

## Development of aluminium scrap melting technology

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The article shares the problems of development of technology of melting of aluminium scrap and wastes on the secondary metallurgy enterprises of the Soviet Union and modern Russia. An overview of fuel melting furnaces, applied on these enterprises is given together with modern tendencies of development of secondary aluminium metallurgy. There is given a brief review of technology of melting and refining of secondary aluminium alloys. There is given a detail description of technology of melting of aluminium scrap and wastes in rotor furnace with inclined axis "UNIVERSAL-180". The results of melting of various aluminium-containing wastes are given together with the comparative characteristics of Russian rotary furnaces with inclined axis and their import analogues. There is described the operation of the furnaces with external metal receiver and circulation of melt with usage of mechanical mixing devices and devices with a MHD-pumps. Usage of this type of furnaces makes it possible to reach high extraction of metal in the process of melting of swarf and fire scrap. However, this usage requires a careful preparation of this metal for melting: crushing, roasting, separation. The inclined rotary furnaces and rotary furnace with inclined axis do not have such disadvantages – they do not require any special preparation of the scrap and waste for melting. Melting of various types of scrap (including low-quality scrap in these rotor furnaces to reach high technological values. This article also shows the disadvantages of rotary furnace, increased removal of dust, application of special burners, high qualification of the personnel.

**Key words:** fuel furnaces, circulation of the melt, the quality of alloys, melting of aluminium scrap, preparation of scrap, rotary kiln, burners, salt slags, technological indicators.

Starting from the middle of the 1970-s, recycling metallurgy plants used mostly double-chamber reverberatory furnaces, working on natural gas. On some plants, especially in regions with well-developed machine industry, cutting was melted in IAT6-type crucible electrical furnaces.

Preparation of scraps and wastes for melting consisted in the form sorting of lump scrap and waste, and drying with magnetic separation of cutting, where drying of cutting was performed in domestic construction drier drums (by direct heating with torch flames).

Back at that time, reverberatory furnaces with offset bag and short drum furnaces (Fig. 1) were exploited in foreign countries (USA, France). According to this, as a rule, factories used regeneration of salt slags with return of fluxes to melting and dumping of oxide part in specialized landfills (Germany, Italy, Spain).

The considered technology was tried to be implemented on some Russian factories. Particularly, "Remetal" aluminium slags processing equipment worked for some time on Sukholozhsk factory. But for a number of organization and economic reasons, operation of this line was terminated in a short period of time.

Later, melting technology was implemented in salt short drum furnaces at the Mtsensk plant – the biggest factory of "Vtortsvetmet" JSC. However, this technology did not last long as well. Considerable slag muck was piled up and furnaces were stopped. Unfortunately, future of this technology at Mtsensk plant is unknown. It is only known, that "Vtortsvetmet" JSC has established some kind of aluminium slags recycling.

The melting technology in short drum furnaces existed comparatively long at Sverdlov factory in Lugansk Region (Ukrainian and Spanish Joint Enterprise). There was implemented a classical technology of melting in a short drum furnace with overflow of alloys into mixers and their further dispensing into ingots on a conveyor with automated ingot stacker. Salt slag was placed in mucks, which nowadays is developed by attempts of small enterprises. Shot metal, recovered on the Spanish line

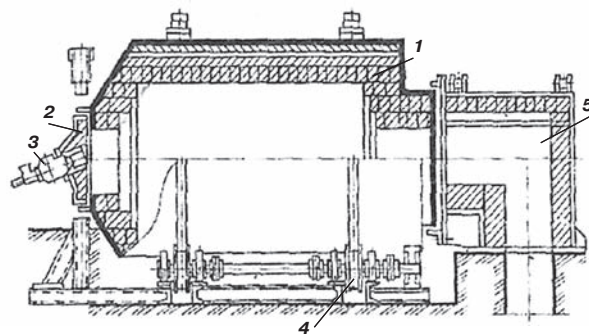
"Remetal" from foreign slags, was also melted in 20 t short drum furnaces. But at the same time, quantity of fluxes in charging material was increased in proportion to quantity and quality of shot metal. Eventually, sharp increase in prices of fluxes and aluminium scrap makes many factories to give up operation of these furnaces.

As it was mentioned above, fuel reverberatory furnaces were the main melting units on the Soviet Union factories. Main peculiarities of these furnaces was presence of mixers, where molten metal on melting completion was recasted, mixed with scraps, silicon, primary aluminum and dispensed into ingots at conveyors.

Melting of dry and separated cutting was carried out in induction crucible furnaces, which, by the way, were not installed at all factories of "Vtortsvetmet" JSC. After drying and separation cutting was melted in reverberatory furnaces in case of absence of such induction furnaces at a factory.

Construction of furnaces, applied at the factories of "Vtortsvetmet" JSC is explicitly described in the references [1, 2]. Fig. 2 describe the constructions of reverberatory furnaces.

Technology of melting in double-bath reverberatory furnaces supposed melting in a melting chamber of a furnace with further recasting to mixer, mixing and delivery to



**Fig. 1.** Short drum rotary furnace:  
1 – barrel; 2 – sliding damper; 3 – burner; 4 – rotating mechanism; 5 – smoke conduit

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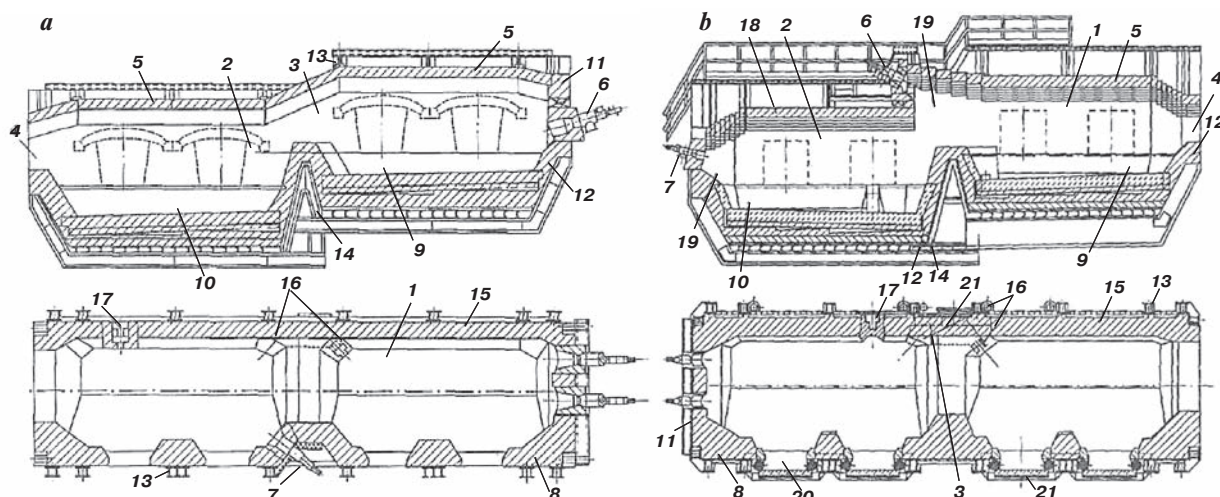


Fig. 2. Double-chamber reverberatory furnaces:

*a* – uniflow; *b* – counterflow;

1 – melting chamber; 2 – forehearth; 3 – overflow port; 4 – smoke conduit; 5 – arch; 6 – burner of melting chamber; 7 – burner of forehearth; 8 – front wall; 9 – bath tank of melting chamber; 10 – bath tank of forehearth; 11 – burner wall; 12 – bevel; 13 – frame member; 14 – interchamber cooler; 15 – back wall; 16 – overflow taphole; 17 – exit taphole; 18 – arch of forehearth; 19 – prechamber; 20 – altar; 21 – shutter

conveyor. After publication of an enactment of the Central Committee and Council of Ministers “About organisation of secondary refined alloys manufacturing” in 1986, the large – scale tests on refining of secondary aluminium alloys were carried out on the Soyuzfortsvetmet factories. Various refining schemes were tested on Kharkiv, Tashkent, Rustav, Mtsensk and Moscow factories: with active fluxes, melted fluxes, inert purging with further filtration through fibreglass mesh, and via vacuum and argon ladle refining [3, 4]. Positive results were achieved in removal of excesses of magnesium, nonmetallic inclusions and hydrogen from casting alloys. More than 6,000 t of refined aluminium alloys were produced within a year at different factories, via experimental and industrial modes.

The most tangible results in obtaining of high-quality alloys were achieved on Mtsensk factory of “Vtortsvetmet” JSC in vacuum and argon refining unit [4] and in Kharkiv association of “Vtortsvetmet” in a molten metal refining unit in a stream with dispensing to conveyor. Received alloys were tested at Melitopol casting factory and at Kharkiv factory of electric motors. Their usage made it possible to reduce refused material in casting at Melitopol factory from 15 to 2% and to reduce this material at Kharkiv factory from 10 to 1.5%.

An impeller unit of aluminium alloys ladle refining was built at Mtsensk factory of aluminium casting. Usage this unit, coupled with refining with active fused fluxes, made it possible to reduce refused material at the factory from 18 to 12%, which, with annual consumption of metal about 25,000 t, considerably reduced expenses on recurrent remelting of refused material and increased quality of casting (engine blocks).

During 1980-s the research within the subindustry was held in building of furnaces with an offset bag and assisted circulation of molten metal for melting of secondary aluminium alloys cutting. After extended laboratory tests, carried out in the “VNIPIVtortsvetmet” institute (Donetsk, Ukraine) in Kharkiv association, a 40 t furnace (with offset bag and mechanical pump with a productivity rate of 160–180 t/h of molten metal) was built and started up in pilot

production. Recycling of dry casting alloys, cutting, which was preheated with gases from melting furnace was carried out. At the furnace the furnace capacity by cutting was 2.0–2.5 t/h with gas consumption of 150 m<sup>3</sup>/t of aluminium. Recovery of metal from cutting, which contained 92% of metal, was 97.2%. During tests, there was found that with proportion of bag volume and furnace, equal to 1:5, slags discharge from metal generally occurs within the furnace bag, which requires a turnaround charging machine use for purification of metal bath surface from slags. Otherwise, the slag on bath surface will vitrify into monolithic spinel skin, which removal from the furnace is possible only after a complete discharge of metal and cool down of the furnace. Later, at Zaporozhye aluminium factory, a similar to Kharkiv circulation system was used on a 30 t mixer, which showed high efficiency of mixing of hard master alloys into alloys (copper) (Fig. 3).

This system acquired its further development in a fusing furnace at one of microfactories in Veliky Novgorod. This system was used at this factory for mixing into molten aluminum fluoride for the purpose of removing magnesium excess. Application of this technology allowed to use aluminum fluoride in stoichiometric amounts according to reaction with magnesium. The system was used during

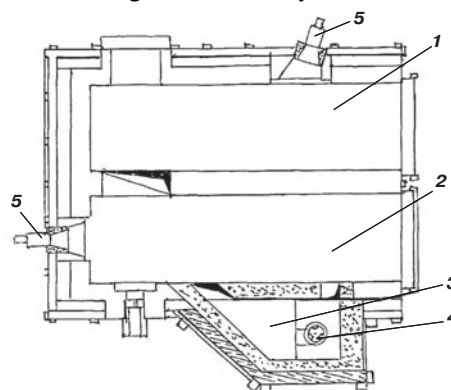


Fig. 3. Fusing furnace with mixer and molten metal circulation: 1 – melting chamber; 2 – mixer; 3 – offset bag; 4 – circulation system with rotary pump; 5 – burners

3 years, and then it was liquidated, as it often happens at the factories, administered by owners ignorant in metallurgy issues, and with appearance of ignorant operational staff. The gas consumption in this furnace for 1 ton of alloy was 160–180 m<sup>3</sup> using new heat insulating materials, new furnace lining up technology, burners with internal mixing up and regulated length of flare. Hydrogen fluctuation (0.18–0.20 cm<sup>3</sup>/g) and nonmetallic quality of metal corresponded to the first grade of porosity.

In recent years, according to the publications and messages at different international conferences (for example, a conference of “ALUSIL” company about aluminium recycling (2010, 2008, 2006, 2004)), nothing conceptually new for melting of scrap and scrap materials of aluminium and its alloys was created. In recent decades, technologies and constructions of reverberatory furnaces are only complemented with updates, which make possible to economy the fuel by means of the flue gas heat and to slightly improve the quality of alloys, increase speed of melting and metal extraction into finished products [6]. These updates primarily include installation of various electromagnetic stirrers, and employment of discontinuous and continuous action recuperators, and to use flue gas heat for the burner warming. Both operations are simultaneously used at furnaces, produced by “Jasper” company (Germany).

It should be noted, that intensification of melting by means of forced mixing up of metal bath presents raised requirements towards the initial scrap, preparation and requires its milling for the purpose of further thorough removal of iron and other metals via different methods of separation. This leads to considerable increase of the scrap recycling process cost. Naturally, the use of such furnaces is within the power of only big factories. This technology is used quite successfully for the can scrap melting at the Saint-Petersburg factory of Vsevolozhsk plant of Aluminium Alloys. Before the process of melting, all scrap undergoes milling, magnetic separation and roasting in spinning furnaces. After such preparation, scrap is continually supplied to liquid funnel, created by electromagnetic stirrer built into a wall of double-chamber reverberatory furnace. Such preparation of raw materials allows to get high-quality alloys, suitable for additional charging into virgin alloys.

Slags are formed on the molten metal surface, containing 30–40% of metal, are recycled in two-rotor 5 t furnaces with separation of metal into the same alloys, which are obtained in reverberatory furnaces with extraction of 88.0–92.0% slags, containing 20–25% of salts. The slags are moved out to the landfill.

It should be noted, that rotor tilting furnaces (Fig. 4) in Russia have been used comparatively late and particularly for recycling of slags, resulting both from melting of scrap, aluminium alloys scrap and slags from virgin aluminium factories (“Mosoblprommontazh” company). Although, first attempts to build a project of a rotor tilting furnace for melting of scrap were made in Donetsk Institute of Non-Ferrous Metals in the early 1990-s.

Unfortunately, absence of financing due to dissolution of the USSR onto independent states did not allow to complete this work. Besides, domestic recyclers, due to appearance of Soviet and Spanish Joint Enterprises (Samara Metallurgical Plant, Sverdlov Factory of “Vtortsvetmet” JSC in Lugansk Region) of rotor salt furnaces [1] have not noticed “Vtortsvetmet”

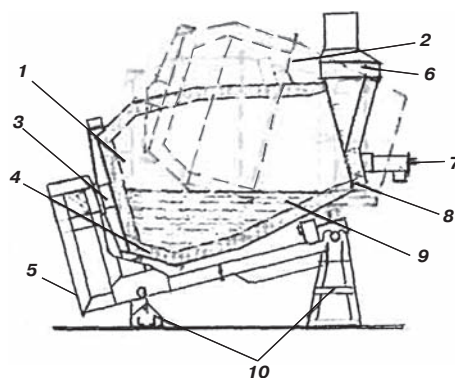


Fig. 4. Rotor Tilting Furnace Scheme [2]:  
1 – operating position; 2 – position for dispensing; 3 – axle bearing; 4 – furnace drum; 5 – revolving frame; 6 – flue; 7 – burner; 8 – door; 9 – molten metal; 10 – support frame

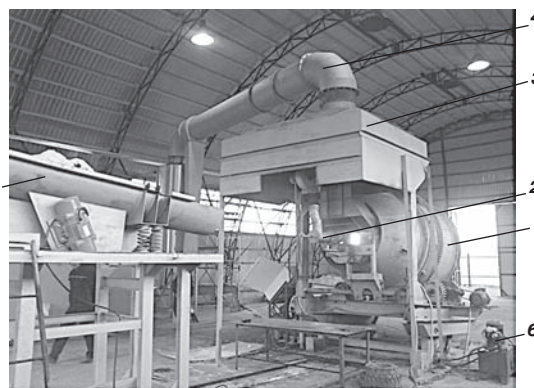


Fig. 5. Rotor furnace “Universal-180” with tilting axle:  
1 – furnace housing assembly; 2 – burner; 3 – gas exhaust umbrella; 4 – horizontal cyclone-gases cooler; 5 – sliding vibroloading machine; 6 – hydrostation

JSC benefits of tilting furnaces, though European factories had already used them at that time. Rotor tilting furnaces, which are exploit nowadays at some large factories in Russia, are, basically, produced by foreign companies or their analogues [7], built by domestic engineers. These furnaces are used both for melting of slags and for production of graded alloys both from standard gathering of scrap materials and from can scrap.

Review of technology of recycling aluminium scrap materials and wastes from the point of view of melting processes essence, represents a combination of several well-known technologies: melting in reverberatory furnace on a “dry hearth bottom”; melting with dipping scrap in metal bath; slag maturation for the purpose of maximal recovery of metal from it; mechanized removal of scrap melting residues from furnace, but without using special rake automated devices.

Advantages of each foregoing technology may be reasonably used in rotor furnaces with tilting axle [7]. For the purpose of enhancing of nomenclature of recycled scraps and simplification of solving ecological issues, there was created a rotor furnace (Fig. 5), which construction differs from the construction of Russian and foreign – produced furnaces exploit at Russian enterprises\* [8].

Main differences of the specified furnace from foreign standard rotor titling furnaces are the following: proportion of drum

\* First industrial samples of the furnace were created with direct participation of a Kharkiv metallurgic engineer Ivan P. Ivanov.

diameter to the length of 1.5–4.0; furnace tilting axle is moved back from loading hollow throat; the furnace may be spun and fixed during the tilting on support rollers.

The less is the proportion of drum diameter to its length, the more is the effect of work with charge distributed along the furnace in a uniform layer. This provides its even heating, formation of shallow bath of metal and steady interspersing of charge layer by means of continuous interaction of slag pieces with furnace inner wall, and their intensive autodestruction (automilling).

Lengthened furnace drum has a long bath collecting metal drops, for which reason the process of transferring residual (immeshed) metal drops within slag is held in horizontal position of furnace axle in a thin layer, which facilitates their pooling, but not destruction by layer of charge. The process goes in the following way: after dispensing of the bulk of metal, contained within slag, the furnace axle is moved to horizontal position, and is spun at low speed during short time. Repeating this operation for two-three times gives maximum extraction of metal from slag. Residual contents of metal in remaining slag, according to practice, may be up to 2.5–3.0% (type sorting).

This is a main mode of intensive melting process. Direction of the drum spinning does not matter, but it determines direction of fixed burner – opposed to the spinning direction, so that the burner flame would not touch the charge and would heat the furnace wall. In this case, the furnace torch flame should be elongated.

The furnace cost with simultaneous enhancing of its technological potential was reduced considerably due to the following differences: use of domestic parts, which construction and reliability is acknowledged by decades of drying drums work, asphalt-concrete and cement furnaces, use of relatively cheap domestic flameproof and heat insulating materials and paints [9, 10].

The furnace construction is made in such a way, that allows to implement melting technologies for widely differing scraps and wastes, which recycling requires special purpose furnaces. For example, the furnace sliding damper is furnished with a window, which makes it possible to observe melting and its control. The furnace back wall contains a thermocouple, which makes it possible to control not only the flue gases temperature, but also the temperature inside the furnace. Burner installation is adapted to the movement.

These differences make it possible to hold the melting process in a certain way, when the heating of charge layer by irradiation is both from torch, and the furnace lining. According to this, during the tilting of furnace towards the back wall with formation of bath of metal, these differences allow to hold the melting with dipping scrap into it.

It should be noted that successful implementation of various scrap and waste melting processes within the furnace is implemented not only via its construction peculiarities, but also, primarily, due to the technological “know-hows” and furnacemen experience.

Enhancing of the furnace free volume allows to increase the life time of gases within the furnace by up to 5–6 seconds. These gases are necessary for dioxides and furanes postcombustion within the furnace volume, i. e. “postcombustion chamber” resides inside the furnace. Besides, sharp cooling of gases leaving the furnace with the help of air (from 850 to 250 °C) results in their seasoning, which also contributes to permissible content of dioxins and benzopyrenes in them.

For neutralization of acids contained in gases, appearing in case of usage of chlorine and fluorine-containing fluxes in melting technology, and usage of sulfur-containing liquid hydrocarbons as fuel, wet washing is used in the device by means of irrigation with lime-wash. Besides, contamination of scrap materials and wastes of aluminium always includes oils containing sulfur and cutting oil, which also determines the presence of sulfur oxides in furnace gases, which require neutralisation.

Table 1 contains characteristics of melting of various types of raw materials and wastes in the furnace with tilting axle (PRNO180 (ПРНО180)). Spent wash oil was used as fuel.

During the melting of combined raw materials (lump slag, palletized scrap, cutting, pallets of foil)? metal output is increased by 5–6%, fluxes consumption is reduced by 1.5–2 times. Relatively high metal output (in comparison to reverberatory melting) may be explained by reservation of high heat exchange inside the furnace with low volumetric heat liberation rate within furnace space. This is achieved by means of simultaneous heat exchange both from burning torch, and from heated furnace lining during its spinning: charge in the furnace is not overheated, and melting speed is high. I.e. the furnace has such conditions provided

Type of raw materials	Loaded, kg	Fluxes consumption, %	Metallurgic output, %	Fuel consumption, l/t	Alloy grade	Time of melting, hours
Simple slag (own from reverberatory furnace)	825.5	20	47.0	125 (Rotor furnace “Universal”+ mixer)	AK5M2	2.0
Own slag, mesh size +0.5 mm	797	10	60.0	110 (Rotor furnace “Universal”+ mixer)	AK5M2	1.5
Painted foil, >20 µm thick, palletized	1100	20	85.0	95 (Rotor furnace “Universal”+ mixer)	A0	2.5
Palletized profile and palletized electrical scrap	7944 (993-scrap D1(Д1), 997 mixed clipping, 4300 profile, 1654 electrical)	10	92.4	85 (Rotor furnace “Universal”+ mixer)	AD31 (АД31)	10.0
Wet oiled cutting	10 250	20	78.2	35 (Rotor furnace “Universal”)	AK5M2	18
Palletized beer can	3100	15	83.4	52 (Rotor furnace “Universal”)	Alloy 3104 >0.5% Fe	6.0

Characteristics	Rotor furnaces tilting around dispensing nose (foreign analogue)	Rotor furnaces tilting around offset axis "Universal" (Russian development)
Capacity according to molten metal, t	5.0	5.0
Capacity of gas space, m <sup>3</sup>	9.2	12.0
Tilting angle during melting, degrees	-16 towards back wall	0
Tilting angle during manipulations, degrees	+8 towards hollow throat	-15+20
Drive	Chain gear	Via tooth rim
Metal dispensing	Through loading opening	Via tap hole or loading opening
Fuel type	Natural gas	Natural gas, spent oil
Process handling	Via collection of large massive of statistical data about meltings	Via visual control of the process
Raw material	Lump scrap, palletized can, enriched slag	Wet and oiled cutting, slag, palletized foil and can, lump scrap
Metal contents in dump slag, %	6-10	<3.0-6.0
Firebrick type	Heat-proof mullite and silicic concrete, high alumina firebrick	Fireclay brick

in it, in which aluminium is less oxidized with furnace gases, moreover, this has a favourable impact on lining endurance, and, therefore, on expenses for its building and periodic renewal. At one of Moscow region factories, furnace fireclay lining has been in service for 2 years already. Cost of furnace "UNIVERSAL-180" equals to 30-40% from the cost of foreign analogues.

Nowadays, capacity of this furnace achieves 350 t/month of alloys of widest nomenclature (from A0 to AK12M2) at average consumption of fuel (spent oil) of 70 l/t. At the same time alloys are prepared directly inside the rotor furnace, and the mixer serves, in most cases, for standing and subtle refining of molten metal up to needed conditions according to contents of impurities before dispensing to conveyor.

Table 2 contains the characteristics of the rotor furnace "UNIVERSAL-180" in comparison to rotor tilting furnaces, foreign production analogues.

Main disadvantages of melting technology in rotor furnaces are following:

- relatively high dust discharge, which is due to constant stirring of charge in the furnace chamber;
- difficulties with utilization of flue gases heat due to their boosing with cold air at furnace outlet;
- complexity of the furnace construction (mechanisms for rotation and tilting, handling, requiring high qualification of staff).

There are offered technical solutions, which allow to reduce these disadvantages considerably. A horizontal cooling cyclone construction is developed and used, which is able to collect coarse grained dust (-200+10 µm - mechanical carryover) and reduce dust content from 5.0 g/m<sup>3</sup> to 40-50 mg/m<sup>3</sup>. The cyclone, together with dust catching, cools flue gases down to 120-150 °C. Ventilator air is used as a cooling agent. Air temperature at escape from the cooling cy-

clone is 45-35 °C, proportion of cooling air volume to the chimney gases volume is 1:5-1:4.

### Conclusions

1. There were considered the constructions of melting furnaces for melting aluminium scrap and waste, used in the past and at present at factories of Russia and CIS countries.

2. There are given main technical characteristics of melting and refining of secondary aluminium alloys in reverberatory and rotor furnaces.

3. There are considered some peculiarities of melting slags in rotor furnace with tilting axle.

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