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Detonation thermal spraying process of metal-ceramic coating of the inner body of a regulating valve for maintenance of turbine condensate level in a deaerator for a nuclear power plant

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Abstract

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The objective of the research was to examine a process of metal-ceramic detonation spraying, technology and realization of the procedure and its features for the given component.
The work was commissioned by main process engineer Shvedov N. G.

This study was carried out at the Center of Scientific-Technical Service "Prometey". The information was gathered from internal documentation of the enterprise, manuals, literature and by interviewing process engineers.

As a result of this thesis the detonation coating process was investigated for a particular unit – the regulating valve. All the stages and requirements were presented. The results can be applied to any detonation coating case or surface treatment matter where complex approach is necessary.

Keywords: coating, valve, deposition, spraying, mixture, powder, assembly, component, aluminum oxide, spraying gun, surface, nozzle, plunger, process.

Table of contents

List of standards and normative documents

The given thesis includes references to following documents:

GOST 9.010-80 ESZKS. Compressed air for spraying of paintwork materials. Technical requirements. Methods of control.

GOST 12.1.003-83 Noise. General safety requirements.

GOST 12.4.008-84 Occupational safety standard system. Personal protective facilities. Determination procedure of field of vision.

GOST 12.4.009-83 Fire-fighting equipment for protection of units. General requirements. Placing and maintenance.

GOST 12.4.010-75 Personal protective facilities. Special gloves. Technical conditions.

GOST 12.4.028-76 Respirators. Technical conditions.

GOST 12.4.051-87 Ear defenders. General technical requirements and test methods.

GOST 1497-84 Metals. Methods of tension tests.

GOST 2768-84 Acetone technical. Specifications.

GOST 2789-73 Surface roughness. Parameters and characteristics.

GOST 2999-75 Metals and alloys. Vickers hardness test by diamond pyramid.

GOST 3134-78 White spirit. Technical conditions.

GOST 5457-75 Dissolved gaseous acetylene. Technical conditions.

GOST 5583-78 Technical and medical oxygen gas. Specifications.

GOST 9293-74 Gaseous and liquid nitrogen. Specifications.

GOST 9450-76 Measurements microhardness by diamond instruments indentation.

GOST 9722-97 Nickel powder . Specifications.

GOST11964-81 Technical cast iron and steel shot. Common technical requirements.

GOST 17433-80 Industries purity. Compressed air grades of contamination.

GOST 18898-89 Powder products. Methods for determination of density, oil content and porosity.

GOST 20448-90 Liquefied hydrocarbon fuel gases for domestic use. Specifications.

GOST 24484-80 Industrial purity. Compressed air. Methods of measuring contamination.

GOST 25706-83 Magnifiers. Types, basic parameters. General technical requirements.

GOST 27953-88 Detonation coatings. General requirements.

RD 5R.9537-80 Non-destructive control methods. Metal semi-finished products and constructions. Liquid-penetrant methods and surface quality control means.

GOST 12.4.021-75 Occupational safety standards system. Ventilation systems. General requirements.

GOST 17.0.0.01-76 System of standards in nature protection and improving utilization of nature resources. Fundamentals.

GOST 4960-75 Electrolytic copper powder. Specifications.

GOST 8136-85 Active alumina. Specifications.

TU 2-17-103-77 Bronze powders.

TU 6-09-4272-84 Chromium oxide (III) micropowder.

TU 14-22-113-97 Self-fluxing alloys powder.

TU 14-22-123-99 Metallide powders for protective coatings.

TU 14-22-153-01 Surfacing powder ПР-КХ-26В14С.

TU 14-22-119-98 Alloys for sputtering targets.

GOST 12.1.005-88 Occupational safety standards system. General sanitary requirements for working zone air.

GOST 18442-80 Nondestructive testing. Capillary methods. General requirements.

GOST 12.4.021-75 Occupational safety standards system. Ventilation systems. General requirements.

PB 03-576-03 Rules of arrangement and safe exploitation of vessels working under pressure.

1 Introduction

The objective of the thesis is to investigate the process of metal-ceramic detonation spraying of the regulating valve for maintenance of turbine condensate level in a deaerator on a nuclear power plant. The task for the process department of "Prometey" is to manufacture all the parts of the assembly and to choose technology and realization methods for metal ceramic coating of the body and the plunger of the valve. The shape peculiarity and service conditions of these parts require detailed consideration of process fulfilment.

In modern technology one of the most serious problems is the necessity to provide correspondence between the properties of materials used in mechanical engineering and increasingly hard conditions of their exploitation. Usually the most vulnerable point of units and elements is their surface which is exposed to multiple-factor loads. The improvement of properties of constructional materials is possible by strengthening them by coatings. The composite obtained through the operation allows combining the properties of centerpiece and coating materials. The quality of the “centerpiece-coating” composite is appreciably defined by mechanical properties of coating: adhesion and cohesion strength, micromechanical characteristics (microhardness, wear resistance, crack growth resistance and local strength), phase-structural condition, etc.

There are more than a hundred various technologies of coating. Gas-thermal methods are one of the most widely applicable (electric-arc, gas-flame, plasma, detonation, etc.). These methods have actively been becoming developed since the late 1950s when problems of machine element hardening, protective coating, new material and item production have been arising. In all gas-thermal methods high-temperature streams are used when coating materials are applied on a substrate. In these streams particles of coating material get warm and obtain high speed. The forming of the coating happens by interaction of these particles with the substrate on which the coating is applied. The significant advantage of gas-thermal methods of coating is the fact that they make possible to apply different materials of coatings, such as metals, alloys, oxides, borides, carbides, etc.

The analysis of classic gas-thermal methods of coating shows that the highest strengthening properties are provided by detonation coatings. For example, detonation coating is frequently used in various units and parts of marine and aircraft engineering (stern-tube glands of ship shafts, isolation valve seals, bearing units of pumps and compressors, turbine blades, baffle fins, etc. of aircraft gas-turbine engines). The coating enables to extend the working life of these components (3-10 times).

As an example, some of the most widely used materials for detonation coatings are aluminum oxide (Al_2O_3) and alloys and composites based on nickel. Aluminum oxide has enough good wearing qualities in a wide range of velocities and loads, high heat resistance, corrosion resistance. The main disadvantages of these coatings are low strength properties and low plasticity. Coatings based on nickel have greatly better mechanical properties but less wear resistance.

Nowadays the wide application of detonation coatings is suppressed by certain circumstances. Many components used in such sectors of production as petroleum industry, chemical industry, metallurgy, aviation and shipbuilding operate in high-level load conditions, which considerably exceed the maximum for typical detonation coating. At the same time, these parts are commonly exposed to unfavorable factors of environment (high temperature, corrosive medium, abrasive and erosive influence). For the increase of the durability of detonation coatings working in hard conditions it is necessary to improve their operating characteristics by combination of high indexes of different properties (adhesion strength, wear resistance, corrosion resistance, etc.). One of the most effective methods of solution is the development of combined and multi-layer coatings. (Blank, E.D. Research and creation of detonation coatings with increased performance properties. St.Petersburg Polytechnic University, 2003.)

1.1 The process of detonation spraying

Detonation deposition of coating is a form of gas-thermal spraying process. The formation of coating occurs due to interaction of the sprayed powder particles warmed and accelerated by detonation products of a mixture of gases with the treated substrate. Detonation or detonation combustion represents an explosion proceeding with a constant velocity. The velocity is maximal for given conditions and it exceeds velocity of sound in given mixture of gases. The acceleration and warming of particles happens because of their interaction with detonation products. Detonation combustion of gases allows achieving great power in a pulsed mode. During the detonation of equimolar oxy-acetylene mixture the detonation products reach velocity of 1280 m/s, temperature 4480°K and pressure about 4,0 MN/m^2. The interaction of sprayed particles with the detonation products enables to accelerate the particles to a speed up to 700 m/s and to melt them down.

Detonation thermal spraying has a number of advantages over other thermal spraying methods:

- detonation coatings have high adhesive and cohesive properties;
- during the process of spraying the temperature of a part is not high and usually does not exceed 40-60°C;
- the velocity and the temperature of sprayed particles are easy enough to regulate;

- the construction of detonation spraying equipment is uncomplicated, reliable in operation and has long service life;
- there are a few means to control the detonation spraying process in contrast to other methods of thermal spraying;

The main disadvantage of this method is the necessity of acoustic insulation because the process is accompanied by a high level of sound (about 140 dB).

As an example, some basic parameters of detonation coatings in comparison with other methods of thermal spraying are presented by Table 1. The material used for these coatings is WC-12Co powder which consists of tungsten carbide with cobalt. It is often applied for wear-resistant coating formation in aircraft industry. Properties of such coating strongly depend on the spraying technique, processing parameters and heat treatment. (Blank, E.D. Research and creation of detonation coatings with increased performance properties. St.Petersburg Polytechnic University, 2003.)

2 Technological process requirements

2.1 Generalities

Detonation coatings are deposited on the components made of cast iron, carbon steel corrosion-resistant steel, titanium, magnesium and aluminum alloys, bronze and brass. The technology of detonation coating deposition relates to welding technology and represents its relatively new field.

According to the purpose the detonation coatings are divisible into wear resistant, antifriction, friction, corrosion resistant, heat resistant, dielectric, erosion-resistant, heatproof, etc.

The formation of dense coatings (porosity < 1%) is realized by high-velocity flow of heated to liquid state particles of sprayed material. Heating and acceleration of particles is carried out in the stem of the spraying gun (See Figure 6) by interaction with detonation products. Spaying conditions, velocity of particles and nonoxidizing characteristics of detonation products exclude the possibility of oxidation of particles or component surfaces. (РД5.УЕИА, “Prometey”. Internal technical documentation.)

2.2 Safety requirement

Performing of detonation thermal spraying operation is accompanied by negative effect on workers of such dangerous industrial factors as:

- increased concentration of suspended fine-dispersed particles of sprayed powder in the air of working environment;
- the formation of combustion products of propane-butane-oxygen mixture;
- increased content of metal and abrasive dust in the air of working environment;
- increased noise level in the workplace;
- dangerous voltage value of electric circuit

Detonation coating deposition should be realized in a sealed box to avoid emissions and hazardous substance concentration (See Figure 2).

When organizing and executing of manufacturing method it is necessary to establish the process control and management system to guarantee the protection of workers and emergency shutdown (See Figures 3, 4).

The production area should be equipped with the ventilation system according to the standard (GOST 12.4.021 for Russia).

It is necessary to fit out the workplaces for degreasing by local ventilation systems if flammable liquids are in use. The quantity of such liquids should not exceed the demand.

The exploitation of gas-filled cylinders should correspond to general requirements of pressure vessels usage.

The pipes leading to equipment, hoses for electric wiring and gas supplement should be protected at the places where mechanical damages may occur.

The production area should be supplied with the fire-extinguishing system in conformity with the standard (GOST 12.4.009 for Russia).

The sound pressure level at operator's workplace should correspond to the standard (GOST 12.1.003 for Russia).

The spraying gun operators should be provided with working clothes in accordance with current standards.

If harmful factor levels at the workplace exceed the legitimate value it is necessary to use means of personal protection such as respirators (standard GOST 12.4.028 for Russia), ear protectors (standard GOST 12.4.051 for Russia) and safety glasses (standard GOST 12.4.008 for Russia).

Access to performance of technological process of detonation coating deposition is permitted only for the people who are not younger than 18 years who are medically examined and instructed about industrial safety rules. They should have passed certification of board of experts.

The service team of detonation spraying gun should have II skill category of professional safety. This category gives the right to maintain electrical equipment and to exploit gas cylinders.

The administration of a plant which organizes and performs detonation coating works according to the current guiding document must work out safety manuals for each profession or make necessary additions to actual instructions. These manuals/additions should be conformed and ratified in accordance with the established procedure. The administration should deliver the documents to workers and ensure the fulfilment of them.

Primary and secondary facilities and tools, protective devices, transport and hoisting devices, as well as safety methods should be represented in actual technological documentation. (РД5.УЕИА, "Prometey". Internal technical documentation.)

2.3 Requirements for sprayed components and applied materials

In accordance with the internal technical documentation РД5.УЕИА, "Prometey" the sprayed components and the materials applied should satisfy the following requirements:

- General requirements for construction and material of details should correspond to the standard (GOST 27953).
- Sprayed surface should not have any coatings, sharp edges, agnails, blisters and other discontinuities.
- The hardness of the surface on which the coating is deposited should be no more than 45 HRC.
- Sharp edges should have facets with the size of 2x45° or they should be rounded off to the desired radius of 2 mm.
- The parts ready for coating deposition should be dried out and heated to the temperature of at least 10°C.
- List of powder materials used for detonation spraying and their purposes is presented in Table 2.
- Detonation coating powder materials specified for the technological process should pass input quality control procedure to prove compliance with granulometric composition, physicochemical properties and storage conditions stated in product certificate.

2.4 List of abrasive materials and requirements for them

Jet-abrasive treatment is a polishing process which is based on liquid-abradant mixture flow. This flow is supplied on the component surface under pressure from the nozzle with a speed of 50 m/s and higher. The goal of such treatment is polishing, rust/ paint removal, stated roughness achievement, etc.

The abradant applied for jet-abrasive treatment should be dried and not polluted by oil, rust and other substances. The list of abrasive materials and requirements for them is shown in Table 3.

As an abrasive material abrasive grit of normal electrolytically produced corundum should be used, grades 12A, 13A, 14A, 15A (standard GOST 28818-90 for Russia).

In addition, silicon carbide is used for the treatment, grades 53C and 54C (standard GOST 26327-84 for Russia) with grain size 63H and 63 for surface hardness less than HRC40 and 80П, 80H, 100П and 100H for surface hardness

HRC40 (grain size standards: GOST 3647-80 for Russia; equivalent grain sizes F30, F24 and F20 correspondingly, regulated by ISO 8486 and new GOST 52381-2005;).

To activate the surface with hardness not exceeding HRC40 it is admissible to use steel shot with grain size 0,5 - 1,5 mm (standard GOST 11964-81 for Russia).

Metal abrasive material should not be used for preparation of components made of copper, copper alloys, titanium and aluminum alloys and other materials upon deposition of heat and corrosion resistant coatings.

For satisfactory quality assurance of surface preparation, it is necessary to execute periodic metal shot replacement and separation of crushed part in case of corundum or silicon carbide usage. (РД5.УЕИА, “Prometey”. Internal technical documentation.)

The average service life of abrasive materials during surface preparation process is presented in Table 4.

2.5 Gas requirements

The list below presents the substances which are used as the working gases:

- gaseous nitrogen according to the standard (GOST 9293 for Russia);
- gaseous oxygen according to the standard (GOST 5583 for Russia);
- technical acetylene according to the standard (GOST 5457 for Russia);
- propane-butane according to the standard (GOST 20448 for Russia);
- compressed air according to the standard (GOST 9.010 for Russia);

The compressed air used for component surface preparation and coating deposition should be purified of oil and moisture and it should comply with the requirements of standard (7 and 9 pollution classes by GOST 17433 for Russia). The equipment for air purification has to be chosen depending on purification rate. Methods of pollution measuring are regulated by the standard GOST 24484. (РД5.УЕИА, “Prometey”. Internal technical documentation.)

3 Description of components and coating material selection

The technical task for the process department of Center of Scientific-Technical Service "Prometey" was to manufacture the parts of regulating valve unit for maintenance of turbine condensate level in a deaerator for a nuclear power plant, to accomplish metal ceramic coating deposition and to create final assembly. Before the announcement of the task engineers of the design department executed all the calculations and material selection in accordance with conditions stated by the customer. Though, the responsibility for the decision of detonation coating material and choice of technological parameters rested with the process department.

The regulating valve adjusts the condensate level passing in the pipeline. This unit is located in the line of one of the most important piping systems so sustained performance of the whole nuclear station complex depends on it. Such a great importance makes high demands of designing and manufacturing engineering.

3.1 Working conditions

The list below shows the main parameters of working conditions of the valve stated by the customer:

- Actuating medium – condensate
- Design pressure P = 3,1 MPa (31 kgf/cm^2)
- Design temperature 120 °C
- Actuating medium temperature 120 °C
- Maximum pressure differential ΔP = 2,5 MPa (25 kgf/cm2)
- Nominal flow capacity Kv = 2550 m^3/h
- Flow capacity – linear
- Nominal actuating mechanism torque 1000Nm

The steam condensate is corrosive medium. Working conditions present considerable pressure loads and temperature impact. Moreover, the characteristics of the condensate imply the presence of small solid particles in it which may lead to fast wear of valve components. Even perfectly surface-treated metal (steel) is not able to withstand stated spectrum of loads. But working surfaces of such an important unit should be surely protected. Therefore the goal of metal ceramic spraying is to form a wear and corrosion resistant coating for surfaces exposed to abrasive effect.

3.2 Assembly and components of the unit

The total valve assembly consists of about 50 parts but most of them relate to actuating mechanism system (See Appendix 3). There are two parts subjected to coating deposition: the inner body of the valve and the plunger (See Figures 8 -17).

Both parts were manufactured from a series of components with the help of welding technology. The plunger was designed to be installed into the body of the valve with the possibility for it (plunger) to rotate (See Appendix 3). Rotation mechanism is based on plunger shafts and sockets in the cross and the cap of the valve.

The structure of the valve body includes ten components welded together (See Appendix 1):

1. Cross
2. T-Joint
3. Inlet branch pipe
4. Flange
5. Sleeve
6. Ring
7. Stiffening rib x2
8. Stiffening rib x2

Steam condensate enters the inlet branch pipe (Appendix 1, part 3) and flows around the sleeve (Appendix 1, part 5). There are two opposite inlet holes for passing of the condensate on both sides of the sleeve (See Figures 8, 9, 12). Suitably matched holes are situated on the plunger tube (Appendix 2, part 1; Figures 14, 15, 17;). The difference of the plunger holes is that they have slightly different shape and that every hole is divided across: in fact instead of cutting one hole two slots were produced on both sides of inner stiffening rib of the plunger (See Appendix 2; Figures 14, 15, 17;). It is possible to define geometrical correspondence between the holes of the sleeve and the plunger by looking through the assembly drawing (See Appendix 3), where the sleeve hole is presented by dotted rectangle in the center of main section view and the plunger holes are situated inside it.

The plunger rotates upon its axis inside the valve body with the help of actuating mechanism and depending on its position passes the condensate flow through the valve or stops it (If the holes coincide with each other the valve system lets the condensate go through the assembly).

The plunger consists of five welded parts (See Appendix 2):

1. Tube
2. Bottom
3. Shaft
4. Cross
5. Shaft

The total assembly is not designed to be hermetically sealed: the valve system should allow moderate leakage of the condensate. Moreover, a spiral groove with the depth of 1.75 mm (before coating) is turned on the surface of the plunger. This feature is designed to collect impurity particles from the condensate and to direct their travel (See Figures 14, 15).

As the result there are two surfaces of two welded joints which have to be sprayed: inner surface of the valve body (sleeve surface) and outer surface of the plunger (tube surface).

3.3 Sizes and materials of sprayed surfaces

In accordance with technological acts the valve body and the plunger were finished to 450,5H7(+ 0,063) and 448,5h7(- 0,063) correspondingly for coating deposition. The detonation coating thicknesses of both parts should be 0,22-0,25 mm.

Technical drawings of the parts give the following information about the final sizes after coating spraying:

- Inner valve body diameter: 450H7(+ 0,063)

- Outer plunger diameter: 449h7(- 0,063)

These sizes represent the final condition after finishing treatment of sprayed coatings. It means that the maximum valve body inner diameter is 450,063 mm and the minimum is equal to basic size (450 mm). The maximum shaft diameter is equal to the basic size of 449 mm and the minimum is 448,937 mm. Hence there is at least 1 mm gap between parts left for small leakage.

Materials:

The sleeve of the valve is made of steel 09Г2С. Steel grade 09Г2С is construction low alloy steel for welded structures. It is widely used for pipe production.

- Temperature range: -70…+450 °C for exploitation under pressure load.
- Weldability: not limited
- Hardness: depends on terms of delivery
- European analogs: 13Mn6, 9MnSi

The plunger tube is made of steel 15ГС. Steel grade 15ГС presents construction low-alloy steel for welding applications. The steel finds a use for pipeline structures.

- Temperature range: -40…+475 °C for exploitation under pressure load.
- Weldability: not limited
- Hardness: depends on terms of delivery

Both steel grades have hardness lower than 45 HRC (not hardened condition purchased) and unlimited weldability. Piping systems are primary field of their usage. It is possible to state that they are completely appropriate for detonation coating deposition under given technical conditions.

3.4 Coating material selection

According to the information mentioned in Paragraph 3.1 the coating should be wear and corrosion resistant. Furthermore, ability to withstand great abrasive effect and temperature influence is required.

After comprehensive consideration the decision to choose aluminum oxide based metal-ceramic mixture A12O3+50%ПРХ 16С3Р3 (See Tables 2, 6) was made. The coating produced by this powder shows the greatest hardness and perfect adhesion strength (in comparison with other powders applied on “Prometey”). As the spraying gun “Prometey”, some other powders shown in the tables and technological conditions for them this mixture is own creation of Central Research Institute of Structural Materials "Prometey" (Main partner of Center of Scientific-Technical Service "Prometey". Both companies were departments of one national enterprise in Soviet times.)

3.4.1 Composite detonation coatings on the basis of aluminum oxide

Composite detonation coatings on the basis of aluminum oxide find a wide use for different friction units of machines and mechanisms, especially in cases of significantly loaded components. The reason is that these coatings show high wear and corrosion resistant properties. At the same time, the significant disadvantage of the coatings is relatively low strength property rate.

Central Research Institute of Structural Materials “Prometey” carried out a research of development of two-component composite detonation coatings on the basis of aluminum oxide. The goal of the research was to improve the strength properties of composite coatings by creation of metal-ceramic coatings with certain proportion of metal component: bronze БрОК 4-3 and nickel alloy ПРХ16С3Р3.

Research methods and materials

Coating deposition was executed on spraying gun “Prometey” with tube diameter of 30 mm. Propane-butane-oxygen mixture was used as the working gas. Coating was deposited on samples made of low-carbon plain steel. Powder composition consisted of aluminum oxide Al_2O_3 (fraction 20-53 μm) with bronze БрОК 4-3 (fraction up to 53 μm) or nickel alloy ПРХ16С3Р3 (fraction up to 53 μm).

The following mixtures were prepared in «Drunken barrel» mixing machine for coating deposition: Al_2O_3 + 30% БрОК 4-3 and Al_2O_3 + 50% ПРХ16С3Р3 (weight).

Before coating deposition the samples were subjected to jet-abrasive treatment. Corundum with fraction of 1200 μm was used for the operation.

X-ray diffraction analysis was performed on the unit DRON-3. Adhesion strength was defined with the help of adhesion samples with pin diameter of 2 mm. Microhardness of coatings and crack resistance K_{1c} was determined by Evans method with the help of PMT-3 unit.

Evans method of crack resistance determination requires quite a simple equipment and presents quickness of result receiving. According to this method crack resistance is defined by the length of radial cracks forming in fragile materials from corners of Vickers indicator print. Formula 1 below shows semi-empirical dependence of radial cracks length on crack resistance and hardness:

$K_{1c} = 0{,}028Ha\frac{1}{2}\left(\frac{E}{H}\right)0{,}5\left(\frac{C}{a}\right) - 1{,}5$ Formula 1.

where H – Vickers hardness;

E – modulus of elastic;

C – half-length of radial cracks;

a – half-length of indicator print diagonal;

K_{1c} – critical coefficient of stresses intensity, crack resistance characteristics;

The results of the research are presented in Table 5.

X-ray diffraction analysis indicated that in the initial state almost 100 per cent of aluminum oxide consisted of α-phase. The coating analysis shows 93-94 per cent of nonequilibrium γ-phase, 6-5 per cent of δ- and θ-phase, as well as small amount of α-phase. This fact announced that when forming the coating incomplete phase transformation happens on principle $\gamma \rightarrow \delta \rightarrow \theta \rightarrow \alpha$. Small amounts of α-phase apparently demonstrated that it was residual initial α-phase. Solid solutions of nickel and zinc in copper, small content of copper and tin intermetalloid and small amount of nickel and silicon oxides were detected in metal ceramic coatings.

The research showed considerable increase of micromechanical properties and abrasive wear resistance of composite detonation coatings. Hardness increase was caused by dispersion hardening effect of near-lamellar secondary phase formation in oxide matrix as well as by partial dissolution of secondary components in phases of aluminum oxide. Service properties of such coatings are defined by optimal combination of high hardness index, adhesion strength and considerable wear and crack resistance. Mixture of aluminum oxide and nickel alloy ПРХ16С3Р3 was marked as preferable. (Blank E.D., Slepnev V.N., Galeev I.M., Topolyanskiy P.A. Composite detonation coatings based on aluminum oxide. Central Research Institute of Structural Materials “Prometey”, 2008.)

4 Technological process of detonation coating deposition

The technological process of detonation thermal spaying includes the following stages:

- sprayed surface preparation;
- preparation of powders and their mixtures;
- coating deposition;
- intermediate control of quality and dimensions of coatings;
- final quality and dimension control of coatings;

4.1 Preparation of sprayed surfaces

4.1.1 General instructions

A. Surfaces of components liable to coating deposition have to be thoroughly cleaned and washed of oil, dirt and rust with the help of hair or metal brushes and white spirit (standard GOST 3134 for Russia) or acetone (standard GOST 2768 for Russia). Adjoining surfaces in the area of 50 mm and oil polluted surfaces are liable for cleaning and washing too.
B. Component surfaces which are prepared to be sprayed have to pass jet-abrasive treatment to achieve roughness. Roughness parameter has to be not less than R_z = 20 μm (standard GOST 2789).
C. Conditions for jet-abrasive treatment are presented in Table 3.

D. After the treatment the component surface should be blown off by compressed air with pollution class not lower than the 2nd according to standard (GOST 17433 for Russia).
E. The component after surface preparation should be contained in location at the temperature not lower than +10°C and relative humidity not higher than 70%. In the time of transportation and installation of parts cotton gloves are used according to standard (GOST 12.4.010 for Russia).
F. A time break between component surface preparation and coating deposition should not exceed 3 hours.

4.1.2 Surface preparation

Manufacturing of sprayed components was realized taking into account forthcoming coating spraying (Paragraph 2.3) therefore any special treatment or finishing operations were not required. There were no agnails, sharp edges, blisters on the surfaces.

The surfaces were checked and then cleaned of any pollutants with the help of cloth, hair brush and white spirit. In addition all the adjoining areas of both surfaces were cleaned in accordance with instructions.

After cleaning procedure both part surfaces passed jet-abrasive treatment. Electrolytically produced corundum with fraction diameter of 1200 μm was used. Treatment parameters were set to average value (See Table 3). For valve body where direct treatment is not possible because of the part geometry the angles of treatment did not fall outside the limits. After jet-abrasive process the roughness parameter was measured by profilometer. The required roughness was achieved.

Conditions of pre-coating maintenance corresponded with points E and F of Paragraph 4.1.1.

4.2 Preparation of powders and mixtures

4.2.1 General instructions

Before use of metal powders and their mixtures, metal alloys and composite powders it is necessary to dry them. Ceramic powders and their mixtures should be ignited.

Drying of powders has to be realized in a desiccator at a temperature of 130 - 150°C within 2-3 hours on trays made of stainless steel with recurring stirrings. The thickness of tray filling should not exceed 40 mm.

Igniting of powders should be done in electric furnace at a temperature of 360 - 450°C within 2-3 hours on stainless steel trays. The thickness of tray filling should not exceed 20 mm.

For powder mixtures the «Drunken barrel» mixing machine should be used.

Powder prepared for spraying of items during the working shift should be stored in a desiccator at a temperature of (50±5)°C. Filling of the spraying gun feeder is carried out directly from the desiccator. (РД5.УЕИА, “Prometey”. Internal technical documentation.)

4.2.2 Mixture preparation

At first the quality control was carried out for both components of the mixture. Then the «Drunken barrel» mixing machine was proportionally filled up by the powders. After the mixing achieved powder substance was placed on trays and installed into the desiccator for 2 hours drying in the temperature of 145°C. Filling thickness control was conducted. The last step of preparation – mixture ignition, was realized with the following parameters:

- Filling thickness – 10-15 mm
- Temperature – 420°C
- Time – 2.5 hours

The procedures of mixture and surface preparation were realized concurrently for the compliance with the time gap instructions.

4.3 Experiment

In accordance with Paragraph 5.1 the samples of identical materials should pass the adhesion strength pin-testing. Generally, this procedure is realized only for new coating compositions. But the regulating valve unit is the part of great importance. Furthermore, the shape peculiarity of the valve body gives only angular access for spraying gun nozzle for coating deposition on its inner surface (sleeve) which might affect its properties.

Therefore two rounded pin samples were produced: one made of steel grade 09Г2С (valve sleeve material) and another one made of steel grade 15ГС (plunger tube material). The construction of the samples is shown on Figure 1.

Instructions for the test:

Every sample consists of three elements: a pin, a screw and a washer. The pin and the washer are manufactured of the corresponding steel grades. The main point of the manufacturing is to produce the hole the internal shape of which would be identical with the shape of the pin. After the installation of the pin inside the washer their face surfaces should completely coincide with each other without any gaps forming visually unbroken surface. (РД5.УЕИА, "Prometey". Internal technical documentation.)

1. The surface of the sample should pass jet-abrasive treatment in accordance with technological process (See Table 3).
2. The sample should be disassembled and cleaned of abrasive dust.
3. The assembly of the cleaned sample should be carefully realized to achieve visually unified surface produced by pin and washer face surfaces (See Figure 1).
4. Coating deposition has to be sprayed on the assembly according to technological process (See Table 6).
5. The adhesion strength of sample unit is defined by Formula 2 below:

$G_{ad} = \frac{P}{\pi r^2}$ Formula 2.

Where G_{ad} – calculated adhesion strength, Pa (kgf/mm^2);

P – tension, N (kgf);

r – pin end radius;

π =3,14

Results:

- The sample made of steel grade 09Г2С was sprayed at critical angle of 45 ° - the minimum angle allowed. The sample test indicated the value of adhesion strength of 77,2 MPa. The value exceeds the minimum requirements.
- The sample made of steel grade 15ГС was sprayed at the angle of 75°. The sample test indicated the value of adhesion strength of 83,7 MPa. The value exceeds the minimum requirements too.

The surface hardness requirement minimum demand was 10000 MPa for both elements. After a series of hardness tests on the surfaces of the components it was established that the hardness parameters exceeded the minimum value in both cases.

The samples were cleaned of the coating to repeat the test after the coating deposition.

4.4 Coating deposition

The process of coating deposition is regulated by technological certificates of “Prometey” company.

For coating deposition gas mixture of oxygen and propane-butane (acetylene) is used. For mixture thinning and powder transportation compressed air is used. The properties of the detonation coatings are presented in Table 6.

The angle between the spraying gun stem axle and sprayed surface should be within the limits of 60 - 90°, in narrow conditions – not less than 45° ± 5°.

Because of the geometry of the body of the valve the stem of the spraying gun was dismantled, carried out and installed on the support to achieve suitable angle of spraying (See Figures 8, 9, 10). Result – degree interval about 50 - 80°.

The duration of time gap for filling up the gun feeder, coating thickness control and other operations should not exceed 10 minutes. The operation team followed this direction.

The groove on the plunger surface was not pointed out as a problem – the experience of process engineers showed that such a shape peculiarity would be coated by angular flows of the mixture and by changes of the spraying angle.

The process

a) The spray system unit was prepared in accordance with technical description.
b) The gun feeder was filled up with Al_2O_3 + 50% ПРХ16С3Р3 mixture powder.
c) Sprayed component (valve body) was fastened with in facilities of manipulator which is designed to allow the rotation of the component (See Figures 8, 11, 12).
d) The expenditure of combustible mixture components and powder expenditure were set up corresponding to technical specifications (See Table 6). All the parameters of spraying were entered to the control panel outside of the spraying room (See Figures 3, 4).
e) The distance between the spraying gun stem nozzle exit section and the component was set to its lower limit – 120 mm because of the spraying angle (See Figures 9-11). The fire rate was installed to its medium value of 7 shots per second.
f) The coating deposition was realized. The required coating thickness was achieved by a series of successive shots and movement of sprayed surface in front of the nozzle exit section with overlap of coating spots from one to two thirds of their size. The approximate coating thickness per one shot was 7 µm (See Table 6) and the required thickness is 0,22-0,25 mm. The change of spraying spot area was achieved by the rotation of the valve body on the stand and stand movement. The spraying was executed gradually with the gaps for thickness control and component positioning change exceeding the desired thickness parameter to provide

small reserve for the final treatment to the required size. The last operations were polishing and chemical coating.

g) For plunger different angle of spraying (mostly 90°) and medium distance were applied (See Figures 13-15). Moreover, the interchange of spraying angles was realized to stow the coating in all of the surfaces of the groove.

5 Quality control of coatings

5.1 Fundamental rules

In accordance with the internal technical documentation РД5.УЕИА, “Prometey” the components with detonation coating are subjected to the control of external appearance criteria, thickness of coating and geometric size.

External appearance control is realized for the purpose of the detection of external defects such as chips, bulging, blisters, exfoliations, cracks, etc. The control is carried out with the help of tenfold magnifying glass in accordance with the standard GOST 25706 (for Russia) and daylight factor on the component surface not less than 1,50. When the light at the workplace is produced by incandescent lamps, the illuminance rate on the workplace level should be at least 150 lx, in conditions with luminescent lamps – 300 lx.

The geometric sizes of sprayed components and coating thicknesses are measured by universal measuring device and special technical templates. For coating thickness measurement technical personnel may use thickness gauges of the following types: VT-10NC, MT-10MC (for Russia) with the relative measurement error of ±10%.

Such mechanical properties of coatings as adhesion strength and microhardness are defined with the help of adhesion samples.

The adhesion strength of coating with substrate is defined by pin method mentioned in Paragraph 4.3 (See Figure 1). Coating deposition on adhesion samples is realized before and after spraying of a series of components (for new powders and mixtures).

Coating microhardness is determined in accordance with standard (GOST 9450 for Russia) using PMT-3 device if the thickness of coating is tenfold greater than the depth of its imprint. The hardness of coatings is defined by Vickers number – standard GOST 2999 for Russia.

As circumstances may require, the porosity of coatings is measured by hydrostatic weighing according to standard (GOST 18898 for Russia).

Coatings of products for critical applications should be exposed to nondestructive control by methods of liquid-penetrant test according to the 2nd and the 3rd classes of sensitivity.

In the presence of chips, bulging, blisters, exfoliations, cracks or other defects as well as in the presence of insufficient thickness it is necessary to remove the coating and prepare the part for repeated coating deposition.

Spraying process is controlled by changes in the flow and pressure rates of working gases, which should not exceed ±5% of nominal values. It is inadmissible for coating thickness growth value to exceed 11 μm for one shot.

If quality control on adhesive samples is not realizable it is permitted to guarantee the coating quality by thorough correctness of technological process performance. Material and mechanical processes of adhesive samples should correspond with material and mechanical properties of parts. (РД5.УЕИА, "Prometey". Internal technical documentation.)

5.2 Quality control

After coating deposition both components were grinded to the required sizes and polished.

Then general external appearance control was carried out. The necessary illumination parameters were set in the examine room of the quality control department. The coated surfaces of the valve body and the plunger were examined with the help of tenfold magnifying glass. No chips, blisters, cracks or any other defects were found. Then coating thickness and geometric sizes were checked with the corresponding minimum of measurement devices.

Hardness and adhesion strength parameters were tested again in accordance with the procedure (See Paragraph 4.3). The results exceed those which were achieved during the test before spraying.

The final step of quality control was the liquid-penetrant test.

The second and the third classes of sensitivity enable to find defects in the interval of 1 – 100 μm. The developer activates the penetrant remained in cavities of defects and the reaction of these two components indicates the areas of surface problems by produced color signs.

At first, the sprayed surfaces of the components were cleaned and dried. Then the penetrant liquid was sprayed on the surfaces. The surplus of the penetrant was removed by a piece of cloth. The surfaces were dried and the developer was sprayed. No significant defects were found (single isolated pores only).

Both components were directed to the final assembly.

6 Conclusion

The present thesis investigated all stages of metal-ceramic detonation coating of the components of the regulating valve. The description included requirements for the components, the materials used, unit specification, the procedures of preparations, coating deposition and quality control means. On account of shape peculiarity and high reliability of the component the series of considerations and experiments were intended.

The results prove the formation of uniform wear and corrosion resistant metal-ceramic coating with high adhesion and hardness parameters. The main aspect of goal attainment is the observance of all the technical requirements at all stages of the process.

The present investigation shows the necessity for compact and flexible spraying gun systems which might be involved in coating spraying of areas which are difficult of access. It will lead to the expansion of the application range of the method.

Figures

Tables

No transliteration is applied for the names of powders and “Prometay” internal documentation abbreviation.

Table 1. Spraying method comparison. Blank, E.D. Research and creation of detonation coatings with increased performance properties. St.Petersburg Polytechnic University, 2003.

Spraying method’s name	**Properties of sprayed coatings**			
	Adhesion strength, MPa	**Porosity, %**	**Hardness $HV_{0,3}$**	**Sprayed material**
Plasma	55-70	3-5	960	WC-12Co
Flame	30-40	3-12	-	WC-12Co
Detonation	80-220	0,3-1,0	1350	WC-12Co
High velocity oxygen fuel spraying	60-80	2-3	1100	WC-12Co

Table 2. List of powder materials for detonation coating deposition and their functions. РД5.УЕИА, “Prometey”. Internal technical documentation.

Powder	Code	Particle size, μm	Supply document	Coating purpose
Nickel	ПНЭ-1 ПНЭ-2	5-63	GOST 9722	Size restoration as pre-coat, corrosion protection
Nichrome	ПРХ20Н80	20-63	TU 14-22-119	Same
Copper	ПМС-В, ПМС-1	20-63	GOST 4960	Current-conductive layer achievement
Bronze	БрАЖНМц-9-4-4-1 Бр ОЦ 8-4	20-63	TU 2-17-103	Wear resistance improvement
Nickel-aluminum alloy	ПРН7ОЮ30,ПН75 Ю23В, ПН85Ю15	20-63	TU 14-22-123	Size restoration, increase of heat resistance
Aluminum oxide	23A, 24A	10-63	GOST 8136	Wear and corrosion resistance improvement
Mech. Mixture of aluminum oxide and chromic oxide	Al_2O_3+5%Cr_2O_3	10-63	GOST 8136 ТУ6-09-4272	Wear and corrosion resistance improvement
Composite powders	КХН-15,КХН-20, ВК-15, ВК-20, ПС-12НВК	20-63	TU 14-22-153	Increase of wear resistance
Mech. Mixture of aluminum oxide with nickel alloy and bronze	$A1_2O_3$+50%ПРХ16 С3Р3, $A1_2O_3$+30%БрА ЖНМц9-4-4-1	10-63	GOST8136, TU 14-22-113, TU2-17-103	Wear and corrosion resistance improvement
Zirconium oxide stabilized be 7% Yttrium oxide	ZrO_2-f7%Y_2O_3 M204NS	<40	TU 1-595-2-659	Increase of heat resistance
Nickel alloys	ПРН77Х15С3Р2; ПРН73Х16С3Р3; ПРН70Х17С4Р4; ПРН80Х13С2Р	20-63	TU14-22-33-90	Wear and corrosion resistance improvement
Note: the list of powder materials for detonation coatings is not limited by the data presented in the table and it might be expanded during the process of development of coatings.				

Table 3. Conditions of jet-abrasive treatment. РД5.УЕИА, "Prometey". Internal technical documentation.

Parameters	**Substrate (component) material**			
	Cast iron	**Steel HRC < 40**	**Steel HRC > 40**	**Non-ferrous metal and alloys**
Abrasive fraction, mm	0,8-1,0	0,8-1,5	0,8-1,5	0,6-0,8
Abrasive fraction	Shot, corundum, silicon carbide	~//~	corundum, silicon carbide	~//~
Nozzle diameter, mm	8-14	8-14	8-14	8-14
Compressed air pressure, MPa	0,4-0,6	0,4-0,6	>0,6	0,4-0,6
Distance from nozzle exit section to processed surface, mm	50-120	50-120	40-100	100-120
Angle of incidence of stream on processed surface, °	80-90	60-90	60-90	60-90

Table 4. Average service life of abrasive materials. РД5.УЕИА, "Prometey". Internal technical documentation.

Abrasive material	**Quantity of repeated cycles of abrasive usage**	**Irretrievable losses, kg/h**
Corundum(silicon carbide)	10-30	3,0-5,0
Metal shot	60-100	1,0-1,3

Table 5. Results of the research. Blank E.D., Slepnev V.N., Galeev I.M., Topolyanskiy P.A. Composite detonation coatings based on aluminum oxide. Central Research Institute of Structural Materials "Prometey", 2008.

Source material of coating	**Adhesive strength σ, Mpa**	**Microhardness Hμ, Gpa**	**Crack resistance, K_{1c}**
Al_2O_3 + 30% БрОК 4-3	52 - 65	11,6 - 13,9	Cracks not detected
Al_2O_3 + 50% ПРХ16С3Р3	68 - 84	8,2 -12,2	2,5 - 2,9

Table 6. Recommended technological conditions of spraying and properties of detonation coatings. РД5.УЕИА, “Prometey”. Internal technical documentation.

Coating	Proportions of gases O_2:C_3H_8: compressed air	Powder transportation compressed air ratio, m^3/h	Total flow ratio of gases, m^3/h	Spraying distance, mm	Coating thickness per one shot, μm	Adhesion strength, (no less than) MPa	Hardness GPa
ПНЭ-1, ПНЭ-2 Nichrome ПРХ20Х80	(3,1-1,8) :1: (1,2-2,2) (3,0-1,5) : 1: (2,0-4,0)	0,15-0,25 0,25-0,3	2,6-3,2 2,8-3,5	130-150 130-150	7-8 8-9	120 60	1,8-5,4 2,8-4,8
Nickel-aluminum alloy ПРН70Ю30, ПРН85Ю15, ПН75Ю25В	(1,2-1,3) : 1: (2,0-2,3)	0,2-0,3	3,3-3,65	130-140	5-10	80	3,8-6,4
Aluminum oxide $A1_2O_3$	(3,0-4,0): 1: 0	0,15-0,25	2,8-3,1	150-180	7-10	30	9,5-14,5
Mechanical mixture: $A1_2O_3$+13%$TЮ_2$; $A1_20_3$+5%Cr_20_3	(3,6-2,4): 1:0 (4,0-2,8): 1: 0	0,15-0,25 0,15-0,25	2,4-3,2 2,8-4,2	120-150 130-160	7-8 7-8	35 40	7,0-12,0 8,0-15,0
Coating types: КХН-15, КХН-20	(2,8-3,2) :1: (0,1-0,6)	0,3-0,4	3,0-3,8	130-150	7-8	60	8,4-14,0
ВК-15, ВК-20, ВК-25	(2,8-3,4) :1: (0,1-0,3)	0,2-0,4	2,8-4,4	110-150	6-10	60	7,7-15,0
Metal-ceramic from mixtures: $A1_2O_3$+50%ПРХ 16С3Р3; $A1_2O_3$+30%БрАЖНМц-9-4-4-1	(3,2-3,5): 1: 0	0,20 0,24	3,2-3,8 3,2-3,6	120-130 120-130	6-8 6-8	70 55	9,8-12,0 9,8-12,4
Nickel alloys: ПРН77Х15С3Р2; ПРН73Х16С3Р3	(2,8-3,4)) :1: (0,2-1,2) (2,8-3,6)):!: (0,7-0,8)	0,15-0,25 0,15-0,25	2,4-3,8 2,4-3,8	120-150 120-150	7-8 7-8	80 85	3,8-5,1 4,9-6,4
ZrO_2+7%Y_2O_3	(3,8-5,0): 1:0	0,1-0,15	3,2-4,2	100-130	4-6	30-34	6,2-9,4

Figures

Figure 1. Adhesive strength testing sample. РД5.УЕИА, "Prometey". Internal technical documentation. The scheme is translated.

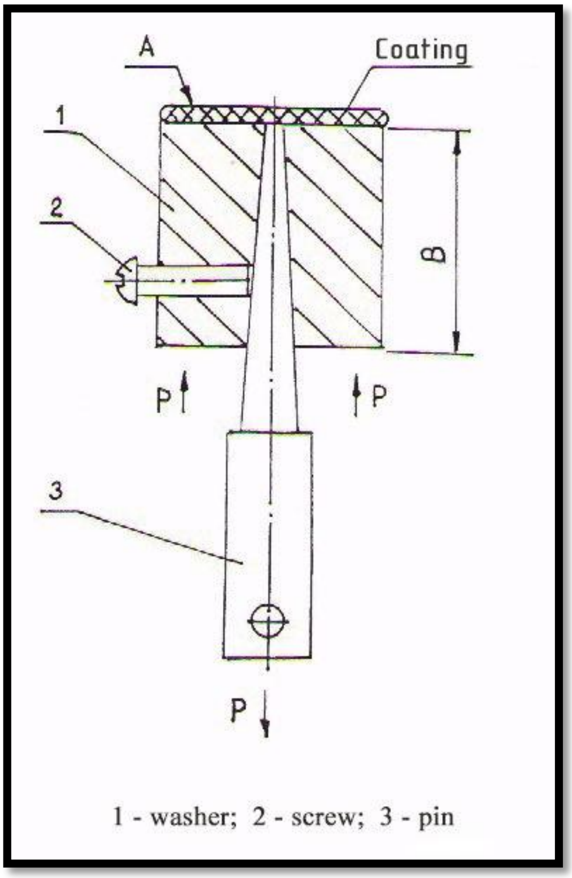


Figure 2. Isolated chamber for spraying.

Figure 3. Control unit is situated outside the isolated chamber.

Figure 4. Control panel.

Figure 5. Gas hoses and gas mixing equipment inside the chamber (the unit is a part of the spraying gun)

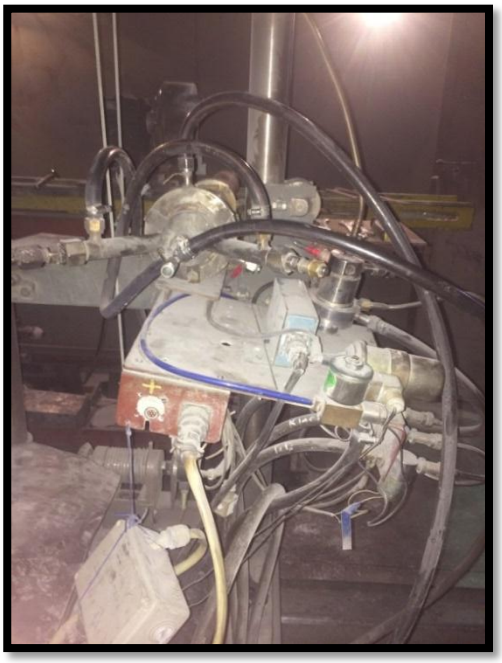


Figure 6. Sprayin gun "Prometey" system with gas mixing unit.

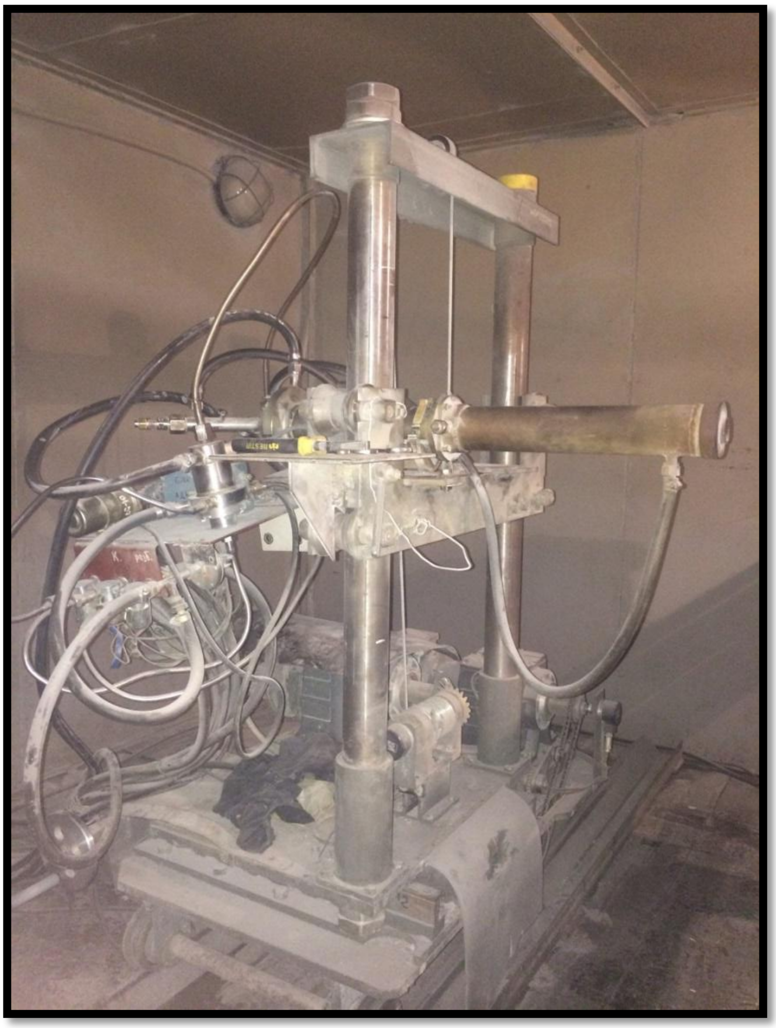


Figure 7. Powder example: the mixture of aluminum oxide and chromium oxide

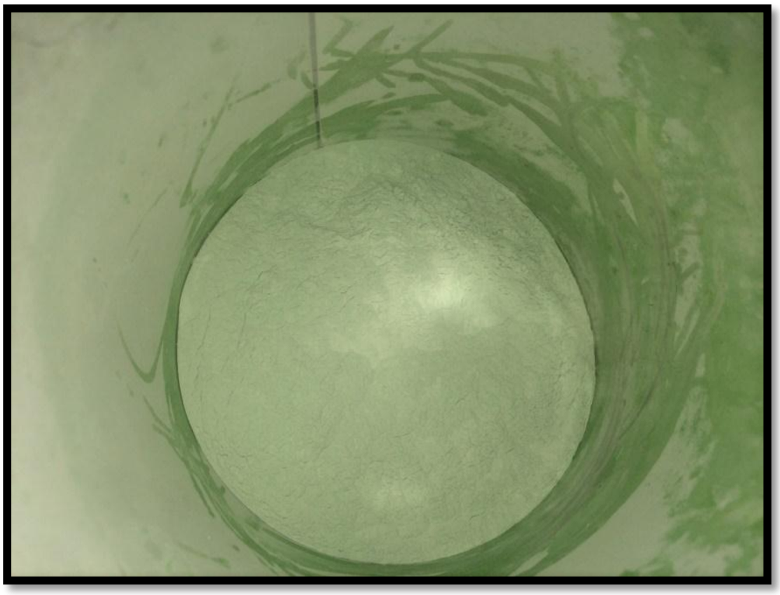


Figure 8. The valve body on the rotating manipulator stand.

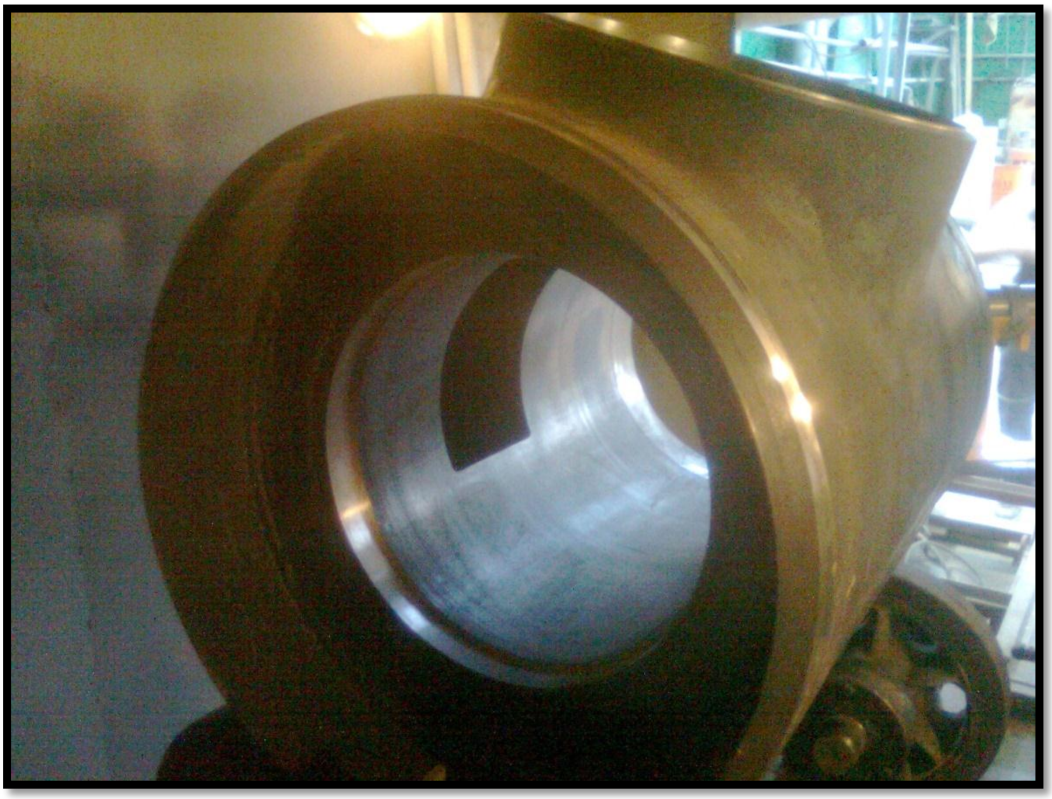


Figure 9. The angle of spraying (valve body).

Figure 10. The angle of spraying (valve body).

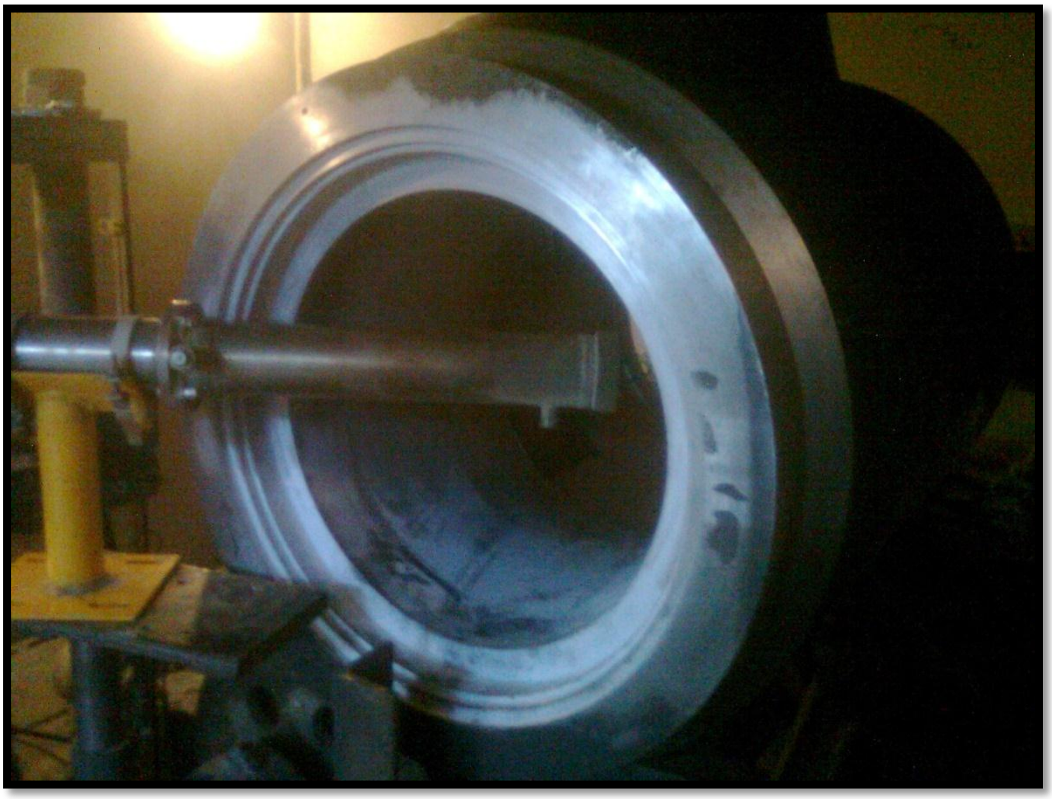


Figure 11. The process of spraying (valve body).

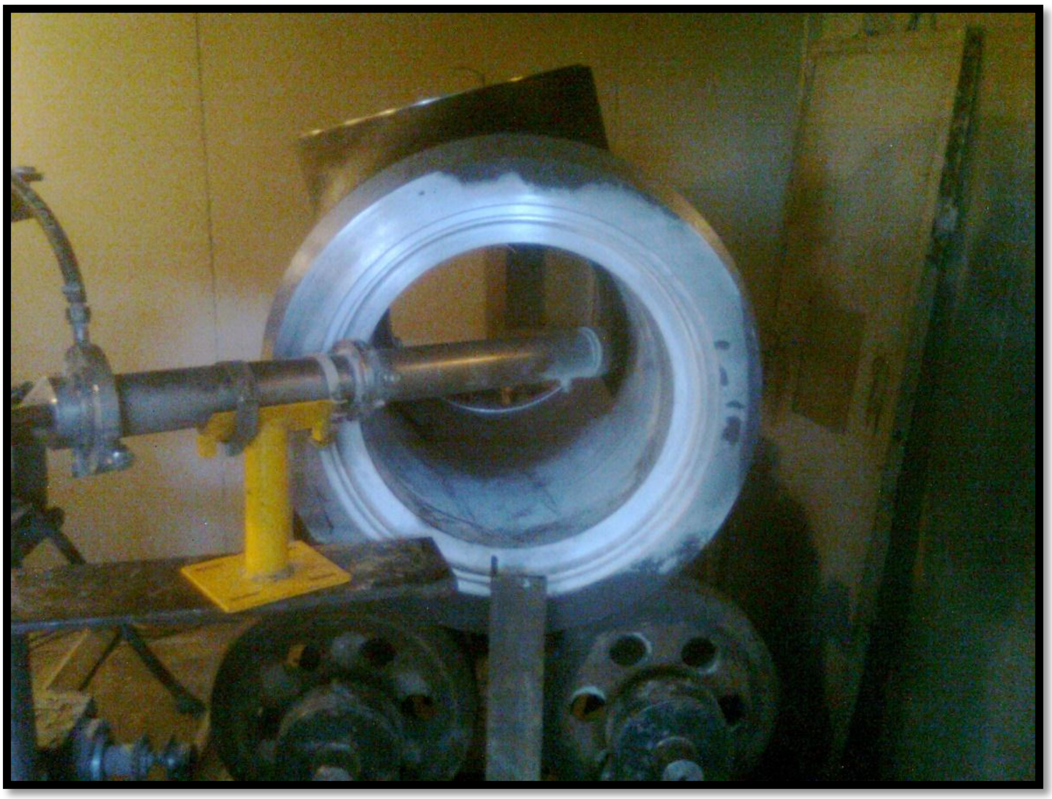


Figure 12. The sprayed component (valve body).

Figure 13. The plunger on the rotating stand.

Figure 14. The plunger on the rotating stand.

Figure 15. The plunger before the coating deposition.

Figure 16. The plunger after the coating deposition.

Figure 17. The plunger after the coating deposition

List of references

Blank, E.D. Research and creation of detonation coatings with increased performance properties. St.Petersburg Polytechnic University, 2003.

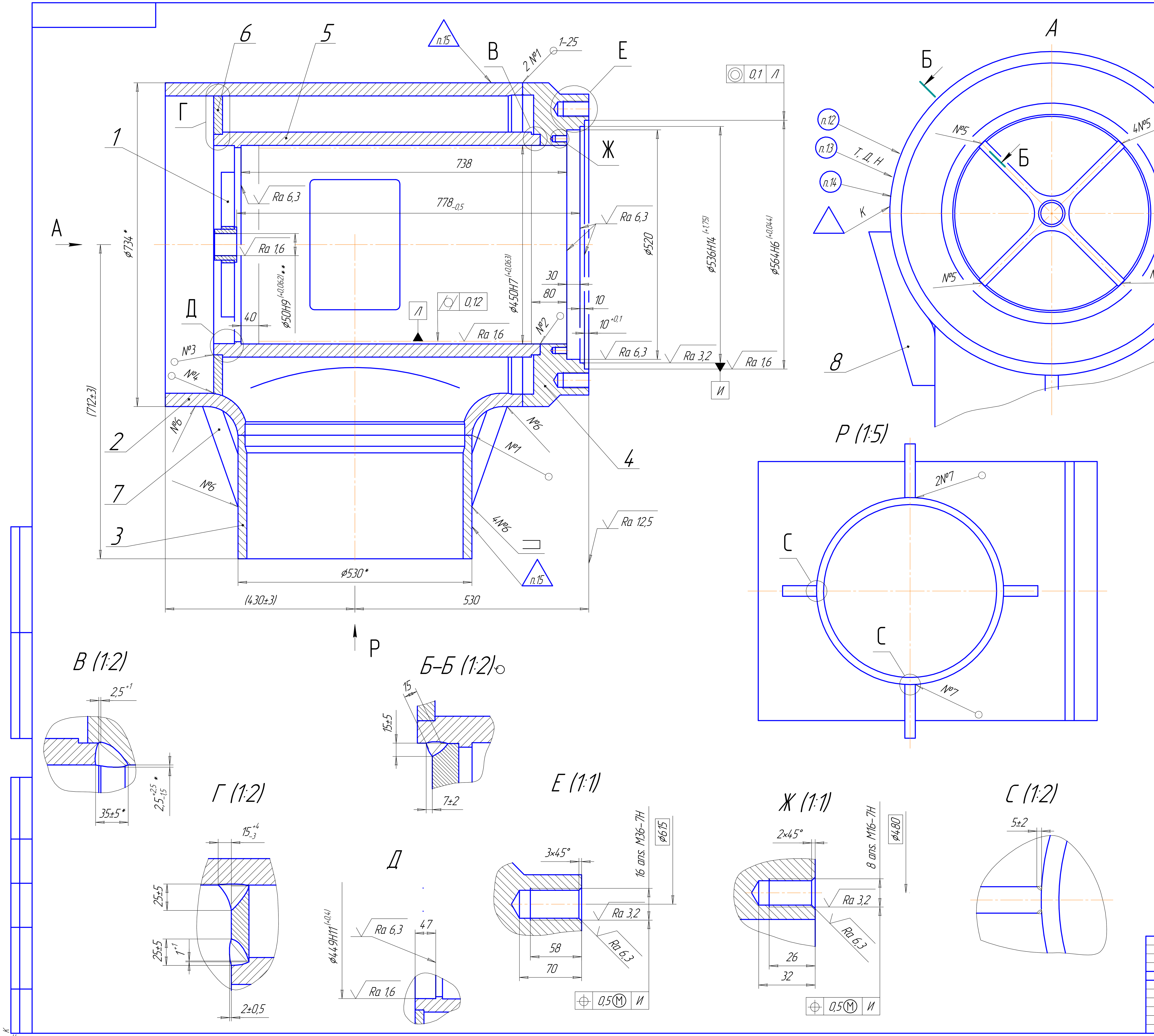
Blank E.D., Slepnev V.N., Galeev I.M., Topolyanskiy P.A. Composite detonation coatings based on aluminum oxide. Central Research Institute of Structural Materials “Prometey”, 2008.

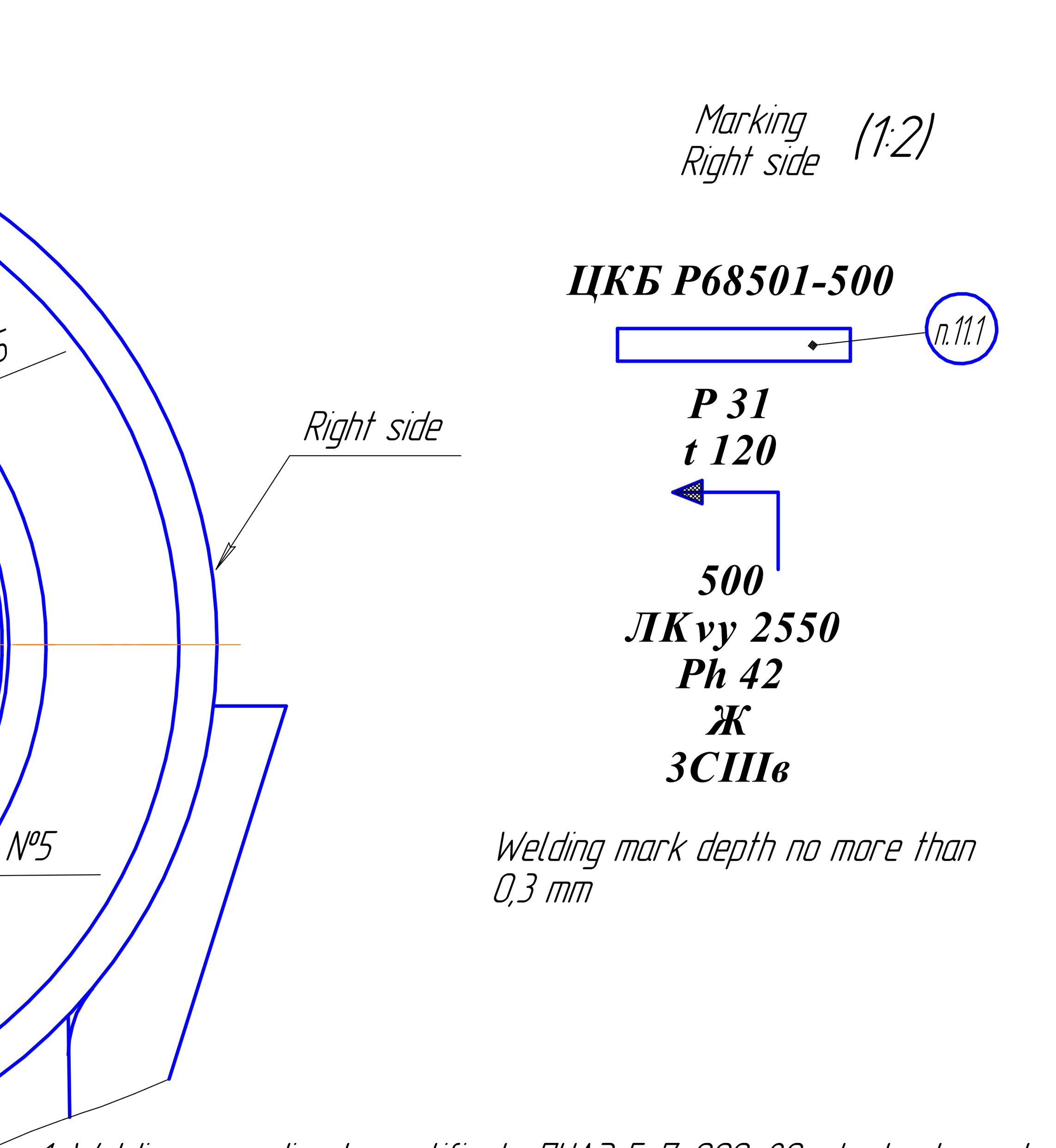
РД5.УЕИА, “Prometey”. Internal technical documentation.

Appendices

There are three technical drawings (A1 size) attached to the thesis:

- Appendix 1. Technical drawing 1. The body of the valve
- Appendix 2. Technical drawing 2. The plunger
- Appendix 3. Technical drawing 3. The assembly of the valve

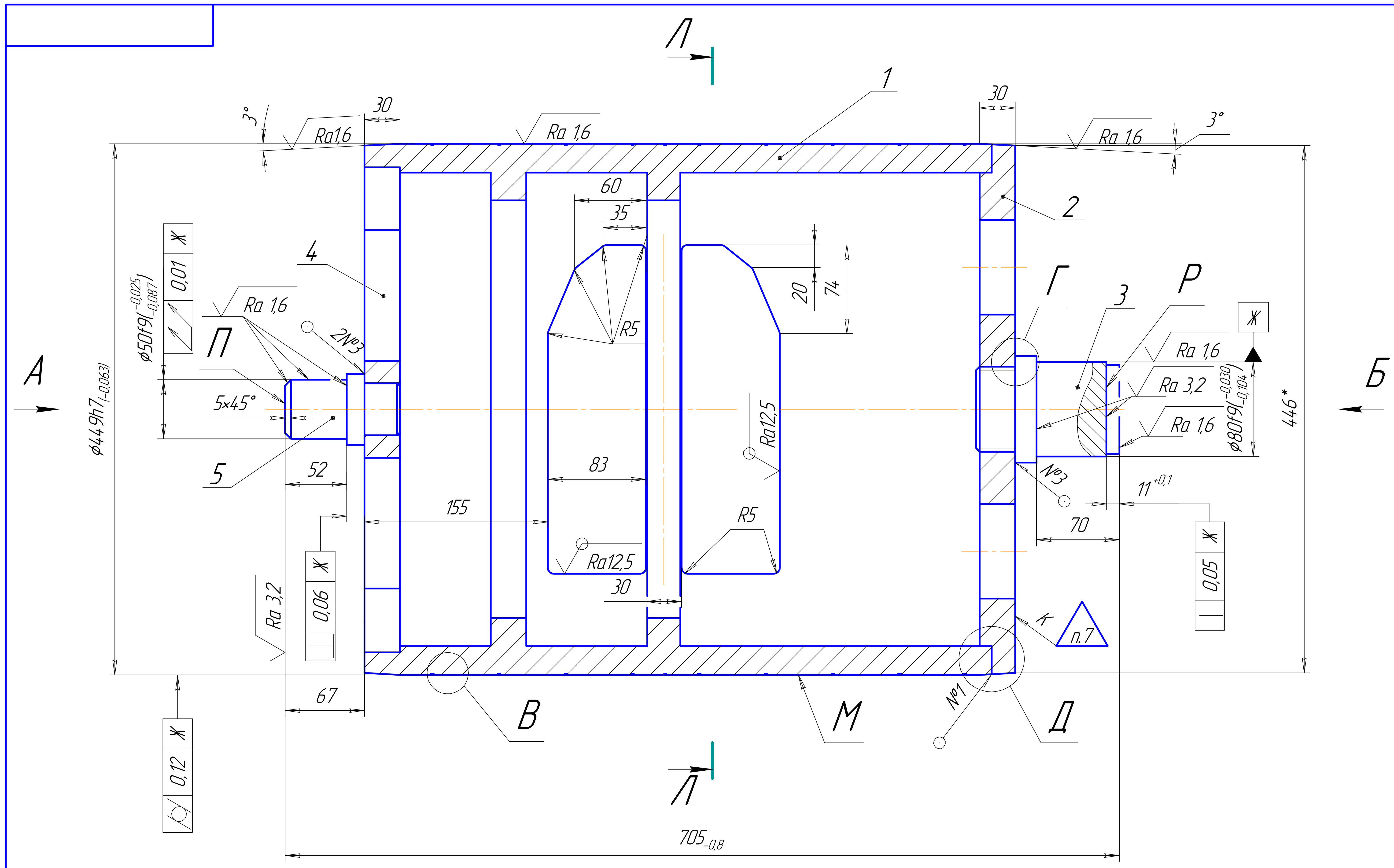


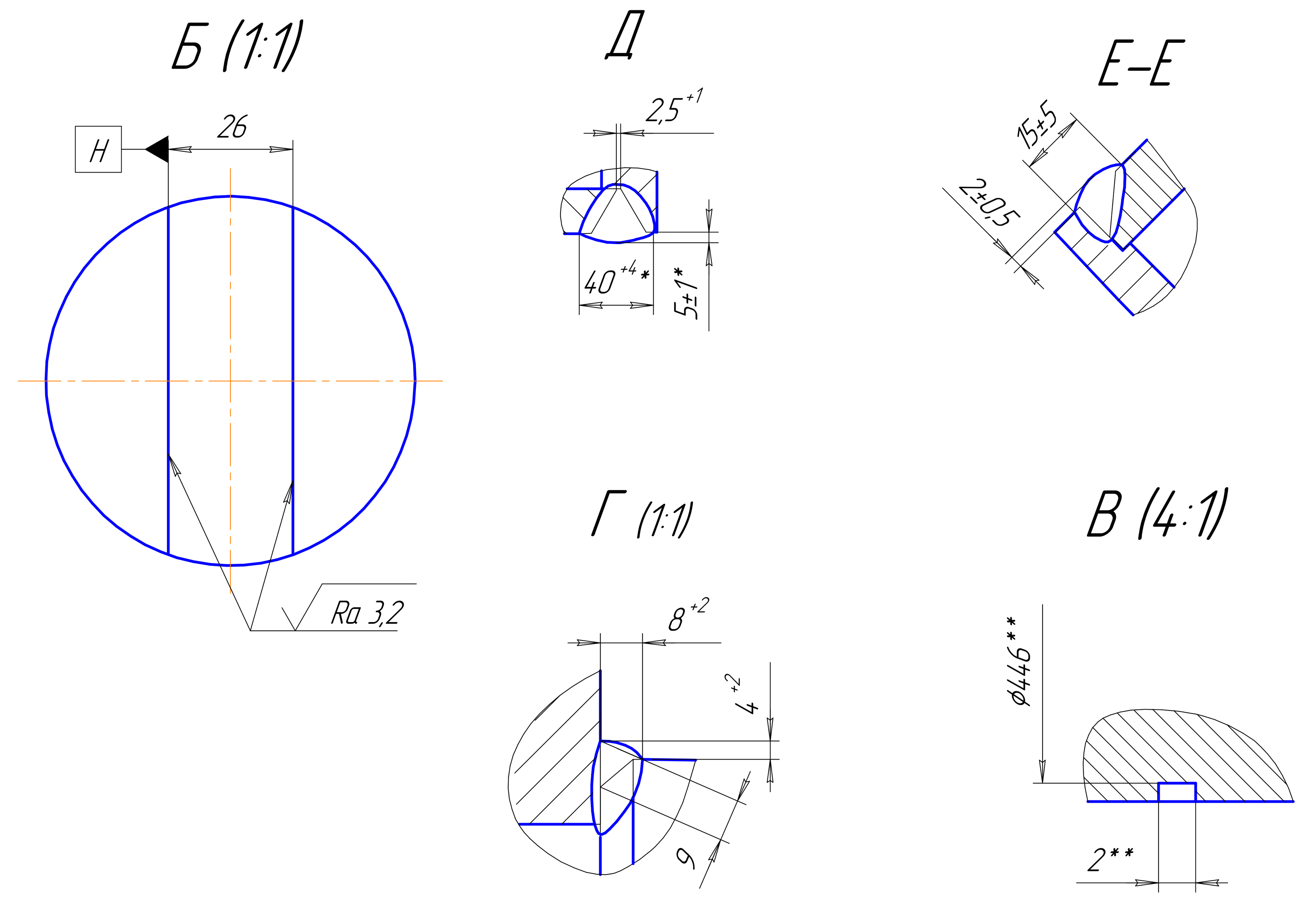


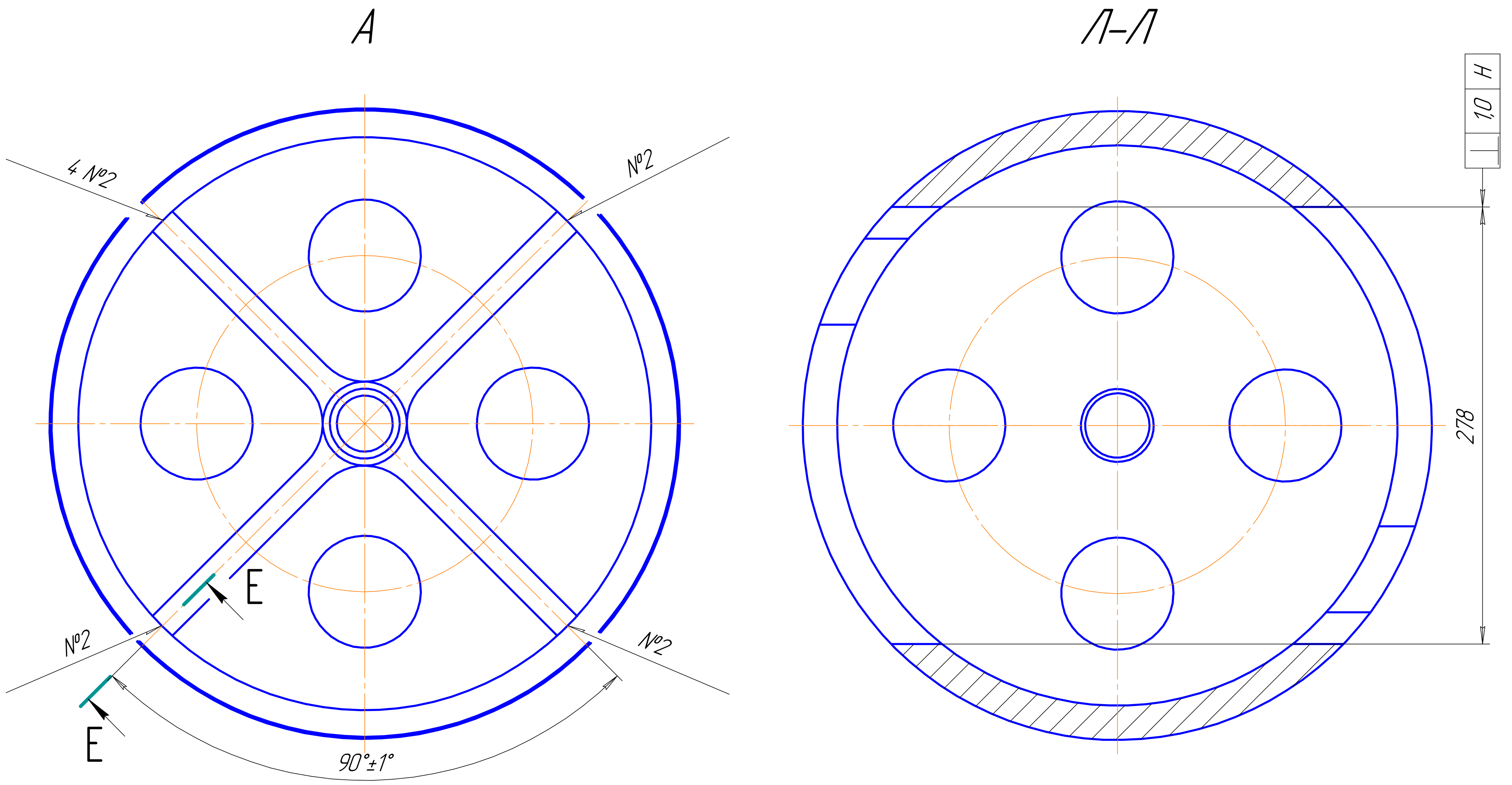
1. Welding according to certificate ПНАЭ Г-7-009-89, electrode mark УОНИИ-13/55,
ОСТ 5.9224-75, wire Св-08Г2С ГОСТ 2246-70 and others.
After welding heat treatment: tempering – (650±15)°C, 2...2,5 hours.
2. Quality control of welded joints according to ПНАЭ Г-7-010-89 by IIIв category.
Weld №1:
- visual and measurement control according to ПНАЭ Г-7-016-89;
- radiographic inspection according to ПНАЭ Г-7-017-89 – 25%;
- ultrasonic inspection according to ПНАЭ Г-7-014-89 – 25%;
Welds № 2, 4, 6, 7, acc. ЦКБ Р68501-500 СК:
- visual and measurement control according to ПНАЭ Г-7-016-89;
- liquid penetrant inspection according to II level of sensitivity according to ПНАЭ Г-7-018-89.
3. Standard for quality control of welds № 3, 5 according to ПНАЭ Г-7-010-89 by IIIc category:
- visual and measurement control according to ПНАЭ Г-7-016-89;
4. H14, h14, ±JT15/2.
5. *Size for reference.
6. **Size should be executed in common with baffle fin ЦКБ Р68501-500Е СБ.
Coaxiality tolerance relative to ϕ50H9 no more than 0,08 mm.
7. Dimensions in parenthesis – after hydro-testing.
8. Sleeve holes dissymetry relative to horisontal axis of the body no more than 1 mm.
9. Surface Л -detonation metal ceramic coating. Thickness 0,2...0,25 mm, HV no less than 10000 MPa,
according to certificate РД 5.УЕИА 3290-2000.
10. Chemical phosphate coating should be realized after detonation coating of surface Л.
11. Marking of the right side. Type 10-Пр3 ГОСТ 26.008-85.
11.1. Unit number and valve label according to KKS.
12. Marking "СДЕЛАНО В РОССИИ". Type 10-Пр3 GOST 26.008-85.
13. Marking. Type 10-Пр3 GOST 26.008-85.
14. Marking of technical certificate №. Type 10-Пр3 GOST 26.008-85.
15. Welding mark should be realized. Welding mark depth no more than 0,3 mm.
16. Quality control surface Л – liquid-penetrant test of II level of sensitivity according to certificate ПНАЭ Г-7-018-89.
Single breaks with max size of 1,5 mm (0,2 – 1,5 mm) are not allowed, if their quantity exceed four per 100mm of length.

Ph 42

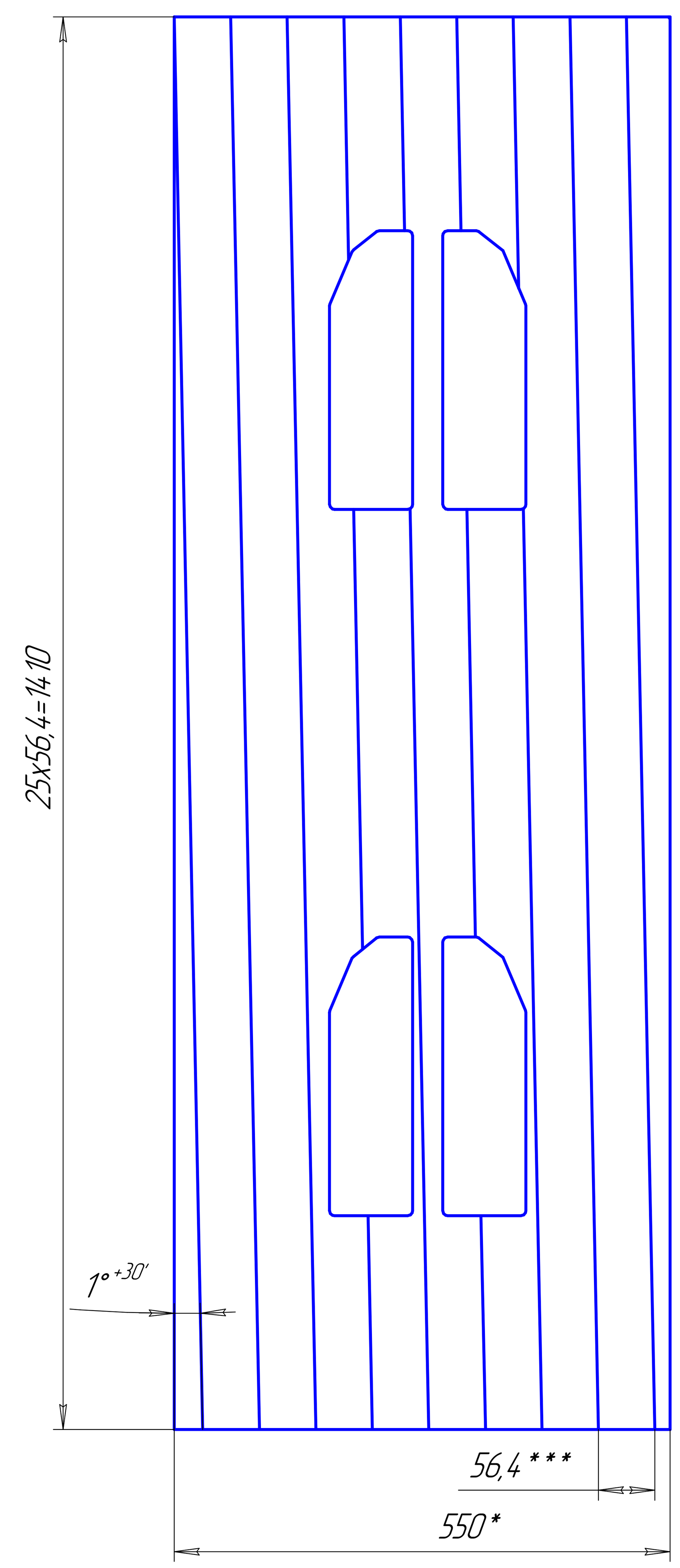
Appendix 1			
Valve body		Mass	Scale
		925	1:4
ЗАО "НПФ "ЦКБА"			







Surface view (1:5)



1. Welding according to the certificate ПНАЭ Г-7-009-89
– welds №1, 2 – electrode mark УОНИИ-13/45, УОНИИ-13/45А, УОНИИ-13/55 ОСТ 5.9224-75, wire Св-08Г2С, GOST 2246-70 and other in accordance with section2, after welding (before weld № 3 execution) heat treatment – tempering (650±15) °C, 2...2,5 hr;
– weld №3 – electrode mark ЭА395/9 OST В5.9374-81.
2. Welding quality control standard according to the certificate ПНАЭ Г-7-010-89 by class IIIс:
– visual and measurement control according to ПНАЭ Г-7-016-89. Additionally for weld №3 – liquid-penetrant test of II level of sensitivity according to the certificate ПНАЭ Г-7-018-89.
3.* Sizes for reference.
4. H14, h14, ±JT15/2.
5. Surface M -detonation metal-ceramic coating. Thickness 0,2...0,25 mm, HV no less than 10000 MPa, according to the certificate РД 5.УЕИА 3290-2000.
6. Chemical phosphate coating should be realized after detonation coating of surface M.
7. Welding mark should be realized. Welding mark depth no more than 0,3 mm.
8.Quality control surface M – liquid-penetrant test of II level of sensitivity according to the certificate ПНАЭ Г-7-018-89.
Single breaks with max size of 1,5 mm (0,2 – 1,5 mm) are not allowed, if their quantity exceed four per 100mm of length.
9. **Sizes – after coating.
10. ***Sizes provided by equipment
11. On surfaces П and Р centre holes are admitted in accordance with the certificate GOST 14034-74.

Appendix 2		
Plunger	Mass	Scale
	165,1	1:2,5
ЗАО "НПФ "ЦКБА"		

Technical specifications

1. Actuating medium – condensate
2. Design pressure P = 3,1 MPa (31 kgf/cm²).
3. Design temperature 120 °C.
4. Actuating medium temperature 120°C.
5. Maximum pressure differential ΔP = 2,5 MPa (25 kgf/cm²).
6. Nominal flow capacity Kv = 2550 m³/h
7. Flow capacity – linear
8. Nominal actuating mechanism torque 1000 Nm
9. Valve class – 3СIIIв according to certificate ОТТ-87.
10. Seismic stability class II according to certificate НП-031-01

Technical requirements

1.* Sizes for reference.
2. Manufacturing and supply according to the certificate ТУ 3742-084-34390194-2005.
3. The installation position of the valve – horizontal sections of pipelines..
4. Branch pipe splacing type for welding according to documentation ПНАЭ Г-7-009-89 in/-1-25 (С-25).
5. H14, h14, JT15/2.
6. Before the assembly all the static treaded joints should be greased with the paste ВНИИНП-232 according to GOST 14068-79. Active tread joints and all the friction surfaces not adjoining the actuating medium should be greased with the lubricant ЦИАТИМ-221 according to GOST 9433-80.
The bearing pos.31 should be filled with the lubricant ЦИАТИМ-221 according to GOST 9433-80.
7. Dissymetry of the sleeve holes pos. 1 and the plunger pos. 2 relative to common axis should not exceed 1 mm.
8. Clearance K should be set to 0,08-0,15 mm by adjusting the compensator pos. 20.
9. Before mounting of the gasket pos. 32 the faces of the body pos.1 and the cap pos.3 should be rubbed with graphite powder
10. Sealing ring molding should be realized in accordance with the service instructions ЦКБ Р68501-500 РЭ.
11. After the assembly the correctness of plunger-valve operarion should be checked. Jerks or jams are not allowed. Rotation torque ≤ 180 Nm.
12. The valve position on the drawing is open.
13. Nut tightening torque at pos. 21 should not exceed 906,3 Nm.
14. After assembly and testing the valve should be painted according to following order:
- organic-silicate composite mixture ОС-51-03 – green, ~ 4 layers according to TU 84-725-78, except the welding endings on 20 mm of length at pos. 1, the scale at pos.10 u and the marking areas,
- The welding endings should be preserved on 20 mm of length at pos. 1 by oil K-17 GOST 10877-76;
-the scale at pos. 10 and the marking places should be painted with organic-silicate composite mixture ОС-51-03 – green, ~ 2 layers according to TU 84-725-78.
15. The preservation stamps should be placed according to OST 26-1479-76 with bright green paint.
16. Components pos. 25, 26, 28, 29, 38, 39, 40 according to OST 26-07-262-77.
17. End caps – in accordance with technical documentation of manufacturing company.

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Appendix 3			
Regulating valve DN 500, P 31, t 120 °C Assembly		Mass	Scale
		1430,6	1:2,5
	ЗАО "НПФ "ЦКБА"		