APPLICATION OF METHOD OF DRY UNDERWATER WELDING IN REPAIR OF UNDERWATER PASSAGES OF GAS AND OIL PIPELINES IN RUSSIA

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Application of dry underwater welding in repair of underwater passages of main gas and oil pipelines across rivers is considered. A new specialized mobile diving complex, designed for repair main gas pipelines of 1020 and 1220 mm diameter at the depth from 2 up to 30 m using the dry underwater welding, passed the full-scale tests, is described in detail.

Keywords: *dry underwater welding, main gas pipelines, repair of underwater passages, mobile diving complex*

Nowadays the method of hyperbaric underwater welding which started its development since the 1960s is the most challenging in solution of tasks connected with construction and repair of underwater oil and gas pipelines and other hydraulic engineering constructions at different depths. The development of this method was proceeded by application of materials with higher mechanical properties, increase of depth of works performance and requirements to performers which should provide joints with predicted quality level. In this welding method the contact with water of reaction zone and metal being welded is absent and more convenient conditions for the work of divers-welding operators are provided in comparison with wet welding methods, that allows producing welded joints of equal strength independent of environmental conditions and depth of works fulfillment. This has particular importance for Russian Federation, where by the end of 2008 a number of underwater passages of main pipelines (MP) across water barriers of total length 5800 km was 1855 units (or 2687 lines). Due to different reasons the influence of environment and hard-to-reach underwater passages of MP are complex objects for conductance of underwater technical operations using underwater welding.

Aim of the work is to present information about technology of dry welding of underwater passages of oil and gas pipelines and equipment used for its realization in Russian Federation during last 30 years.

The main volume of works in dry chambers is performed in repair of underwater pipelines. The chambers are designed and manufactured individually according to the order [1–3]. Such a chamber of weight from 8 to 20 t, as a rule, is included into ship diving complex. A number of mobile simplified modifications of chambers has also been designed for quick delivery to the site of failure in the containers. Except the chamber itself, the complex includes hydraulic hoists and aligning devices necessary for displacement of pipes in vertical and horizontal planes at their fixation and sealing in the chamber ends. The chambers are completed with a set of sealing elements providing sealing pipes of different diameters. The additional set includes equipment for cleaning, cutting and fitting-up of pipes, a sealed power source allowing welding using the technology of manual arc welding (MAW), TIG and MIG/MAG welding and heat treatment of welded joints, sealed containers for storage of tools and accessories, equipment for heat treatment and control of welded joints.

The camera equipment includes also systems of smoke removal, fire extinguishing, control of composition of gas environment and hydraulic system for fixation and movement at small distances of a pipe being repaired in case of its aligning during its assembly. In the upper part of the chamber a hatch is located to which a diving-bell is connected. From the bell the divers-welders can travel directly to the chamber. In the period of assembly on the pipe, when the chamber is sunk, the welders perform work in diving suits. After the site works are finished they work without diving suits, but put on a face mask, when necessary, which is connected to the system of gas supply of diving-bell.

Underwater welding works are performed by experts who passed many-month training under the supervision of specially trained engineers and technologists, who constantly monitor the physical state of divers-welders, composition and humidity of gas mixture, and also control all electric parameters of the arc process.

In the practice of repair of underwater passages at the territory of the former USSR the dry welding practically was not almost used excluding repair of oil pipeline Aleksandrovskoe–Anzhero-Sudzhensk in the place of its crossing through the Ob river [4, 5]. In this case both defects of the 1020 mm diameter steel 18G2AF pipe of 16 mm wall thickness were in the upper part of site butt welds. In February-March 1979, at the depth of 6 m the first defect — a crack, the visible part of which was 250 mm — was repaired in caisson. As a caisson a vessel for water of 1.8 × × 1.5 × 2.2 m, found in the nearest region, was used, that allowed performance of welding jobs on the pipe in the «sector» from 9 to 3 h. The water was forced out by compressed air, and welding aerosol from the burning zone was removed by local exhaustion. The entry and exit of divers-welders and also supply of all necessary things were performed through a lower part of the caisson. The defective area of 400 × 650 mm size was removed using gas-oxygen cutting, and a patch with a backing were placed into the formed hole. A root weld was performed using a wet mechanized welding and the groove was filled using covered electrodes in the dry environment. The diving equipment allowed diver-welders to perform only two divings for 45–50 min during one working day. The total time spent for manufacturing of chamber, its assembly and performance of welding works was 65 days.

The second defect was repaired in February-March, 1980. The soil washing out was carried out in summer-autumn period, and cleaning of pipe from hydraulic insulation and installing the same caisson used during repair of the first defect was performed during 10 working days. As in the first case the crack was located in the «sector» from 13 till 14.30 h, its visible part was 200 mm. The technology of welding works performance was the same as during repair of previous butt. During welding works the welders applied the machine ShAP-62, that allowed working under water without coming out to the surface during 3–4 h. In repair of this defect welding works were carried out for 10 h (including preheating of pipe and welds cleaning).

Nowadays in Russian Federation a number of works was performed in MP using dry welding [6]. For this purpose a specialized underwater caisson of Zakharov (SUCZ) of the modification I was used, representing an open diving-bell installed by a side surface on MP. The SUCZ of different types and sizes provides repair of MP of diameter from 325 to 1420 mm.

SUCZ, the schematic diagram of which is shown in the Figure 1, is composed of a metallic casing *18*, connected to four guides *9* and fastening bracket *16*, to hinged devices *3*. The side surfaces of the casing *18* have segment cut *6*, the radius of which corresponds to the radius of MP being repaired *4*. The air-tightness of installation SUCZ on the outer surface of MP is provided by a packing *7*, made of a microporous rubber, positioned in the circumferential gap between a casing segment cut *6* and surface of MP. At the surface of the casing *18* two ventilation holes *10* and *14* (respectively, main and auxiliary) are located where taps to control discharge of shielding gas and welding fume are mounted. To the main vent hole *10* the ventilation bell is linked through the hose providing removal of welding fume from the caisson. The casing *18* is fixed on two rods-weights *2* at the required height using hinged devices *3*. The stability of structure is provided by ballast boxes *19* with ballast loads *1* positioned in them. The SUCZ is fixed on the defective area of pipeline being repaired by means of clamping semi-rings *11* and turnbuckles *12*, *13*, and its position on the MP surface is fixed by four bolts-rests *5*, arranged on guides *9* which provide the fixation of required position of SUCZ relative to MP axis. Assembly loops *15* are welded-on to fastening brackets *16* for mounting of casing *18* of SUCZ on a load-carrying frame in its lifting and lowering under the water.

SUCZ made it possible to perform a number of repair works using a MAW in shielding gases on MP, the list of which is given in the Table.

For all the works, described in the Table, the technological process was approximately the same and included the following operations:

• washing out and cleaning of surface of pipeline from hydraulic insulation;

• installing of caisson and water forcing out by supply of argon or carbon dioxide;

• cleaning of pipe surface for the width of not less than 150 mm from the boundaries of supposed removal of defective area using mechanical method;

• fixation of crack ends by drilling and removal of defect metal by grinding with formation of two edges;

• preheating up to 100–150 °C and welding;

• non-destructive testing of welded joint;

• dismantling of chamber, installing of coupling, restoration of damaged hydraulic insulation and hydraulic deposition of soil on repaired area of pipeline.

During repair of a through defect of circumferential butt welded joint of underwater passage of gas pipeline Khatassy–Pavlovsk across the Lena river a coupling PGM was not installed.

The preparation of defects of circumferential butt welded joints of pipes for MAW was performed in the following sequence:

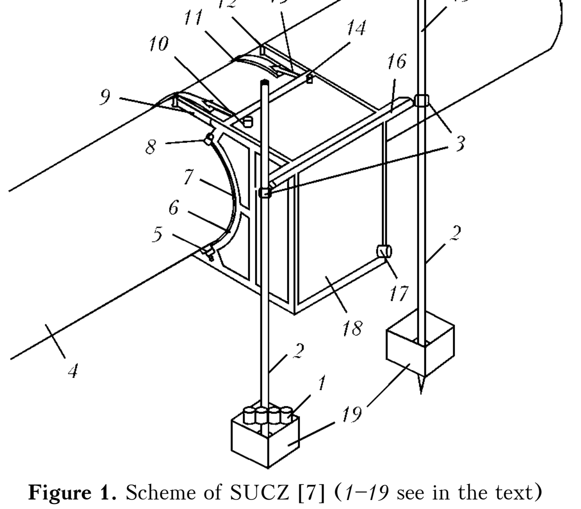

Figure 1. Scheme of SUCZ [7] (*1–19* see in the text)

Repair of defects of MP, made by «Spetspodvodremont Ltd» using method of a dry underwater welding

MP and its characteristics (depth of defects location)	Customer, year of performance	Defect	Method of repair
Petrovsk–Novopskov, 1020 mm diameter at the Don river (5 m)	«Volgogradtransgaz Ltd», 2006	Through defect in the form of a crack in cross weld of 180 mm length	MAW with further installing of coupling MPSS (length L = = 1400 mm, pressure P = 217 MPa)
«Pipe-bend for Zarechie», 350 mm diameter at the Lena river (10 m)	«Sakhatransneftegaz Ltd», 2006	The same of 360 mm length	MAW with further installing of coupling PGM (length L = = 990 mm, P = 171 MPa)
Gas pipe-bend Hatassy–Pavlovsk, 530 mm diameter at the Lena river (10 m)	The same, 2007	The same of 280 mm length	MAW
Yamburg–Elets 2, 1220 mm diameter at the Ob river (8 m)	«Tyumentransgaz Ltd», 2007	Cracks (stress-corrosion) on the body of a pipe in longitudinal direction: the first crack of the 1660 mm length and 8 mm depth; the second crack is 580 mm length and 10 mm depth	MAW with further installing of coupling MPSS (length L = = 5200 mm, pressure P = 1060 MPa)

• the pipe surface was cleaned in mechanical way for the width of not less than 150 mm from the boundaries of supposed removal;

• to prevent crack propagation its edges were fixed by 5 mm diameter drill at the distance of 15–30 mm from crack boundaries in the direction of its possible propagation;

• the layered removal of defective metal by abrasive discs was performed to produce necessary shape of edges for welding, here the removal should have U-shape with parallel boundaries and rounded angles; its length should overlap a defect for not less than by 30–50 mm on each side (+30–50 mm at run of abrasive disc to each side from the boundaries of defect). In case if the through removal was not required, the defective area was removed by grinding until residual thickness of metal of 3.0–3.5 mm. If a through removal was required, the welding of a root layer was performed by areas of a length of not more than 75 mm at a curvilinear position of a crack along the circumferential area of welded joint. At its straight-linear position the simultaneous removal and welding of weld root layer is admitted. Welding of filling layers of a weld was performed by a step-back method along the whole length of defective area, and a finishing weld layer was made along the whole length of defective area to suit requirements.

The works on preparation for repair, welding and quality control of welded joint after repair were performed by divers-welders in diving outfit in caisson in CO_2 atmosphere.

To weld a root layer, the electrodes of the type E50A of 2.0–3.25 mm diameter of LB-52U grade, and for welding of filling and finishing layers the electrodes of the type E60 of 3.2–4.0 mm diameter of OK 74.70 grade were used.

The quality control of welding was performed in operation-by-operation way visually and by check out of continuity of deposited metal using ultrasonic method in the volume of 100 %. The admissible sizes of defects of welds should not exceed values given in RD 558–97.

SUCZ of modification II is the following step in the development of technology of repair of gas pipelines using dry underwater welding in Russian Federation. It represents a specialized underwater complex (SUC) consisted of a caisson and installation frame (Figure 2) and designed for welding pipelines of 1020 and 1220 mm diameter with 14–20 mm wall thickness at the depth from 2 to 30 m. The full-scale tests were held in the period of 27–31 October, 2009. Using SUC one can cut out and replace damaged areas of pipelines, reweld through and non-through defects, to butt weld the pipelines under water and perform other welding works on underwater MP. The total weight of complex is 25.5 t.

A casing of caisson of this modification is made sectional for reducing dimensions during transportation (Figure 3). Caisson is composed of five main parts (see Figure 2): casing *5* (upper and lower part); sealing flap *9*; supporting beam *6*; outrigger *8*; pneumatic sealing *7*.

The caisson of 5.9 t weight of sizes 2.74 × 4.14 × × 3.06 m and 16.2 m^3 volume allows performing works of two divers-welders simultaneously using standard welding consumables and technologies. In the ends of caisson changeable sealing flaps *9* are located which are opened inside during installing. Sealing of flaps is provided by a porous rubber gasket and around the pipeline — by floating rubber packings *7*. In the upper part of caisson the П-shape projection is foreseen where fastening of loading pulley blocks, reducers of expiration and inputs of TV cables, lighting and hoses of inlet-outlet of gas mixture are located. In the upper part of the caisson, support beams *6*, aligning the

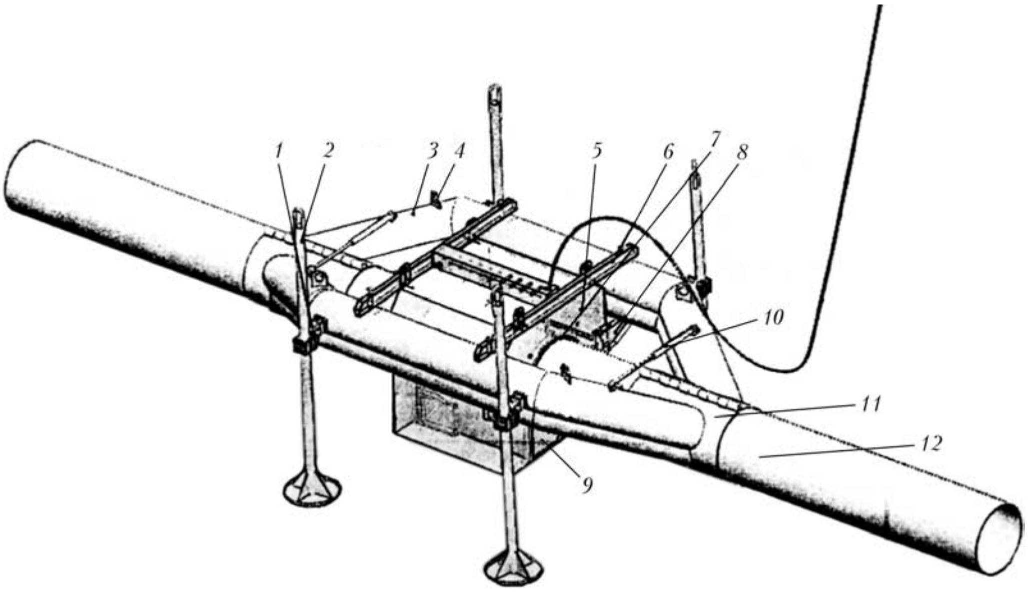

Figure 2. Scheme of SUC (*1–12* see in the text)

caisson relative to a pipe, along which it slides along the frame, are located and on the forward and backward wall of the caisson the rests *8*, maintaining the caisson from the coming to the surface and aligning it are located. The caisson is filled with carbon dioxide or argon to prevent explosion in case of ingress of gas from a pipeline being repaired inside the working zone. The air expired by divers-operators through special system, is removed to the surface without penetration inside the caisson. In the corners four video cameras with lighting are located to control the state of divers and sequence of performance of operations by them. The set of equipment includes two pulley blocks of 2 t loading capacity each used for assembly of pipe insert. The voltage for lighting and operation of equipment is supplied by electric cable of 70 m length with a connecting coupler. The electrodes are transported to the working area in a specialized sealed container.

Installation frame *3* (see Figures 2 and 4) is designed for rigid fixation in the initial position of emergency area of a pipeline *12*, during cut out of a pipe section, and also to prevent caisson from floating during its complete blowing. It is composed of two halves of 9.8 m length and 8.8 t weight each, pipe grips *11* with polyurethane gaskets, hydraulic stretchers *10*, supports *2*, hinges *1* and loading staples *4*. The hinges of frame are axles of pipe grips *11* positioned on the edges of installation frame. The as-assembled frame width is 6.1 m, height — 3.1 m. To clamp the pipe on installation frame, two hydraulic stretchers *10* are mounted, providing the closing-opening of pipe grips of a force up to 300 kN, operating from pump station with a pneumatic drive. Fixation of the installation frame on pipeline from a longitudinal movement is realized on both sides by bolts through the grip flaps, which are tightened a dynamometric wrench. The clamping force is transferred to the pipeline through the polyurethane inserts of pipe grips *11*, mounted in edge parts of the installation frame *3*. The inner cavity of the installation frame is divided into six ballast bays of 12.8 m^3 total volume, which can be filled with water or blown, in this case the vertical load to the pipeline is changed.

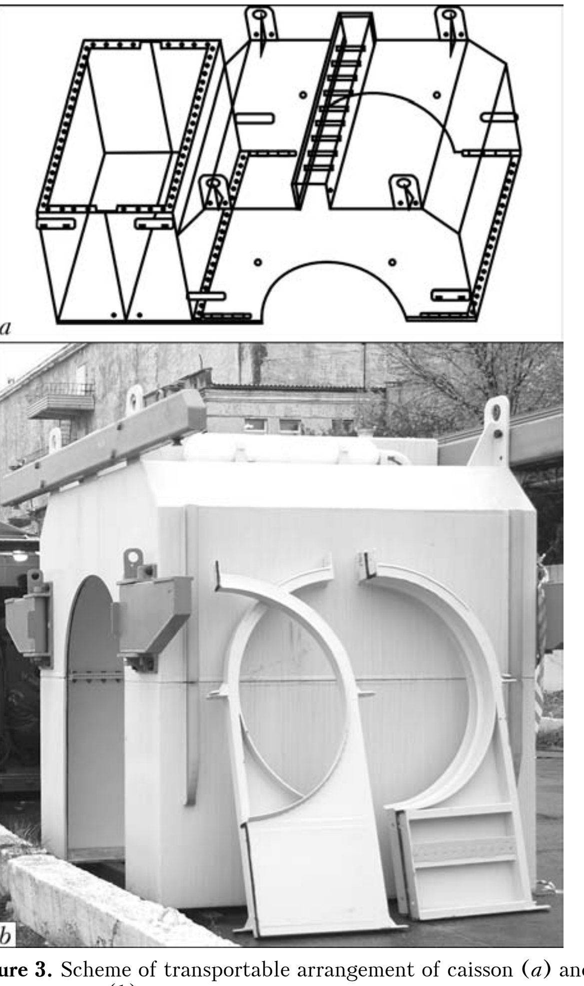

Figure 3. Scheme of transportable arrangement of caisson (*a*) and its appearance (*b*)

Figure 4. Appearance of installation frame

Installation frame *3* is rested on soil by four adjustable vertical supports *2*, which release the weight load of the complex to the pipeline. They have hydraulic inserts with a manul pumping, developing the force of 200 kN each, the piston stroke is 360 mm. The supports are connected to the frame by hinges *1*, having two degrees of freedom. This allows all the complex to move in a horizontal plane thus helping to align pipeline during mounting of a pipe section.

To purify the caisson gas medium from fumes, the ventilation is provided. The welding fumes from the caisson inner cavity enter the fume filter with changeable filtering element and gas analyzer by a separate hose. The purified gas is returned to the caisson inner cavity by hose through a low-pressure compressor and dryer with a selicogel filter. The gas leakage in system is compensated from transported cylinders with CO_2 and argon, located on the surface.

Welding and other kinds of operations are also realized inside the caisson by divers-welders, having diving suits. Air for breathing is supplied by a hose-cable through a lower part of the caisson. The air breathed out by divers is removed from masks through hose connected to an outlet reducer connection pipe into an expiration reducers located in opposite corners inside the upper part of the caisson casing and beyond it. Operation of pneumatic tools inside the caisson is realized by connection of hoses through connection pipes to receivers valves located inside its upper part.

The cutting out of defective area of the caisson is made by mechanical mill cutter, having a pneumatic drive. Cutting out of defect by oxygen cutting is possible. Pneumatic tool used for fitting up the welded-in pipe section and cleaning of welds is supplied by compressor which removes the inert gas from the caisson through a dryer and filter. The aligning and fixation of pipe insert is realized using two standard aligning devices. The complex includes two inverter arc power sources with falling and rigid external volt-ampere characteristics.

All the constituent elements of the complex can be transported in parts using different kinds of transport including automobile with a body of 12 m length. The installation can be assembled on the shore in any convenient place and then towed afloat to the site of works performance at minimal depth of fairway of 2 m. The asymmetry of installation frame allows using complex in shallow water, for its installing the foundation pit of minimal size is required. These peculiarities are very important in performance of works in non-navigable and small rivers.

The described examples of application of technology of dry welding in the chamber are most probably will be widely used in assembly and repair under water of critical hydraulic engineering constructions and also at low level of transparency of water.

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