DETERMINATION METHODS OF FUEL CONSUMPTION IN LABORATORY CONDITIONS

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Abstract. Nowadays fuel consumption by motor vehicle becomes very actual proposition. Fuel price increases without interruption. Not each one can buy a new motor vehicle and be pleased to its fuel consumption. It is known that fuel consumption for elder vehicles increases. That is important to ascertain real fuel consumption of vehicle. For that there exist several methods and manners to determinate fuel consumption. More charismatic methods of determination of fuel consumption are following: volume, scale and flow methods. Advantages and disadvantages of each one of them are described in this report.

Key words: fuel consumption, determination methods, test conditions.

Introduction

One of the most important parameters of exploitation of the motor vehicle is fuel consumption. Especial attention is proselyted to that in lately years, when with every year resources of fossil fuels are going out, amount of motor vehicles are increases and charge for one litter of fuel goes up. Fuel consumption is actual both for human who wants to provide oneself with the car, both for automobile holders who already are exploiting their motor vehicle and whose vehicles fuel consumption rarely coincide to data given in technical literature.

For determination of fuel consumption of the motor vehicle several methods exist. Fuel consumption can be determined both on road probation, when vehicle is in real motion, both in laboratory conditions, when road conditions are imitated on specially contrived revolver stand. In determination trial can be used several methods – volume method (determination of consumed fuel volume), scale method (determination of consumed fuel weight), flow method (determination of consumed fuel quantity in volume or weight units), as well as electronic method (under conditions of control impulses of supply system) and method when quantity of consumed fuel is determined in way of analyzes of structure of exhaust gases.

In laboratory conditions first three methods mainly are used, i.e., volume method, scale method and flow method. These methods are common and they are able to provide adequate accurateness of consumed fuel. These methods will be more discussed in following. Electronic method of determination of fuel consumption is indirect method of metering of consumed fuel. There consumed quantity of fuel is calculated according control signals of supply system. The accuracy of measurements in this case can be proposed by several factors such as technical conditions of vaporization nozzle, technical condition of pressure regulator and pump etc. Method of analyze of exhaust gases gives exact results, but to provide that, it is necessary a special laboratory equipped with present-day and wherewith expensive machinery of analyze of exhaust gases.

Materials and Methods

Requirements connected to measurements of fuel consumption

Let the measurements of fuel consumption occurs correctly and obtained data could be compared by objective considerations to the data of other similar measurements of fuel consumption as well as they could be comparable with data given in technical literature, it is important to notice a rope of requirements during measurement of fuel consumption in condition of laboratory.

1.   General Specification

Fuel consumption for motor vehicles equipped with internal combustion engine can be determined by several tests. Measurements of fuel consumption can be performed by under way of cycles who imitate driving in the city, driving with immutable speed of 90 km h^{-1}, as well driving with immutable speed of 120 km h^{-1} in cases when maximal projected speed of vehicle is not less than 130 km h^{-1} (Directive 80/1268/EEK).

As a fuel for the test are used accordant conventional fuels, prescribed by appendix VI of the Directive 70/220/EEK or appendix V of the Directive 72/306/EEK. Results of the test are enounced by liters on 100 kilometers, what are rounded up to the next tenth (0.1). Distance has to be measured with accurateness of 0.5 % and time limit with accurateness of 0.2 seconds.

2. Test Conditions

Motor vehicle has to be trained and covered at least 3000 km before the test. During measurement of fuel consumption only wellhead equipment necessary for operation of motor vehicle has to be driven. For operation of motor vehicle only lubricants required by producer have to be used and tires have to be such as producer has appointed as basic equipment.

During test fuel has to be delivered to the engine through device that is potent to measure quantity of consumed fuel with accurateness of ± 2 % and this device couldn't baffle normal supply. If method of volume of consumed fuel is used, temperature of the fuel has to be measured in the point of test. It has to be valve system to provide quick change-over from common fuel travel system to system of measurements. Time limit for this switchover is 0.2 seconds.

Base conditions during tests:

- pressure H_o = 1000 m bar;
- temperature T_o = 293.15 K (20 ˚C).

3. Measurement of Fuel Consumption

If fuel consumption is measured during cycle that is imitating going in the condition of the city, fuel consumption has to be calculated on basis of consumed fuel during time of two consecutive cycles. Before performance of measurements cold engine has to be warmed up in way of performance of five full cycles. Temperature of the engine has to be maintained in the diapason of ordinary function of the engine, in the case of necessity it has to be collateral cooled.

If the fuel consumption is measured gravimetrically, fuel consumption is enounced as litres on 100 km, modifying measurement of M (consumed fuel enounced in kg) and using following equation:

$$C = \frac{100 \cdot M}{L \cdot \rho}, [l \cdot 100km^{-1}]$$
(1)

where C – specifically fuel consumption, $l \cdot 100km^{-1}$;
M – measured quantity of fuel, kg;
L – distance done during the test, km;
ρ – density of fuel in the basis conditions, kg dm^{-1}.

If it is measured volume of consumed fuel, consumption is enounced according equation

$$C = \frac{V(1 + \alpha[T_o - T_F])}{L} \cdot 100, [l \cdot 100km^{-1}]$$
(2)

where V – volume of consumed fuel, l;
α – coefficient of expansion of fuel. Both for diesel and petrol it is 0.001 per 1 K;
T_o – standard temperature, ˚C;
T_F – temperature of fuel, measured in the point of test, ˚C

Enouncing results standard consumption driving the city cycle is arithmetical mean of three consecutive measurements, which are performed according to previously enumerated predictions. If the marginal measurements diverge from arithmetical mean on more than 5 %, it is needed to perform additional tests according this procedure while the grade of precision of 5 % is achieved.

Preciseness p of the measurements is calculable according following equation

$$p = k \frac{S}{\sqrt{n}} \frac{100}{C}, \%$$
(3)

where k – coefficient, attainable from Table 1;
n – number of performed measurements;

$\overline{C}$ – arithmetical mean of specifically fuel consumptions, $l \cdot 100 \, \mathrm{km}^{-1}$;

S – standard deviation:

$$S = \sqrt{\frac{1}{n-1} \cdot \sum_{i=1}^{n} \left(C - \overline{C}_i \right)^2} \, . \tag{4}$$

Table 1

Values of coefficient k accordant to number of measurements

Number of measurements	4	5	6	7	8	9	10
k	3.2	2.8	2.6	2.5	2.4	2.3	2.3

If after 10 measurements necessary precision of 5 % is not overtaken, fuel consumption has been determinated with other motor vehicle the same type. If the fuel consumption is measured at changeless imputes of the vehicle, measurements can be performed both on the road, as well with dynamometer. If motor vehicle is equipped with manual gear-box, used gearing has to be the uppermost that has been recommended by producer for driving in each of regimes of the test. If the test is performed on the dynamometer, dynamometer has been adjusted accordant to regulations (Directive 70/220/EEK). For additional cooling can be used air cooling devices, to maintain working conditions, as well as working temperature of lubricants and coolants what usually are achieved in the same conditions on the road. Before performance of measurements motor vehicle has cover a distance on the dynamometer with speed of test regime to achieve working temperature, but this distance in no cases can't be less than 10 km. Test distance can't be less than 2 km what is measured on revolution counter on the dynamometer. Without reference of used method of measurements results has to be enounced in liters per 100 km.

Results and Discussion

1.   Volume Method

This method of determination of consumed fuel is one of the easiest methods and it could be widely used for determination of fuel in conditions of laboratory. As a basement are changes of fuel level in the measuring-basin. As a measuring-basin usually are used transparent bulb with cylindrical form, on its walls volume is divided. To achieve necessary precision of consumed fuel, it is necessary to use bulb with diameter as small as possible. To such bulb can graduate volume into small particles and changes of fuel level in the bulb during measurement will be relevant. Main disadvantage of this method is connected with complexity of computerized accounting of the data.
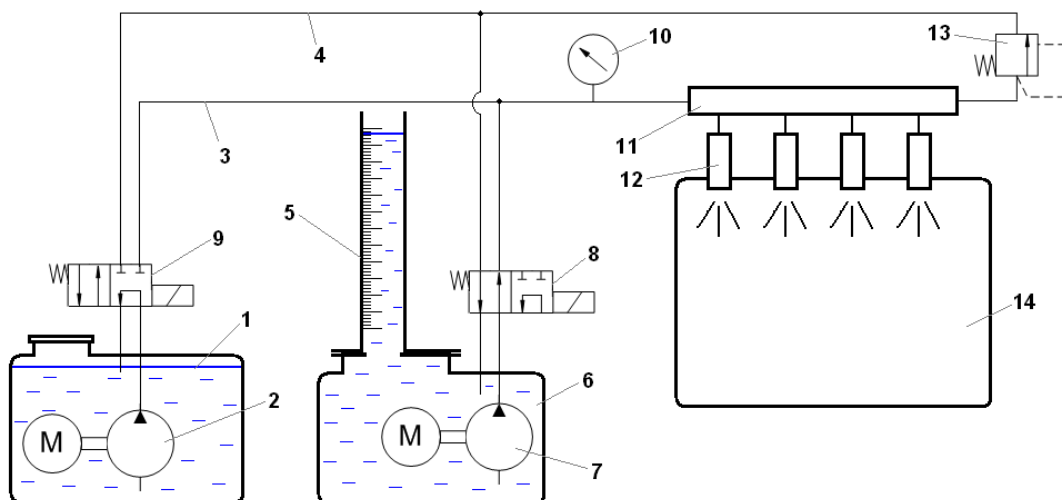

Fig. 1. **Volume method of determination of consumed fuel:** 1 – fuel tank; 2 – fuel pump; 3 – fuel line; 4 – reflux; 5 – measuring bulb; 6 – additional vessel; 7 – secondary pump; 8, 9 – solenoid valves; 10 – manometer; 11 – fuel rail; 12 – vaporization nuzzle; 13 – pressure regulator; 14 – Otto engine

In Fig. 1 it is shown hydraulic scheme of volume method for determination of fuel consumption for up-to-date vehicles with internal combustion engines with indirect fuel vaporization. System is made such as engine could be driven as from fuel tank (Fig. 1) with standard fuel pump 2 as well from pointedly originated fuel vessel 6 witch is equipped with measuring-bulb for determination of changes of fuel level. Switching from normal engine driving to measuring regime occurs with solenoid valves 8 and 9. Switchover of electrical circuit in the actual moment can be performed by switch. Before performance of measurements it is needed to fill additional vessel and measuring-bulb with the fuel near to upper border. Engine must be driven a little bit in test regime in order to bleed system. Than switch over back to ordinary regime and read level indicator on measuring-bulb to attain point of reference.

During measurements leads of solenoid valve 8 are locked and fuel can flow from secondary pump to the fuel line and nuzzles but needless fuel can reflux to the additional vessel. During measurement leads of solenoid valve 9 are closed to hinder for fuel to reach fuel tank from additional vessel. When it is switched from measurement regime to regime of ordinary working, operation of solenoid valves are reverse, i.e., fuel reflux from fuel tank to additional vessel gets no concede. Exploitation of solenoid valves can overtake high-speed and simple controllable system.

2. Scale Method

Scale method of determination of fuel consumption in Fig. 2 is shown. On its merits this method is similar to scheme of volume method; merely in this method is not determinated difference of fuel levels, but weight correlation. Switchover of measurement regime occurs with solenoid valves 8 and 9 similar to previously looked volume method.
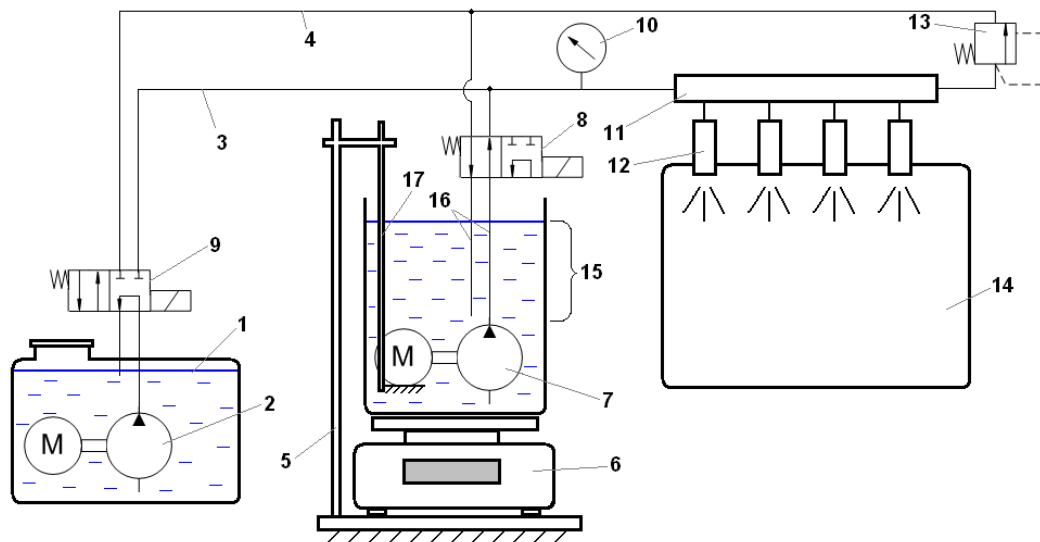

Fig. 2. **Scale method of determination of consumed fuel:** 1 – fuel tank; 2 – fuel pump; 3 – fuel line; 4 – reflux; 5 – foot; 6 – electronically weighbridge; 7 – secondary pump; 8, 9 – solenoid valves; 10 – manometer; 11 – fuel rail; 12 – vaporization nuzzle; 13 – pressure regulator; 14 – Otto engine; 15 – boundary of measurements; 16 – fuel lines; 17 – bulwark of the pump

Fuel consumption with exploitation of scale method has been determinated with calculations of difference between initial and concluding indications of electronically weighbridge 6. It is important to keep fuel lever in vessel over level of fuel pump (Fig. 2 position 15). That is important because of several reasons. Firs of all – let the immersed fuel pump all the time be located under fuel; secondly – occupied volume of fuel by fuel pump substantially affects to correct readings of electronically weighbridge or weight of really consumed fuel.

When fuel consumption is determinated by this method, it is necessary to assess an error of electronically weighbridge what creates because of pipes 16 and foot 5 immersed into fuel. Yet the both electrical pump, and fuel lines and bulwark of the pump are supported on the foot but not on the bottom of measuring vessel, volume occupied by these bodies affect to indications of electronically weighbridge and wherewith to actual consumed fuel during cycle.

3. Flow Method

There exist a lot of types of constructions and producers who are processed devices of fuel determination with flow method. Producers who are offering dedicated measurement devices for fuel consumption as often as not are offering measurement devices that are provided for specific type of engine supply system. Device for fuel measurements have to be chosen abut on several aspects:

- type of used fuel (petrol, diesel, gas, methanol etc.);
- pressure of fuel next to intake of meter (with negative pressure (rarefaction) – in the case of classic diesel engine, or positive pressure – in the case of vaporization in Otto engine);
- number and direction of flows. In former times produced motor vehicles that are fitted with carburetor supply systems, usually one drawn fuel line without reflux are constructive prevised, but general part of present-day engine supply systems of motor vehicles collateral to main fuel feeder line are equipped with fuel reflux line, too. It is specific as for Otto engines, as well as for diesels.

In details one of fuel flow measurement devices that are prevised for precise determination of fuel consumption following are described. This device of flow measurements are provided for determination of one-way fuel flux. As we have told before, general part of fuel supply systems of present-day motor vehicles are constructed with two fuel blows – supply and reflux and wherewith in direct way this device for measurement of fuel consumption can't be used practically. To determine precisely fuel consumption used by engine instead fuel volume what are flown through engine supply line, it is necessary to originate special scheme (Fig. 3).
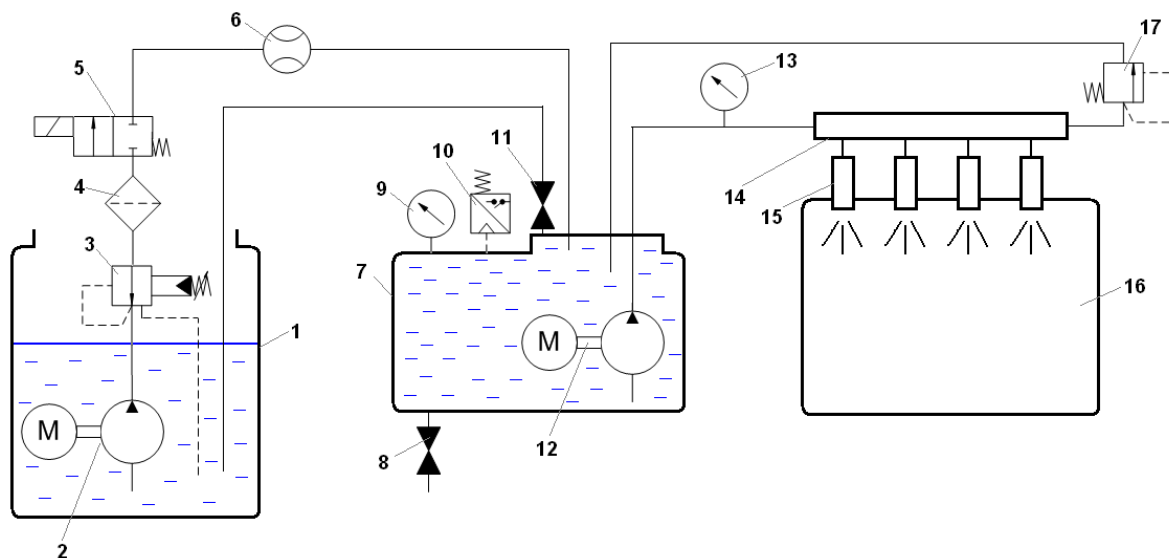

Fig. 3. **Flow method of determination of consumed fuel:** 1 – primary fuel tank; 2 – primary fuel pump; 3 – reduction valve; 4 – fine fuel filter; 5 solenoid valve; 6 – measurement device for flown fuel; 7 – secondary fuel tank; 8 – fuel run-out valve; 9, 13 – manometers; 10 pressure switch; 11- bleeding valve; 14 – fuel line; 15 – vaporization nuzzles; 16 – Otto engine; 17 – fuel pressure regulator

Hydraulic scheme of measurement of fuel consumption is shown in Fig. 3. In this case fuel consumption is determinated in mass units of volume units for four-stroke Otto engine 16 that is equipped with widely common fuel dot vaporization system. Main aggregate of fuel measurement system is fuel consumption meter 6. In concrete case high punctuality fuel consumption meter MASS – DI 1.5 offered by SANDER Messtechnik BmbH are used. As a basic for this device *Coriolis Effect* is used, i.e., determination of vibrations of U-shape pipes.

System consists of two fuel tanks – primary fuel tank 1 and secondary fuel tank 7. In the primary than fuel taped is. It is opened, connected with atmosphere. Primary fuel pump in this tank is inserted. This pump is necessary to procure secondary fuel tank 7 with fuel and for providing necessary fuel flow through fuel meter 6. Secondary fuel tank originated to imitate real fuel supply system of the motor vehicle. This fuel tank is closed-type. Fuel from this tank with pump 12 is bringed to the tapped

line of engine feeding system 14 and further to the fuel vaporization nuzzles. Pressure regulator 17 maintains necessary pressure in fuel line and needless fuel gets delivered back to fuel tank 7. Wherewith the reserved cycle is set that coincide with real feeding system of the engine.

Problem is arising because in secondary fuel tank it is necessary to provide boundary pressure in within ~ 0 – 0.2 bar what coincide to real fuel pressure in fuel tank of vehicle. Increased pressure operates negatively to correct working of the feeding system of the motor vehicle because in this case free reflux of fuel from engine to tank will be baffled.

In order to maintain immutable pressure in fuel tank of ~ 0.2 bar this tank is equipped with pressure switch 10. In normal position switch is with closed contacts. This pressure switch drives solenoid valve 5. When pressure in secondary fuel tank is less than 0.2 bar contacts of switch 10 are engaged and voltage to solenoid valve is delivered that in this case is opened. Wherewith, fuel from primary fuel tank is pumped to the secondary fuel tank through reduction valve 3, fine fuel filter 4, opened solenoid valve 5 and fuel meter 6. When pressure in secondary fuel tank increases over 0.2 bars, contacts of pressure switch tunes out and voltage to solenoid valve becomes discontinued. Fuel supply to fuel tank 2 becomes discontinued. Bleeding valve 11 is necessary to eliminate aid from secondary fuel tank when it is filled. Filling befalls with primary pump when bleeding valve is opened. When secondary fuel tank is full, bleeding valve becomes closed. Valve 8 is necessary to run-out fuel.

To the secondary fuel tank it is delivered thus fuel, how much it is vaporized through fuel vaporization nuzzles. This consumed volume of fuel is counted by fuel meter. Wherewith it is originated system that with one-way fuel flow meter can precisely determinate volume of consumed fuel for motor vehicles equipped with up-to-dated fuel vaporization systems. With slightly modifications of this system, it is possible to use this system for determination of fuel consumption for diesel engines.

Conclusions

1. There exist a number of determination methods of fuel consumption in laboratory conditions and simplest and widely used are: volume, scale and flow methods.
2. Main disadvantage of volume method is complicated origination of data computerized registration processes.
3. When it is scale method used, it is important to judge error of electronically weighbridge what is originated by fuel pump and fuel lines steeped into fuel.
4. When it is flow method used, it is possible to attain high precision of measurements as well it is possible to attain simply computerized data registration, but development of system is complicated.

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