Aspects of aluminum alloy utilization in vertical cylindrical tank construction

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Abstract: Background: One of the most popular structures in the production and transportation of oil and petroleum products are vertical cylindrical tanks. Nowadays, the greatest demand is for tanks whose main structural material is steel. When working at low temperatures, the performance of steel deteriorates, ductility and toughness decrease, which leads to various emergency situations, while aluminum alloys are free of these disadvantages and their performance improves as the temperature decreases. Objective: First: determination of the economic effect when using aluminum alloy 1915T in the construction of vertical cylindrical tanks; second: determination of structural and technological advantages when using aluminum alloy 1915T over steel 09G2S. Methods: Methodology for calculation and design of vertical cylindrical tanks made of steel 09G2S and aluminum alloy 1915T. Results: The characteristics of aluminum alloy 1915T when used at low temperatures have been revealed. An algorithm for calculating and designing tanks using aluminum alloy 1915T and steel 09G2S as materials has been determined. A technology for constructing tanks from both materials has been developed, and labor intensity has been calculated. Conclusion: Calculation of labor intensity revealed that welded joints of aluminum structures differ in labor intensity from steel ones, while the overall labor intensity of constructing a tank made of aluminum alloy 1915T is lower.

1 Introduction

Nowadays, the oil production and oil refining industries play a significant role in the development of the economic power of the Russian Federation. By December 2021, oil production reached 1,260 thousand m3 per day, positioning the Russian Federation as the second-largest producer globally, following the United States with a daily output of 1,356 thousand m^3. The share of oil exports in the total volume of Russian exports in 2021 amounted to 22.4%, in the export of fuel and energy goods – 41.3%. It is also important that production figures for December 2021 increased by 8.6% compared to figures for the same period in 2020 [1].

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At the same time, proven reserves of deposits in the European part of the Russian Federation are rapidly declining [2]. In recent years, there has been an active search for new deposits and the development of existing ones throughout the country, including in the Far North. The active development of the above-mentioned sectors of the national economy contributes to the constant search for new technologies and materials that would help both speed up and reduce the cost of construction of various infrastructure facilities.

Since March 2021, the Russian Federation Government has issued Decree No. 484 dated March 30, 2021, approving the state program “Socio-economic development of the Arctic zone of the Russian Federation.” [3]. One of the goals of this program is to create competitive conditions for executing investment projects within the Arctic zone of the Russian Federation. As of 2021, the share of oil produced by Gazprom OJSC in the Arctic Circle is more than 30%, and 58% of oil and gas reserves in the Arctic remain undiscovered. Currently, the advancement of oil production infrastructure in the Arctic regions stands out as one of the most sought-after and promising sectors in construction and other sectors of the national economy.

Among the large range of structures that are used in oil production and transportation, vertical tanks play an important role, which in this case are used for temporary storage of oil and petroleum products [4,5].

In the construction of vertical tanks, a variety of steel grades are commonly used. Over the years, this material has proven itself to be the most affordable and justified in terms of design and operational features [6]. However, structural low-carbon and low-alloy steels also have disadvantages, such as low corrosion resistance [7,8,9] and cold brittleness at low temperatures [6,9-11]. These problems can be avoided by using aluminum alloys in the construction of vertical cylindrical tanks, which are less susceptible to corrosion and do not reduce their mechanical characteristics at low temperatures [12-15].The aim of the work is to determine the efficiency of using aluminum alloys 1915T in the installation of vertical cylindrical tanks.

2 Materials and Methods

1.1 General aspects of the construction of vertical cylindrical tanks

For the installation of tanks with a volume of up to 20,000 m^3, it is allowed to use the roll assembly method. The roll method of manufacturing tanks was invented in 1944 by an employee of the Electric Welding Institute E.O. Paton, G. Raevsky.

The advantages of this method are:

1) Low cost compared to the sheet assembly method;
2) Short period of work due to reduction in the volume of welding work;

The disadvantages of this method are:

1) Logistical difficulties during construction in remote regions;
2) Difficulties with the availability of heavy equipment in the far north;
3) Impossibility of use in cramped conditions.

1.2 Sequence of work on installation of metal structures of a cylindrical tank

1.2.1 Bottom installation

Installation of the bottom, consisting of a central rolled part and edges, must be carried out in the following sequence:

1) Laying the edges in the design position, checking the accuracy of the placement using a marking device fixed in the center of the base. Upon completion of assembly, the edge rings must be checked:
   a. No kinks in edge joints;
   b. No deflections or bulges;
   c. Horizontality of the edge ring;
   d. Compliance of gaps in joints with design ones.
2) Tacking the assembled ring of edges and welding radial joints;

Roll the bottom rolls onto the base along a specially constructed ramp using a rope encircling the roll, the ends of which are secured to tractors (winches).

Upon completion of installation and welding of the bottom, it is marked.

1.2.2 Wall installation

Basic operations when installing a wall:

1) Installing the roll on the hinge;

2) Lifting a roll while simultaneously monitoring the permissible deviation of the crane pulley from the vertical.

3) Unrolling a roll with a tractor using a rope and a traction bracket welded to the roll.

4) Formation of panels;

5) Closing assembly joints;

6) Installation of support rings.

1.2.3 Installation of stationary covering

Basic operations when installing a stationary coating:

1) Laying the initial shield, which has 2 load-bearing beams;
2) Sequential laying of the remaining panels, welding them to each other.

When installing arched panels, they are pre-assembled on a special conductor panel.

1.3 Nomenclature and scope of construction and installation work

Previously, calculations were performed and construction of vertical cylindrical tanks made of 09G2S steel and 1915T aluminum alloy was carried out using regulatory documents [4,5, 16-25] in Yakutsk.

TABLE 1. Specification of sheet metal for 1 tank V=2000m^3 made of 09G2S steel.

No.	Name of elements	Nomenclature of rolled metal	Element weight, t	Quantity, pcs	Total weight, t
1	Wall roll	11920x47665 mm t=6 mm – 1 bottom belt t=5 mm – 7 belts	22.71	1	22.71
2	Bottom roll	t=6 mm	7.77	2	15.54
3	Plate	t=6 mm	0.096	12	1.156
5	Roof panel		0.627	16	10.04
Total consumption of steel 09G2S, t:					49.46

TABLE 2. Specification of sheet metal for 1 tank V=2000m^3 made of 1915T aluminum alloy

No.	Name of elements	Nomenclature of rolled metal	Element weight, t	Quantity, pcs	Total weight, t
1	Wall roll	11920x47665 mm t=10 mm – 2 bottom belts t=8 mm – 2 bottom belts t=6 mm – 4 upper belts	9.6	1	9.6
2	Bottom roll	t=7 mm	3.2	2	6.4
3	Plate	t=8 mm	0.044	12	0.53
6	Roof panel		0.278	16	4.45
Total consumption of aluminum alloy 1915T, t:					20.98

As can be seen from the specifications, the actual consumption of sheet metal (metal weight) is 2.36 times less when constructing a tank from 1915T aluminum alloy.

Due to the fact that one of the goals of this paper is to compare the volume of labor costs during the construction of a vertical cylindrical tank made of aluminum alloys, the labor intensity and volume of welding work during the installation of the above-ground part will be examined in detail.

TABLE 3. List and volume of construction and installation works for the installation of metal structures during the construction of a tank made of steel 09G2S

No.	Standard	Process name	Unit	Scope of work
1	GESN 09-02-014-01	Tank bottom installation	t	16.7
2	GESN 09-02-014-03	Installation of a tank wall from one roll	t	22.71
3	GESN 09-02-014-06	Installation of roofing from panel blanks	t	10.04

TABLE 4. List and volume of construction and installation works for the installation of metal structures during the construction of a tank made of aluminum alloy 1915T

No.	Standard	Process name	Unit	Scope of work
1	GESN 09-02-014-01	Tank bottom installation	t	6.93
2	GESN 09-02-014-03	Installation of a tank wall from one roll	t	9.6
3	GESN 09-02-014-06	Installation of roofing from panel blanks	t	4.45

1.4 Calculation of labor intensity of welded joints

The calculation was made according to [26,27]. Welding is known to be a labor-intensive procedure. Meanwhile, welding aluminum structures differs from welding steel structures, particularly when it comes to welding aluminum structures with a thickness exceeding 4 mm. In such cases, non-consumable tungsten electrodes are used in an inert gas environment, typically a combination of argon and helium. The main feature of welded joints of aluminum alloys is that a dense, refractory oxide film of Al2O3, formed on the surface of aluminum, prevents the fusion of the metal of the weld pool with the base metal, while remaining in the weld, forming non-metallic inclusions.

1.4.1. Calculation of the standard time for welding tank elements made of aluminum alloy 1915T

The calculation was made according to [26].

Piece time is determined by the formula:

$$\mathrm{T}_p = \left(T_{ip}L + T_{AP}\right)K_{1-n} \tag{1}$$

Where T_{ip} – incomplete piece time per 1 m of seam when welding in the lower position under stationary conditions, L – seam length in m, T_{AP} - auxiliary time related to product and type of equipment.

In turn, T_{ip} is determined according to the tables in paragraph 4 [26].

Initial data for welding the wall to the bottom of the tank:

Seam type – T7

Material thickness – 10mm;

Welding wire diameter – 6 mm;

Seam length – 47.67 m;

Number of passes – 5.

Next, we need to create a table with all the conditions from the handbook.

TABLE 5. Conditions of work performance

No.	Process name	Card number and position	Time, min	Coefficient value
1	Preparation of the workplace	86.6(a)	17	-
2	Welding	54.19(e)	28.6	-
3	Work is carried out in an open area	87.3(c)	-	1.04

4	Heating metal over 200ºC	90.25(d)	-	1.49
5	Cleaning edges from oxide film before welding	75.6(a)	36.22	-
6	Cleaning the seam from the oxide film after each pass	69.2(b)	104.88	-
7	Moving the welder during welding of multi-pass seams	84.3 (i)	7.56	-
8	Seam position in space - lower	88.1(a)	-	1.00
9	Inspection and measurement of the seam	70.1(b)	14.3	-

$$T_p = (28.6 * 47.67 + 36.22 + 104.88 + 7.56 + 14.3) * 1.04 * 1.49 = 2365.19\ min$$

The time standard is calculated using the formula:

$$S_t = T_p + \frac{T_{ms}}{n}, \tag{2}$$

Where T_{ms} - machine-setup time, which includes time spent on organizational measures and setting up welding equipment, min, n – number of parts.

The standard time for welding the wall of an aluminum tank to the bottom will be equal to:

$$S_t = 2365.19 + \frac{17}{1} = 2382.19\ min = 39\ h\ 42\ min$$

Initial data for manual argon arc welding of a butt seam of a wall from the outside:

Seam type – C4, C8

Material thickness – 6-10 mm;

Welding wire diameter – 5 mm;

Seam length – 11.92 m;

Number of passes – 1.

TABLE 6. Conditions of work performance

No.	Process name	Card number and position	Time, min	Coefficient value
1	Preparation of the workplace	86.6(a)	17	-
2	Welding	50.(40,38,36) (d)	14.3(5.96m), 19.0(2.98m), 24.2(2.98m)	-
3	Work is carried out in an open area	87.3(c)	-	1.04
4	Heating metal over 200ºC	90.25(d)	-	1.35
5	Cleaning edges from oxide film before welding	75.1(b)	6.44	-
6	Inspection and measurement of the seam	70.1(a)	2.38	-
7	Seam position in space - vertical	88.1(b)		1.18

$$T_p = (24.2 * 2.98 + 19.0 * 2.98 + 14.3 * 5.96 + 6.44 + 2.38) * 1.04 * 1.35 * 1.18 = 463.52\ min$$

The standard time for welding the external butt seam of the wall will be equal to:

$$S_t = 463.52 + \frac{17}{1} = 480.52\ min = 8\ h\ 1\ min$$

Initial data for semi-automatic argon arc welding of a butt weld of a wall from the inside:

Seam type – C4 (semi-automatic)

Material thickness – 6-10 mm;

Welding wire diameter – 2 mm;

Seam length – 11.92 m;

Number of passes – 2.

TABLE 7. Conditions of work performance

No.	Process name	Card number and position	Time, min	Coefficient value
1	Preparation of the workplace	86.6(a)	17	-
2	Welding	23.(12,14,16)(e)	3.7(5.96m), 3.9(2.98m), 4(2.98m)	-
3	Work is carried out in an open area	87.3(c)	-	1.05
4	Heating metal over 200ºC	90.25(d)	-	1.35
5	Cleaning edges from oxide film before welding	75.1(b)	6.08	-
6	Cleaning the seam from the oxide film after each pass	69.2(b)	5.96	-
7	Moving the welder during welding of multi-pass seams	84.3(i)	4.59	
8	Seam position in space - vertical	88.1(b)	-	1.18
9	Inspection and measurement of the seam	70.1(a)	2.38	
10	Changing filler rods 2mm	72.1(b)	31.34	
11	Cleaning and degreasing filler rods before welding	77.1(b)	2.14	

12	Tightening wires, nipping and removing wire residues, feeding wire into the head of an automatic or semi-automatic machine and changing cassettes, welding wire diameter 2mm	71.1(e)	2.98	

$$T_p = (4 * 2.98 + 3.9 * 2.98 + 3.7 * 5.96 + 6.08 + 5.96 + 4.59 + 2.38 + 31.34 + 2.14 + 2.98) * 1.05 * 1.35 * 1.18 = 169.04\ min$$

Time standard for welding the external butt seam of the wall will be equal to:

$$S_t = 169.04 + \frac{17}{1} = 186.04\ min = 3\ h\ 6\ min$$

Initial data for semi-automatic argon arc welding of a bottom butt weld:

Seam type – C4 (semi-automatic)

Material thickness – 7 mm;

Welding wire diameter – 2 mm;

Seam length – 15.18 m;

Number of passes – 2.

TABLE 8. Conditions of work performance

No.	Process name	Card number and position	Time, min	Coefficient value
1	Preparation of the workplace	86.6(a)	17	-
2	Welding	23.16(e)	4.0	-
3	Work is carried out in an open area	87.3(b)	-	1.05
4	Heating metal over 200ºC	90.22(d)	-	1.35
5	Cleaning edges from oxide film before welding	75.1(a)	8.65	-
6	Cleaning the seam from the oxide film after each pass	69.1(b)	7.59	-
7	Moving the welder during welding of multi-pass seams	84.2(i)	4.76	
8	Seam position in space - vertical	88.1(a)	-	1.00
9	Inspection and measurement of the seam	70.1(a)	3.04	
10	Changing filler rods 2mm	72.1(b)	45.12	
11	Cleaning and degreasing filler rods before welding	77.1(b)	2.73	
12	Tightening wires, nipping and removing wire residues, feeding wire into the head of an automatic or semi-automatic machine and changing cassettes, welding	71.1(e)	3.80	

	wire diameter 2mm			

$$\mathrm{T}_p = (4 * 15.18 + 8.65 + 7.59 + 4.76 + 3.04 + 45.12 + 2.73 + 3.8) * 1.05 * 1.35 = 193.36\ min$$

The standard time for welding a butt seam on the bottom will be equal to:

$$S_t = 193.36 + \frac{17}{1} = 210.360\ mni = 3\ h\ 31\ min$$

1.4.2. Calculation of the standard time for welding tank elements made of steel 09G2S

The calculation will be made according to [2].

Piece time is determined by the formula:

$$\mathrm{T}_p = \left(T_{ip}K_1K_3K_{10} + T_{aw1}K_6\right) * LK_2K_5K_8 + T_{ap}K_5 + T_{et}, min \qquad (3)$$

Where: T_{ip} – incomplete piece time, min; K_1- coefficient taking into account the diameter, brand of electrodes and metal being welded, the value is given in the numerator of card 33 [27]; K_3 - coefficient taking into account the type of welding, seam and its length, card 37 [27]; K_{10} - coefficient taking into account welding of products from asymmetrical elements (clause 1.15) [27]; T_{aw1} - auxiliary time depending on the length of the weld (cards 20, 22 and 24) [27], min; K_6 - coefficient that takes into account the position of the edge to be grinded in space and the method of grinding (map 38) [27] ; L – seam length, m; K_2 - coefficient taking into account the position of the seam in space (card 34) [27]; K_5 - coefficient taking into account the condition and location of work (map 36) [20]; K_8 - coefficient taking into account the angle between the parts being welded (card 40) [27]; T_{ap} - auxiliary time depending on the product and type of equipment (cards 25 - 32) [27] and is taken into account in each individual case when performing these works by an electric welder; T_{et} - time to perform electric tack welding is calculated using the formula:

$$\mathrm{T}_{et} = T_{ip}K_1K_2K_5K_7K_8, min \qquad (4)$$

K_7 - coefficient taking into account the type of edge cutting when determining the time for electric tack welding (map 39) [27].

The time standard is calculated using the formula:

$$S_t = \mathrm{T}_p * (1 + \frac{a_{ms}}{100}), min \qquad (5)$$

Where T_p - standard piece time for welding one product, a_{ms} - machine-setup time, includes time spent on organizational activities and setting up welding equipment. Machine-setup time is expressed as a percentage of the piece time (for simple work - 4%, for complex work - 5%).

Initial data for welding the wall to the tank bottom (manual arc welding with a consumable electrode):

Seam type – T7

Material thickness – 6 mm;

Electrode diameter – 3 mm;

Seam length – 47.67 m;

Number of passes – 2.

It is necessary to create a table with all the conditions from the handbook.

TABLE 9. Conditions of work performance

No.	Process name	Card number and position	Time, min	Coefficient value
1	Welding	5.27(d)	14.5	-
2	Seam position – horizontal, angle 90º	34.2(c)	-	1.32
3	Workplace in an open area outside the workshop	36.3(a)	-	1.05
4	Curvilinear seam	37.2(d)	-	1.05
5	Cleaning the weld from slag after each pass (tvs)	16.2(b)	0.41	
6	Cleaning the edges of products made from rolled sheet metal before welding from rust deposits and oxide film	20.37(e)	0.78	
7	Movement (transitions) of the electric welder during the welding of multi-pass seams (tvs1)	17.1(a)	0.132	
8	Changing electrodes (tvs2)	18.2(b)	0.27	
9	Inspection and measurement of the seam (tvs3)	19.1(b)	0.3	
10	Installing and removing welding arc protection shields	26.1(a)	40.52	
11	Intra-shift transitions of an electric welder when changing places of work	27.10(a)	1.24	
12	Coefficient taking into account the diameter, electrode grade and metal being welded	33.3(b)	-	0.944
13	Position of the grinded edge in space	38.6(b)	-	0.75

$$\mathrm{T}_p = (14.5 * 1.33 * 1 + (0.264 + 0.41 + 0.27 + 0.3 + 0.78) * 0.75) * 47.67 * 1.32 * 1.05 + (40.52 + 1.24) * 1.05 = 1418.31\ min,$$

The time standard is calculated using the formula:

$$S_t = 1418.31 + \left(1 + \frac{5}{100}\right) = 1489.22\ min = 24\ h\ 49\ min$$

Initial data on the tank walls - external seam (manual arc welding with a consumable electrode):

Seam type – C4

Material thickness – 6 mm;

Electrode diameter – 3 mm;

Seam length – 11.92 m;

Number of passes – 1.

Next, it's necessary to create a table with all the conditions from the handbook.

TABLE 10. Conditions of work performance

No.	Process name	Card number and position	Time, min	Coefficient value
1	Welding	1.2(d)	5.2(1,49) 4.9(10,43)	-
2	Seam position – horizontal, angle 90º	34.2(c)	-	1.18
3	Workplace in an open area outside the workshop	36.3(a)	-	1.05
4	Straight seam	37.1(d)	-	1.00
5	Cleaning the weld from slag after each pass (tvs)	16.1(a)	0.20	
6	Cleaning the edges of products made from rolled sheet metal before welding from rust deposits and oxide film	20.37(e)	0.78	
7	Movement (transitions) of the electric welder during the welding of multi-pass seams (tvs1)	17.1(a)	0.132	
8	Changing electrodes (tvs2)	18.1(a)	0.16	
9	Inspection and measurement of the seam (tvs3)	19.1(a)	0.2	
10	Installing and removing welding arc protection shields	26.1(a)	40.52	
11	Intra-shift transitions of an electric welder when changing places of work	27.10(a)	1.24	
12	Coefficient taking into account the diameter, electrode grade and metal being welded	33.3(b)	-	1.33
13	Position of the grinded edge in space	38.6(b)	-	0.75

$$\text{T}_p = (5.2 * 1.33 * 1 + (0.264 + 0.20 + 0.16 + 0.2 + 0.78) * 0.75) * 1.49 * 1.18 * 1.05 + (4.9 * 1.33 * 1 + (0.264 + 0.20 + 0.16 + 0.2 + 0.78) * 0.75) * 10.43 * 1.18 * 1.05 + (40.52 + 1.24) * 1.05 = 158.6\,min,$$

The time standard is calculated using the formula:

$$S_t = 158.6 * \left(1 + \frac{5}{100}\right) = 166.53\,min = 2\,h\,47\,min$$

Initial data for the tank walls - internal seam (semi-automatic):

Seam type – C4

Material thickness – 6 mm;

Electrode diameter – 1 mm;

Seam length – 11.92 m;

Number of passes – 2.

Next, it's necessary to create a table with all the conditions from the handbook.

TABLE 11. Conditions of work performance

No.	Process name	Card number and position	Time, min	Coefficient value
1	Welding	1.2(d)	5.1(1,49) 4.9(10,43)	-
2	Cleaning the weld seam from the oxide film after each pass	69.1(b)	5.96	
3	Inspection and measurement of the weld seam	70.1(a)	3.58	
4	Tightening of wires, feeding wire into the head of the semi-automatic machine	71.1(b)	2.38	
5	Moving the welder during welding of multi-pass seams	84.3(i)	4.59	
6	Cleaning edges before welding	76.1(a)	6.43	
7	Cleaning filler rods before welding	77.1(a)	1.91	
8	Changing filler rods	72.1(a)	14.8	
9	Work is carried out in an open area	87.3(c)	-	1.05
10	Position of the seam in space - vertical	88.1(b)	-	1.18
11	Coefficient taking into account the diameter, type of welding, seam and its length	90.1(d)	-	1.00

$$\text{T}_p = (5.1 * 1.49 + 4.9 * 10.43 + 5.96 + 3.58 + 2.38 + 6.43 + 1.91 + 14.8 + 4.59) * 1.05 * 1.18 = 121.86\,min$$

The time standard for welding the internal butt seam of the wall will be equal to:

$$S_t = 121.86 + \frac{17}{1} = 138.86\,min = 2\,h\,19\,min$$

Welding bottom panels:

Seam type – C4

Material thickness – 6 mm;

Electrode diameter – 2 mm;

Seam length – 15.18 m;

Number of passes – 2.

Next, it's necessary to create a table with all the conditions from the handbook.

TABLE 12. Conditions of work performance

No.	Process name	Card number and position	Time, min	Coefficient value
1	Welding	1.2(d)	6.1	-
2	Cleaning the weld seam from the oxide film after each pass	69.1(b)	7.59	
3	Inspection and measurement of the weld seam	70.1(a)	3.04	
4	Tightening of wires, feeding wire into the head of the semi-automatic machine	71.1(e)	3.8	
5	Moving the welder during welding of multi-pass seams	84.3(i)	4.76	
6	Cleaning edges before welding	76.1(a)	8.20	
7	Cleaning filler rods before welding	77.1(a)	2.43	
8	Changing filler rods	72.1(a)	4.55	
9	Work is carried out in an open area	87.3(c)	-	1.05
10	Position of the seam in space - lower	88.1(b)	-	1.00
11	Coefficient taking into account the diameter, type of welding, seam and its length	90.1(d)	-	1.00

$$T_p = (6.1 * 15.18 + 7.59 + 3.04 + 3.8 + 4.76 + 8.2 + 2.43 + 4.55) * 1.05 * 1.00 = 133.31\ min$$

The time standard for welding the bottom panels will be equal to:

$$S_t = 133.31 + \frac{17}{1} = 150.31\ min = 2\ h\ 31\ min$$

3 Results

Below are the results of calculating the time limit for performing welded joints of tank elements made of steel 09G2C and aluminum alloy 1915T.

TABLE 13. Time standards for welded joints for steel 09G2S

Steel 09G2S	S_t
Welding the wall to the bottom (manual arc welding)	21h 39min
External butt seam of the wall (manual arc welding)	2h 47min
Internal butt seam of the wall (semi-automatic)	2h 19min
Welding bottom panels (semi-automatic)	2h 31min

TABLE 14. Time standards for welded joints for aluminum alloy 1915T

Aluminum alloy 1915T	S_t
Welding the wall to the bottom (manual arc welding)	39h 42min

External butt seam of the wall (manual arc welding)	8h 1min
Internal butt seam of the wall (semi-automatic)	3h 6min
Welding bottom panels (semi-automatic)	3h 31min

As can be seen from the above calculation results, the time required for welding aluminum alloys is significantly higher than for steel; therefore, the labor intensity of constructing tanks made of aluminum alloys increases in proportion to the increase in the time required for welding joints. Based on the calculated standards of time for welding, it is possible to determine some coefficients for the ratio of the labor intensity of welding aluminum and steel structures. For installation of the tank wall, the coefficient of increase in the labor intensity of welding work k_{usr} = (39h 42 min + 8h 1 min + 3h 6 min)/(21h 39 min + 2h 47 min + 2h 19 min) = 50h 49 min / 26h 45 min = 1.9. For installation of the tank bottom, coefficient k_{usr} = 3h 31 min / 24 31 min = 1.4.

Accordingly, the calculation of labor costs for the installation of steel structures made of steel 09G2C and aluminum alloy 1915T are shown in Tables 15 and 19.

TABLE 15. Calculation of labor costs when installing metal structures made of steel

09G2S

No.	Name of technological process	Unit	Scope of work	Standard	Time standard		Labor costs	
					Workers man-hours	Machinists man-hours	Workers man-hours	Machinists man-hours
1	Tank bottom installation	t	16.7	GESN 09-02-014-1	20.45	3.36	341.52	56.11
2	Tank wall installation	t	22.71	GESN 09-02-014-3	17.46	6.57	396.52	149.21
3	Installation of roofing from panel blanks	t	10.04	GESN 09-02-014-6	64.73	20.77	649.9	208.53
Total:							**1387.93**	**413.85**

According to GESN 09-02-014-1, the machinery and mechanisms include the following items:

TABLE 16. Machinery and mechanisms according to GESN 09-02-014-1

Code	Name	Unit	Consumption
91.17.04-042	Gas welding and cutting equipment	machine-hours	0.51
91.17.04-171	Welding converters with rated welding current 315-500 A	machine-hours	6.09

According to GESN 09-02-014-3, the machinery and mechanisms include the following items:

TABLE 17. Machinery and mechanisms according to GESN 09-02-014-3

Code	Name	Unit	Consumption
91.17.04-042	Gas welding and cutting equipment	machine-hours	0.05
91.17.04-171	Welding converters with rated welding current 315-500 A	machine-hours	6.56

According to GESN 09-02-014-6, the machinery and mechanisms include the following items:

TABLE 18. Machinery and mechanisms according to GESN 09-02-014-6

Code	Name	Unit	Consumption
91.17.04-042	Gas welding and cutting equipment	machine-hours	0.69
91.17.04-171	Welding converters with rated welding current 315-500 A	machine-hours	23.29

Welders are workers, therefore, the labor intensity of installing a tank made of 1915T aluminum alloy must be performed in the following sequence:

1) Determination of labor costs specifically for welding from the total labor costs of workers;

2) Multiplying the labor intensity of welding work by labor intensity increasing factors k_{usr};

3) Calculation of the total labor intensity of the structure installation.

Total labor intensity when constructing the bottom of a tank made of aluminum alloy 1915T:

1) Installation of the tank bottom, per 1t: 20.45 – 6.09 = 14.36 man/h, 6.09*1.4=8.53 man/h,14.36+8.53 = 22.89 man/h.

2) Installation of the tank wall, per 1t: 17.46 – 6.56 = 10.9 man/h, 6.56*2.8 = 18.37 man/h, 10.9+18.37 = 29.27 man/h.

3) Installation of the tank roof, per 1t: 64.73 – 23.29 = 41.44 man/h, 23.29*2.8 = 65.21 man/h, 41.44+65.21= 106.65 man/h.

TABLE 19. Calculation of labor costs when installing metal structures made of aluminum alloy 1915T

No.	Name of technological process	Unit	Scope of work	Standard	Time standard		Labor costs	
					Workers man-hours	Machinists man-hours	Workers man-hours	Machinists man-hours
1	Tank bottom installation	t	6.93	GESN 09-02-014-1	***221.89***	3.36	158.63	23.28
2	Tank wall installation	t	9.6	GESN 09-02-014-3	***29.27***	6.57	202.84	63.07
3	Installation of roofing from panel blanks	t	4.45	GESN 09-02-014-6	***106.65***	20.77	739.08	92.43
Total:							**1100.55**	**178.78**

4 Discussion

Vertical cylindrical tanks are critical structures in various areas of the national economy, including the oil production and oil refining industries. Typically, tanks are built from various types of steel, the choice of which is determined both by the type of tank and the climatic conditions of the construction area. The paper discusses the elements of the construction of a vertical cylindrical tank for storing oil and petroleum products with a density of 900 kg/m^3, construction region of Yakutsk, Republic of Sakha (Yakutia), tank volume – 2000 m^3. Structural low-alloy steel 09G2S was chosen, and alloy 1915T was chosen for the construction of the tank from an aluminum alloy. Calculations were made and metal specifications were determined for both tanks. To build a tank made of 09G2S steel, 54.19 tons of rolled stock are required. To build a tank made of aluminum alloy 1915T, 22.05 tons of rolled stock are required. Based on the calculations carried out, the technology for constructing both tanks using the rolling method was determined. This technology ensures a minimum number of welded joints produced at the construction site. Labor intensity, a specific set of basic devices and tools, as well as the use of lifting machines were determined for this technology.

5 Conclusions

Based on the above, we can conclude that even taking into account the significant increase in labor costs for welded joints during the construction of tanks made of aluminum alloy 1915T, the total labor costs of workers for installation are 20.1% less due to the reduction in the weight of the metal. Moreover, the labor expenses for machinists are reduced by 56.8% due to the decreased operating time of lifting machines and other mechanisms during the construction of an aluminum alloy tank, that is consistent with the results of the work [28]

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