Fire and explosion characteristics of E85

Interest in renewable motor fuels is increasing, and Ethanol E85 (normally referred to simply as E85) is the fuel that has achieved the greatest success in Sweden. However, at the same time, there has been only limited knowledge of the fuel's fire and explosion characteristics. On the initiative of the National Road Administration, and with support from several other sources of finance, SP has quantified these characteristics. The project has been carried out in several stages, from an evaluation of more fundamental ignition properties through to investigating the effects of igniting fuel vapours in a fuel tank in a vehicle.

Introducing new motor fuels on to the market involves considerable work. It is not merely a matter of designing a vehicle that can run on the new fuel, but also of identifying (and, if necessary, managing) any new risks that can arise in the entire chain from source to user. This chain covers manufacture and handling in production plants, refineries and depots, transport for distribution to petrol stations and, finally, filling the fuel into, and using it in, different types of vehicles.

As mentioned in BrandPosten No. 35, 2006, SP has carried out a series of trials concentrated on handling of the fuel at petrol stations on behalf of the Swedish Petroleum Institute (SPI). These trials examined the differences in fire behaviour of E85 and petrol, and also investigated the consequences of ignition of fuel vapours in an underground fuel storage tank. In comparison with petrol, it was found that E85 had a lower heat release rate than petrol, and produced less smoke. The tank trials showed that, in most cases, the fuel vapour concentration in the tanks was too rich to be ignited.

Additional ignition tests were carried out in the spring of 2007, with the conditions in the tanks being 'provoked' such as to produce a flammable mixture. Ignition then resulted in a rapid increase in pressure in the tank, with associated discharge of combustion gases through the vent pipe for a few seconds. Apart from this, the consequences were only marginally noticeable above ground, with no visible damage being found to the tank after it had been uncovered.

The objective of this most recent project has been to obtain more fundamental information on the behaviour of E85 by quantifying its fire and explosion characteristics. As the quality of E85 can vary with the time of the year (see the panel on Page 18), both winter and summer grades were investigated. For comparison, some tests were also carried out on ordinary unleaded 95 octane petrol. Detailed planning of the project was carried out to address a number of questions that were defined in conjunction with the interested parties and financing sources: the National Road Administration, the Swedish Rescue Services Agency, Stockholm City Council, SEKAB, SPI, the Swedish Energy Agency, SAAB and Volvo. Within SP, the departments of Fire Technology, Electronics, Chemistry and Materials Technology, and Measurement Technology were all involved.

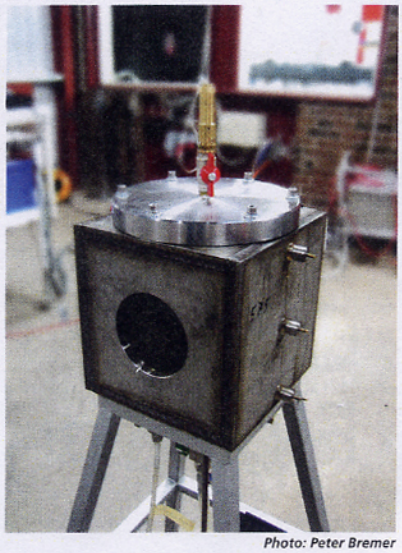

Photo: Peter Bremer

Figure 1 The explosion chamber as used for the tests.

Investigation divided up into five experimental stages

The project was divided into five experimental stages, with the first two stages being intended to provide more fundamental knowledge of the characteristics of E85, and the three subsequent stages being of more applied character.

The first stage measured the concentrations and compositions of fuel vapours in a closed vessel, e.g. a fuel tank, at different temperatures. The fuel samples were conditioned in closed vessels at various temperatures, after which the vapours were injected into a gas chromatograph with a flame ionisation detector (GC-FID).

The second stage investigated the temperature range over which the fuel vapours in a fuel tank could be ignited. The fuel was conditioned at a range of temperatures in a closed vessel, after which the vapours were sucked into an explosion chamber ('bomb test equipment'). Within this was an ignition device consisting of two electrodes connected

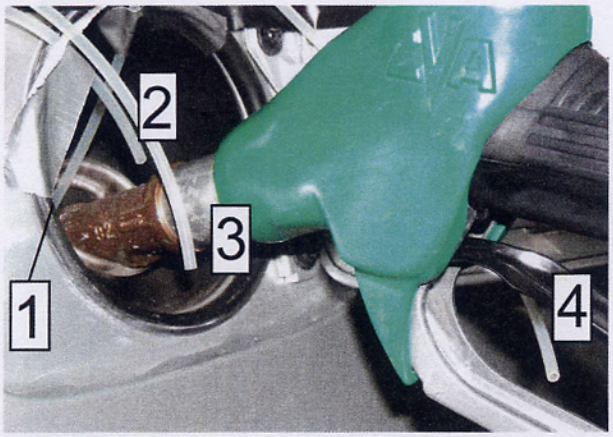

Photo: Kent Lindström

Figure 2 Gas analysis points 1 to 4 for the filling tests.

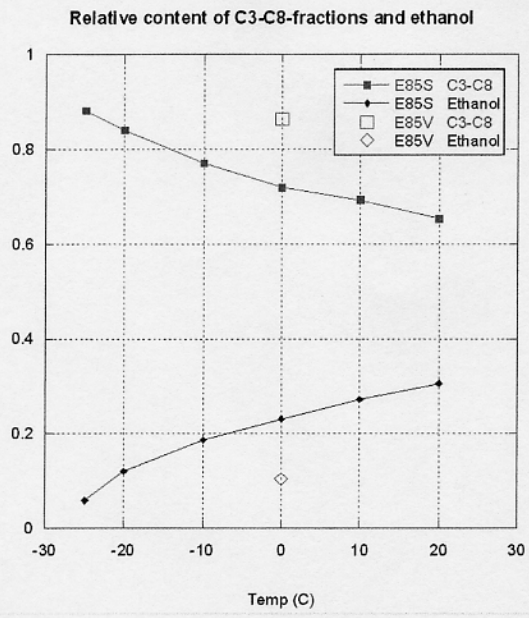

Figure 3 Relative contents of ethanol and petrol fractions in fuel vapours from E85 at different temperatures. Although the liquid phase contains only 15 % petrol, 70-90 % of the vapour phase consist of petrol.

to an inductive ignition system of the same type as used in cars. The explosion pressure resulting from each ignition in the chamber was recorded, which meant that the combustion properties could also be characterised. For comparison, a number of tests were also made using standardised test gases as used in connection with type-testing of explosion-proof enclosures.

Stages 3 and 4 were concentrated primarily on investigating the effects of igniting fuel vapours in a fuel tank in a car. Again, the conditions in the tank were 'provoked' in order to produce worst-case conditions. Stage 3 saw a number of commercial fuel tanks being filled with a test gas having essentially the same properties as the fuel vapours from E85 at the 'optimum' fuel/air ratio. The gases were ignited with a spark plug, and the results plotted. Tests were carried out with ignition of the gases both inside the tank and at the opening of the filling pipe.

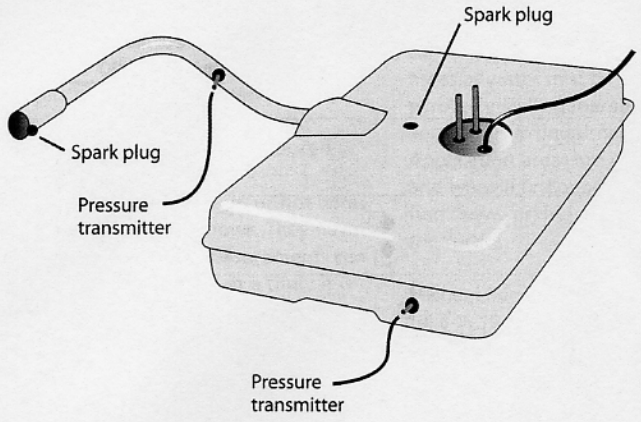

Figure 4 Schematic diagram of the test arrangement for Stage 3.

Stage 4 exposed three different tanks, containing 15 litres of E85, to the effects of a limited fire of spilt fuel. In order to ensure worst-case conditions, both the tanks and the fuel were cooled to a temperature of about –15 °C when exposure to the fire started.

Stage 5 measured the fuel concentration and gas composition around the filling pipe when filling the tank. This was of interest not only to be able to assess the risks of ignition, but also to provide a basis for determining the need for gas recovery systems for E85 in the interests of reducing environmental impact. Tests were carried out in the form of filling two different tank types/vehicle models with fuel, and with and without the gas recovery system in operation. Gas samples were tested at four different points around the filling opening and dispenser valve, and analysed by GC-FID in the same way as for Stage 1.

Results – Stages 1 and 2

One of the results found is that the fuel vapours in a closed vessel containing E85 consist largely of petrol, of the order of 70-90 %, despite the fact that petrol constitutes only about 15 % of the liquid phase. This high proportion of petrol fractions in the fuel vapours means that the flammability range is very different from that of pure ethanol.

The fuel vapours present in a closed vessel or fuel tank containing summer-grade E85 are flammable over a temperature range from about –18 °C up to +2 to +5 °C. This temperature range varies somewhat, depending on the fuel grade and on the amount of fuel in the tank, i.e. how full it is. For winter-grade E85, the upper temperature limit is assessed as about –8 °C to –9 °C, while for summer-grade unleaded 95 octane petrol it is about –20 °C. The trials show that E85 can be classed in explosion group IIA, in the same way as for petrol.

Results – Stages 3-5

Ignition tests in the fuel tanks showed that, in the worst case, ignition can result in a pressure rise in the tank sufficient to deform the tank or rupture it. The