TECHNICAL AND COMMERCIAL OFFER

for the manufacture and supply of the equipment

Automated system for immersion ultrasonic testing of finished and semi-finished railway axles

AUTS Axle-4 OS-4

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1 DESIGNATION

Automated system for the ultrasonic immersion testing of finished railway axles AUTS Axle-4 OS-4 *(hereinafter – the System)* is designed for the automated ultrasonic testing of the railway axles in radial and axial directions to perform scanning and detect internal (inner) defects in accordance with the norms of the following regulatory documents: ISO 5948, EN 13261, M-101, BN 918275, DSTU 31334.

2 ASSORTMENT AND MAIN SPECIFICATIONS OF TEST OBJECT

2.1 Test objects that are subject to ultrasonic testing by the System are the railway axles manufactured in compliance with the following regulatory documents:

– ISO 5948 – Railway rolling stock material. Ultrasonic acceptance testing.

– EN 13261 – Railway applications. Wheelsets and bogies. Axles. Product requirements.

– M-101 – Association of American Railroads. Axles, Carbon Steel, Heat-Treated. Specifications.

– BN 918275 – Axles for motor wagons.

– DSTU 31334 – Axles for rolling stock of 1520 mm gauge railways. Specifications

2.2 Geometry and quality of the axle surfaces under test shall meet the requirements of EN 13261. Surface roughness of the wheel-seat parts and journals for any type of the axles shall be not more than Ra=25 μm.

2.3 Axles with no bolt holes can be inspected by the System. When testing the axles with the bolt holes in radial directions, the “dead” zone is increased as much as the depth of the bolt holes. Testing of axles with the bolt holes in axial direction is not possible.

2.4 Surface of the axles that are subjects to testing is a normal surface after a typical machining before the inspection that should not contain visual large contaminations (oil, dust dirt etc.) or adhered chips.

Configuration of the System to be supplied ensures testing of the railway axles of any sizes with the length of up to 2500 mm; and diameter of up to 300 mm.

3 COMPOSITION AND SUPPLY KIT OF THE SYSTEM

3.1 The System is composed of:

Ultrasonic Testing (UT) Station including:

– Base frame
– Immersion tank with axle holders and rotators
– Bearing console
– Linear movement modules (LMM)
– UT probe units
– Special-purpose UT probes for immersion testing
– Set of electronics
– Software
– Power equipment of the System
– Reference standards (calibration blocks) for setting and calibration of UT
– Water treatment system.

3.2 Supply kit

No.	*Part description*	*Quantity*
1	Computing complex (operator's control panel, industrial PC, monitor, keyboard, UPS unit, switch, B/W laser printer, ventilated industrial cabinet) with installed specializedsoftware	1 set
2	UT module OKO-24 UT*	6 +4 pcs.
3	Mechanical equipment including: 3.1 Bearing (base) frame of the System — 1 pc. 3.2 Radial UT module — 2 pcs. 3.3 Probe unit suspension for axial ultrasonic testing — 2 pcs. 3.4 Immersion liquid tank — 1 pc. 3.5 Right axle receiver — 1 pc. 3.6 Left axle receiver — 1 pc. 3.7 Non-driven spindle (right) — 1 pc. 3.8 Driven spindle (left) — 1 pc. 3.9 Replaceable centres — 1 set. 3.10 Reference block for setting up the receives wedges — 1 set. 3.11 Driven spindle moving device — 1 pc. 3.12 Electric drive for rotating the driven spindle — 1 pc. 3.13 Linear movement mechanism for moving the radial UT module — 1 pc. 3.14 Special-purpose UT probes (for radial scanning — 4 pcs; for axial scanning — 4 pcs.) 3.15 Pneumatic system for axle lifting/lowering	1 set
4	Power cabinet	1 pc.
5	Cabinet with OKO-24 UT* channels	
6	Automation control system based on Simatic S7 (Siemens) controller, with installed specialized software	1 set
7	Integrated water treatment system	1 set
8	Calibration block (axle)**	1 pc.
9	Connecting cables	1 set
10	Automation sensors	1 set
11	HVAC equipment	1 set
IMPORTANT! **a)** The Supplier undertakes under this TCO to manufacture the reference/calibration block from the Customer's material (workpieces), which can be further stipulated in a supply agreement for the System. **b)** Such workpieces shall be provided by the Customer non later than in 90 calendar days from the date of effecting the first prepayment by the Customer. **c)** Shipping costs associated with the delivery of workpieces from the Customer to the Supplier, and with the delivery of calibration blocks from the Supplier to the Customer, as well as metrological certification of calibration blocks are included into the price of this TCO. **d)** Final design & engineering documentation (drawings) for calibration blocks shall be mutually approved by the Customer and Supplier. After that, the Supplier shall start manufacturing the calibration blocks. **e)** Final design & engineering documentation for calibration blocks shall be mutually approved by the Customer and Supplier non later than in 90 calendar days from the date of effecting the first prepayment by the Customer.		
12	Spare parts	1 set
13	Operating documents	1 set

Remark:

** 6 OKO 24 UT modules – to comply with EN, BN, AAR M-101 requirements; 10 OKO 24 UT modules – to comply with DSTU 31334 requirements.*

***– Number (quantity) of the calibration blocks in a set, as well as steel grade of the workpieces shall be determined at the stage of Technical Task approval. The workpieces for calibration blocks shall be provided by the Customer at the stage of Detail Engineering.*

- Mechanical equipment which assures axles loading and unloading within the testing process line shall be provided by the Customer, so it is not included into the scope of this TCO.

– Supply kit of the System can be modified at the stage of Technical Task approval.

4 STRUCTURE, MAIN SPECIFICATIONS AND OPERATION PROCEDURE OF THE SYSTEM

4.1 Main specifications

4.1.1 The System represents a standalone non-destructive testing post and can be operated either as a mechanism integrated into process line of railway axles production or an independent UT station.

4.1.2 The System performs automated ultrasonic immersion testing to detect such defects as discontinuities and inhomogeneities as well as evaluate material structure in compliance with the requirements for the UT of axles stipulated in regulatory documents mentioned in chapter 2.1 of this TCO.

Metal structure evaluation is carried out by:

- the comparative method of the axles «scannability» from each end surface using the longitudinal waves in axial direction with the echo signal amplitude in a reference standard
- echo-shadow technique of testing from the cylindrical surface in radial direction by assessing the back wall echo attenuation.

Internal defects can be detected by pulse echo testing technique:

- from each end surface by longitudinal waves in axial direction
- from cylindrical surfaces by longitudinal waves in radial direction.

4.1.3 The assessment of the material structure is carried out by echo-shadow testing technique from the cylindrical surface of an axle in radial direction, based on the back wall echo attenuation by 6 dB or by 4 dB. The algorithms for estimating the back wall echo attenuation in the axle envisages an actual assessment of the attenuation value at each scanning point.

4.1.4 The System ensures assessment of the metal structure by the echo-shadow technique from both end surfaces of an axle in axial direction by the longitudinal waves by comparing the amplitude of the echo signal from the opposite end with the amplitude of the echo signal from the calibration reflector in the reference standard.

4.1.5 Ultrasonic inspection for the presence of internal defects is based on immersion pulse echo technique with normal ultrasound wave entry.

4.1.6 The System provides for the UT of axles at mutual relative movement of the UT probe unit and rotation of an axle non less than every 1 mm of the surface (by the spiral trajectory of scanning).

4.1.7 Ultrasonic inspection of axles in radial direction is performed during motion of the UT module in relation to the axle surface along the spiral trajectory with the inspection helix of 3 mm at the axle rotation speed of up to 1 revolution per second. Electronic synchronizing of the relative motion of the probe unit and axle is based on a steady rate of the angular rotation speed of the axle.

4.1.8 Ultrasonic inspection in axial direction is performed from both ends of the axle during motion of the axial probe units along the preset scanning path: in radial direction – with a step of not more than 5 mm/rev., longitudinal-and-transverse scanning with a crosswise step of not more than to 5 mm.

4.1.9 The number of probes in the probe units for radial scanning – 4 pcs.

4.1.10 The number of probes in the probe units for axial scanning from radial surface – 4 pcs.

4.1.11 The number of probes in the probe units for axial scanning from the end surface – 2 pcs.

4.1.12 The UT module with the supplied probes for radial scanning ensures detection of defects that are in terms of their reflection (echoing) properties equivalent to artificial flat-bottomed holes with the following diameters: 1 mm (recordable defect) and 2 mm (unacceptable defect) at 20-mm depth from the radial surface of the axle, and at least 3 mm through the entire depth of the axle in radial direction.

Table 1 — Test areas and defect sizes for radial scanning of axles

Test areas	Scanning range	Near dead zone, up to mm		Lateral dead zones (from the ends of test areas), up to	Equivalent diameter of artificial reflector	Note
Axle journal	Entire surface	5	5	(35-40) mm depending on the length of center hole	5 mm; 3 mm; 2 mm; *	Minimum non-scannable areas are present under line deflections
Pre-wheel-seat part	Entire surface	5	5	(5 - 7) mm	5 mm; 3 mm; 2 mm; *	
Wheel-seat part	Entire surface	5	5	(5 - 7) mm	5 mm; 3 mm; 2 mm; *	
Axle body	Entire surface	5	5	(5 - 7) mm	5 mm; 3 mm; 2 mm; *	
* - According to clause 8.8.9 of BN 918275 - Axles for motor wagons						

4.1.13 UT module supplied with probes for axial scanning ensures the detection of defects which are in terms of their reflection (echoing) properties equivalent to artificial flat-bottomed holes with the following diameters:

- 3.0 mm (equivalent area: 7.1 mm^2) at a depth up to 380 mm
- 6.0 mm (equivalent area: 28.3 mm^2) at a depth from 380 to 700 mm
- 9.0 mm (equivalent area: 63.6 mm^2) at a depth from 700700 to $l_3 / 2 + 50$ mm.

4.1.14 The System is capable of detecting flaws in the structural parts of an axle taking into account the ‘dead’ zones as stated in Table 1.

4.1.15 Accuracy of flaw depth evaluation is as good as ± 2 mm. Accuracy of the determination of the relative location of defects along the scanning path is no more than the operating width of UT probe.

4.1.16 Sensitivity of testing per each UT channel is set by means of DAC curves obtained on the reference standards with flat-bottomed reflectors according to drawing of the reference standard that is attached to this TCO.

4.1.17 Operation and maintenance of the System shall be carried out by one operator who has been certified to Level II as per EN 473, and trained by the System Developer in accordance with a training program to be approved by the Customer and Developer.

4.1.18 Maintenance of the System shall be carried out by the Customer's personnel in accordance with the Maintenance Manual that will be supplied to the Customer together with the System. As a part of this project, the Developer will provide training to instruct the operating and service personnel how to manage and service the System's equipment. The scope of routine maintenance of the System will include the condition monitoring of movable mechanical parts and their lubrication, periodic cleaning of the tank and filters within the water treatment unit, archiving of data based on testing results, as well as periodic maintenance of the computer equipment that complement the System.

4.1.19 Axles are rotated at the testing station by a rotating device at a adjustable speed from 10 to 60 rpm, with the following tolerances:

a) radial runout: ±0.5 mm

b) axial runout: ±0.5 mm.

4.1.20 Capacity (output) of the System is up to eight axles of one type/size per hour (for the largest axles), provided that the axles are rhythmically supplied to the testing station. Estimated time for testing one axle is 5 minutes.

Note: The above mentioned capacity is achieved by the set of equipment that is proposed in this offer, and can be modified if mutually agreed by the Customer and the Developer at the stage of Technical Task approval.

4.1.21 Operating air temperature limits for the System are from 1 to 40 °C; the maximum relative air humidity is 80 % at 25 °C. The System is typically installed in the workshops of industrial enterprises.

4.1.22 The System is vibration resistant.

4.1.23 Protection class of the System's electronics is IP 54.

4.1.24 The System is powered by the following utilities:

- Three-phase 50Hz 380V AC mains, installed electric power: max. 10 kVA
- Single-phase 50Hz 220V AC mains not connected with power equipment to energize the computing complex of the System; installed electric power: max. 2 kVA.
- Compressed air with at least 5 atm pressure; design flowrate of compressed air is max. 50 L/min.

4.1.25 Drinking water with the addition of anticorrosive additives is used as an immersion liquid for the System. The type and grade of the corrosion inhibitor should be agreed with the Developer with regards to the possibility of propagation and attenuation of ultrasonic waves with the specified frequencies in the liquid. Estimated flowrate of the liquid (due to entrainment on the axle surface) is 1.2 liters per each inspected axle. The replacement interval for the immersion liquid is determined by the time of its contamination, i.e. by the cleanliness of the inspected axles; volume of the immersion liquid in the System is 1000 liters.

Note: River water is allowed to be used as an immersion liquid, provided that it has been additionally purified from mechanical impurities and chemicals.

4.1.26 Average estimated service life of the System is 10 years.

4.2 Specifications of electronics and instrumentation of the System

- UT frequencies range is 1 to 10 MHz. The flaw detector provides the possibility of setting an individual operating frequency value from the specified range, for each channel (that is, the nominal UT frequency is set by the operator for each channel and is not changed during the testing). Nominal operating frequencies for UT channels are: 2.5; 4; 5 MHz.
- Absolute sensitivity is no less than 30 μV.
- Dynamic range of the amplifier is not less than 80 dB with a step of gain coefficient adjustment of 1 dB. The user can set up additional steps of gain adjustment from 1 to 10 dB with the time of at least 400 ns. The number of UT channels is 8.
- The flaw detection System provides for the possibility of creating cycle testing scheme having maximum cycles number of 30, a possibility to adjust the cycle duration with its minimum of 200 μs.
- Maximum probing pulse frequency is 2 kHz.
- Sweep range is up to 10000 mm in steel (It is possible to specify the “delay + testing range” within (0 – 10000) mm).
- Total number of measuring gates per each channel (or per each pulse sending) is up to 2.
- Number of actuators control inputs/outputs is at least 32. The parameters of actuators control system (such as axle rotation speed, linear motion speed of UT probes, etc.) can be changed by the user through the interface of the flaw detection unit.
- The flaw detection unit is powered by 220V 50 Hz AC mains. The unit has a data safety system which is enabled in case of short-time power interruptions. The installed electric power is up to 2 kVA.

4.3 Design of the System

The System represents a standalone independent station for immersion ultrasonic testing of railway axles. All parts of the System, except for the computing complex, are placed on the base frame. The computing complex and operator room are arranged next to the testing station (see attachments 2).

According to this TCO, loading and unloading of axles should be provided by the Customer.

During the immersion ultrasonic testing, the axles are entirely submerged into the immersion tank filled with water that also contains corrosion inhibitors.

The rotating mechanism (hereinafter – the rotator) performs the rotation of the tested axle with the preset speed at the test station. UT probes for immersion testing submerged into the immersion liquid move as programmed along the testing surface not contacting with it.

4.4 UT Station

Ultrasonic scanning of the axle’s test areas is performed by a group of special-purpose UT probes with normal wave entry, which are moved in radial and axial directions, using pulse echo technique.

The UT probes are structurally grouped into the probe units.

Each probe in the probe unit occupies a strictly defined position, determined by the design of the unit and providing a preset angle of entry of ultrasonic waves into the tested axle. The probe unit comprises mechanisms for positioning the probes with respect to the tested axle surfaces in order to ensure the correct position of the probe for a certain scanning scheme.

Linear movement modules for UT probe units are intended for positioning the units into a working position and automatic correction of such position (using electric drives) during testing, in order to ensure a stable distance between the probe work surface and surface of the tested part of an axle.

Electronics provide for acquiring and processing of the signals from the probes, as well as for controlling the System. The Computing Complex is based on an industrial-type computer. The signals from probes are received and processed by a dedicated UT module. Test results per each axle are displayed on the screen, then saved to the database, and can be further printed out in a form of B-scan for each UT channel, or in a tabular form. The scope and format of presenting test results should be agreed with the Customer at the stage of detail engineering.

If any of the test results is unacceptable, light and sound alarms are generated for the operator.

Operation of the System is supervised by specialized software that allows for automatic control of the mechanical parts of the System, as well as for collecting, processing and recording of the UT results.

4.5 Specialized software

4.5.1 The software package includes:

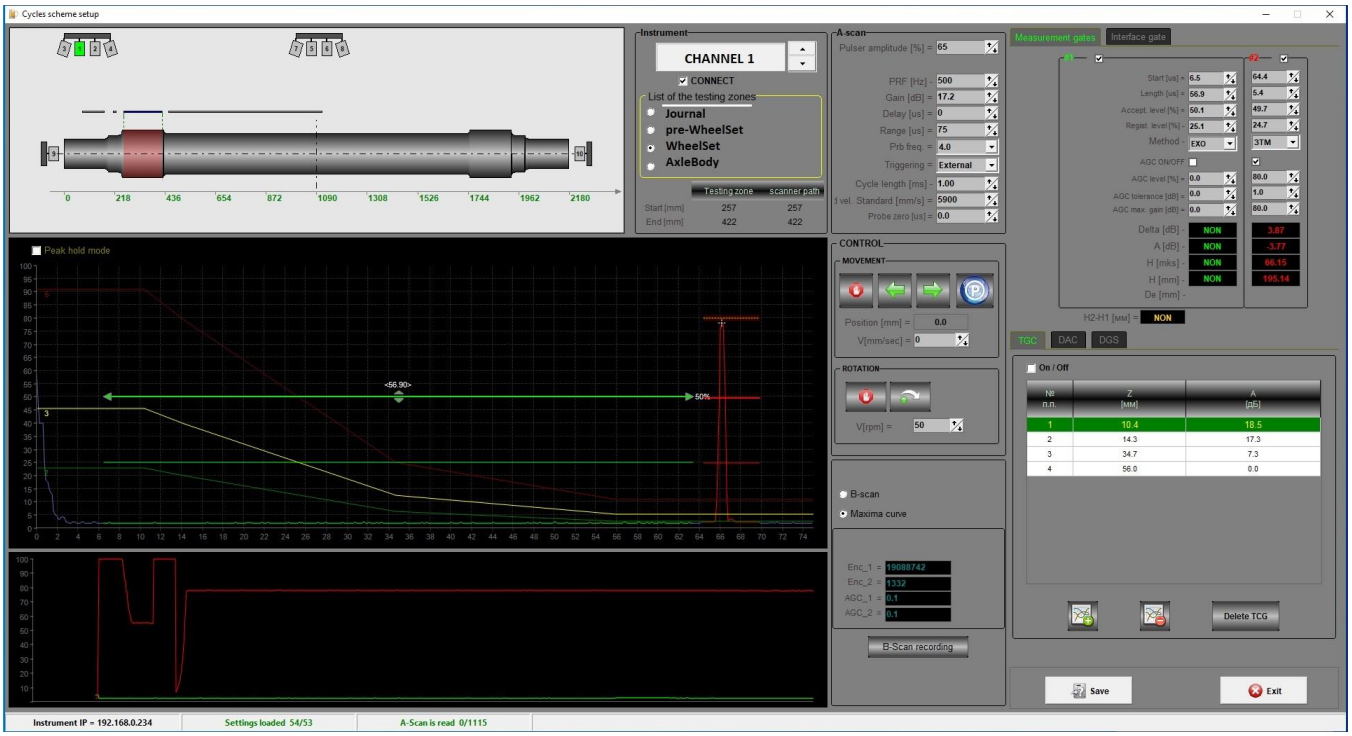
- actuators programmable control panel
- setup program
- testing program
- database
- test results viewing program.

4.5.2 Actuators programmable control panel

Actuators programmable control panel

This program allows to controlling the actuators and changing the parameters of their control system.

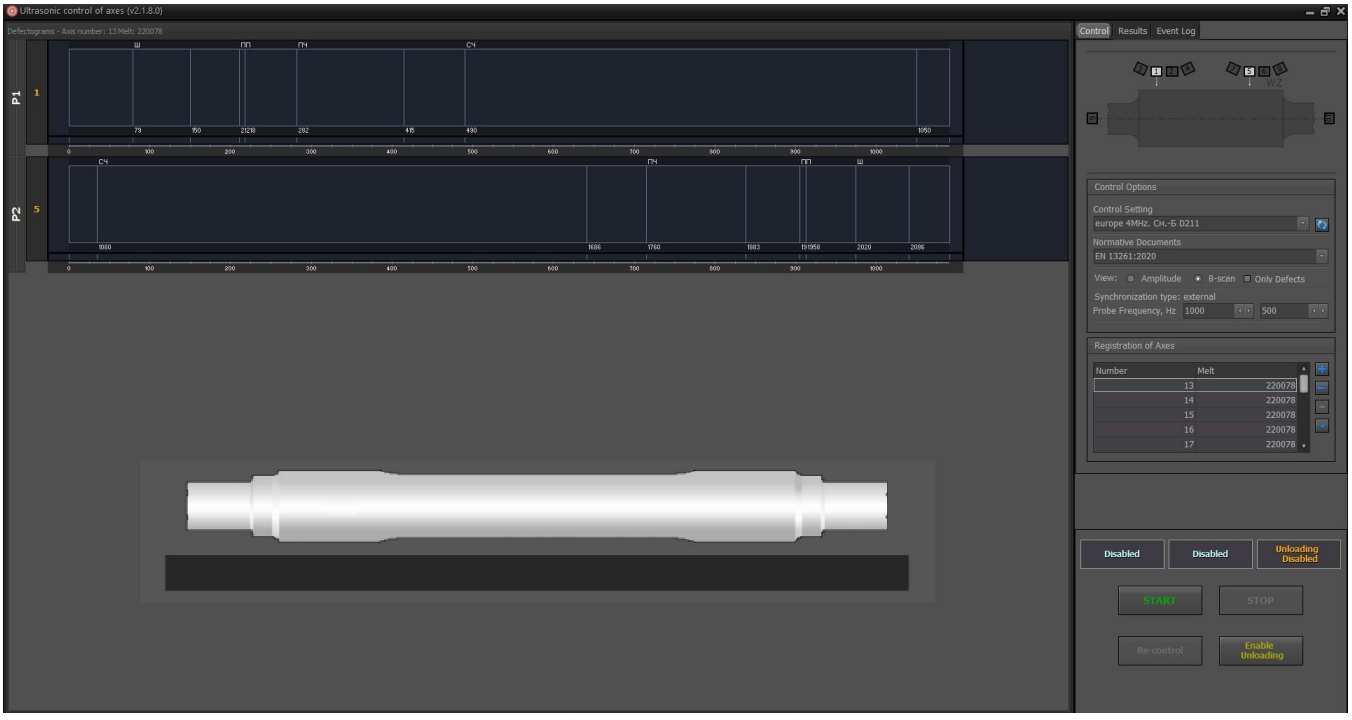
4.5.3 Setup program



System setup program

The setting of cycle scheme and each individual channel is performed via this program.

4.5.4 Testing program

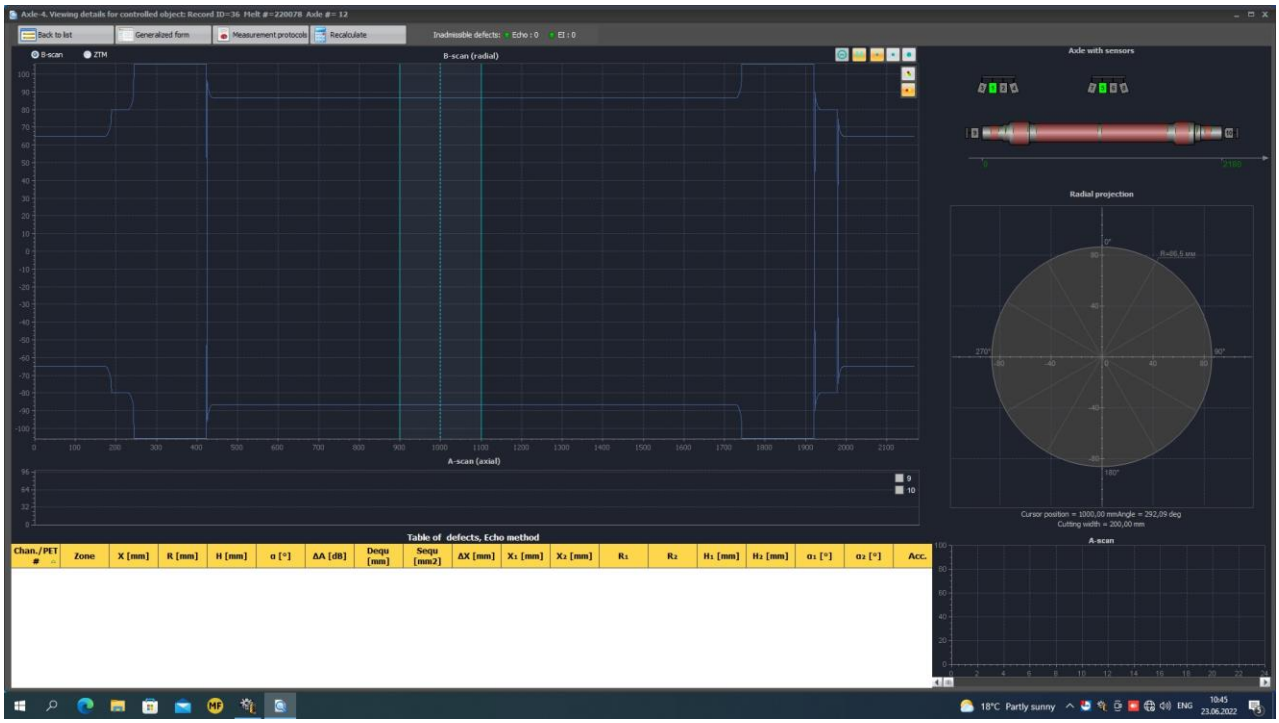


Testing program of the System

This program manages the testing process and takes a decision about the acceptability of the tested axle.

Database. Test results for each axle are recorded and stored in the database.

4.5.5 Test results viewing program



Test results viewing program

Test results viewing program enables to view the test results, perform the analysis of the received results, as well as print test reports. The test results are taken from the database. It is possible to view the test results on any computer connected to a local Ethernet network of the System.

5 ACCEPTANCE TEST PROCEDURE

5.1 The acceptance test procedure will be specified in a separate syllabus and methods document to be agreed with and approved by the Customer, based on the results of the System's engineering, manufacturing, installation and commissioning.

5.2 The following documents shall be agreed with and approved by the Customer:

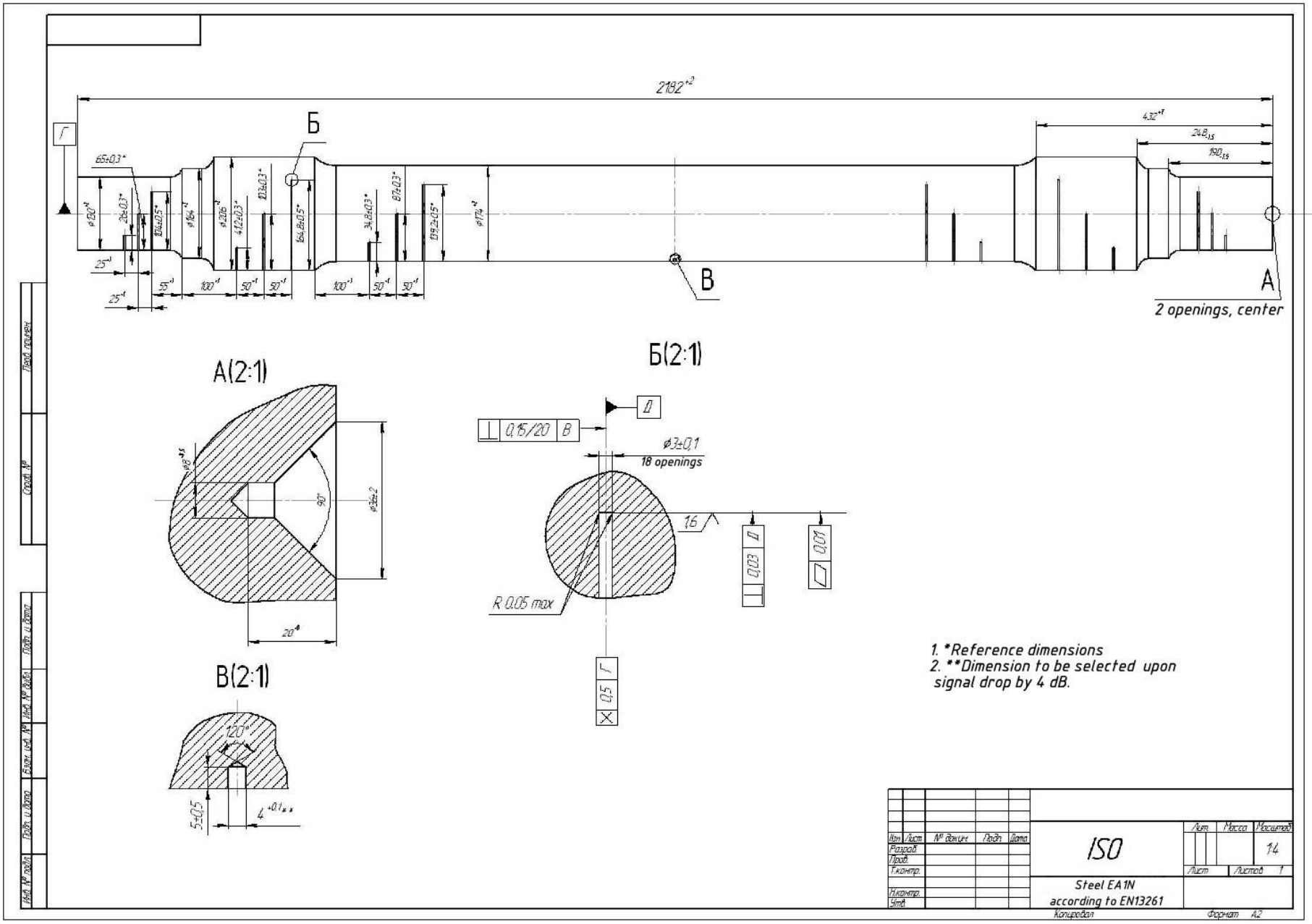
- technical task (specifications);
- acceptance test procedure (syllabus and methods).

6 LIST OF DOCUMENTS PROVIDED WITH THE SYSTEM

6.1. The list of documents to be submitted to the Customer is as follows:

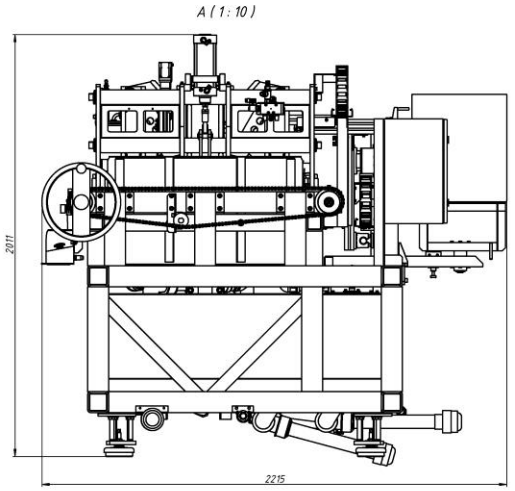
1. Operation Manual
2. Maintenance manual
3. Metrological calibration and certification procedure.
4. Engineering documents and drawings:
    - 4.1. General arrangement drawings and units with sectional views
    - 4.2. Datasheet of the equipment
    - 4.3. Layout of the equipment
    - 4.4. Drawings of non-standard & high-wear parts.
5. Schemes and descriptions of:
    - 5.1. Pneumatic system
    - 5.2. Electric and control systems
    - 5.3. Lubrication system
    - 5.4 Liquid circulation system.
6. Lists of:
    - 6.1. Spares and high-wear parts with indication of their service life.
    - 6.2. Lubricants with indication of their service life, recommended brands and product codes.
    - 6.3. Consumables with indication of their service life, recommended brands and product codes.
    - 6.4. Possible failures and troubleshooting procedures.
7. Soft copies of the documents and software on hard disc drives.

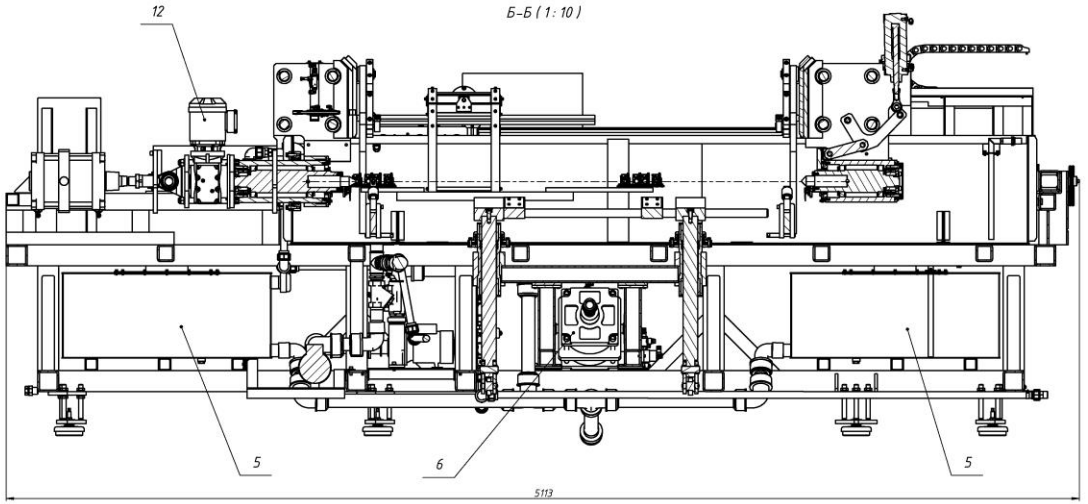
6.2. The above mentioned documents will be submitted to the Customer only after the commissioning and transfer of the System to the Customer, since they contain copyright and intellectual property rights.

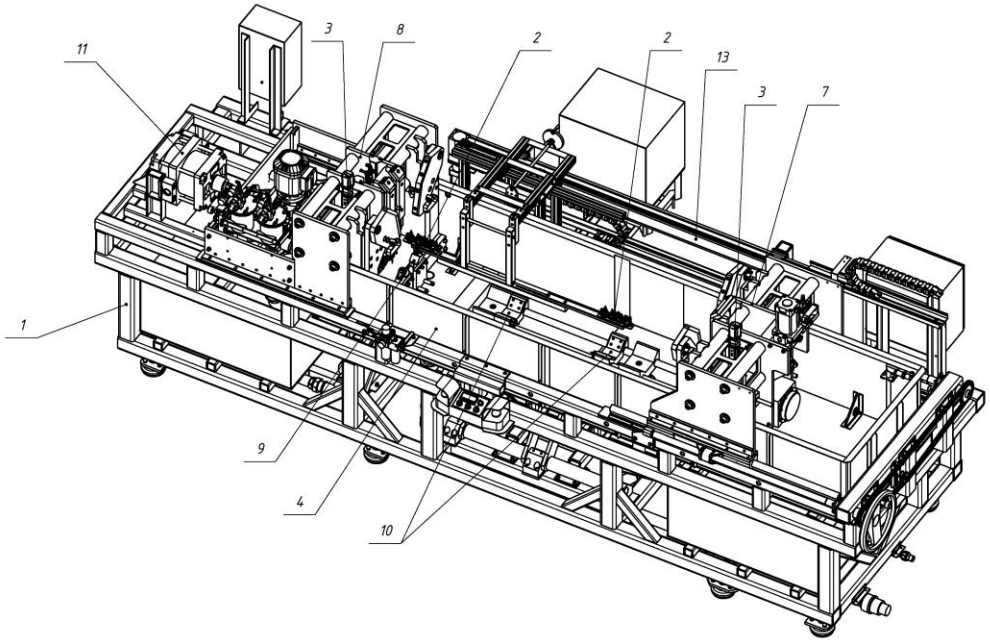


Reference standard of the Railway axle #2 (acc.to EN)

“AXLE-4” Automated system for ultrasonic testing of railway axles







1. Bearing (base) frame of the System
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