DEVELOPMENT OF A STANDARD DRIVING CYCLE FOR FAIRBANKS, ALASKA

FINAL REPORT

by

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March 1984

Prepared for:

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DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
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IMPLEMENTATION

(by Department of Transportation and Public Facilities)

This report covers one facet of the work that the Department of Transportation and Public Facilities (DOT&PF) has supported on the air pollution-automotive emissions problems in Fairbanks and Anchorage. The results provide one more piece of technical information that helps to increase our understanding of the cause and effect of carbon monoxide and other pollutants generated by vehicles.

The results of this study indicate that the difference between a typical Fairbanks driving cycle and the California cycle used by the Environmental Protection Agency is not large enough to affect the results of the Federal Test Procedure for determining automotive emissions (within the uncertainty of the test). The study also suggests that an Anchorage driving cycle, if developed, would compare similarly.

Implementation of the results of this study is currently underway, since the results are part of the technical information used to justify and plan auto inspection/maintenance programs for Fairbanks and Anchorage. These programs are now in their early stages, with start-ups planned for mid-1985.

PREFACE

This report was prepared by H. Jack Coutts, Research Civil Engineer, formerly with the U. S. Army Cold Regions Research and Engineering Laboratory (CRREL); Henry Elliott, Engineering Technician, formerly with CRREL; and Byron Young, Civil Engineering Technician of the Alaskan Projects Office, CRREL. Funding and the necessary support for this project were provided by the State of Alaska, Department of Transportation and Public Facilities, under contract no. F18211.

The authors thank Steve Kailing, Alaska Department of Transportation and Public Facilities, for technical review.

FAIRBANKS DRIVING CYCLE

Background

Anchorage and Fairbanks, Alaska, experience high concentrations of ambient carbon monoxide (CO) during the winter months. Automobiles and trucks account for 85 to 96% of the problem.[1,2] At low temperatures (LT) gasoline-fueled internal combustion engines emit several times as much CO as they do at 70°F. However, the relative emission ratio (LT emissions/ 70°F emissions) is thought to depend somewhat upon driving patterns, i.e., the driving cycle.

The Alaska Department of Environmental Conservation has recently acquired test equipment to measure exhaust emissions using the approved Federal Test Procedure (FTP).[3] In the FTP, the test vehicle is driven on a dynamometer following a speed versus time schedule (on a moving chart trace) to simulate on-the-road driving. The driving schedule used in the FTP is one based upon southern California driving patterns. It is called the LA-4 schedule. That schedule involves rapid acceleration rates and a top speed of 57 miles per hour (MPH) that is reached within 6 minutes. The first 200 seconds after start-up is shown in Figure 1. At 20°F many vehicles cannot attain the acceleration that is called for from 190 to 200 seconds, but at the FTP temperature range of 60-86°F, these same vehicles have no problem in keeping up with the trace.

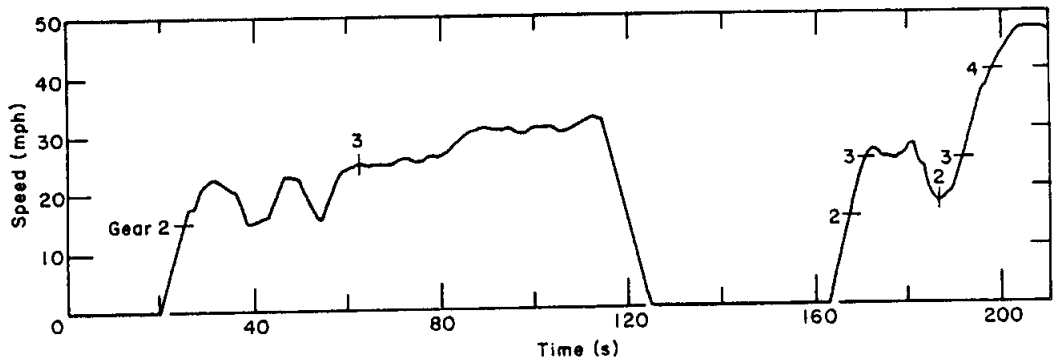

Figure 1. The LA-4 driving schedule.

Exhaust emissions from the LA-4 schedule are sequentially divided into sample bags 1 and 2, which collect exhaust samples that are representative of total vehicle exhaust. Bag 1 collects its sample from the first 505 seconds of the LA-4 schedule; bag 2 follows. For the full FTP, the driving schedule for bag 1 is repeated after a 10 minute rest with the engine off. This is to simulate a brief stop followed by a hot start. The repeated portion of the driving schedule is called bag 3.

Midwinter driving in either Anchorage or Fairbanks seldom involves rapid acceleration or speeds above 50 mph. Icy intersections, opaque vehicle exhaust plumes and darkness by 3 p.m. tend to limit acceleration rates and speed. Emissions are heavily dependent upon acceleration, speed and ambient temperature. Therefore, the writers decided to develop an urban driving schedule in the Alaskan winter for emissions testing at low temperatures. Our original intent was to develop two different cycles, one for Fairbanks and one for Anchorage, because the two cities have dissimilar road systems, different meteorological conditions and different traffic densities. These might result in quite different driving schedules.

In recognition of the importance of driving cycles to low temperature automotive emissions, the University of Alaska developed two Fairbanks cycles during the winters between 1974 and 1976.[4] Two cycles were developed because of the changes in traffic controls during the period of investigation. Both of these cycles were designed to be compatible with the FTP for measuring emissions. The report covering this work did not document road selection criteria, although it is apparent that traffic data were used for developing the driving cycles. Also, it is not clear what type of weighting factor was used to obtain a final driving schedule from all the collected speed versus time data for the various road conditions. The final cycle was synthesized from speed versus time data. That study did not have a budget sufficient to provide equipment such as a fifth wheel and chart recorder for data collection, so the test vehicle's speedometer and a stop watch were used.

There have been several changes in the Fairbanks area road and traffic patterns between 1976 and 1982, so it was decided to develop an updated driving cycle.[4] Recognizing the need for this updated cycle, the Alaska

Department of Transportation and Public Facilities (DOT&PF) has supported the U. S. Army Cold Regions Research and Engineering Laboratory (CRREL) in this research effort. The writers planned to use more analysis and less synthesis in developing the updated driving cycle.

Objectives

The specific objectives of this driving cycle project were to:

1. Develop a driving cycle characteristic of winter driving in Anchorage and Fairbanks, and compare it with the previous cycles (1974, 1976) that had been developed.

2. Measure emissions from a vehicle driving that cycle at low temperatures, and compare these with emissions from the same vehicle driving the FTP cycle at the same low temperature.

Scope

This report includes the criteria, method of data collection and results from the Fairbanks driving cycle research. Also, the relationship to existing cycles is discussed and emissions are compared with the FTP cycle.

APPROACH

Area selection criteria

Since this was to be an emission-related driving cycle, the writers decided that it should be developed from data taken from speed versus time traces on heavily trafficked roads in areas where CO levels exceed the EPA standard (9 ppm for an 8 hour average). Based on air quality data provided by Fairbanks North Star Borough's Environmental Services, the area of concern in Fairbanks includes all urban roads south of the Chena River and College Road, University Avenue and Airport Road.[5] Traffic volume data for the major roads in and around Fairbanks and for city streets were provided by a 1979 report from DOT&PF.[6]

The ambient CO readings on Fort Wainwright have in the past (early 1970's) exceeded the EPA standard of 9 ppm for an 8 hour average.[7] However, its roads are not included in this study because of a major reduction in traffic volume from a recent reduction in access to Fort Wainwright; three of the four gates were closed, and only those with government business are now allowed to enter the post. The impact these changes have made on the roads has not been determined, making road classification uncertain because of the lack of updated Average Daily traffic Counts (ADC). For this study it was assumed that the reduced traffic on Fort Wainwright is no longer a significant source of CO, so its roads were not included when driving data were collected.

Road selection criteria

The roads from which driving traces were obtained are shown in Figure 2. Average daily traffic counts (ADC) from 1979 were used to select the roads, and to apportion or weight the representative trace from each for development of the final driving schedule. Only road sections with an ADC greater than 5000 (5000 ADC) were selected. Data was not collected from small feeder roads, parking lots and driveways. This limitation seems applicable for four reasons: 1) any driver going in or through town would

probably spend the major portion of his driving -- hence CO emission -- on these 5000 ADC roads; 2) it is likely that only a very small portion of the total CO emissions in Fairbanks is contributed by vehicles using small feeder roads or traveling from a parking lot to one of the 5000 ADC roads; 3) in the downtown area the distance from any parking lot or driveway to a 5000 ADC road is usually less than 1/2 mile; 4) because of lower traffic density on some feeder roads, the vehicle speed traces may be similar to those on some of the 5000 ADC roads.

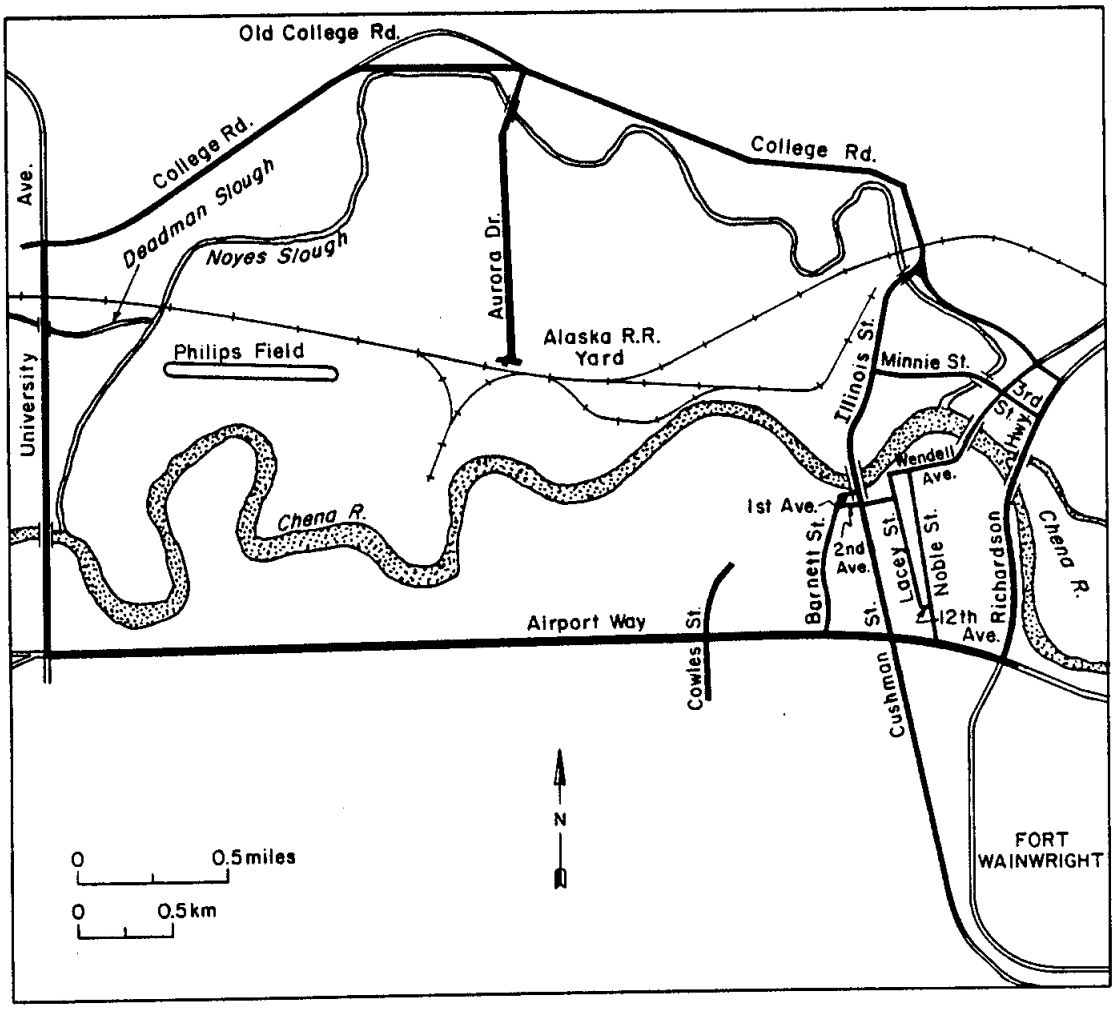

Figure 2. Map of Fairbanks showing roads (solid black lines) from which driving traces were obtained.

Road sections on which speed versus time data-gathering drives were conducted are called roadlinks, and roadway intersections that begin or end each link are called end points. The 22 selected roadlinks with end points, the number of required data-gathering drives and their relative importance (percent of all ADCs) are listed in Table 1. One data-gathering drive was conducted per every 1000 ADC on each roadlink using two methods.

Table 1. Road sections that were sampled to make the Fairbanks driving cycle.

	Roadlink	End points	Number of drives*	Percent of total ADC**
1	Airport	University-Cowles	17	7.8
2	Airport	Cowles-Gaffney	19	8.7
3	Cushman	Bridge-17th	15	6.9
4	Cushman	17th-23rd	11	5.0
5	Cushman	23rd-27th	9	4.1
6	Lacey	Wendell-Airport	5	2.3
7	Noble	Airport-Wendell	8	3.7
8	Wendell	Lacey-College Road	8	3.7
9	New Steese	Airport-College Road	12	5.5
10	Minnie	Illinois-3rd	6	2.8
11	3rd	Minnie-New Steese	9	4.1
12	Illinois	1st-College Road	10	4.6
13	1st	Cushman-Barnette	5	2.3
14	Barnette	1st-Airport	6	2.8
15	Cowles	E-W Split-Airport	10	4.6
16	Cowles	Airport-Smythe	6	2.8
17	University	Airport-College Road	13	6.0
18	College	University-Aurora	11	5.0
19	Aurora	College-Phillips	6	2.8
20	College	Aurora-Margaret	14	6.4
21	College	Margaret-New Steese	13	6.0
22	2nd	Barnette-Lacey	5	2.3
			Total	100.0

*Number of drives is also the integer result of ADC/1000.
**ADC -- Average Daily traffic Counts.

The first method, driver selection, involved following a chosen vehicle that seemed to represent the average (within basic speed law guidelines) acceleration and deceleration rates. (The vehicle's driving patterns would be duplicated until the driving link was completed or the selected vehicle violated traffic rules, turned off the driving link or its driver became aware that he was being followed.) This method is a standard procedure for monitoring driving habits.[8]

The second method, flow of traffic, involved matching acceleration and deceleration with representative vehicles on either side of the chase car. When there was no vehicle to follow, legal traffic speed limits and road conditions (such as snow and ice) were used as guidelines. In either case, the same instrumented chase vehicle was used. The driver selection method was used on more than half of the urban driving links. The flow of traffic method was used for the remaining driving links, which were mainly highway links.

Equipment and data collection

The chase car was equipped with a Sangomo Western Tracster Model 728 fifth wheel and a chart recorder. The recorded trace was speed (mph) versus time. The strip chart was annotated with the following data: operator, date, time of run, weather, roadlink and road condition. After each trace, the chart was marked to show the location of stops and the beginning and ending of each link. A section of a recorded trace is shown in Figure 3.

The driving traces were conducted only between the hours of 11 a.m. and 7 p.m. because those are the hours during which the 8 hour CO standard is usually exceeded. Driving traces were not conducted during wind or snow conditions because the natural air circulation associated with both of these keeps the 8 hour CO standard from being exceeded. The traces were conducted from January 21 through March 13, 1982. Most of the data were collected in March. We had planned to collect most of the data during December, January and February, but equipment breakdowns delayed that schedule.

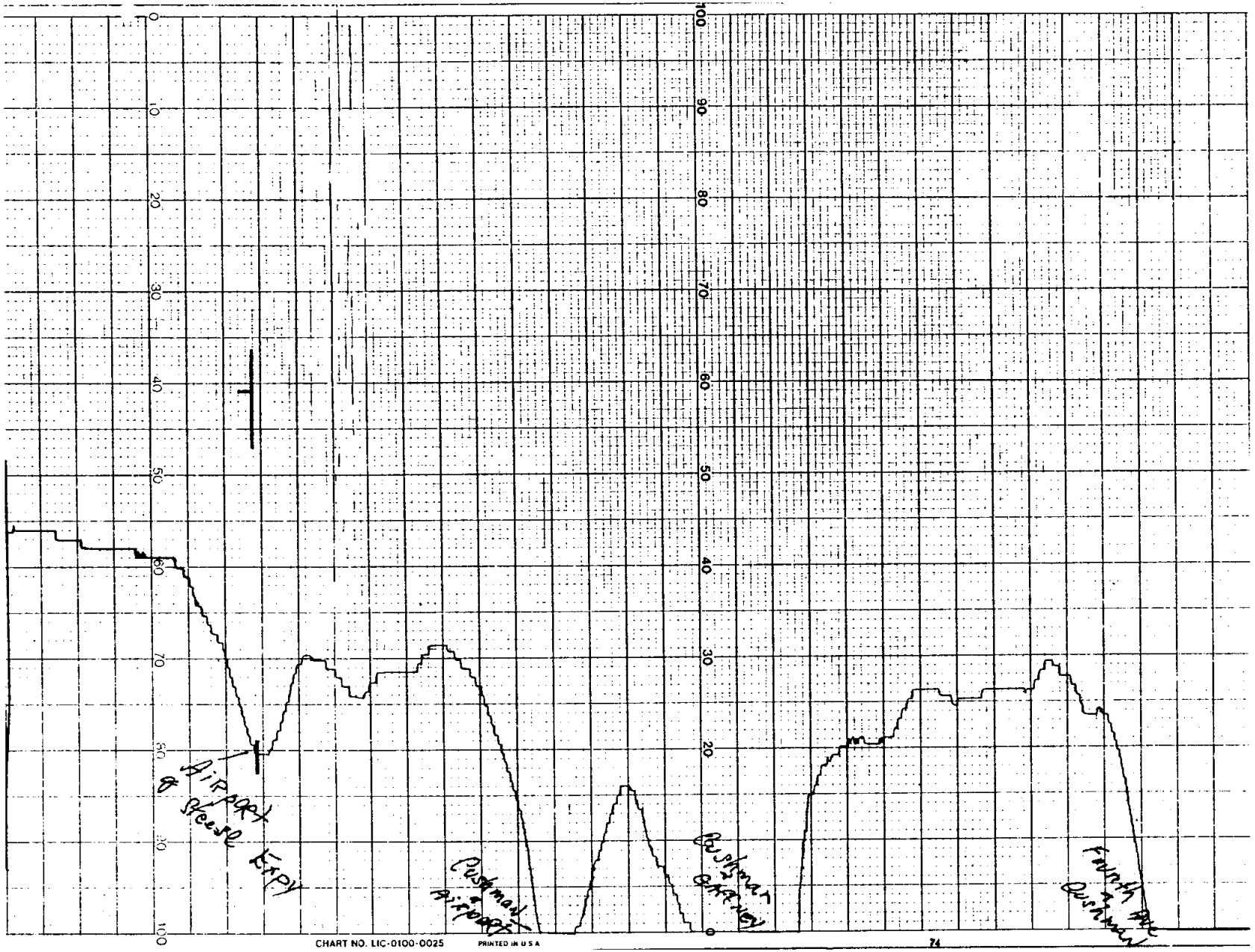

Figure 3. Section of an actual recorded driving trace.

RESULTS

Data analysis

The speed versus time data were taken from the chart records for each individual data-collecting drive of the 22 roadlinks. This information was read at intervals of 1.2 seconds and assigned coordinates (digitized) for computer analysis.

All traces for each roadlink were averaged to compute the percentage of time spent in each speed band for all operating modes and in cruise mode only. The actual time spent in acceleration was also averaged for each roadlink. Tables A1 through A3 in the Appendix list the average times in each speed and acceleration band for the first of the 22 roadlinks; Appendix A also contains mode definitions. A complete data listing for the remaining 21 roadlinks is available from DOT&PF, Research Section.

The tables plus actual driving traces were used to calculate the average speed, average number of stops and average acceleration rates on each roadlink. A representative trace for each roadlink was then selected by comparing the average speed, average number of stops and average acceleration rates for all traces to each individual trace. The trace that best fit the average was called the representative trace.

The representative traces were then joined to form a complete Fairbanks driving cycle using a Weighted Percentage (WP) length, which was conveniently selected as 10 times the percentage of ADC (see Table 1). The traces were joined together by matching a selected WP length of a representative trace to the WP length of a representative trace for an adjacent link. The WP lengths were joined at points where they had nearly the same speed. A WP length equal to 10 times the percentage of ADC was chosen so the resulting cycle length would be close to the 7.5 mile length of the LA-4. The result was a continuing chain of representative traces which form the Fairbanks driving cycle (Tables 2-4 and Figure 4).

Joining the traces was accomplished, for example, by taking a 23% portion of roadlink 13 and matching it to a 28% portion of roadlink 14 (see Table 1). The WP lengths of representative traces were chosen so that the vehicle speeds were the same, or as close as possible, at the joining points. With this method, the roadlinks with the heaviest traffic (highest

ADC) accounted for the largest percentage of the final Fairbanks driving cycle (Figure 4). Also, those same roadlinks had the largest number of data collecting drives. The writers believe that concentrating the largest number of data collection drives into roadlinks that make up the major portion of the final cycle was the best way to reduce sampling error.

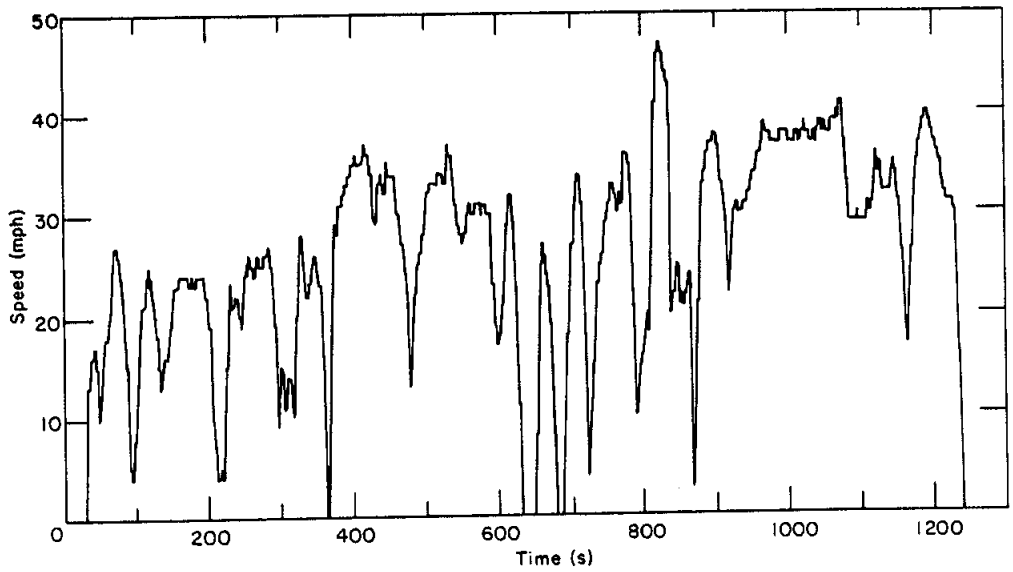

Figure 4. The Fairbanks driving cycle.

In the final Fairbanks cycle, the portions of the various representative traces were pieced together sequentially such that intersections and traffic control signal influences were included. Adding destinations would have put more stops followed by hot starts in the cycle. This was not done because we wanted to be able to make direct comparisons with the LA-4 schedule.

All the urban roads were pieced together as the first group. The outer highways such as Airport Way, University Avenue and College Road then were added on as the second group. When emission tests are conducted, the idle period between the urban roads and the outer roads is a good place to switch from sample bag 1 to bag 2, which then collects emissions from the

Table 2. Fairbanks driving cycle characteristics, time spent in speed bands; all operating modes; all roadlinks.

Speed (mph)	Time (s)	% of Total
0.0	71	6
2.5	19	2
5.0	23	2
7.5	11	1
10.0	41	3
12.5	36	3
15.0	67	5
17.5	48	4
20.0	103	8
22.5	113	9
25.0	110	9
27.5	74	6
30.0	179	14
32.5	98	8
35.0	128	10
37.5	91	7
40.0	14	1
42.5	7	1
45.0	10	1
47.5	--	0
50.0	--	--
Total	1243	100

Table 3. Fairbanks driving cycle characteristics, time spent in speed bands; cruise mode only; all roadlinks.

Speed (mph)	Time (s)	% of Total
0.0	---	---
2.5	64.8	11
5.0	7.2	1
7.5	2.4	0
10.0	0	0
12.5	4.8	1
15.0	6.0	1
17.5	20.4	4
20.0	8.4	1
22.5	36.0	6
25.0	49.2	9
27.5	38.4	7
30.0	38.4	7
32.5	92.4	16
35.0	54.0	9
37.5	74.4	13
40.0	61.2	11
42.5	8.4	1
45.0	3.6	1
47.5	3.6	1
50.0	0	0
Total	574.0	100

Table 4. Fairbanks driving cycle characteristics, time spent in acceleration bands; all roadlinks.

Acceleration (g)	Time (s)	% of Time
0.000	--	--
0.025	574	46
0.050	404	32
0.100	146	12
0.150	61	5
0.200	32	3
0.250	20	2
0.300	4	0
0.350	1	0
Total	1242	100

outer road group. For a bag 3 sample, it makes sense to redrive the urban portion (bag 1), since that procedure is followed in the FTP. This was done so that the bag contents from the Fairbanks and FTP cycles could be directly compared.

Discussion

How reasonable or close to reality does this winter Fairbanks cycle appear? The urban road portion includes only one stop. To make sure that stops were not cut out of the urban traces when only selected portions (23 to 87%, 10 times percent ADC) were used, the following computation was made. The products of percent ADC and number of stops for each trace were summed. The sum of the stops was then divided by the sum of the percent ADC. The result indicated slightly less than one stop for the urban portion. Therefore, the urban portion is a true representation of actual Fairbanks driving patterns for the road conditions in March 1982, when most of the data were collected.

The very first start-up for the Fairbanks cycle has an acceleration rate exceeding 4 mph per second for the first 2 seconds. Since the dynamometer rolls would slip too much at that rate, we decided arbitrarily to reduce the rate to 3 mph per second.

Historical comparison

To identify historical trends in driving patterns, the LA-4 cycle and other Fairbanks driving cycles are compared in Table 5. In 1974 through 1976, University of Alaska researchers collected considerable driving cycle data.[4] They found the average speed increased by 6.6 mph between the two winters. The writers of this report found the average speed to have increased by 7.7 mph in 6 years (1976 to 1982). In keeping with the increasing speed trend, the number of stops decreased by three from 1974 to 1976, and by five from 1976 to 1982. The routes (driving links) determined in 1982 and in 1974-76 were somewhat similar, except that the higher speed

Steese bypass (45 mph limit) has been added for the 1982 cycle. Because of instrument problems, most of the 1982 data were taken during early March when traffic appeared to be moving faster than at midwinter and road conditions were good. Changes in traffic signals may have tended to increase the average speed.[10] A check of traffic volume data for 1976 versus 1982 was made to see if there was less traffic in 1982, which would increase the 1982 average speed. The findings for most roadlinks indicated that the ADCs did not appear different enough to cause any speed difference.[11] A major reason for the higher speeds in 1982 may be the lack of destination stops. Another reason for the increase in average speed may be that approximately 40% of the final 1982 trace was collected from perimeter roads where the speed limits were 40 to 45 mph. It is not known how much driving data came from these roads in the 1974-76 driving cycle.[4] If few of them were from these perimeter roads, then the 1974-76 average speeds would be lower then the 1982 average speeds.

Table 5. Comparison of driving cycles.

Parameter/cycle	FTP LA-4	Fairbanks 1974-75*	1975-76*	1982
1 Length, miles	7.5	4.2	6.7	8.7
2 Duration, seconds	1370.0	1370.0	1370.0	1240.0
3 Average speed (mph)	19.7	11.0	17.6	25.3
4 Max. speed (mph)	56.7	30.0	30.0	47.0
5 No. of stops	18.0	11.0	8.0	3.0
6 % Idle time	19.0	24.0	7.0	6.0
7 % Steady-state	25.0	20.0	42.0	46.1
8 % Transient	68.0	56.0	51.0	47.9

*Leonard.[4]

Emission comparison

Cold-start automotive emission tests were conducted during the winter of 1982-83 at ADEC's Fairbanks test garage at temperatures of 20°F. For all but one of these tests, the FTP (LA-4) driving cycle was used. The remaining test was conducted using the newly developed Fairbanks cycle. The emission tests were conducted with a 1980 Ford Fiesta; the vehicle had not been tuned up before these tests. The CO results in grams per mile are shown in Table 6.

Table 6. CO emissions (in grams).

Driving cycle	Bag 1	Bag 2	Bag 3	Weighted total*
FTP (LA-4)	103	103	29	82.9
Fairbanks	186	63	27	69.1
Avg. % difference	58	-48	-7	18

*Calculated by the FTP method, which includes only 43% of bag 1 emissions and 57% of bag 3 emissions.

This shows that there is considerable difference in the CO emissions between the cold-start bag (bag 1) and the stabilized bag (bag 2). By the time bag 3 collection is started, the engine is fully warmed up and its CO emission is not affected by low ambient temperature. The reason for the large difference between the Fairbanks and FTP cycles with bag 1 might be from the shorter distance in the Fairbanks cycle. The CO emission rate is highest just after start-up, but it decreases with time. Therefore, it makes more sense to look at bag 1 plus bag 2 emissions. In that case, the driving distances are about the same -- 8.7 miles for Fairbanks versus 7.5 miles for the LA-4. The Fairbanks cycle CO emission is then 17% less than the LA-4 cycle CO emission at 20°F. The difference may seem large but it is not uncommon to get a 50% difference in bag 1 CO for replicate tests (those repreated under the same conditions) at 20°F. For FTP testing, EPA usually only reports composite emissions. The composite grams per mile formula is:

$$g/mile = [0.43(bag\ 1) + bag\ 2 + 0.57(bag\ 3)]/(bag\ 1 + bag\ 2\ driving\ distance)$$

The composite grams per mile difference is 18% between the two cycles. The precision for replicated FTP composite results is generally considered to be plus or minus 15%. Therefore, it appears that, for this one test case, the Fairbanks driving cycle does not yield CO emissions much different from the LA-4 cycle. This leaves the comparison obscure because it is from only one test and the difference is close to the precision limit.

SUMMARY AND RECOMMENDATIONS

A Fairbanks winter driving cycle has been developed from actual on-the-road speed traces. Most of the data were taken during March 1982. The results were compared to a similar study conducted 6 years earlier. Changes in traffic patterns may not be entirely responsible for the large speed increase. The writers think that if the 1982 data had been collected in the darker winter months, the average speed would have been lower.

Emissions of CO from the same vehicle for the LA-4 and for the Fairbanks cycles were compared at 20°F. The bag 1 grams per mile for the Fairbanks cycle was 58% higher than that for the LA-4 cycle. The shorter bag 1 distance in the Fairbanks cycle may explain most of the difference because gasoline engines have their highest CO emission rate just after starting. There was an 18% difference in the composite CO grams per mile emission. But in FTP testing, replicate test differences may approach this limit. More testing needs to be done with replicates and different vehicles before there can be any thorough emission comparison.

The Anchorage driving cycle has not been developed. It is anticipated that it will involve higher speeds and therefore be more like the LA-4 schedule, and the difference in composite CO between the Fairbanks and LA-4 schedules is not substantial. It is therefore recommended that the Anchorage driving cycle development be delayed at this time. Unless more testing with the Fairbanks cycle shows that it gives large differences in CO emission results compared with the LA-4 schedule, work on the Anchorage driving cycle is probably not warranted.

LITERATURE CITED

1. Municipality of Anchorage Municipal Planning Department (1982) Anchorage Air Quality Plan, SIP revision. Volume 2. Comprehensive alternatives analysis.

2. Fairbanks North Star Borough, Environmental Services Division (1982) Air Quality Attainment Plan. Volume 2. A decision-making guide. Fairbanks, Alaska, May.

3. U.S. Government Code of Federal Regulations (1979) Title 40, Part 86. July.

4. L.E. Leonard (1977) Carbon monoxide emissions from moving vehicles in Fairbanks, Alaska. Volume 3. University of Alaska, Geophysical Institute, Report No. UAG R-252. Fairbanks, Alaska, August.

5. R. Joy (1983) Personal communication on existing air quality data. Fairbanks North Star Borough Environmental Services. August.

6. State of Alaska Annual Traffic Volume Report (1979).

7. T.F. Jenkins, R.B. Murrann and B.E. Brockett (1975) Accumulation of Atmospheric Pollutants Near Fairbanks, Alaska, During Winter. CRREL Special Report 225.

8. R.F. Gray (1975) A survey of light vehicle operations. Engineering Publication 6313. General Motors Proving Ground.

9. State of Alaska Annual Traffic Volume Report (1976) Alaska Department of Transportation and Public Facilities.

10. W.R. Scouten (1983) Personal communication on signalization and traffic changes. August. As-built plans on signalization and traffic changes, 1976-1983. Fairbanks City Engineering Division.

11. State of Alaska Annual Traffic Volume Report (1982) Alaska Department of Transportation and Public Facilities.

APPENDIX A

The following tables list average values for three modes from all driving traces for the example roadlink.

The modes are defined below:

1. All operating modes -- the entire chart recorder speed trace. For the tables the speeds were divided into continuous bands 2.5 mph wide.

2. Cruise mode -- a constant or nearly constant road speed. Any rate of change in speed greater than 0.05 g (1.10 mph/s) was considered to be acceleration, not cruise.

3. Acceleration mode -- since very few portions of the actual speed traces were at an exact constant speed (no acceleration), the entire trace was divided into acceleration bands. The first two bands were 0.025 g (0.55 mph/s) wide. The rest of the bands were 0.05 g (1.10 mph/s) wide.

Table A1

Time spent in speed bands
All operating modes
Cushman 1 Roadlink

Speed (MPH)	Time(Sec)	% of Total
0.0	41	22
2.5	4	2
5.0	8	4
7.5	2	1
10.0	9	5
12.5	7	4
15.0	28	15
17.5	13	7
20.0	18	10
22.5	22	12
25.0	26	14
27.5	6	3
30.0	0	0
32.5	0	0
35.0	0	0
37.5	0	0
40.0	0	0
42.5	0	0
45.0	0	0
47.5	0	0
50.0		
Total	184	100

Table A2

Time spent in speed bands
Cruise mode only
Cushman 1 Roadlink

Speed(MPH)	Time(Sec)	% of Total
0.0	40	44
2.5	2	2
5.0	1	1
7.5	0	0
10.0	1	1
12.5	0	0
15.0	11	12
17.5	4	4
20.0	4	4
22.5	10	11
25.0	15	16
27.5	3	3
30.0	0	0
32.5	0	0
35.0	0	0
37.5	0	0
40.0	0	0
42.5	0	0
45.0	0	0
47.5	0	0
50.0		
Total	91	100

Table A3.

Time spent in acceleration bands
Cushman 1 Roadlink

Acceleration(g)	Time(Sec)	% of Time
0.000	91	49
0.025	61	33
0.050	23	13
0.100	5	3
0.150	1	1
0.200	3	2
0.250	0	0
0.300	0	0
0.350		
Total	184	100