MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL TRANSPORT UNIVERSITY

Department «Technical Vehicle Maintenance and Auto Service»

METHODICAL RECOMMENDATIONS FOR LABORATORY WORK «TECHNICAL MAINTENANCE OF CAR DIESEL POWER SUPPLY SYSTEM»

for students of the first (Bachelor's) higher education level in the speciality 015 «Professional Education (by specialisation)», specialisation 015.38 "Professional Education (Transport)", educational and professional programme " Professional Education (Transport)" in the discipline «Transport machine operation»

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Approved
at the Scientific and Methodological Council of National Transport University
Protocol №_____of «___»_____2023
First Vice-Rector, Professor
_____Oleksandr GRYSHCHUK

KYIV NTU 2023

Methodical recommendations for the laboratory work «Maintenance of the car diesel engine power supply system» for students of the first (Bachelor's) higher education level in the specialty 015 «Professional Education (by specialisations)», specialisation 015.38 «Professional Education (Transport)», educational and professional programme «Professional Education (Transport)» in the discipline «Transport Machines Operation» / Authors: O.M. Ivanushko, O.S. Buhaichuk, O.O. Parkhomenko − K. : NTU, 2023. – 18 p.

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Approved at the department meeting
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Protocol № 4 of « 24 » November 2022

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Educational edition

CONTENTS

SAFETY RULES DURING LABORATORY WORK

1. Students are allowed to carry out laboratory work after a safety instruction at the workplace, as well as after a thorough study of the methodological recommendations, study of safety rules for the operation of equipment, as well as on the preparing condition of the protocol and the laboratory report form.

2. Students **are not allowed** to perform laboratory exercises:

- to start the engine without the teacher's or instructor's permission;
- to switch on and off the equipment, vehicle ignition, connect and disconnect electrical wires without the teacher's or instructor's permission;
- independently carry out maintenance and repairs of the engine and its components without the teacher's or instructor's permission;
- independently carry out adjustment work on the engine and its equipment, simulate and troubleshoot the vehicle.

3. Before turning the engine crankshaft with a wrench, disconnect the battery with the mass switch.

4. Diesel fuel is flammable, so spilled fuel should be covered with sand and cleaned up.

5. Starting the KamAZ-740 engine and using the BAHCO BE13ZL11 stand is allowed with the teacher's permission.

6. If the diesel engine continuously increases its revs (revs up) or does not stop after the fuel supply is switched off, quickly remove the air filter and block the air flow to the inlet nozzle using any available means.

7. Make certain that rotating parts of the equipment do not catch clothing, hair, etc.

8. Do not touch heated exhaust pipes, as burns may result if you touch them.

9. When doing the laboratory work, it is **obligatory** to follow the safety requirements set out directly in the sections of the methodological recommendations and take into attention the comments marked «**important**».

10. At the end of the laboratory work, you must clean the workplace.

LABORATORY WORK
"Technical maintenance of the car diesel power supply system"

LABORATORY WORK AIMS

The aim of the work is to study the methods and master the practical controlling techniques and regulation of the 4-stroke automotive diesel engine power supply system.

ASSIGNMENTS FOR LABORATORY WORK

1. Get an overview of the equipment necessary for the laboratory work, study the design and principle of operation of the high-pressure fuel pump (HPFP) and injectors for diesel power systems.
2. To master the order of checking, regulation, adjustment of HPFP and injectors of the diesel engine KamAZ-740.
3. . Prepare a laboratory report.

EQUIPMENT AND TOOLS

1. KamAZ-740 engine.
2. Injector of the KamAZ-740 engine.
3. Device for checking injectors BAHCO BE13ZL11.
4. Torque gauge;
5. Stopwatch;
6. Educational and normative and technical literature.

1. GENERAL CONCEPTS

The power supply system of any internal combustion engine is used to prepare a fuel-air mixture, due to the combustion of which the engine operates in the cylinders. Depending on which device is used to form the fuel-air mixture in automotive technology, two types of fuel systems are distinguished:

- carburettor fuel supply system - in which the main device for forming the fuel-air mixture is a carburettor (fuel enters the combustion chamber through suction);
- injector fuel supply system - in which the formation of the fuel-air mixture is carried out by means of an injector (fuel enters the combustion chamber by injection).

The typical *malfunctions of the diesel fuel supply system* are:

- contamination of fuel filters (coarse and fine), which leads to a decrease in fuel supply;
- leakage and fuel leaks (mainly through high-pressure pipelines);

- wear of the fuel injection HPFP, which leads to a change in the injection moment relative to the crankshaft angle;
- wear and misalignment of the plunger pairs of the HPFP, which leads to a change in the volume of fuel injection;
- failure or incorrect operation of the fuel pressure regulator (for modern electronically controlled diesel engines), which leads to difficulty starting and uneven operation of the diesel engine;
- wear of the injector outlets, their coking and clogging, which leads to uneven fuel supply, resulting in a lean fuel-air mixture;
- loss of injector tightness and a decrease in needle lift pressure, which leads to a deterioration in the quality of fuel spraying, increased smoke from exhaust gases, a significant increase in fuel consumption and a decrease in engine power.

Control of the power supply system includes: checking the system tightness and condition of the fuel and air filters, checking the fuel booster pump (if available), high-pressure pump and injectors.

The leakage of the high-pressure part of the system is checked visually by fuel leaks when the engine is running. Leaks in the inlet part (from the tank to the fuel pump), which can lead to air suction and disruption of the diesel fuel system, are checked using a special tank tester. The part of the line that is under low pressure can also be checked for leaks when the engine is not running by pressurising it with a manual fuel booster pump.

The condition of dry air filters, which are equipped on all the latest car models, is checked by the vacuum behind the filter using a water piezometer (should not exceed 700 mm Hg).

The condition of the fuel filters can be checked to a first approximation at engine idle by the pressure behind the filter (at least 150 kPa is allowed), or rather by the pressure difference before and after the filter (no more than 20 kPa). A lower pressure also indicates a malfunction of the fuel booster pump, which, after being tested in the workshop, must provide (at 1050 rpm) a vacuum of at least 50 kPa, a pressure of at least 400 kPa and a flow rate of at least 25 cm3 per 100 strokes (the above standards are for 8-cylinder engines of KrAZ, MAZ and KamAZ).

Control of the high-pressure fuel pump and injectors directly on the vehicle is carried out when the engine exceeds the exhaust emission standards and to identify and eliminate faults.

In the absence of diagnostic tools, to reduce smoke, it is necessary to carry out labour-intensive preventive maintenance, primarily on injectors and high-pressure fuel pumps, with their disposal and following inspection and testing in a specialised workshop.

The removed injector is checked:

- for tightness - at a pressure of 30 MPa, with a pressure drop time from 28 to 23 MPa of at least 8 s;
- at the beginning of the needle-valve lift (injection pressure), which should be 16.5 + 0.5 MPa for KamAZ engines, 14.7 + 0.5 MPa for YAMZ engines;
- the quality of the spray, which should be clear, foggy and even across the cross-section of the cone, and have a characteristic "metallic" sound.

The injection pressure of the injector can be regulated by changing the thickness of the shims (Fig. 1.1) located under the spring or by means of an adjusting nut.

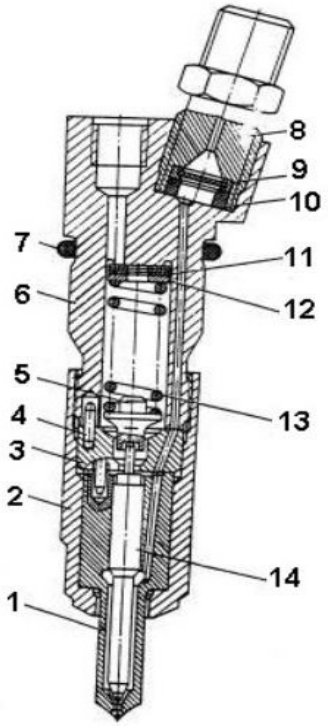

Figure 1.1 - Injector structure:

1 – spray nozzle corps; 2 – spray nozzle nut;
3 – spacer; 4 – setting pin;
5 – rod; 6 – nozzle body; 7 – sealing ring;
8 – fitting; 9 – filter;
10 – sealing sleeve; 11, 12 – adjusting washers;
13 – spring; 14 – spray needle.

The most difficult process is checking and regulating the high-pressure pump, which requires special stands to check the pressure at the beginning of the supply, its uniformity and fuel supply. The deviation of the start of fuel supply by each section relative to the first should not exceed ±20 (units), and the unevenness when the rail is set to the maximum supply position should not exceed 5%. The stand regulates the starting and maximum cycle fuel supply, as well as the operation of the fuel regulator (fuel supply off at engine stop, automatic fuel supply off at the set maximum engine crankshaft speed and automatic regulator start frequency).

Mounting of the HPFP on the engine is carried out using a torque gauge (a glass tube with an internal diameter of 1.5-2.0 mm, Fig. 1.2), which is installed on the outlet fitting of the first or previous pump section in the order of operation.

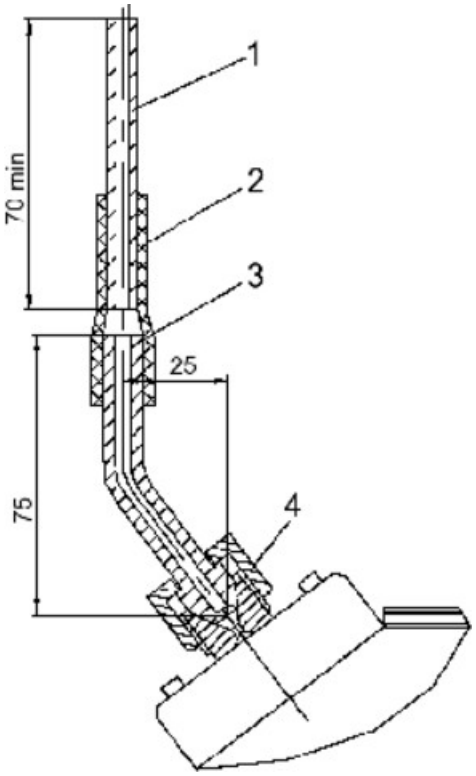

Figure 1.2 - Installation diagram of the torque gauge:
1 – glass tube; 2 – adapter tube; 3 – high-pressure fuel line section; 4 – cap nut.

When fuel appears in the torque tube, the drive clutch is fixed so that the advance angle is 16-19° to the first cylinder's timing. Performing these operations (with correct regulation of the valves and appropriate compression in the cylinders) provides minimal smoke and maximum efficiency of the diesel engine.

2. BRIEF DESCRIPTION OF THE EQUIPMENT

The BAHCO BE13ZL11 device (Fig. 2.1) is designed to test diesel injectors with mechanical regulation of the fuel delivery torque. The stand consists of a corps 1, inside which there is a single-section high-pressure fuel pump with a manual drive 2, a fuel tank, which serves as a transparent glass for monitoring the quality of the sawing 3. The pressure gauge 4 has a shut-off valve that protects the injector from hydraulic shocks during sudden fuel pumping. When the valve is completely closed, the channel leading to the pressure gauge is blocked. The injectors to be tested are assembled in the clamping device 5.

Figure 2.1 - BAHCO BE13ZL11 injector tester:

1 – device corps; 2 – pump drive lever; 3 – transparent glass for spray quality control and fuel tank (two in one); 4 – pressure gauge; 5 – injector clamp.

The principle of operation of the BAHCO injector tester is as follows.

The injector is connected to the BAHCO injector test device using the appropriate size adapter. At this stage, it is important to make sure that all connections are fixed securely and do not leak.

By physically acting on the lever 2 of the pump drive, the fuel is pumped into the injector. The value of the fuel injection pressure is controlled by the pressure gauge 4. When the pressure reaches a small value, it is recommended to pause to check the injector for leaks. If the pressure doesn't decrease and fuel doesn't leak out of the injector (fuel leakage in the form of drops or wetting of the end of the spray nozzle during the measurement indicates an unsatisfactory condition of the injector), then continue to increase the pressure until the injector opens (until fuel is injected).

При When the injector is in operation, the spray nozzle opens at the required moment when the needle valve opens overcoming the spring's downward force. When the nozzle is opened, fuel is sprayed, which can be clearly seen through the transparent glass 4 and the quality of the spray can be assessed (the shape of the «torch spray», shape, dispersibility and uniformity).

3. CHECKING THE POWER SUPPLY SYSTEM OF THE KAMAZ-740 DIESEL ENGINE

3.1. Checking the condition of the devices and the tightness

Check the diesel fuel supply system by inspecting all its elements in sequence: from the fuel tank to the injectors (fuel supply); from the air intake to the air filter (air supply). External damage is not allowed. Any malfunctions must be removed.

The tightness of the supply system is checked by external inspection. The tightness of the fuel system discharge line ("fuel - booster pump - high-pressure fuel pump") is checked by pumping it with a manual drive (Fig. 3.1).

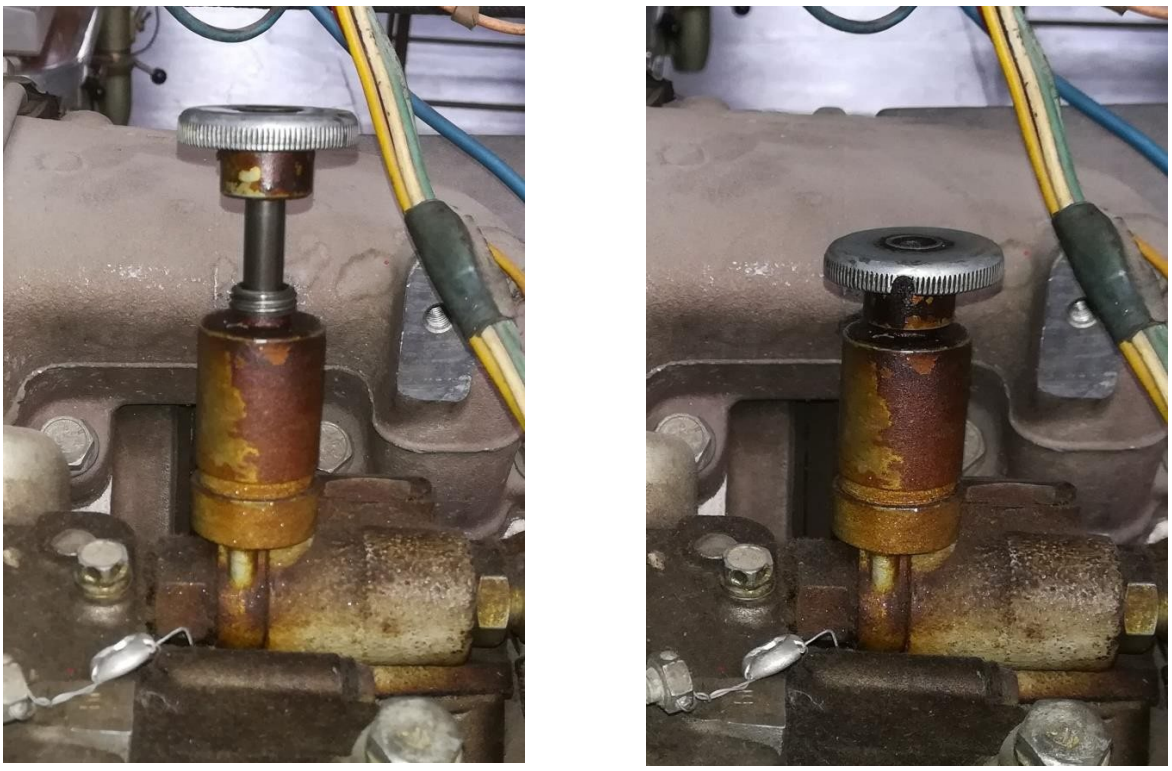

Figure 3.1 - Manual booster pump

Filling the system with fuel and pumping it is carried out by moving the handle with the rod up and down. When not in operation, the manual pump handle must be tightly screwed onto the upper threaded tail of the cylinder. The pumping operation is obligatory for removing air from the system. With regard to the fuel lines, no leakage or seepage of fuel is allowed at the connection points.

The airtightness of the air path is most often violated due to cracking of rubber tubes or their loose fastening to the air ducts, as well as due to loose welds. The detected malfunctions are corrected by tightening the fasteners or replacing the gaskets and tubes.

3.2. Checking and regulating the injection advance angle

The initial fuel injection advance angle is 18° to the VMT. During operation, the fuel injection timing angle may change unauthorisedly (e.g. due to play in the fuel pump drive), which leads to a change in the combustion chamber pressure by 150...200 kPa (1.5...2.0 kgf/cm2) and an increase in fuel consumption by 0.4...1.36 g/(kW· h) (0.3...1 g/(hp.· h)) for each degree of decrease in the fuel injection angle. Therefore, it is necessary to check the fuel injection advance angle periodically after one maintenance service No. 2 (MOT-2).

The check and adjustment is performed in the following sequence.

1. Disconnect the battery pack.

2. Turn the crankshaft until the tags on the high-pressure fuel pump and automatic fuel injection advance clutch match (Fig. 3.2). Turn the shaft by inserting a crowbar into the holes located on the flywheel.

3. Turn the crankshaft half a turn against the direction of rotation (clockwise from the flywheel side).

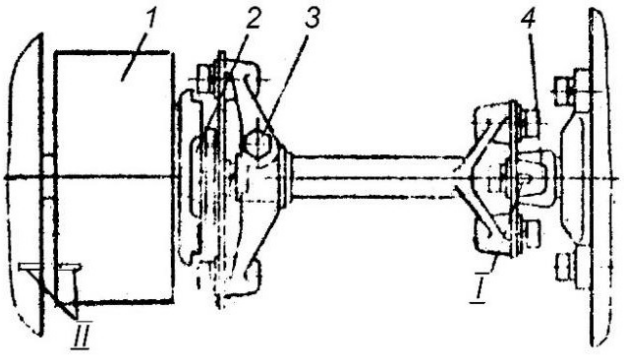

Figure 3.2 - Setting the moment of fuel injection start in the first cylinder of the engine by the tags:

1 – automatic injection advance clutch; 2 – driven half clutch; 3 – coupling bolt; 4 – rear flange of the driven half clutch; I, II – tags.

4. Set the fixture mounted on the flywheel crankcase to the lower position (Fig. 3.3) and turn the crankshaft in the direction of rotation until the fixture enters the groove of the flywheel. If the fuel injection advance angle is set correctly, the tags on the HPFP and automatic clutch housings connect in this crankshaft position (see Fig. 4).

а) б)

Figure 3.3 - Position of the flywheel lock:

а) – during operation (upper); б) – in engagement with the flywheel (lower)

Move the lock into the "small" groove. If the tags do not align, make adjustments.

5. Loosen the upper bolt of the drive half clutch, turn the crankshaft in the direction of rotation and loosen the second mounting bolt.

6. Turn the fuel injection advance clutch by the flange of the drive half-clutch in the direction opposite to its rotation until the bolts stop in the groove walls (the working direction of rotation of the clutch is to the right on the drive side).

7. Lower the lock into the deep groove and turn the crankshaft in the direction of rotation until the lock aligns with the hole in the flywheel.

8. Slowly turn the fuel injection advance clutch over the flange of the driven half-clutch in the direction of rotation of the fuel pump drive until the tags on the pump housing and the injection advance clutch align.

9. Secure the upper bolt of the drive half-clutch , place the lock in the the "small" groove, turn the crankshaft and secure the second bolt.

10. Perform step 4 to check that the injection advance angle is set correctly.

11. Connect the accumulator battery and start the engine to check its operation.

3.3. Checking and regulating the engine for the minimum crankshaft speed

According to the technical characteristics of the KamAZ-740 diesel engine, the minimum crankshaft speed in idling mode should not exceed 600 rpm. Checking and, if necessary, regulating it is carried out during the scheduled maintenance 2 in the following sequence.

1. Start the engine and warm it up to a cooling liquid temperature of 80°C.
2. Check the tightness of the power supply system. Remove any deficiencies.
3. Check the engine crankshaft speed with the fuel control handle retracted using a tachometer. The engine should operate steadily, and the rotational speed should not exceed the standard value of 600 rpm. If necessary, make adjustments.
4. Loosen the lock nut of the minimum speed limit bolt on the speed regulator (Fig. 3.5) and by screwing it in (speed increases) or out (speed decreases), set the necessary crankshaft speed, monitoring its value on the tachometer. To tighten the lock nut of the adjusting bolt.

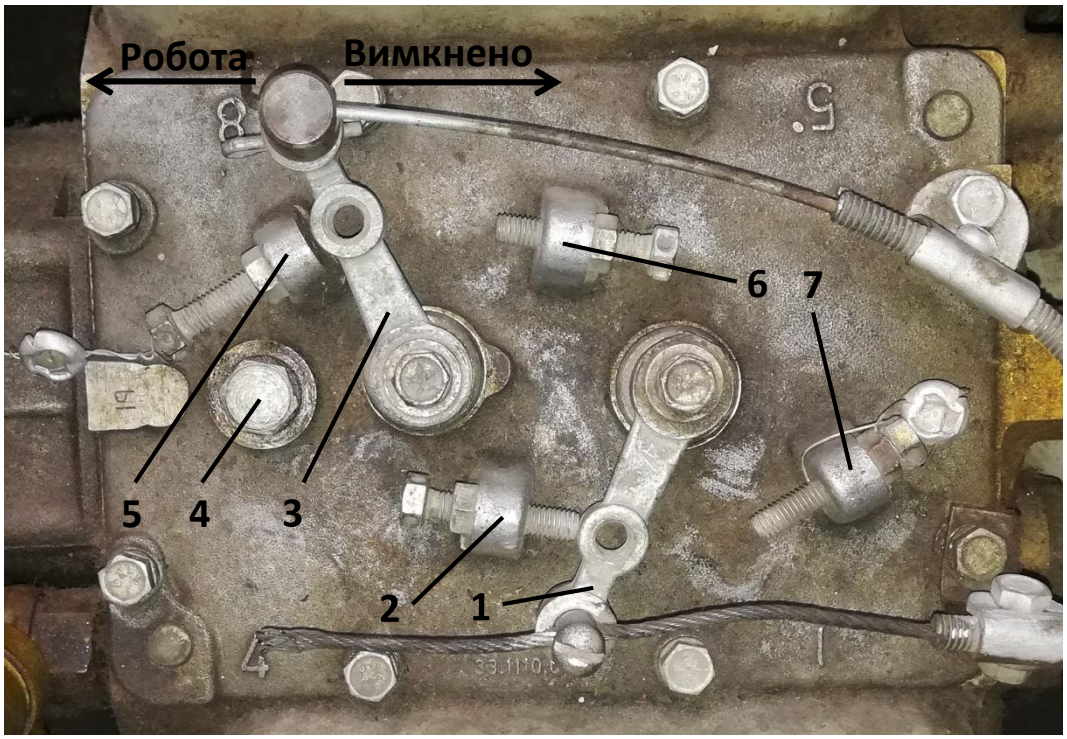

Figure 3.5 - Cover of the HPFP speed regulator:

1 – fuel supply control lever (regulator); 2 – minimum speed limiting bolt; 3 – stop lever; 4 – filler plug; 5 – bolt for adjusting the starting flow; 6 – bolt for limiting the stroke of the stop lever; 7 – bolt for limiting the maximum rotation speed.

5. Stop the engine. Record the results in the table of the protocol for the laboratory work.

4. CHECKING AND ADJUSTING THE INJECTOR ON THE BAHCO BE13ZL11

4.1. Checking the injector tightness

To check the injector tightness of the YAMZ-236, 238 engine, install the injector in the clamping device of the BAHCO device (see Fig. 2.1). By pumping fuel with the pump lever, increase the pressure to 30 MPa, stop the fuel supply when this pressure is reached and determine the time of pressure decrease from 28.0 MPa to 23.0 MPa using a stopwatch. For a functioning injector, this time is not less than 5 s, for an injector with a new nozzle - not less than 20 s. Fuel leakage in the form of drops or wetting of the nozzle end during the measurement is not allowed.

The tightness of the locking cone of the injector nozzle of the KamAZ-740, 741 engine is determined at a pressure lower than the injection pressure (the standard value for new injectors is 18.0 + 0.5 MPa, for those that have been operating for a long time, 17.0 MPa is allowed) by 1.0 MPa for 1 min. The nozzle is considered suitable for use if no more than two fuel drops are produced per minute.

Separately, the injector is checked for tightness by " droplet detachment". Checking the tightness of the nozzle locking cone is controlled by the degree of wetting of the nozzle nose while keeping the fuel pressure in the nozzle less than the injection pressure by 1.0 MPa for 60 seconds. If two drops of fuel per minute are formed and detached from the nozzle nose, the nozzle must be replaced.

4.2. Checking and adjusting the injector for needle lift pressure (injection start)

The injector, which has already been checked for tightness, is further checked and, if necessary, regulated to the beginning injection pressure. Use the BAHCO pump lever to force the fuel into the injector while observing the pressure gauge. When the pressure reaches 12.5 MPa, the speed of further pressure increase should not exceed 0.5 MPa per second.

Important! *The fuel pressure injection speed must be reduced, but it must be greater than the excess pressure release speed of the BAHCO device.*

Carefully observing the pressure gauge, determine the pressure at which fuel is injected (Fig. 4.1).

The injectors of the YAMZ-236, 238 engines must have a needle lifting start pressure equal to 15.0 ± 0.5 MPa. If the value of the injection start pressure of the injector does not correspond to the standard value, it is necessary to make an adjustment by turning the spring tension screw (when turning in, the pressure increases, when turning out, it decreases). After adjusting the needle lift pressure, tighten the lock nut and check the injection pressure again. If the value of the needle lift pressure has not changed, repeat the the adjustment.

Figure 4.1 - Determining the injection pressure

The standard value of the nozzle injection pressure for KAMAZ-740, 741 engines is given in Section 1. If necessary, the needle lifting (injection) pressure is controlled by changing the number of regulating washers under the injector spring (increasing the total thickness of the washers increases the pressure, decreasing it reduces it). A change in the thickness of the washers by 0.05 mm leads to a change in the pressure of the injector needle lifting by 300...350 kPa (3.0...3.5 kgf/cm2).

4.3. Checking the injector for spray quality

To check, it is necessary to make several sharp injections with the pump lever, and then operate the pump lever at a speed of 60-70 strokes per minute to observe the spray pattern. The spray quality can be considered satisfactory if the fuel is injected in a in a misty state and is evenly distributed over the cross-section of the jet cone and through each nozzle opening. The beginning and end of the injection should be clear, fuel leakage near the injector is not allowed.

To record the results in the table of the protocol for the laboratory work «Injector test results».

THE PROTOCOL FOR LABORATORY WORK
«TECHNICAL MAINTENANCE OF CAR DIESEL POWER SUPPLY SYSTEM»

The results of checking the power supply system of the KamAZ-740 engine

Results of the external inspection of the power supply system	Minimum crankshaft speed in idle mode, rev/min		
	standard	during the check	after regulation
	600		

The conclusion: _____

_____

_____

Results of checking the diesel injector of the KamAZ-740 engine

Tightness				Injection starting pressure, MPa		The quality of the spraying
By the time of falling pressure, s		By droplet detachment		standard	during the check	
standard	during the check	standard	during the check			

The conclusion: _____

_____

_____

General conclusion: _____

_____

_____

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7. Methodical recommendations for laboratory work № 2 «Maintenance of the car diesel engine power supply system» for students of the first (bachelor's) level of higher education in the specialities 274 «Automobiles and automotive industry» in the discipline «Technical car operation»; 015 «Professional education (transport)» in the discipline «Operation of transport machines»; 133 «Branch engineering»; 142 «Power engineering» in the discipline «Operation and maintenance of machines» / By: P.I. Bortnytskyi, M.M. Hordiienko, O.O. Hryzlov, L.F. Kryshan - K.: NTU, 2020. - 16 c.