Design of a system for fastening the pipelines’ elements to be brazed of an automated gas metering unit

V S Tynchenko¹², V A Kukartsev¹, N V Kuzmin³, A V Lysyannikov¹, S N Katargin¹ and A E Stashkevich²

¹ Siberian Federal University, 79, Svobodny pr., Krasnoyarsk, 660041, Russian Federation
² Reshetnev Siberian State University of Science and Technology, 31, Krasnoyarsky Rabochy Av., Krasnoyarsk, 660037, Russian Federation
³ Krasnoyarsk State Agrarian University, 90, Mira Av., Krasnoyarsk, 660049, Russian Federation

E-mail: vadimond@mail.ru

Abstract. The article discusses an automated measuring installation, and also analyzes the subject area. Some types of soldering are considered (capillary, diffusion, contact-reaction and others). The choice of induction brazing for the soldering of pipeline elements of an automated gas metering installation has been substantiated. The work presents the installation of induction heating, considering the required technological parameters. Based on this installation, the basic diagram of the Fitting and the schematic diagram of the connecting sleeve were corrected, which will allow the development of a mobile induction installation as well as collapsible inductors. Potential induction equipment and the developed designs can be used to connect pipelines in the oil and gas industry.

1. Introduction

The automated metering unit consists of a technological unit, a monitoring and control unit, made in the form of a block of containers.

The technological block includes:

- Vertical measuring container.
- Horizontal separation tank.
- Electric flow switches.
- Level gauges with flag indication.
- Limit switches for doors.
- Temperature sensors.
- Gauge pressure transmitters and differential pressure transmitter.
- Gauge pressure gauge showing.
- Safety spring valve.
- Shut-off valves (gate valves, valves, check valves).
- Gas contamination sensor.

The automated metering unit consists of a technological unit, a monitoring and control unit, made in the form of a block of containers.

The technological block includes:

- Vertical measuring container.
- Horizontal separation tank.
- Electric flow switches.
- Level gauges with flag indication.
- Limit switches for doors.
- Temperature sensors.
- Gauge pressure transmitters and differential pressure transmitter.
- Gauge pressure gauge showing.
- Safety spring valve.
- Shut-off valves (gate valves, valves, check valves).
- Gas contamination sensor.
• Fire detector.

Control and management unit:

• Manages the process of measuring parameters, produced liquid and gas.
• Provides power supply to the sensors installed in the technological unit, receiving and processing signals from the sensors.
• Transmits information to the upper level via the standard MODBUS interface.
• Provides connection of a laptop and information output on its screen.
• Stores information about measurement results in its memory.

“MERA” has the following features [1]:

• The software of the complex (controller-computer) allows, without additional technical means, to carry out automatic and manual control of the measurement process.
• In the commissioning mode, control is carried out by the operator through a touchscreen liquid crystal display, which also displays a mnemonic diagram in real time.
• The control system is based on the Direct Logic 250 controller.
• In the instrument part, imported sensors, terminal blocks are used. relays of renowned KRONHE companies. YOKOGAWA. VEGA.
• The measurement is carried out according to the improved algorithm of the hydrostatic measurement method, approved by the All-Russian Scientific Research Institute of the Metrological Service VNIIMS.
• Display of information about the process of measurement, calculation and measured parameters on the screen of a personal computer.
• Visual indication of displaying the filling of the measuring container additionally allows using a stopwatch to check the liquid flow rate in the filling cycle, and the gas flow rate in the drain cycle.
• Ability to measure high-rate wells with foamy oils;
• The control and management unit house the operator's workplace for performing work on the periodic maintenance of the unit; internal anti-paraffin and anti-corrosion coating of pipelines and measuring vessel.
• When operating at high flow rates with low-water-cut and foaming oils, an automatic transition to measuring the hydrostatic pressure of the liquid column is provided after a pause, ensuring full bubble gas outlet, and after determining the filling level of the calibrated volume of the measuring tank at a predetermined filling time. Thus, in this mode, the processes of measuring the flow rate and density of the oil-water liquid occur in statics in the complete absence of bubble gas.

The principle of operation of the installation:

• The well production through pipelines enters the separation tank, in which the gas is separated from the liquid and then enters the measuring tank. The separated gas under the separation pressure is sent to the collection header.
• When the liquid level reaches the lower gauge of the measuring container, the countdown of the filling time of the calibrated part of the container begins and the hydrostatic pressure of the liquid column in the container is recorded, and when the upper level sensor is reached, the time counting stops and the hydrostatic pressure of the liquid column is also recorded. The monitoring and control system calculate the flow rate of the well for oil and water.
Measurement of gas flow rate is performed according to the principle of “Volume displacement” when draining the liquid from the measuring tank. The entire process of the installation is automatic. Average values for the flow rate of liquid, gas, oil, water is transferred to the upper level and stored in the controller’s memory.

2. Materials and methods

Today, there are many ways to solder. In this paper, we will consider some of them and choose a suitable soldering method for connecting pipelines in the oil and gas industry.

2.1. Capillary brazing

Capillary soldering is the most common. Many, using it, do not even know about such a name. The essence of the technology is as follows.

The solder is melted, it heats up and fills the space between the two prepared parts. The wetting of the surface of the parts and the retention of the solder is largely due to the capillarity effect [2].

This brazing is widely used in the connection of copper pipelines. It allows the joining process to be carried out very efficiently and firmly [3]. The name capillary brazing indicates a very small gap between the pipes to be connected, it is 0.1 - 0.3 mm. This creates surface tension. Solder, falling into the gap, rises up and fills the free space.

Capillary soldering is common in everyday life and in various industries [4]. To carry it out, you will need a soldering iron or torch. In fact, any type of soldering can be considered capillary to a certain extent, since each type of soldering involves capillary wetting of the workpiece surfaces with liquid solder.

2.2. Diffusion soldering

This type of soldering differs from the others in the duration of the process, since diffusion takes time [5,6].

The solder inside the seam zone is kept at a certain temperature longer than, say, with conventional capillary soldering [7]. The connection of the two blanks occurs due to the diffusion of the solder and the metals to be brazed.

The diffusion process itself consists in the penetration of molecules of one substance into the structure of another substance [8]. Adhesion occurs at the molecular level and makes it possible to obtain a stronger seam.

The diffusion view requires strict adherence to the temperature and time regime. The heating temperature in the soldering zone is always higher than the melting point of the solder.

2.3. Contact reaction soldering

The type of soldering called “contact-reaction” or “reactive” means the process of fusion when two parts of different metals come into contact [9].

There is a phase transition of the metal from a solid to a liquid state, followed by solidification and fusion. Often, such a connection is carried out through a thin layer, which is applied to one of the blanks by electroplating or otherwise [10].

Low-melting materials are used - eutectics. So you can combine silver and copper, where a copper-silver alloy will be formed between the parts. Soldering of tin and bismuth, silver and beryllium, graphite and steel is carried out [11].

It is possible to solder aluminum with other materials through an interlayer of copper or silicon. The connection is strong, the soldering time takes a fraction of a second.

2.4. Reaction flux brazing

The reactive-flux type of soldering is based on a chemical reaction in which a solder is formed from the flux when combined with the metal [12]. This is clearly seen when aluminum parts are connected to each other [13].
For their docking, a zinc chloride-based flux is used. When heated, zinc begins to interact with aluminum, turning into a metal solder [14].

It fills the entire space of the gap, making the place of the soldering zone a strong connection. In this case, it is very important to precisely observe the proportions of the applied flux. There must be a lot of it so that pure zinc in the required amount can be released from the flux powder [15,16].

2.5. Soldering-welding

The technology got this name because the process itself is very much like welding metal with filler material (wire or powder) [17].

But in this case, a solder is used instead of an additive. This type is most often used to repair defects and flaws on the surfaces of metal parts (cast).

The process itself can be carried out in different ways [18]:

- Soldering in ovens.
- By dipping in a bath with liquid solder.
- Resistance by means of electric current.
- Induction method.
- Radiation.
- Using soldering irons and gas torches.

Some species have appeared relatively recently, are still being researched and refined [19].

2.5.1. In ovens. The first option provides a uniform distribution of the solder over the defective parts of the part and uniform heating, which is especially important when it is necessary to solder large-sized workpieces with a complex configuration.

At the same time, heating in the furnace can take place in one of many existing methods, ranging from heating by a flame, and to complex technological processes, such as induction, electrical resistance.

The design of the furnaces themselves differs from each other only by the hearths on which the brazed workpieces are laid. For large parts, furnaces are used in which the underneath does not move, and for small parts, they are movable in the form of conveyors on rollers.

The main task of this type of soldering is to create a special gaseous substance inside the furnace. Furnace brazing can be fully mechanized, leading to increased productivity. And for industries with a mass output of finished products, this is an ideal option.

2.5.2. Immersion in the bath. Immersion soldering is carried out either in molten solder or in a mass of special salts. The last type of soldering is a quickly carried out operation due to direct heating of the workpieces from salts, which perform the functions of both a heating element and a flux. With regard to immersion in solder, it should be noted the possibility of full or partial immersion.

2.5.3. Radiation method. The radiation type of soldering is produced by a powerful luminous flux, which is formed by a quartz lamp, laser or cathode defocused beam.

The technology appeared relatively recently, but has shown that in this way it is possible to achieve high quality soldering of two metal blanks. In addition, a real opportunity has appeared to control the process both in terms of the degree of heating and in terms of time. At the same time, the laser removes the oxide film from the solder and from the metal, which guarantees a high quality of the soldered seam.

The gas envelope in the connection zone, formed by heating the metals, makes it possible not to use fluxes during the connection. Therefore, when today they talk about soldering without flux, they mean laser technology.
2.5.4. Vacuum method. Soldering in a vacuum is still not used always and not everywhere today. The complexity of this type is that it is necessary to create a rarefied atmosphere without air in the soldering zone.

As you know, the oxygen present in the air is the cause of the formation of an oxide film that covers metal workpieces and solder.

The film is very refractory; during soldering, temperature degrees are lost for heating the parts to be joined. Therefore, all scientists are still looking for ways to remove the oxide coating or carry out the process without it. Vacuum brazing is one such option.

Such factors prevent the introduction of the vacuum type into production:

- Low productivity of the process, because every single part has to be heated.
- Only small workpieces can be soldered in this way.

2.5.5. Selective method. This is not to say that the selective type of soldering is fundamentally different from the capillary one. Similarly, it uses solder and heating. But the solder is melted only in selective places (local points) to which the elements are planned to be attached.

Selective soldering is used mainly for the manufacture of circuit boards and pin components. It is similar to the wave method used to solder smd chips. Selective soldering plant - equipment belonging to the category of semiautomatic devices. It is not cheap, but it saves consumables almost tenfold compared to the wave, so it spreads wider and wider.

3. Results and discussion

The most suitable method for connecting pipelines is induction brazing. For the development of an installation consisting of an alternating current source, a generator, an industrial computer, a soldering station control unit, an inductor, a control panel, a pyrometer, an ammeter. Initially, it is necessary to develop a coupling for connecting pipelines of an automated gas metering installation. Based on the calculated power consumption of the inductors and the frequency, the existing equipment was selected that can implement this method in the area under consideration.

All induction brazing machines operate through physical processes that occur through the unique properties of electricity, one of which is induction heating. Induction heating is the heating of materials by electric currents that are induced by an alternating magnetic field. Induction heating is widely used in industry.

Installations of induction heating THV PETRA (figure 1) are used in many industries to implement effective technological processes for electrothermal treatment of products. THV units are used where fast contactless heating of metals and other conductive materials is required.

![Figure 1. Installation of induction heating THV PETRA.](image-url)
In the course of the work, the authors developed a schematic diagram of the Nozzle (figure 2), as well as a schematic diagram of the coupling (figure 3).

**Figure 2.** Schematic diagram Fitting: 1. Pipe 90mm; 2. Flange; 3. Solder PSr-45.

**Figure 3.** Schematic diagram of the coupling.
The proposed solution will allow to connect pipelines of oil and gas equipment by means of induction brazing, which will improve the reliability of such connections and increase the efficiency of the structures themselves.

4. Conclusion
In the course of this work, an analysis of existing soldering methods was carried out, and induction soldering was selected as the most suitable for the area under study. The THV PETRA was selected as the induction heating unit. As a result, a schematic diagram of the Fitting has been developed, as well as a schematic diagram of a connecting sleeve, which will allow connecting pipelines using induction heating.

Acknowledgments
The study was funded by a subsidy from the Ministry of Science and Higher Education of the Russian Federation for the creation of a youth laboratory "Laboratory of Biofuel Compositions" as part of a government assignment.

References
[1] Kojima M 2016 Fossil fuel subsidy and pricing policies: recent developing country experience. World Bank Policy Research Working Paper 1(7531) 12-20
[2] Zhao W W, Yan J C, Yang W and Yang S Q 2008 Capillary filling process during ultrasonically brazing of aluminium matrix composites Science and Technology of Welding and Joining, 13(1) 66-9
[3] Murygin A V, Tynchenko V S, Kurashkin S O, Bocharova O A, Seregin Y N and Bocharov A N 2021 Automated installation for pipelines brazing in protective environments using induction heating IOP Conference Series: Materials Science and Engineering 1047(1) 012110
[4] Eustathopoulos N, Hodaj F and Kozlova O 2013 The wetting process in brazing Advances in brazing 3-30
[5] Khaja A S, Kaestle C, Reinhardt A and Franke J 2013 Optimized thin-film diffusion soldering for power-electronics production In: Proceedings of the 36th International Spring Seminar on Electronics Technology pp 11-6
[6] Khaja A S, Kaestle C and Franke J (2013 Reliable packaging technologies for power electronics: Diffusion soldering and heavy copper wire bonding In: 2013 3rd International Electric Drives Production Conference (EDPC) pp 1-6
[7] Murygin A V, Tynchenko V S, Lapitenok V D, Emilova O A and Bocharov A N 2017 Complex of automated equipment and technologies for waveguides soldering using induction heating IOP Conference Series: Materials Science and Engineering 173(1) 012023
[8] Hou L, Moelans N, Derakhshandeh J, De Wolf I and Beyne E 2019 Study of the effect of Sn grain boundaries on IMC morphology in solid state inter-diffusion soldering Scientific reports 9(1) 1-14
[9] Yokota K, Minami T, Michitsuji H, Fujio T and Yamada S 2004 Occupational dermatitis from soldering flux Industrial health 42(3) 383-4
[10] Tynchenko V S, Murygin A V, Petrenko V E, Emilova O A and Bocharov A N 2017 Optimizing the control process parameters for the induction soldering of aluminium alloy waveguide paths1 IOP Conference Series: Materials Science and Engineering 255(1) 012017
[11] Qu L, Zhao N, Zhao H J, Huang M L and Ma H T 2014 In situ study of the real-time growth behavior of Cu6Sn5 at the Sn/Cu interface during the soldering reaction Scripta Materialia 72(2) 43-6
[12] Hawksworth D K 2013 Fluxless brazing of aluminium In: Advances in brazing pp 566-85
[13] Tynchenko V, Kurashkin S, Tynchenko V, Bukhtoyarov V, Kukartsev V, Sergienko R, Kukartsev V and Bashmur K 2021 Mathematical Modeling of Induction Heating of Waveguide Path Assemblies during Induction Soldering Metals 11(5) 697
[14] Yao Z, Xue S and Zhang J 2020 Comparative study on the activity of GaF3 and Ga2O3 nanoparticle-doped CsF-AlF3 flux for brazing 6061 Al/Q235 steel joints Crystals 10(6) 498

[15] Milov A V, Tynchenko V S, Kurashkin S O, Petrenko V E, Rogova D V and Tynchenko Y A 2021 The induction heating process modelling of the waveguide paths’ flanges IOP Conference Series: Materials Science and Engineering 1047(1) 012027

[16] Takemoto T, Matsunawa A and Shibutani T 1997 Chemical reaction of non-corrosive flux with magnesium containing aluminium alloys and the improvement of brazeability Welding international 11(11) 845-51

[17] Tynchenko V S, Milov A V, Kurashkin S O, Petrenko V E, Tynchenko Y A and Rogova D V 2021 Mathematical model of the waveguide pipe heating in the process of induction brazing IOP Conference Series: Materials Science and Engineering 1047(1) 012112

[18] Shi Y, Wang Z, Dong B. T, Lu L H, Huang J K and Fan D 2012 Test of thermal cycling curve of pulsed melting-soldering welding DE-GMAW and CMT for bonding steel with aluminum [J] Journal of Lanzhou University of Technology 4(2) 1-10

[19] Bartocha D and Baron C 2021 Repair of a Cracked Historic Maryan Bell by Gas Welding Materials 14(10) 2504