Common Rail Tester

TCR-4

User manual

Read the user manual carefully before using this device. Ignorance of this user manual may cause damage to the device or components and sub-assemblies operated by it. Persons who are unfamiliar with the user manual will not be given technical support.

1. Introduction

The requirements for diesel injection system are more and more stringent. Higher pressure, quicker responses and more flexible injection control makes diesel engine more efficient, cleaner and developing more power. Therefore, in recent years that is noticeable increase of popularity of this engine type.

One of the highly developed injection systems is a reservoir injection system called Common Rail. Its main advantage is the ability to precisely adjust fuel pressure and injection time. This is possible thanks to separation of high pressure source (high pressure pump) and elements injecting the fuel to the cylinders (injectors) with a high pressure fuel accumulator (Rail).
Compared to conventional cam driven injection pumps, the Common Rail system provides greater flexibility of adapting the injection system to the engine and has the following advantages:
- High injection pressure of up to 180 MPa (1800 bar),
- Adjusting the injection pressure to the engine operating conditions in wide range (20…180 MPa {200 .... 1800 bar}),
- Precise injection timing,
- Ability to deliver multiple pre-injections and post-injections.

As a result, the Common Rail injection system significantly contributed to increasing the engine power, reducing fuel consumption and limiting harmful emissions and noise.
Nowadays, the Common Rail system is the most popular injection system used in direct injection compression-ignition engines in passenger cars.

2. Design and operation of Common Rail injection system

The Common Rail system consist of three main parts (Figure 2.1):
- low pressure subsystem for supplying the fuel,
- high pressure subsystem with high pressure pump, high pressure accumulator , injectors and high pressure pipes,
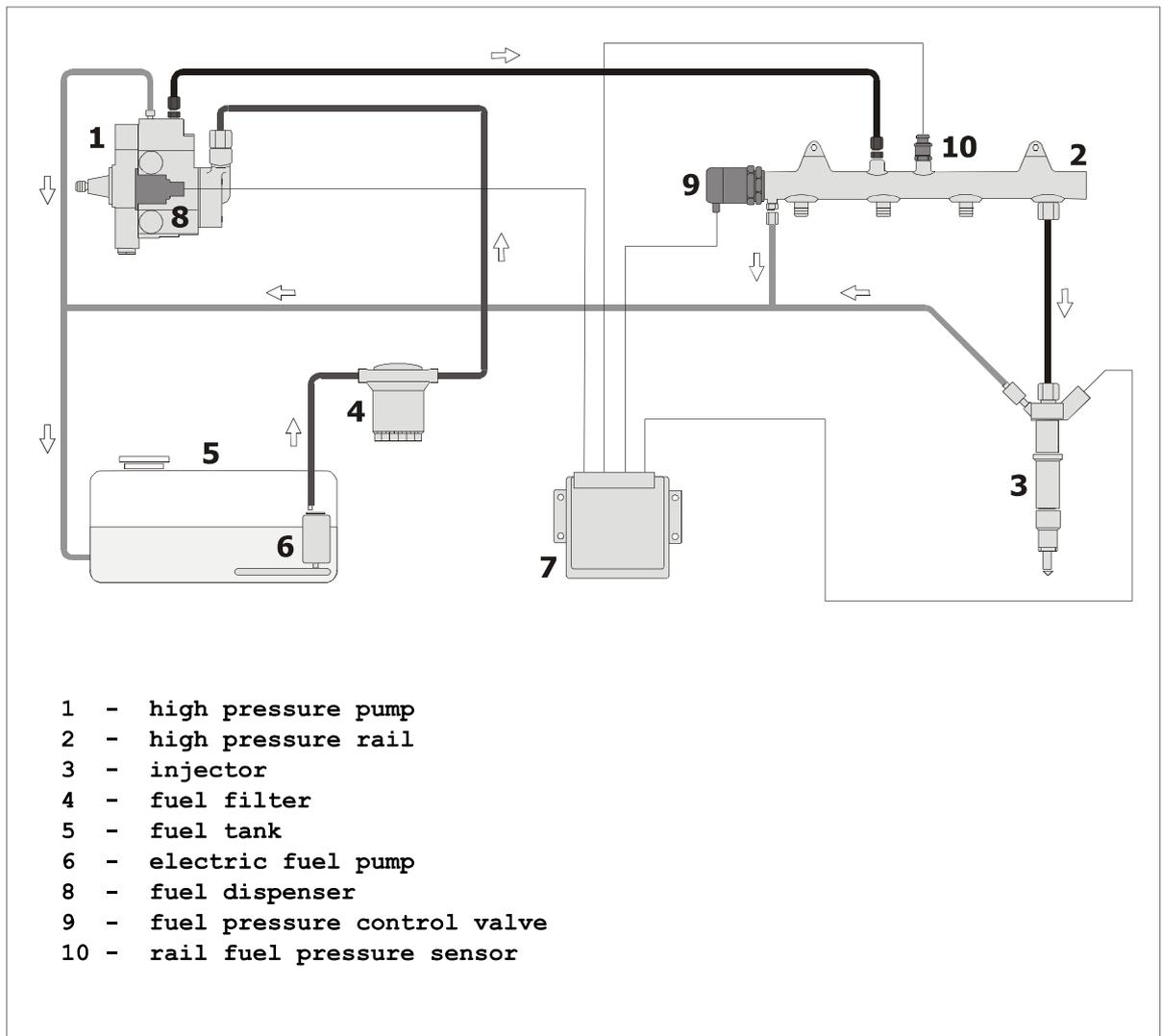- Electronic Control Unit (ECU) with sensors and actuators.


```
1  -  high pressure pump
2  -  high pressure rail
3  -  injector
4  -  fuel filter
5  -  fuel tank
6  -  electric fuel pump
8  -  fuel dispenser
9  -  fuel pressure control valve
10 -  rail fuel pressure sensor
```

Figure 2.1 Common Rail system general scheme.

The injectors are connected to the common high pressure fuel accumulator (rail) from which the name of the Common Rail system derived.

Characteristic feature of this system is the ability to adopt fuel pressure in the rail to current engine state. The pressure is set using a control valve or fuel dispenser. Modular design of Common Rail system facilitates adaptations to different engines.

In Common Rail system high pressure generation and injection are separated. High fuel pressure is generated independently of engine speed and fuel dosing. Individual elements of the injection system is controlled by the electronic engine controller.

Separation of pressure generation and fuel injection allows relatively large rail volume. Fuel under pressure is continuously ready for injection.

High pressure pump is responsible for the creation of a proper injection pressure. This pump is typically a radial piston pump or an inline pump.

Depending on the Common Rail system variant there are different ways to control high pressure value.

- control in high pressure circuit (Figure 2.2A) –

    desired rail fuel pressure is controlled in the high pressure circuit using control valve (3). Through this valve the unused fuel flows back to the low pressure circuit lowering the rail pressure to a given setpoint. This method of control enables short response time and fast accommodation to different states of engine. Control valve is mounted on the high pressure rail.

- fuel intake control (Figure 2.2B) –

    the dispenser placed on the high pressure pump flange (6) provides precise dosage of fuel pumped to the rail, maintaining the injection pressure required by the fuel injection system. Reducing valve (5) protects against excessive rail pressure in case of failure. This method of control ensures lower amounts of fuel to be compressed and as a result lower power consumption of the pump. This has beneficial effect on fuel consumption and temperature of fuel returning to the tank.

- mixed type of control (Figure 2.2C) –

    this method of control combines the advantages of both high pressure control methods. In this case there is both a control valve (3) and the fuel dispenser (6).
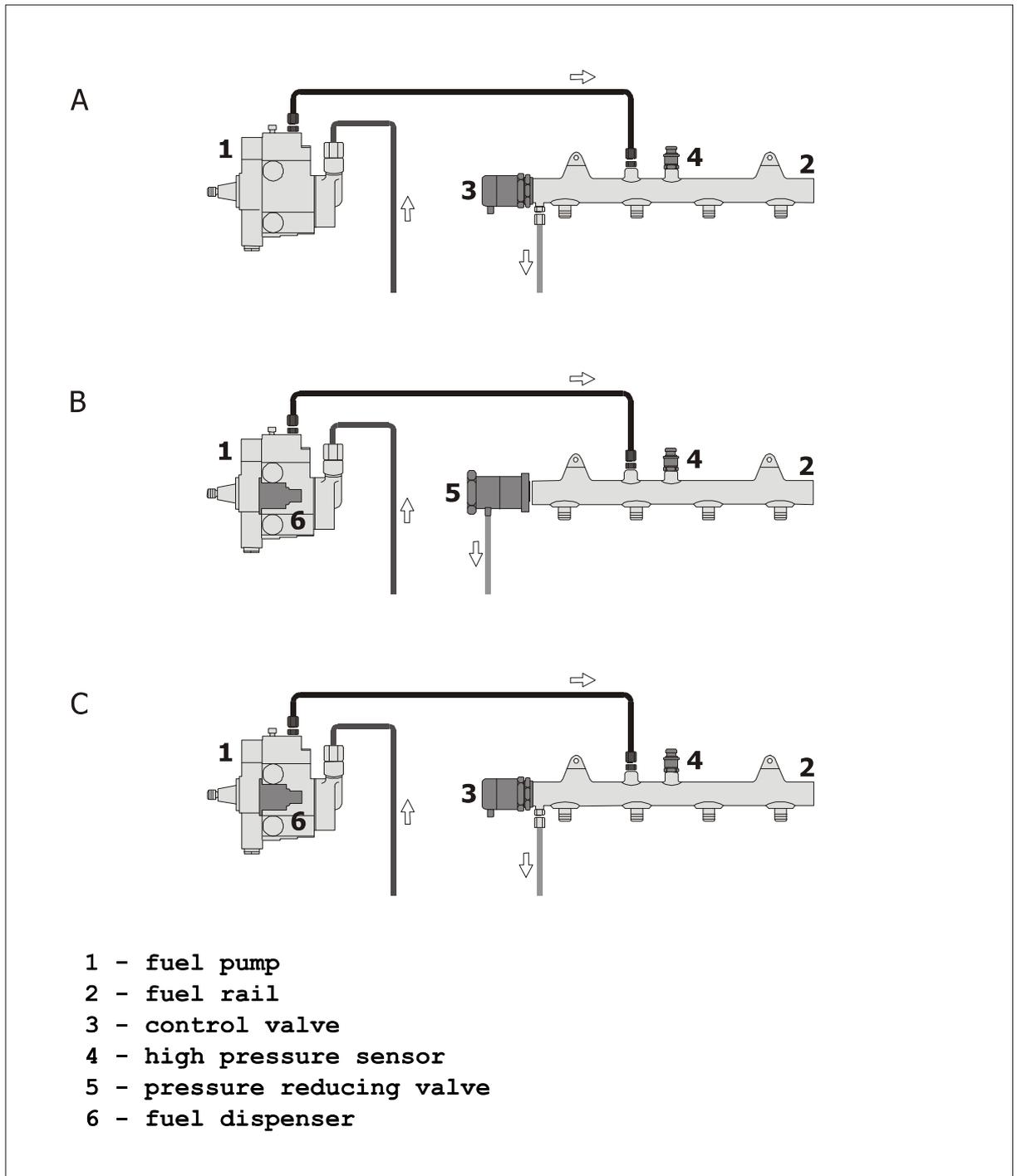
Figure 2.2 Methods for high pressure control in Common Rail system.

1 - fuel pump
2 - fuel rail
3 - control valve
4 - high pressure sensor
5 - pressure reducing valve
6 - fuel dispenser

Engine controller receives different signals indicating the engine operating parameters such as:

- rotational speed and crankshaft angle,
- fuel pressure in high pressure accumulator,
- boost pressure,
- air temperature in the intake manifold, coolant temperature and fuel temperature,
- mass of air entering the engine,
- car speed, etc.

The controller processes the input signals and calculates the sequences of driving values for fuel pressure control valve or fuel dispenser, injectors and other actuators (exhaust gas recirculation valve, boost pressure control valve, etc.).

Short injection times can be achieved using optimized high-pressure electromagnet valves and special control. Engine controller timer sets injection time based on data from crankshaft rotational speed sensor and camshaft position sensor. Electronic Control Unit enables precise dosage of injected fuel and control of additional functions – enhancing engine parameters or driving comfort.

2.1. Design and operation of high pressure sensor

The high pressure sensor is used to measure the pressure of fuel in high pressure accumulator (rail) of the Common Rail system.
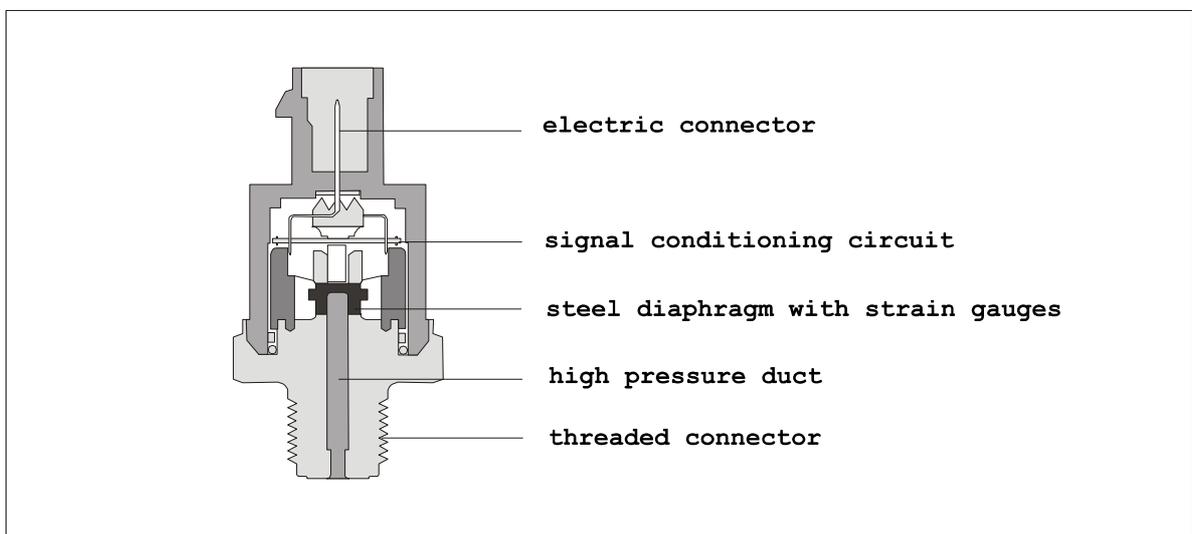

Figure 2.3 High pressure sensor cutaway.

The core of the sensor is a steel diaphragm with strain gauge sensors placed on it. The range of measured values depends on diaphragm thickness (thicker diaphragm for higher pressures). When the high pressure fuel acts on one side of the diaphragm, the strain gauge sensors change their resistance due to diaphragm strains. The output voltage produced this way is amplified to signal of amplitude 0…5%. This signal is sent to the Engine Control Unit which samples this signal and using preprogrammed sensor characteristics calculates current fuel pressure.

Each sensor is characterized by the parameter called the maximum working pressure or maximum rated pressure (Pmax). This parameter correspond with the measuring range of the sensor. The maximum pressure that may be measured by the sensor is Pmax.

2.2. Design and operation of pressure control valve

The pressure control valve sets and keeps the required rail pressure valve. It can be fitted to high pressure pump or fuel rail.
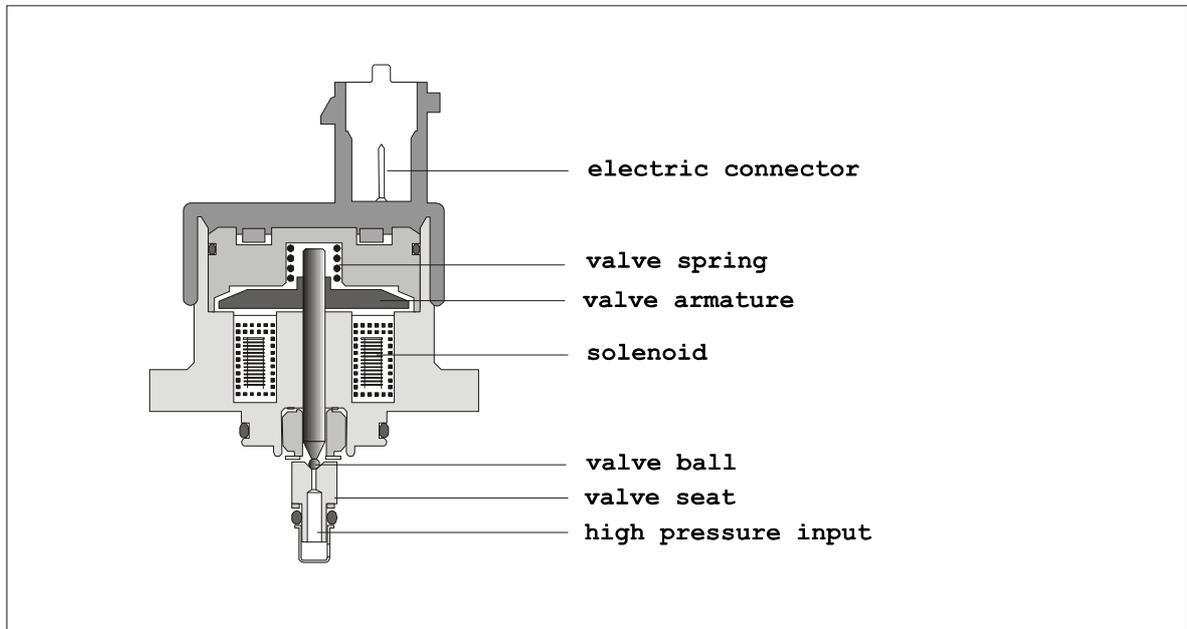

Figure 2.4 Pressure control valve cutaway.

The armature presses the valve ball against the mortise and closes connection between high pressure and low pressure circuits. This action is caused by resultant of spring and electromagnet forces.

When the valve is closed, electromagnet does not produce additional force acting on the valve ball. As a result, the force caused by high fuel pressure is higher than spring force and the control valve opens and stays partly opened. The spring is chosen so that the pressure is set at about 10MPa (100 bar).

When the valve is engaged the spring and electromagnet forces act against the valve ball. The valve stay closed until the rising high fuel pressure overcome the spring and electromagnet force.
Then, the valve opens and stays partly opened at constant pressure. Changes in pumped doses of fuel are compensated by varying degree of valve opening.
Electromagnet force is proportional to the control current. Changes of this current are carried by the pulse width modulation control, or by changing PWM signal.

In view of methods of high pressure control the are two types of valves:
- **normally opened valve** – the one that completely lets pass the fuel when the current does not flow through the solenoid (control signal disabled). Increasing the solenoid current (increasing PWM value) reduces the fuel flow.

- **normally closed valve** – the one that blocks fuel flow when there is no current flowing through valve (control disabled). Increasing the solenoid current (increasing PWM value) increases the fuel flow.

3. Device specification

Supply voltage	DC, 12...15V
Current draw	up to 4A (fuse)
Pressure measurement	
sensor supply voltage	5V
input range	0...5V
Controlling valve 1 and 2	
output type	PWM
PWM signal range	0...70%
PWM signal precision	0.05%
output amplitude	0V up to supply voltage
type of control	controlling the ground terminal

4. Tester application

TCR-4 tester is intended to diagnose Common Rail injection systems. TCR-4 enables measuring the rail pressure as well as controlling two control valves at the time

The device can be used both for measuring the rail pressure and controlling pressure valves in the car as well as to diagnose high pressure pumps on the test bed.
The tester is necessary to monitor fuel rail pressure so it is possible to properly evaluate the high pressure pump condition.

The TCR-4 tester can also be used to monitor the fuel pressure in a FSI injection systems.

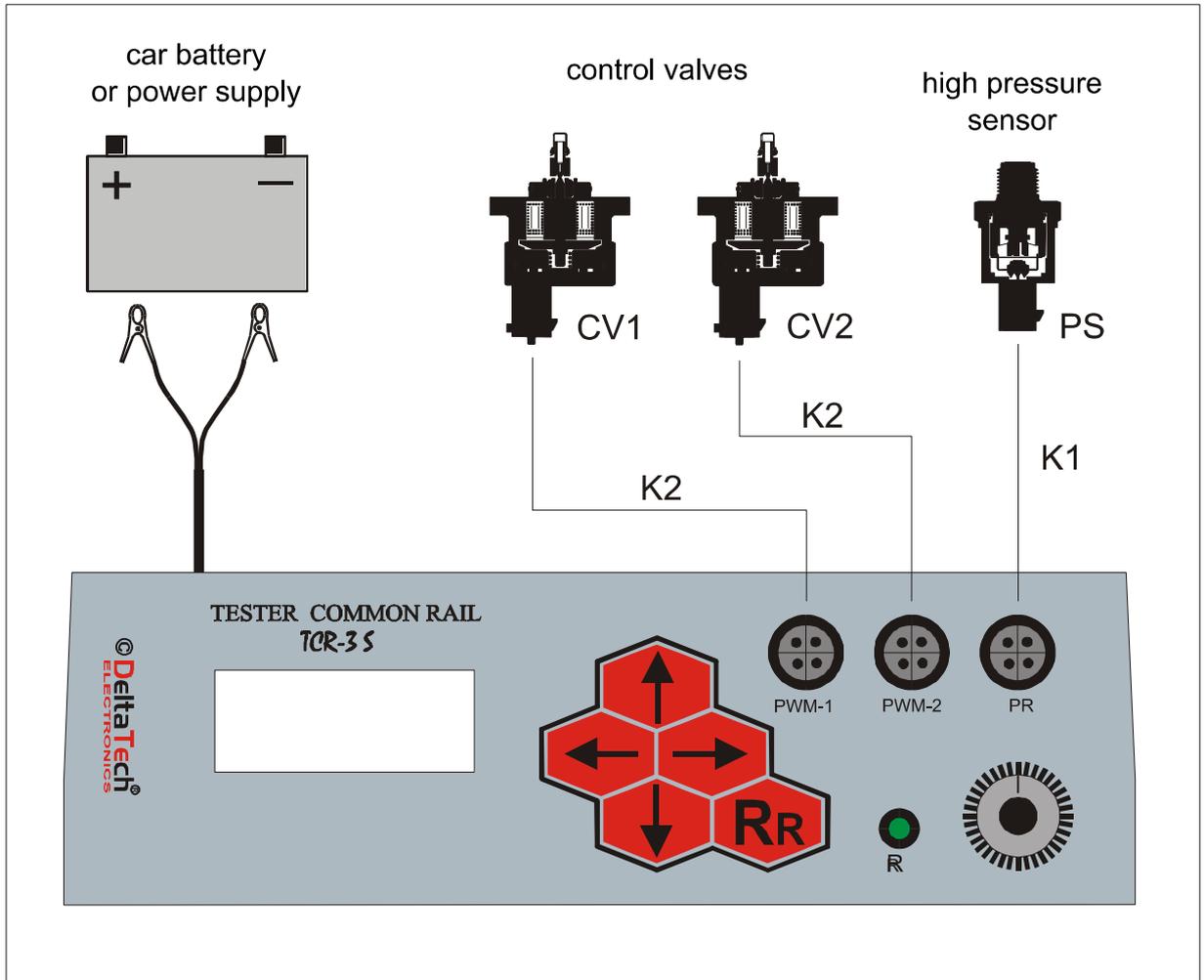# 5. Connecting the device

Proper device set up is shown in Figure 5.1.

Figure 5.1

5.1 Connecting high pressure sensor

High pressure sensor require connecting three wires:
- ground,
- pressure sensor output,
- power supply +5V.

There are two variants of sensor pinouts. This variants are put together in Table 5.1.

Table 5.1

signal name	pin number, variant 1	pin number, variant 2
GND	1	1
output	2	3
+5V	3	2

Connection cable for K1 pressure sensor is ended with three separate contacts. The contacts description is given in Table 5.2.

Table 5.2

signal name	K1 cable color
GND	brown
output	yellow/green
+5V	blue

Proper connection of high pressure sensor and the tester is shown in Table 5.3.

Table 5.3

K1 cable color	sensor contact number, variant 1	sensor contact number variant 2
brown	1	1
yellow/green	2	3
blue	3	2

! Always check the pinout variant in technical specifications provided by sensor producer. Improper connection may cause sensor damage.

When using the device in the car, it is necessary to connect pressure sensor output to the Engine Control Unit (ECU). K1 cable sharing sensor output so that it reaches both the VPX-3 tester and ECU.

5.2 Connecting control valves

ZR1 and ZR2 control valves requires two-wire connection for operation, observing polarity is not necessary.

K2 cables are ended with two separate contacts. Contact description is given in Table 5.4.

Table 5.4

signal name	K2 wire cable
power (12...15V)	blue
control	brown

6. Device operation

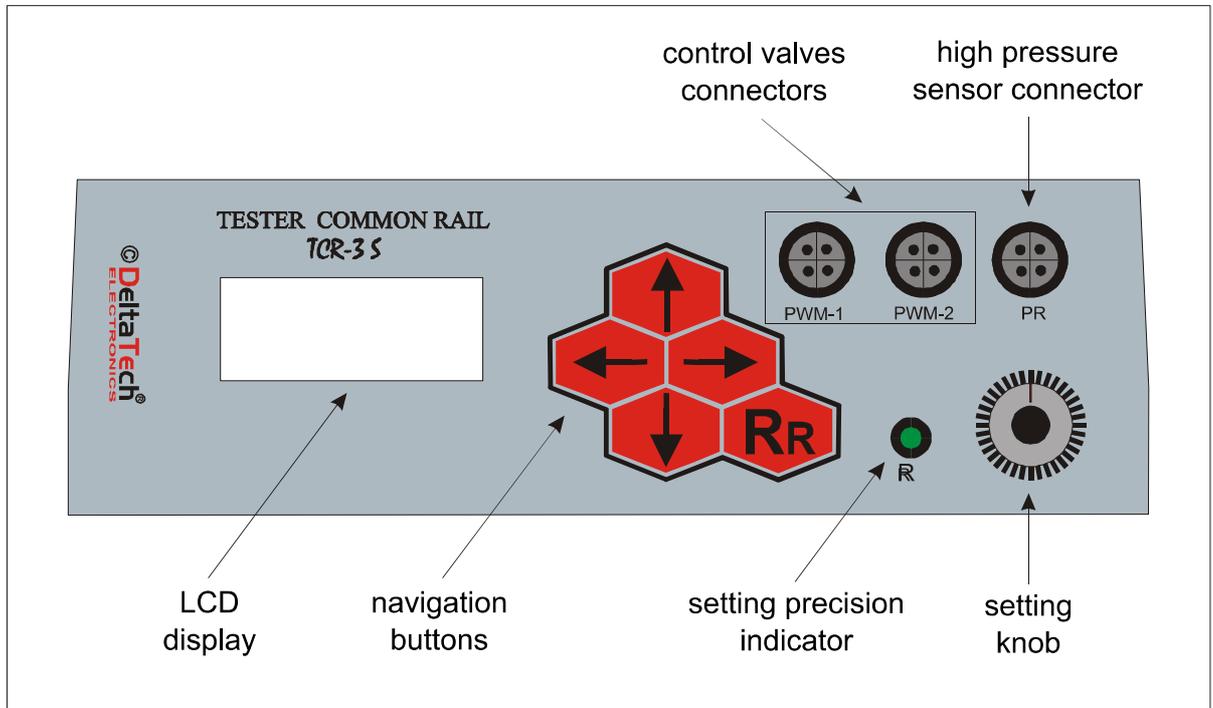The tester is operated with the panel shown in Figure 6.1.

Figure 6.1

Use navigation buttons to select and confirm required action. Input knob enables adjustment of control values. Depending on selected input precision rotating this knob cause changing a value in small or big steps. Input precision button toggles input precision (coarse/fine). Precision indicator lights shows current input precision (it lights up when small steps are selected)..
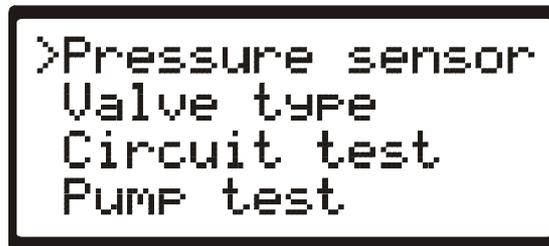
Details on use of panel items are included in descriptions of tester functions.

7. Tester functions

After connecting the power supply the tester shows the welcome screen.

```
 Common Rail
    tester

       (C)DTE
```

This screen is displayed for 3 seconds, then in automatically switches to function selection screen.

```
>Pressure sensor
 Valve type
 Circuit test
 Pump test
```

Select desired type of function using navigation buttons ⬆ ⬇. Current choice is indicated by the symbol ❯ on the left. To confirm selection press the ➡ button.

7.1. Pressure sensor

This function enables entering high pressure sensor parameters. These parameters include:
-                       sensor type (determining sensor output voltages),
-                       pressure range (Pmax value).

After confirming selection using the ➡ button, the device displays the sensor parameters adjustment screen.

Select appropriate sensor type using navigation buttons ⬆ ⬇. Current choice is indicated by the ❯ symbol on the left.
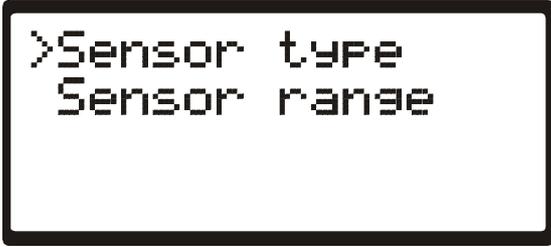
```
>Sensor type
 Sensor range
```

To return to function selection screen press the back button [←].

7.1.1 Type of sensor

This submenu enables setting the sensor output voltage range. This range depends on sensor manufacturer:
- range of 0.5V-4.5V – Bosch and other sensors,
- range of 1.0V-4.2V – Denso sensors.

[!] Setting proper output voltage range of high pressure sensor is necessary for adequate pressure measurement by the TCR-4 device.

The selected voltage range is indicated by the ⟩ symbol on the left.
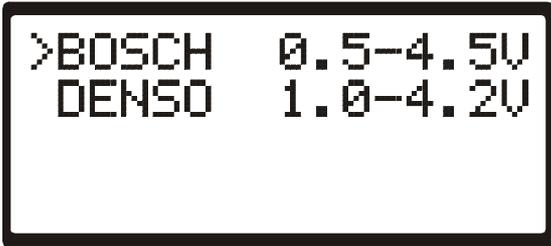
```
>BOSCH  0.5-4.5V
 DENSO  1.0-4.2V
```

To select required range use navigation buttons [↑] [↓].

To confirm the selection press the [→] button.

Press back button [←] to cancel changes.

7.1.2 Sensor measurement range.

Select this item to enter Pmax (see section 2.1) of used high pressure sensor.

[!] Setting proper range of high pressure sensor is necessary for adequate pressure measurement by the TCR-4 tester.

After selecting this item the device displays the maximum operating pressure of the sensor Pmax („Current value").

```
Present value
        200   [MPa]
New value
        250   [MPa]
```
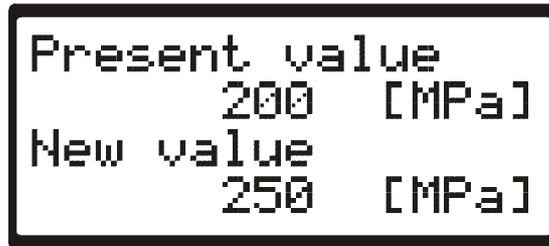
The "New value" can be adjusted using input knob. This parameter can be changed in steps of 1 MPa or 10 MPa depending on the selected input precision. To switch input precision (coarse/fine) use the precision button R_R .

The value can also be changed using up and down buttons ↑ ↓ . These buttons allow switching between predefined values. The values stored in device memory corresponds with most popular sensors used.

To set new Pmax value press the → button.

To cancel press the ← button.

In both cases this will make device return to parameter selection screen.

7.2 Type of valve

This function is used to set type of valve. The user can select the type of valve 1 and valve 2 used to control high pressure in Common Rail system (see section 2.2). There are two types of valves:

-                 normally open valve,
-                 normally close valve.

Appendix A contains general information about type of valves used depending on manufacturer and type of Common Rail system.

!   Specifying the type of valve is necessary if using pressure control function (see section 7.4.2).

After accepting the selection with the → button, the valve selection screen will appear which enables selecting type of valve of valve 1 and valve 2.

To select required pressure range use navigation button [↑] [↓]. Current choice is indicated by the symbol ❯ on the left.

```
>Valve 1 type
 Valve 2 type
```

To cancel changes press back button [←].

7.2.1 Type of valve 1 and valve 2

After selecting this submenu the device displays list of two possible choices and the symbol ❯ on the left of currently selected type.

```
>Normally open
 Normally closed
```

To select required type use navigation buttons [↑] [↓].

To confirm the selection press the [→] button.

To cancel changes press back button [←].

7.3 Test of circuits

After selecting this function, the device performs check of continuity of the following circuits:

- high pressure sensor circuit – labeled as „Sensor",
- valve 1 circuit – labeled as „Valve 1",
- valve 2 circuit – labeled as „Valve 2".

```
Sensor :    ok
Valve 1:    fault
Valve 2:    ---
```

The TCR-4 device is able to state whether a circuit adequately responds to control signals.
On the right part of display the results of continuity tests are displayed:

- „---" – indicates currently ongoing test,
- „good" – indicates proper response of the given circuit, the element is properly connected and the circuit is continuous.
- „fail." – indicates incorrect circuit response. The cause may be a bad connection or damage to the tested item.

When performing high pressure sensor test the correct result does not give full certainty about its failure free performance in whole range of pressure. Full confidence can be obtained by analyzing the sensor output during engine operation.

To repeat the test use the button ⬡.

To return to function selection screen press the back button ⬡.

7.4 Pump test

Pump test allows high pressure measuring while controlling up to 2 pressure control valves and displaying other parameters available in additional functions (the description of these functions is provided later in this document).

7.4.1 High pressure readout

First line (1) of display contains current rail pressure as measured by high pressure sensor.
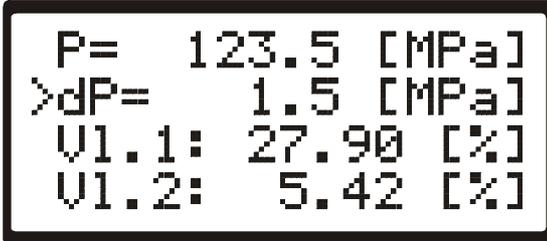
(1)
```
P=   123.5 [MPa]
>dP=   1.5 [MPa]
 V1.1: 27.90 [%]
 V1.2:  5.42 [%]
```

! To assure correct pressure readout the maximum working pressure of the sensor must be set (see section 7.1).

7.4.2 Additional functions

The line (2) of display shows one of the following functions:
function (a) – pressure ripple
> indicates maximum pressure change in given interval,

function (b) – maximum pressure
> indicates maximum pressure value since beginning of measurement or last reset by any change of input knob position.

function (c) – pressure setpoint (for valve 1)
> displays pressure setpoint to be maintained using control valve 1. The user can adjust this value using input knob. To change input precision (size of steps) use precision button **R_R** .
>
> Before using this function, please pay attention to the type of valve used to regulate the high pressure(see section 7.2).
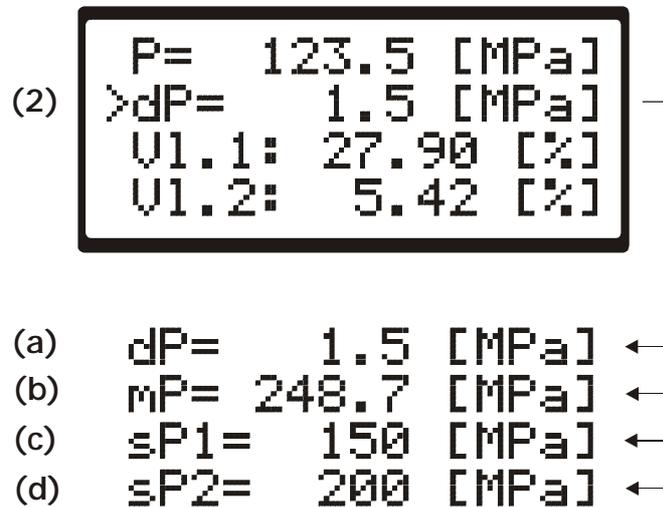
function (d) – pressure setpoint (for valve 2)
> displays pressure setpoint to be maintained using control valve 2. The user can adjust this value using input knob. To change input precision (size of steps) use precision button **R_R** .
>
> Before using this function, please pay attention to the type of valve used to regulate the high pressure(see section 7.2).

```
        P=   123.5 [MPa]
 (2)   >dP=    1.5 [MPa]
        V1.1: 27.90 [%]
        V1.2:  5.42 [%]


 (a)   dP=    1.5 [MPa]
 (b)   mP= 248.7 [MPa]
 (c)   sP1=   150 [MPa]
 (d)   sP2=   200 [MPa]
```

To reset maximum pressure value (function b) or change the pressure setpoint (functions c and d) the selection indicator must point line (2).

To change the list of additional functions displayed use the button .

7.4.3 Setting the control value for valve 1

(3)
```
P=   123.5 [MPa]
dP=    1.5 [MPa]
>V1.1: 27.90 [%]
 V1.2:  5.42 [%]
```
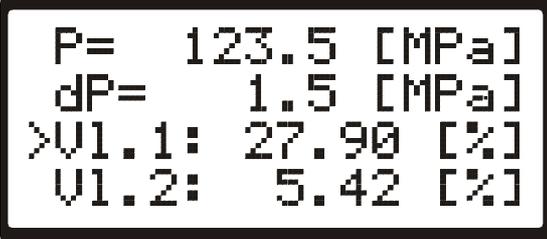
The line (3) of display shows duty cycle value of the PWM signal controlling valve 1. This parameter may take values between 0 and 30%. Use input knob to adjust this value (the selection symbol ❯ should point line (3) To change input precision use the precision button **R**R .

7.4.4 Setting the control value for valve 2

(4)
```
P=   123.5 [MPa]
dP=    1.5 [MPa]
 V1.1: 27.90 [%]
>V1.2:  5.42 [%]
```
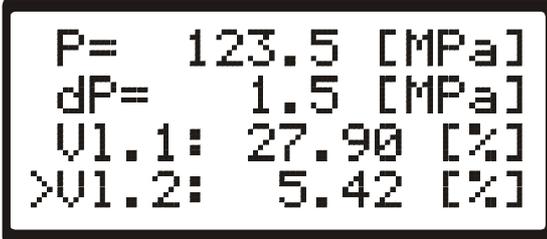
The line (4) of display shows duty cycle value of the PWM signal controlling valve 4. This parameter may take values between 0 and 30%. Use input knob to adjust this value (the selection symbol ❯ should point line (4) To change input precision use the precision button **R**R .

To change position of selection symbol use up ⬆ and down ⬇ buttons.

To return to function selection use the button ⬅ .

If the pressure setpoint for valve 1 was set (function c) it is not possible to access line (3) because the device already uses setpoint 1 for rail pressure control.

Similarly if the pressure setpoint for valve (2) was set (function d) it is not possible to access line (4) because the device already uses setpoint 2 for rail pressure control.

Appendix A. Methods of high pressure control and types of control valves in various Common Rail systems

Table A.1

Manufacturer	Method of high pressure control and type of valve	
	Low pressure circuit	**High pressure circuit**
Bosch CR1	-	1. Electromagnetic valve 2. Disconnecting the pumping sections in high pressure pump
Bosch CR2	1. Reducing the suction using the longitudinal electromagnetic valve (in the axis of pump), normally open; 2. Reducing the suction with transverse electromagnetic valve (perpendicular to the axis of the pump), normally closed.	Electromagnetic valve
Bosch CR3	Reducing the suction with electromagnetic valve, normally open	Electromagnetic valve;
Bosch CR4	Reducing the suction with electromagnetic valve, normally open	Electromagnetic valve, normally open
Delphi	Reducing the suction with electromagnetic valve, normally open	1. Mechanic valve 2. Electromagnetic valve
Denso	1. Reducing the suction with electromagnetic valve, normally closed; 2. Reducing the suction with electromagnetic valve,; normally open	1. Mechanic valve 2. Electromagnetic valve
Siemens	Reducing the suction with electromagnetic valve, normally closed	Electromagnetic valve

<u>Warning !!!</u>

When enabling the ignition with the high pressure pump and pressure sensor cables disconnected the Engine Control Unit will record error codes associated with these circuits. After completing the tests it is necessary to clear these error codes using scanner device or diagnostic program.

All tests, in particular starting the engine should be performed with special caution and in accordance to applicable working place safety and health rules.

DeltaTech Electronics company not responsible for any damage and consequences of misuse of the TCR-4 device. Please always refer to service manual supplied by the car manufacturer.

The warranty do not cover any damage caused by incorrect use.

DeltaTech Electronics company is liable up to the amount paid for the device and is not responsible for any damage and consequences of misuse.

DeltaTech Electronics Company has do their most in order to write this manual properly, but can not guarantee that it does not contain any errors. During any workshop activities please always refer to vehicle service manuals, local regulations and laws, workplace and fire safety rules.