

LIST OF ENGINE DATA FOR DIESEL -RK

The list includes data which are necessary for simulation of the super- turbo-charged internal combustion engine with DIESEL-RK software www.diesel-rk.bmstu.ru .

There are not included in the list:

- the data for realization of multidimensional optimization;
- the coefficients for calibration of mathematical models;
- the Turbine and Compressor Maps; the data should be presented as SAE format files.

These data are not necessary for the first acquaintance with the program.

The code DIESEL-RK allows simulation of any scheme of a turbocharging including two-stage free one, electrically or mechanically assisted as well. The maximum amount of data is required for simulation taking into account the matching the characteristics of the engine with turbines and compressors maps. The minimum data set is required for calculation of an engine when the maps of turbines and compressors are not taken into account but parameters of boost and turbocharger efficiency are specified explicitly or calculated by the software as functions of pressure ratio and efficiency of compressor. The pressure of gas at the inlet of the turbine may be set directly or calculated by the software using equation of power balance between the turbine and compressor. In the last case the turbocharger efficiency has to be specified.

Input data are grouped together according to main systems of an engine.

1. GENERAL ENGINE PARAMETERS

- Bore of cylinder.
- Stroke of piston.
- Nominal engine speed (RPM).
- Mechanism of transformation of a movement of the piston in rotation of the shaft: crank or other (For other mechanism it is necessary to set the function of the piston position versus CA).
- Length of the connecting-rod. For Junkers engine specify length of the both connecting rods and angular offset.
- Number of cylinders.
- Design: (V or L, etc.).
- Compression ratio in the cylinder.
- Material of the piston or piston crown (iron / steel / aluminium).
- Material of the cylinder head (iron / steel / aluminium).
- Average thickness of the cylinder head wall: one is marked by Δ in the fig. 5.
- Type of engine cooling (liquid-cooling /air-cooling).
- Parameters of a fur layer and casting skin on a cooled wall of water cooling system:
 - thickness;
 - thermal conductivity Wt [W/(m K)].
- Parameters of a blades on the cylinder head at air cooling:
 - step of blades;
 - average height of blades;
 - average thickness of a blade .

2. COMBUSTION CHAMBER DESIGN, FUEL INJECTION EQUIPMENT

- Swirl Ratio R_s (it is the relation between swirl angular velocity and crank rotation velocity). R_s may be specified by one of two ways:
 - by the velocity of air in a combustion chamber at the end of compression;
 - by the velocity of air in the cylinder at the end of intake.Specify R_s and way of its obtaining.
- Number of injectors. (It is actual for side injection system.)

- Number and Diameter of the injector nozzles.
- Nozzle discharge coefficient obtained as a result of the tests in atmospheric conditions.
- Design of injector nozzles: orientation of each nozzle in both planes (see fig. 1.)

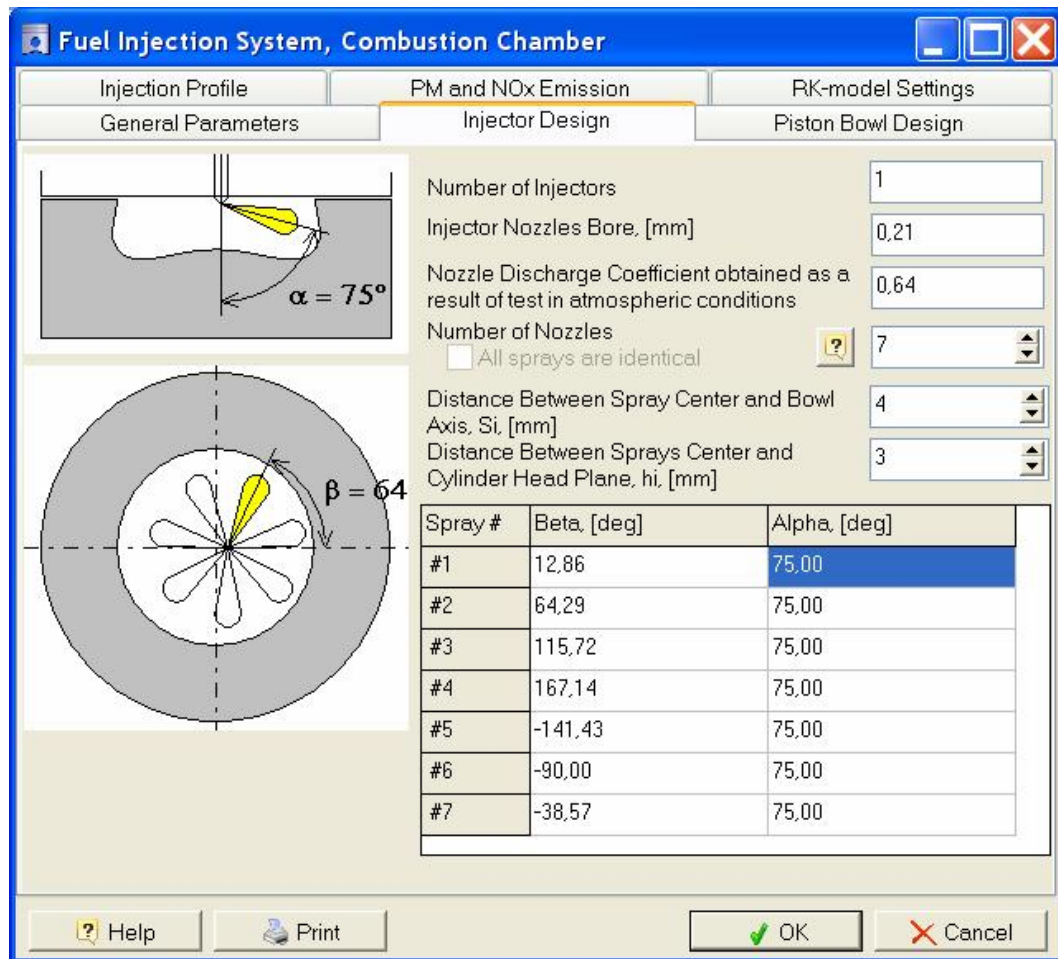


Fig. 1. Injector design parameters

- Location of sprayer center:
 - Distance between sprayer center and bowl axis: S_i , [mm].
 - Distance between sprayer center and cylinder Head Plane h_i , [mm].
- Design of piston bowl may be set by two ways. In both cases the drawing is necessary.
 1. Using main dimensions, fig. 2.

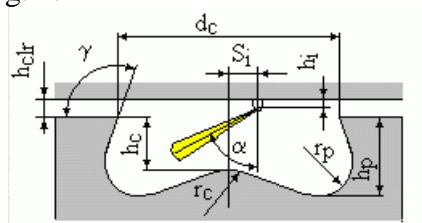


Fig. 2. Specification of piston bowl by main dimensions.

Notations:

- Depth of a combustion chamber in periphery h_c , [mm].
- Radius of sphere in center of piston bowl r_c , [mm].
- Depth of combustion chamber in periphery h_p , [mm].
- Radius of hollow chamfer in periphery of bowl r_p , [mm].
- Inclination Angle of a Bowl Forming to a Plane of the Piston Crown γ , [deg].
- Top-clearance at TDC h_{clr} , [mm].

2. Using coordinates of points: radius R and depth Y , fig 3. The 16 points have to be set in [mm].

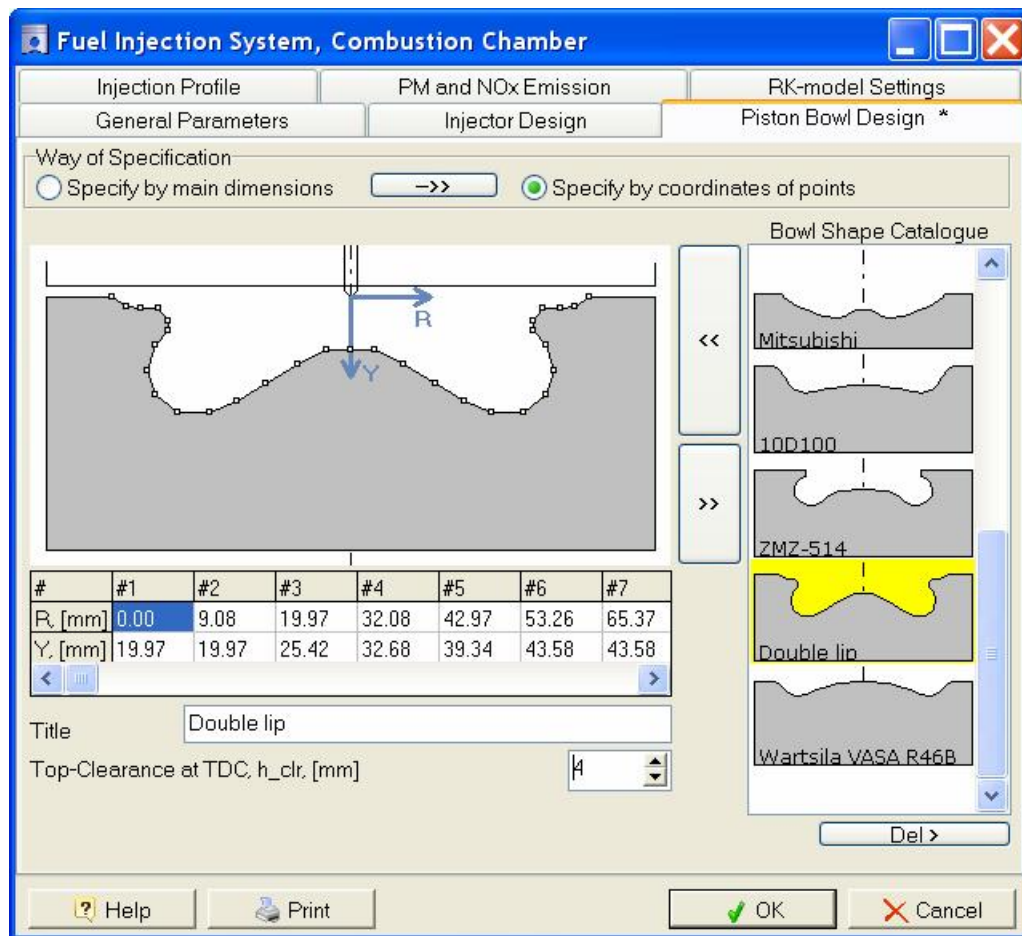


Fig. 3. Specification of piston bowl by coordinates of points.

3. GAS EXCHANGE SYSTEM

There is example for the four stroke engine only. For the two stroke engine see help system and DIESEL-RK preprocessor.

EXHAUST PORTS

- EVO: Angle of the exhaust BEGINNING [deg. before BDC].
- EVC: Angle of the exhaust ENDING [deg. after TDC].

Sometimes in engine data documentation the Valve Timings are specified in Crank Angles corresponding with 1 mm of Valve Lift. (Because this value may be measured easy.)

To provide robustness of valve train a cam profile starts the rising much early as it shown in fig. 4 by "Technological curve".

At thermodynamic simulation of the engine a "Theoretical curve" is used. This curve describes real motion of the valve from Valve Lift = 0. This moment of CA must be set as valve opening and closing.

The range before Theoretical Valve Opening does not effect on gas exchange due to very small valve lift or absence of real valve lift. It is important to adjust Theoretical curve with real Technological curve where valve lift is considerable.

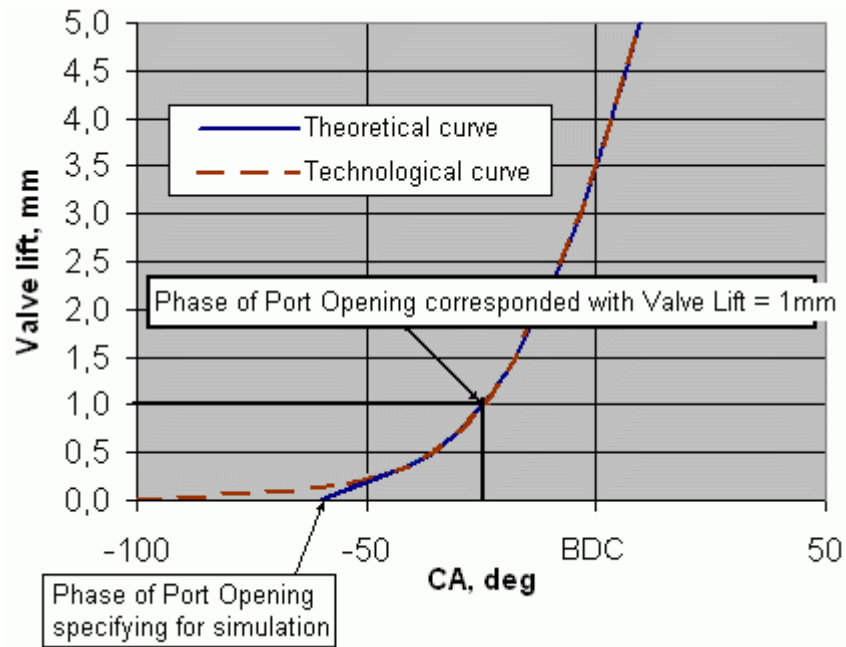


Fig. 4. Illustration for specification of the port timing of four stroke engine.

- Diameter for calculation of the cross sectional area of exhaust port dk [mm] (fig. 5).
- Perimeter of cross section of exhaust port Pk [mm] (fig. 5).
- Length of the exhaust port lk [mm] (fig. 5).

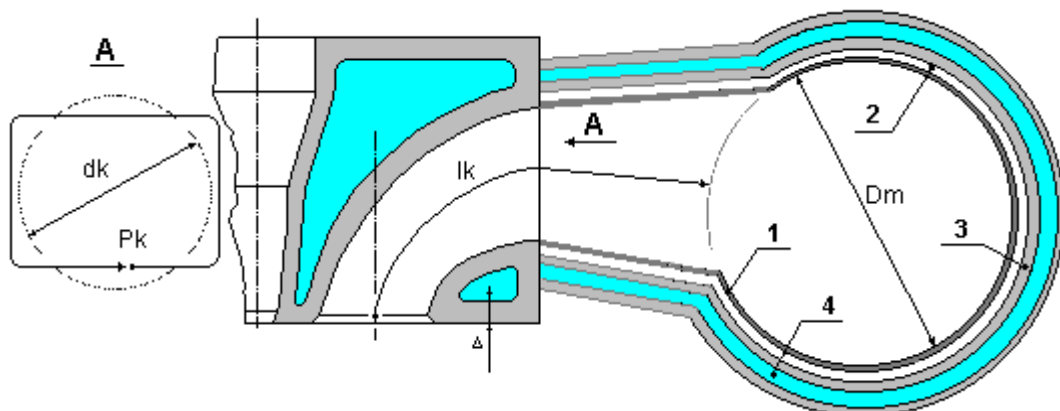


Fig. 5. Longitudinal section of the exhaust port. Notations for cooled exhaust system: 1 – heat liner, 2 – air layer, 3 – exhaust manifold internal wall, 4 – water jacket.

- Number and design of exhaust valves per cylinder (see fig. 6).

Select kind of the port design: Tandem; Forked; Single:

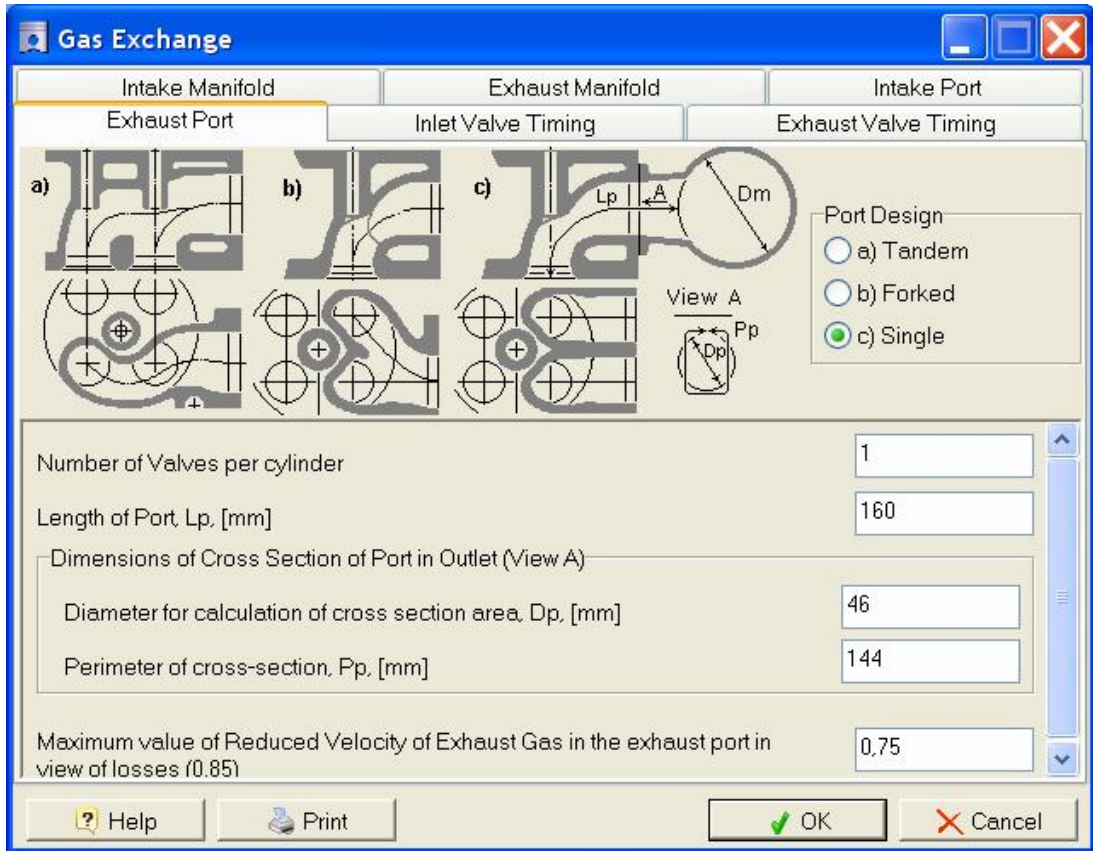


Fig. 6. Engine ports design.

- Results of the steady flow testing of exhaust ports (the effective flow area [cm²] as a function of CA). Specify only site of rise (fig. 7). Data in MS Exel format are acceptable. Put attention: first point ordinate must be equal 0 and MUST be corresponded with EVO. Same with EVC.

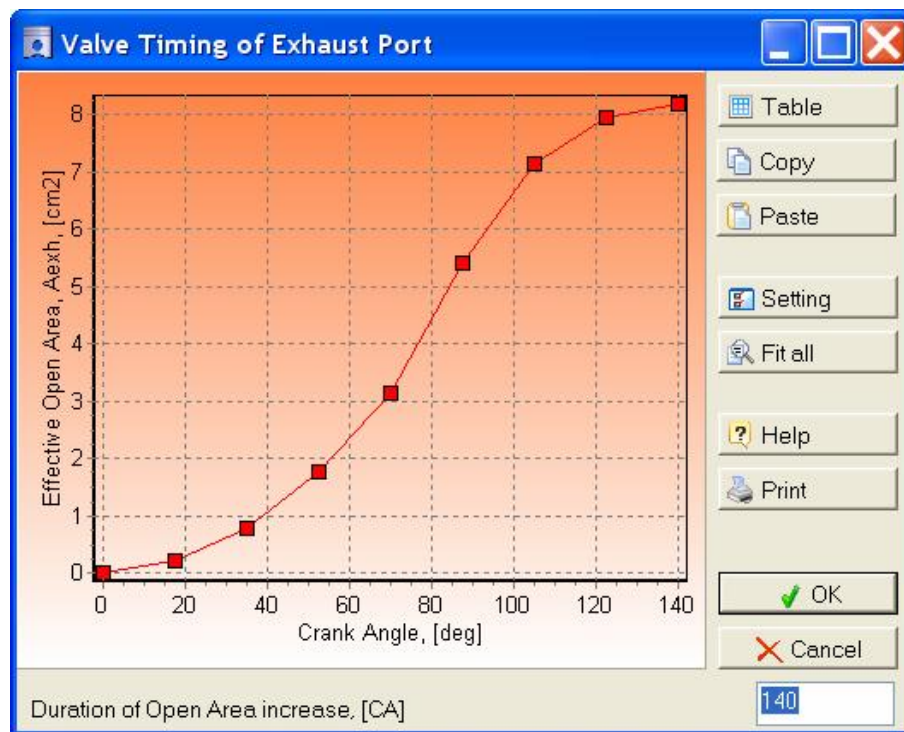


Fig. 7. Exhaust port effective flow area (rise).

- Effective flow area vs. CA for the valve downwards motion (similar to shown in above figure 7)
Specify this function if one is not symmetric to the site of rise (fig. 8).

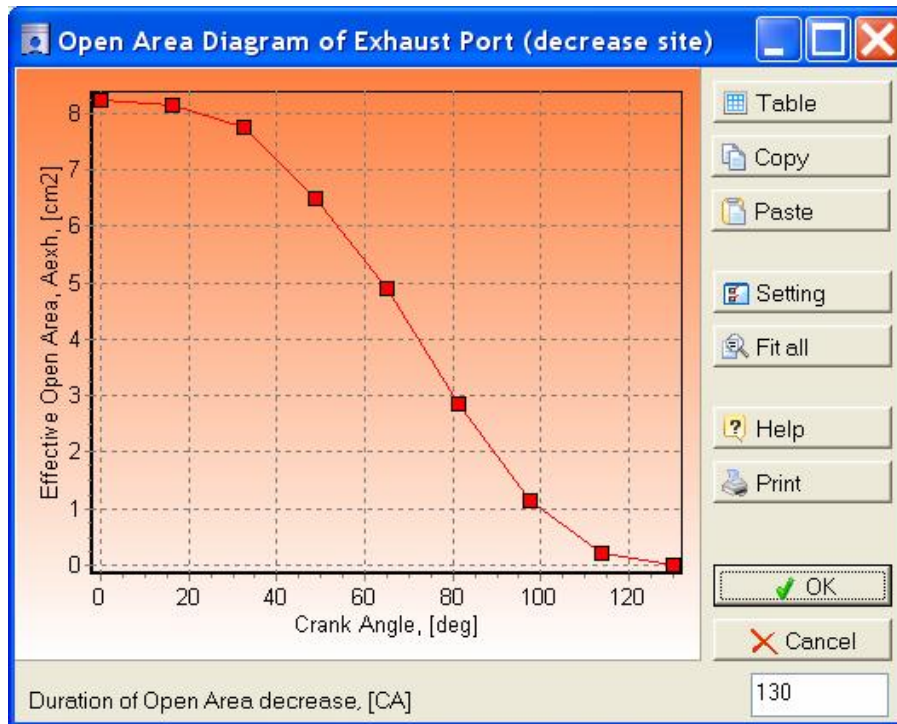
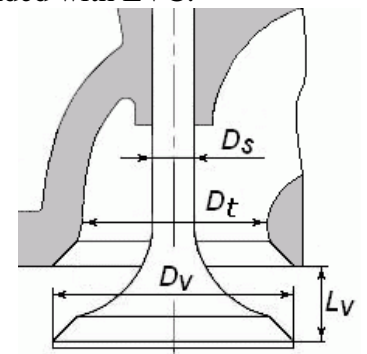


Fig. 8. Exhaust port effective flow area (decrease)

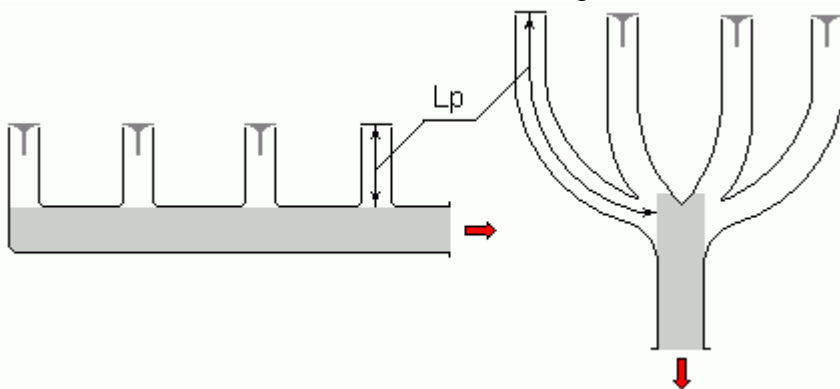
All diagrams may be presented as MS Exel data (2 columns: argument and function).
In the case of absence the steady state flow test data it is possible to set the valve lift diagrams in mm vs. crank angle. The first point of ordinate must be equal 0 and MUST be corresponded with EVO, the last point of ordinate must be equal 0 and MUST be corresponded with EVC.

EXHAUST VALVES DESIGN

- Valve stem diameter, D_s , [mm].
- Valve seat throat diameter, D_t , [mm].
- Valve Head diameter, D_v , [mm].
- Maximum valve lift, L_v , [mm].



EXHAUST MANIFOLD DESIGN (drawing or sketch is necessary)



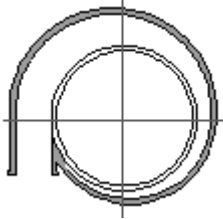
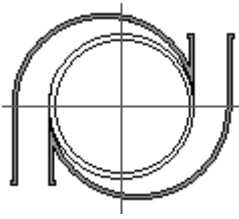
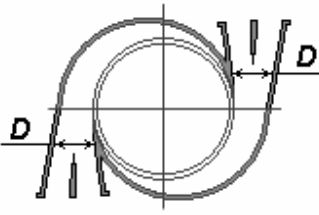
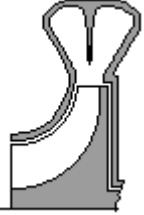
<= Variants of design

- Length of the manifold (gray colored part), [mm].
- Diameter of the manifold (gray colored part), [mm].

- Number of cylinders connected with one common manifold.

The exhaust manifold may have special fire-prevention system of cooling (fig. 5), including the heat liner (1), the air layer (3) between the heat liner and the wall of the manifold (2). The manifold may be cooled by water (4). Design of this system accounted by the program.

- Temperature of material cooling the manifold (air: < 330 K, water: > 330 K), [K].
- Existence of a heat liner (1) in the exhaust manifold (fig. 5.):
 - thickness of the heat liner wall [mm];
 - thickness of the air layer (3) between the heat liner and manifold wall (fig. 5.). [mm];
 - thermal conductivity of the material of the heat liner [W/(m K)];
 - relative area of contact of the heat liner with the exhaust manifold in the fastening places.
- Diameter of a tail pipe in section located after the union of manifolds (only for an engine without the turbine), [mm].
- The type of connection of exhaust manifolds:

	1) one manifold is connected to one turbine (for the engine without the turbine - connected to one tail pipe);		2)- each manifold is connected to an individual inlet of turbine;
	3) -few manifolds are united in front of the turbine (for the engine without the turbine: - are united before the tail pipe);		4)- two manifolds are united along whole length of the turbine scroll duct and are separated by a blade.

- Number of manifolds connected to one turbine inlet.
- Number of turbine inlets.
- Cross section diameter of the exhaust manifolds junction, D , [mm].

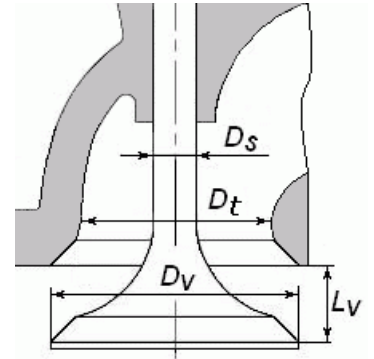
INTAKE PORTS (Longitudinal section of an intake port is alike as it shown in fig. 5, 6).

- IVO: Angle of the intake BEGINNING [deg. before TDC] (fig. 4).
- IVC: Angle of the intake ENDING [deg. after BDC].
- Diameter for calculation of the cross sectional area dk [mm] (fig. 5).
- Perimeter of cross section Pk [mm] (fig. 5).
- Length of the intake port lk [mm] (fig. 5).
- Number and design of intake valves per cylinder (see fig. 6).
Select intake port design: Tandem; Forked; Single.
- Results of the steady flow testing of intake ports (the effective flow area [cm²] as a function of CA). Specify only site of rise (fig. 7). Data in MS Exel format are acceptable. Put attention: first point ordinate must be equal 0 and must be corresponded with IVO. Alike with IVC.
- Specify a function similar to shown in figure 8 if the valve downwards motion differs from a site of rise.

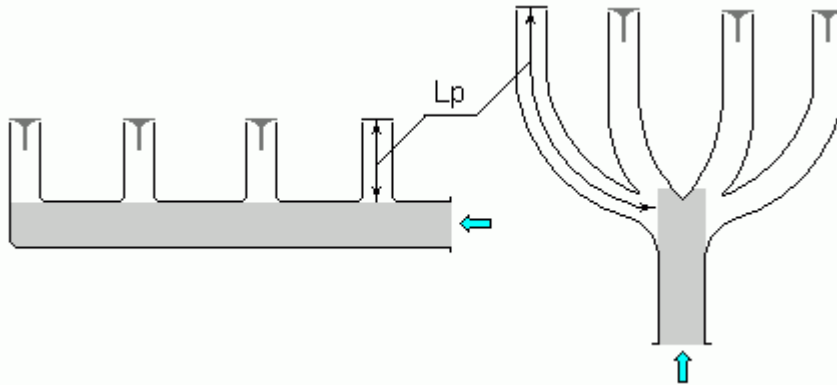
In the case of absence the steady state flow test data it is possible to set the valve lift diagrams in mm vs. crank angle. The first point of ordinate must be equal 0 and MUST be corresponded with IVO, the last point of ordinate must be equal 0 and MUST be corresponded with IVC.

INTAKE VALVES DESIGN

- Valve stem diameter, D_s , [mm].
- Valve seat throat diameter, D_t , [mm].
- Valve Head diameter, D_v , [mm].
- Maximum valve lift, L_v , [mm].



INTAKE MANIFOLD DESIGN (drawing or sketch is necessary)



<= Variants of design

- Diameter of the pipe delivering air to the intake manifold, [mm].
- Number of cylinders connected with one common manifold.
- Diameter of the manifold (gray colored part), [mm].
- Length of the manifold (gray colored part), [mm].
- Perimeter of cross section of the manifold (gray colored part), [mm].

4. SUPER- or TURBO- CHARGING AND EGR SYSTEM

General engine scheme is presented in the fig. 9.

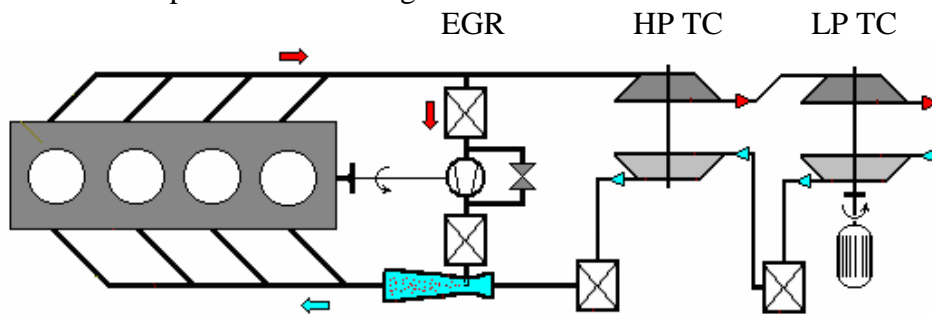
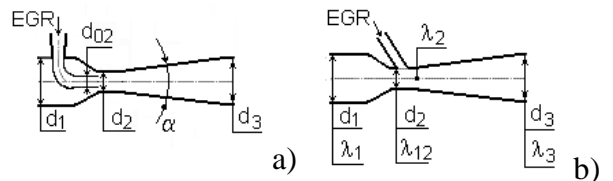


Fig. 9. General engine scheme.

- Number of High Pressure Turbines on engine.
 - High Pressure Turbine Map (in SAE format)*.
- Number of Low Pressure Turbines on engine.
 - Low Pressure Turbine Map (in SAE format)*.
- Type of the turbines: axial or radial.
- Number of Low Pressure Compressors on engine.
 - Low Pressure Compressor's Map (in SAE format)*.
- Electrical or mechanical assistance for LP or HP stage presented / not presented.
 - Efficiency of Electrical or mechanical assistance for LP or HP stage.
- Intercooler after the Low Pressure Compressor presented / not presented.
 - Thermal efficiency of Intercooler at nominal point,

- Pressure losses in Intercooler at nominal point,
- Temperature of coolant in Intercooler at nominal point,
- Number of High Pressure Compressors on engine.
 - High Pressure Compressor's Map (in SAE format)*.
- Intercooler after the High Pressure Compressor presented / not presented.
 - Thermal efficiency of Intercooler at nominal point,
 - Pressure losses in Intercooler at nominal point,
 - Temperature of coolant in Intercooler at nominal point,
- First EGR Intercooler presented / not presented.
 - Thermal efficiency of EGR Intercooler at nominal point,
 - Pressure losses in EGR Intercooler at nominal point,
 - Temperature of coolant in EGR Intercooler at nominal point.
- EGR pump presented / not presented.
 - Efficiency of EGR Intercooler at nominal point.
- Second EGR Intercooler presented / not presented.
 - Thermal efficiency of EGR Intercooler at nominal point,
 - Pressure losses in EGR Intercooler at nominal point,
 - Temperature of coolant in EGR Intercooler at nominal point.
- Venturi nozzle presented / not presented.
- Number of Venturi nozzles and design.
 - Inlet diameter, d_1 , [mm],
 - Throat diameter, d_2 , [mm],
 - Diameter of EGR supply pipe, d_{02} , [mm],
 - Outlet diameter, d_3 , [mm].



* The Compressor and Turbine Maps are necessary if simulation of engine is planning to be done in whole operating field, but not only in the points where compressor and turbine parameters are known. If boost pressure ratio and turbocharger efficiency are known in the fixed operating points, the maps are not required.

5. ENGINE OPERATING POINTS DATA

The data being presented in Table 1 are necessary for setting of engine operating modes and for calibration of engine models. For correct calibration of engine models it is necessary to specify data for several engine operating points with different engine speed and loads (4-5 points are desirable). The pre-processor of the code automatically offers only those data which are necessary for a chosen configuration of engine and configuration of its simulation. The presented document has not functions of the pre-processor therefore the list of input data includes only data for conventional diesel engine working in conditions at sea level.

Table 1. Engine parameters at different operating points.

Parameter	case #1	case #2	case #3	case #4	case #5
Speed (RPM)					
Fuel mass per cycle or Air Fuel equivalence ratio					
Injection timing, CA deg. before TDC					
Diagram of injection profile ¹ as a function of CA	#1	#2	#3	#4	#5
Ambient pressure on a sea level, bar					
Pressure losses in inlet filter, bar					
Environmental temperature on a sea level, K					
Exhaust back pressure, bar (before silencer) , bar					
Fraction of the air charge by-passed after the					

compressor into atmosphere.					
Fraction of the gas charge by-passed before the turbine into atmosphere.					
Temperature of the coolant in the engine cooling system, K					
Pressure of water in the cooling system of engine (absolute)					
Temperature of the coolant in the air intercooler, K					
Pressure in front of turbine, bar					
* Temperature in front of turbine, K					
* Turbine efficiency					
* Compressor efficiency					
Compressor discharge pressure (absolute, before air intercooler), bar					
Compressor discharge temperature (before air intercooler), K					
Pressure after inter-cooler, bar					
Temperature after inter-cooler, K					
EGR ratio, %					
* Power, kW					
* SFC, g/(kW h)					
* Mass Airflow rate (through inlet air filter), kg/s					
* Residual gas mass fraction					
* Max cylinder pressure, bar					
* NO emission, ppm					
* Smoke emission, [Bosch], [Hartridge], [1/m]					
* PM emission, g/(kW h)					
* Max fuel pipe-line pressure, bar					
* Diagram of Heat release rate as function of $CA^{2, 3}$					
* Diagram of in-cylinder pressure versus CA^2					
* Average cylinder head wall temperature, K					
* Average piston crown wall temperature, K					
* Top cylinder liner wall temperature, K					

* Data marked with * are necessary for calibration of the engine model only.

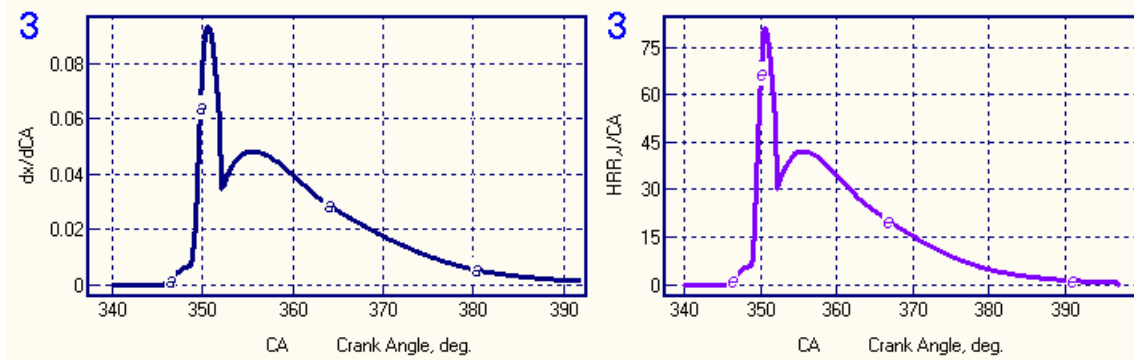
¹ Injection profiles are injection velocity versus crank angle (any scale of injection velocity is possible because the software will rescale it for conditions where area below the curve is fuel cycle mass). Diagrams of fuel pipe line pressure are possible too if the injection velocity diagrams are unavailable. Special tool (included into DIESEL-RK) will be used to obtain injection profile from pipeline pressure diagram.

Examples of injection profiles are presented below (double, triple, etc. injection profiles are acceptable too):

	<p>Injection profile for mode #1</p>
	<p>Injection profile for mode #2</p>
	<p>Injection profile for mode #3</p>
	<p>Injection profile for mode #4</p>

² All diagrams can be presented as MS Excel data (2 columns: argument and function).

³ The diagrams of heat release rate are desirable only for model calibration. They can be presented as MS Excel data (2 columns: argument and function) in 1/CA deg. or in J/CA deg.

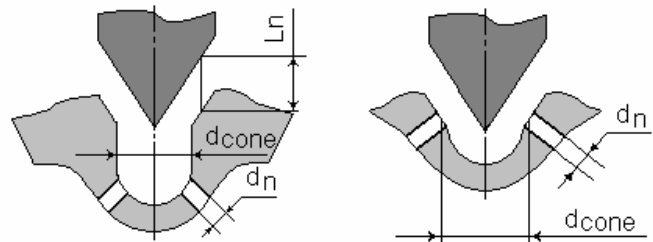


6. FUEL INJECTOR DESIGN

To calculate injection profile as a function of fuel pipeline pressure there are necessary following data:

Sprayer design dimensions:

- Lock cone diameter, d_{cone} , [mm].
- Max. needle lift L_n , [mm].



Fuel pipeline pressure profile and needle lift diagram are used for simulation of fuel flow in lock cone and nozzle to obtain the injection profile. The data being necessary for simulation at every operating mode are presented in figure 10.

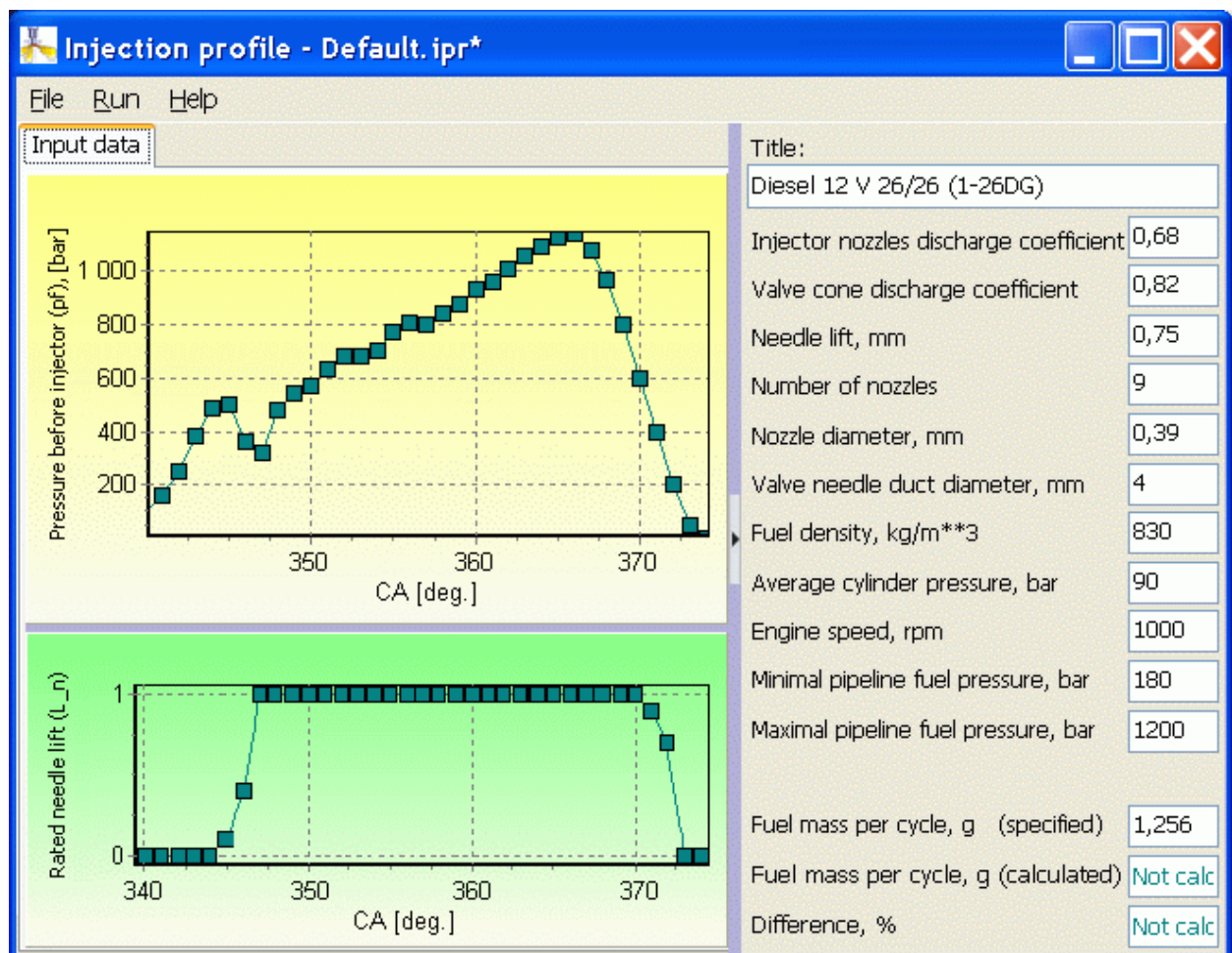


Fig. 10. Window and data for injection profile simulation at every operating mode.

7. FUEL PROPERTIES

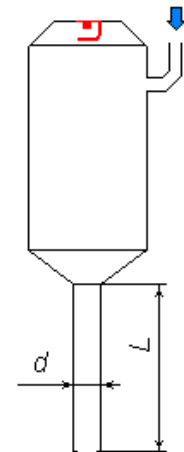
The following fuel properties are necessary if the fuel is not the diesel oil.

- Composition of fuel (C, H, O), [%].
- Low Heating Value, [MJ/kg].
- Density of fuel at 323 K, [kg/m³].
- Specific Vaporization Heat, [J/kg].
- Fuel Thermal Capacity at temperature of injector, [J/kg/K].
- Molecular Mass (or weight).
- Sulfur Fraction in the fuel, S, [%], is used for SO₂ emission calculation.
- Apparent Activation Energy for the Autoignition Process is used for autoignition delay calculation in diesel.
- Cetan Number is used for autoignition delay calculation in diesel.
- Surface Tension Factor of fuel at 323 K (50°C), σ_f , [N/m].
- Dynamic Viscosity Coefficient for different fuels at 323 (50°C) μ_f , [Pa·s].
- Diffusion factor at atmospheric condition, [m/s].
- Critical temperature of evaporation, [K].
- Saturated vapor pressure at critical temperature, [bar].
- Small temperature where Saturated vapor pressure is known, [K].
- Saturated vapor pressure at noted above small temperature, [bar].

8. DATA FOR GAS ENGINE.

If the engine has a prechamber, the prescambler dimensions are necessary:

- Length of connecting duct, L , [mm].
- Diameter of connecting duct, d , [mm].
- Volume of the prechamber, V , [cm³].
- Fraction of gas delivered into prechamber at every operating mode.
- Ignition timing for prechamber at every operating modes, [deg. BTDC].
- To estimate the prechamber wall temperature the drawing with cooling system is required.
- To estimate the effective flow cross section area of connecting prechamber duct, the nozzle drawing with dimensions is required.



Because the list of input data is so large, it is recommended to have the drawings of main engine parts as sources of these data:

- Engine cross section;
- Cylinder head cross section with intake and exhaust valves being visible;
- Valves and its seats with dimensions;
- Diagrams of valves lift as a function of crank angle;
- Piston cross section with piston bowl dimensions;
- Intake manifold;
- Exhaust manifold.
- Prechamber for prechamber gas engine.

The absence of some data or drawings is not a critical problem because the DIESEL-RK includes special tool: **Wizard of new project creation** intended for estimation of all necessary data using internal data base of engines design and typical relationships of the engine parts dimensions. This tool allows creation of correct data file and research in the condition of deficit of data.

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