Preliminary Draft Do Not Quote
TRU Regulatory Staff are continuing to receive more data.
Emission estimates are subject to change.

OFFROAD Modeling Change Technical Memo

SUBJECT: Revisions to the Diesel Transport Refrigeration Units (TRU) Inventory

LEAD: Sandee Kidd

SUMMARY

Transport refrigeration units (TRUs) are diesel powered cooling units that are installed on vehicles used in transporting produce, meat, dairy products, and other perishable goods. TRUs are found on refrigerated vans, trucks, trailers, and railroad cars.

TRU emissions are estimated in the Air Resources Board's (ARB or Board) OFFROAD model. In late 2002, ARB staff obtained more up to date population and activity estimates from surveys of TRU manufacturers. We analyzed these data and are proposing to use the results to revise the input factors to the OFFROAD model. Staff proposes to revise the population, activity, load factor, average horsepower, survival rates, and useful life estimates for TRUs. These modifications are projected to increase the emissions inventory of particulate matter (PM) for this category of engines by 0.26 tons per day and reduce the inventory of oxides of nitrogen (NOx) by 4.53 tons per day, statewide in the year 2000 (See Table 1). For 2010, the emissions inventory is projected to increase by 0.26 tons per day for PM and decrease by 1.07 tons per day for NOx compared to the current estimates (See Table 2).

Table 1.

Statewide TRU Emissions Inventory in Tons per Day in 2000

	PM	PM	NOx	NOx	HC	HC
Horsepower	**Existing**	**Proposed**	**Existing**	**Proposed**	**Existing**	**Proposed**
<15 hp	NA	0.10	NA	1.37	NA	0.18
15-25-hp	0.02	0.07	0.20	0.79	0.03	0.14
25-50 hp (Ca)	0.43	1.94	2.80	13.66	1.64	7.15
25-50 hp Out of state	NA	0.64	NA	4.51	NA	2.36
25-50 hp (Rail)	NA	0.13	NA	0.92	NA	0.48
> 50 hp	2.17	NA	22.78	NA	3.39	NA
Totals	**2.62**	**2.88**	**25.78**	**21.25**	**5.06**	**10.31**

Table 2.

Statewide TRU Emissions Inventory in Tons per Day in 2010

	PM	PM	NOx	NOx	HC	HC
Horsepower	**Existing**	**Proposed**	**Existing**	**Proposed**	**Existing**	**Proposed**
<15 hp	NA	0.07	NA	0.99	NA	0.11
15-25-hp	0.01	0.05	0.15	0.70	0.02	0.08
25-50 hp (Ca)	0.40	1.78	2.64	12.30	1.35	5.43
25-50 hp Out of state	NA	0.59	NA	4.06	NA	1.79
25-50 hp Rail	NA	0.12	NA	0.83	NA	0.37
> 50 hp	1.94	NA	17.16	NA	2.56	NA
Totals	**2.35**	**2.61**	**19.95**	**18.88**	**3.93**	**7.78**

BACKGROUND

The emissions inventory for TRUs is calculated in the OFFROAD model in tons per day using the following equation:

Emission Inventory = Emission Rate*Population*Activity*Average Horsepower*Load Factor

The emission rates are pollutant specific and are expressed in grams/horsepower-hour (gms/hp-hr). Activity is expressed in hours/year or hours/day of engine run time. The ”average horsepower” is defined as the average maximum rated horsepower within each horsepower group. The “load factor” is the average operation level in a given application and is expressed as a percent of the engine manufacturer’s maximum horsepower ratings. The population estimate is a function of original sales, useful life and survival rate of the equipment.

With the exception of the emission rates, all other factors used in the current emissions inventory calculations were obtained from the 1997 Power Systems Research (PSR) report. PSR is an independent marketing firm involved in research and development related to engine product life cycles. The current emission inventory for diesel-powered TRUs was approved by the ARB in January of 2000.

INPUT FACTORS

Useful Life

Useful life is defined as the age at which at least fifty percent of the originally sold equipment population still exists, however, some of the remaining engines could last twice as long. Currently, the useful life for TRU’s in the OFFROAD model is assumed to be 16 years. The staff proposes to reduce this estimate to 10 years based on the responses to the survey of TRU manufacturers.

Survival Rate

The survival rate curve describes the percentage of the original equipment population remaining in the fleet as a function of age. For TRU's, this estimate was obtained from the PSR database. However, based on conversations with manufacturers, it was determined that in the last ten years, the trend showing a rapid decrease in the population may not be realistic. Therefore, the survival rate of TRUs 11 to 20 years old was revised to reflect a more gradual decrease in population. In addition, survival rate for age 0 was modified from 0.5 to 1.0 to reflect that age 0 included sales for the entire calendar year. Table 3 compares the survival rates form PSR at the useful life of 10 and 16 years, to the proposed survival rate.

Table 3. Comparison of TRU Survival Rates from Original Sales (%)

Age	Current (PSR) Survival Rate Useful Life = 10	Proposed Survival rate Useful Life = 10	Current (PSR) Survival rate Useful Life = 16
0	0.50	1.00	0.50
1	0.98	0.98	0.99
2	0.97	0.97	0.98
3	0.95	0.95	0.97
4	0.92	0.92	0.96
5	0.90	0.90	0.95
6	0.87	0.87	0.93
7	0.83	0.83	0.91
8	0.80	0.80	0.90
9	0.75	0.75	0.88
10	0.50	0.67	0.84
11	0.25	0.59	0.83
12	0.20	0.49	0.82
13	0.17	0.38	0.80
14	0.13	0.26	0.76
15	0.10	0.12	0.70
16	0.08	0.08	0.50
17	0.05	0.05	0.30
18	0.03	0.03	0.24
19	0.02	0.02	0.20
20	NA	NA	0.18
21	NA	NA	0.17
22	NA	NA	0.16
23	NA	NA	0.12
24	NA	NA	0.10

25	NA	NA	0.09
26	NA	NA	0.07
27	NA	NA	0.05
28	NA	NA	0.04
29	NA	NA	0.028
30	NA	NA	0.017
31	NA	NA	0.010
32	NA	NA	0.005

TRU Sales

The current estimate of the population of TRUs by horsepower group was obtained from PSR. The proposed revision to the population was derived from national TRU sales data provided by TRU manufacturers and TRU engine manufacturers, reported for a ten year period between 1991 and 2000 for each horsepower category. A curve fit of the data was performed to estimate the sales going back to 1981 for each horsepower category (See Charts 1, 2 and 3). The "Original Sales" data shown in Charts 1,2, and 3 represent an estimate of the number of TRUs originally sold in a particular year and should not be confused with the actual population in a given calendar year. As an example, in Chart 2 there were 400 (15-25 hp) TRU's sold in 1991. Actual sales data is not shown on Charts 1 to 3.

Using the 1997 Commodity Flow Survey data from the U.S. Census Website (www.census.gov), it was determined that the truck ton-mile share in California compared to the entire U.S. for refrigerated goods is 6.4%. Refrigerated goods include meats, agricultural products and other prepared perishable goods. Therefore, 6.4% of the U.S. TRU sales in all horsepower groups were assumed to be in California.

Chart 1: TRU U.S. Sales for < 15 hp engines.

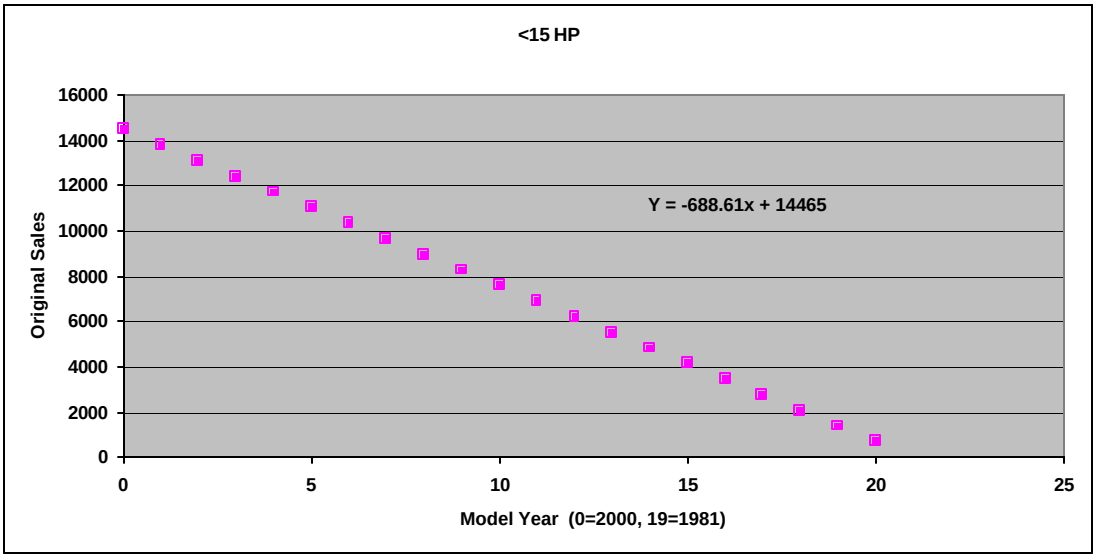


Chart 2: TRU U.S. Sales for 15-25 hp engines.

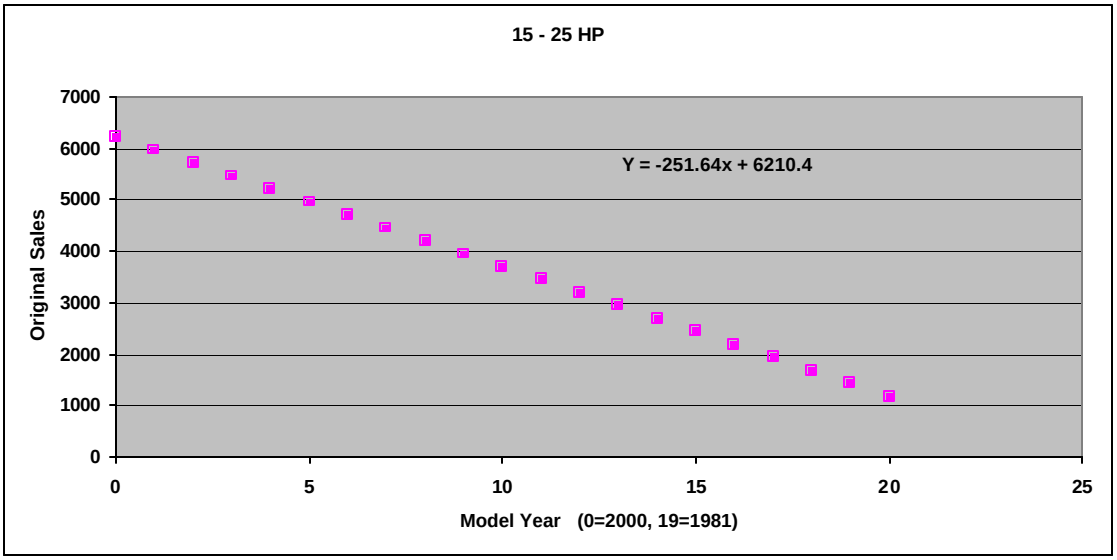
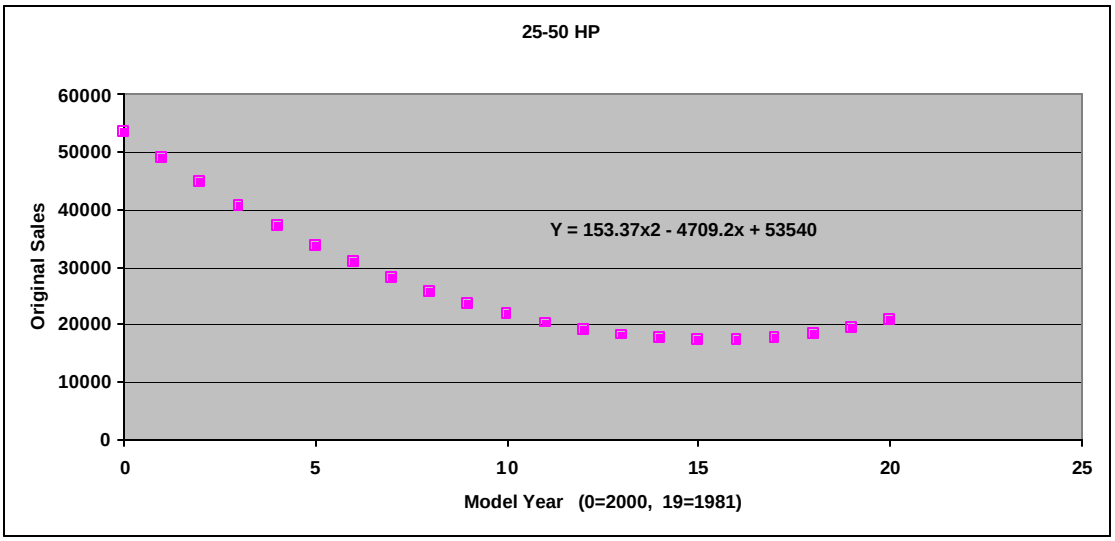


Chart 3: TRU U.S. Sales for 25-50 hp engines.



Population

(California Registered TRU)

Using the sales equation, 20 years of sales were estimated and the revised survival rates were applied to update the TRU population assumed to be installed on California registered, on-road vehicles as shown in Table 4. These numbers will be used in the OFFROAD model.

(Out of State TRU)

In California's on-road vehicle emissions inventory model, EMFAC 2002, it is assumed that 25% of the total, or 33% of the California only heavy-heavy duty diesel (HHDD) population that travels on California roads are trucks registered outside of California. Using the estimate, cited above for the 25-50 hp category, staff included an additional 8,225 TRUs into the 25-50 hp group to account for TRUs operating in California that are installed on trucks registered out of state. For purposes of emissions calculation, staff assumed that these out of state TRUs have the same age distribution and usage as TRUs installed on California registered trucks.

(Railcars TRU)

ARB staff also sent surveys to several railroad operators that do business in California regarding the use of refrigerated railcars. Staff used the American Association of Railroads UMLER files to obtain the U.S. population of railcars with mechanical refrigeration systems (reefer railcars). Reefer railcars use TRUs in the 25-50 hp group. Using the Commodity Flow Survey data mentioned earlier, it was determined that the rail ton-miles in California compared to the entire U.S. for refrigerated goods is 19%. Therefore, 19% of the U.S. reefer railcar usage was assumed to occur in California. Due to the lack of additional information, staff again assumed the same age distribution and usage for railcar TRUs as that used for TRUs that are installed on California registered trucks (See Table 4).

Table 4.
Statewide TRU Population in CY 2000

Horsepower Group	Existing Population	Proposed Population
<15 hp (Ca)	0	7682
15-25 hp (Ca)	1517	3497
25-50 hp (Ca)	8412	24925
25-50 hp (Out of State)	0	8225
25-50 hp (Rail)	0	1678
>50 hp	30902	0
Total	**40831**	**46007**

Contrary to the existing estimates in the OFFROAD model, data provided manufacturers and railroad operators indicated that there are a significant number of TRUs under 15 hp and there are no TRUs over 50 hp.

Average Horsepower, Load Factor, and Usage

Each engine in a specific application is assumed to operate for the average annual number of hours at the average load factor number. The average horsepower values, load factor, and usage estimates currently used in the OFFROAD model were taken from the PSR database. Survey responses obtained from the manufacturers also provided data to update these estimates. The revised estimates are compared to current estimates in Table 5 that summarizes all of the current and proposed input factors used to calculate the TRU emissions inventory.

Growth Factors

Growth factors used to forcast yearly sales beyond the year 2000 are derived from socio-economic indicators (e.g., housing units and manufacturing employment) that are assumed to have a close relationship with the off road equipment categories. Growth factors contained in the OFFROAD model were obtained from the 1994 study by California State University, Fullerton (CSUF) entitled “A study to Develop Projected Activity for Non-Road Mobile Categories in California, 1970-2020.” Growth factors for the proposed revisions of the OFFROAD model for the TRU category are based on DRI/MCGraw – Hill’s estimate of employment trends in categories such as construction, transportation, trucking and warehousing. Based on this data, staff assumes the growth in TRU population between 2000 and 2010 is 1.3% per year.

Table 5.

TRU Input Factors

HP GROUPS	<15 hp	15-25 hp	25-50 hp	>50 hp
Average hp				
Existing	NA	17	39	56
Proposed	10	17	34	NA
Activity (hrs/yr)				
Existing	NA	750	1341	1341
Proposed	1038	1038	1465	NA
Load Factor				
Existing	NA	0.50	0.28	0.28
Proposed	0.64	0.64	0.53	NA
Population				
Existing	0	1517	8412	30902
Proposed	7682	3497	34828	NA
Useful Life (yrs)				
Existing	NA	6	16	16
Proposed	10	10	10	NA
Fleet Average NOx gms/hp-hr (CY 2000)				
Existing	NA	6.82	7.53	11.61
Proposed	8.93	6.62	6.88	NA
Fleet Average PM gms/hp-hr (CY 2000)				
Existing	NA	0.60	1.15	1.10
Proposed	0.64	0.56	0.98	NA
Fleet Average HC gms/hp-hr (CY2000)				
Existing	NA	1.03	4.04	1.73
Proposed	1.16	1.20	3.60	NA

Emission Rates

The emission rates used in this analysis are those currently used in the OFFROAD model. These rates are based on pre-1995 diesel fuel. Fuel correction factors are applied in the model to reflect lower emissions due to low sulfur and aromatic content of 1995+ diesel fuel in California. Staff is not proposing to modify these estimates at this time (See Appendix A). Although the basic emission rates did not change, the proposed fleet average emissions as shown in Table 5 differ because the population distribution has been revised.

REASON FOR CHANGE

In support of pending regulation and in light of new data made available by TRU manufacturers, staff is proposing to update the emissions inventory for this segment of the off-road engine population as outlined above.

METHODOLOGY

The current estimates of population, average horsepower, activity and load factor will be updated to conform to the data recently provided by TRU manufacturers. Reflecting these proposed changes will affect the emissions inventory for this category of engines.

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Appendix A

MY Specific Emission Rates for Diesel Engines

		ZH (g/hp-hr)	DR (g/hp-hr2)	ZH (g/hp-hr)	DR (g/hp-hr2)	ZH (g/hp-hr)	DR (g/hp-hr2)	ZH (g/hp-hr)	DR (g/hp-hr2)
HP	**Year**	**ROG**	**ROG**	**CO**	**CO**	**NOX**	**NOX**	**PM**	**PM**
15	1994	1.50	0.00	5.00	0.00	10.00	0.00	1.00	0.00
15	1999	1.05	0.00	5.00	0.00	9.35	0.00	0.57	0.00
15	2004	0.68	0.00	3.47	0.00	6.08	0.00	0.47	0.00
15	2020	0.49	0.00	3.47	0.00	4.37	0.00	0.38	0.00
25	1994	1.84	0.00	5.00	0.00	6.92	0.00	0.764	0.00
25	1999	0.90	0.00	5.00	0.00	6.92	0.00	0.573	0.00
25	2004	0.64	0.00	2.34	0.00	5.79	0.00	0.382	0.00
25	2020	0.51	0.00	2.34	0.00	4.57	0.00	0.382	0.00
50	1987	1.84	2.35E-04	5.00	5.13E-04	6.90	1.04E-04	0.76	5.89E-05
50	1998	1.80	2.30E-04	5.00	5.13E-04	6.90	1.04E-04	0.76	5.89E-05
50	2003	1.45	1.85E-04	4.10	4.20E-04	5.55	1.03E-04	0.60	4.65E-05
50	2004	0.64	9.80E-05	3.27	3.34E-04	5.10	9.33E-05	0.43	3.36E-05
50	2005	0.37	6.90E-05	3.00	3.05E-04	4.95	9.67E-05	0.38	2.93E-05
50	2007	0.24	5.45E-05	2.86	2.90E-04	4.88	9.83E-05	0.35	2.72E-05
50	2020	0.10	4.00E-05	2.72	1.27E-04	4.80	1.00E-04	0.32	2.50E-05

*NOTE:
15 - 0 to 15 hp
25 -16 to < 25 hp
50 - 25 to 50 hp

Composite Emission Factor = ZH + (DR * cumulative hours)
ZH - Zero hour
DR - Deterioration rate