

**TARGETED COMPREHENSIVE PROGRAM
SCIENTIFIC RESEARCH
NAS OF UKRAINE**

*Development of scientific foundations for obtaining,
storage and use of hydrogen in autonomous
power supply systems*

**Development of a technological complex for the manufacture of light
metal-plastic high-pressure cylinders for the accumulation, storage
and use of hydrogen
project № 10-21
the third stage**

Scientific director : doctor of technical sciences Savytskyi M.M.

Performers: laboratory manager, candidate of technical sciences Savytskyi O.M.,

deputy head of department Vaschenko V.M.,

junior researcher Shkrabalyuk Yu.M.

E.O. Paton Electric Welding Institute NAS of Ukraine



The purpose of the research at the third stage of the project was :

development of the design of equipment for the formation of the outer shell of light combined high-pressure cylinders for the accumulation, storage and use of hydrogen.

Tasks of the 3rd stage :

- refinement of three-dimensional models of equipment assemblies for the formation of power shells of cylinders in accordance with the requirements of the technical specification and technical proposals;
- development and correction of missing three-dimensional models of equipment executive mechanisms;
- working out, on the basis of three-dimensional models, the design documentation of the equipment for formation of external power covers of the combined high-pressure tanks;
- development and debugging of software for control of equipment for power tubes of high-pressure cylinders.

Features of a design and the cores technical high-pressure tanks



The welded hermetic case of a cylinder with a thin wall

External power cover from a composite material on the basis of a high-strength fibre

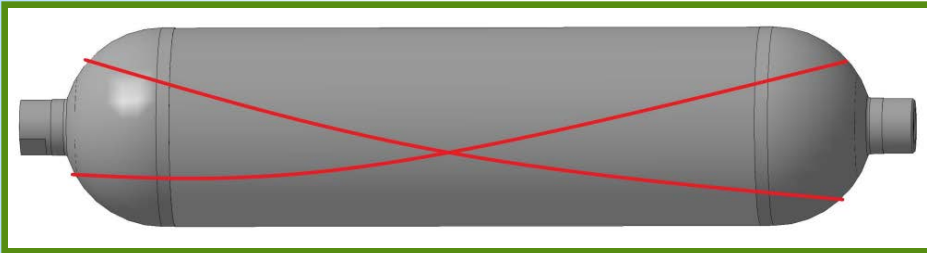
Technical characteristics of high-pressure tanks, working volume of 30 l

Case material	σ_T , MPa	Thickness of a wall of the case of a cylinder, mm	Material of a power	Durability of a fibre, MPa	$K_{s,r}$	Thickness of a power cover, mm		Weight of a power cover, kg		Weight of a cylinder, кг		M/V
						$P_{w,=}$ 35MPa	$P_{w,=}$ 70MPa	$P_{w,=}$ 35MPa	$P_{w,=}$ 70MPa	$P_{w,=}$ 35MPa	$P_{w,=}$ 70MPa	
08Kh18N10 (12Kh18N9)	216 (206)	1,0	Fiber glass	1010	2,6	12,0	27,0	18,2	43,9	22,3	48,0	1,6
			Basalt fibre	1070		10,0	22,0	17,9	41,6	22,0	35,7	1,52
			Carbon fibre	4000		2,6	5,3	2,7	5,4	6,8	9,5	0,32
				6000		1,8	3,6	1,9	3,6	6,0	7,7	0,26

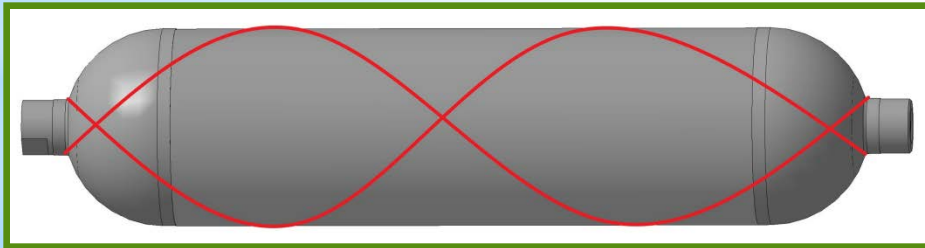
Algorithms of formation of external power covers of type a "COCOON"



The welded hermetic case of a cylinder with a thin wall



The eight scheme provides a crossing of fibres in the centre cylindrical cases of a part of a cylinder. After the power part of a cover reaches a necessary thickness, on a cylindrical part of a cylinder ring winding in some passes which fix the basic layer of a fibre is carried out and fits it, condensing and pressing to a surface of the case of a cylinder.



The spiral scheme provides spiral packing of a high-strength fiber material on the case of a cylinder with certain step. After formation of a layer of a certain thickness ring fixing winding of a fibre is carried out. The specified sequence of laying of a fibre repeats before achievement of a necessary thickness of a power cover. After that on a cylindrical part of a cylinder ring winding of a fibre in some passes to similarly previous case is carried out.

The standard documentation, регламентуюча a design and features of configuration of the equipment for formation of an external power cover of high-pressure tanks

Національна Академія наук України
Інститут електрозварювання ім. С.О. Патона

ЗАТВЕРДЖУЮ

Заступник директора

І.З.Ім. С.О. Патона НАНУ
Академік НАНУ
С.І. Кучук-Яценко
06 2020 р.


Верстат (установка) для формування силової оболонки
(технічні вимоги)

Завідувач відділу №11
д.т.н.

 М.М. Савицький

Розробники:


Завідувач лабораторії
к.т.н.

 О.М. Савицький

Заступник керівника відділу №11

 В.М. Ващенко

Молодший науковий співробітник

 Ю.М. Шкрабалок

Київ - 2020 р.

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Інститут електрозварювання ім. С.О. Патона

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І.З.Ім. С.О. Патона НАНУ
Академік НАНУ
С.І. Кучук-Яценко
09 2020 р.


Верстат (установка) для формування силової оболонки
(технічне завдання на розробку конструкції)

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д.т.н.


 М.М. Савицький

Розробники:


Завідувач лабораторії
к.т.н.

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Інститут електрозварювання ім. С.О. Патона

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Заступник директора

І.З.Ім. С.О. Патона НАНУ
Академік НАНУ
С.І. Кучук-Яценко
11 2020 р.

Верстат (установка) для формування силової оболонки
(технічні пропозиції)

Завідувач відділу №11
д.т.н.

 М.М. Савицький

Розробники:

Завідувач лабораторії
к.т.н.

 О.М. Савицький

Заступник керівника відділу №11

 В.М. Ващенко

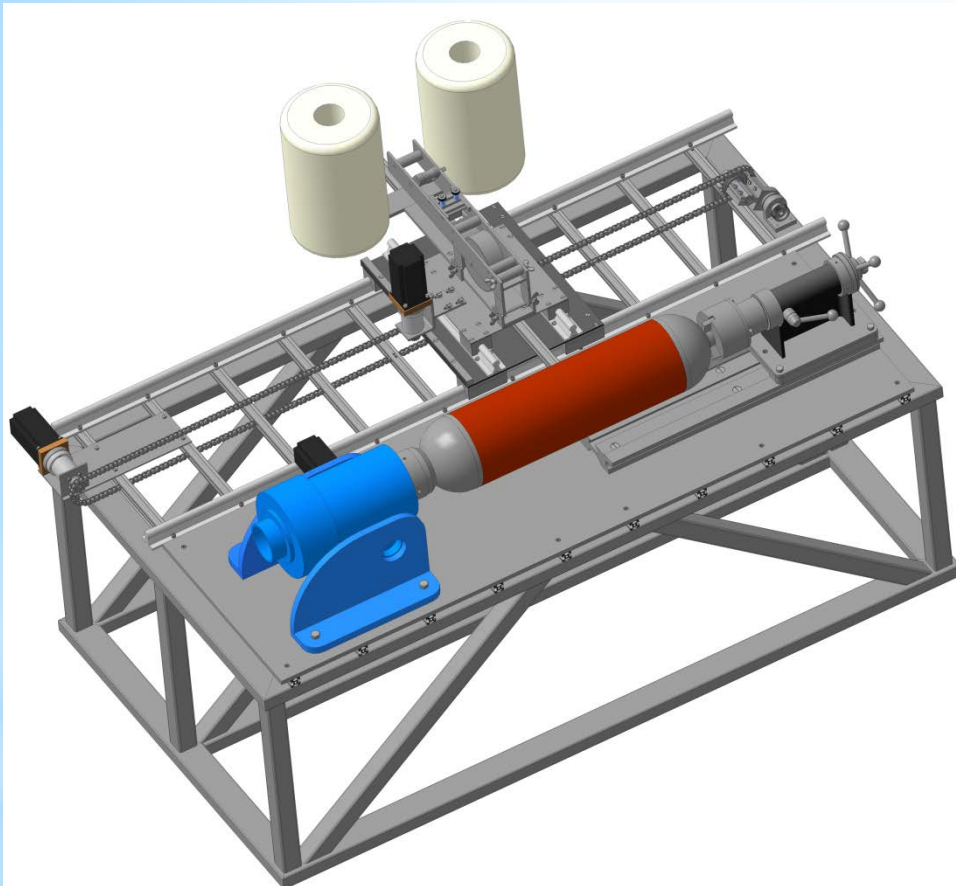
Молодший науковий співробітник

 Ю.М. Шкрабалок

Київ - 2020 р.

The documentation was developed taking into account: research results; design features of cylinders, results of computer modeling; prototyping and testing of main units and mechanisms. In accordance with the requirements of this documentation, the refinement of three-dimensional models of equipment assemblies was carried out for the formation of power shells of cylinders and the development and correction of the missing three-dimensional models of the actuators of the equipment

Three-dimensional model of the equipment for formation of an external power cover



Three-dimensional model of the equipment under the three-co-ordinate scheme

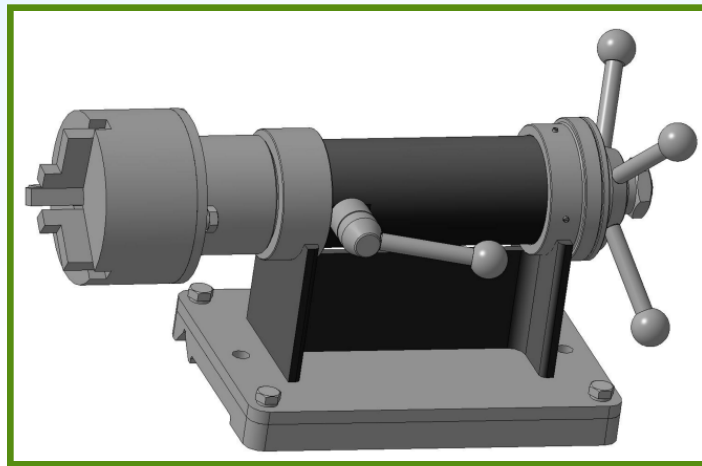
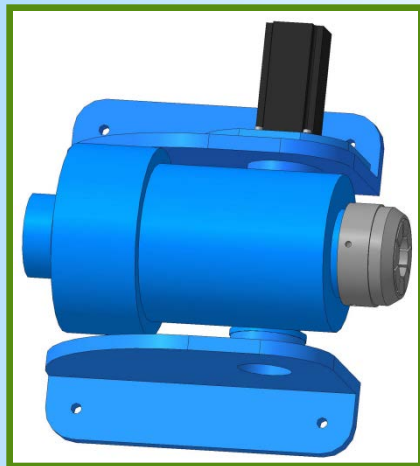
The first co-ordinate - rotation of the case of a cylinder.

The second co-ordinate - longitudinal moving of the stacker of a fibre.

The third co-ordinate - cross-section moving of the stacker of a fibre to extreme points (opposite to the union and the pseudo-union)

Advantages - are weakened requirements to a surface of the case of a cylinder. Strengthenings of seams and other roughnesses of a surface are supposed

Three-dimensional models of the basic knots providing functioning of the equipment for formation of an external power cover

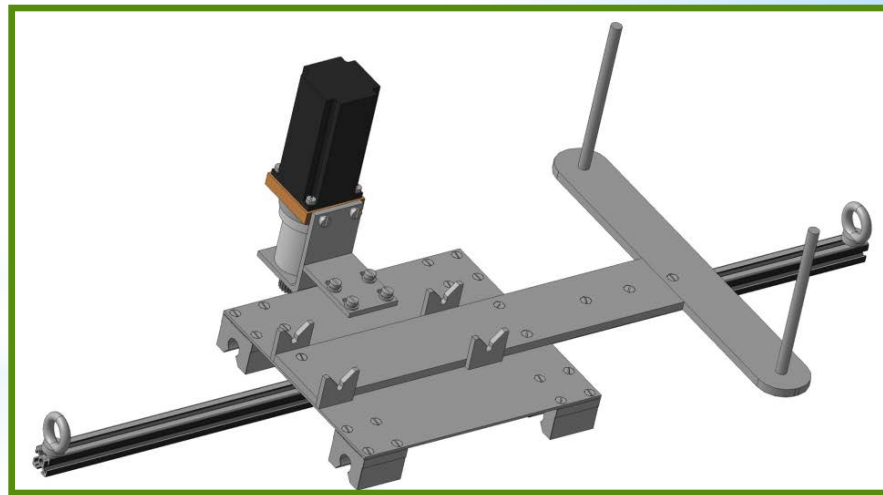


Forward and back grandmas
Provide functioning of the first co-ordinate - rotation of the case of a cylinder



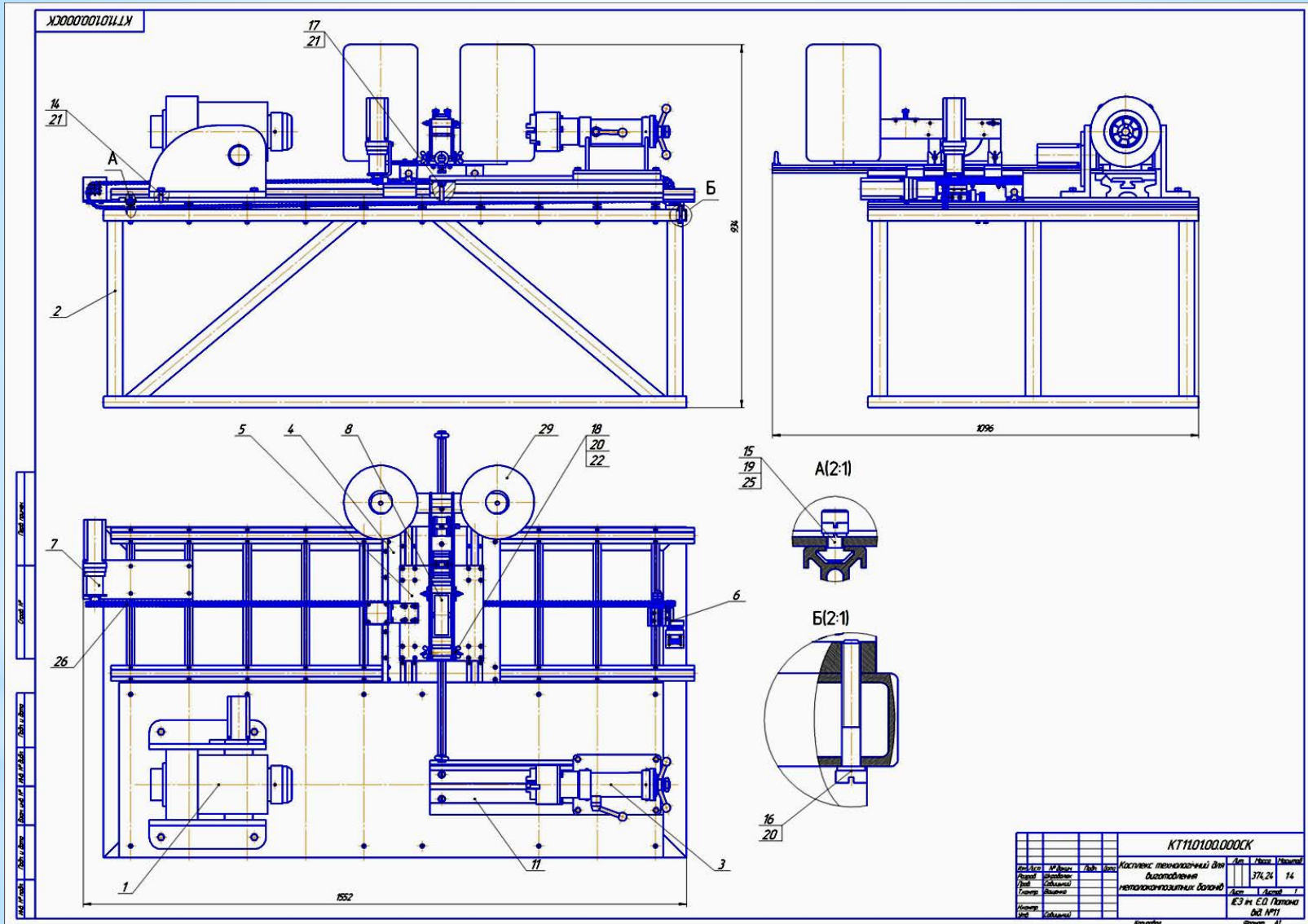
The device of longitudinal moving of the stacker of a fibre.

Provides functioning of the second координаты - longitudinal moving of the carriage with the stacker of a fibre concerning the cylinder case

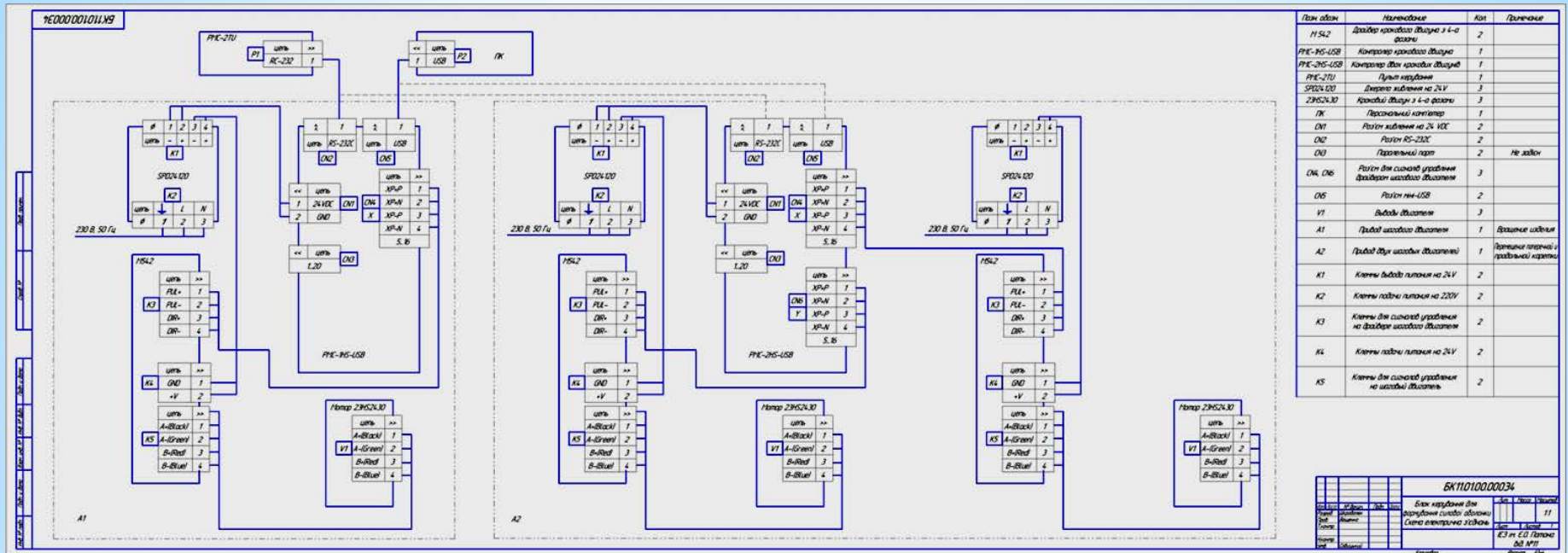


The stacker of a fibre with a drive of cross-section moving
Provides functioning of the third co-ordinate - cross-section moving of the stacker of a fibre to extreme points

The equipment for formation of an external power cover



The scheme of electric connections of the block of management of the equipment for formation of external power covers of tanks



As electric drives of the equipment step-by-step engines are applied to formation of external power covers with programmed control. Therefore the management block is executed under the block scheme with use of elements with which the specified electric drives are completed.

The base software is developed for realisation of the programmed management by electric drives and all complex of the equipment.

APPLIED ASPECT.

In the process of project implementation, the following were developed: design of high-pressure cylinders for accumulation, storage and use of hydrogen, methods to improve their quality, reliability and performance; principles of construction of automatic technological complexes with software control for production of high-pressure cylinders; design of equipment for the formation of the outer power shells of light combined high-pressure cylinders.

COMPETITIVENESS.

Foreign equipment for the manufacture of high-pressure cylinders with power composite shells is worth at least 500 thousand US dollars. According to preliminary estimates, the domestic complex will be 2-3 times cheaper and will provide a low mass and dimensional indicator (m / V) of combined cylinders.

FOREIGN ANALOGUES.

Production of equipment for the manufacture of high-pressure combined cylinders: the company X-Winder (Europe), the company «Hurgo» (USA), the International Joint Stock Chinese Company «Honkong Tien» (China), the engineering center «Stankomposite» (Russia). The capacity of tanks for accumulation, storage and use of hydrogen: «ECD Ovonics» (USA), «HERA Hydrogen Storage Systems» (Canada), «Dynetek» (Canada), «Millennium Cell» (USA), «Euro India Cylinders Ltd».

WAYS OF THE FURTHER DEVELOPMENT.

Technological complexes can be used in the manufacture of high-pressure tanks for various purposes: in hydrogen energy, in aircraft industry, to accumulate the transportation and use of natural gas, etc.

CONCLUSIONS

1. Maximum reliability and performance of light combined high-pressure cylinders with a thin-walled welded body is provided by an external power shell of the "Cocon" type.
2. The maximum mass indices are for cylinders with a glass-roving load-bearing shell, and the minimum - with a vugleroving shell. Intermediate mass indicators are provided by basalt roving.
3. For the formation of external power shells of the "cocoon" type, the most promising are schemes for laying fibers "figure eight" or "spiral" with intermediate fixation of the layers of the shell by in-line winding of the cylindrical part of the cylinder.
4. Regulatory documentation has been developed that regulates the design and layout features of equipment for the formation of an external load-bearing shell. In accordance with its requirements, trimirnitmodel of equipment assemblies and mechanisms has been improved.
5. The design of the equipment for the formation of external power shells of high-pressure cylinders has been developed.
6. A control unit for the entire complex of equipment and basic software for its programming have been developed.
7. Published 5 works, 2 of them in foreign publications.

PUBLICATIONS UNDER THE PROJECT 2021

1. Technological complex for manufacturing easy metal-plastic high-pressure tanks for accumulation, storage and hydrogen use / Savytsky M.M., Savytsky O.M., Vashenko V.M., Shkrabalyuk Yu.M. *Development of scientific foundations for the production, storage and use of hydrogen in autonomous power supply systems*. December 2021.: Kyiv. I. M. Francevich Institute for Problems of Materials Science.

PUBLICATIONS UNDER THE PROJECT 2019-2021

1. Influence of thermophysical properties of materials on formation conditions and quality of welded joints / Oleksandr M. Savitskyi, Mychailo M. Savitskyi, Darko Bajic. *10. International scientific-professional conference SBW 2019 «Engineering technologies in manufacturing of welded constructions and product, SBW 2019»*. Slavonski Brod, 16-18.10.2019. P. 27-36
2. Elaboration of technical solutions to optimize the design of a welded thin-walled sealed body, the formation of its cylindrical part and the spatial orientation of welded joints / Savytsky M.M., Savytsky O.M., Vashenko V.M., Shkrabalyuk Yu.M.. *Development of scientific foundations for the production, storage and use of hydrogen in autonomous power supply systems*. 11.12.2019 p.: abstracts Kyiv. I. M. Francevich Institute for Problems of Materials Science. P. 19.
3. Specificities of application of activating fluxes in electrical welding in protective atmosphere / Oleksandr M. Savitskyi, Mychailo M. Savitskyi, Darko Bajic. *FME Transactions*. 2020. №3. p. 576-580.
4. Prototyping and three-dimensional computer modeling of units and mechanisms of the complex, development of technical requirements for it, technical specifications and technical proposals for its design / Savytsky M.M., Savytsky O.M., Vashenko V.M., Shkrabalyuk Yu.M.. *Development of scientific foundations for the production, storage and use of hydrogen in autonomous power supply systems*. December 2020.: abstracts Kyiv. I. M. Francevich Institute for Problems of Materials Science. P. 11.
5. Technological complex for manufacturing easy metal-plastic high-pressure tanks for accumulation, storage and hydrogen use / Savytsky M.M., Savytsky O.M., Vashenko V.M., Shkrabalyuk Yu.M. *Development of scientific foundations for the production, storage and use of hydrogen in autonomous power supply systems*. December 2021.: Kyiv. I. M. Francevich Institute for Problems of Materials Science.



**E.O. Paton Electric Welding Institute, NASU,
11, Kazimir Malevich str., 03680 Kyiv,
Ukraine**

Thank you for attention