Extreme Low-Temperature Cold Starts

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Introduction

Item (xii) of Section 108(f) defines the following transportation control measure:

> "Programs to reduce motor vehicle emissions, consistent with Title II, which are caused by extreme cold start conditions."

Two key aspects of this measure are: 1) that these are actions that can be taken by states and local areas over and above the new cold temperature carbon monoxide (CO) vehicle engine emissions standard, and 2) that these actions are intended to be applicable under temperature conditions that can be described as extremely cold; e.g., temperatures in the range of 0 degree F to -20 degree F, or even colder. In brief, the extreme low-temperature cold start TCM is intended as a supplement to the new cold start CO emission standard and to apply at even lower temperatures.

Prior to passage of the 1990 amendments to the Clean Air Act, the CO emission standard for light-duty vehicles (LDVs) was 3.4 grams per mile, applicable at temperatures between 68 degrees F and 86 degrees F. Evidence over the past 10 years, however, indicates that CO cold start emissions are much greater at lower temperatures. Nonattainment of CO air quality standards is a problem mainly at temperatures below 68 degrees F.

The new regulations on low-temperature CO emissions are intended to provide interim standards that can be quickly implemented; they also provide for the possibility of additional future vehicle emission standards based on the degree to which CO standards have actually been attained by 1997. For LDVs, the new CO vehicle emission standards are as follows:

- (Phase I) After the 1993 model year, vehicles must meet a CO emission standard of 10.0 g/mi at 20 degrees F. This standard is in addition to the 3.4 g/mi standard at 68 degrees F to 86 degrees F. The new standard will be phased in to apply to an increasing percentage of each manufacturer's sales as follows:

Model Year	Percentage
1994	40
1995	80
1996 and after	100

- (Phase II) By June 1997, EPA shall complete a study assessing the need for further reductions in emissions of CO and the maximum reduction in such emissions achievable from model year 2001 and later LDVs operated at 20 degrees F. If, as of June 1, 1997, 6 or more nonattainment areas (except Steubenville, Ohio and Oshkosh, Wisconsin) have a CO design value of 9.5 ppm or greater, the regulations shall contain standards for CO emissions for model years 2002 and later of 3.4 g/mi at 20 degrees F for LDVs and 4.4 g/mi for light-duty trucks up to 6,000 GVWR, and a comparable level of stringency for light-duty trucks over 6,000 GVWR.

- EPA may also promulgate regulations for cold temperature CO emissions from heavy-duty vehicles and engines.

These standards reflect the maximum reductions felt to be technologically feasible in the near term. Because there is still not complete certainty in all cases over the causes of CO nonattainment and the amount and type of mobile source controls needed to bring all areas into compliance, EPA is carrying out a long-term study to identify where further regulation is needed. The results of this study will be used as a basis for establishing long-term CO emission standards.

EPA has found that exceedances of the CO National Ambient Air Quality Standard (NAAQS) typically occur during cool or cold ambient conditions. Another study of CO nonattainment as a function of ambient temperature has shown that over 90% of the nonattainment occurs at temperatures below 68 degrees F. Approximately 20 percent are at temperatures of 20 degrees F and colder.

EPA tests of recent model year properly operating vehicles indicate that 90 percent of the increase in CO emissions at 20 degrees F compared to CO emissions at 75 degrees F occurs during the cold start. Comparisons of emissions of recent model year vehicles and a group of 1969-1974 model year vehicles show that the first group has 75 percent lower emissions at about 75 degrees F, but only 51 percent lower at 20 degrees F. Cold temperature CO emissions vary widely across different vehicles. Tests of recent model year vehicles that had emissions below the 3.4 g/mi standard at 75 degrees F have shown emissions at 20 degrees F that range from 2.7 g/mi to 35.9 g/mi. There is also evidence that CO emissions may increase nonlinearly with decreases in temperature, as shown in Figures 1 and 2, so that CO emissions at temperatures of 0 degree and -20 degree will be disproportionately higher.

There are several reasons for higher emissions at low temperatures:

- Gasoline has low volatility at low temperatures. Hence, engines require an enriched mixture to ensure that an adequate amount of fuel is vaporized to achieve a combustible mixture. The fuel-rich mixture leads to incomplete combustion, resulting in partially burned fuel (CO emissions) and unburned fuel (HC emissions).

- Low-temperature starts require longer engine cranking times than would be needed at higher temperatures. This adds to the emission of incomplete combustion products.

Figure 1. CO Cold Start Emissions - Bag Test

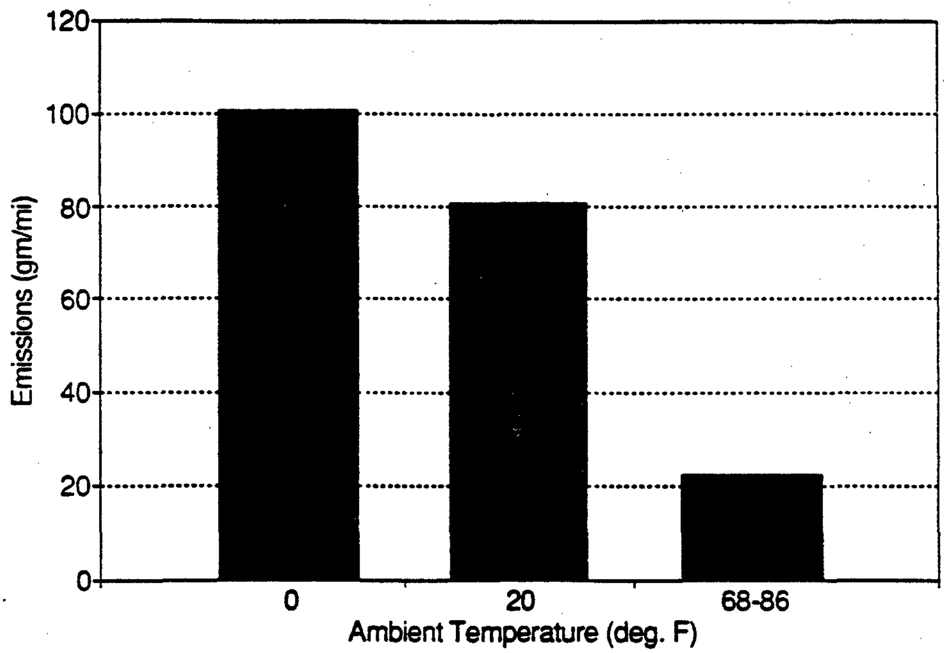
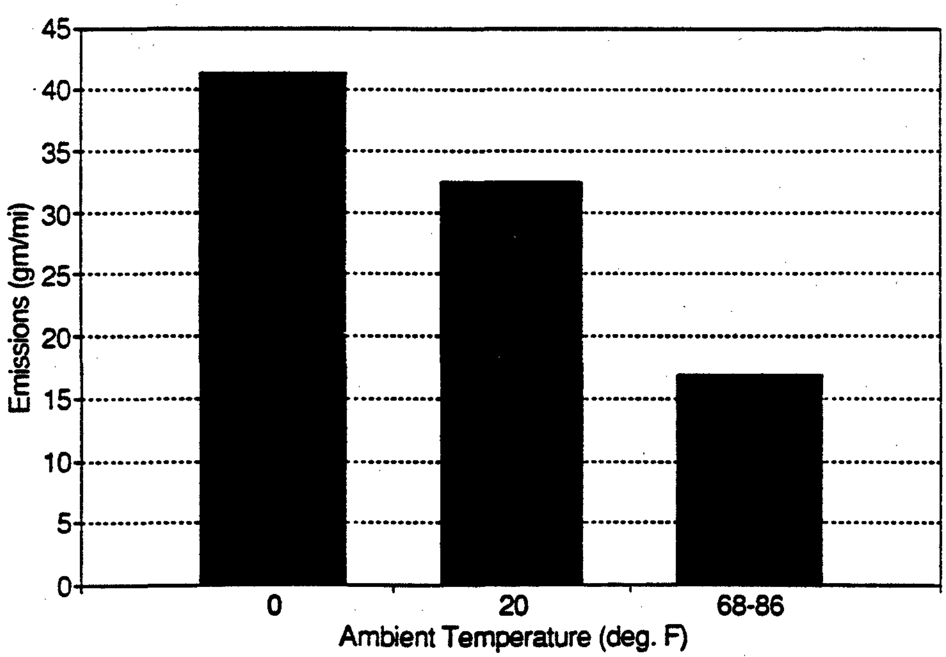


Figure 2. Variation in CO Emissions with Temperature Under the FTP Driving Cycle



Source: Alaska Department of Environmental Conservation, 1983.

- Internal friction in the engine and drive train is greater than at higher temperatures, requiring greater power output from the engine during warm-up.

- The catalyst is cold, and hence is not effective, during the first few minutes of operation.

- On many vehicles, air injection to the catalyst is delayed by a timer while the vehicle warms up. Air injection with high levels of unburned or incompletely burned fuel entering the catalyst (as typically occurs during warm-up of cold engines) can cause catalyst temperatures to rise and possibly damage the catalyst. This delay is typically between 5 and 15 minutes.

Of these causes, the first contributes the most to extreme cold start emissions emissions.

Description of Measures

Most testing and research to date has focused on mechanical modifications to vehicles to reduce their emissions. Inspection and maintenance can reduce low-temperature CO emissions somewhat, but is not itself sufficient to achieve the new CO standards. Other nonmechanical measures that have been considered include low-viscosity oils and oxygenated fuels.

The following mechanical devices have been considered for reducing CO emissions:

- **Block Heaters** – These are electrical devices that warm the coolant in the engine block, thereby increasing the block temperature. This increases the amount of fuel vaporization during startup and the first few minutes of engine operation, thereby allowing a leaner mixture than would otherwise be necessary in cold temperatures. The amount of incomplete combustion products is therefore reduced.

- **Intake Manifold Heaters** – These devices are ceramic grids that are attached between the carburetor and the intake manifold. These can be retrofitted on all engines that use carburetors or single-point fuel injection. Like block heaters, they increase fuel vaporization, reducing emissions of incomplete combustion products.

- **Monolithic Catalysts** – These catalysts have lower heat content than the pelletized catalysts currently in use. Hence, they warm up, and begin to take effect, more quickly than conventional catalysts.

- **"Start" or "Warm-up" Catalysts** – These catalysts are monolithic catalysts located close to the outlet of the exhaust manifold. Because of their small size and low mass, catalytic CO control is much more rapid than is possible with conventional catalytic converters.

- **Multipoint Fuel Injection Systems** – Carburetor and single-point (throttle body) fuel injection systems inject fuel into the intake manifold. As a result, there is further condensation of gasoline as it travels through a cold manifold to the cylinders. Multipoint fuel injection systems inject the fuel directly at the cylinder, thereby eliminating condensation due to a cold manifold. The fuel mixture also can be better controlled than is possible with carburetor and single-point fuel injection systems.

Low-temperature CO emissions can be reduced for vehicles that use timers which delay air injection into the catalyst. EPA has found that there is no reason for long delays for air injection. Reducing the delay can substantially improve CO emissions without a change in technology or increased hardware costs.

More traditional transportation control measures also could be potentially applied under extreme cold temperature conditions. For example, special incentives could be offered to utilize transit thereby eliminating the use of the automobile and the consequent cold start. Also, an episodic voluntary no-drive day could be established, patterned after the programs in Denver and Phoenix, where people are encouraged to rideshare, use transit or even work at home during these extreme cold temperature situations, thereby avoiding the vehicle cold start altogether. (Reference the chapter on Vehicle Use Limitations/Restrictions for a description of the Denver and Phoenix voluntary no-drive day programs.) Fleet operations for light and heavy duty vehicles also may provide opportunities; for example, by scheduling trips so that a warm, rather than a cold vehicle can be used.

■ Case Study Example

An example of a local program to reduce cold start emissions was a voluntary program initiated by Fairbanks North Star Borough in 1984. The purpose of the program was to encourage the use of block heaters at the workplace.

Almost all vehicles in Fairbanks have block heaters; the problem was to encourage employers to turn on outlets at parking sites at a warmer temperature than they normally did. Before the program, most employers turned on the outlets at 0 to -10 degrees F. The program was intended to encourage employers to turn on the outlets at 20 degrees F. The program was directed primarily at public employers: e.g., University of Alaska, GSA and state facilities, and military installations. There also was a publicity campaign directed at the public to "plug in at plus 20 [degrees]." The program, however, had only limited success because of the cost to employers of electricity. About 1 to 2 years after the start of program, the oil recession hit Alaska; budgets were slashed, and this program became a casualty.

The program was even more difficult to promote for private employers. Most private employers provide parking lot outlets only for management. Hence, the capital cost of installing outlets was the key deterrent to promoting the use of block heaters at the workplace.

Because of the short lifetime of this program, no formal evaluation data on actual usage were collected.

■ Program Impacts

It is estimated that the proposed EPA cold-temperature standards as originally defined (the original rule contained standards for light-duty trucks) would reduce annual CO emissions by 2.6 to 3.1 million tons annually by the year 2000 and by 5.8 to 7.7 million tons when complete fleet turnover has been achieved. Application of the standard will help mitigate the effect of travel growth beyond the year 2000, bringing areas into attainment and reducing CO inventories by 10 to 18 percent.

The use of block heaters and manifold intake heaters can have the additional benefit of reducing fuel consumption during the cold start portion of engine operation.

■ Program Costs and Other Considerations

An evaluation of the various retrofit devices described above to reduce extreme low-temperature CO emissions showed that the cost of installation typically was typically between $100 and $300 per vehicle, in 1982 dollars.

Although the use of block heaters can reduce low-temperature cold start emissions, this measure is effective only in cold climates where vehicles typically already have block heaters installed. The only further cost of increasing the use of block heaters (other than at the home), therefore, is the capital cost to install outlets to plug in the heaters and the operating cost of providing the electricity.

■ Implementation Considerations

EPA has found that 70 to 80 percent of 4-cylinder multipoint fuel injection (MPI) engines, 65 to 75 percent of 6-cylinder MPI, and 10 to 15 percent of 4-cylinder throttle-body injection (TBI) engines could meet the 10.0 g/mi level simply with cold start fuel enrichment strategies. The remainder of the 4-cylinder and 6-cylinder LDVs should be able to comply with some combination of improved cold start fuel enrichment strategy, improved closed-loop control strategy, air pumps, aspirators, or adoption of MPI. Eight-cylinder vehicles may have greater difficulty meeting the standards, but even with these vehicles, a 20 to 30 percent reduction in cold temperature emissions could be achieved by either injecting supplemental air during cold starts or reducing cold start fuel enrichment.

Additional cold temperature CO programs that could be applied by state and local jurisdictions in extreme cold temperature conditions have been shown to be technically feasible, but have a limited area of application and may be resisted by private and public employers as well as commercial parking operators as not justified by the cost. The new 20 degree CO vehicle emission standard will be of significant benefit. Extreme areas that could benefit from additional control would be those geographic regions that routinely experience temperatures well below zero. These are principally within the State of Alaska. Implementation, and expanded usage, at the work place will require an educational program, so that people understand the incremental benefits that can be achieved and the value of additional episodic controls. The next level of implementation would involve expansion of block heater availability to parking meters and commercial parking lots, together with the use of additional and more traditional transportation control measures.

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