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EFFECT OF TEMPERATURE ON VALVE SEALS WHEN OPERATING ON ALTERNATIVE FUELS

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ABSTRACT

The head of SI engine, in which are pressed intake and exhaust seat valves is one of the most complex part of the SI engine. There are stored in it intake and exhaust ports, spark plug, the timing mechanism and channels for cooling and lubrication. Much of the final form of this component also contributes its load, which is both thermal and mechanical. The biggest influence on deformation inserted seat valves has a temperature distribution in the cylinder head. These temperatures are influenced by many factors, including temperature and coolant flow, load and engine speed, which affect the combustion process and exhaust gas temperature (these factors in normal mode, the engine is constantly changing, therefore the thermal load valve seat is different). The paper describes the temperature measurement in hard to reach places in the cylinder head of the engine when operating on alternative fuel - namely butanol and a mixture of gasoline and compares the temperature on the valve seats when operating on alternative fuel and gasoline.

Keywords: butanol, SI engine, cylinder head, temperature, thermocouple, valve seats.

INTRODUCTION

The cylinder head of the automotive four-stroke engine is used to close the cylinder chamber and to create a system for exchanging the cylinder charge between work cycles. Construction of cylinder head depends on the engine type, the method of solving the timing device, the number and distribution valve, supply and exhaust ports, spark plug location, injectors, combustion chamber solution, a method of cooling the engine etc.

For trouble-free operation must be assured coolant supply in critical areas. The main supply is directed to the most critical point which is between the seat of the exhaust valve and injector, or between the plug and the valve seat together. Secondary supply is performed under the exhaust channel by promoting cooling of the exhaust valve seat. Engineers are trying to make seats cooling intake valves and exhaust around, causing more uniform distribution of temperature along the perimeter of seat and provides uniform deformation, which do not releasing valve seats. Priority is heat dissipation from the exhaust valve, as the most thermally burdened piece of the cylinder head (from the burning fuel mixture during the flue gas exhaust port). Reduce the heat load of the individual critical parts can be achieved by changing the fuel.

Currently there is ongoing interest in and commitment to the use of renewable fuels, motivated by the final supplies and price volatility of fossil fuels, energy security, and concern about climate change caused by fossil fuels. For road transport, which is attributed to the large share of total energy consumption and is almost dependent on reciprocating internal combustion engines burning fossil fuels, a search for renewable fuels is of paramount importance. Many different fuels were tested in both gasoline and diesel engines with varying degrees of technical and overall success. At present, it is added a small amount of ethanol and methyelester fatty acids into gasoline or diesel fuel.

Butanol is the fourth from the homologous series of alcohols, which can be produced from biomass as well as the ethanol, but in comparison with the ethanol has significant advantages such as higher energy density, lower absorption of humidity, less corrosive, less heat of evaporation, a higher flash point and lower pressure saturation vapor [1]. Interest in butanol is still relatively new and is formed, wherein the published results with relatively few gaps that need to be filled. Published work particularly hamper the operation at several operating points of the engine in the laboratory conditions under typical operating conditions corresponding to the driving [2], [3].

The paper is focused on the monitoring of temperatures at valve seats of the cylinder head of the engine when running on gasoline, butanol and a mixture of both fuels.

EXPERIMENT

Measurement was carried out on the Skoda engine, whose parameters are shown in Table 1. The engine was controlled by an electronic control unit with version control software SIMOS 11. Within the measurement was used as a fuel: n-butanol - butanol isomer straight chain and a hydroxyl group bonded to carbon atom extreme. This isomer has, with regard to production possibilities with regard to its properties, the highest potential as a fuel.

Table 1: The engine parameters specified for laboratory measurements.

Type	SI, 12 valves, DOHC
Bore X Stroke	76,5 X 86,9 mm
Number of cylinders	3
Swept volume of engine	1198 cm3
Maximum power	51 kW
Maximum torque	112 Nm
Compression ratio	10,5 ± 0,3:1
Cooling	water

The cylinder head of the engine was to measure the temperature at the valve seats compared to the standard engine cylinder head adjusted as follows - for shafts for ignition module has been increased in diameter from 23 mm to 26 mm, there is a bore of 8 holes with a diameter of 1.5 mm by the surfaces of the valve seat and the cylinder head of the engine to the shaft of the ignition module and two holes (a cylindrical unit) with a diameter of 2 mm from the exhaust pipe to the contact area of the valve seat and the cylinder head of the engine.

Thermocouples are in the cylinder head of the engine kept using steel tubes of small dimensions. For thermocouples (diameter 0.5 mm) running shaft ignition module are selected steel tube of internal diameter 0.67 mm and outer diameter 0.91 mm. The tubes are in the shaft for the ignition module fastened by means of two spacer rings with a height of 10 mm relative to each other rotated. From the side of the exhaust manifold thermocouples are guided by steel tubes having an outer diameter of 2 mm (diameter 0.75 mm thermocouples), which are in the cylinder head of the engine glued (line thermocouple passes through canals, using the product of Loctite 648). Fixation thermocouples is conducted using such compositions to ensure the power contact of the thermocouple on the valve seat. Fixation method is shown in the following figure.

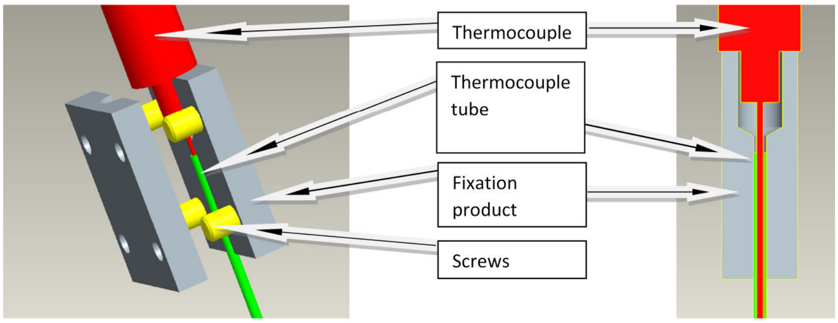

Fig. 1 - Views of fixation and ensuring positive contact thermocouple on the valve seat. On the left is a layout view 3D model, cut right across the assembly.

The main part of the measuring circuit is MGCplus data logger, enabling capture up to 2400 samples per second in an eight-channel amplifier design (4 amplifiers are used in eight-channel version). Working environment for measuring and recording data is created by software Catman Easy. From sensors, it is possible to record a sampling rate of 2400 samples per second, recording time is not limited.

For clarity and uniqueness of the measuring points are marked according to this key: label bearing the example. EXH3 V2, is marking the third measuring point on the second cylinder unit. The direction of the marking according to the clockwise direction, or left to right (f.e. thermocouples on intake side of the cylinder head).

Table 2 - The technique used for measurement and signal processing on the testing device.

Sensing data:	
MGCplus data logger (by Hottinger company) software Catman®Easy	
Used sensors	
Temperature	Thermocouple type E, diameter 0,5mm, lenght 200mm (Omega company) - 24 pieces
Temperature	Thermocouple type E, diameter 0,75mm, lenght 200mm (Omega company) - 6 pieces

RESULTS

Measurements were made while the RPM full load engine characteristics. The results of monitored operating characteristics of the engine are shown in the following graph. Assigning the angular position of the measured points around the circumference of the two seats of the exhaust valves when "develop" in the x-axis position of the two seats in the cylinder head shown in Fig. 6, wherein the indication is also the first and the second valve seat in each cylinder in relation to the position of the spark plug. Graphs of temperature trends around the perimeter of the first and second valve seat are drawn in the 'mirror' display, as shown by the arrows around the valve seats Fig. 4 and will be contained in the presentation because of the considerable contribution comprehensiveness. Designation of measuring points on the valve seats in each cylinder is shown in Fig. 7.

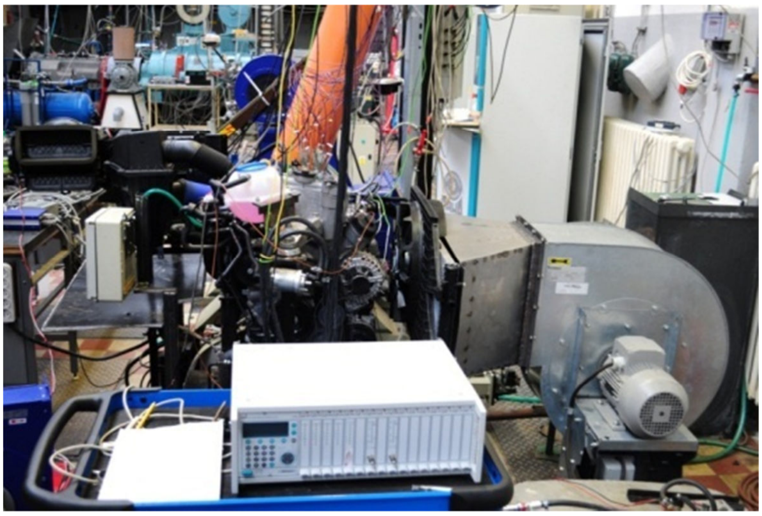

Fig. 2 - View of measuring stations.

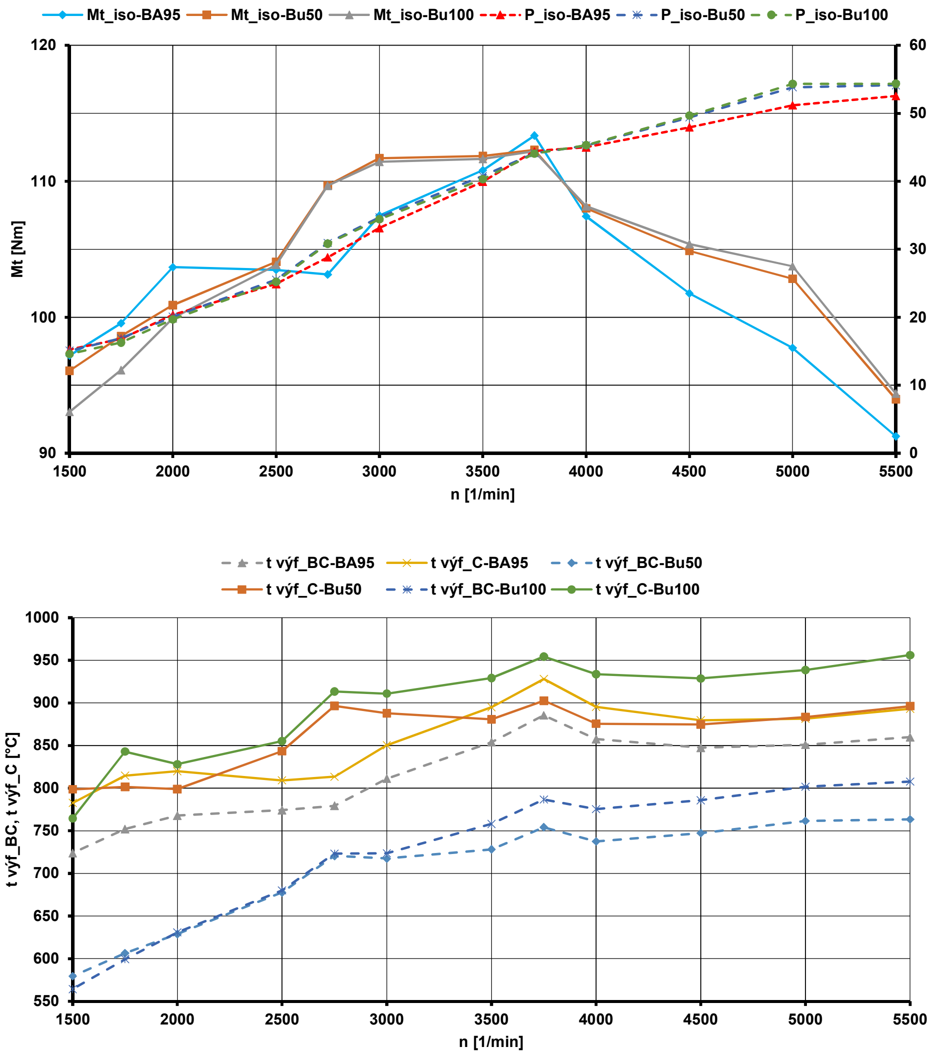

Fig. 3 & 4. - Performance parameters of the engine for RPM characteristic when operating on Gasoline (BA95), Butanol (Bu100) and Mixed fuel (Bu50).

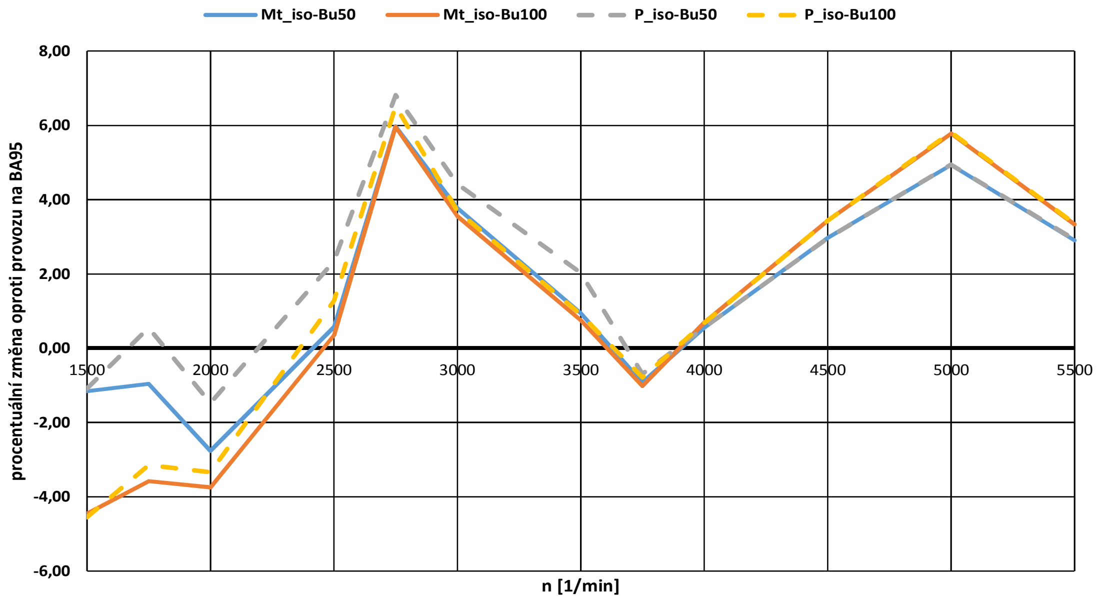

Fig. 5 - Percentage change in performance parameters of the engine when running on alternative fuel (butanol, a mixture of butanol and petrol) compared to petrol mode.

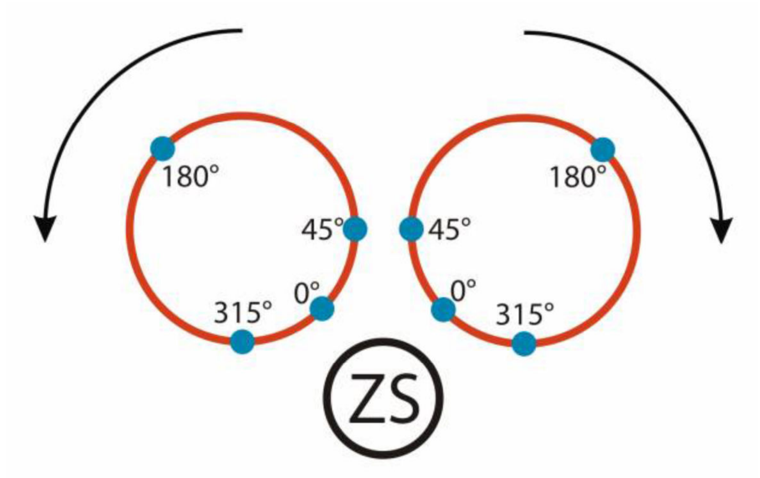

Fig. 6 - Scheme marking the angular position of measuring points along the circumference on the first and the second exhaust valves seats and the orientation of the first and the second exhaust valves seats to spark plug (ZS) position in the engine cylinder head.

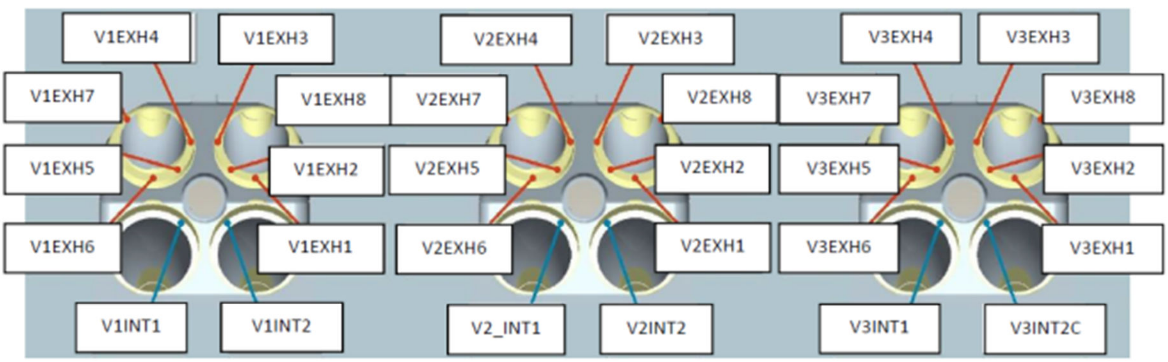

Fig. 7 - Identification of all measuring points and their position on the circumference of the valve seats in each cylinder.

Performance parameters of the engine to run on alternative fuel or blended exhibit changes, especially in torque measurement. The highest increase was measured torque at medium speed (measured at wide open throttle) for all fuels. In contrast, in the area of speed torque peak there was a slight decline. This can be attributed mainly to regulation and maps in the ECU - have not been adapted to run on alternative fuels - reflecting the fact that they practiced many drivers.

Range of measurements provides a large amount of experimental data on temperatures and especially the impact of various alternative fuel to temperatures in monitored locations exhaust valve seats. For temperatures at the valve seats is important (known) the observation that the temperature reduction is necessary to ensure an increase in the flow rate of coolant in the cylinder head parts, which are the highest measured temperature. The adjustment made to regulate the flow of coolant from the block to the cylinder head so far proved insufficient, with the result but we can assume that it will be possible in this way to seek appropriate solutions.

To optimize the thermal conditions at the valve seats can be used computational modeling of flow coolant inside (cooling) area of the cylinder head, possible adjustments should be assessed primarily in terms of the feasibility of interventions in the current structure of the block and cylinder head.

Table 3 - Temperature difference at each place during engine operation, Butanol 100.

n [1/min]	5500	5000	4500	4000	3750	3500	3000	2750	2500	2000	1750	1500
V1_EXH1	-5,5	-1,5	-1,6	-2,2	-2,8	-2,3	-1,9	-0,2	-2,5	-4,8	-4,9	-3,1
V1_EXH2	-6,3	-2,8	-2,8	-2,8	-3,1	-2,5	-2,1	0,0	-2,8	-5,6	-5,7	-4,0
V1_EXH3	-2,9	0,6	0,2	-0,2	-0,7	0,0	0,2	2,0	-0,8	-3,5	-3,6	-1,8
V1_EXH4	-1,8	1,8	1,4	0,9	0,3	1,0	1,2	3,1	0,1	-2,9	-3,0	-1,3
V1_EXH5	-5,0	-1,5	-1,5	-1,7	-2,2	-1,5	-0,9	1,0	-2,3	-5,4	-5,4	-3,6
V1_EXH6	-5,0	-1,3	-0,8	-1,2	-2,0	-1,4	-1,0	0,3	-2,5	-4,6	-5,0	-2,9
V1_EXH7	1,2	4,4	4,9	3,6	3,2	3,9	3,5	4,5	2,0	-0,6	-1,3	0,3
V1_EXH8	1,4	5,3	4,6	3,5	2,6	2,9	2,8	4,9	2,5	0,0	-0,4	1,1
V2_EXH1	-5,7	-1,8	-1,8	-1,6	-3,3	-2,1	-1,3	-0,2	-2,5	-4,8	-4,1	-2,6
V2_EXH2	-6,7	-2,8	-3,1	-2,4	-4,2	-2,7	-1,5	0,2	-2,6	-5,8	-5,0	-3,7
V2_EXH3	-2,5	1,3	0,3	0,1	-1,5	-0,5	0,5	2,2	-0,6	-3,8	-3,4	-1,9
V2_EXH4	-2,2	2,4	0,4	0,0	-1,4	-0,4	0,5	2,1	-0,7	-3,7	-3,3	-1,7
V2_EXH5	-5,8	-2,2	-2,2	-1,8	-3,5	-2,4	-1,3	0,7	-2,0	-5,3	-4,8	-3,4
V2_EXH6	-4,9	-1,0	-1,3	-1,4	-3,1	-2,1	-1,3	0,5	-1,9	-4,9	-4,5	-2,9
V2_EXH7	0,6	5,2	4,6	3,4	2,4	3,1	3,1	4,6	2,7	0,0	-0,3	1,3
V2_EXH8	1,8	6,0	4,8	4,1	2,2	3,1	3,3	4,3	2,6	-0,3	-0,5	0,9
V3_EXH1	-5,4	-2,7	-2,5	-3,3	-4,1	-3,7	-2,7	-1,4	-3,9	-5,9	-6,1	-4,6
V3_EXH2	-5,2	-2,5	-2,2	-2,9	-3,5	-3,1	-1,9	-0,4	-3,1	-5,4	-5,7	-4,5
V3_EXH3	-2,3	0,5	0,4	-0,5	-1,1	-0,6	0,4	2,2	-1,0	-3,7	-4,1	-3,1
V3_EXH4	-2,2	0,7	0,6	-0,3	-0,9	-0,4	0,6	2,4	-0,8	-3,5	-3,9	-2,9
V3_EXH5	-4,7	-1,9	-1,9	-2,5	-3,0	-2,5	-1,3	0,1	-2,5	-4,9	-5,3	-4,1
V3_EXH6	-4,7	-1,6	-1,3	-1,8	-2,5	-2,1	-1,1	0,2	-2,0	-4,2	-4,5	-3,2
V3_EXH7	0,9	4,6	4,2	3,1	2,1	2,6	2,6	3,7	1,5	-0,3	-0,5	1,0
V3_EXH8	0,2	4,1	3,1	1,8	0,9	1,4	2,2	3,4	1,7	-0,1	0,1	0,9
V1_INT1	-16,4	-13,4	-13,3	-13,2	-12,5	-12,0	-11,2	-8,0	-10,6	-11,6	-11,1	-8,7
V1_INT2	-18,1	-15,0	-14,9	-14,2	-13,2	-13,0	-11,8	-9,1	-11,2	-11,5	-11,2	-9,0
V2_INT1	-19,0	-16,1	-15,9	-14,1	-16,4	-14,9	-12,7	-9,8	-11,8	-12,6	-10,7	-8,6
V2_INT2	-18,1	-14,8	-14,9	-13,3	-15,4	-13,7	-11,9	-8,7	-10,7	-12,0	-10,1	-8,2
V3_INT1	-14,9	-13,0	-12,9	-13,6	-12,9	-12,9	-11,0	-8,4	-10,1	-11,3	-10,8	-8,8
V3_INT2	-14,7	-12,8	-11,9	-12,3	-12,2	-12,0	-9,7	-8,0	-10,3	-10,1	-9,9	-8,0

SUMMARY

Temperatures on the valve seats are clearly dependent on the performance of the engine. Temperatures around the perimeter of exhaust valve seats are highly variable. The greatest temperature differences at opposed locations along the circumference of the valve seat reach a size of approximately 60°C. Perpendicular to the plane of the greatest temperature differences are temperature differences at opposite points of the circumference to the valve seat approximately one third. This disparity thermal load exhaust valve seats causes a deformation of the ring-shaped seat with possible loss of tightness. Variation of temperature along the perimeter of the valve seat is determined by the design of the flow channels for the coolant inside of the cylinder head. The highest temperature on the valve seats are of course the seating (sealing) surface of the valve. The temperature gradient between the sealing seat surface and the bearing seat surface in the bore in the cylinder head together with an asymmetrical cross-section inserted saddles can then cause further deformation of the valve seat with a further potential for deterioration of tightness of the valve. Appropriate use of alternative fuels allows you to lower the temperature on each valve seats and thereby reduce deformation of the parts without any interference into the construction of either individual parts of the cylinder head of the engine or cooling system.

Temperature measurement of the valve seats is feasible. The results show that the temperature in the corresponding locations on each valve seat is caused by certain (but apparently irrelevant) changes state (i.e., temperature and pressure) and flow rate of the coolant cooling spaces in the cylinder head differ relatively little. The modified engine is now configured and ready for vehicle installation and measurements of real traffic.

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