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Exhaust Emission Temperature Correction Factors for MOBILE6:

Adjustments for Engine Start and Running LA4 Emissions for Gasoline Vehicles

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1.0 OVERVIEW

In the MOBILE model series vehicle exhaust emissions have always been adjusted for the effects of ambient temperature. In previous versions of MOBILE these correction factors were determined separately for each segment (bag) of the Federal Test Procedure (FTP), and were applied in the model using the user supplied operating mode temperature correction factor inputs. The new MOBILE6 model will estimate exhaust emissions separately for engine running emissions and the effects of engine start. The operating mode temperature correction factor inputs will be removed, and replaced by a count of engine starts per day.

For MOBILE6, the existing MOBILE5 temperature correction factors (one for each FTP bag) will still be used. However, they will be applied separately to cold start, hot start, and running LA4 emissions rather than weighted together into an overall FTP correction using the operating mode temperature correction factor inputs like in MOBILE5. For MOBILE6, the Bag1 temperature correction factor (Equation 1) will be applied to the cold start emissions (a 12 hour soak prior the start). The Bag3 temperature correction factor (Equation 2) will be applied to the hot start emissions (a 10 minute soak prior to the start). A VMT weighted combination of Bag2 and Bag3 temperature correction factor (Equation 3) will be applied to the running LA4 emissions. Linear interpolation between the hot start (10 minute soak) and the cold start (12 hour soak) will be done to obtain temperature correction factors (TCF(x)) for starts with soaks in between these two values (Soak value of ‘x’ in Equation 4). The one exception to this general methodology are the CO start temperature corrections below 75 F. They use an additive correction factor rather than a multiplicative correction factor.

$$TCF_{MOBILE6}(\text{COLD engine start}) = TCF_{MOBILE5}(\text{Bag 1}) \quad \text{Eqn 1}$$

$$TCF_{MOBILE6}(\text{HOT engine start}) = TCF_{MOBILE5}(\text{Bag 3}) \quad \text{Eqn 2}$$

$$TCF_{MOBILE6}(\text{running}) = TCF_{MOBILE5}(\text{Bag 2}) * 0.521 + TCF_{MOBILE5}(\text{Bag 3}) * 0.479 \quad \text{Eqn 3}$$

$$TCF(x) = TCF(h) + [(TCF(c)-TCF(h)) / (Soak(c)-Soak(h))] * (Soak(x)-Soak(h)) \quad \text{Eqn 4}$$

where:

subscript ‘h’ means hot engine start and ‘c’ means cold engine start, and ‘x’ is the soak length of interest.

TCF is the temperature correction factor;

Soak is the soak length in minutes. Soak(c) is defined to be 720 minutes (the FTP cold start soak duration), and Soak(h) is defined to be 10 minutes (the FTP hot start soak duration). The values of 0.521 and 0.479 are the VMT (vehicle miles traveled) weighting factors for the running LA4.

The two FTP bags (bags 2 and 3) are weighted together by these factors to produce the running LA4.

The temperature correction factors in Equations 1 through 4 are not perfectly associated with the basic emission rates to which they will be applied. This is because the individual Bag1 and Bag3 correction factors used in MOBILE5 contain both running emissions and start emissions, and these components cannot be separated. The inconsistency arises because in MOBILE6, both the cold and hot start emissions have been separated from the running emissions, and the start estimates contain only the effect of engine starts on exhaust emissions (See EPA document M6.STE.002 - "The Determination of Hot Running Emissions from FTP Bag Emissions"). Similarly, the running LA4 estimates in MOBILE6 contain only running emissions and do not contain start emissions. Thus, utilizing the MOBILE5 temperature correction factors directly in MOBILE6 will add a small component of running emissions to the start estimates and a small component of start emission to the running LA4 estimate.

Because of a lack of data, we cannot develop new correction factors based directly on start and running LA4 emissions, nor estimate the magnitude of the error introduced by using the individual bag correction factors from MOBILE5. However, the error in applying the MOBILE5 Bag 1 temperature correction factors to engine start emissions in MOBILE6 should be small. This is because the temperature corrections for starts are based on bags. These include some stabilized running emissions, but these stabilized running emissions are less sensitive to ambient temperature, and should not strongly bias the results.

Similarly, VMT weighting the Bag 3 with Bag 2 temperature correction factors from MOBILE5 to determine the hot running emission temperature correction factors for MOBILE6 assumes that the affect on the temperature correction factor from emissions from the engine start following a 10-minute soak are negligible. The reason for combining Bag 3 and Bag 2 is to make the underlying driving cycle identical to the cycle used for the basic hot running emission estimates in MOBILE6 (the running LA4). Both Bag 1 and Bag 3 use the same driving cycle and contain engine starts, so the difference in their temperature correction factors should be only a function of their soak time.

Another possible source of error in applying the MOBILE5 temperature correction factors to MOBILE6 start and running emissions is a possible dependence of vehicle model year on the correction factors. The MOBILE5 correction factors are based mostly on testing from 1980's model year vehicles ,whereas the model now predicts emission effects of 1990's and later model year vehicles. Some error could occur in modeling 1990's vehicles in MOBILE5 if the temperature dependence on emissions has changed with newer model year vehicles and technology. For example, the emission control system on newer model year vehicles may now reach full operating temperature sooner than vehicles of the past. Unfortunately, due to a lack of data, the correction factors cannot be updated to fully reflect 1990's technology, nor any subsequent changes due to advancing technology.

Since the existing MOBILE5 temperature correction estimates are being used in MOBILE6, they will not be reproduced in their entirety in this document. The interested reader is referred to Pages H-23 and H-24 in Appendix H of "Compilation of Air Pollution Emission Factors, Volume II: Mobile Sources" (AP-42, June 1995) for a complete listing of the correction factor coefficients.

2.0 TEMPERATURE AND RVP RANGE

In MOBILE5, exhaust emissions for vehicles of model year later than 1979 are adjusted for the combined effects of fuel volatility (as measured by the Reid Vapor Pressure (RVP)), and temperature for temperatures between 45° and 95°F. Within this temperature range, there are two regions of interest-- above and below the reference temperature of 75° F. All Temperatures using the symbol "T" are in degrees Fahrenheit.

2.1 Corrections Above 75°F

The form of the temperature correction factor for temperatures above 75°F is shown in Equation 5a for pre-1980 model years and in Equation 5b for 1980 and later model years. It is used in MOBILE6 as a multiplicative factor. An example of the coefficients used in Equation 5a and Equation 5b for light-duty gasoline vehicles are shown in Appendix A-2. The coefficients labeled Test Segment 1 are used for the cold start, the coefficients labeled Test Segment 3 are used for the hot start, and a weighted percentage of Test Segment 2 and Test Segment 3 coefficients are used for the hot running LA4 corrections. The weighting for Test Segment 2 and Test Segment 3 is shown in Equation 3.

$$TCF(b) = EXP[\ TC(b)*(T-75)] \qquad \text{Eqn 5a}$$

$$TRCF(b) = EXP[\ RC(b)*(RVP-9.0) + TC(b)*(T-75) + TRC(b)*(RVP-9.0)*(T-75)] \qquad \text{Eqn 5b}$$

Where b	=	1:	Cold Start (Bag1)
	=	2:	Hot Stabilized (Bag2)
	=	3:	Hot Start (Bag3)

2.1.1 Adjustment Between 75°F and 95°F

At temperatures above 75°F, the temperature correction factor is a combined temperature and fuel volatility factor. This factor is a function of both temperature in degrees Fahrenheit and fuel RVP in units of psi. Graphically, it can be thought of as a family of curves, each curve representing the impact of emissions versus temperature for a given fuel volatility. The emission rate corresponding to 9.0 psi fuel RVP and 75°F temperature is the base rate. It is the lowest emission rate allowed for temperatures above 75°F regardless of RVP. This means that the combined affect of temperature and RVP for fuels which have RVP values less than 9.0 are the same as the affect for a 9.0 psi RVP fuel at 75°F. The effect only increases when the combined affect of temperature and RVP for that fuel exceed the effect at 9.0 psi RVP and 75°F. In other words, the correction factor has a minimum value equal to the 9.0 psi and 75°F case. This is the same methodology as used in MOBILE5.

2.1.2 Adjustments Above 95°F

Emissions at temperatures between 95°F and 110°F are adjusted only as a function of temperature. The terms in the equation related to fuel volatility (RVP) are set to their value at 95°F and only the temperature effects are allowed to increase beyond 95°F. In some model years the correction factors are further differentiated by fuel delivery system (carbureted versus fuel injection). Equation 5b is used, and the RVP terms are removed.

2.2 Corrections Below 75°F

2.2.1 HC and NOx Correction Factors

Below 75°F there is only a temperature correction factor. There is no RVP component to the overall temperature/fuel volatility correction factor. The form of the temperature correction factor below 75°F is shown in Equation 6. This equation applies to HC and NOx for cold start, hot start and running LA4 emissions. It also applies for running LA4 CO emissions (the coefficients for Equation 6 are shown in Appendix A-2), and for CO start emissions of pre-1980 model year vintage. The analogous weighting between cold and hot start like in Equation 4 is also applied to these correction factors to make them a function of soak time.

$$TCF(b) = EXP[\ TC(b) * (T-75)\ ] \qquad \text{Eqn 6}$$

Where b	=	1:	Cold Start (Bag1)
	=	2:	Hot Stabilized (Bag2)
	=	3:	Hot Start (Bag3)

2.2.2 CO Start Correction Factors

The methodology for Start CO on 1980 and later model year vehicles is slightly different than for the other pollutants. For Start CO the correction factor is <u>additive</u>, and there is a temperature correction factor coefficient only for cold start CO (soak time = 720 minutes). The correction factor will increase the CO emissions as temperature (T in Equation 7) is lowered. It has the mathematical form shown in Equation 7.

$$TCF(1) = Coeff * (T - 75.0) \qquad \text{Eqn 7}$$

The values of the coefficients (Coeff) are shown in Table 1 below by model year for the 1980 - 1982 model years, and by technology type for the 1983 and later model years. They are the values of the Start CO temperature correction factor coefficients at a soak length of 720 minutes in units of g/mi-°F. MOBILE will also correct Start CO emission for soak times other than 720 minutes. The methodology for this is discussed in Section 3.4 because of the relationship between the additive Start CO temperature correction factor and additive Cold CO emission standard effects.

Table 1
Temperature Correction Factor Equation Coefficients for Start CO

Model Year Group	ALL or CARB (g/mi -°F)	TBI** (g/mi -°F)	PFI** (g/mi -°F)
1980	-1.24480		
1981	-1.30945		
1982	-1.28402		
1983 +	-1.22620*	-1.22620	-0.65727

* For Carbureted Vehicles Only
** TBI is throttle body fuel injection type
** PFI is ported fuel injection type

3.0 Effects of the Cold Temperature CO Certification Standard(s)

As part of the Clean Air Act requirements, EPA developed a new cold temperature CO certification standard and a 20°F test. The new requirements have two phases. Under the first phase, passenger cars were built to pass a 10 g/mi cold CO standard, and light-duty trucks were built to pass a 12 g/mi cold temperature CO standard as well as the traditional FTP CO standard at 75°F. The requirements for Phase 1 of the cold temperature CO standard were phased into the fleet starting in 1994 and ending in 1996. For passenger cars and light trucks the phase-in requirement was 40 percent of the fleet, 80 percent of the fleet and 100 percent of the fleet were required to pass the cold temperature standard in 1994, 1995 and 1996 respectively.

Because of the unknown nature of the Phase 2 standard, the parameters will not be 'hard-coded' into MOBILE6. Instead, the default case will be no implementation. Optional user inputs will be coded in case a new cold temperature CO standard is implemented. These inputs will include the implementation year, the phase-in schedule (three percentages), and the car and truck standards in grams per mile.

3.1 Data

An additive temperature correction factor for cold start CO will be used in MOBILE6 to model the effects of the cold CO certification standard. This assumes that only engine start emissions will be affected by the cold temperature CO standards. Table 1 shows a summary of the 1997 cold temperature CO certification data used to develop cold CO offsets for vehicles certified for Phase 1 cold CO standards (10 g/mi certification standard at 20°F). The summarized certification data were provided by the American Automobile Manufacturers Association (AAMA).

Table 2
1997 Certification Data Summary

		FTP CO @ 75°F (g/mi)		FTP CO @ 20°F (g/mi)	
Manufacturer	Vehicle Type	4K Miles	50K Miles	4K Miles	50K Miles
All	Car	0.95	1.15	4.68	5.51
	LDT	1.32	1.54	4.81	5.76
Big Six[1]	Car	**0.98**	1.23	**4.80**	5.86
	LDT	**1.36**	1.55	**4.60**	5.48

[1] Sales-weighted average of GM, Ford, Chrysler, Honda, Nissan and Toyota.

CO Offsets

CO Offsets for cars @ 4K = 4.8 - 0.98 = 3.82 g/mi
CO Offsets for trucks @ 4K = 4.6 - 1.36 = 3.24 g/mi

The results from the Big Six Dataset were used. The 4.8 g/mi number for cars is the 20°F FTP emission result and the 0.98 g/mi number is the 75°F FTP emission result.

3.2 Use in MOBILE6

The Phase 1 CO offset (P1 CO Offset) value in MOBILE6 is the CO offset for Bag1 or cold start emissions. It is used for all temperatures below 75°F, and is in units of g/mi-°F. It is a negative number because it reflects the lower CO emissions due to the new CO Cold Start certification standards. It is used in MOBILE6 to reduce the cold start CO emissions calculated in Equation 7. Equation 8 shows how the P1 CO Offset is calculated from the FTP difference determined in the previous section. The value of 0.206 is the standard Bag 1 cold start FTP vehicle miles traveled (VMT) weighting. The value of -3.82 g/mi is based on the entire FTP. The Bag1 VMT weighting of 0.206 is used to transform the full FTP emissions into equivalent Bag1 emissions. The temperature Delta is 55°F. This is the difference between the standard FTP temperature condition of 75°F and the cold CO certification temperature of 20°F.

<u>Estimate of P1 CO Offset values:</u>

P1 CO Offset = -CO Offset FTP / (Bag1 FTP Weighting * Temp Delta) Eqn 8

For example, the offset for cars certified to the Phase 1 Cold CO Standard would be:

P1 CO Offset = -3.82 g/mi / (0.206 * 55°F) = -0.33709 g/mi -°F

and

P1 CO Offset for LDTs certified to Phase 1 cold CO = -0.28600 g/mi -°F

Since cold start emissions in MOBILE6 are in grams per start rather than grams per mile, the value of -0.33709 g/mi -°F can be converted to g/°F by multiplying the value by 3.59 miles. This is the distance of Bag1 (cold start bag) of the FTP. This produces values of P1 CO Offset in grams / start -°F of:

P1 CO Offset for cars certified to Phase 1 cold CO = -1.210 g/start -°F
P1 CO Offset for LDTs certified to Phase 1 cold CO = -1.027 g/start -°F

The cold start CO offsets are shown on a per degree basis with the baseline temperature of 75°F, and soak time length of 720 minutes (full cold start). An evaluation showing an example calculation of the CO cold start correction factor at a soak time of 720 minutes and application of the phase 1 offset at 60°F is as follows:

TCF(T) = Coeff * (T - 75°F) Eqn 9

Then, from Table 1, the TC(1) coefficient for 1992+ model years is -0.7739. Thus:

TCF(60) = -0.65727*(60-75) = 9.859 g/mi CO

Converting to grams per start by multiplying by 3.59 miles produces 35.39 g/start CO.

The CO offset as the result of the cold start CO rulemaking is: -1.210 g/start -°F

Multiplying this by the change in temperature from 75°F to 60°F (delta is 15°F) gives -18.15 g/start.

The final TCF at 60°F for a soak time of 720 minutes (full cold start) is the sum of the cold start temperature correction factor and the CO offset from the rulemaking. It is shown by:

Final TCF(T) = TCF(T)*3.59 - P1 CO Offset*(T - 75) Eqn 10

or

Final TCF(Temp=60, soak=720) = 35.39 - 18.15 = 17.24 g/start

This value is added to the base CO emission factor at 75°F to correct the CO emissions for the lower temperature of 60°F.

3.3 The Effects of Potential Phase 2 Cold CO Standards

In the current MOBILE5b, Phase 2 cold CO standards are assumed to affect only the CO offset for Bag 1. For vehicles certified to Phase 2 standards, the CO offset for Phase 1 vehicles is reduced by the difference between pre-Phase 1 cold CO emissions at 20° F and an estimated Phase 2 CO level assuming a certification margin of about 20%. The MOBILE5b approach has two problems: (1) the CO offset for a low proposed Phase 2 standard (i.e. 3.4 g/mi) could be less than zero, and (2) the CO offset for vehicles certified to the Phase 1 standard was higher than the certification data now shows.

The cold CO offset for vehicles certified to the Phase 1 cold CO standard was discussed in the previous section. The proposed method for Phase 2 also assumes that only Bag 1 CO is affected by a potential Phase 2 standard. However, in this new method, the Phase 1 CO offset is reduced in proportion to the standard, so that it is equivalent to the Phase 1 CO offset at a Phase 2 standard of 10 g/mi (equal to the Phase 1 standard for cars) and is zero at a Phase 2 standard of 3.4 grams/mi (the standard for cars at 75°F) by using Equation 11.

Phase 2 CO Offset = Phase 1 CO Offset * [1-((10-x)/(10-3.4))] Eqn 11

Where :
10 = Phase 1 CO standard (g/mi)
x = User Input Phase 2 CO Standard (g/mi)
3.4 = Minimum Phase 2 CO standard (g/mi)

In MOBILE6 the Phase 2 CO Offset will be applied as a multiplicative factor to the Phase 1 CO Offset.

The Bag 1 CO offset is linearly interpolated at all points in between 10 and 3.4 g/mi. In this manner the CO offset cannot be negative, unless the Phase 2 CO standard is less than 3.4 g/mi (an unlikely scenario). Proposed Phase 2 standards of less than 3.4 g/mi will not be allowed in MOBILE6. The temperature sensitivities of Bags 2 and 3 are assumed to be unaffected by the Phase 2 standard (same assumption as for Phase 1).

3.4 Start CO Effects Versus Soak Time Length

The Start CO temperature correction factor is also a function of soak time which can range from 0 minutes (an immediate restart after a fully warmed up engine is shut down) to 720 minutes. The relationship between soak time and the Start CO temperature correction factor was developed from the value at 720 minutes, and the assumption that the start CO temperature correction factor at a soak time of zero minutes is 0.00. This means that there is no temperature correction for warmed up vehicles which were immediately restarted after being shut off. Also, there is no P1 CO Offset or P2 CO Offset at soak times of zero minutes. These are also assumed to be 0.00, since if there is no effect, there could not be an offset to that effect. These are reasonable assumptions also since ambient temperature is not likely to be a major factor on a warmed up vehicle which has not had any time to soak and cool down.

For example for the 1983+ PFI vehicles the Start CO emissions at 500 minutes are:

Final TCF(Temp=60, soak=720) = 35.39 - 18.15 = 17.24 g/start

Final TCF(Temp=60, soak=500) = (17.24 / 720 minutes)*500 = 11.972 g/start

4.0 The Temperature Correction Factor in MOBILE6

The application of the temperature correction factor in MOBILE6 is slightly different depending on whether it is a multiplicative correction factor or an additive correction factor. Also, the running emission temperature correction factors are handled slightly different than the start temperature correction factors.

The multiplicative correction factors are of the form in the MOBILE6 function BEF:

BEF = BEF * TEMPCOR * FUEL_CF Eqn 12

Where BEF is the basic emission factor, TEMPCOR is the multiplicative temperature correction factor and FUEL_CF is the fuel type correction factor.

Subsequent to this subroutine multiplicative correction factors are applied to BEF. For running emissions these correct for speed, A/C, Load, Humidity and RVP. For HC and NOx start emissions, these correct only for humidity and RVP.

The additive correction factors are of the form in the MOBILE6 function BEF:

$$BEF = (BEF + TEMPCOR) * FUEL\_CF \qquad \text{Eqn 13}$$

Where TEMPCOR is the additive temperature correction factor. Since the additive correction factor is only for start CO emission, these are corrected subsequently only for humidity and RVP.

APPENDIX A-1

LOW (< 75F) TEMPERATURE CORRECTION FACTOR COEFFICIENTS FOR
LIGHT DUTY GASOLINE POWERED VEHICLES

* TCF(1) = TC(1)*(T - 75.0), 1980+ CO,
TCF(b) = EXP [TC(b)*(T - 75.0)], all others

Pol	Model Years	Test Segment 1	Test Segment 2	Test Segment 3
HC	Pre-1968	-0.20623E-01	-0.24032E-02	-0.10081E-02
	1968-1969	-0.24462E-01	-0.32017E-02	-0.86884E-03
	1970-1971	-0.21255E-01	-0.52755E-03	0.93659E-03
	1972-1974	-0.21427E-01	-0.39442E-03	0.49731E-02
	1975-1979	-0.23517E-01	-0.88057E-02	-0.16222E-02
	1980	-0.26820E-01	-0.75815E-02	-0.51660E-02
	1981	-0.32775E-01	-0.83176E-02	-0.90264E-02
	1982	-0.32082E-01	-0.85130E-02	-0.90264E-02
	1983	-0.36491E-01	-0.74210E-02	-0.59700E-02
	1984	-0.35513E-01	-0.81506E-02	-0.65977E-02
	1985	-0.32437E-01	-0.78173E-02	-0.63349E-02
	1986	-0.30471E-01	-0.84450E-02	-0.68826E-02
	1987	-0.30325E-01	-0.90327E-02	-0.73839E-02
	1988	-0.27959E-01	-0.94236E-02	-0.77326E-02
	1989	-0.26867E-01	-0.85843E-02	-0.70257E-02
	1990	-0.24273E-01	-0.83468E-02	-0.68413E-02
	1991	-0.23768E-01	-0.82591E-02	-0.67700E-02
	1992+	-0.23768E-01	-0.82591E-02	-0.67700E-02
CO	Pre-1968	-0.13487E-01	0.15784E-02	0.11097E-02
	1968-1969	-0.21126E-01	-0.15289E-02	0.15749E-02
	1970-1971	-0.20843E-01	-0.59951E-02	0.18253E-02
	1972-1974	-0.19091E-01	-0.42373E-03	0.57982E-02
	1975-1979	-0.24835E-01	-0.88336E-02	-0.11553E-02
	1980	-0.12448E+01	-0.12478E-01	-0.74106E-02
	1981	-0.13095E+01	-0.14584E-01	-0.11371E-01
	1982	-0.12840E+01	-0.14584E-01	-0.11371E-01
	1983	-0.11761E+01	-0.13550E-01	-0.90777E-02
	1984	-0.11636E+01	-0.14658E-01	-0.90777E-02
	1985	-0.10515E+01	-0.14282E-01	-0.90777E-02
	1986	-0.10032E+01	-0.15277E-01	-0.90777E-02
	1987	-0.10146E+01	-0.16146E-01	-0.90777E-02
	1988	-0.94629E+00	-0.16807E-01	-0.90777E-02
	1989	-0.88655E+00	-0.15614E-01	-0.90777E-02
	1990	-0.79324E+00	-0.15360E-01	-0.90777E-02
	1991	-0.77390E+00	-0.15250E-01	-0.90777E-02
	1992+	-0.77390E+00	-0.15250E-01	-0.90777E-02
NOx	Pre-1968	-0.16897E-03	-0.89245E-02	-0.72580E-02
	1968-1972	-0.25074E-03	-0.59791E-02	-0.62690E-02
	1973-1974	0.38855E-02	-0.24156E-02	-0.21188E-02
	1975-1976	-0.45504E-04	-0.12575E-02	-0.53153E-03
	1977-1979	-0.76044E-02	-0.68045E-02	-0.54198E-02
	1980	-0.19000E-02	-0.61656E-02	-0.49643E-02
	1981	-0.45479E-02	-0.74823E-02	-0.90882E-02
	1982	-0.47657E-02	-0.69890E-02	-0.90882E-02
	1983	-0.43258E-02	-0.97539E-02	-0.10132E-01
	1984	-0.43258E-02	-0.93986E-02	-0.10036E-01
	1985	-0.43258E-02	-0.85213E-02	-0.91794E-02
	1986	-0.43258E-02	-0.78839E-02	-0.88096E-02
	1987	-0.43258E-02	-0.77871E-02	-0.88966E-02
	1988	-0.43258E-02	-0.70534E-02	-0.83745E-02
	1989	-0.43258E-02	-0.68079E-02	-0.79177E-02
	1990	-0.43258E-02	-0.60641E-02	-0.72042E-02
	1991	-0.43258E-02	-0.59229E-02	-0.70563E-02
	1992+	-0.43258E-02	-0.59229E-02	-0.70563E-02

* WHERE :
  - TCF(b) = Low temperature correction factor for appropriate pollutant, ambient temperature (< 75F), and model year, for test segment b,
  - T = Ambient temperature (Fahrenheit),
  - TC(b) = Low temperature correction factor coefficient for appropriate pollutant, reference temperature, and model year, for test segment b.

NOTE : The low temperature correction factor is used in conjunction with the correction factor given in Table 1.7C.

DATE : JUNE 30, 1995

APPENDIX A-2

HIGH (> 75F) TEMPERATURE CORRECTION FACTOR COEFFICIENTS
AND FUEL RVP CORRECTION FACTORS FOR
LIGHT DUTY GASOLINE POWERED VEHICLES

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  * TCF(b) = EXP [ TC(b)*(T - 75.0) ], Pre-1980
TRCF(b) = EXP [ RC(b)*(RVP - 9.0) + TC(b)*(T - 75.0)
         + TRC(b)*(RVP - 9.0)*(T - 75.0) ], 1980+
```

Pol	Model Years	Parameter	Test Segment 1	Test Segment 2	Test Segment 3
HC	Pre-1968	TC	-0.14381E-01	0.13219E-02	0.34799E-02
	1968-1969		-0.12552E-01	0.42667E-02	0.75843E-02
	1970-1971		-0.10888E-01	-0.47925E-03	0.76666E-02
	1972-1974		-0.66107E-02	0.26288E-02	0.12320E-01
	1975-1979		-0.14095E-01	0.26179E-01	0.24297E-01
	1980-1982	RC	0.91402E-01	0.42060E-01	0.93179E-01
		TC	0.44270E-02	0.48358E-02	0.74688E-02
		TRC	0.29466E-02	0.00000E+00	0.47276E-02
	1983+	RC	0.23202E-01	0.15373E+00	0.13263E+00
		TC	0.00000E+00	0.86550E-02	0.83730E-02
		TRC	0.00000E+00	0.00000E+00	0.56009E-02
CO	Pre-1968	TC	-0.14691E-01	0.37462E-02	0.11014E-01
	1968-1969		-0.38767E-01	0.84685E-02	0.25179E-01
	1970-1971		-0.21165E-01	0.23603E-01	0.28483E-01
	1972-1974		-0.13146E-01	0.24717E-01	0.25848E-01
	1975-1979		-0.19612E-01	0.48537E-01	0.31439E-01
	1980-1982	RC	0.91345E-01	0.13968E+00	0.16322E+00
		TC	0.62182E-02	0.14943E-01	0.14923E-01
		TRC	0.00000E+00	0.00000E+00	0.00000E+00
	1983+	RC	0.40748E-01	0.26214E+00	0.23218E+00
		TC	0.35170E-02	0.14966E-01	0.20695E-01
		TRC	0.00000E+00	0.56416E-02	0.82344E-02
NOx	Pre-1968	TC	0.38841E-02	-0.87325E-02	-0.10839E-01
	1968-1972		-0.10389E-02	-0.92466E-02	-0.10108E-01
	1973-1974		-0.18301E-01	-0.10925E-01	-0.18042E-01
	1975-1976		-0.71420E-02	-0.87910E-02	-0.75470E-02
	1977-1979		-0.26153E-01	-0.18603E-01	-0.20878E-01
	1980-1982	RC	0.00000E+00	-0.40024E-01	0.00000E+00
		TC	0.00000E+00	0.00000E+00	0.00000E+00
		TRC	0.00000E+00	0.00000E+00	0.00000E+00
	1983+	RC	0.14219E-01	0.27491E-01	0.00000E+00
		TC	0.00000E+00	0.37789E-02	0.00000E+00
		TRC	0.00000E+00	0.00000E+00	0.00000E+00

```
* WHERE :
    TCF(b) = High temperature correction factor for appropriate pollutant,
             ambient temperature, and model year, for test segment b,
    T      = Ambient temperature (Fahrenheit),
    TC(b)  = High temperature correction factor coefficient for appropriate
             pollutant, temperature, and model year, for test segment b,
    TRCF(b)= High temperature and fuel RVP correction  factor
             for appropriate pollutant, ambient temperature, fuel RVP,
             and model year, for test segment b,
    RC(b)  = Fuel RVP correction factor coefficient for appropriate
             pollutant, fuel RVP, and model year, for test segment b,
    RVP    = Fuel volatility in psi,
    TRC(b) = Combined temperature and fuel RVP correction factor coefficient
             for appropriate pollutant, fuel RVP, ambient temperature,
             and model year, for test segment b.
NOTE : The temperature correction factor is used in conjunction with
       the correction factor given in Table 1.7C in APP42.
```

Appendix

Response to Stakeholder Comments

AAMA Comments:

The American Automobile Manufacturers Association had the following comment regarding temperature corrections:

1. *Regarding the application of various correction factors to the start emissions, AAMA is unsure whether the use of Bag 1 factors is appropriate. The Bag 1 factors reflect a significant amount of warm running operation. It is unlikely, therefore, that the Bag 1 temperature correction factors at 20 degrees Fahrenheit would be appropriate for use on 100 seconds of cold start emissions. However, AAMA also recognizes that there is little other data on which to base these factors. Therefore, AAMA recommends a longer term testing program in which these correction factors (for temperature and fuels) for start emissions can be developed. Such a testing program should probably focus only on Tier I and LEV-type vehicles (to assist in making accurate future projections), and the ten model years prior to 1996.*

Certainly data specific to the operating condition we are modeling (i.e., engine start emissions) will be preferable to Bag 1 correction factors. However, as AAMA noted, this will require new testing, which will not be available in time for use in MOBILE6.

2. *We think more attention should be given to updating the model in the area of cold temperature CO emissions. In our meeting with you on this subject on November 14th, we shared a number of specific concerns, and you indicated that there was possibility that a separate CO model could be issued prior to MOBILE6 if it is determined that this was necessary. We fully support that concept and will continue to provide you the analyses you requested.*

A special version of the MOBILE5 model was produced to address the AAMA concerns. These changes are included into the MOBILE6 model as well.

3. *EPA is proposing to use the MOBILE5 Bag 1 temperature correction factors to adjust start emissions for soaks 12 hours or longer; to use the Bag 3 temperature correction factors for start emissions for soak periods 10 minutes and shorter; and to linearly interpolate between these temperature correction factors for the intermediate soak periods. EPA is further proposing to use the MOBILE5 Bag 2 temperature correction factors for running emissions.*

   EPA's temperature correction factors are based on FTP testing using a minimum 12-hour soak. Examination of the temperature correction factor database shows that the latest model year vehicles tested are 1987, which are now ten years old. AAMA realizes that EPA may have to use these factors for MOBILE6, because of the lack of temperature test data. However, the Bag 1 temperature correction factors may not be appropriate for cold start emissions, because Bag 1 includes a certain amount of "stabilized" operation. EPA's use of Bag 3 temperature correction factors is probably appropriate for very short *soak periods (i.e., less than 15 minutes long). Finally, EPA's use of the Bag 2 temperature correction factors for running emissions is probably appropriate.*

No new data addressing the effect of temperature on exhaust emissions is available for the development of MOBILE6. EPA believes that the existence of some stabilized vehicle operation in Bag 1 emissions will have only a small effect on the overall estimate of the effect of temperature on engine start emissions.

4. AAMA's and EPA's analysis of emissions data at normal summer temperatures (i.e., 75 degrees Fahrenheit) shows that later model Tier 0 vehicle (i.e., 1990-1993) generally have much lower emissions than cars and light duty trucks built in the 1980s. These vehicles probably also have less emissions sensitivity to variations in temperature. AAMA believes that EPA's approach of separating cold start and running emissions creates a significant need for further temperature testing, both on later model year cars and light duty trucks, and with a different test procedure. New testing should use a test procedure that incorporates a cold start and no start, similar to EPA's test program which it conducted to determine emissions from a hot running 505 (HR505). In addition, there is a need for data at different temperatures at intermediate soak periods, for example, 30 minutes, 1-hour, 3 hours, etc.

EPA is now planning a new generation of emission models which will address these concerns, including the collection of data on later model year vehicles.

5. On November 14, 1997, AAMA members met with EPA OMS and AIR, Inc., to discuss changes in the MOBILE5b model that would more accurately reflect vehicle CO emissions at cold temperatures. AAMA's specific comments are contained in the November 14, 1997 AIR briefing entitled "Impacts of MOBILE6 Development on CO Emissions at Cold Temperatures", which was provided to EPA at that meeting. AAMA was pleased with the outcome of the meeting in that it resulted in an agreement to work together to determine model modifications that should be incorporated to best reflect vehicles designed to meet Phase 1 cold temperature CO standards. AAMA is confident that our work efforts can continue and that they will result in model modifications that are technically correct and agreeable to all involved. AAMA would also like to continue work efforts related to Phase II cold temperature standards, should they be required.

AAMA is hopeful that agreed upon changes related to the Phase I standards can be quickly incorporated and that states will be allowed to utilize a model having these revisions in their SIP planning for CO attainment/maintenance. In this regard, we again request that, once the revisions are completed, EPA make the revised model available for the states/municipalities to use prior to release of the official MOBILE6 model. This is critical because the changes result in major reductions in forecasted CO emissions, and will thus have significant implications on possible CO control strategies and costs.

A special version of the MOBILE5 model was produced to address the AAMA concerns. These changes are included into the MOBILE6 model as well.

AIR Comments:

Air Improvement Resource, Inc., has five areas of comment on the update to the hot soak emission rates:

1. *EPA should design and implement a temperature correction factor test program for Tier 1 and LEV vehicles and implement the results in MOBILE6.*

EPA proposes to rely on the MOBILE5 temperature correction factors for MOBILE6, when the MOBILE5 Temperature Correction Factors (TCFs) were based on early Tier 0 vehicles. These TCFs probably are inappropriate for late model Tier 0 vehicles (1998-1993), Tier 1 vehicles (1994-2000), LEVs, and Tier 2 vehicles.

EPA has been in the process of updating MOBILE5 for about 3 years. Over the last few years, EPA has committed resources to test programs to develop basic emissions rates at FTP temperatures, and speed correction factors, however, little or no resources have been devoted to updating the temperature correction factors. This is a very serious problem for all MOBILE6 users, because all MOBILE6 users run MOBILE6 at nonstandard conditions. For example, all states that prepare inventories, and those that must submit ozone SIPs, run MOBILE5 at nonstandard temperature conditions. EPA, when it produces inventories for the nation on a county-by-county basis for its Emission Trends Report, also runs the model at nonstandard conditions.

AIR believes that EPA should commence a test program immediately to determine TCFs for Tier 1 and LEV vehicles, at low and high temperatures.

No new data addressing the effect of temperature on exhaust emissions is yet available for the development of MOBILE6.

2. *EPA should examine the cold CO data on LEVs to determine a separate Cold CO offset for LEVs.*

EPA adopted AIR's suggestions for the cold CO portion of the model. AIR estimated cold CO offsets for Tier 1 vehicles, which EPA is proposing to use for all Tier 1 and later vehicles. However, the CO offsets for LEVs and Tier 2 vehicles may be very different. AIR accessed the 1999 certification data for CO emissions at 20 degrees Fahrenheit and 75 degrees Fahrenheit for Tier 1s, TLEVs, LEVs and ULEVs. The results for cars and LDTs are shown in Table 1 below.

EPA is using a 3.8 g/mi increase for Tier 1 passenger cars for 20 degrees Fahrenheit relative to 75 degrees Fahrenheit. This was based on the difference in 4,000 mile certification results. The above table shows a 4.3 g/mi difference based on 50K results for Tier 1 vehicles in 1997, 3.9 g/mi for 1998 vehicles, and 3.9 for 1999 Tier 1 vehicles. Thus, the 3.8 g/mi for Tier 1 vehicles which EPA proposes to use still appears to be a good value. For LEVs, the CO difference between 75 degrees Fahrenheit and 20 degrees Fahrenheit is 3.0 g/mi in 1998, and 3.2 in 1999. For ULEVs, the increase is about 2.3 g/mi. These data show that the CO offsets for LEVs, ULEVs, and Tier 2 vehicles should be substantially less than the Tier 1 offsets. AIR recommends using 3.1 g/mi for National LEV vehicles (NLEVs).

Table 1 EPA 50,000 mile Certification CO Emission Rates							
Vehicle			**CO (75F)**		**Cold CO (20F)**		**Diff.**
Class	**MY**	**Tier**	**N**	**g/mi**	**N**	**g/mi**	**g/mi**
LDV	1997	T1	124	1.156	328	5.467	4.311
	1998	T1	887	1.121	209	5.011	3.89
		TLEV	279	0.916	33	5.324	4.407
		LEV	60	0.727	7	3.779	3.052
		ULEV	2	0.314	None	None	None
	1999	T1	894	1.285	213	5.211	3.926
		TLEV	341	0.964	49	4.305	3.341
		LEV	248	0.798	48	4.083	3.285
		ULEV	16	0.311	2	2.6	2.289
LDT	1997	T1	54	1.598	203	5.742	4.144
	1998	LEV	40	1.362	7	5.373	4.011
		T1	212	1.533	57	5.366	3.833
		TLEV	120	1.382	24	6.916	5.535
	1999	LEV	342	1.491	65	5.129	3.638
		T1	730	1.897	153	5.593	3.696
		TLEV	126	1.361	22	5.738	4.377
		ULEV	12	0.757	1	1.669	0.912

EPA had not proposed updating the cold temperature CO offset for MOBILE6. The changes proposed by AIR are very reasonable and will be included in our plans for updates to the MOBILE6 model after it's initial release.

3. *EPA should examine the interaction between the air conditioning correction factor, the cycle or speed correction factors, and the temperature correction factors, to ensure that no double-counting of the emission effects at higher temperatures takes place in the model.*

   AIR is unsure, and the report is unclear about how EPA intends to handle the interaction of the high temperature correction factors, the air conditioning correction factor, and the cycle correction factors. Previous reports from EPA have developed the air conditioning correction factors at 95 degrees Fahrenheit, and air conditioning activity (M6.ACE.001 and M6.ACE.002). If these factors have been developed at 95 degrees Fahrenheit, then perhaps the use of a separate temperature correction factor is not necessary. Also, depending on the cycle that was used to develop the air conditioning correction factors, a *cycle correction factor may not be necessary also. EPA should clearly explain how all of these correction factors are applied at high and low temperatures, and what data sources they are being estimated from, so that it is clear that EPA is not double-counting the effects of any given parameter (cycle, temperature, or activity).*

Air conditioning effects are only applied to running emissions (not including engine start emissions). The effect is calculated as an additive emission offset from a basic exhaust emission rate which has not yet been adjusted (multiplicative) by the temperature correction factor. The basic emission rate is then adjusted by the temperature correction factor before the air conditioning effect is added to the basic exhaust emission rate. In this way the temperature correction is never applied to the emissions represented by the air conditioning offset.

The air conditioning offset itself is calculated by comparing emissions with and without air conditioning at 95 degrees Fahrenheit. Therefore, the air conditioning offset is primarily the effect of the air conditioning load on emissions (at 95 degrees), rather than a combination of temperature and air conditioning effects. These air conditioning effects are, in turn, adjusted to account for differences in air conditioning load at different temperatures. Air conditioning effects are discussed in the reports, "Air Conditioning Activity and Intermediate Conditions," (M6.ACE.001) and "Air Conditioning: Full Usage Correction Factors," (M6.ACE.002) found on the EPA web site (http://www.epa.gov/otaq/m6.htm).