SECTION 8
INSPECTION AND ADJUSTMENT OF MAIN MECHANISMS OF ENGINE

- **1. Check and adjustment of valve timing**
- There are timing mark lines only on the camshaft gear and the timing gear housing. As long as the engine is rotated to the top dead center of the first cylinder (the first cylinder top dead center flywheel mark line "OT" is aligned with the mark line one the flywheel casing, and all of the intake and exhaust valves of the first cylinder are closed), and the mark line on the camshaft gear is aligned with the mark line on the timing gear housing, so that the valve timing of the diesel engine can be guaranteed.
- **2. Check and adjustment of valve clearance**
- Valve clearance can be checked and adjusted cylinder by cylinder or by the "method of two-step adjustment".

- The cylinder-by-cylinder adjustment is to rotate each cylinder to its top dead center, and adjust the intake and exhaust valves at the same time. The procedure is: rotate the flywheel in the direction of engine operation until when No.6 cylinder exhaust valve is fully closed and the intake valve just begins to open, adjust the clearance of the intake and exhaust valves of the first cylinder. As for a 6-cylinder diesel engine working in the sequence of cylinders 1-5-3-6-2-4, cylinders can be adjusted in pairs of cylinders 1 and 6, 2 and 5, and 3 and 4 using the above adjusting method.
- The two-step adjusting method is to put the No.1 cylinder to its top dead center (No.6 cylinder intake valve "nods"), and adjust both intake and exhaust valves of cylinder 1, the exhaust valves of cylinders 5 and 3, and the intake valve of cylinder 4 and 2. Then rotate the flywheel by one full revolution, and adjust all the remaining valves.
- **3．Adjustment of fuel injection timing of the complete engine**
- First rotate the engine to the top dead center of the No.1 cylinder. As for an engine with timing mark lines on the injection pump timing device and the pump casing, rotate the flywheel in the direction of the engine rotation to align the timing mark lines, and then observe the fuel injection advance angle through the viewing window in the flywheel casing and make sure it is satisfactory. If it is necessary to make any adjustment, rotate the flywheel in the opposite direction of engine rotation, and then rotate the flywheel slowly in the normal rotating direction until the fuel injection advance angle mark line is aligned with the flywheel mark line. Upon the completion of the adjustment, tighten and lock the drive flange fastening bolts to their specified torque. As the injection pump gear and the drive shaft are coupled by means of tapered hole and tapered shaft without the use of any keys, the injection timing can be adjusted steplessly by loosening the drive gear fastening nuts. Similarly, upon the completion of the adjustment, tighten and lock the nuts to their specified torque.

- If there are no timing mark lines on the injection pump body and the timing device, the adjustment can be made by the "observation". That is, remove the No.1 cylinder high-pressure pipe union from the injection pump, and lower the fuel level in the outlet pipe union of No.1 cylinder by blowing. Manually set the injection pump load control lever (throttle lever) at the full-load (max. fuel supply) position. Rotate the flywheel in the same way as mentioned above, and observe the fuel level in the outlet pipe union of No.1 cylinder. When the fuel level begins to rise, stop the flywheel immediately, and observe the flywheel mark line and make sure it complies with the requirement of the fuel injection advance angle. If it is necessary, conduct the adjustment in the same way as mentioned above. When using this method, it is better to rotate the flywheel intermittently, so as to make the fuel level at the start of injection pulsate distinctly. When check is repeated, care must be taken to first rotate the flywheel in the opposite direction by a given angle, and then rotate it in the normal rotating direction of the engine, so as to eliminate the erroneous effect of the side play of the timing gear on timing and guarantee the accuracy of injection timing.

- **4. Check and tester adjustment of fuel injection system**
- **(1) Check and adjustment of fuel supply pump:**
- WD615 series diesel engines use piston-type fuel supply pump with manual fuel pump. The fuel supply pump is directly mounted on the casing of the fuel injection pump and its piston is driven by the fuel injection pump to move reciprocally to supply fuel.
- The fuel supply pump needs the following checks:
- 1) Piston check. Check if the reciprocating movement of the fuel supply piston is flexible and free from jamming.
- 2) The check of manual fuel pump. When the screw rod of the manual fuel pump is loosened, the manual fuel pump rod will be pushed up under the action of the spring. If it fails to move up, it indicates that the manual fuel pump piston is jammed.
- 3) One-way tightness test. Check if the check valve is tightly sealed.

- If the valve plug is not well sealed, apply some fine lapping compound on the valve plug and lap it on a flat glass surface repeatedly.
- To check the fuel supply pump on the tester, the following requirement must be met:
- 1) With the rotating speed of the pump less than 700 rpm and the fuel outlet passage of fuel pump fully closed, the max. fuel supply pressure must not be lower than 3.5 Bar.
- 2) When the negative suction pressure of the fuel supply pump is not lower than 0.12 Bar (the fuel supply pump is 1 meter above the fuel tank), the inner diameter of the fuel inlet pipeline is 10 mm, the length of the fuel inlet pipeline is 2 m, and the fuel supply pressure is 1.5 Bar, the displacement of the fuel supply pump must not be lower than the following:

Pump rotating speed (rpm)	Displacement (l./m)
300 700 1200	0.7 1.8 2.0

- 3) With the fuel supply pump 1 m positioned above the fuel tank, the inner diameter of the fuel inlet pipeline being 10 mm, the length of the fuel inlet pipeline being 2 m, and the fuel supply passage fully open, crank the manual fuel pump at a speed of 80-100 cycles per minute, fuel should come out of the fuel outlet port within 30 seconds.
- **(2) Check and adjustment of the timing device**
- For the fuel pump with the timing device, after the timing device is removed, check the wearing condition of the shaft of the flyweight frame and the pinhole of the flyweight, and that of the spring pin on the flange and the curvature of the flyweight. If they are worn seriously, replacement must be made. After being assembled and lubricated, the timing device should be character checked on the fuel injection pump tester. For example, the test result (obtained on the tester) of the timing device of the Bosch pump of WD615-67 engine should conform to the following standards:

Pump rotating speed (rpm)	Advance angle (cam angle – degree)
Start to function 700±50 800 900 1000 1100 1200	0 1 2 3 4 5

In case of nonconformance, correction can be made by adjusting the spring shim or replacing the timing spring.

(3) Check and adjustment of smoke limiter

Smoke limiters used by various types of fuel injection pumps each has its own characteristics curve. The manufacturers usually determine the standards of test and adjustment of the smoke limiters in terms of the standard value of the travel of the fuel adjusting gear lever of the fuel injection pump as a function of the boost pressure under a certain condition of the pump rotation.

For example, the smoke limiter of the Bosch pump of WD615-67 engine tested on the fuel injection pump tester must conform to the following standards:

Air pressure (Bar)	0.7	0.42	0.33	0
Lever travel (mm)	12.4~12.6	11.5~11.6	10.2~10.4	9.8~10.0

- When the smoke limiter is tested on the tester, the air pressure should be gradually reduced from the maximum (0.7 Bar) to zero. The air pressure when it starts to function should be 0.50-0.60 Bar, and that when it stop functioning is 0.30-0.25 Bar.
- **(4) Check and adjustment of the fuel injector**
- Before the fuel injector is disassembled for checking, it should be cleaned carefully to remove any exterior dirt and impurities so as to avoid scratching various precision mating surfaces of the injector during disassembly and reassembly. Pull out the needle valve out of the fuel injection nozzle, use a brush to clean the head of the needle valve in cleaning oil, and remove any carbon deposit from the head of the needle valve by a piece of wood stick. Use the brush to clean the hole of the needle valve in the valve seat. Use a special scraper to remove any carbon deposit from the inside of the needle valve. The stem of the special scraper must mate with the needle valve precisely so as to avoid scratching the mating surface of the valve seat bore when removing the carbon deposit. Use special steel cleaning needle to clean the spray orifice of the fuel injection nozzle.

- The diameter of the steel needle should usually be 0.02-0.03 mm smaller than that of the spry orifice. In order not to damage the spray orifice, use thinner steel needle first and gradually increase the diameter of the needles. For example, to clean the spray orifice in 0.35 mm diameter, use a steel needle in 0.30 mm diameter first.
- Then use steel needle in 0.32 mm diameter. If the steel needle in 0.35 mm diameter is used, particular care must be taken. To clean the orifice, insert the steel needle into the orifice and rotate the needle back and forth. After cleaning by steel needles, use clean kerosene to wash and blow off any dirt out of the orifice with compressed air.
- Lubricate the fuel injection nozzle with light diesel fuel and rotate the needle valve back and forth repeatedly. Position the fuel injection nozzle upright, pull up the needle valve by one third, then release it, and check if the needle valve may fall to its seating position slowly and smoothly by its own weight. If it fails to do so, apply a small amount of high-grade lubricating oil with low viscosity on the needle valve and the valve seat bore in the fuel injection nozzle, and insert the needle valve into the hole in the injection nozzle and rotate it reciprocally to make it meet the requirement of smoothness.

- Check the tightness of the needle valve and injection nozzle conical surface. If serious wear is found, you can smear a little precision aluminum oxide lapping compound (paste) on the conical surface of the needle valve and lap it against the injection nozzle valve seat. After lapping, wash it clean with clean kerosene. While lapping, care must be taken to avoid lapping compound getting onto the precision mating surfaces of the needle valve stem and the injection nozzle.
- Check if there is any damage on the contacting surfaces between the injection nozzle seat and the fuel injector body, any rust and crack on the fuel injector spring, any sign of offset wear on the needle valve and inside the valve hole in the injection nozzle, and any serious wear on the contacting surfaces between the needle valve and the push rod and the contacting surfaces between the spring and the push rod. Replace if any damage or serious wear is found. Check the wear of the locating pin of the fuel injection nozzle.
- When reassembling the fuel injector assy., the following precautions should be taken:

- 1) Tighten the fuel injection nozzle cap to its specified torque, otherwise, it would result in poor atomization of the fuel injected.
- 2) When replacing new fuel injection nozzle matching parts, soak and clean the new matching parts in clean kerosene, and move the needle valve inside the injection nozzle reciprocally, so as to get the preserving oil out of the injection nozzle completely.
- Upon the completion of all checks and reassembly, the following tests must be made:
- 1) Check and adjust the fuel injection pressure: set the fuel injector on the tester. Manually depress the handle of the tester for several times to remove the air inside the fuel pipeline, and flush again the inside of the fuel injector. Then manually depress the handle of the tester, and observe if the pressure of fuel injection is within the range of 300000+800kPa. If not, adjustment is needed. As for fuel injector of Type-A engine (as shown in Fig. 2-43A), the fuel injection pressure is adjusted by replacing spring shims of different thickness. And as for fuel injector of Type-B engine (as shown in Fig. 2-43B), the fuel injection pressure is adjusted by adjusting the fuel injection pressure adjusting screw. Upon the completion of the adjustment of fuel injection pressure, tighten the fuel injector locking nut, and then check again the initial pressure of the fuel injection. If unsatisfactory, readjust.

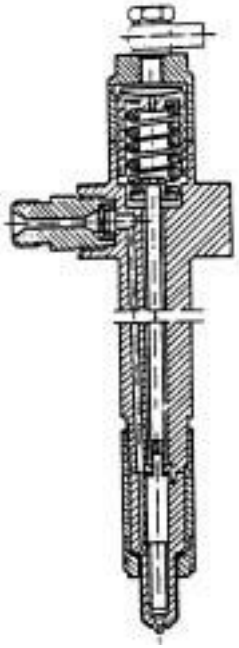


Fig. 2-43 Type-A Bosch fuel injector

Fig. 2-43 Type-B Bosch fuel injector

- 2) Check of the spray status It is advisable to use a stroboscope to check the state of the spray. Actuate repeatedly the handle of the fuel injector tester in the maximum travel at the speed of 40-80 cycles per minute, and observe the state of the fuel spray. The fuel should sprayed in fine mist, there should be no large particles in fuel mist, the mist beams sprayed from various orifices should be the same and uniform, and there should not be any fuel columns and any signs of unevenness of fuel spray density. Fuel beamss in Details 1-5 in Fig. 2-44 are all unsatisfactory. When the injection begins and terminates, there should be clear sound. After fuel injection, there should be no fuel dripping from the fuel injector head or any fuel drops suspending from the fuel injector head.
- 3) The check of the tightness of the fuel injection nozzle. Actuate the handle of the fuel injector tester to slowly increase the pressure to 200～215 Bars (10～20 Bars lower than the nozzle opening pressure, and maintain some time (usually 2～3s). If the fuel injector head does not leak fuel and there is no obvious drop in the pressure, it indicates that the air tightness complies with the requirements.

- **(5) The check of fuel injection pump.**
- After being disassembled, the injection pump should be checked systematically as follows:
- 1) The check of the plunger matching parts.
- The plunger and its sleeve are of precision matching parts with a fitting clearance of 0.001～0.003mm. Although there is a filter in the fuel system, it is unavoidable that some fine impurities would enter into the fuel injection pump, wearing and scratching the plunger matching parts. The wearing of the plunger matching parts may delay the fuel injection starting time, advance the fuel supply terminating time, and at the same time, decrease the amount of fuel supply, lower the power of the diesel engine, and result in such faults as the difficulty in starting, unstable idle and flameout. When the wear of the plungers of various branch pumps is uneven, it would result in different fuel supply into various cylinders. Therefore, the wear of the plunger matching parts directly affects the power performance of the diesel engine. So, the following checks must be made on the plunger matching parts:
- Exterior check: wash the plunger and its sleeve in clean kerosene or light diesel fuel, and check the mating surface of the plunger and its sleeve, especially the upper part and guiding portion of the plunger. If it is found that the surface of the plunger is seriously discolored (the worn surface is usually whitish), there is rust in the spiral groove or at the groove edge of the plunger, the plunger is cracked or deformed, or the plunger sleeve is

- Plunger sliding test: as shown in Fig. 2-45, hold the plunger matching parts soaked with kerosene at an angle of 60°, and pull the plunger out of its sleeve by two thirds, and when the plunger is released, the plunger should be able to slide into its sleeve by its own weight. Rotate the plunger to different position and repeat the above checks. If there is any jamming at some local position, apply some lapping compound on the plunger, insert the plunger into its sleeve, and lap the both the plunger and its sleeve in pairs. Lap them in reciprocal motion while rotating the plunger at the same time.

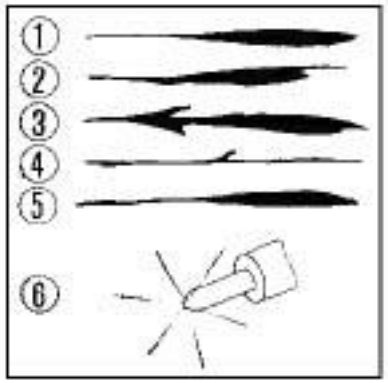


Fig. 2-44 Fuel atomization test

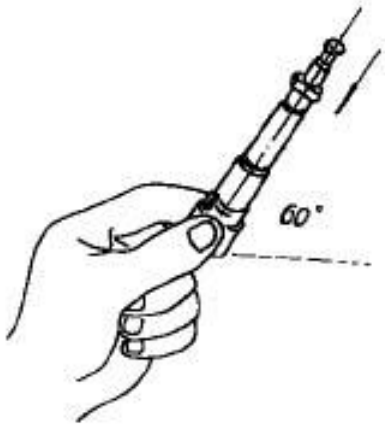


Fig. 2-45 Plunger sliding test

- The tightness check of the plunger matching parts: as shown in Fig. 2-46, block the upper port of the plunger by using your index finger to put the plunger at the position of its medium or maximum supply, and pull the plunger downwards (do not pull the plunger to block the fuel inlet hole). If your index finger can feel a force of suction, and when release the plunger, the plunger is able to return to its original position. It shows that the plunger complies to the requirements.
- **2) The check of the fuel delivery valve**
- The delivery valve has two pairs of contacting surfaces: one is for the precision matching and sealing of the pressure reducing ring and the valve seat bore. When the delivery valve is seriously worn, the sealing between the pressure reducing ring or the conical face would fail, which would lead to afterburning and fuel dripping, resulting in deterioration in burning and white smoke emission, and decease of the engine power. When the problem is serious, piston knocking might occur. Therefore, the tightness of the fuel delivery valve must be checked.

- Exterior check: Wash the fuel delivery valve in clean kerosene or light diesel fuel, and visually or by using a magnifying glass inspect the conical face of the fuel delivery valve. If it is found that the pressure-reducing ring is seriously worn (i.e. there is a clear and comparatively wider or deeper whitish wearing sign on the conical face of the fuel delivery valve), or there is obvious longitudinal scratches on the pressure reducing ring, then the delivery valve must be replaced. And at the same time, observe if there is any cracks or rust on the fuel delivery valve and its seat.
- Sliding test: Set the delivery valve upright, pull up the valve by one third of its height, and release it, the valve should be able to slowly fall to its seating position by its own weight. Rotate the delivery valve to different position and repeat the above test. If there is sign of jamming, lap the delivery valve and its seat in pairs. However, be sure to apply the lapping compound on the guide rod, not up to the pressure reducing ring, and do not insert the pressure reducing ring into the valve seat for lapping.

Fig.2-46 Plunger tightness test

- Tightness test: as shown in Fig. 2-46, block the bottom port of the delivery valve with one of your fingers, press the valve plug downward, and then release it. If the valve plug automatically springs up, it means that the tightness
test of the pressure reducing ring is satisfactory, otherwise, the delivery valve should be replaced.
- The tightness of the delivery valve can also be made on the fuel injector tester. Fit the delivery valve and its seat onto the special adaptor (on the seat of this adaptor, there is an adjusting screw in diameter slightly smaller than that of the delivery valve seat bore. When testing the tightness of the pressure reducing ring, use this adjusting screw to push the valve plug away from the valve seat, however, with the pressure reducing ring still at the sealing position inside the valve seat bore.) Connect the adaptor to the fuel injector tester, loosen the adjusting screw to let the valve plug fall down completely, adjust the tester to increase the pressure to 250 Bars, and make sure the time for the pressure to drop to 100 Bars is not less than 60s. Use the adjusting screw to push the valve plug up by 0.3～0.5mm, also increase the pressure to 250 Bars, and make sure the time for the pressure to drop to 100 Bars is not less than 2s. When making tightness test, the influence of the tightness of the tester itself must be taken into consideration. Therefore, prior to test, the

- **3) The check of other parts of the fuel injection pump**
- Check the plunger flange and the control sleeve. Check the clearance between the plunger flange and the fuel control sleeve, which should be 0.02～0.08mm. If it exceeds 0.12mm, the control sleeve should be replaced.
- Check the tappet assy. Observe the wear and corrosion of the tappet and the roller. Use a dial indicator to check the radial clearance between the tappet roller and the roller bushing and between the roller bushing and the roller shaft, and if the clearance exceeds 0.2mm, replace the tappet assy. Check the clearance between the tappet and the pump body, and if the clearance exceeds 0.2mm, replace the tappet assy. or the pump body.
- Check the camshaft and observe if there is any wear, corrosion or crack on or scale from the cam surface. Use oilstone to lap or replace the camshaft depending on the condition of its damage. If the wear of the cam exceeds 0.2mm, the camshaft bends by over 0.15mm, or the cam height exceeds the limit of the use, the camshaft must be replaced.
- Check if there is any crack or corrosion on or surface scaling from the plunger spring. Check if the free length of the spring is satisfactory. The maximum offset at the middle point of the spring must not exceed 1.5mm.
- Check the fuel control device. The play between fuel control lever (or gear rack) and the fuel control sleeve must not exceed 0.25～0.30mm. Otherwise, they should be replaced.

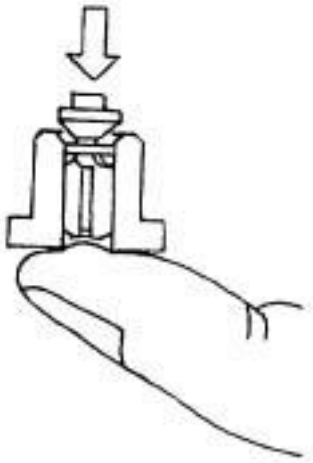


Fig.2- 47 Pressure-reducing ring tightness test

Check the resistance of the fuel control lever (or gear rack). Check the sliding resistance of the fuel control lever (or gear rack) on the fuel injector tester in its entire travel and make sure that it does not exceed the following values:

Pump rotating speed (rpm)	Sliding resistance (N)
0	1.30
600	0.50
1000	0.70

- **(6) The adjustment of the fuel injection pump tester**
- The purpose of the adjustment of fuel injection pump is to make fuel injection pump meet its technical specifications. The injection pump is a key unit to guarantee the normal operation of the fuel injection system.
- The adjustment of the fuel injection pump tester must be made under the specified conditions. It is better to be done under the conditions fully simulating the operation of the diesel engine. However, as there are a great variety of diesel engines, it is actually difficult to simulate the operating mode of every kind of the fuel injection system on the tester. In order to standardize the test and adjustment, and to provide a same basis for the test data, a comparatively unified criterion has been set up for various factors that might affect the result of the test in the adjustment of various types of fuel injection pumps. These are the test conditions for the fuel injection pumps.
- Generally, the test conditions for the fuel injection pump tester include the following aspects:

- The fuel injection nozzle has direct influence on the amount of the fuel spray. Generally speaking, the larger the jet orifice is and the more jet orifices there are, the greater the amount of the fuel spray. Similarly, the lower the opening pressure of the injector is, the greater the amount of the fuel spray. In order to eliminate the influence of the above-mentioned factors of the fuel injection nozzle and the fuel injector on the test result of the fuel injection pump under test, regulations are also formulated for the types of the fuel injection nozzle and the fuel injector under test and adjustment. In order to guarantee the accuracy of the test and adjustment, it is specified that the fuel injector must be checked for proper pressure and adjusted after a certain period of use, or replaced with new ones after a certain number of operating cycles.
- The opening pressure of the fuel injection nozzle. The injection pressure of the fuel injector has great influence upon fuel injection. Therefore, standard must be set for the injection pressure of the fuel injector during the test. It must be kept in mind that the fuel injection pressure specified in test conditions might not be the same as that required by actual operation.
- Fuel supply pressure. Low fuel supply pressure of the fuel injection pump has a great influence on the amount of fuel injection. In general, the higher the fuel supply pressure , the greater the amount of the fuel supply by the fuel injection pump is. Therefore, the fuel supply pressure must be specified in the test.

- Fuel used for test and fuel temperature. The fuel used for test and the fuel temperature determines the viscosity of the test fuel. And the viscosity of the test fuel has an indispensable influence on the amount of the fuel supply by the fuel injection pump. In general, the greater the viscosity of the test fuel, the greater the amount of fuel supply by the fuel injection pump is. Therefore, the type and temperature of the test fuel are specified in the test conditions.
- The specifications of the high-pressure fuel pipe. The high-pressure fuel pipe connecting the fuel injection pump and the fuel injector must be in specified length, inner diameter and wall thickness. In pulsating operation, the high-pressure fuel pipe may generate fuel-pipe effect. That is to say, the fuel pipe may suffer from elastic expansion during the process of fuel supply, and the fuel injection of the injector would lag behind the fuel supply beginning time of the fuel injection pump. Fuel pipes of different specifications have different influences on the amount of fuel injection, therefore, the specifications of high-pressure fuel pipes must be given for the test.
- In order to guarantee the accuracy of the test, all standards specified in the test conditions must be followed during the test and adjustment of the fuel injection pump. If some of the items are not satisfactory or the requirements of the test conditions can be met, then the results obtained from the test must be corrected accordingly.
- The following are the procedures of the tester adjustment with Bosch fuel injection pump on WD615-67 (280 hp) engine as an example. Table 2-7 lists the standard of test and adjustment of Bosch fuel injection pump of this type of engine.

- Table 2-7 The standard of the amount of the fuel injection of the PE6P110A721RS3101 Bosch pump of WD615-67 (280 hp) engine

Test conditions	Pump rotating speed (rpm)	Boost pressure (Bar)	Gear rack travel (mm)	Fuel supply (mm^3/time)	Permitted difference between various cylinders (mm^3/time)	Remarks
Test fuel：ISO4113 Fuel temp.: 40 + 5℃ Fuel injector pressure: 172 ~175 Bars Fuel supply pressure: 1.5 Bars High-pressure pipe: ϕ6×ϕ1.5 ×600mm	1200 300 700 700 100	0.7 0.7 0	12.1~12.2 5.8~6.0 12.5~12.6 9.8~9.9	159.0~167.0 9.5~20.5 163.0~171.0 117.0~125.0 236.0~274.0	8.0 7.0	Reference Start fuel supply

- 1) Preparation before test and adjustment.

  Fit the fuel injection pump on the tester, and connect it with the drive shaft of the tester. As there is a smoke limiter on the fuel injection pump of the supercharged diesel engine, there must a pressure-adjustable air supply unit on the fuel injection pump tester, so that a specified air pressure can be supplied to the smoke limiter by the fuel injection pump during testing. Fit the measuring gage of the fuel supply gear rack on the fuel injection pump, and calibrate the gear rack travel to " Zero".
- 2) Adjustment of fuel supply timing
- In order to guarantee accuracy of the fuel injection rate (law of injection) and to ensure the optimum operation of the diesel engine, the plunger lift (pre-travel of the plunger) of the fuel injection pump is fixed when various branch pumps of the fuel injection pump starts to supply fuel (the plunger begins to close the fuel inlet port), and the check and adjustment of the timing of the fuel supply of the fuel injection pump are just the check and adjustment of the pre-travel of the plunger. In other words, correct adjustment of the pre-travel of the plunger may ensure that the working zone of the cam is within the designed type curve of the pump, i.e. to guarantee that the fuel injection rate is within the designed range and the fuel supply timing of the fuel injection pump is correct. As for the fuel injection timing of the complete engine, it must be adjusted on the engine as mentioned above.

- Table 2-8 The pre-travel of the plunger of the fuel injection pump of WD615.67 diesel engine

Engine model:	BOSCH pump	
	Pump type	Pre-travel (mm)
WD615·67/77	PE6P100A721 RS3101	2.75~2.95

- The measurement of the plunger pre-travel must be made by means of special measuring set. There are two methods for measuring the plunger pre-travel: one is to measure the lift of the plunger by means of a measuring set, and another is to measure the lift of the tappet by means of the measuring set.
- As shown in Fig. 2-48, disconnect the high-pressure fuel pipe connector from the branch pump of the first cylinder, remove the fuel delivery valve unit and the sealing washer, and then fit the measuring set on the fuel outlet connector of the branch pump. The measuring set is actually composed of a dial indicator fit on the fuel outlet pipe sleeve and an overflow pipe. After the measuring set is installed, let the gage pin of the dial indicator touch the top of the plunger directly. Open the low-pressure fuel supply pipe of the tester, rotate the camshaft to set the plunger at the bottom dead center (the bottom dead center of the plunger can be seen on the dial indicator), zero the pointer of the dial indicator, operate the load lever of the fuel injection pump to put the injection pump at its maximum fuel supply position, and fuel will flow out of the overflow pipe. Then, slowly rotate the camshaft in the operating direction of the fuel injection pump, stop the operation when the fuel flow from the overflow pipe of the measuring set. The value indicated by the dial indicator at this time is just the pre-travel of the plunger. If the value obtained is unsatisfactory, adjustment should be made.

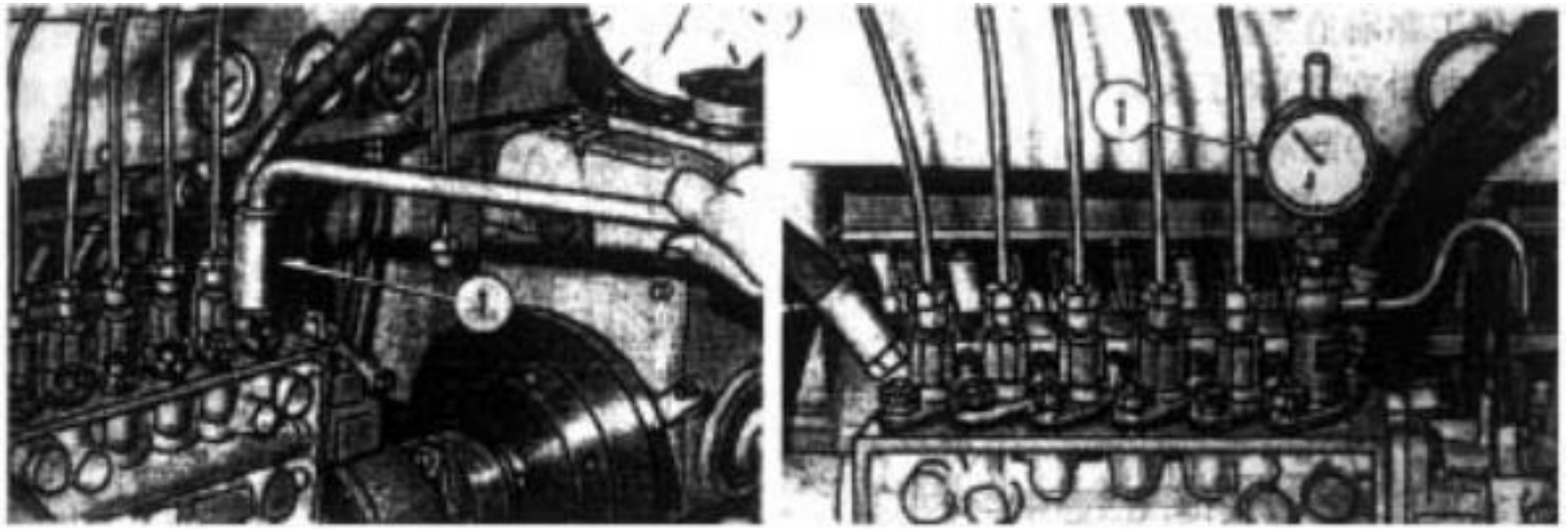


Fig. 2-48 Measure the pre-travel of the plunger by using the method of overflow

- The adjustment of fuel supply timing is made through adding and reducing the number of timing shims. As shown in Fig. 2-49, remove the branch pump assembly. If the plunger pre-travel is smaller than the specified value, add timing shims below the flange of the branch pump, and vice versa. Make sure that the O-ring is intact when the branch pump is reinstalled. Upon the completion of the adjustment of the fuel supply timing of the branch pump of the first cylinder, put the pump at the position of starting fuel supply of the branch pump of the first cylinder (i.e. the position of the pre-travel of the plunger), as shown in Fig. 2-50, check and make sure that the fuel injection pump fuel supply timing scale lines are aligned properly. Otherwise, new aligned timing scale lines should be imprinted on the timing device and the fuel injection pump casing, for future check and adjustment of the fuel injection timing of the engine.

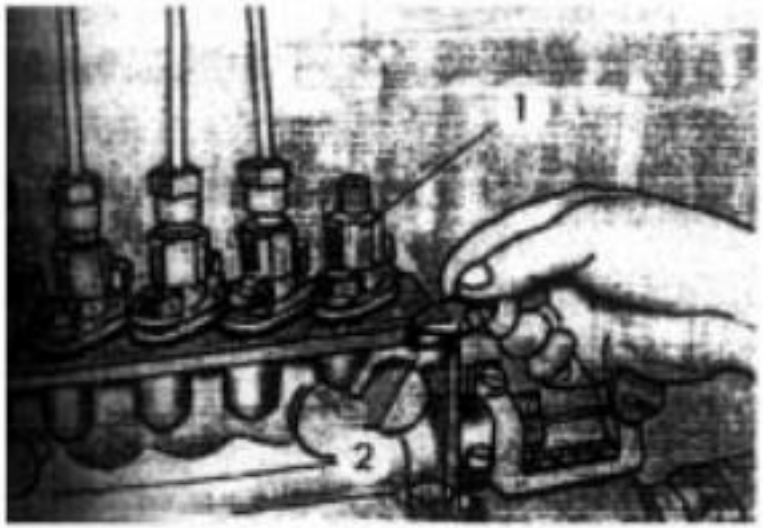


Fig. 2-49 Adjustment of fuel supply timing

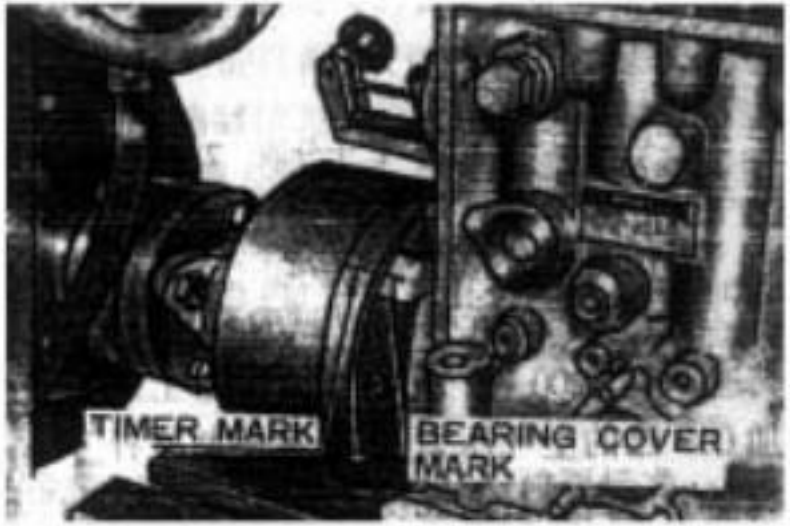
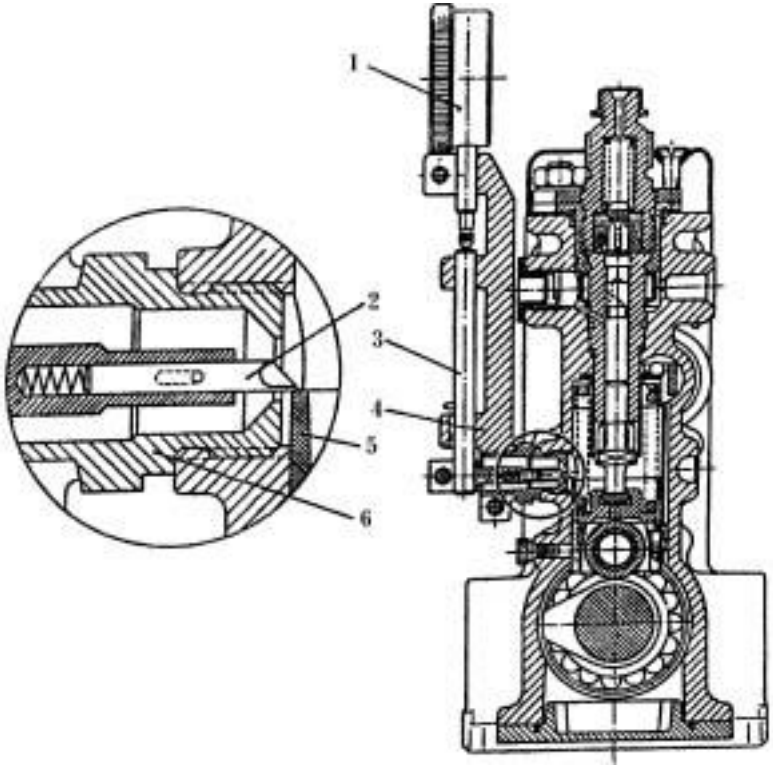


Fig. 2-50 Fuel supply timing scale lines

- Using the same method, check and adjust the commencement of fuel supply of various branch pumps in the order of fuel supply of 1-5-3-6-2-4, making them supply fuel at the interval of 60°+0.5° cam angle. Now the adjustment of the fuel supply timing of the fuel injection pump is completed.
- The pre-travel of the plunger can also be measured by means of tappet lift measuring set. As shown in Fig. 2-51, fit the measuring set in the special measuring hole in the fuel injection pump (the measuring hole is usually located on the tappet of the first cylinder) with the measuring pin in contact with the upper edge of the tappet. Remove the fuel delivery valve of the branch pump of the first cylinder, start the tester to supply fuel to the fuel injection pump (or do not remove the delivery valve, but allow the fuel supply pressure to reach 25+2 Bars), set the fuel injection pump to its maximum fuel supply position, and now fuel will overflow from the branch pump. Rotate the camshaft to put the tappet of the plunger at the bottom dead center, zero the dial indicator, and then slowly rotate the camshaft in the direction of the normal operation of the pump. When the fuel flow from the branch pump stops (i.e. the plunger begins to close the fuel inlet port), observe the lift of the plunger as indicated by the dial indicator and make sure it meets the specification of the pre-travel. If unsatisfactory, make adjustment by adding or removing the timing shims. Upon the completion of the adjustment of the pre-travel of the plunger of the first cylinder, use the same method and adjust the pre-travel of other branch pumps in the order of 1-5-3-6-2-4, making them supply fuel at the interval of 60°+0.5° cam angle.



1. dial indicator 2. measuring pin 3. guide rod 4. measuring frame 5. tappet 6. measuring body
Fig. 2-51 The measuring set of plunger pre-travel

- 1) Adjustment of fuel supply
- As listed in Table. 2-7, start the tester, adjust the rotating speed of the pump to 1200 rpm, apply an air pressure of 0.7 Bar on the smoke limiter, use the load control lever to control the fuel supply gear rack travel within 12.1～12.2mm, and measure the amount of fuel supply of each branch pump which should be within the range of 159.0～167.0ml/1,000 times, and make sure the maximum difference among various branch pumps in the amount of fuel supply does not exceed 8.0mm3/time. If unsatisfactory, adjustment should be made. The adjustment of the amount of fuel supply is realized by rotating the plunger sleeve.
- As shown in Fig. 2-52, each plunger sleeve can be turned by 10° relative to the pump body, which corresponding to the relative travel of 2.5mm of the fuel supply gear rack. Therefore, before adjusting the amount of fuel supply of the branch pumps, the fixing screw on the branch pump flange should be loosened first. Use a screwdriver or a similar tool to tap lightly the branch pump flange to make it turn. Pay attention to the direction of increase or decrease in the amount of fuel supply while the adjustment is being conducted. After the adjustment of fuel supply is completed, tighten the flange fixing screw to the specified torque. The data in the first column of Table 2-7 is used to adjust the reference of the pump. The amount of fuel supply must well meet the requirement under this working condition. The data in the following columns in the Table are used for checking the conformity of the amount of the fuel supply of the plungers. As there is some error in machining of the spiral shaped plunger, the amount of fuel supply of the fuel injection pump might be satisfactory under standard working conditions and the difference among various cylinders in the amount of fuel

- be within the permissible range, and operating under other working conditions, the amount of fuel supply and the unevenness of fuel supply by various cylinders would be out of tolerance. Therefore, after the fuel supply of the fuel injection pump is adjusted under standard (full load) working conditions, check for fuel supply must be carried out under various working conditions given in the Table. If the amount of fuel supply and the difference of the amount of fuel supply of a certain branch pump from other branch pump are satisfactory under the standard (reference) working conditions, but out of tolerance under other working conditions, then the plunger matching parts of this branch pump must be replaced so as to ensure that the fuel supply and the difference between the branch cylinders are within the specified range under all the working conditions and that the diesel engines operate stably under all the working conditions.
- Upon the completion of the adjustment of the amount of fuel supply under normal working conditions, adjust the pump speed to 100 rpm, set the load lever at full-load position (advance the throttle lever to the maximum fuel supply position), and adjust the gear rack limiter, so as to make the amount of the fuel supply of start reach 236.0～274.0 mm3/time.

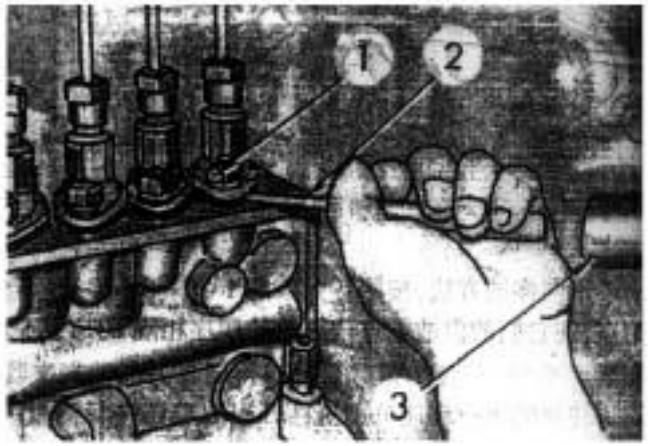


Fig. 2-52 Adjustment of the amount of fuel supply

- After all adjustments are completed, check again the amount of fuel supply under the "reference" working conditions.
- In practical operations, the test site might be unable to meet the standard test conditions. In such cases, the standard data for the test and adjustment can not be used directly. By using a new fuel injection pump calibrated in its manufacturer, test the amount of fuel supply on the tester under the existing conditions and various specified working conditions (pump speed, gear rack travel , boost pressure, etc.), record the results, and use them as references for calibration of the pump. These reference data can only be used for pump calibration under the same conditions.
- In practices, it is unable to guarantee absolute accuracy of the test of the fuel injector and the injection pump, and the error in these two devices would certainly increase the difference among various cylinders of the engine. In order to guarantee a good match of the fuel injector and the injection pump and obtain the optimum amount of fuel supply by various cylinders, check and calibrate the fuel injectors of various cylinders first, then use the calibrated and qualified fuel injector for the tester to calibrate the injection pump, and finally install all the fuel injectors and the injection pumps on the diesel engine with the same matching relationship between the injection pump and the fuel injector on the tester. Thus, a optimum practical effect can be gained.
- The unevenness ϕ of various cylinders can be calculated by the formula below:
- $\phi=Qmax-Qmin/Q\times100\%$
- where, Qmax - maximum fuel supply of the cylinder among various cylinders
- Qmin - miniimum fuel supply of the cylinder among various cylinders
- Q - average fuel supply of various cylinders

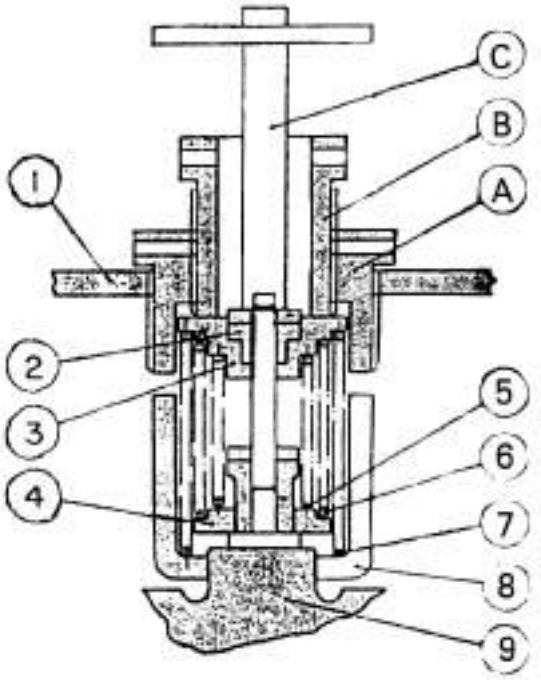
- For vehicles used on highlands, the fuel supply of the diesel engines will be corrected as per Table below:
- Table 2-9 Coefficient of correction for fuel supply of engines operating on highlands

Sea level elevation (m)	Sea level	1,000~2,000	2,000~3,000	above 3,000
Coefficient of correction (%)	100	94	86	78

- **(7) Adjustment of the governor on tester**
- The methods for adjusting the RQ governor and the RDV full-range governor used on the Bosch Type-P fuel injection pump installed on WD615 series diesel engines are basically the same. The adjustment of the governor on the tester mainly includes: the adjustments of idle speed control, high-speed control and corrected fuel supply control. The test and adjustment will be explained with RQ300/1200PA412 governor fit on Bosch fuel injection pump used by WD615-67 diesel engines as an example.
- Table 2-10 Parameters for the adjustment of the governor of WD615-67 diesel engines

Load control lever at idle speed position		Load control lever at full-load position			
Idle speed control		High-speed control		Corrective control	
Pump rotating speed (rpm)	Gear rack travel (mm)	Pump rotating speed (rpm)	Gear rack travel (mm)	Pump rotating speed (rpm)	Gear rack travel (mm)
405~445 300 100	2.0 5.8~6.0 > 7.5	1245~1260 1325~1355 1450	11.0 4.0 0.0~1.0	1200 1075 965 600	12.0~12.1 12.0~12.2 12.3~12.4 12.4~12.5
The type of governor: RQ300/1200PA412					

- 1) Preparation prior to test. Recalibrate the "zero" position of the gear rack travel. Check if the maximum travel of the gear rack determined by the load control lever is satisfactory.
- 2) Adjustment of high-speed control. Turn on the tester, increase the pump speed to 1,240 rpm, and use the load control lever to set the gear rack at the location of 11.0mm of the its travel. Keep the load control lever unchanged, increase the pump speed to 1,245～1,260 rpm. Then continue to increase the pump speed with the lever unmoved, the gear rack should begin to move towards the direction of decreasing fuel supply. When the pump speed reaches 1,325～1,355 rpm, the gear rack should withdraw to the location of 4.0mm of its travel. When the pump speed reaches 1,450 rpm, the gear rack should move back to the fuel shutoff position of 0～1.0mm of its travel.
- If the rotating speed of the high-speed beginning to function does not comply with the above-mentioned specifications, as shown in Fig. 2-53, use the special tool to adjust the pretension of the high-speed spring. i.e., use the special tool (press sleeve B) to press the outer seat of the adjusting spring downward, and then use a box spanner to adjust the speed-adjusting nut 2. If the rotating speed of beginning to function is lower than the standard value, turn the nut towards the direction of tightening, and vice versa. When adjusting, attention should be paid that the adjusting nuts of the two flyweights are adjusted uniformly, i.e. to turn both nuts outward or inward by the same number of turns. Otherwise, internal force would be produced between the two flyweights and speed up the wear of the parts.



1. Governor casing 2. Adjusting nut 3. Upper seat 4. Lower seat 5. Correction spring 6. High-speed spring 7. Idle speed spring 8. Flyweight 9. Flyweight body
Fig. 2-53 Adjustment of high-speed

- If the rotating speed of the high-speed beginning to function complies with the requirements, but the adjusting rate does not meet the requirement (i.e. when the pump speed reaches 1,325～1,355 rpm, the gear rack is not at the location of 4mm of its travel), it is necessary to replace the high-speed spring of the governor. After the adjustment of the high-speed control is completed, adjust the full-load limiting screw to a position just touching the stop of the full-load control lever and fix it.
- 3) Adjustment of idle-speed control. Move the load control lever towards the direction of idle speed. When the pump speed reaches 300 rpm, the gear rack should be at the location of 5.8～6.0mm of its travel, and fix the load control lever at this position. Increase the pump speed to 405～445 rpm, the gear rack is at the location of 2.0mm of its travel. When the pump stops running completely, make sure that the gear rack is at the location of 7.5mm of its travel. If the result of the test does not comply with the standard, adjustment can be made by adding or reducing the number of the idle-speed spring shims or replacing the idle-speed spring. Upon the completion of the adjustment of the idle speed, adjust the idle-speed limiting screw to a position just touching the stop of the load control lever.
- 4) This type of governor has a correction spring, so the corrected fuel supply should also be calibrated. Set the load control lever at the full-load position, adjust the pump speed to 1,200 rpm, and check if the gear rack is at the location of 12.0～12.1mm of its travel. Lower the pump speed to 1,075 rpm, 965 rpm and 600 rpm, and observe if the gear rack is at the locations of 12.0～12.2mm, 12.3～12.4mm and 12.4～12.5mm of its travel respectively. If the rotating speed of the correction beginning to function does not comply with the requirement, it can be adjusted by using the adjusting shims of the correction spring. If the travel of the correction gear rack is unsatisfactory, it can be adjusted by adding or reducing the