EMFAC Modeling Change Technical Memo

SUBJECT: REVISE BRAKE WEAR PM EMISSION FACTOR

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SUMMARY

The on-road emissions inventory model, EMFAC, estimates the directly emitted emissions of total particulate matter (PM) for exhaust, tire wear, and brake wear. The current version of the model uses an emission factor of 12.8 milligrams per mile (12.8 mg/mi PM) to estimate the amount of airborne dust attributable to brake wear. This emission factor, based on twenty-year-old tests of asbestos friction-materials from automobile disc brakes, is applied to all vehicles. It is also assumed in EMFAC that all vehicles are equipped with four brakes.

This modeling change proposes an adjustment to the assumed number of brakes per vehicle by tech group or weight class. Only heavy heavy-duty trucks and motorcycles will be assumed to have other than four brakes.

Implementation of the proposed modification would result in an increase in the PM inventory of 0.4 tons per day statewide in 2002. A summary of the increases for various areas in the State is shown in Tables 1 and 2 below.

Table 1
Summary of Emissions Changes due to Revised Brakewear Emission Factors
Calendar Year 2002

Air Basin	Emission Changes by Pollutant, tons per day				
	ROG	CO	NOx	CO_2	PM_{10}
Statewide					0.4
South Coast					0.2
San Joaquin Valley					0.1
Sacramento Valley					0.04
San Diego					0.03
San Francisco Bay Area					0.1

Table 2
Summary of Emissions Changes due to Revised Brakewear Emission Factors
Calendar Year 2015

Air Basin	Emission Changes by Pollutant, tons per day				
	ROG	CO	NOx	CO_2	PM_{10}
Statewide					0.6
South Coast					0.2
San Joaquin Valley					0.1
Sacramento Valley					0.04
San Diego					0.05
San Francisco Bay Area					0.1

NEED FOR REVISION

It was brought to the attention of staff that the single emission factor for brake wear currently used in the model was obviously not valid. For example, heavy-duty trucks have 10 brakes, and, being heavier than cars, require much more braking power to stop.

In researching the origin of the present emission factor, the staff determined that the value was carried over from earlier versions of U.S. EPA mobile model. The U.S. EPA in turn derived the 12.8 milligram per vehicle-mile estimate from a 1983 paper by Cha et al.[1] (U.S. EPA and Northrop). That work collected the particles generated from operating a disc brake dynamometer with asbestos friction materials on a schedule of braking events typical of Raleigh City driving.

The original result was expressed as follows:

(2 x 2.43 mg/application front disc + 2 x 1.68 mg/application rear drum)
x 31% airborne x 5.1 applications/mi
= 12.8 mg/mi

The experimental results were 0.75 mg/application airborne (out of a total brake pad weight loss of 2.43 mg/application) for one disc brake.

[1] Cha, S., P. Carter, and R. Bradow. 1983. Simulation of Automobile Brake Wear Dynamics and Estimation of Emissions. SAE Paper 831036. Society of Automotive Engineers, Warrendale, PA.

The variables here are:

- Number of brakes per vehicle
- Dust emissions per brake application
  - Function of friction material and brake type (drum or disc)
  - Function of deceleration rate (braking pedal effort) or braking speed
  - Function of vehicle weight or brake pad size
- Fraction of dust airborne
- Number of brake applications per mile

The variables of deceleration rate and number of applications per mile are bound up together in the braking or driving cycle.

In many studies, the experimental method is to measure only the airborne dust per application (the product of the gross dust emissions per application and the fraction of dust airborne), so the variables of dust emission per application and fraction of dust airborne might be bound together.

Number of brakes per vehicle

The original work of Cha (1983) was applied to cars with four brakes (two front discs and two rear drums). The assumption of four brakes per vehicle is valid for almost all weight categories, including buses and motor homes, with the exception of tractor-trailer heavy heavy-duty diesel trucks.

These eighteen-wheelers have six brakes on the tractor, two steering-wheel brakes and four driving wheel brakes, and four brakes on the trailer. The steering-wheel brakes are typically disc brakes and the four driving wheel brakes are typically drum brakes. The brakes on the trailer are typically drum brakes. Motorcycles have only two brakes which are primarily discs.

The methodology proposed here is only to modify the number of brakes per vehicle assumed in the model. The friction material and braking circumstances remain the same as Cha's work from 1983. However, staff feels that other improvements should be made with respect to the assumed friction material composition, the driving cycle, brake size, and the force required to stop vehicles of varying weights. Although staff does not believe that sufficient information exists to implement these changes at this time, it is the intention of ARB that these issues be addressed in a future revision of the inventory.

AFFECTED SOURCE CODE/VERSION

BER_DATA.for (8/9/02) containing PM emission factors (g/mi) by Tech Group.

Mechanically, the source-code revisions for brakewear PM and fuel anti-correction factors were done simultaneously. The fuel anti-correction factor amendments did not change PM at all, and the brakewear PM changes did not alter ROG, NOx, or CO. A summary of the lines changed is shown in Attachment A of the fuel anti-correction factor technical memo.

METHODOLOGY FOR REVISION

The brake wear emissions for heavy heavy-duty trucks were taken to be the automobile rates given by Cha plus with the addition of three more rear axles with drum brakes.

Each drum brake axle in Cha's formulation had:

Emissions per axle = 2 brakes/axle x 1.69 mg/application x 31% airborne
x 5.1 brake applications/mi
= 5.3 mg/mi/axle

Therefore, 12.8 mg/mi + 3 axles x 5.3 mg/mi/axle = 28.8 mg/mi/vehicle for a 5-axle truck.

The rate for motorcycles will be assumed to be half of the passenger car rate.

The existing brake wear emissions and proposed emission rates by technology group (TG) are shown in Table 3 below.

Table 3
Brake wear emission rates

TG grouping	Description	Present Braking	Proposed
		g/mi	g/mi
TGs 1-37	PCs, LDTs, MDVs Gas	0.0128	*
TGs 40-43	PCs (Mexican)	0.0128	
TGs 46-57	M4 Truck Gas	0.0128	
TGs 60-71	M4 Truck Diesel	0.0128	
TGs 76-87	M5 Truck Gas	0.0128	
TGs 90-101	M5 Truck Diesel	0.0128	
TGs 106-114	HDL&M Truck Gas	0.0128	
TGs 120-131	HDL&M Truck Diesel	0.0128	
TGs 136-144	HDH Truck Gas	0.0128	0.0288
TGs 150-161	HDH Truck Diesel	0.0128	0.0288
TGs 170-177	PCs Diesel	0.0128	
TGs 178-185	LDTs Diesel	0.0128	
TGs 186-194	MDVs Diesel	0.0128	
TGs 200-211	HDH Truck Diesel Federal	0.0128	0.0288
TGs 216-225	Urban Buses Diesel	0.0128	
TGs 228-237	School Buses Gas	0.0128	
TGs 240-251	School Buses Diesel	0.0128	
TGs 260-277	Motorcycles	0.0128	0.0064

*Note: blank means unchanged.

INVENTORY EFFECTS

Table 4 shows an example estimate for the change in the statewide inventory of brake wear emissions before and after the proposed change.

Table 4
Statewide PM Inventory Effects in 2005 (tons per day)

		Present		Revised	
	mi/d	g/mi	tpd	g/mi	tpd
PC	481,507,424	0.0128	6.79	0.0128	6.79
LT1	127,606,552	0.0128	1.80	0.0128	1.80
LT2	134,516,192	0.0128	1.90	0.0128	1.90
MDV/T	58,278,588	0.0128	0.82	0.0128	0.82
M4	14,464,287	0.0128	0.20	0.0128	0.20
M5	4,345,560	0.0128	0.06	0.0128	0.06
HDL&M T	12,865,033	0.0128	0.18	0.0128	0.18
HDH T	27,636,096	0.0128	0.39	0.0288	0.87
UB	3,344,801	0.0128	0.05	0.0128	0.05
MC	3,012,986	0.0128	0.04	0.0064	0.02
SB	1,092,497	0.0128	0.02	0.0128	0.02
MH	4,214,100	0.0128	0.06	0.0128	0.06
Total	872,884,116		12.30		12.77

The effect is an additional 0.5 tpd statewide of particulate matter.

Tables 5 through 8 show the estimated PM increases for the years 2002, 2010, 2015, and 2020 for the areas of Statewide, South Coast Air Basin, San Joaquin Valley Air Basin, Sacramento Valley Air Basin, San Diego Air Basin, and San Francisco Bay Area Air Basin.

Table 5
Summary of Emissions Changes due to Revised Brakewear Emission Factors
Calendar Year 2002

Air Basin	Emission Changes by Pollutant, tons per day				
	ROG	CO	NOx	CO_2	PM_{10}
Statewide					0.4
South Coast					0.2
San Joaquin Valley					0.1
Sacramento Valley					0.04
San Diego					0.03
San Francisco Bay Area					0.1

Table 6
Summary of Emissions Changes due to Revised Brakewear Emission Factors
Calendar Year 2010

Air Basin	Emission Changes by Pollutant, tons per day				
	ROG	CO	NOx	CO_2	PM_{10}
Statewide					0.5
South Coast					0.2
San Joaquin Valley					0.1
Sacramento Valley					0.04
San Diego					0.04
San Francisco Bay Area					0.1

Table 7
Summary of Emissions Changes due to Revised Brakewear Emission Factors
Calendar Year 2015

Air Basin	Emission Changes by Pollutant, tons per day				
	ROG	CO	NOx	CO_2	PM_{10}
Statewide					0.6
South Coast					0.2
San Joaquin Valley					0.1
Sacramento Valley					0.04
San Diego					0.05
San Francisco Bay Area					0.1

Table 8
Summary of Emissions Changes due to Revised Brakewear Emission Factors
Calendar Year 2020

Air Basin	Emission Changes by Pollutant, tons per day				
	ROG	CO	NOx	CO_2	PM_{10}
Statewide					0.6
South Coast					0.2
San Joaquin Valley					0.1
Sacramento Valley					0.05
San Diego					0.05
San Francisco Bay Area					0.1