63 | 1.91 |
| **2am-3am** | 1.63 | 2.03 |
| **3am-4am** | 2.52 | 3.23 |
| **4am-5am** | 2.43 | 3.74 |
| **5am-6am** | 4.51 | 4.14 |
| **6am-7am** | 5.97 | 4.98 |
| **7am-8am** | 7.32 | 6.93 |
| **8am-9am** | 6.94 | 7.65 |
| **9am-10am** | 8.71 | 7.93 |
| **10am-11am** | 7.49 | 8.12 |
| **11am-12pm** | 6.38 | 5.93 |
| **12pm-1pm** | 5.91 | 5.74 |
| **1pm-2pm** | 5.47 | 5.58 |
| **2pm-3pm** | 5.36 | 4.78 |
| **3pm-4pm** | 5.47 | 5.34 |
| **4-pm-5pm** | 3.92 | 4.06 |
| **5pm-6pm** | 2.63 | 2.59 |
| **6pm-7pm** | 2.65 | 2.23 |
| **7pm-8pm** | 2.32 | 2.31 |
| **8pm-9pm** | 1.93 | 2.11 |
| **9pm-10pm** | 2.13 | 1.63 |
| **10pm – 11pm** | 1.63 | 2.75 |
| **11pm – 12am** | 2.07 | 1.67 |
| **Total** | **100.00** | **100.00** |

# Emissions Impact

Tables 4 and 5 below shows the estimated impact of adding extended idle for on-road heavy heavy-duty-diesel vehicles, statewide in 2002 and 2010.

**Table 4.**

**Estimated Emissions Impacts (Statewide 2002)**

**On-Road Heavy-Heavy Duty Diesel Trucks**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Pop.** | **Trips**  **/Veh** | **% Idle Trips** | **Idle Trips** | **Min**  **/Trip** | **Grams**  **/Min** | **Tons**  **/Day** |
|  | HYDROCARBONS | | | | | | |
| Current | 163923 | 10.33 | 26% | 440,264 | 4.80 | 0.07 | 0.16 |
| Proposed | 163923 | 5.06 | 100% | 829,450 | 20.82 | 0.07 | 1.33 |
|  | CARBON MONOXIDE | | | | | | |
| Current | 163923 | 10.33 | 26% | 440,264 | 4.8 | 0.44 | 1.03 |
| Proposed | 163923 | 5.06 | 100% | 829,450 | 20.82 | 0.44 | 8.37 |
|  | OXIDES OF NITROGEN | | | | | | |
| Current | 163923 | 10.33 | 26% | 440,264 | 4.80 | 1.35 | 3.14 |
| Proposed | 163923 | 5.06 | 100% | 829,450 | 20.82 | 1.35 | 25.68 |
|  | PARTICULATE MATTER | | | | | | |
| Current | 163923 | 10.33 | 26% | 440,264 | 4.80 | 0.04 | 0.09 |
| Proposed | 163923 | 5.06 | 100% | 829,450 | 20.82 | 0.04 | 0.76 |

**Table 5.**

**Estimated Emissions Impacts (Statewide 2010)**

**On-Road Heavy-Heavy Duty Diesel Trucks**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Pop.** | **Trips**  **/Veh** | **% Idle Trips** | **Idle Trips** | **Min**  **/Trip** | **Grams**  **/Min** | **Tons**  **/Day** |
|  | HYDROCARBONS | | | | | | |
| Current | 186481 | 10.33 | 26% | 500,851 | 4.80 | 0.07 | 0.19 |
| Proposed | 186481 | 5.06 | 100% | 943,594 | 20.82 | 0.07 | 1.51 |
|  | CARBON MONOXIDE | | | | | | |
| Current | 186481 | 10.33 | 26% | 500,851 | 4.80 | 0.44 | 1.16 |
| Proposed | 186481 | 5.06 | 100% | 943,594 | 20.82 | 0.44 | 9.52 |
|  | OXIDES OF NITROGEN | | | | | | |
| Current | 186481 | 10.33 | 26% | 500,851 | 4.80 | 1.35 | 3.57 |
| Proposed | 186481 | 5.06 | 100% | 943,594 | 20.82 | 1.35 | 29.21 |
|  | PARTICULATE MATTER | | | | | | |
| Current | 186481 | 10.33 | 26% | 500,851 | 4.80 | 0.04 | 0.11 |
| Proposed | 186481 | 5.06 | 100% | 943,594 | 20.82 | 0.04 | 0.87 |

# Remaining Issues

Those trucks instrumented in the Batelle and JFA studies represent a wide variety of truck types. Through analysis of the global positioning system data, it can be seen that these trucks also represent both rural and urban truck operations. It should be noted, however, that this data set is limited to California registered vehicles only and therefore may under or over estimate the idling activity of this segment of the fleet. For example, it could be argued that out-of-state trucks are more likely to experience overnight idling events.

Due to the lack of instrumented data for of-state registered trucks, idle emissions of these vehicles will be accounted for in the inventory with the assumption that their activity and emissions are equivalent to their California registered counterparts.

This proposed modification to the inventory does not address the spatial allocation of idle emissions, that is idling at truck stops and distribution centers can not be represented given that the resolution of EMFAC is limited to the county level. Therefore, it is assumed that a particular vehicle will spend all of its idle time in the county to which it is registered.

This modification is being suggested for heavy-heavy-duty diesel trucks only. Further analysis of the instrumented truck data is likely to suggest similar modifications to the medium-heavy and light-heavy duty categories. Given the relative contribution of these segments of the heavy-duty fleet, staff believes that priority should be given to heavy-heavy diesels.

Finally, no attempt is being made to address the possibility that idle behavior may vary by vehicle age. The small sample size of the fleet simply does not allow for such analyses. These topics can be addressed in future revisions to the model as research is performed and more data become available.

# Affected EMFAC Matrices

See attachment 1

## Attachment 1

The new data are to be incorporated into two modules of the EMFAC program:

1. run\_assign.for for (MODULE RUN\_DATA), and
2. trip\_assign.for (MODULE START\_\_DATA)

The affected portions of the code are highlighted in bold.

1. For the Module run\_assign.for, A) hourly starts distribution, and B) time-on idle are affected:
2. in the MODULE RUN\_DATA,

in the SUBROUTINE RUN\_INIT,

in the matrix (array) RUN\_FREQ,

for the vehicle class “HDT – DIESEL,

for the hourly weekday trip start distribution,

the following 24 values should be replaced by the 24 values in Table 2.

**1.96, 2.63, 1.63, 2.52, 2.43, 4.51, 5.97, 7.32,**

**6.94, 8.71, 7.49, 6.38, 5.91, 5.47, 5.36, 5.47,**

**3.92, 5.63, 2.65, 2.32, 1.93, 2.13, 1.63, 2.07**

As noted above, these 24 values (in bold) should be replaced by the values in Table 1.

2.63, 1.91, 2.03, 3.23, 3.74, 4.14, 4.98, 6.93,

7.65, 7.93, 8.12, 5.93, 5.74, 5.58, 4.78, 5.34,

4.06, 2.59, 2.23, 2.31, 2.11, 1.63, 2.75, 1.67

1. in the MODULE RUN\_DATA,

in the SUBROUTINE RUN\_INIT,

in the matrix (array) TIME\_ON\_IDLE

The value of 20.82 minutes per trip in the above item 2) HHDT Fleet-average amount of total (idle + non-idle trips) idle time per-vehicle per-trip, should replace the value of 20 in the matrix (array) containing 124 values in the TIME\_ON\_INDEX matrix (array). All other values should be set equal to zero.

e.g.

1, 2, 3, 4, 5, 10, 15, 20, 25, 30

35, 40, 45, 50, 55, 60, 65, 70, 75, 80

….

585, 590, 595, 600

The value of 20 becomes 20.82 (or 21 in integer values) and the rest of the values are set to zero.

1. For the Module tripassign.for for. A) the amount (percent) of idle time and B) number of starts affected.
2. in the Module tripassign.for (MODULE START\_DATA),

SUBROUTINE START\_DATA\_INIT,

IDLE\_ frac,

for HHDV,

for each of the 69 areas (Area1 – Area69),

the amount of idle should be changed from 0.280 to 1.000.

|  |  |  |
| --- | --- | --- |
| **GAS** | **DSL** |  |
| 0.000 | 0.000 | ! PC |
| 0.000 | 0.000 | ! LDT1 |
| 0.000 | 0.000 | ! LDT2 |
| 0.000 | 0.000 | ! MDV |
| 0.042 | 0.049 | ! LHDV1 |
| 0.067 | 0.049 | ! LHDV2 |
| 0.000 | 0.047 | ! MHDV |
| 0.000 | **0.280** | ! HHDV |
| 0.000 | 0.280 | ! LHV |
| 0.000 | 0.000 | ! UB |
| 0.000 | 0.000 | ! MCY |
| 0.000 | 0.000 | ! SBUS |
| 0.000 | 0.000 | ! MH |

The value of 0.280 becomes 1.000.

1. in the MODULE START\_DATA,

SUBROUTINE START\_DDTA\_INIT,

In the matrix 9array) VEHICLE\_STARTS:

The number of trips per day should be revised from 10.33 trips/day to the new value of 5.06 trips/day, in VEH 8: Heavy-heavy-duty trucks (T7), Diesel for each of the 69 areas in this module.

e.g.,

**10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,**

**10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,**

**10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,**

**10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,**

**10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,**

**10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,**

**10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,10.33,**

As noted above, all of the values of 10.33 (starts per vehicle per day) should be changed to 5.06 (starts per vehicle per day).