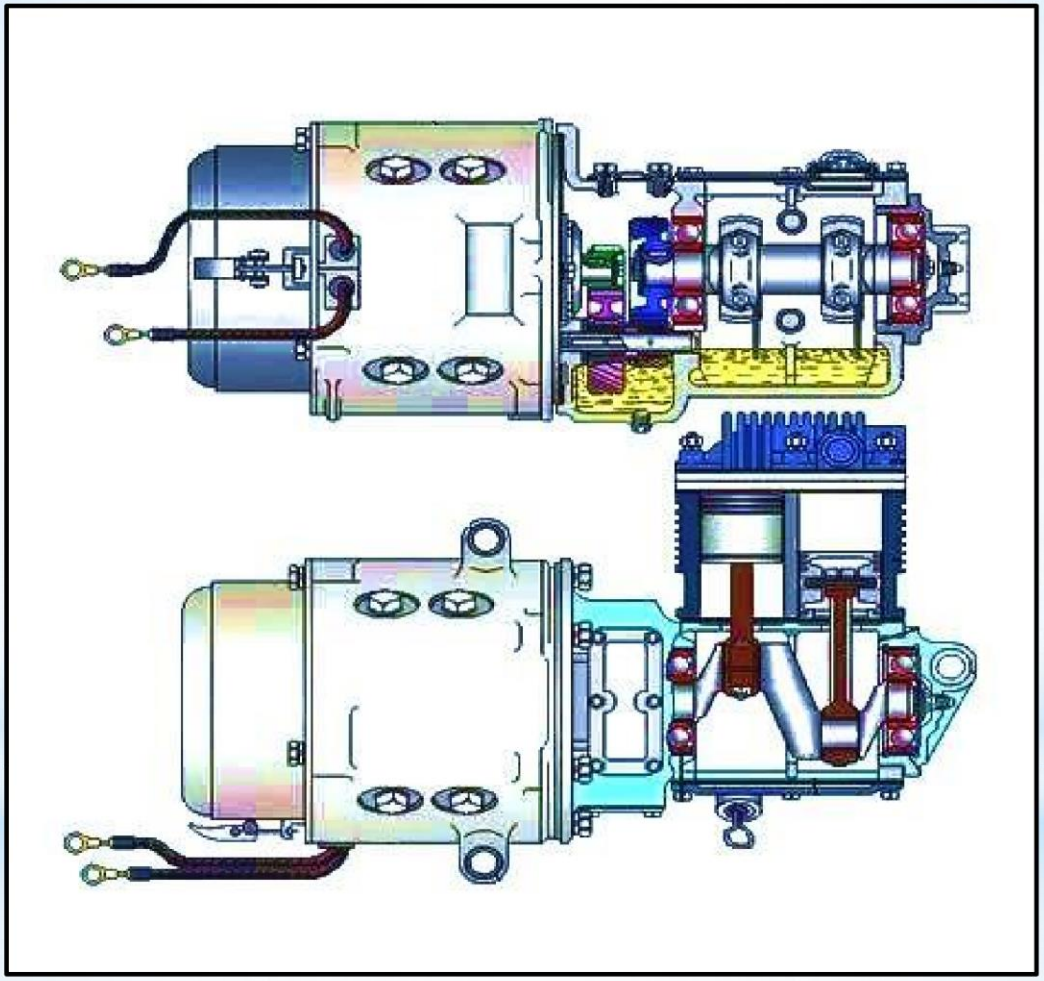


MODIFIC

ПРИДНІПРОВСЬКА ДЕРЖАВНА АКАДЕМІЯ БУДІВНИЦТВА ТА АРХІТЕКТУРИ

DNIPRO POLYTECHNIC 1899

Report on operational tests of non-disassembly engineering of friction surfaces. Air compressors, piston, with horizontal arrangement of cylinders

INTRODUCTION

In accordance with the program and testing methodology for friction surface engineering technology developed by LLC "MODIFIK""(LLC Mineral Special Project is the supplier), approved by Volodymyr Viktorovych Kobets, the director of the municipal enterprise "Dniprovskyi Elektrotransport" of the Dnipro City Council, operational tests were conducted from June 7, 2022, to August 9, 2022. These tests took place at the industrial facilities of trolleybus depots 1 and 2 of the municipal enterprise "Dniprovskyi Elektrotransport" of the Dnipro City Council. The tests focused on piston air compressors of type EK-4 and pneumatic systems of trolleybuses.

The objectives of the tests were to:

- Verify the efficiency of tribological treatment of piston air compressors type EK-4 using the friction surface engineering technology by LLC "MODIFIK""(LLC Mineral Special Project is the supplier).
- Demonstrate the restoration effect on the main operational characteristics of air compressors type EK-4 in a non-disassembly manner under real operating conditions of trolleybuses.

- Implem

Technology of continuous engineering of friction surfaces

The set of methods for extraction/synthesis, enrichment, activation, homogenization, separation, and processing of minerals, chemical compounds, reaction catalysts, and surfactants, manufacturing of fillers (lubricants), friction surface treatment, and other processes, works, and operations that alter the state and structure of materials (objects), products, and aggregates in the process of achieving new technical results with specified quality indicators without performing extensive disassembly and assembly operations.

During the treatment of friction surfaces of aggregates (units), depending on their design, technical condition, and operating conditions, lubrication systems, lubricants, and fuels are filled with solid lubricating technological fillers, or fillers are applied directly to the surfaces of the parts.

Solid lubricant fillers

ТУ У 20.5-42277844:2019 (змін.2022)

Solid lubricating fillers (NT) are in each case a unique composition of rocks and minerals, their chemical compounds with the addition of catalysts and surfactants.

The use of NT leads to a reduction in mechanical power losses, compensates for the lifespan of machines (mechanisms) and their resource-determining parts, and restores the operational characteristics of machines (mechanisms).

Test trolleybuses

Depot 1

1.ЮМЗ Т1Р2, інв. № 1064, буд.1993 р., КР 06.2017р., СР 05.2022р.
2.ЮМЗ Т2, інв. № 1511, буд.1995 р., КР 12.2019р.,
3.ЮМЗ Т2, інв. № 1508, буд. 2009 р., КР 03.2022р.
4.ЮМЗ Т2, інв. № 1516, буд.1995 р., КР 06.2022р.

Test trolleybuses

Depot 2

1. ЮМЗ Т2, інв. № 2533, буд. 2000 р., КР 08.2015р.
2. ЮМЗ Т1Р2, інв. № 2048, буд. 1992 р., КР 01.2019р.
3. ЮМЗ Т1Р2, інв. № 2071, буд. 1994 р., КР 03.2018р.

Air compressor

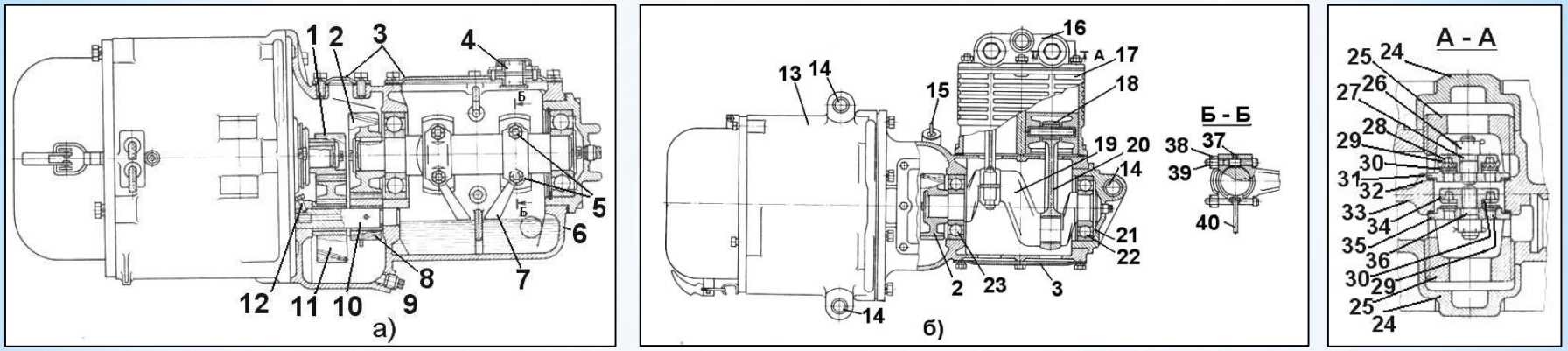


Figure 1. Compressor EK-4. Drawing.

a) - side view, b) - top view; A-A - valve box, section, 1, 2, 8, 11 - reducer gears, 3 - covers, 4 - soap, 5 - tightening bolts, 6 - casing, 7 - sprinkler, 9 - plug, 10 - eccentric shaft, 12 - locking bolt, 13 - electric motor, 14 - brackets for unit suspension, 15 - lubrication dipstick, 16 - valve box, 17 - cylinder block, 18 - piston, 19 - crankshaft, 20 - connecting rods, 21 - cover, 22, 23 - ball bearings, 24 - valve cover, 25 - valve cup, 26 - nut M8, 27 - stud, 28 - valve check ring, 29 - spring, 30 - valve plate, 31 - check valve seat, 32 - gasket, 33 - valve box body, 34 - suction valve clamp, suction valve seat, 36 - stud, 37 - adjusting gaskets, 38 - nut, 39 - connecting rod bolt, 40 - sprinkler.

Compressor 1.

EK-4 compressor consists of a housing (casing) 6, a block of two cylinders 17, a valve box (cylinder block head) 16, a connecting rod-crank mechanism, and a two-stage gearbox. The compressor housing 6, cylinder block 17, and valve box 16 are cast from gray cast iron. All compressor units and parts are mounted on the housing. The housing has windows for access to the compressor unit parts. These windows are covered with lids 3, under which cardboard gaskets are laid for sealing. The compressor housing is connected to the atmosphere through the sump 4.

The cylinder block is secured on studs screwed into the housing body. A pressboard gasket is placed between the housing and the cylinder block for sealing. The outer surface of the cylinder block is finned for better cooling. Within the cylinder block, two horizontal channels (cylinders) are machined and ground, serving as guides for the pistons. The cylinder surfaces are processed to a high precision class.

The valve box 16 is attached to the cylinder block 17 using studs, nuts, and spring split washers. A metal-asbestos gasket is placed between the valve box 16 and the cylinder block 17 for sealing.

The valve box houses two intake and two discharge valves (see Figure 1). Each valve consists of a seat with holes arranged in a circle and a central spindle that serves as a guide for the annular disc valve. The valve disc is pressed against the seat by a conical spring. The valve is positioned in the housing, which is sealed by a plug. The internal cavity of the valve box is divided by a partition separating the suction cavity from the discharge cavity. The suction cavity connects to the atmosphere through an air filter, while the discharge cavity connects to the air reservoirs via the compressor's check valve. The air filter is used to purify the intake air. The filtering element consists of fibrous stuffing mixed with grease.

The connecting rod-crank mechanism consists of a crankshaft 19 and two horizontal cylinders.

The mechanism comprises a crankshaft 19, two connecting rods 20, and two pistons 18. The crankshaft is double-cranked and rotates in two radial single-row ball bearings, 22 and 23. One bearing (23) is mounted in a bore of the end wall of the housing, while the other (22) is located in the bearing cap 21.

Compressor 2.

Connecting rods 20 are steel, stamped, with a double-T profile and two heads at the ends. One rod head is detachable, filled with babbitt, forming a sliding bearing for the connecting rod. The other head is non-detachable, and a bronze bushing is pressed into it, serving as a sliding bearing for the piston pin. Both parts of the detachable head are tightened on the connecting rod neck of the crankshaft with tightening bolts 5. After tightening the nuts on the bolts, they are pinned. A spray nozzle 7 is attached to one of the head bolts. There are lubrication channels at the base of the connecting rod heads through which the lubricant passes to the connecting rod neck of the crankshaft and the piston pin.

The piston 18 is made of gray cast iron. It is a cylindrical cup with four grooves—channels on its lateral surface where the piston cast iron rings are placed. The rings are split, and due to their elasticity, they snugly fit against the cylinder walls. The first two rings are compression rings, serving to seal between the piston and the cylinder walls, while the third and fourth rings are oil rings designed to remove excess oil from the cylinder walls.

In the guiding walls of the piston, there are two recesses with holes for installing the piston pin. The piston pin provides a hinge connection between the piston and the connecting rod. The axial movement of the pin is retained by steel retaining spring rings installed in the recesses of the piston recess.

The torque is transmitted from the electric motor to the compressor through a two-stage reducer with a gear ratio of 3.9. Two spur gears—1 and 2—are seated on keys, respectively, on the motor shaft and the crankshaft of the compressor, while the other two—8 and 11—rotate on bronze bushings of the eccentric axis 10..

The eccentric axis 10 has two bearing necks, one of which fits into a horizontal bore in the end wall of the housing, while the other fits into a bore in the flange. The eccentricity of the eccentric axis allows for adjusting the meshing of the reducer gears as tooth wear occurs during operation.

To secure the axis, it is locked with bolt 12. The eccentric axis is hollow with four through lubrication channels. Along these channels, the lubricant reaches the bronze bushings pressed into the gears, which freely rotate on this axis.

To lubricate the compressor, compressor oil of grade 12M is used in winter and grade 19T in summer. The oil is poured into the housing up to the upper level of the opening, after which the oil filling hole is closed with a screw plug. A hole is drilled in the plug for the oil dipstick 15, which is used to monitor the oil level. The mark on the lower end of the dipstick indicates the permissible oil fill level. When the crankshaft 19 rotates, the oil from the crankcase is picked up by the atomizer 7, creating an oil mist that settles on the working surfaces of the rubbing parts (cylinder walls, bearings), lubricating them. The reducer gears are partially submerged in oil and pick it up during compressor operation to lubricate the entire reducer. There is a drain hole in the lower part of the housing, which is closed with plug 9.

The flange of the compressor housing 6 is connected to the motor housing 13 with studs and nuts. When the compressor crankshaft rotates, the pistons connected to the shaft by connecting rods perform a reciprocating motion. As the piston moves away from the valve box, a reduced-pressure space is formed above the piston. Under the pressure of atmospheric air, the intake valve opens, and air is sucked in from the atmosphere through the air filter - this is the intake cycle. Both valves are closed at the bottom "dead" point of the piston. As the piston moves towards the valve box, the air in the cylinder is compressed. In this case, the intake valve closes due to the action of the spring and compressed air, while the discharge valve opens under the pressure of the compressed air, releasing the compressed air into the compression chamber of the valve box and further through the check valve into the reservoirs. If air is being sucked in from the atmosphere in the first cylinder, then in the second cylinder, the air is compressed and pumped into the reservoirs. Three brackets 14 are provided for suspending the unit.

Compressor 4.

Compressor EK – 4/EK – 4V. Main technical specifications:.

1) Number of compression stages – 1;
2) Number of cylinders – 2;
3) Cylinder arrangement – in-line, horizontal;
4) Nominal crankshaft rotation speed, rpm – 280;
5) Final discharge pressure, MPa – 0.8;
6) Cooling – air-cooled.

The compressor treatment is carried out by pouring the selected lubricating composition (250ml), consisting of a mixture of fillers (tribological treatment technology package) and standard compressor oil (12M;19T), into the unit's crankcase 1 through the dipstick hole 2 and starting the unit in depot conditions, in a repeated-short-term mode of electric drive operation (ED=50%), for a duration of ≤120 minutes.

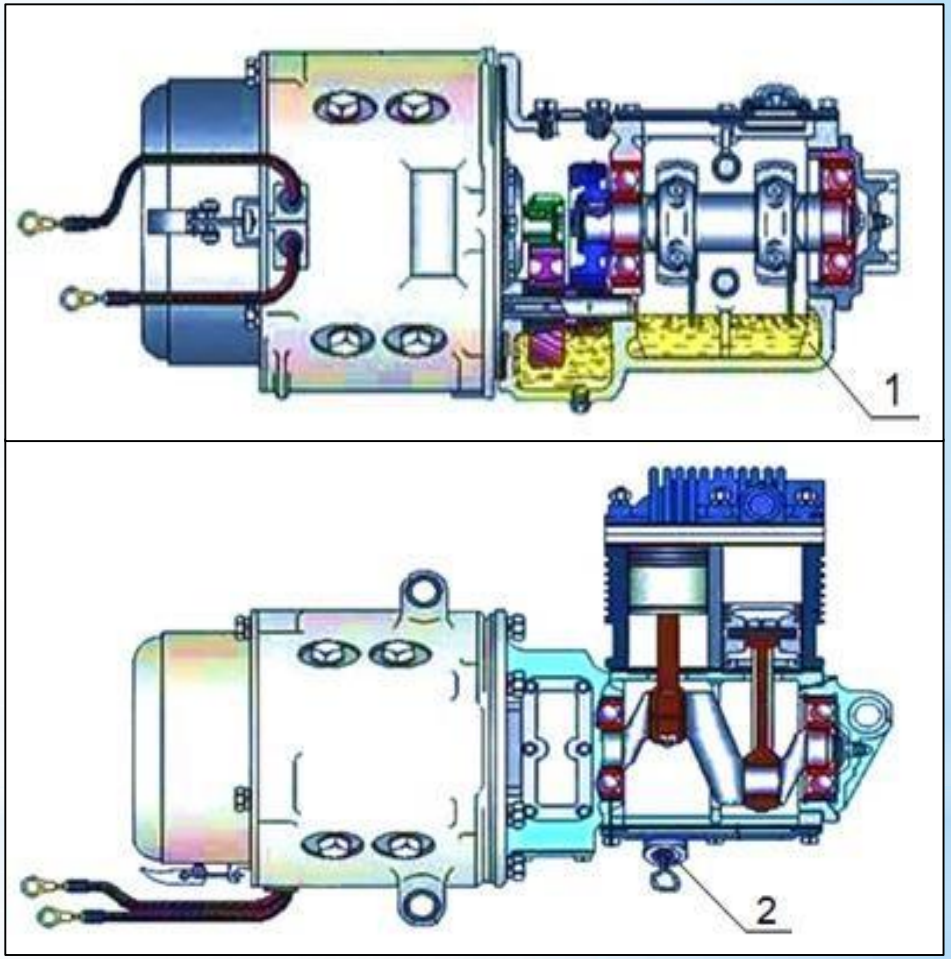
After the break-in period, in depot conditions, the trolleybus is immediately dispatched on its route and operates in regular mode for ≥ 4 hours.

The treatment is considered complete after the trolleybus has operated, in regular mode, for ≥ 28 motor hours or traveled 1000 km, whichever comes first.

A break in the trolleybus operation during the compressor treatment, lasting more than 48 hours (2 days), is not allowed.

In case of a forced interruption in the trolleybus operation, the compressor treatment should be repeated.

Concise compressor processing technique



1. Compressor crankcase;
2. Oil level dipstick hole.

Test data of trolley bus compressors that during the tests met the requirements of the "Test programs and methods"

№ з/п	Name of the indicator	Inventory number of the trolleybus			
		2533	2048	1508	1516
1	Start/Completion date of work	10.06/14.07	10.06/07.07	14.07/01.08	18.07/09.08
2	Operating time in the depot, min.	120	120	5	10
3	Interval of performance measurement, kgf/cm²	5,0-8,0	5,0-8,0	5,0-8,0	5,0-8,0
4	Performance of the unit before/after treatment, s	109/85	133/111,33	92/82,7	123/121,3
5	Noise load, before/after treatment, dB	111/98	115/115	98/90,3	91/88,7
6	Vibration level, before/after treatment, mm/s	7,9/6,7	8,0/6,6	4,8/4,7	6,4/6,8
7	Operating current of the electric drive, A	5,8-6,3	6,5-6,2	6,3-6,4	6,3-6,5
8	Characteristics of the construction of the cylinder-piston group of the compressor	--	--	--	2 м.з. .

9	Were repair works performed that affect the initial/final testing conditions and/or the sealing of the unit? Yes/No	No	No	No	No
10	Trolleybus mileage since compressor ring replacement, km	--	--	12972	4076
11	Change in unit productivity indicators, ±%	+22,02	+16,29	+10,11	+1,4
12	Change in unit noise load, ±%	-11,77	0	-7,86	-2,53
13	Change in unit vibration indicators, ±%	-15,19	-17,5	-2	-6,12