**INTERNATIONAL SYMPOSIUM
ON AUTOMOTIVE TECHNOLOGY AND AUTOMATION
29.th Conference Florence Italy 3rd-6th june 1996
Dedicated Conference on The Motor Vehicle and the Environment - Demands of the Nineties and Beyond**

REDUCED COLD START EMISSIONS THROUGH USE OF ELECTRIC ENGINE HEATERS

By Anders Ydstedt*, Stefan Björklund, Paul G Höglund*****

* ScanTech Development Ltd, Utställningsg 9, PO Box 583, S-201 25 Malmö, Sweden
Telephone +46 40 12 37 45, Telefax +46 40 12 37 22, e-mail: anders.ydstedt@scantechab.se
* * Skandia Environment Commission c/o Skandia Insurance (Plc), S-103 50 Stockholm, Sweden
Telephone +46 8 99 40 00, Telefax +46 8 99 40 08 e-mail stefan@scantechab.se
** * Traffic and Transport Planning, Royal Institute of Technology, S-104 44 Stockholm, Sweden
Telephone +46 8 7907936, Telefax +46 8 212899, e-mail:

ABSTRACT

Swedish automobile industries , Skandia Insurance Plc and electrical utilities started 1995 to act in a coordinated way to promote the use of electric engine heaters in cars. The main objective is to reduce the harmful emissions from cold starts. This paper shows that cold start emissions from cars with catalytic emission control can be as much as CO and HC 80 %, of the total emissions during driving in the FTP75 city cycle. Electric heating of the engine block and coolant can reduce those emissions by 80%.
Electric heating can also reduce the CO2 emissions ,even if as much as 60 % of the electricity is generated from fossile fuels. (OECD average).
This project will also demonstrate other options by connecting the car to electric power supply. Permanent connection at parking lots make it possible to charge the battery, use an electrical climate control and get access through powerline communication to onboard diagnostics systems, alarms and pay-systems for parking.

1. Introduction

According to the declaration at the UN Conference on substainable developement in Rio, local governements in Sweden, have introduced measures with the intention to reduce environmental impact of traffic. Power outlets for engine heaters are already taken almost as a matter of course, both at workplaces and in residential areas in Nordic part of Scandinavia. In the south of Sweden some of the larger local authorities are investigating the advantages of establishing an infrastructure of power outlets in parking lots. This can also facilitate a future introduction of hybrid electric cars.
One third of Swedens three million cars are to-day fitted with electric engine heaters, mostly for use in the winter. There are, however, good reasons to connect cars to the electric power net and use engine heaters throughout most of the year.

2. The environmental benefits of engine heaters

Data on travel patterns show that the median journey with cars in Sweden is about 5 km. This corresponds aprox. to the first driving cycle used in emission tests (FTP 75). For a large proportion of short car trips, the percentage of emissions from cold starts can be equated with results obtained in this driving cycle tests.

Catalytic converters

Modern three-way catalytic converters transforms toxic chemical compounds such as carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxides (NO_x) into water (H_2O) , carbon dioxide (CO_2) and molecular hydrogen (H_2).
The catalytic converter is heated by exhaust gases from the engine. A relatively high temperature is required before the reaction starts. During this period — usually a couple of minutes — the engine runs without any effective emission control. In order to let the engine start and run easily, when starting cold, a richer fuel mixture is used (this also applies to engines with catalytic converters), which contributes even more to the high emission levels, particularly of carbon monoxide and hydrocarbons. The problem is exacerbated in the winter since the fuel mixture must be even richer and it takes longer for the catalytic converter to light up.

Calculation of cold-start emission percentages in the driving cycle

Using data from MTC, ScanTech (1) has calculated emissions from cold starts as a percentage of total emissions in the driving cycle. The calculations were based on Skandia's model for cold starts (2).
The Swedish Motor Vehicle Inspection Company has been commissioned by the Swedish Environmental Protection Agency to inspect the service life (using what are known as A60 tests) of the catalytic converters on cars approved according to the Swedish A13 regulations. The cars in the ScanTech study, which used data from 132 cars from the 1989/1990 model year, had been on the road for around three years and had generally driven between 30,000 and 60,000 km.
The emission samples were collected in bags for the different phases of the driving cycle. Using data from the individual bags, cold start figures were calculated (in grams). The figures have been weighted according to the market share of each make of car. A sensitivity analysis using a more precise breakdown in terms of percentage sales per model yielded much the same results.
Cold starts account for a very high proportion of the total emissions. "Ageing" of emission control equipment is largely attributable to the high emission levels in conjunction with cold starts, because the light-up temperature increases if the catalytic converter is exposed to lead, phosphorus and sulphur (9).

Test criteria

Emissions in conjunction with a cold start can be calculated from the different parts of the FTP 75 driving cycle as used in the A60 test. The difference between YCT and YHT gives the specific cold start emissions. The distance driven is 5.78 km for both YCT and YHT. It should be borne in mind, however, that YHT involves a ten-minute cooling period following the previous cycle. This means that there is a

certain cold start contribution in YHT that involves a slight underestimate of the part played by cold starts in this model. Even with this reservation, however, cold starts account for such a large part of the total emissions that they represent the vast majority of carbon monoxide and hydrocarbons.
Cold start emissions in grams for a single start are calculated as follows:

(YCT[g/km]-YHT[g/km]) x 5.78[km]

Total emissions in grams for YCT are calculated as follows:

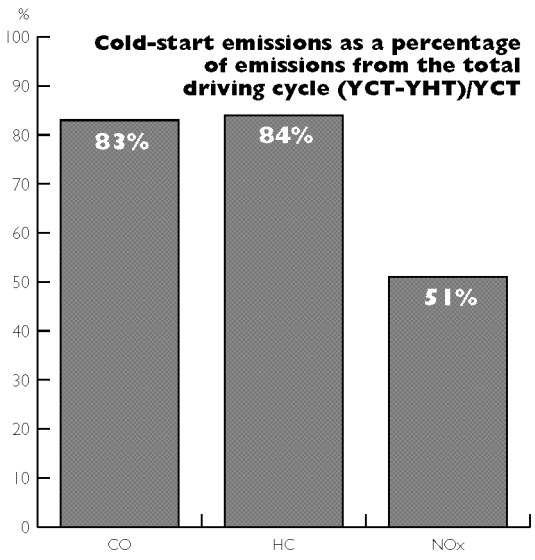
YCT[g/km] x 5.78[km]

Finally, the percentage of cold-start emissions in YCT is calculated as:

((YCT[g/km]-YHT[g/km]) x 5.78[km]) /(YCT[g/km] x 5.78[km])

Of the total emissions in the FTP 75 driving cycle, cold starts account for the majority of emissions of carbon monoxide and hydrocarbons.
Calculations of the percentage of cold-start emissions in total emissions show that the cold starts account for 83% of carbon monoxide, 84% of hydrocarbons and 51% of nitrogen oxides.

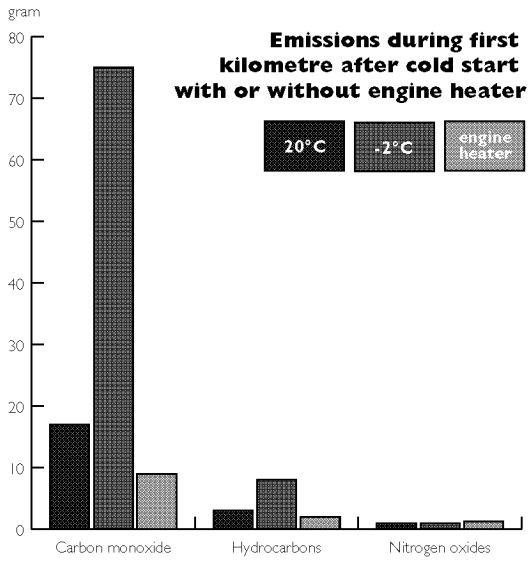
In the Swedish Motor Vehicle Inspection Company's A60 test, the cold starts take place at +20°C. In reality, the cold-start emissions of carbon monoxide and hydrocarbons are probably higher, although the figure for nitrogen oxides is much the same. In the ECE-cycle the importance of cold starts emissions will increase even further.



Cold start emissions as a percentage of total emissions in the driving cycle. Data for average car, 1989 model. Source: ScanTech and MTC.

Engine heaters reduces cold start emissions

The Swedish Motor Vehicle Inspection Company has made tests with electrical engine heaters. Six passenger cars were tested at different temperatures with and without engine heaters (3). For the first kilometer in the FTP-test the use of engine heater make substantial decreases in the amount of carbon monoxide and hydrocarbons. Tests made by Volvo show the same results.



Emissions at 20°C and -2°C with and without engine heater. Data for six cars with catalytic converters. Source: MTC report 9001.

3. Reduced fuel consumption and carbon dioxide emissions

Measurements of the influence of engine heater use on fuel consumption have been performed by the Swedish Motor Vehicle Inspection Company (3). These measurements were made on new cars equipped according to the most stringent California requirements. By comparing fuel consumption with and without engine heater in the cold-start phase of the FTP 75 cycle (YCT) it is possible to calculate the savings. A figure of 0.08 litres/start is obtained if an engine heater us used at -2°C.

The Swedish Road and Traffic Research Institute, VTI, states that fuel consumption increases by 1-2 dl per cold start, depending on the temperature (4). Measurements by the Norwegian Institute of Technology on cars without catalytic conversion (with automatic choke) show that fuel consumption is 0.1 litres lower if an engine heater is used at -10°C (5). Another report from the Swedish Motor Vehicle Inspection Company (6) states that a fuel saving of 15% can be achieved at +22°C. The average fuel consumption for new cars in Sweden was 8.3 litres/100 km in 1993 (7) which means an increase of 1.2 litres/100 km if consumption rises by 15%. Measurements by VTT in Finland in 1987 state that fuel consumption declines by 0.3 litres/cold start if an engine heater is used (8).

There is no doubt that older models have a higher cold-start increment than more recent corresponding models. The car manufacturers have successively improved

injection systems in order to reduce cold-start emissions. For old or poorly maintained cars, the fuel consumption is higher than it was when they were new. MTC has observed increases in average fuel consumption of between 10 and 30% on older models.

For Sweden, the fuel saving is assumed to be approximately 0.2 litres/cold start, which is a conservative estimate. The average motorist makes 300-500 cold starts per year (2). In Scandinavia, France and Switzerland where hydro- and/or nuclear-power is the main supply, the reduction of carbon dioxide will be substantial with engine heaters.

If electrical engine heater is used at 500 cold starts the emission of carbon dioxide will decrease with about 250 kg per year. This is about 10 % of the total emissions from 15000 km driving.

A calculation on effects in carbon dioxide emission for Germany

Engine heater
The electrical heater is rated 550 W. The average connection time needed in German temperatures is 45 min. a day. This increases the engine temperature aprox.30°C.

Climate
A heater is most benificial when the engine is quite cold. Its indeed so in the mornings, when the outdoor temperature is at the lowest point. In the afternoon the temperature tend to be higher. In Germany the average temperature (over the year) is 7,0-9,5°C.

Fuel consumption.
The average reduction in fuel consumption when using an engine heater is 0,1 litre/ cold start. In Germany the as temperature is than in the Nordic countries the gain in fuel consumption will be lower.

Power system
In Germany (old states) the use of electricity will give a smoke-stack emission of 550 g CO2 /kWh (netto). HC and CO emissions from large power-plants is negligible compared with cold starting automobiles (10).

Calculation
The electricity consumption per cold start is 45/60 h x 550 W = 0,41 kWh
The emissions from power generation is 0,41 kWh x 0,55 kg/kWh = 0,23 kg CO2
The carbon dioxide emission per cold start is 0,1 l x 2,36 kg/l = 0,23 kg CO2

In Germany the use of an engine heater reduces the total emissions of carbon dioxide if the saving of fuel is more than 0,1 l per cold start. But the most evident gains is the substantial reduction of harmful gases such as CO, HC. Those gases can affect human health. They also contribute to global warming effect and the formation of ground level ozone. From an environmental point of view its reasonable to use an engine heater all year, even in summer time.

4. Impact on the electricity supply

Today, 95% of Swedish electricity comes from hydro-electric or nuclear power stations and thus involves no emissions of carbon dioxide or acidifying substances. Sweden has already reduced its emissions of carbon dioxide by 40% since 1970. In an international context, Sweden has undertaken not to allow carbon dioxide emissions to rise after the year 2,000. By linking up with power stations in other Nordic countries, there is always enough power in the system.

In Sweden, over a million cars are already fitted with engine heaters, usually with a power rating of 550W — about half that of a standard hotplate on an oven. Engine compartment heaters are often rated somewhat higher — 600-1200 W — i.e. around the same as a hotplate. The optimum connection time is between 30 minutes and two hours depending on the ambient temperature. There is never any justification for using an engine heater at full power for more than three hours at a time.

The existing car population would be connected during time periods that coincide with other morning and afternoon peaks. It is unlikely, however, that all engine heaters would be connected simultaneously — not more than 30-50% according to power industry estimates. The increased power requirement for a million more engine heaters would thus be 500 MW, if we assume that every second one would also use an engine compartment heater.

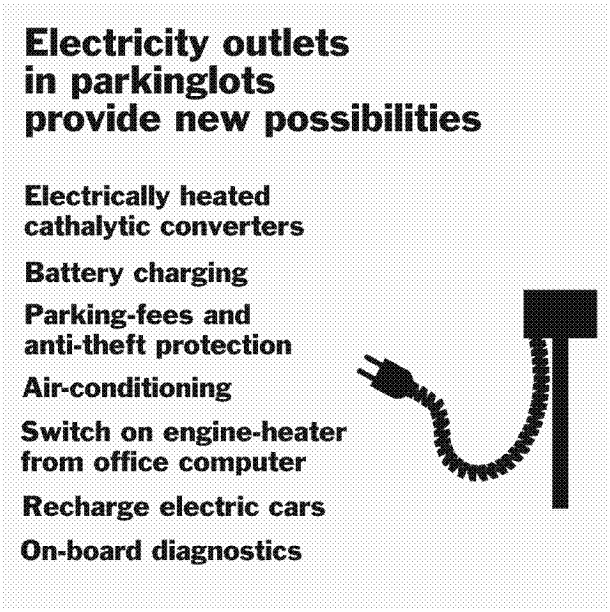
The average connection time today is 1-2 hours. It should be possible to regulate heaters better in the future using electronic devices, and this will reduce the average connection time. At the same time, we can expect engine heaters to be used throughout most of the year in order to gain the other benefits.

Here, we use a connection time figure of 1.25 hours, which involves a further 600-1,000 million kWh - a few percentage units of the electric heating used in households and businesses.

In the OECD countries the electricsupply is based on 3/5 fossile fuels (coal, oil and natural gas) and 2/5 non fossile fuel (hydro and nuclear). The reduction of carbon dioxide due to engine heaters will be diminutive, but the other benefits, such as less carbon monoxide and hydrocarbons emissions, will be the same as in Sweden.

5. Future technological developments

The development of an infrastructure of power outlets in parking lots in residential areas and at workplaces is essential to the future introduction of electric or hybrid-electric vehicles. One of the problems facing electric vehicles is the lack of charging facilities. If more power outlets were to be installed for engine heaters, we would also have an infrastructure for future electric vehicles when battery technology improves. We should therefore dimension the power outlets with 16 Ah fuses from the start. The power outlets at parking lots could also be used for other purposes, such as lawn mowers.



Heating elements for rapid catalytic converter light-up

If the car is connected to the electricity grid, it is possible to fit the catalytic converter with a heater element which turns on a few seconds before start and ensures that the catalytic converter lights up immediately. Using this, perhaps supplemented with a heat accumulator (as in the BMW 5 series) , today's catalytic converter cars could easily meet the ULEV (Ultra Low Emission Vehicle) requirements. If the car were to carry its own power to heat the catalytic converter quickly, extra batteries would be required, along with a much more powerful alternator (3-4 kW). It is therefore both cheaper and simpler to use power from the mains. Fuel consumption would also be reduced.

Built-in battery charger

The possibility of built-in battery chargers means that it would be possible to reduce the size of the car battery and alternator rating. The efficiency of the electricity generated by the car engine is only 10-25%. A built-in battery charger and engine heater would offer completely new possibilities for optimising the ignition and injection system and thus achieve much lower emissions and fuel consumption.

Demand side management

If millions of cars use engine heaters every day, the power companies needs to encourage electricity consumption at times that enable optimum utilisation of the power supply. This could be done by sending control signals via the electricity network to the vehicle. Combined with a heat accumulator, this would also make it possible to optimise electricity consumption in relation to the ambient temperature, particularly in cases where the car has an engine compartment heater. Sydkraft in Sweden is currently conducting a pilot study on the possibility of steering the load. The Swedish Electrical Utlities R & D Company - Elforsk AB is studying the possibility of borrowing current from distributed sources. Three million cars connected to the network could constitute distributed energy sources to even out peaks.

IT and electrical comfort systems

Car manufacturers are currently looking into comfort systems that make it possible to run air-conditioning units or fans from the power network in parking lots. If the parked car is connected to the network it would also be possible to develop new services. It is possible to use signals on the network for two-way communication with the car. Modern technology would enable remote control of engine heaters and other functions in the car. A tone-dial telephone or an e-mail could be used to set or change the starting time for engine or compartment heaters. Experiments along these lines are included in the Sydkraft study.

Alarms and theft-protection

A car connected to the electricity supply could be fitted with an alarm with a link-up to the police or security company via the electricity cable. If the parking fee is lower than it would otherwise be for cars not connected to the supply, there is an added incentive for the motorist to use the service all year round. Few would have any objection to having their cars guarded in such a profitable manner.

6. Summary

Cold starts account for a very high proportion of the total emissions from cars. Use of electrical engine heaters can substantialy reduce emissions. Connecting cars to the power net will also facilate electric heating of the catalytic converter. In Scandinavia, France and Switzerland where non fossil power is the main supply, the reduction of carbon dioxide can be substantial with engine heaters. In other countries the reduction of carbon dioxide will be diminutive. But the other benefits, such as less emissions of carbon monoxide and hydrocarbons, will be the same. The investment in a system for connecting cars to the power net can in the future also be used for hybrid and electric vehicles. Two-way communications through the power net offers new possibilities such as alarm, climate control and pay-system for parking fees.

7. References

1. ScanTech Utvecklings AB, Analys av A60-prov, Emissionsfaktorer för personbilar av årsmodell 1989.(A60 test analyses. Emission factors for cars, 1989 model).
2. Skandia Environmental Commission, Cold starts and emissions from cars equipped with catalytic converters, Environmental Report No. 3, Stockholm 1991.
3. A Laveskog, Emissions at regulated and non regulated test cycles, MTC rapport 9001, Swedish Motor Vehicle Inspection Company, Haninge 1990.
4. M Lenner, Pollutant emissions from passenger cars. Influence of cold start, temperature and ambient humidity. Rapport 400A. VTI, Linköping 1994
5. J Bang, Avgasutslipp, bensinforbruk og motorslitage med og uten bruk av motorvarmer. (Exhaust emissions, petrol consumption and engine wear with and without engine heaters). Statens Teknologiske Institutt, Oslo 1982.
6. L Erlandsson, Sammanställning av provresultat för lätta fordon (Test results for light vehicles), MTC9228, Swedish Motor Vehicle Inspection Company, Haninge 1992
7. AB Bilstatistik, Bilismen i Sverige 1994 (Driving in Sweden), Stockholm 1994
8. J Laurikko, VTT, Espoo, information by word of mouth, 1995.
9. A. Ydstedt, Dep of Environmental and Energy Systems Studies Alternatives to lead fuel additives and catalytic exhaust emission control, Lund University, Lund Institute of Technology, Lund 1995
10. KfA Jülich, VDEW, Germany, information by word of mouth, 1995