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Approved by:  
Director General of ZAO Energometall

\_\_\_\_\_ V.S. Vakin

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**STEEL-TITANIUM CLAD PLATES  
PRODUCED BY EXPLOSION WELDING  
STANDARD SPECIFICATION  
TU-1880- 001-15190236-2011  
(Instead of TU-TS 002-07-09)**

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This specification covers steel-Titanium bimetal plates received by the explosion welding method, further referred as Clad plates, used as a semi-product to manufacture the components of heat-exchanger and vessels in energetic and chemical engineering.

Clad plates are produced with the base metal in carbon, low-alloyed steel of grades 09G2S, 20K, 22K of all classes according to GOST 2520-79, or ASTM A516 Gr60, Gr65, Gr70, ASTM A387 Gr.11, Gr.12, Gr.22, or EN10028-2 P235 – P355NH (normalized), or EN10028-3, etc., or a flat forgings according to GOST 8479, ASTM A105, ASTM A182, ASTM A336, EN10222-3 etc., and the clad metal in Titanium of grades BT1-0, BT1-00 according to GOST 19807, or ASTM B-265 Gr.1, Gr.2.

### **Example of ordering information and designation code in other documentation**

When making the order, the customer should specify to the manufacturer the following information:

- scope of supply;
- steel grade of the base metal;
- Titanium grade of the clad metal;
- nominal dimensions of clad plates (thickness of base metal, thickness of clad metal, length and width);
- permissible variation in thickness of both the base and clad metal;
- mechanical properties and impact strength of the base metal;
- class (level) of bond integrity between the layers and location of the initiation point (the start point of explosion welding process);
- as-delivered conditions including additional kinds of treatment;
- heat-treatment conditions;
- other requirements (if necessary a drawing of the ordered work piece should be submitted);
- specification and norms for bond integrity control and homogeneity of a clad metal (methods of Ultrasonic control, liquid-penetrant test, X-ray control, etc.);
- requirements to the size and integrity of the zone of detonation initiation point;
- other specifications and norms for determination of bond quality, if they are not indicated in this specification.

An example of designation code for the bimetal plate in 40 mm thick, thickness of a clad metal 3 mm, width of 1000 mm, and length of 3000 mm, for the combination of carbon steel 09G2S of category 5 by GOST 5520 and Titanium BT1-0 by GOST 22178, of the class 1 (level) bond integrity.

**40 (37+3)x1000x3000 TU 1880-001-15190236-2011**

**Bimetal plate** -----  
**(09G2S-5 + BT1-0)**

For the complete list of all norms and standards indicated in these specifications see Annex A.1.

## **1 Technical requirements**

The Steel-Titanium bimetal plates produced by a method of explosion welding must conform this standard specification and other technological documentation within the prescribed procedure.

### **1.1 Range of sizes**

1.1.1 Bimetal plates are rectangular type sheets/plates in thickness of 5 to 300 mm, width of 300 to 5000 mm, and length of 400 to 9000 mm.

Bimetal plates can be furnished in other types of configurations (different from the rectangular type) by an agreement with the Customer.

Overall dimensions of each bimetal plate in a lot must be specified in the order.

1.1.2 Thickness of a clad metal can be from 2 up to 12 mm.

1.1.3 On the edges of a two-layer work-piece delivered with no trimming, some individual chips of clad metal are allowed at a depth of not more than 10 mm from the edge of the base layer. In all cases not specifically agreed with the customer clad plates are supplied with cut edge.

1.1.4 Deviations of thickness, width and length of 2-layer plates must conform the normal accuracy according to GOST 19903 or requirements of the Customer.

1.1.5 The deviation from flatness per 1m of length for the clad plate should not exceed 5 mm. By agreement with the customer different values of deviations from flatness may be accepted.

### **1.2 Main parameters and properties**

#### **1.2.1 Mechanical properties**

1.2.1.1. Mechanical properties of base metal of bimetal plates must conform to the requirements for the steel grades to be used as a base metal indicated in the Table 1 or the requirements ASTM A516, ASTM A387, EN10028-2, EN10028-3.

Table 1

Base metal Steel grade	Yield strength $\sigma_T$ , N/mm <sup>2</sup> (kg-f/mm <sup>2</sup> ) Not less	Ultimate strength $\sigma_B$ , N/mm <sup>2</sup> (kg-f/mm <sup>2</sup> )	Elongation $\delta_5$ , % not less	Impact strength KCU J/cm <sup>2</sup> (kg-fm/cm <sup>2</sup> ) not less
20K	235 (24)	400-510 (41-52)	24	54 (5,5)
22K	265 (27)	430-590 (44-60)	22	59 (6)
09G2S	305 (31)	not less 460 (47)	21	59 (6)
	285 (29)	not less 450 (46)	21	59 (6)
	295 (30)	not less 430 (44)	21	59 (6)

1.2.1.2. While determination of the clad plate bond quality, shear strength must be at least 200 MPa.

1.2.1.3. Delaminating strength while separation of the clad metal from the base metal will be determined optionally and it must be at least 180 MPa.

1.2.1.4. The strength of bond will be defined by the cold bend test performed through an angle of 120 degrees with the clad metal in compression.

Bending of the specimen must not show any separation of the clad metal from the base metal and visible cracks in the contact zone of the bonded layers.

1.2.1.5. The double-layer blanks are produced heat-treated for residual stress relief. The type and mode of thermal treatment are settled by the Manufacturer.

The recommended modes of heat treatment are in the range of temperature from 380 °C up to maximal 520 °C, holding time at the specified temperature is 2 to 4 hours.

## 1.2.2. Bond integrity

1.2.2.1 Continuity and integrity of bond between the layers in the bimetal plate must correspond to class 01, 0, or 1 according to the requirements of GOST 22727 and as shown in the Table 2:

Table 2

Class of plates	Specified area of bond discontinuity, cm <sup>2</sup>	
	to be taken into consideration, minimal	permissible, maximal
01	as agreed with the Customer	
0	5	20
1	10	50

The Customer can stipulate the more restrictive requirements in the certain case.

### 1.2.3. Surface finishing

1.2.3.1. Any bimetal plate can be furnished with the following clad surface finishing:

- as-welded condition;
- sandblast cleaned;
- machine grinded;
- vacuum-arc cleaned.

1.2.3.2. Condition of the plate surface after explosion welding and sandblast cleaning:

- any blisters, pockets, scab, cracks or grubs on the plate surface are not permissible.

1.2.3.2. Condition of the plate surface after mechanical grinding and vacuum-arc treatment:

- surface roughness must be minimum Ra 6.3 according to GOST 2789.

## 1.3 Materials requirements

1.3.1 Materials used for clad plates manufacturing should meet the requirements of technical specifications on these materials and provide obtaining of items according to the stipulated parameters.

Materials used for the clad plates manufacturing should be supplied with the mill test certificates.

1.3.2 The requirements to the initial sheet/plates:

1.3.2.1 The base metal workpieces should meet the requirements of GOST 5520, ASTM A516, ASTM A387, and EN10028-2, EN10028-3 with integrity and ultrasonic inspection of a base layer according to GOST 22727 class 1, or ASTM A578/A578M-07, EN10160 or other corresponding standards.

1.3.2.2 The titanium clad layer workpieces should meet the requirements of GOST 22178 with ultrasonic inspection as per GOST 22727 cl.1 or ASTM B265. The hydrogen content in rolled sheets should not exceed 0,007%.

1.3.2.3 It is allowed to weld BT1-0, BT1-00, B265 Gr.1, Gr.2 titanium plates together to produce larger plates by using of argon-arc welding grades with the weld quality control in accordance with the Customer's instructions and requirements, in particular as per OST B5P.95118-2001. Intersection of welds is not permitted. The weld location must be agreed with the customer.

1.3.2.4 The surfaces to be bonded by explosion welding should be preliminary machined until scale pits, scale and corrosion is completely removed.

The recommended finishing methods for the surfaces to bond are as follows:

- mechanical grinding operation,
- vacuum-arc preparation as per technology of ZAO Energometal.

The surface roughness after machining Rz must not be worst than 6.3 mcm as per GOST 2789.

1.3.2.5. The method of surface preparation for explosion welding as per technology of ZAO Energometal is protected by copyright: RF patent No. 2311274 “Method of obtaining bimetal material”.

#### **1.4 Marking**

1.4.1 Marking and packing of two-layer workpieces should guarantee the integrity of the clad surface and corrosion protection of the base layer made of carbon and low-alloy steel.

Marking and packing of a bimetal workpiece may be performed on a Customer’s request.

1.4.2 Transport marking must be made as per GOST 14192.

### **2 Requirements on the staff safety and environment protection**

2.1 The clad plates must be produced in accordance with the safety regulations effective at the enterprise.

2.2 As the protection measures against hazards the workers must be provided with the personal protective equipment according to the typical industrial norms.

2.3 The materials used must not contain hazardous, extra-hazardous and highly hazardous substances (hazard class 1 or class 2 according to GOST 12.1.007), indicated in the table of hazardous substances according to GOST 12.1.005, polluting the environment and badly affecting the men’s health.

### **3. Acceptance regulations**

3.1. Clad plates are accepted in lots.  
Each lot should consist of the clad plates of the same thickness, of clad and base metals, and the same heat treatment mode.

3.2 Each lot of clad plates should be provided with the quality assurance document according to GOST 7566 with annexes and should provide the following data:

- steel grade of the base metal;
- grade of titanium clad;
- heat number and chemical content of base metal;
- heat number and chemical content of titanium clad;
- thickness of titanium clad;
- shear strength and tearing strength;
- results of bend test;

- class of bond continuity between layers;
- ultrasonic control chart;
- a scheme of enlargement of the initial clad sheets (plates);
- test certificate EN10204/3.1.

3.3 After explosion welding each clad plate should be visually inspected and measured, including control of dimensions, surface defects and edge condition.

3.4 Each clad plate should be ultrasonically checked for bond continuity between the layers.

3.5 Two clad plates from each lot should be subjected to the control of the thickness of the clad metal.

3.6 Two bimetal plates from each lot should be subjected for the bending, shear and tearing tests.

3.7. If the test results for at least one of the tested parameters are unsatisfactory, then the tests should be repeated for the doubled quantity of the specimens for that kind of test that was not passed. The results of the repeated tests are considered the final results.

#### **4. Test methods**

4.1. Quality of the surface and edges of each clad plate should be checked by visual inspection and measurements.

The dimensions and non-flatness of the bimetal plates should be checked according to the requirements of GOST 19903, if otherwise is not agreed with the customer.

4.2. The following specimens should be taken from each clad plate tested:

- for control of clad metal thickness – two specimens;
- for shear test of clad metal – three specimens;
- for tearing test of clad metal – three specimens;
- for bending test - two specimens;
- for elongation test of base metal – one specimen;
- for impact bending test of base metal – three specimens;

4.3. Test specimens for the shear test, delamination of clad metal, bending of bimetal plate, and elongation and impact bending of the base metal should be sampled according to the requirements of GOST 7564 or OST 5.9311-78 or other standards indicated in the customer's order.

It is not tolerated to sample the test specimens of double-layer blanks from 50 mm wide

area along edge of a double-layer blank.

4. 4 The chemical composition of the base metal is defined according to GOST 10885 or ASTM A516, ASTM A387, EN10028-2, EN10028-3. The chemical content of titanium clad metal must be defined according to GOST 19863.1 - GOST 19863.13 or ASTM B 265.

4. 5 Bending test should be performed at the normal temperature.

For the bend test of a double-layer blank the thickness (diameter) of a mandrel should be equal to double thickness of the specimen. For the double-layer blank with thickness over 30mm, the bending test specimens must be machined up to the necessary thickness.

4. 6 The thickness of the clad metal should be checked by the metallographic method by a magnifier or microscope by us of two micro-section metallographic specimens of 30x30mm size taken from the front and rear ends of the double-layer blank.

4.7 Specimens and test schemes are described in Appendix B.

## **5. Transportation and storage**

5.1. The clad plates must be transported by any kind of transport, observing the transportation regulations applicable to the given transportation mode.

5.2 The clad plates are allowed to be stored either in open or closed storage facilities. In case of being stored at open areas, surface of base metal must be additionally preventive treatment

## **6. MANUFACTURER'S WARRANTY**

6.1 The Manufacturer guarantees that bimetal plates will be in conformity with the requirements of the presented specifications within 1 year since their shipment to the Customer provided the Customer follows the transportation and storage requirements.

6.2 The warranty period must be one year from the date of shipment to the customer.

Appendix A  
(for reference)

List of norms, referenced herein

Designation	Description
GOST 12.1.005-88	General sanitary requirements for air in the working zone
GOST 12.1.007-76	Noxious substances. Classification and general safety requirements
GOST 2789-73	Surface roughness. Parameters and characteristics
GOST 5520-79	Carbon, low-alloy and alloy sheet steel for boilers and pressure vessels. Specifications
GOST 7564-97	Rolled products. General rules of sampling, and selection of blanks and specimens for mechanical and technological testing
GOST 7566-94	Metal products. Acceptance, marking, packing, transportation and storage
GOST 8479-79	Forging of construction carbon and low alloy steel. General specifications
GOST 10885-85	Hot-rolled corrosion-resistant double-layer steel plates. Specifications
GOST 14192-96	Cargo marking
GOST 19903-74	Hot-rolled steel sheets. Dimensions
GOST 19807-91	Wrought titanium and titanium alloys. Grades
GOST 19863.1-91 - - GOST 19863.13-91	Titanium alloys. Methods for the determination of elements
GOST 22178-76	Titanium and titanium alloys sheets. Specifications
GOST 22727-88	Rolled sheet. Ultrasonic test methods
OCT 5.9311-78	Explosion welding of metals. Bimetal blanks for tubular plates of heat exchangers
ASTM A105	Standard Specification for Carbon Steel Forgings for Piping Applications
ASTM A182	Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
ASTM A336	Standard Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts
ASTM A387	Standard Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum
ASTM A516	Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
ASTM B265	Standard Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate

Designation	Description
EN 10028-2	Non-alloy and alloy steels for pressure purposes. Part 2. Non-alloy and alloy steels with specified elevated temperature properties
EN10028-3	Flat products made of steels for pressure purposes Part 3: Weldable fine grain steels, normalized.
EN 10222-3	Steel forgings for pressure purposes Part 3: Nickel steels with specified low temperature properties

APPENDIX B  
(compulsory)







