pliers readily sign such contracts directly or through branch enterprises (if raw finishing to required condition is necessary) according to world practice. International practice denied an opinion that the costs can be reduced during in situ processing.

Development of economic relations is effective using a futures-based designing with strict following of world market tendencies. Evolution and improvement of control for activities of enterprises using modern system of information technologies should substitute out-of-date order-supplier system.

Japanese economists related with welding engineering market of goods and services believe that a transfer of economic relations on new level through development of a stable triads manufacturer–dealer– consumer, allowing setting reasonable price and revenue sharing, is a priority. This, in particular, should be taken into account under conditions of passing of property rights and control over the plants of welding consumable manufacture to leading foreign companies on the territory of CIS countries and significant intensification of competitiveness in all range of products.

Low level of equipment and domination of out-of-date technologies arise some alert. In this connect manufacturers of welding consumables for all methods of arc welding should be directed on application of novel achievements in technique and technology, following the situation and also stimulating transfer of consumer to current level of equipment.

Own experience, addressing to printed technical and advertisement publications should not be solely relied upon in solving of arising problems. Specialists of leading research and design-and-technological institutes can provide qualified help, especially, in such questions as choose of reasonable solution, analysis of reasons of problem appearance and searching the ways of their elimination, professional development of personnel, estimation of innovation perspectives etc. All available possibilities are to be used in the world of rapidly developing information technologies.

ELECTRON BEAM WELDING OF MEASURING CHAMBER OF MAGNETIC PNEUMATIC GAS ANALYSER

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The selection of power and time parameters of electron beam for EBW of flat measuring chamber of magnetic pneumatic gas analyzer of stainless steel 12Kh18N10T was considered. Scheme of welding in general vacuum, welding-assembly device and conditions providing formation of overlap and circumferential welds with admissible distortions of gas channel geometric sizes and vacuum-tightness are given.

Keywords: *electron beam welding, stainless steel, overlap joint of (0.2 + 1.0) mm, heat input of welding, assembly-welding device, scheme of welding, vacuum-tightness, deformations*

In 1970 the Siemens (Germany) started the serial manufacture of magnetic-pneumatic gas analyzer of Oxymat type [1], consisting of a flat measuring chamber of stainless steel. It consists of a basement with slots in the form of a sheet 1.0 mm thick 164 × 52 mm in size, upper and lower plates of foil of thickness 0.2 mm, two exhaust pipes and two nipples (Figure 1). The design peculiarities of chamber are featured by the fact that exhaust pipes and nipples are welded-on to the upper plate by circumferential welds, and upper and lower plates are welded-on to the basement using straight-line overlap welds. During development of technology for EBW of measuring chamber of domestic gas analyzer applied for NPP it was necessary to consider that distortion of geometric sizes of gas channel in the form of ripples, sagging and buckling of upper and lower plates is admitted of not more than 0.1 mm, and drop of pressure at the level of $0.59 \cdot 10^3$ Pa for 30 min is not admitted at all.

Welding for the measuring chamber is applied for sealing the inner volume and installing of nipples and exhaust pipes. As is shown in Figure 1, longitudinal and transverse welds are produced at approximately 1 mm distance from the edge of slots. Welds pass along the whole length of the item and cross each other, thus increasing the rigidity of structure and excluding the rounding. As far as width of welds on the prototype was 0.23–0.25 mm, it can be suggested that in this case the EBW or laser welding was applied.

According to conditions of operation the measuring chamber of gas analyzer should be non-magnetic, corrosion-resistant and vacuum-tight.

Austenite Cr–Ni thin-sheet steel 12Kh18N10T (GOST 5632–72) can meet those requirements (wt.%: C < 0.12; 17–19 Cr; 9–11 Ni; 1–2 Mn). However its decreased heat conductivity and high coefficient of linear expansion predetermine the great distortion of structures and assemblies to be welded. To provide minimal postweld deformations and resistance to formation of solidification cracks, and consequently, decrease in overheating the metal of near-weld zone, it is necessary to select the conditions with the least energy input [2].

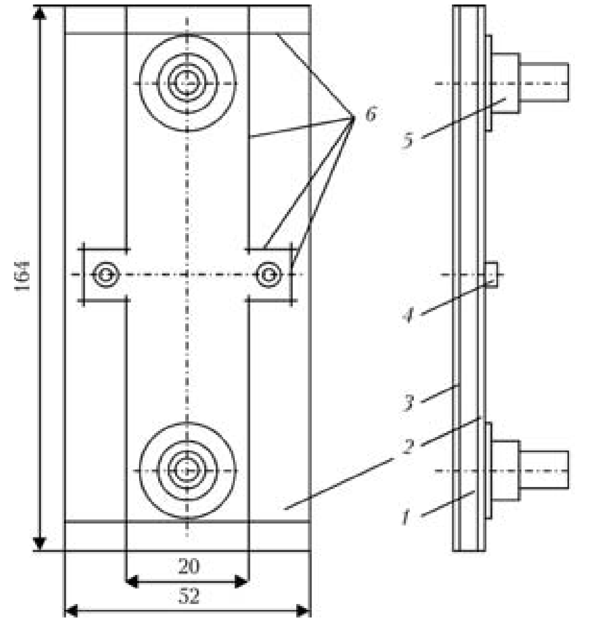

Figure 1. Scheme of measuring chamber of magnetic pneumatic gas analyzer of the Oxymat type: *1* — basement; *2* — upper plate; *3* — lower plate; *4* — nipple; *5* — exhaust pipe; *6* — overlap welds

As is shown in [3] in EBW of kovar and steel 12Kh18N10T sheets 0.3 mm thick using continuous electron beam the energy input $q/v = \eta_s U_{acc} I_b / v_w$ [J/m] (where η_s — efficiency factor of electron heating, for steel 12Kh18N10T it is equal to 0.8; U_{acc} — accelerating voltage, kV; I_b — current of electron beam, mA; v_w — welding speed, mm/s) remains constant in the range of accelerating voltage of 20–70 kV. The investigation of character of dependencies $q/v = f(v_w)$ and $B = f(v_w)$ showed that at $U_{acc} = 60$ kV the minimal heat input is achieved at $v_w = 40$ mm/s, and weld width $B = 0.25$ mm. For overlap joint the thin plate-basement of (0.2 + 1.0) mm of the steel 12Kh18N10T, the value of electron beam current on the product item penetration depth $h_{pen} = 0.3$ mm made $I_b = 2.1$ mA. The heat input at welding conditions $U_{acc} = 60$ kV, $I_b = 2.1$ mA, $v_w = 40$ mm/s was equal to $q/v = 2.52$ kJ/m.

The practicing of conditions of EBW of overlap joints of thin plate-basement of (0.2 + 1.0) mm of steel 12Kh18N10T was performed in laboratory machine OB-1803 with a modified EB column PL-102.* EB gun of triode type with a directly heated thermionic cathode of 0.27 mm diameter from tungsten-rhenium wire VR-20 together with electromagnetic adjustment system and focusing lens provide formation of a heating spot of 0.05–0.30 mm diameter and electron beam with $I_b = 0$–15 mA [4] on the surface of item being welded. The deflection system located under focusing lens provides at its connection to the control system SU-241 [5] the deflection and movement of electron beam along the circumferential butt of a fixed item (nipple or exhaust pipe) at a preset speed. Vacuum chamber with two-coordinate working table allows loading and flat welding of four measuring chambers simultaneously in welding-assembly device at rarefaction of $1.33 \cdot 10^{-2}$ Pa. The working distance is $l_{work} = 105$ mm.

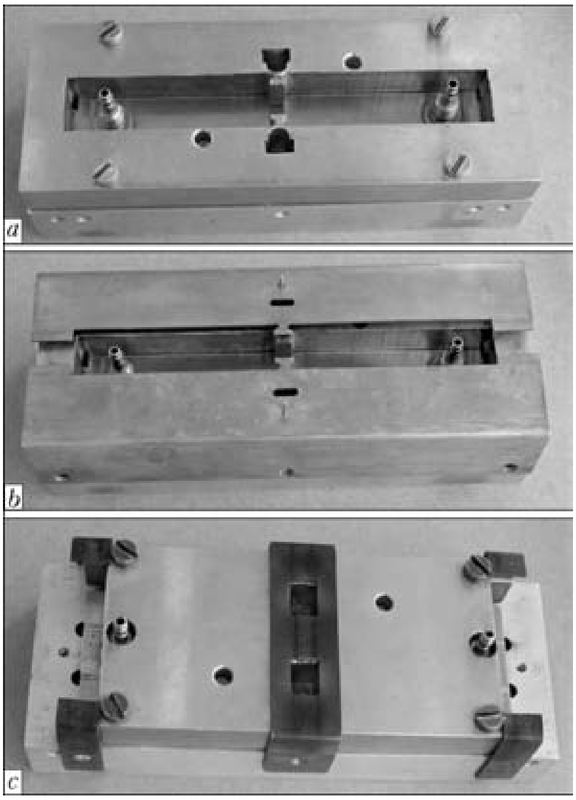

Figure 2. Welding-assembly device for EBW of measuring chamber (×1.67): *a* — assembly without shielding screens; *b* — assembly with shielding screens for performance of overlap welds respectively along the long and short (*c*) sides

The control of electron beam focusing on the surface of overlap joint of thin sheet-basement of stainless steel 12Kh18N10T was performed visually by the brightness of illumination of circular scan of 5 mm diameter and $I_b = 2$ mA on the copper massive plate located at the same level with the item to be welded and also using optical system of observation of electron-optic column PL-102 providing a clear imaging of the welding zone at (5–50)-fold magnification. Welding of overlap joint of (0.2 + 1.0) mm was performed at a sharp focusing which at $l_{work} = 105$ mm was equal to current of a coil of focusing lens $I_f = 765$ mA. Circumferential welds on flanging of nipples and exhaust pipes were produced with incomplete focusing of electron beam at $\Delta I_f = -20$ mA ($I_f = 745$ mA).

To provide a reliable heat contact along the whole length of a butt of overlap joint of (0.2 + 1.0) mm and to obtain defectless welds by analogy with the patent [6], the welding-assembly device for welding (electron beam or laser) was developed consisting of two rigid metallic bars of rectangular shape for tight clamping of measuring chamber (with two nipples and two exhaust pipes) between them, where in one of

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*S.A. Shchyolok, manufacturing engineer of the 1st cotegory, took part in this work.

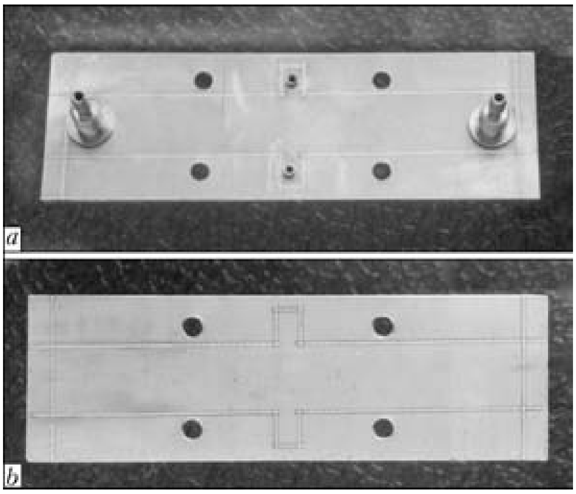

Figure 3. Measuring chamber of gas analyzer with straight-line overlap welds (×1): *a* — appearance on the side of nipples and exhaust pipes; *b* — on the side of lower plate

them the through slots are made on the side of effect of welding beam (Figure 2, *a*).

The distinctive feature of the welding-assembly device is the fact that the shielding screens with through slots of copper plate coinciding by their shape and axes with through slots in the mentioned bar are additionally installed with a gap (Figure 2, *b*). Thus, probable impact of welding electron beam on the upper pressing bar and its postweld deformation is eliminated.

During development of technological process of EBW of measuring chambers of magnetic pneumatic gas analyzer including welding-assembly device, the succession of welds performance turned to be principally important. To prevent sagging and buckling of thin plate of stainless steel 12Kh18N10T 0.2 mm thick in the area of gas channel of more than 0.1 mm, the following succession was accepted:

1) installing the nipple and exhaust pipe into the holes on thin plate of thickness 0.2 mm. The height and thickness of flanging was respectively 0.50 and 0.25 mm;

2) expansion of flanging on nipples and exhaust pipes, control of a gap between flanging and thin plate which should be not more than 0.05 mm;

3) assembly of upper thin plate with expanded two nipples and two exhaust pipes in a set with a basement and without lower thin plate in welding-assembly device (Figure 3);

4) loading of four sets of measuring chambers (nipples and exhaust pipes are directed upwards) into the vacuum chamber of the EB installation and making four straight-line overlap welds along the long side (see Figure 2, *a*, *b*);

5) evacuation of vacuum chamber and assembly of welding-assembly device with shielded screens of copper plates (Figure 2, *c*);

6) loading of four sets of measuring chambers (nipples and exhaust pipes are directed upwards) into the vacuum chamber and making four straight-line overlap welds along the short side. Observation of crossing of eight straight-line welds (Figure 3, *a*);

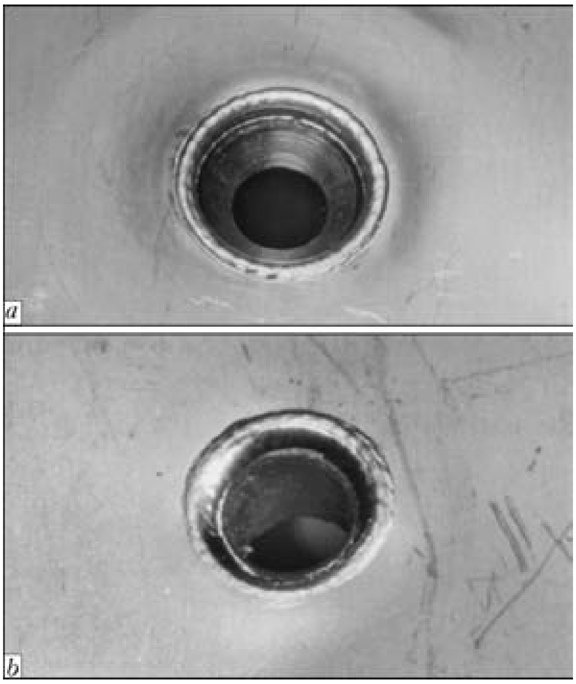

Figure 4. Appearance of circumferential welds in welding of flanging–thin plate (×4) on the exhaust pipe (*a*) and nipple (*b*)

7) evacuation of vacuum chamber and change of position of measuring chambers in welding-assembly device without lower thin plate (nipples and exhaust pipes are directed downwards), when circumferential welds–expanded flanging–thin plate are directed towards the welding electron beam;

8) loading of four sets of measuring chambers into the vacuum chamber and performance of EBW of circumferential welds on the nipples and exhaust pipes using control system SU-241. Welding condition is as follows: U_{acc} = 60 kV, I_b =1.8 mA, v_w = 15 mm/s (Figure 4);

9) evacuation of vacuum chamber and performance of visual inspection of formation of straight-line and circumferential welds for absence of defects in a form of lack of fusion and burn-outs;

10) intermediate chhecking of welded measuring chambers without lower thin plate for vacuum-tightness using method of excessive pressure. Drop of pressure in measuring chamber on the level of $0.59\cdot10^3$ Pa

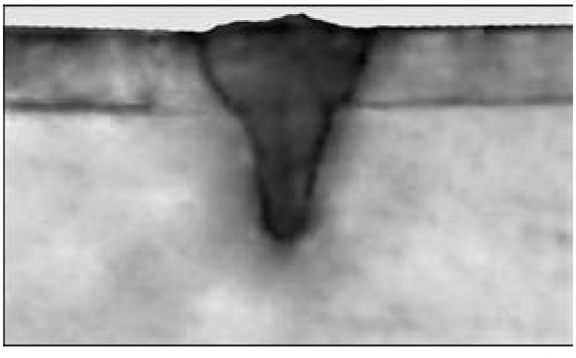

Figure 5. Transverse macrosection (×60) of overlap joint (0.2 + 1.0) mm thick of stainless steel 12Kh18N10T

determined using manometer (model 11202, GOST 6521–72) should not occur during 30 min;

11) assembly of four sets of measuring chambers in welding-assembly device with 0.2 mm lower thin plate of steel 12Kh18N10T (nipples and exhaust pipes are directed downwards), loading into vacuum chamber and making successively firstly four overlap welds along the long side and then four straight-line overlap welds along the short side (see items 4–6). Visual inspection of crossing of eight straight-line welds for absence of defects (Figure 3, *b*);

12) evacuation of vacuum chamber and performance of final testing of completely welded measuring chambers for vacuum-tightness using method of excessive pressure.

The conditions of EBW in general vacuum of measuring chamber of magnetic pneumatic gas analyzer, succession of performance of assemblies and welds, intermediate and final checking of formation of welded joints for lack of defects and vacuum-tightness allowed obtaining 100 % output of annual production. As is shown in Figure 5, the width of face bead of overlap weld was $B \cong 0.24$ mm at the depth of penetration of about 0.5 mm.

It was also established that values of residual deformations of structure of measuring chamber are in direct dependence on heat input of welding which in its turn is determined by welding conditions and depends on weld section. The measuring of postweld deformation was performed using method of comparison with the reference sample. Sagging and buckling of thin plate of foil of thickness 0.2 mm in the area of gas channel did not exceed 0.1 mm.

CONCLUSIONS

1. EBW technology and equipment as applied to precision welding of measuring chamber of magnetic pneumatic gas analyzer of stainless steel 12Kh18N10T meet all requirements for vacuum tightness and geometric sizes of the gas channel.

2. Minimal heat input of electron beam and minimal width of the weld are achieved at $v_w \geq 40$ mm/s.

3. The given conditions of EBW of overlap and circumferential joint, succession of making assembly and welds, stage-by-stage control of quality of welding and vacuum-tightness allowed obtaining 100 % output of annual production.

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LIMITATION OF OVERVOLTAGES IN HIGH-VOLTAGE CIRCUITS AFTER DISCHARGES IN WELDING GUN

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Occurrence of overvoltages in output circuits of a high-voltage power source, cable and welding gun after its discharge was studied using computer modeling. Recommendations are given on optimal parameters of elements of the overvoltage limitation circuit for the powerful power sources.

Keywords: *electron beam welding, electron gun, source of accelerating voltage, limiting resistor, natural inductance, shunting diode, high-voltage cable, discharge in gun, modeling of transition processes*

The development of abnormal non-stationary processes in welding gun, to which electric discharges refer due to the loss of vacuum seal, can result not only in violation of weld formation but also cause damage of a number of assemblies of power unit, such as a high-voltage insulator of welding gun and cable (Figure 1), and also limiting resistor. As far as mentioned assemblies can withstand test voltage twice exceeding the operating one without fracture, it can be assumed that overvoltages exceeding operating voltage at least twice exist.

In welding gun the overvoltages were revealed after discharge as early as at the beginning of application of EBW, however the conductance of device measurements of rapidly flowing processes under high potential relatively to the earth is considerably complicated [1–4]. It partially explains the absence of publications on the problems of prevention of overvoltages after discharge in welding gun. It is managed experimentally to fix only the current overloads of sources of accelerating voltage.

The use of controlling electron pentode as a linear element prevents intense current surges in power source after discharge in welding gun. However, it