EPA-AA-TEB-EF-90-01

Estimation of Trip- and Emission-Weighted Temperatures For MOBILE4

by

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January 1990

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1.0 BACKGROUND

In the MOBILE emission factor prediction model (e.g., MOBILE3), the exhaust HC, CO, and NOx emissions were calculated based on user specified ambient temperatures (in °F), which were usually the average temperature of the days during either high ozone or CO violation periods. The diurnal and hot soak emissions were based on the default FTP temperatures (i.e., 60 to 84°F heat rise for the diurnal emissions, and approximately 82°F ambient temperature for the hot soak emissions). No running loss emissions were assumed in MOBILE3.

During 1986, a revised version of MOBILE3 (MOBILE3 version 9, or M3V9) was created in support of a fuel volatility control proposed rulemaking. In this revised version, in addition to the temperature parameter used for calculating exhaust emissions, users were required to specify another set of temperatures (corresponding to the average daily minimum and maximum ambient temperatures) for use in the diurnal emissions calculation. These temperatures were, in general, area-specific averages during the high ozone days. The model required that the exhaust temperature be consistent with the diurnal temperatures (i.e., the exhaust temperature must be within the minimum and maximum diurnal temperatures). Due to lack of information at the time, the temperature effect on hot soak emissions was not directly modeled, but was indirectly accounted for through adjustment of local fuel volatility level. As in MOBILE3, no running loss emissions were assumed in M3V9.

In MOBILE4, as in M3V9, users are required to specify the minimum and maximum ambient temperatures based on daily averages during the high ozone days for the diurnal emissions calculation. With the user-specified minimum and maximum ambient temperatures, a set of both trip- and emission-weighted temperatures is to be derived . The model will calculate the temperatures used for adjusting the evaporative hot soak and the new added running loss emission factors. Users must also specify a temperature for use in calculating the temperature correction to exhaust emissions. Or, as an option, the model will calculate a trip- and emission-weighted temperature for use of estimating the exhaust emissions on the basis of the minimum and maximum temperatures.

Details of the methodology used to develop this temperature simulation model are contained in the following discussion, along with the results. It is assumed in this paper that users have sufficient information and guidance on how to choose the appropriate minimum and maximum ambient temperatures for MOBILE4 to meet their modeling objectives.

2.0 DISCUSSION

In order to complete this temperature simulation model, the following three types of data were required:

1. Ambient Temperature Profile. One set of temperature profile data used in the analysis was the 20-year average hourly temperatures by month from Pittsburgh, PA. In addition, average hourly temperatures from cities on either high ozone or CO violation days during 1984 were also examined.

2. Trip Data. 1979 GM-National Purchase Diary (NPD) survey data (described in more detail in Step 1, below).

3. Emissions vs. Ambient Temperature Data. The MOBILE4 temperature and fuel RVP correction factor models for the three exhaust emissions, hot soak emissions, and running loss emissions were used. In using these models the following assumptions were made: no vehicle tampering, all vehicles under FTP operating mode conditions (20.6% cold start, 52.1% stabilized, and 27.3% hot start), at average speed of 19.6 mph, with in-use fuel volatilities of 9.0, 10.4, and 11.7 RVP (in psi), fuel tank fill level of 40 percent, and model years 1983, 1988, and 1992 carbureted vs. fuel-injected light-duty gasoline-powered vehicle (LDGV) technology mix. Model year 1983 was chosen because all post-1983 LDGVs are equipped with closed-loop catalyst technology. MOBILE4 has assumed the same carbureted vs. fuel-injected technology mixes for 1992+ LDGVs. Model year 1988 was selected as an intermediate year between 1983 and 1992.

The following is a step-by-step discussion of the methodology and results:

Step 1: Derive a trip weighting factor as a function of daily minimum and maximum temperatures.

The 1979 GM-NPD survey data and the average hourly temperature data from Pittsburgh (Table 1) were used to develop this trip weighting factor. As the emphasis of this simulation was on high ozone days, only temperatures from the months of April through October were used. Figure 1 shows the July temperature profile, in which the minimum temperature (Tmin) of 63°F occurs at both 6 and 7 AM, and the maximum temperature (Tmax) of 80°F occurs from 3 to 5 PM.

The 1979 GM-NPD data base included survey results from a total of 1964 households and 2870 household vehicles (both passenger cars and light-duty trucks). Trips made by these household vehicles during the seven-day survey week (either May 14-20 or June 4-10, 1979) were recorded. A trip was defined as "a one-way journey between two stops, visits, or locations." Data recorded include days of the week, trip number, trip times (both starting and ending), and trip distances (odometer readings). Frequencies of trips by the starting hour were calculated and percents of trips by each hour of the day derived, as shown in Table 2.

It was assumed that the occurrence of trips by each hour of the day remained constant daily. As can be noted from Figure 2, the three peak starting times of trips are 5 PM, 12 noon, and 8 AM. With 5 PM being also the peak temperature of the day, and 12 noon representing about 80% of the total temperature rise of the day, it is anticipated that a large portion of trips occur at the higher end of the range of daily ambient temperatures.

Percents of trips by each hour of the day were matched against the Pittsburgh temperature profile (April through October), to obtain an estimate of trip percentage at each ambient temperature of the day. For the hours that had the same ambient temperature, percents of trips were combined. For example, the Tmax of 80°F for July represented a total of 24.0 percent trips, which included 6.9 percent starting from 3-4 PM, 8.0 percent starting from 4-5 PM, and 9.1 percent starting from 5-6 PM.

Then, for each month between April and October, the percent of trips was expressed as a function of temperature rise (difference between Tmax and Tmin in °F, denoted as F°). Since the absolute temperature rise varies from month to month (for example, from 15F° in April and October to 17F° in May through July in Pittsburgh), they were standardized as fractions of 1:

$$R = (T - Tmin) / (Tmax - Tmin) \qquad (1)$$

where: R = Standardized temperature rise,
Tmin = Minimum ambient temperature, °F
Tmax = Maximum ambient temperature, °F, and
T = Any temperature between Tmin and Tmax.

Note that the R values in equation (1) are always within 0 (when T = Tmin) and 1 (when T = Tmax).

A fourth degree polynomial equation was found to fit the data best in describing the relationships between the percent of trips and temperature rise:

$$WT = a + b*R + c*R**2 + d*R**3 + e*R**4 \quad (2)$$

where: WT = Percent of trips,
R = Standardized temperature rise,
a = 6.4044
b = −75.533
c = 356.29
d = −571.55
e = 307.03

Between any given values of Tmin and Tmax, the percent of trips at all temperatures could be estimated through equation (2). The predicted percents of trips were then re-normalized, as shown in Table 3. Figure 3 is a comparison between the actual (shown as dots) and predicted (shown by the smooth curve) percents of trips by ambient temperature at trip start, for the month of July in Pittsburgh.

Step 2: Derive emission factors at all temperatures between any given values of Tmin and Tmax.

The MOBILE4 temperature correction factor models for exhaust HC, CO, and NOx emissions were used to calculate the exhaust emissions temperature correction at each temperature. For example, at temperatures equal to or above 75°F, the combined temperature/fuel RVP correction equations were used for each portion of the FTP operating mode (cold start, stabilized, and hot start), for each fuel-metering system (carbureted, ported and throttle body fuel-injected) of LDGVs. At temperatures below 75°F, temperature correction factor equations were used to account for temperature effect first. For example, an additive adjustment model was used for cold start CO, and multiplicative adjustment models were used for the other two FTP portions of CO and all three FTP portions of HC and NOx emissions. Then, for temperatures between 41 and 74°F, a RVP effect was added. Figures 4 through 6 show the calculated exhaust emission factors for the month of July in Pittsburgh (from Tmin of 63 to Tmax of 80°F). Note that, although the absolute values of the calculated three exhaust pollutants are different, their trends of emissions vs. ambient temperature are similar, i.e., emissions are higher at low ambient temperatures, decrease as temperature gets closer to 75°F, and increase again when temperature is higher than 75°F.

The MOBILE4 hot soak and running loss emissions models were used to estimate hot soak and running loss emission factors. Between any given values of Tmin and Tmax, when the ambient temperature was above 40°F, hot soak and running loss emissions were calculated (assuming no RVP reduction as a result of fuel weathering). Figures 7 and 8 show the calculated hot soak and running loss emissions at each temperature for the month of July in Pittsburgh. Note that both hot soak and running loss emissions increase with rising ambient temperature.

Step 3: Calculate the trip-weighted emission factors for each pollutant, and find out at what temperatures half of the accumulated emissions occur. These are the approximate trip- and emission-weighted temperatures.

Using the July temperatures from Pittsburgh as an example, as shown in Table 4, emissions at each temperature (top portion) were multiplied by the normalized trip weighting factor from Table 3, and the cumulative trip-weighted emissions were estimated (lower portion). The cumulative trip-weighted emissions are also plotted in Figures 4 through 8. From these cumulative emissions, the temperatures that correspond to half of the accumulated emissions were about 76°F for the exhaust HC, CO, and NOx emissions, and about 77°F for the evaporative hot soak and running loss emissions. As expected, the trip- and emission-weighted temperatures for the three exhaust emissions were about the same because of their similar behavior as a function of temperature, while the temperatures for hot soak and running loss emissions were slightly higher.

Three different levels of fuel volatilities (9.0, 10.4, and 11.7 RVP) were used in the simulation process. Results showed that different fuel RVPs led to different levels of both exhaust and evaporative emissions. In general, the higher the fuel volatility, the higher the emission level. However, for these given temperature ranges, the derived trip- and emission-weighted temperatures were the same regardless of the fuel volatilities. For this reason, only 11.7 psi RVP fuel was used for simulations beyond Step 3.

Step 4: Generate sets of trip- and emission-weighted temperatures by using various combinations of Tmin and Tmax.

The approach adopted here was to examine the average hourly temperatures from cities on either high ozone or CO violation days during the year of 1984, with the emphasis on high ozone days. Two restrictions were placed on the data in describing the temperature rise as a function of the daily minimum ambient: 1) Only data from the months of April through October were used, since these were the most likely potential high ozone occurrences during a year, and 2) Only data with temperature rises greater than 5F° were used. (The majority of days with 5F° and less temperature rises in this 1984 temperature data were from incomplete recordings. For example, some weather stations were open and recording their hourly temperatures only during the daytime.)

For hot soak and running loss emissions, an additional restriction was placed: only days when the minimum ambient temperatures were greater than 40°F were used. This is consistent with the MOBILE4 assumption that there are no evaporative emissions (either hot soak or running loss) when the ambient temperature is at or below 40°F.

Two regression equations were derived from this 1984 temperature data:

$$\text{Rise} = 21.901 - 0.11084 * (\text{Tmin} - 40.0) \qquad (3)$$

$$\text{Rise} = 22.478 - 0.13666 * (\text{Tmin} - 40.0) \qquad (4)$$

where equation (3) was used when Tmin was less or equal to 40°F, and equation (4) was used when Tmin was greater than 40°F.

Using the above steps, trip- and emission-weighted temperatures were calculated for each of the combinations of Tmin and Tmax, with Tmin ranging from 0.0 to 100.0°F, Tmax ranging from Tmin+(Rise-10.0) to Tmin+(Rise+10.0), and Rise calculated from either equation (3) or equation (4), depending on the value of Tmin. Then, for each model year considered (1983, 1988 and 1992), and for each pollutant (exhaust HC, CO, and NOx, and evaporative hot soak), an equation was derived to describe the relationships between the trip- and emission-weighted temperatures and their corresponding given set of Tmin and Rise. Note that for running loss emissions, since the same emission rates were used for all 1981+ LDGVs, only one temperature vs. Tmin and Rise equation is derived (representing all three model years).

Regression coefficients are summarized in Table 5, and predicted temperatures from a few selected combinations of Tmin and Rise are listed in Table 6. As can be seen, for each pollutant, the predicted temperature differences among the three model years are very small, typically less than 1F°. Within the same model year (e.g., 1988), the predicted temperature differences among the three exhaust emissions are also small, typically around 1F°. The only exceptions are at extreme low temperatures, where the predicted NOx temperatures are about 3F° higher than the exhaust HC temperatures.

Considering the very small differences in the results of the simulation for the three model years and three exhaust pollutants, two simplifying assumptions were used in MOBILE4. First, regression coefficients from model year 1988 were selected to represent all model years. Second, coefficients from exhaust HC emissions were also selected to represent the other two exhaust emissions (CO and NOx).

3.0 RESULTS

A set of trip- and emission-weighted temperatures, described as a function of the minimum and maximum ambient temperatures has been derived for use in MOBILE4. The equations are:

$$TEMP_{exhaust} = 2.2857 + 0.97674 * Tmin + 0.56881 * Rise + 0.0024642 * Tmin * Rise$$

$$TEMP_{hot\ soak} = -1.7474 + 1.029 * Tmin + 0.99202 * Rise - 0.0025173 * Tmin * Rise$$

$$TEMP_{running\ loss} = -1.1977 + 1.0205 * Tmin + 1.0181 * Rise - 0.0023797 * Tmin * Rise$$

Using the above three equations, selected combinations of Tmin and Rise are listed in Table 7.

Table 1

Hourly Ambient Temperature Data
Pittsburgh, PA

Time of Day	Average Ambient Temperature (°F)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0100	25	26	36	46	55	63	67	66	60	48	40	31
0200	24	26	36	45	54	62	66	65	59	47	40	31
0300	24	25	35	44	53	61	65	64	58	47	39	31
0400	24	25	35	44	52	60	65	63	58	46	39	30
0500	24	25	34	43	51	59	64	63	57	46	38	30
0600	23	24	34	42	51	59	63	62	57	45	38	30
0700	23	24	33	42	51	60	63	62	56	45	38	30
0800	23	24	33	43	53	62	66	63	56	45	38	30
0900	23	24	34	46	57	65	69	66	59	46	38	30
1000	23	25	36	48	60	68	72	69	62	50	39	30
1100	25	27	39	51	62	71	75	72	66	53	42	32
1200	26	29	41	53	64	73	77	75	68	55	44	33
1300	28	31	42	55	66	74	78	76	70	57	45	35
1400	29	32	44	56	67	76	79	78	71	59	46	35
1500	30	33	45	57	68	76	80	78	72	59	47	36
1600	30	33	45	57	68	76	80	78	72	60	47	36
1700	30	34	46	57	68	76	80	78	72	59	47	36
1800	29	33	45	57	67	75	79	77	71	58	45	35
1900	28	32	43	55	66	74	78	76	69	55	44	34
2000	27	30	42	53	64	72	76	74	66	54	43	33
2100	27	30	40	52	62	70	73	71	64	52	42	33
2200	26	29	39	50	60	68	71	69	63	51	41	32
2300	25	28	38	49	58	66	70	68	61	50	41	32
2400	25	27	37	47	57	64	68	67	60	49	40	31

Table 2

Trip Distributions by Starting Time
1979 GM-NPD Survey Data

Time of Day	Frequency	Percent
0100	0	0.0
0200	38	0.0
0300	110	0.1
0400	65	0.1
0500	203	0.2
0600	969	1.0
0700	3432	3.6
0800	6244	6.6
0900	5272	5.6
1000	5675	6.0
1100	5734	6.0
1200	7017	7.4
1300	6170	6.5
1400	5608	5.9
1500	6585	6.9
1600	7623	8.0
1700	8663	9.1
1800	7086	7.5
1900	5535	5.8
2000	4268	4.5
2100	3473	3.7
2200	2483	2.6
2300	1583	1.7
2400	1029	1.1
Total	94865	100.0

Table 3

Percent of Trips vs. Ambient Temperature
Month of July, Pittsburgh, PA

Ambient Temperature (°F)	Percent of Trips		
	Actual	Predicted	Normalized
63	4.6	6.40	5.51
64	0.2	3.08	2.65
65	0.2	1.58	1.36
66	6.6	1.33	1.14
67	0.0	1.85	1.59
68	1.1	2.77	2.38
69	5.6	3.76	3.24
70	1.7	4.64	3.99
71	2.6	5.26	4.52
72	6.0	5.59	4.81
73	3.7	5.68	4.89
74	–	5.68	4.89
75	6.0	5.82	5.00
76	4.5	6.40	5.50
77	7.4	7.84	6.74
78	12.3	10.62	9.13
79	13.4	15.33	13.19
80	24.0	22.64	19.47
Total:	99.9	116.25	100.00

Table 4

Trip-Weighted Emission Factors
Month of July, Pittsburgh, PA

Temperature (°F)	Exhaust Emissions (g/mi) HC	CO	NOx	Hot Soak(g)	Running Loss (g/mi)
Emission Factors					
63	0.651	8.866	0.751	1.612	0.667
64	0.642	8.694	0.747	1.633	0.696
65	0.634	8.520	0.743	1.655	0.725
66	0.625	8.343	0.739	1.676	0.754
67	0.617	8.165	0.735	1.698	0.783
68	0.609	7.984	0.731	1.720	0.812
69	0.601	7.801	0.727	1.741	0.841
70	0.594	7.616	0.723	1.763	0.870
71	0.586	7.429	0.720	1.853	0.899
72	0.579	7.240	0.716	1.945	0.928
73	0.572	7.049	0.712	2.037	0.957
74	0.565	6.856	0.708	2.131	0.986
75	0.558	6.662	0.705	2.225	1.015
76	0.562	6.821	0.706	2.321	1.044
77	0.566	6.986	0.707	2.417	1.073
78	0.570	7.157	0.708	2.514	1.102
79	0.574	7.334	0.709	2.613	1.131
80	0.578	7.517	0.710	2.712	1.160
Cumulative Trip-Weighted Emissions					
63	0.036	0.488	0.041	0.089	0.037
64	0.053	0.719	0.061	0.132	0.055
65	0.062	0.834	0.071	0.155	0.065
66	0.069	0.930	0.080	0.174	0.074
67	0.078	1.060	0.091	0.201	0.086
68	0.093	1.250	0.109	0.242	0.105
69	0.112	1.502	0.132	0.298	0.133
70	0.136	1.806	0.161	0.368	0.167
71	0.163	2.142	0.194	0.452	0.208
72	0.190	2.490	0.228	0.546	0.252
73	0.218	2.834	0.263	0.645	0.299
74	0.246	3.169	0.297	0.750	0.347
75	0.274	3.503	0.333	0.861	0.398
76	0.305	3.878	0.372	0.989	0.456
77	0.343	4.349	0.419	1.151	0.528
78	0.395	5.003	0.484	1.381	0.629
79	0.471	5.970	0.577	1.726	0.778
80	0.583	7.434	0.716	2.254	1.004
Half	0.292	3.717	0.358	1.127	0.502
Corresponding Temperature (° F) at Half:	75.58	75.57	75.64	76.85	76.64

Table 5

Regression Coefficients*

Pollutant	Model Year	Coefficient A	Coefficient B	Coefficient C	Coefficient D
Exh. HC	1983	2.7519	0.97105	0.51087	0.0031863
	1988	2.2857	0.97674	0.56881	0.0024642
	1992	1.9567	0.98127	0.59618	0.0020810
Exh. CO	1983	1.3244	0.99437	0.61650	0.0016654
	1988	1.3425	0.99013	0.62733	0.0018822
	1992	1.2407	0.99023	0.63723	0.0018631
Exh. NOx	1983	1.1217	0.99526	0.68549	0.00064995
	1988	1.0298	0.99587	0.69668	0.00055230
	1992	0.90704	0.99729	0.70475	0.00046836
Hot Soak	1983	-1.8253	1.0265	0.97658	-0.0018361
	1988	-1.7474	1.0290	0.99202	-0.0025173
	1992	-1.7245	1.0328	1.00120	-0.0030849
Running Loss	All	-1.1977	1.0205	1.0181	-0.0023797

*The trip- and emission-weighted temperature equation has the form:

Temp = A + B * Tmin + C * Rise + D * Tmin * Rise

where: Temp = trip- and emission-weighted temperature in °F,
Tmin = ambient minimum temperature in °F,
Rise = difference (in °F) between ambient maximum and minimum temperatures.

Table 6

Predicted Trip- and Emission-
Weighted Temperatures

Tmin (°F)	Rise (F°)	Tmax (°F)	Temperature (°F)				
			Exhaust			Hot Soak	Running Loss
			HC	CO	NOx		
Model Year 1983							
3.0	26.0	29.0	19.2	20.5	22.0	*	*
24.0	23.0	47.0	39.6	40.3	41.1	44.3	45.4
34.0	22.0	56.0	49.4	49.9	50.5	53.2	54.1
45.0	21.0	66.0	60.2	60.6	60.9	63.1	63.9
60.0	24.0	84.0	77.9	78.2	78.2	80.6	81.0
66.0	18.0	84.0	79.8	80.0	79.9	81.3	81.7
77.0	17.0	94.0	90.4	90.6	90.3	91.4	91.6
88.0	15.0	103.0	100.1	100.3	99.8	100.7	100.7
100.0	14.0	114.0	111.5	111.7	111.2	111.9	111.8
Model Year 1988							
3.0	26.0	29.0	20.2	20.8	22.2	*	*
24.0	23.0	47.0	40.2	40.6	41.3	44.4	45.4
34.0	22.0	56.0	49.9	50.2	50.6	53.2	54.1
45.0	21.0	66.0	60.5	60.9	61.0	63.0	63.9
60.0	24.0	84.0	78.1	78.5	78.3	80.2	81.0
66.0	18.0	84.0	79.9	80.2	80.0	81.0	81.7
77.0	17.0	94.0	90.4	90.7	90.3	91.1	91.6
88.0	15.0	103.0	100.0	100.4	99.8	100.4	100.7
100.0	14.0	114.0	111.4	111.8	111.1	111.5	111.8
Model Year 1992							
3.0	26.0	29.0	20.6	20.9	22.3	*	*
24.0	23.0	47.0	40.4	40.7	41.3	44.4	45.4
34.0	22.0	56.0	50.0	50.3	50.7	53.1	54.1
45.0	21.0	66.0	60.6	60.9	61.0	62.9	63.9
60.0	24.0	84.0	78.1	78.6	78.3	79.8	81.0
66.0	18.0	84.0	79.9	80.3	80.0	80.8	81.7
77.0	17.0	94.0	90.4	90.8	90.3	90.8	91.6
88.0	15.0	103.0	100.0	100.4	99.9	100.1	100.7
100.0	14.0	114.0	111.3	111.8	111.2	111.3	111.8

* MOBILE4 does not calculate hot soak or running loss emission factors at these temperatures.

Table 7

Trip- and Emission-Weighted Temperatures

Tmin (°F)	Rise (F°)	Tmax (°F)	Temperature (°F) Exhaust	Hot Soak	Running Loss
3.0	26.0	29.0	20.2	*	*
8.0	25.0	33.0	24.8	*	*
14.0	24.0	38.0	30.4	*	*
18.0	24.0	42.0	34.6	39.5	40.6
24.0	23.0	47.0	40.2	44.4	45.4
29.0	23.0	52.0	45.3	49.2	50.2
34.0	22.0	56.0	49.9	53.2	54.1
39.0	22.0	61.0	55.0	58.0	59.0
44.0	21.0	65.0	59.5	62.0	62.9
49.0	21.0	70.0	64.6	66.9	67.7
53.0	20.0	73.0	68.5	70.0	70.7
55.0	20.0	75.0	70.1	71.9	72.7
60.0	20.0	80.0	75.2	76.8	77.5
60.0	24.0	84.0	78.1	80.2	81.0
66.0	18.0	84.0	79.9	81.0	81.7
67.0	18.0	85.0	80.9	82.0	82.6
71.0	18.0	89.0	85.0	86.0	86.5
77.0	17.0	94.0	90.4	91.1	91.6
82.0	16.0	98.0	94.7	95.2	95.7
88.0	15.0	103.0	100.0	100.4	100.7
93.0	15.0	108.0	105.1	105.3	105.7
99.0	14.0	113.0	110.4	110.5	110.8
100.0	14.0	114.0	111.4	111.5	111.8

* MOBILE4 does not calculates hot soak or running loss emission factors at these temperatures.

Figure 1 : Ambient Temperature vs. Time of Day
Month of July, Pittsburgh, PA

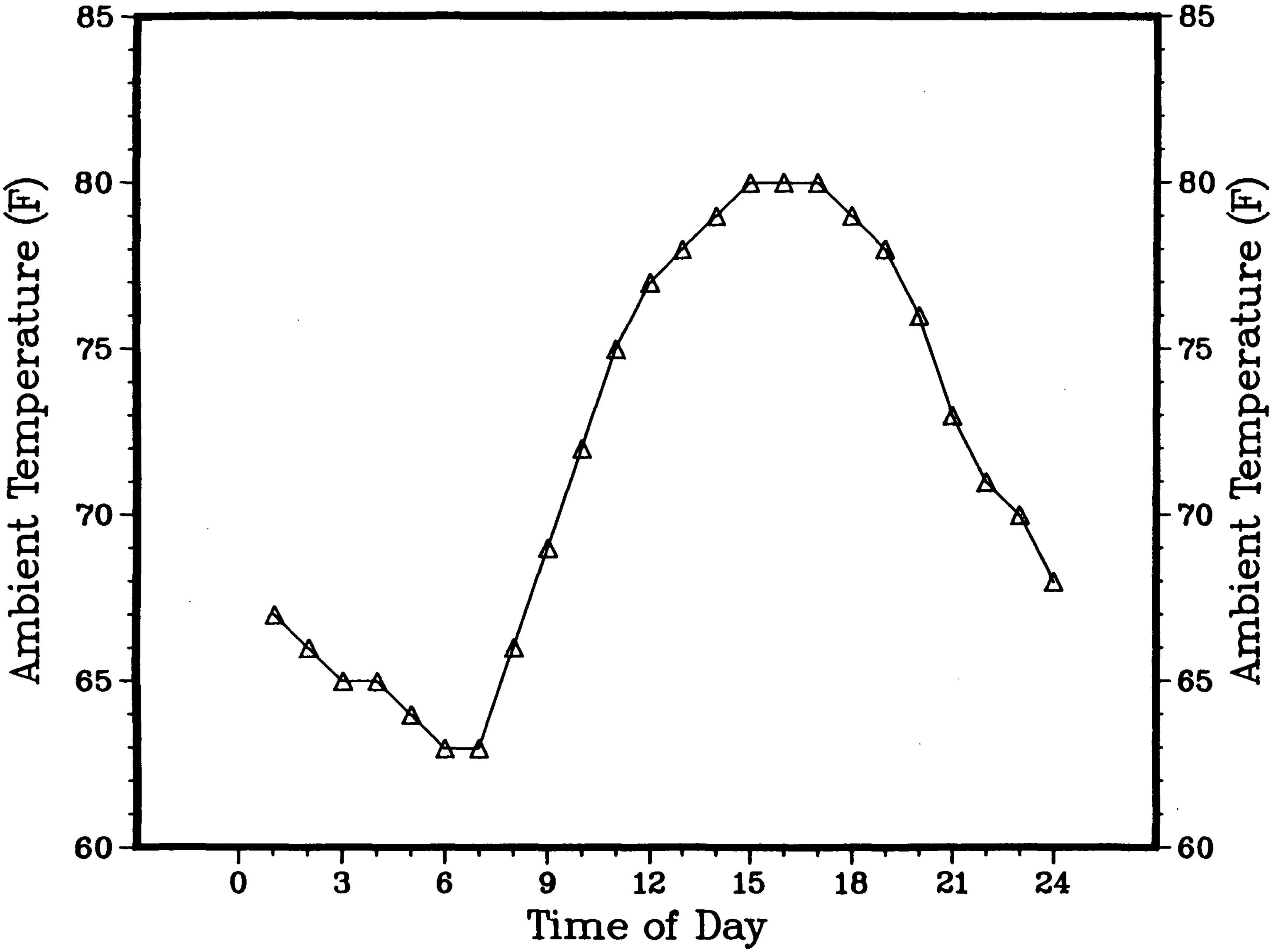

Figure 2 : Percent of Trips vs. Time of Day
1979 GM–NPD Survey Data

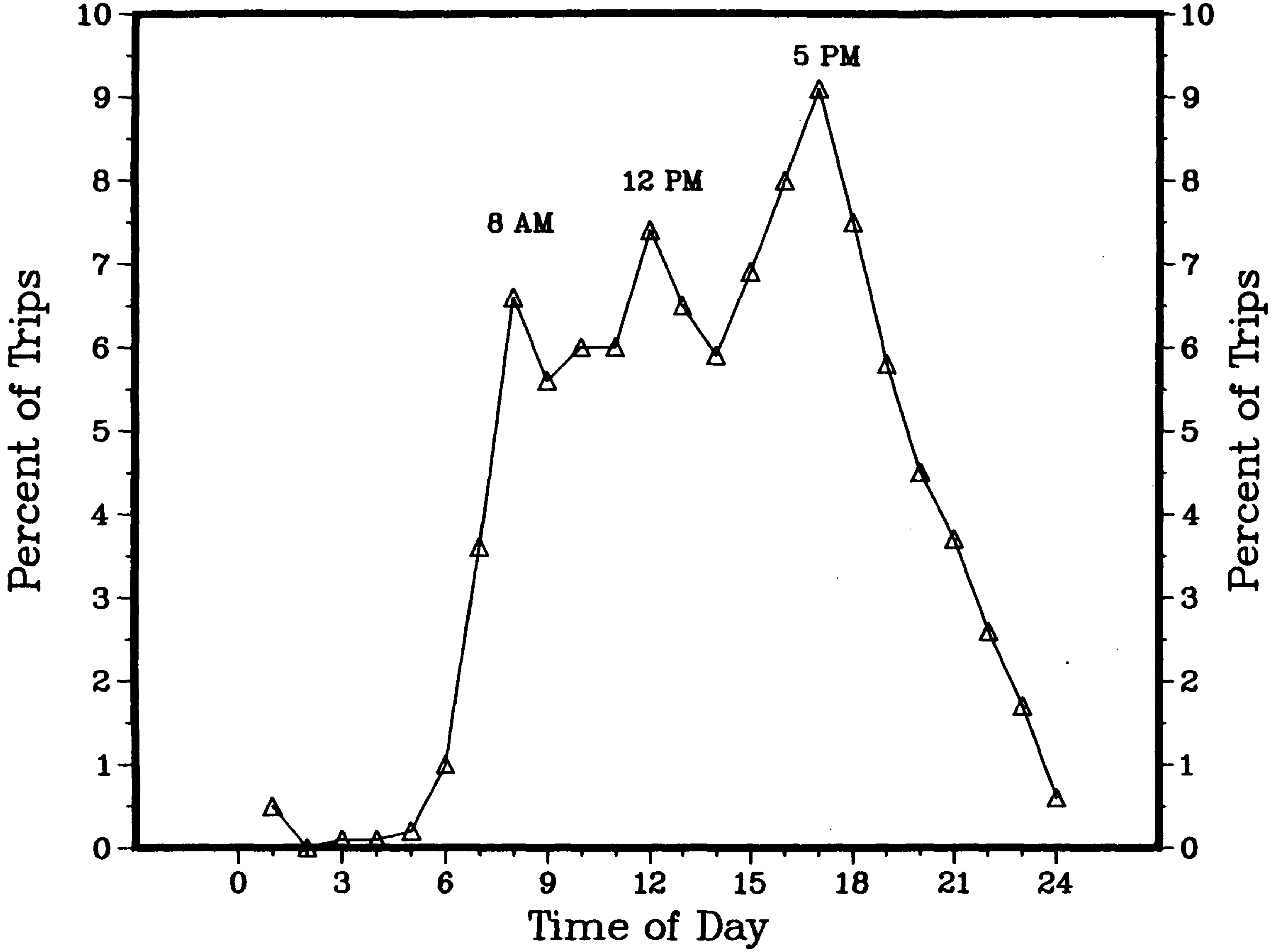

Figure 3 : Percent of Trips vs. Ambient Temperature
Month of July, Pittsburgh, PA

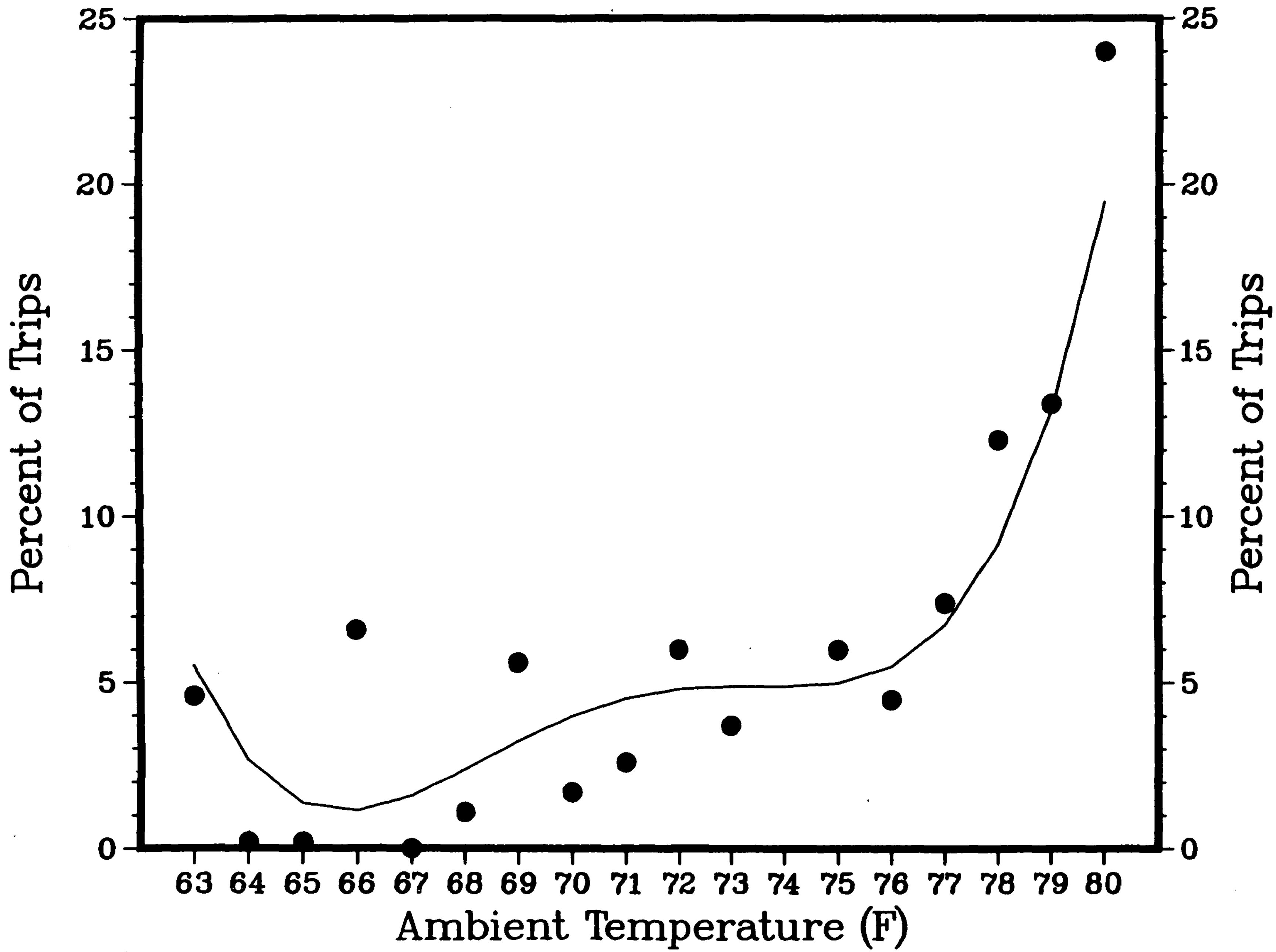

Figure 4 : Exhaust HC Emissions vs. Ambient Temperature
Month of July, Pittsburgh, PA

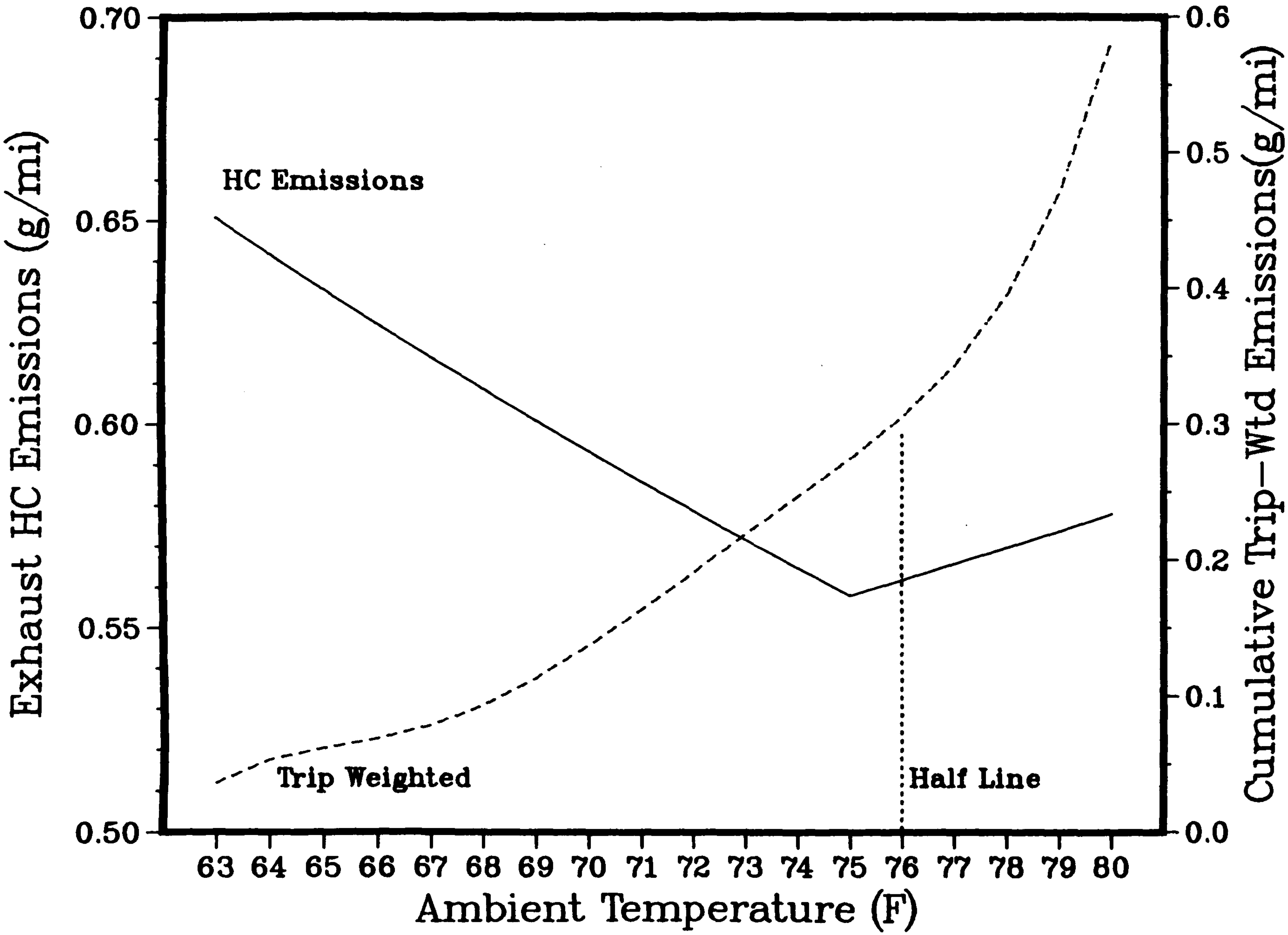

Figure 5 : Exhaust CO Emissions vs. Ambient Temperature
Month of July, Pittsburgh, PA

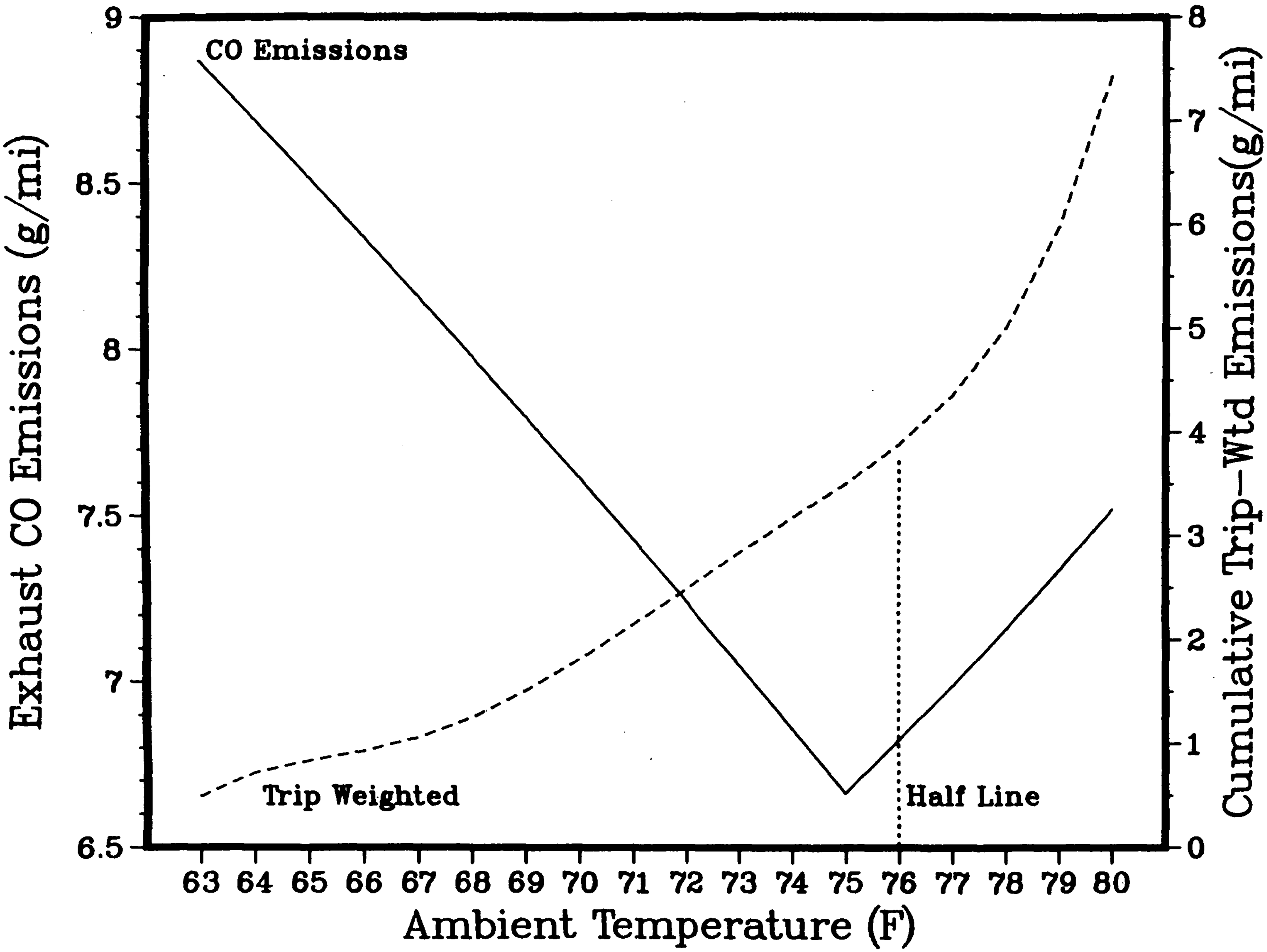

Figure 6 : Exhaust NOx Emissions vs. Ambient Temperature
Month of July, Pittsburgh, PA

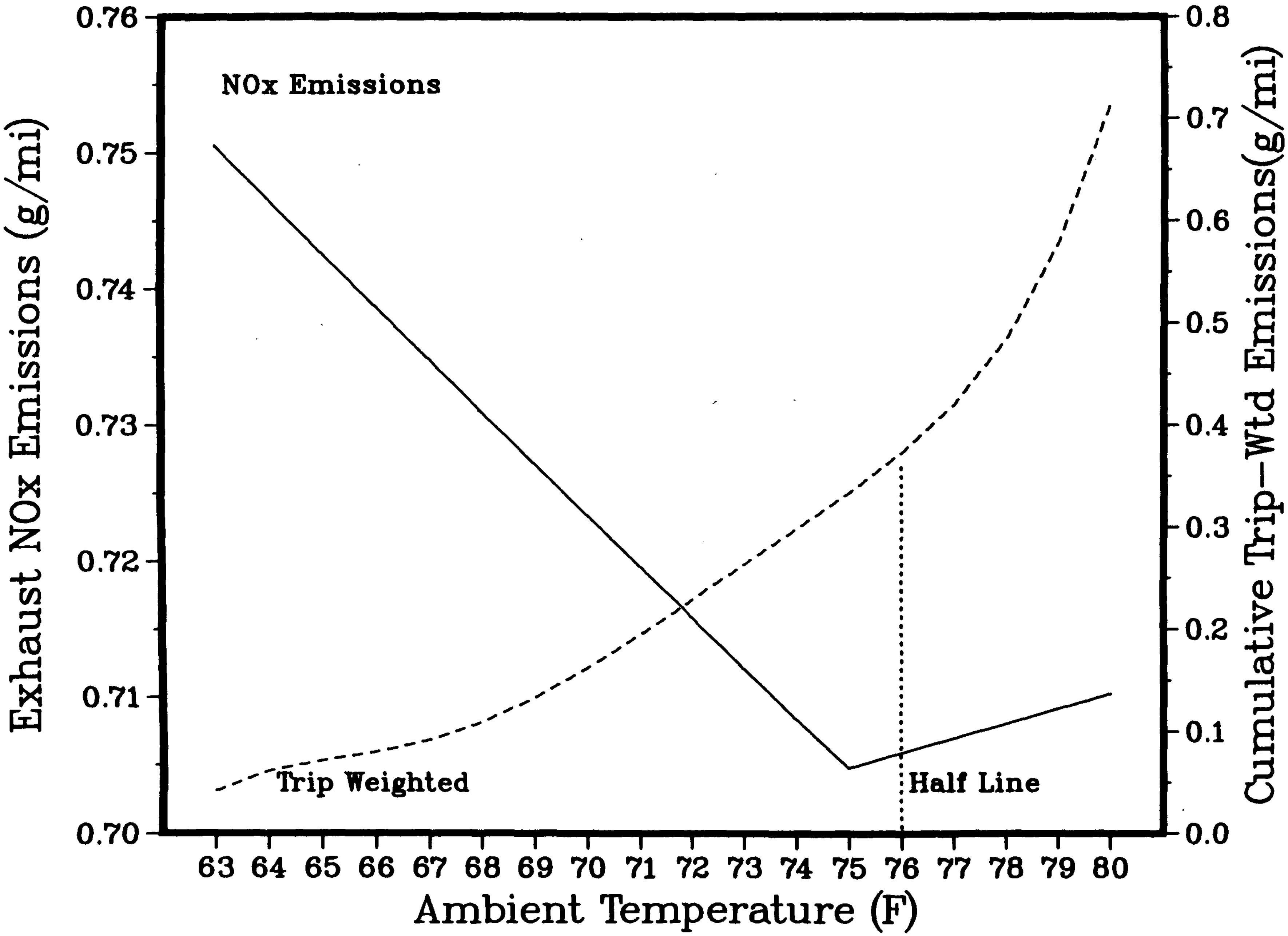

Figure 7 : Hot Soak Emissions vs. Ambient Temperature
Month of July, Pittsburgh, PA

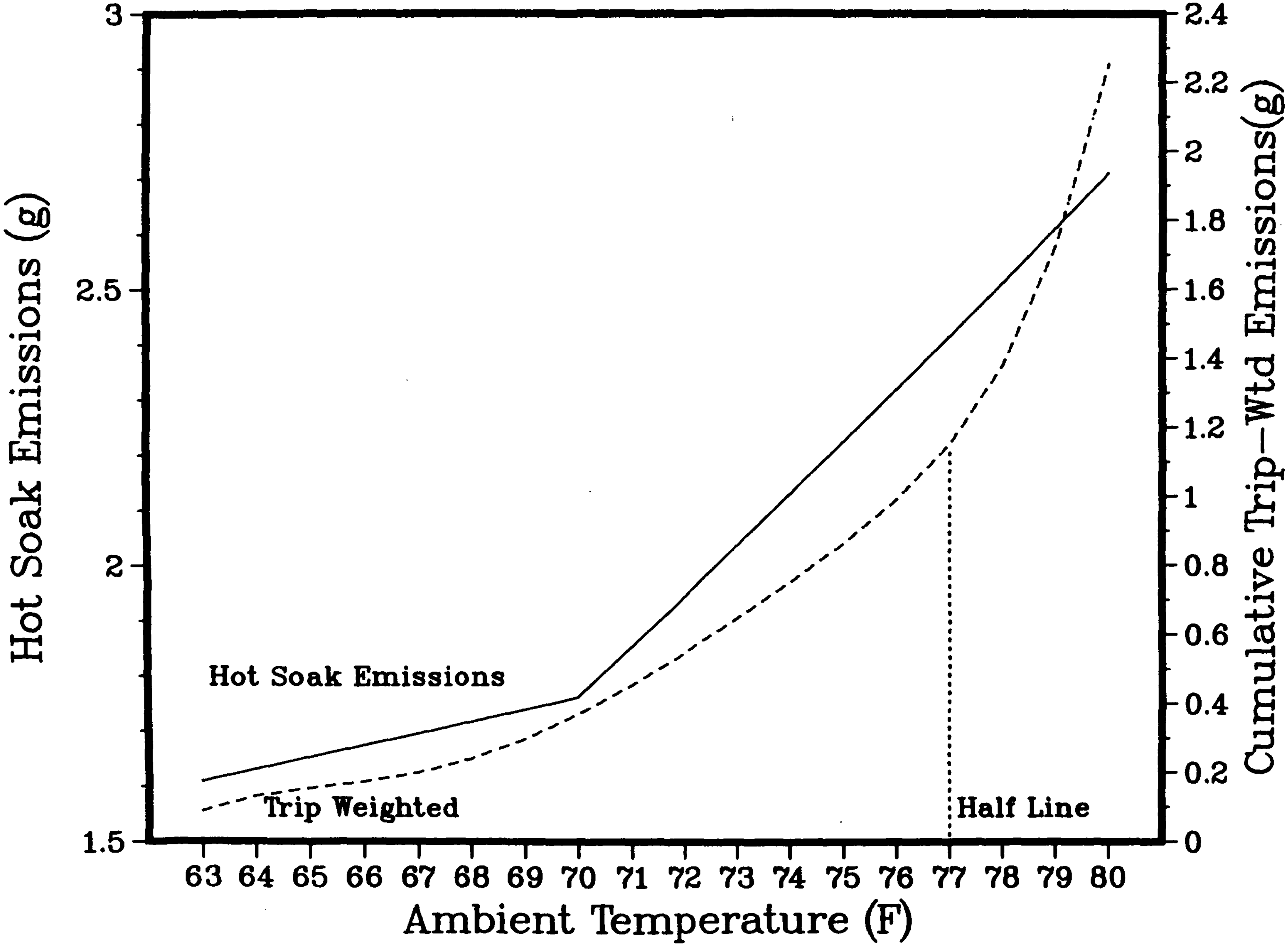

Figure 8 : Running Loss Emissions vs. Ambient Temperature
Month of July, Pittsburgh, PA