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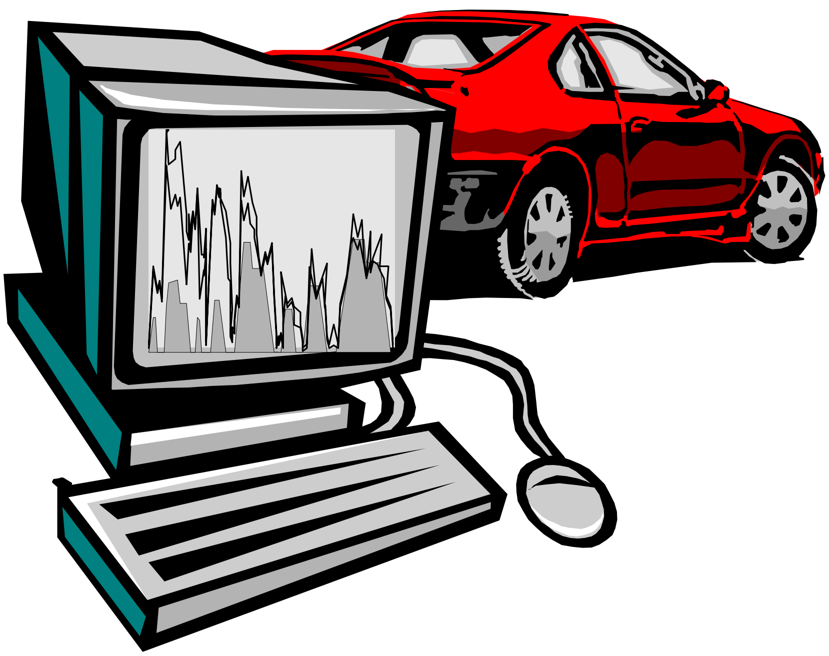

Cycle-Beating and the EU Test Cycle for Cars

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Foreword

Those reading the paper who do not have a technical background may find the content rather technical. This foreword is intended to introduce some of the technical terms used in the report to the uninitiated reader. The basic message from the report is, however, rather simple. The test new cars take on the amount they pollute is unrealistic of real driving and too predictable. This allows car manufacturers to design their cars to pass tests and results in cars producing higher levels of pollution when driven on the road.

The pattern of speeds cars have their exhaust emissions tested at, the so called test "cycle", is quite different from real driving. Not only is the test relatively short and speeds rather low, but acceleration is very slow. This means that the load or strain on the engine is usually well below that normally placed on the engine by drivers.

The predictable pattern (or "cycle") of speeds and low accelerations that do not strain (or load) the engine allows engineers to build cars that pass the test, but do not have low pollution levels when driven normally. This "beating" of the test cycle is known as "cycle beating" and it is this feature of pollution control that this paper addresses.

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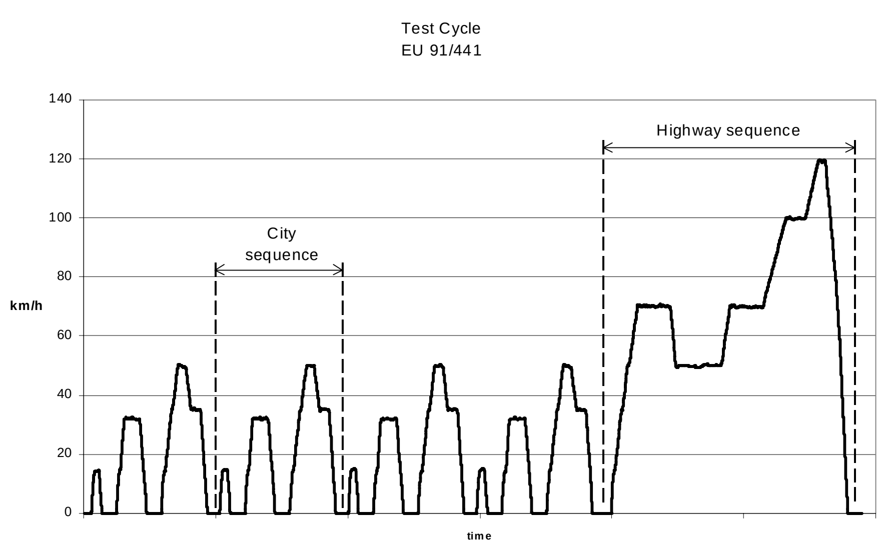
Introduction
All cars sold in the EU have to comply with a series of European standards. The tests for these standards range from road worthiness and crash tests to exhaust emission tests. These test are carried out on each ”type” of car, hence their collective name : type approval tests. The object of this paper is to demonstrate that the exhaust pollution element of the type approval tests are falling short of their objectives. The emission test allows manufacturers to design cars to pass the test rather than have low pollution levels on the road. This report outlines how the current test is flawed and provides a way to address the problem.

Tests carried out by the Swedish exhaust emission laboratory of Rototest AB reveal that some manufacturers do not take responsibility for the exhaust performance of all or some of their models in situations when the car is driven under conditions not covered by the official European test cycle. This kind of “cycle beating” results in high emissions of carbon monoxide (CO), hydrocarbons (HC) and ammonia (NH_3).

The risk of cycle-beating has been recognised by the European Union where heavy duty vehicles are concerned. The proposal for a new directive includes an amendment to the present 13-mode cycle with the effect that the relevant authorities are allowed to measure emissions in some randomly chosen points. This report explains why such a supplement should be used in connection with the test cycle for cars, and it outlines how this could be achieved.

The EU test cycle
The official test cycle for cars in Europé (NEDC) does not contain much accelerations or other transients. Figure 1 shows how the speed of the vehicle varies in the different parts of the cycle (urban and highway driving). The urban section repeats the same driving cycle four times. The heaviest acceleration is from idle to 50 km/h in 28 seconds. The EU test cycle, therefore, is hardly representative of normal driving conditions. For lack of research it is hard to know what exactly constitutes average driving, and average driving may differ between Member States and regions. The legal requirement of road vehicles should ideally cover several different kinds of driving. Tough driving and caravan towing should also be covered. Manufacturers would hardly in the marketing of new cars put such an emphasis on acceleration and top speeds if they thought that most people´s real driving habits come close to those represented by the test cycle.

Figure 1.

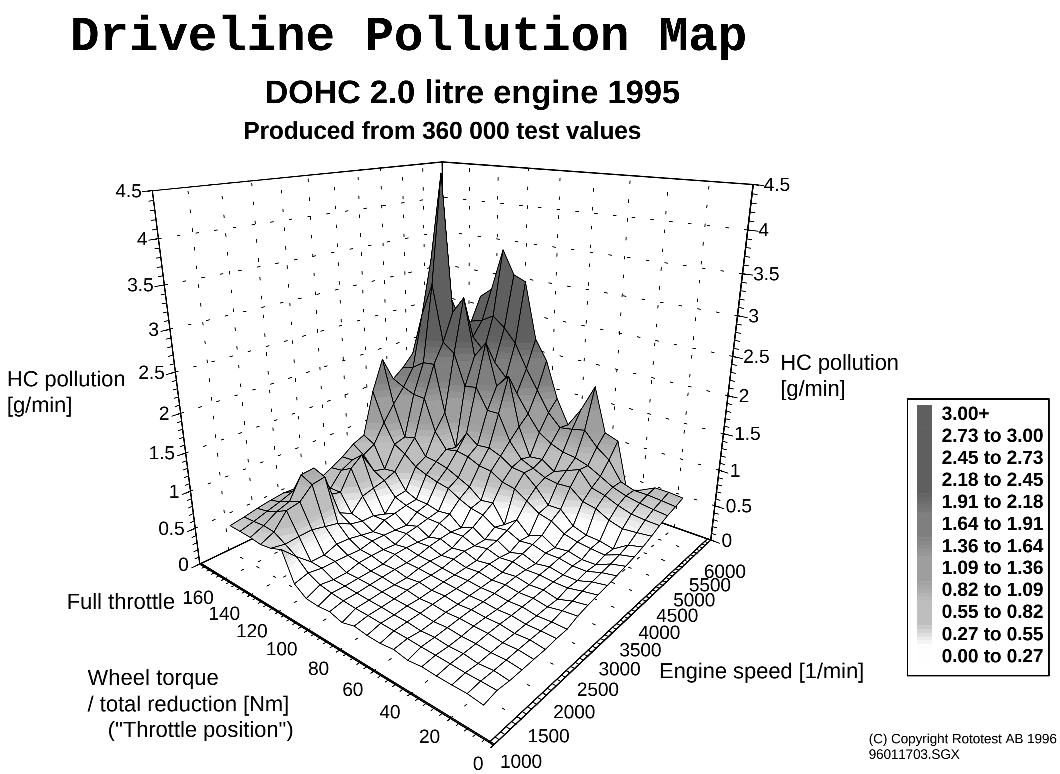


To make the test cycle include more accelerations and heavy loads would be a step in the right direction. All test cycles, including existing cycles such as the US Federal Test Procedure and US06, however, can become subject to cycle-beating. Thus there is scope for investigating other options as well. Before coming back to the issue of how to prevent cycle-beating, let us take a look at how some manufacturers react to the requirements of the present EU test cycle.

Closed loop control outside the range of the EU test cycle - data from Rototest

Rototest AB, an independent exhaust emission laboratory in Rönninge, Sweden, has in the last two years carried out tests on more than one hundred gasoline fuelled car models. The engines have been subjected to different loads and Rototest has thereby been able to draw up an ”exhaust map” for each one of them. An example is provided in Figure 2.

Figure 2



From the exhaust maps it is possible to establish the range of closed loop control. Closed loop control means that the exhausts are being cleaned by the three-way catalytic converter. From Figures 3 and 4 it is obvious that it is technically possible to guarantee closed loop control over a very large part of the working area of the engine. The black line shows the maximum output at different combinations of engine speed and engine power. The dotted line represents the range of closed loop control.

Figure 3 (Audi)

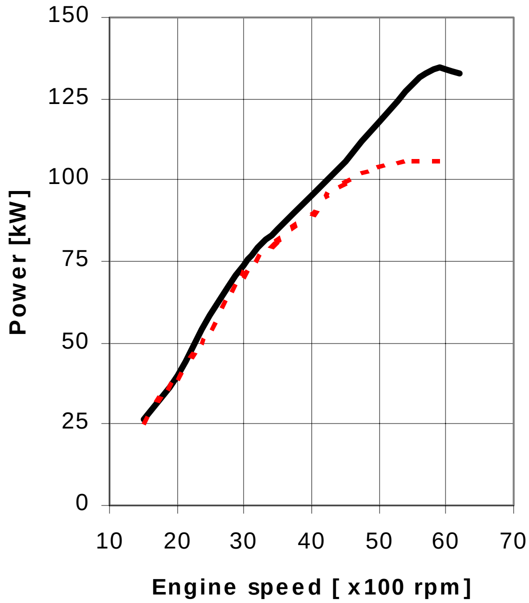
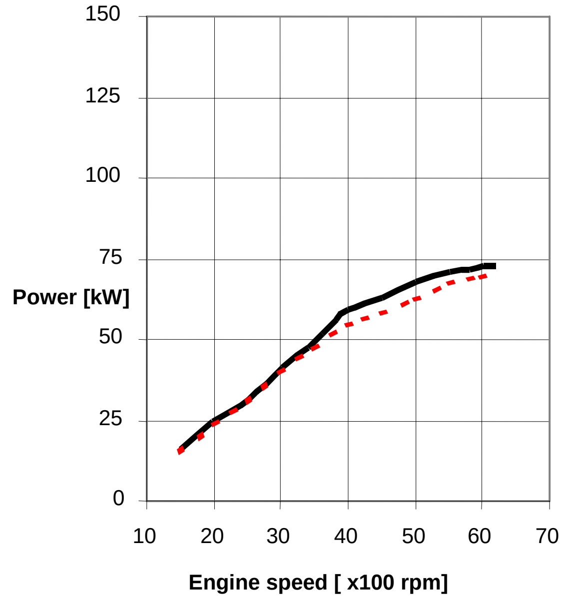


Figure 4 (Opel)



Figures 5 and 6, on the other hand, are clear examples of ”cycle-beating”. The manufactorers in these cases only take responsibility for engine loads which are typical for the official driving cycle.

Figure 5 (Toyota)

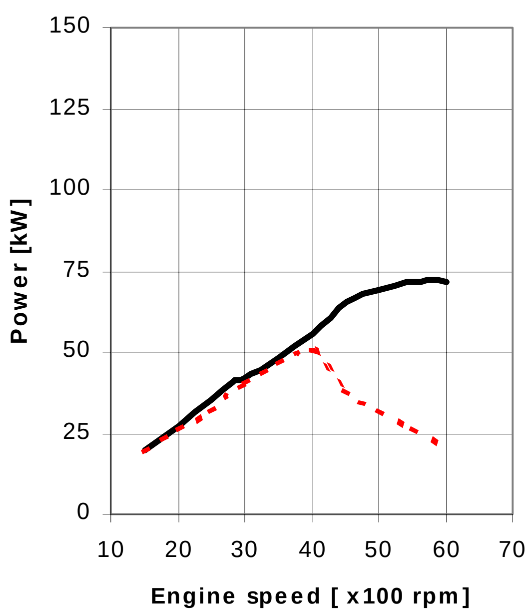
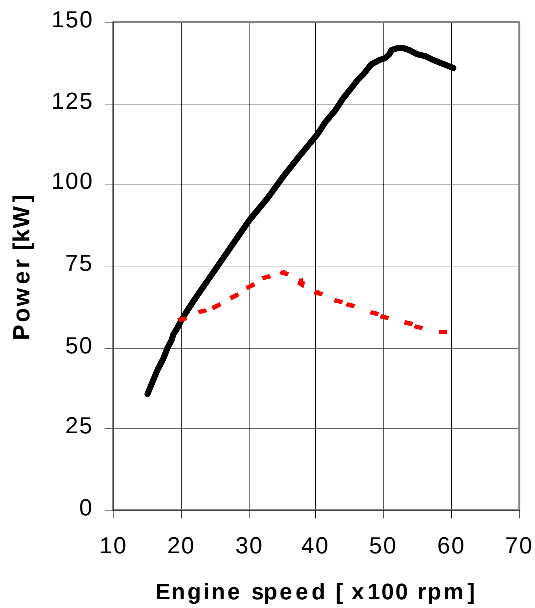


Figure 6 (Volvo)



Why are some cars so much better than others? A good engine design and catalyst and tail pipe materials that can withstand high temperatures appear to be what characterise cars with a wide range of closed loop control. Limited power output (per litre of engine volume) may also be of importance (Kågeson, 1996).

Options for preventing cycle-beating

Car manufacturers can use modern electronic equipment to adapt the engine to any type of test cycle. They can even tell the computer of the car how to recognise when the car is being driven according to a specific test-cycle and adjust the combustion accordingly. It was this kind of software that six truck manufacturers, including two European firms (Volvo and Renault), recently used in the United States to defeat the EPA´s pollution control. As a result emissions of nitrogen oxides from highway driving increased by 300 per cent.

Regulators, then, have only two options if they want to diminish the risk of cycle-beating. One is to extend the test cycle to include many different driving styles and engine loads. This will be rather costly as more time will be required for testing according to an extended cycle. The other option is to add a supplementary requirement to the test cycle, a requirement which the relevant authorities can control through randomly chosen measuring points. This option will be further explored in this paper.

Emissions of hydrocarbons are of primary interest where cycle-beating is concerned. In gasoline fuelled cars, lack of closed loop control results in high emissions of HC and CO, and indirectly of ammonia. One option could thus be to prescribe that closed loop control must be guaranteed under most driving circumstances. A regulation of this kind, however, would not be technically neutral. The EU should avoid any regulation that favours a particular solution as this may turn out to be an obstacle to technological development. Thus it is better to stick to the idea of exhaust emission limits. In this case, the present EU test cycle could be supplemented by a requirement saying that exhausts of HC must when driving with a warm engine nearly always stay below a certain limit expressed as g/km, g/second or g/kWh. For neutrality between different makes and different engine sizes, grammes per kilowatt-hour could be an alternative to grammes per kilometre.

One possibility, therefore, could be to introduce an upper limit for HC/kWh that will (with present technology) require a three-way catalytic converter and closed loop control. The legal requirement could, for instance, be limited to 90 per cent of full load at all engine speeds up to, say, 80 per cent of the maximum engine speed.

Such a requirement will also guarantee low emissions of CO and NH_3 when driving with a warm engine. Ammonia emissions are generally very low during steady state driving but increase when the fuel to air ratio becomes rich and the engine changes to open loop control. In modern cars with a small range of closed loop control ammonia emissions tend to be higher than the overall emissions of NOx. The best way of preventing high emissions of ammonia is thus to make manufacturers take responsibility for closed loop control also in cases of heavy engine loads such as in accelerations and caravan towing (Färnlund and Kågeson, 1998).

In-use compliance tests of how manufacturers comply with the supplementary requirement could be done by carrying out emission tests in a few randomly chosen measuring points representing high engine loads and medium to high engine speeds. To present a concrete proposal for where to put the upper limit for HC emissions has not been possible within the present study. However, the huge amount of data collected by Rototest (covering more than one hundred 1997 and 1998 models) could be used for establishing a preliminary value.

It may be argued that introducing such an emission ceiling is not useful because it has to be high enough to reflect the worst case which presumably has a very low frequency in real driving. This counter-argument would be relevant in a situation where improved engine design was the only possible adjustment mechanism and where there existed a linear relation between engine output and emissions of hydrocarbons. However, with today's dominating treatment technologies there is a big leap in exhaust performance between open loop and closed loop control. Thus a randomly checked emission ceiling, which represents around 85 per cent of the working area of the engine, could be expected to force manufacturers to guarantee closed loop control in an area representing something like 99 per cent of real driving.

High engine loads would, of course, continue to give rise to higher emissions than lower loads but the difference would diminish with closed loop control. One should in this context remember that the difference between closed and open loop control may in these circumstances represent an increase in emissions by a factor of 10 to 100. This means that even in cases where open loop control makes up only 1 per cent of real driving, it may be responsible for more than 50 per cent of overall emissions from a warm engine.

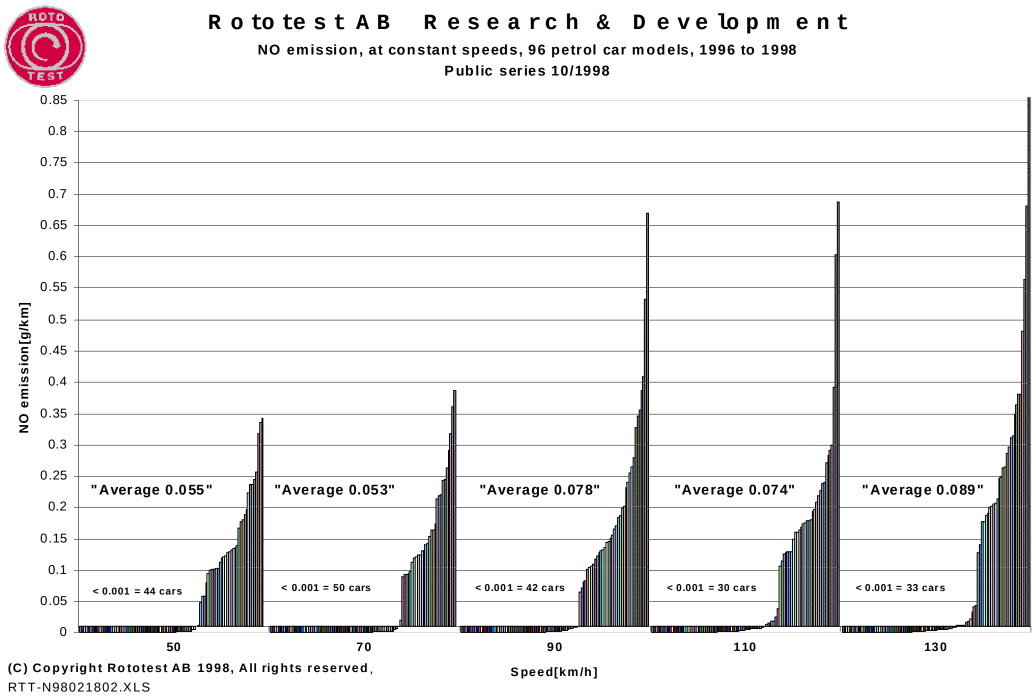
An alternative way of making cycle-beating more difficult would be to shift the official NEDC driving curve randomly within a certain band. This would allow for higher loads and accelerations and make it more difficult for manufacturers to prepare the computer to detect that the car is driven according to a particular cycle.

Additional requirements on NOx?

NOx typically dominates the exhausts when driving at steady speeds. In such conditions the engine is running lean. The tests carried out on cars in Sweden also reveal large differences in NOx emissions at different steady speeds. This is shown in Figure 7. A large number of the cars have emissions of NOx at or below the detection limit of the equipment, while others have relatively high or even very high emissions. In a situation like this average figures do not provide much information about real conditions.

Some of the cars tested by Rototest AB do not give rise to any emissions of NOx at a certain steady speed but give rise to considerable emissions at a steady speed just below or above the first mentioned speed. This and the large variation in exhaust performance illustrated in Figure 7 raise the issue of whether the EU test cycle should also be supplemented with a special ”ceiling” for NOx. Present knowledge based on data from Rototest, however, is not sufficient as a basis for a precise proposal. Additional tests and studies will have to be carried out in order to understand why the differences are so great and where to put the limit. The large differences in NOx emissions between various makes and models occur already under driving conditions covered by the present EU test cycle. In the case of NOx an alternative option therefore could be to continue the process of lowering the emission limit value based on the present test cycle.

Figure 7



Green labelling and consumer information as an alternative to regulation

Green labeling and government-sponsored consumer information may appear to be an alternative to amending the official test cycle. By this approach consumers would get a chance of avoiding cars from producers who involve themselves in cycle-beating, and cycle-beating would presumably diminish when the industry adapts to the new situation. This alternative would, however, require independent tests of most or all models and would thus be more expensive for the EU (or Member States) than a system based on supplementing the test cycle with one or two special requirements. In the latter case a limited sample would suffice. An argument in favour of the green labelling approach is that it may take too long to wait for a legal requirement that makes cycle-beating difficult or impossible. On the other hand, it may also take some time before funds for green tests are available, even though the cost to each country would be low if the burden were shared among all Member States.

Summary and Conclusions

The tests performed by Rototest reveal that car manufacturers are involved in a considerable amount of cycle-beating. The result is very high emissions of hydrocarbons, carbon monoxide and ammonia from high engine loads. Even in cases where lack of closed loop control represents only a small part of real driving this fraction may be responsible for the majority of overall emissions of these substances.

There are in principle two ways of making cycle-beating more difficult. The traditional way would be to include more transients and high loads in the test cycle. This could possibly be done within the official NEDC cycle by allowing the driving curve to shift randomly within a certain band. An alternative would be to supplement the existing official test cycle with an emission ceiling (for HC) which is checked at some randomly chosen measuring points. This paper recommends that both options are more closely investigated .

References

Färnlund, J. and Kågeson, P. (1998), Ammonia Emissions from Cars with Three-way Catalytic Converters, Rototest AB and Nature Associates, Rönninge, Sweden.

Kågeson, P. (1996), Emissions from 36 car models, Test results from cars subjected to heavy loads and a supplementary test cycle, European Federation for Transport and Environment, T&E 96/4, Brussels.

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About this paper

This paper examines the test used to regulate the maximum permitted pollution from new cars as well as the potential for an alternative test. It is argued that a principle flaw of the current approach is that it does not fully reflect real driving conditions. Such a situation allows manufacturers to design to pass an artificial test rather than achieve low on road emissions. This practice of merely designing for a test cycle - so called cycle beating - threatens potential reductions in pollution. Supposedly cleaner cars from some producers reduce emissions under the artificial conditions of a testing centre much more than in real life driving.

It would be very costly to exhaustively test vehicles through a comprehensive test that would reflect more accurately a broad variety of driving habits and engine loads. Additionally any such test could potentially be “cycle beaten” by engineers. An approach that allows a degree of random chance within an agreed range of conditions could provide a solution.

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