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FUEL TANK DESIGN AND OPTIMIZATION FOR DIESEL COMMERCIAL VEHICLES ACCORDING TO ECE R 34 DIRECTIVES

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ABSTRACT

ECE R34 directive concerning the approval of diesel commercial vehicles with regard to the prevention of fire risk represents substantial regulations for fuel system designs and validations. This study propounds the importance of material selection and packaging of fuel system components designed for liquid fuel varieties according to ECE R-34 directive definitions. The directive covers vehicles of categories M, N and O and includes serial of homologative tests intending to evaluated vehicle system reactions in high heat and pressure states.Test results prove passenger safety in extraordinary situations such as roll-over and external fire.

Keywords: ECE R34 Directive, Roll-over, pressure and fire tests.

DİZEL TİCARİ ARAÇLARDA ECE R 34 YÖNERGESİNE GÖRE YAKIT TANKI DİZAYNI VE OPTİMİZASYONU

ÖZET

ECE R34 yönergeleri, dizel yakıtlı ticari araçların yakıt tankı dizayn ve validasyon aşamalarında onaylanan ve potansiyel yangın riskinin önlenmesi için uygulanan en etkin regulasyon konularıdır. Bu çalışmada ECE R 34 yönergeleri baz alınarak tasarlanan yakıt sistemi komponentlerinin malzeme seçimi ve paketlenmesinin önemi üzerinde durulmaktadır. Söz konusu yönergeler M, N ve O kategorisi araçları kapsamakta ve yüksek ısı ve basınç etkisi altında sistem tekpisini belirleyen bir dizi homologatif testleri kapsamaktadır.Test sonuçları, devrilme ve yangın gibi ekstrem durumlarda yolcu güvenliğini doğrulamaktadır.

Anahtar kelimeler: ECE R34 Yönergeleri, Devrilme, basınç ve yangın testleri.

1. INTRODUCTION

The fuel system of automotive vehicles should perform within major safety parameters related to the importance of flammable substances such as diesel fuels which is extensively consumed worldwide. In order to maintain an overall safety standard, ECE R34 directives are respected by the united automotive authorities to keep the devastating effects of fire away from vehicle components.

ECE R34 directives concentrate on fuel related components such as fuel tanks, refueling units – hoses, tank venting hoses - valves and fuel supply routing to engine. In this study, fuel tank and sub-component related issues will be emphasized in common phrases for indicated directives.

2. BACKGROUND

There are four main steps of ECE R34 to be advanced:

- Collusion Resistance
- Overturn Test
- Mechanical Strength
- Resistance to High Temperature
- Hydraulic Test and Fuel Permeability
- Resistance to Fire

Each step has a particular test procedure concerning preparations, proceedings and result evaluations. Validations for the fuel tank and sub-component(s) depend on those results which are evaluated under regulation authority supervision.

Due to the completion of the regulation steps, approval reports are composed. This report represents an accreditation for the manufacturer firm to produce and commercialize vehicles equipped with tested fuel tank and sub-components.

3. TESTS

ECE R34 homologation tests are not supposed to be processed sequentially as the test subjects are separate and physically unrelated. Entire test subjects can be concluded within two days considering all tests steps pass. According to the directive rules, some tests shall be performed more than one or two times.

3.1 Setup

Proper test preparations are crucial in order to maintain tester safety. Every precautionary measures must be undertaken especially during fire tests.

3.1.1 Test Fixture

The test fixture represents only a limited portion of the vehicle where the fuel tank is conditioned. This portion must include all fuel tank and related routing components in order to simulate real vehicle responses.

If the fuel tank is designed with a vented fuel cap usage, an extra fuel cap with vent ability cancelled is required for pressure test.

To prevent fuel leakage from the end of routing, such as fuel supply lines and fuel return lines, end of the routing must be blinded with proper plugs.

The fixture height has an importance on fire resistance tests and depends on vehicle ground clearance values. However the fire resistance test bench is adjustable in heights, optimum height shall be calculated for the test fixture to meet the ground clearance height as some test benches have limited adjustability ranges.

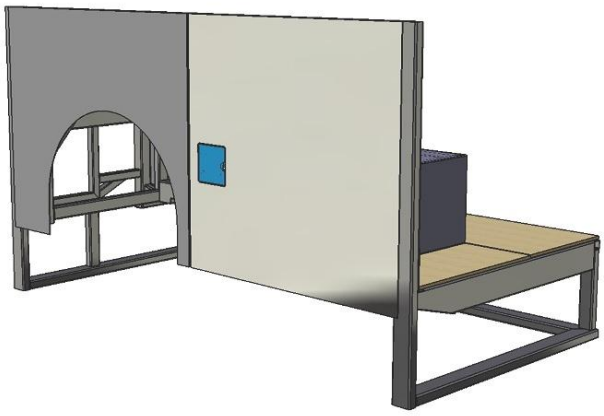

Figure 1 – Test Fixture

3.1.2 Test Plantation

Test team needs the plantation and equipment explained below and a proper transportation to carry the fixture between test scenes:

- Rotation arm to hold and turn the test fixture.
- Burning structure equipped with serious ventilation system, fire extinguishers and gas masks.
- Furnace capable of heating the air up to 95°C and huge enough to take the test fixture inside.
- Proper size refrigerator unit with minimum -40° C coolant capacity.
- Air compression machines and gauges to increase inner tank pressure.
- Water and fuel pumps to fill the tank.

3.2 Collision Resistance

This test is mandatory especially if the fuel tank designed to be assembled at the rear bottom side of the vehicle. The goal is to test the durability and impact resistance of fuel tank and circumferential structure on the vehicle. This is a cold environment test in order to evaluate the reaction of plastic fuel tank crushed under low heat conditions.

The tank shall be filled to its rated capacity with a water-glycol mixture or with another liquid having a low freezing point, which does not change the properties of the tank material, and shall then be subjected to a perforation test. During this test the tank temperature shall be 233K ± 2K (-40° C ± 2° C).

Rather than using a partition of the vehicle, a pendulum collision testing fixture, with the fuel tank assembled, shall be used for the test. The collision body shall be of steel and have the shape of a pyramid with equilateral-triangle faces and a square base, the summit and the edges being rounded to a radius of 3 mm. (Figure 2) The total mass of the pendulum shall be 15 kg. The energy of the pendulum at the moment of collision shall be not less than 30 Nm and as close to that value as possible.

Figure 2 – Collision Test Pendulum

The tests are to be made on the points of the tank which are regarded as vulnerable to frontal or rear collisions. The points regarded as vulnerable are those which are most exposed or weakest having regard to the shape of the tank or the way in which it is installed on the vehicle. Such vulnerable points are generally considered to be the flat surfaces of the fuel tank. The points selected must be indicated in the test report.

During the test, the tank must be held in position by the fittings on the side or sides opposite the side of collision. After the pendulum releases, no fluid leak shall result by the impacts. At the choice of the manufacturer, all the impact tests may be carried out on one tank or each may be carried out on a different tank.

For further tests related to rear impact resistance issues, 70/221/EEC and ECE R58 directives shall be followed with a rear impact test tool as shown in Figure 3. This accelerated crush tool simulates total impacts to rear and side of the vehicle. Therefore instead of a fixture, related tests shall be conducted on a full size vehicle with body and chassis.

Figure 3 – Typical Rear Impact Test Tool

3.3 Overturn Test

The main purpose of overturn test is to examine fuel leakage by simulating accident conditions in which the vehicle tumble on both sides and roof. This test is mandatory for the fuel systems equipped with atmospheric vents on fuel tank and / of fuel filler caps attached on tank or filler necks.

The tank and all its accessories shall be mounted on to a test fixture in a manner corresponding to the mode of installation on the vehicle for which the tank is intended, including design ruled grommets and sealants. This also applies to systems for the compensation of the interior excess pressure.

The test fixture shall rotate about an axis lying parallel to the longitudinal vehicle axis. The test shall be carried out with the tank filled to 90% of its capacity and also 30% of its capacity with a non-flammable liquid having a density and a viscosity close to those of the fuel normally used (water is accepted).

The tank shall be turned from its installed position 90° to the right. The tank shall remain in this position for at least five minutes. The tank shall then be turned 90° further in the same direction. The tank shall be held in this position, in which it is completely inverted, for at least another five minutes.

The tank shall be rotated back to its normal position. Testing liquid that has not flowed back from the venting system into the tank shall be drained and replenished if necessary. The tank shall be rotated 90° in the opposite direction and left for at least five minutes in this position.

The rotation rate for each successive increment of 90° shall take place in any time interval from 1 to 3 minutes.

As the test is conducted with integral fuel system free from damage, at the end of the test steps, no traces of fluid leak shall be observed by the physical attachments of fuel line and ventilation valve areas.

Figure 4 – Roll-Over Test

3.4 Mechanical Strength

In this test, the fuel tank body is stretched by pressurizing and the deformation results are observed. The goal is to evaluate the impermeability of physically deformed plastic fuel tanks.

The tank and all its accessories shall be mounted onto a test fixture in a manner corresponding to the mode of installation on the vehicle for which the tank is intended or mounted in the vehicle itself or mounted in a test fixture. On request of the manufacturer and with the agreement of the Technical Service the tank may be tested without using any test fixture. Water at 326K (53° C) shall be used as the testing fluid and shall fill the tank to its capacity. The tank shall be subjected to a relative internal pressure equal to double the working pressure and in any case to not less than 30 kPa at a temperature of 326K ± 2K (53° C ± 2° C) for a period of five hours. During the test, the tank and its accessories shall not crack or leak; however it may be permanently deformed.

3.5 Resistance to High Temperature

This test is crucial in order to assess the plastic material resistance against high temperature environmental conditions.

The fixture used for the test shall match the manner of installation of the tank on the vehicle, including the way in which the tank vent works. The tank, filled to 50% of its capacity with water at 293K (20° C) shall be subjected for one hour to an ambient temperature of 368K ± 2K (95° C ± 2° C).

The results of the test shall be considered satisfactory if, after the test, the tank is not leaking or seriously deformed.

3.6 Hydraulic Test and Fuel Permeability

This test deals with increased internal pressure of a vent sealed fuel tank, intending to observe tank integrity under extraordinary pressure conditions.

3.6.1 Hydraulic Test

The tank shall be subjected to a hydraulic internal pressure test which shall be carried out on an isolated unit complete with all its accessories. The tank shall be completely filled with a non-flammable liquid (water, for example). After all communication with the outside has been cut off, the pressure shall be gradually increased, through the pipe connection which fuel is fed to the engine, to a relative internal pressure equal to double the working pressure used and in any case to at least an excess pressure of 30 kPa (0.3 bar), which shall be maintained for one minute. During this time the tank body shall not crack or leak; however, it may be permanently deformed.

3.6.2 Fuel Permeability

The fuel used for the permeability test shall a commercial premium-grade fuel. If the tank is only designed for installation on vehicles with a compression-ignition engine, the tank shall be filled with diesel fuel. In Turkey, the permeability tests must be conducted with EN590 diesel fuel.

Prior to the test, the tank shall be filled to 50% of its capacity with testing fuel and stored, without being sealed, at an ambient temperature of 313K ± 2K (40° C ± 2° C) until the weight loss per unit time becomes constant, but for not more than four weeks (preliminary storage time).

The tank shall then be emptied and be refilled to 50% of its capacity with test fuel, after which it shall be hermetically sealed and be stored at a temperature of 313K ± 2K (40° C ± 2° C). The pressure shall be

adjusted when the contents of the tank have reached the testing temperature. During the ensuing test period of eight weeks, the loss of weight due to diffusion during the test period shall be determined. The maximum permissible average loss of fuel shall be 20 g per 24 hours of testing time.

If the loss due to diffusion exceeds 20 g per 24 hour., the test described there shall be carried out again, on the same tank, to determine the loss by diffusion at 296K ± 2K (23° C ± 2° C), but under the same conditions otherwise. The loss so measured shall not exceed 10 g per 24 hours.

Figure 5 – Test Fixture in Fuel Permeability Test Furnace

Figure 6 – Fuel Permeability Test Pressure

3.7 Resistance to Fire

Resistance to Fire test sequences are the major test step for ECE R34, proving the durability of plastic fuel tanks in case of extreme accident scenarios.

The tank shall be subjected to the following test provisions:

- For two minutes, the tank, fixed as on the vehicle, shall be exposed to flame. There shall be no leakage of liquid fuel from the tank.
- As the tanks filled with fuel, three tests shall be made on different tanks
- For each test the tank and its accessories shall be installed in a testing fixture simulating actual mounting conditions. In the case of tanks designed for a specific vehicle use, vehicle parts which protect the tank and its accessories against exposure to flame or which affect the course of the fire in any way, as well as specified components installed on the tank and plugs, shall be taken into consideration. All openings shall be closed during the test, but venting systems shall remain operative. Immediately prior to the test the tank shall be filled with the specified fuel to 50% of its capacity.
- The flame to which the tank is exposed shall be obtained by burning commercial fuel for positive-ignition engines in a pan. The quantity of fuel poured into the pan shall be sufficient to permit the flame to burn for the whole test procedure.
- The pan dimensions shall be chosen so as to ensure that the sides of the fuel tank are exposed to the flame. The pan shall therefore exceed the horizontal projection of the tank by at least 20 cm, but not more than 50 cm. The side walls of the pan shall not project more than 8 cm above the level of the fuel at the start of the test.
- The pan position is important for a precise evaluation of fire exposure. The pan filled with fuel shall be placed under the tank in such a way that the distance between the level of the fuel in the pan and the tank bottom corresponds to the design height of the tank above the road surface at the unladen mass. Either the pan, or the testing fixture, or both, shall be freely moveable.
- During Phase C of the test, the pan shall be covered by a screen placed 3 cm ± 1 cm above the fuel level.
- The screen shall be made of a refractory material such as bricks. There shall be no gap between the bricks and they shall be supported over the fuel pan in such a manner that the holes in the bricks are not obstructed. The length and width of the frame shall be 2 cm to 4 cm smaller than the interior dimensions of the pan so that a gap of 1 cm to 2 cm exists between the frame and the wall of the pan to allow ventilation.

The test shall comprise four phases:

Phase A: Pre-heating:

The fuel in the pan shall be ignited at a distance of at least 3 m from the tank being tested. (Figure 8) After 60 seconds preheating, the pan shall be placed under the tank.

Phase B: Direct Exposure to Flame

For 60 seconds the tank shall be exposed to the flame from the freely burning fuel. (Figure 9)

Phase C: Indirect Exposure to Flame

As soon as Phase B has been completed, the screen shall be placed between the burning pan and the tank. The tank shall be exposed to this reduced flame for a further 60 seconds.

Phase D: End of Test

The burning pan covered with the screen shall be moved back to its original position (Phase A). If, at the end of the test, the fuel tank is burning, the fire shall be extinguished forthwith (Figure 10)

By the conclusion of the phases, the results of the test shall be considered satisfactory if no liquid fuel is leaking from the tank.

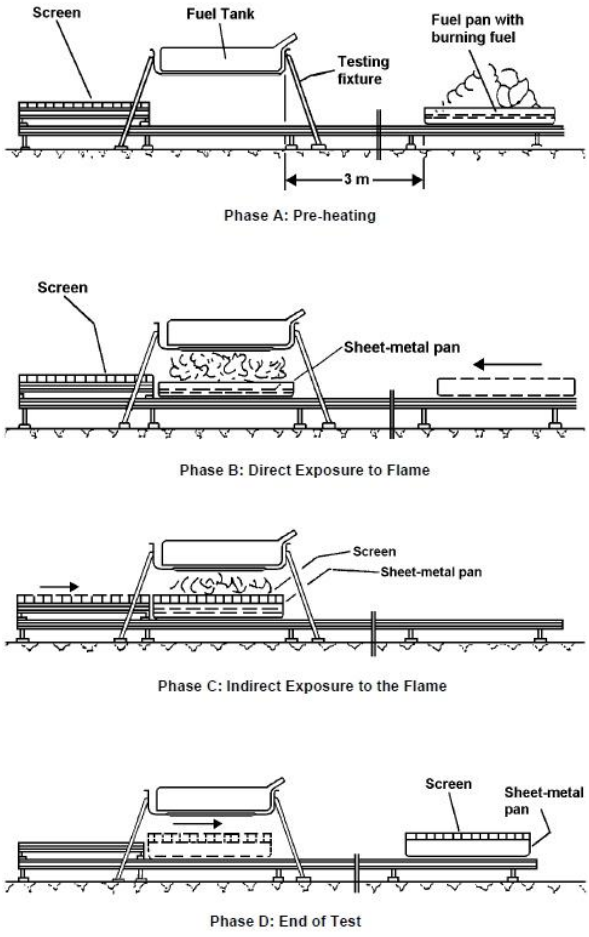

Figure 7 – Fire Test Phases

Figure 8 – Moving the preheated pan under the fixture

Figure 9 – Direct Exposure to Flame

Figure 10 – Fuel Tank After Fire Test

4. INITIAL RESULTS AND EVALUATIONS

Due to conclusion of ECE R34 steps, deformations occurred on fuel tank and related components are observed under supervision of manufacturer and licensed test firms. As described in ECE R34 directives, as a general confirmation rule, the fuel tank may be deformed but shall not leak fluid in the sequel of test steps. (Figure 11)

Figure 11 – Fuel Tank After Fire Test

In order to prevent the fire test failure situations, fail save measures must be taken, such as protection shields assembled under the fuel tank. The material and thickness submitted to the test authorities. Test people may require one or more test steps to be redone and reevaluated if the design changes are decided to be fully or partly involved with directive scopes. of the shield depends on the area to be protected against fire exposure. (Figure 12) Mechanical precautions applied to the test subjects shall be the part of final design which is intended to be carried out for serial production of vehicle. During the time period between the directive approvals and serial production, in case of design changes related to the fuel tank and sub-components, such changes shall be submitted to the test authorities. Test people may require one or more test steps to be redone and reevaluated if the design changes are decided to be fully or partly involved with directive scopes.

Figure 12 – Fuel Tank After Fire Test

5. CONCLUSION

As mentioned, ECE R34 directive tests and reports are top priority validation methods for the safety measures of vehicles powered by internal combustion engines with flammable fluid feed. Acceptance criteria admitted for directive confirmation represents total passenger safety for fuel related issues in case of harsh deformation originated by extreme vehicle failure and/or accident situations. Based upon the importance of the safety matters, this directive and related tests shall be proceeded on ever new design and assembly of fuel tanks.

REFERENCES

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