

INDUSTRIAL REALIZATION TECHNICAL – ECONOMICAL RESULTS OF DIRECT-CURRENT ARC FURNACES NEW GENERATION

The publications represent a comparison of direct-current arc furnaces made abroad with electric arc furnaces. It is fairly evidenced that advantages are insignificant, and we are fully agree with that.

However any comparison is never made with such a furnace type as General-Purpose Direct-Current Arc Furnaces (**GPDCAF**) that originated and made by us. This is despite the fact that this type of furnaces are in industrial operation for a long time and the results of the operation are known at least in Russia. **GPDCAF-NG** (new generation) can not be compared with direct-current arc furnaces including abroad made ones due to the fact that they are fundamentally different in part of furnace body structure, melting methods, and production possibilities.

GPDCAF-NG gives high and industrial operation proven values that are achieved thanks to a special system of patented engineering solutions that includes such a part as the use of direct-current arc. This is a simple solution to change alternating current arc system to direct-current one to make melting systems of minimum costs, however by this way our values are impossible to be realized. Therefore, furnaces with minimized cost thanks to simple engineering solutions can not be a fair base for competition. Any furnaces made by other manufacturers which can achieve our values are unknown to us.

It is considered by us to be necessary to give as much as possible information to specialists about new production possibilities provided by **GPDCAF-NG**, namely process and production organization for steel, iron, and aluminum-based alloys, their mixing process that sharply improves performance characteristics and production process output. In addition, this is necessary to compare them with conventional production methods and equipment.

Russian machine-building industry modernization currently poses an urgent problem to upgrade active foundries and create new ones. Melting facilities of most of foundries have become obsolete and require to be upgrading and replacing. The correct selection of new equipment and technology makes the products competitive for today and will make it in future if only much-advertised and widely spread product made by well-known brand-names is not the only guiding line in your choice but they are fair evaluated in comparison with other ones newly developed including by domestic manufacturers.

Errors in choice of metallurgical equipment are often impossible to be corrected due to its high cost and accompanying work charges that negatively influence the future of foundries and makes them disable to be domestically and abroad competitive.

Certified name of **GPDCAF-NG-0,5-100** illustrates their general-purpose type because all the above-said product range is melted in the same furnace body structure, no replacement is required. **0,5-100** is a capacity of furnaces in tons. For foundries which are supplied by our **0,5-30** capacity furnaces, we are ready for supply furnaces with capacity of up to 100 tons. **GPDCAF-NG** can be supplied as a separate set or by upgrading active alternating-current arc furnaces.

1. Examples of GPDCAF-NG Industrial Realization

GPDCAF-NG performance characteristics are discovered in result of its industrial realization and shown by concrete examples:

STEEL PRODUCTION:

GPDCAF-NG-6x2 JSC “Kurganmashzavod” [1] Melting system consists of a power supply connected to two melting pots with capacity of 6 tons each. The system has been made by switching two arc alternating-current steel melting furnaces with capacity of 5 tons into direct-current supply and is in operation as-upgraded for 5 years.

Production of complex high-quality castings from various steel and iron grades in alternating-current arc furnaces has been mastered at the foundry. By its performance values this foundry is one of the best in Russia and that’s why the achieved advantages of GPDCAF-NG-6x2 are the most objective.

Arc alternating-current steel melting furnace (ACAF) produces iron and steel with use of regular cheap charge and own production returns in accordance with classical technologies. The possibility to solve ecological problems not by new powder-gas cleaning system but by rebuilding the furnaces has motivated this upgrade.

JSC “KURGANMASHZAVOD”, Kurgan city

Furnace unit for melting high-alloyed steels and special irons made by switching ACAF into direct-current supply.

Table No.1 gives the results of emission measurements from GPDCAF-NG-6x2 when melting 110Г13Л steel (magnesium, foundry steel grade).

Table No.1

Emission, gram/second		Maximum permissible emission, gram/second
Dust	0,3301	0,9853
Including Mn	0,0266	0,1486

It results from the table data that the problem put by us has been successfully resolved. In addition, the melting time has been on average shortened by 1 hour, energy consumption has been significantly reduced. The best result is 392 Kwatt-hour/t, when being in stable operation – 450 Kwatt-hour/t. Average consumption of graphitized electrodes has resulted 1,39 kg/t, charge wastes have become less from 6,0-6,5% down to 0,5-1,0%. All of this gives 50-60kg\t of metal saving and 11,6 kg\t of manganese saving.

Significant improvement of 110Г13Л steel mechanical properties should be also mentioned. When melting in ACAF, with metal hardness level HB 255-269 the bending deflection was 2,5-2,8, austenitic grain number was 2-3. When melting in GPDCAF, with hardness level HB 266 the bending deflection is 3,6-44, austenitic grain number is 1.

When 30XMЛ steel melting, the refining processes run on a conventional base with higher speed of sulfur and phosphorus removal. Especially high speed of decarbonization when ore kip which is 0,1 % within 3-5 minutes. Production of castings for 750 atm pressure stop devices for oil-and-gas industry with use of regular cheap scrap have been mastered at the foundry.

When melting a few reference standards were under gas content investigation. The reference standards were made from wedge reference standards pre-0,1% by mass aluminum-killed. Table No.2 gives the gas content investigation results.

Table No 2

Reference standard number	Gas content, %	
	Nitrogen	Hydrogen
1	0,0145	0,00032
2	0,0125	0,00031
3	0,0150	0,00030
4	0,0090	0,00028
5	0,0011	0,00024

The achieved results are standard for various steel grades production. Instead of melting costs increase that would be resulted from new powder-gas cleaning system for active ACAF, very serious performance values and quality improvement have been obtained with short time payback by upgrading the melting system with GPDCAF.

GPDCAF-20 JSC “TAYZHPRESSMASH” [2] The furnace was made by upgrading ACAF 20 ton capacity. The furnace capacity is 22-30 tons; due to its power supply conditions, the power of GPDCAF-NG was increased only from 8,5 up to 10,79 megavoltampere, i.e. the furnace is “slow”. There is a water-cooled roof placed on the furnace, ACAF classical technologies including ore kip are applied.

Table No 3 and No 4 give comparison data resulted from the furnace upgrading.

**Table of performance characteristics comparison data
for ACAF-20 and as-upgraded GPDCAF-20**

Table No. 3

Characteristics	ACAF-20	GPDCAF-20
Dust, mg/m ³	27,2	9,9
Noise, dB (total level)	98	84
Total energy consumption for 1 ton of liquid steel / after melting point, Kwatt hour	880/535	580/450
Liquid metal productivity, ton/hour	4,54	7,16
Average time for melts, hour	4,92	3,0
Average melting time for melts, hour	2,75	2,05
Total metal waste, %	7-7,5	3,5-5
Consumption, kg/ton of liquid metal:		
Graphitized electrodes	14,0	2,12
FeSi	12,5	11,2
SiMn	13,0	11,8
FeMn	11,5	10,6
FeCr	11,2	9,6
FeV	7	4,7
FeMo	2,1	2,1
Lime	48,0	20,7

Fireclay (for slag formation)	12,1	2,7
Deoxidizing mixture (lime, FeSi 45, coke)	272,78,22	192,46,18
Magnesia bricks (for bricklaying)	22	12
Number of samples during a melting, pcs	4-5	3-4
Quantity of slag for a melt, tons	1,31	0,46
Annual output of liquid steel (ingots, shaped castings), tons	12000	20600

**Quality characteristics improvement
(Improvement level in accordance with GOST in %;
“0” values – before the upgrading)**

Table No. 4

Chemical composition	0	35
Yield stress	0	90
Breaking strength	0	60
Tensile strain	0	45
Impact elasticity	0	80
Ultrasonic inspection improvement (SEP1921)	0	45

Homogeneity of chemical composition and melting temperature, decline in non-metallic inclusions significantly increases the supercooling rate during crystallization process and, as a result, makes the most favorable conditions for improving the metal structure. All of this is also confirmed by data from the Quality Management Center and Independent Examination of France.

Chemical composition deviations have become less by 35%, mechanical properties level for steels for castings and forge ingots has improved by 5-20%, the GOST requirements unconformity level has been reduced by 90%, ultrasonic inspection results have been improved by 15% for forged pieces and by 45% for export shafts. Melts with phosphorus content higher than 0,035% are 18% made by the “old” furnace and 2% made by the “new” one. Melts with sulfur content higher than 0,025% are 33% made by the “old” furnace and 15% made by the “new” one. The same changes can be noted for average values of these elements.

The below is the microstructure and macrostructure examination results that was applied to shaft blanks by the Central Laboratory of JSC “TAYZHPRESSMASH”.

The examination has given the following results:

- Melt of steel 35 Ø 300; macrostructure is dotted; non-homogeneity 1 to GOST 10243-75; microstructure is pearlite+ferrit, grain size number 6 to GOST 5699-82
- Melt of steel 35 Ø 380; macrostructure is dotted; non-homogeneity 1 to GOST 10243-75; microstructure is pearlite+ferrit, grain size number 7 to GOST 5639-82
- Melt of steel 45 Ø 400; macrostructure is dotted; non-homogeneity number 1 to GOST 10243-75; microstructure is pearlite+ferrit, grain size number 7 to GOST 5639-82
- Melt of steel 35 Ø 410; macrostructure is dotted; non-homogeneity 1 to GOST 10243-75; microstructure is pearlite+ferrit, grain size number 6 to GOST 5635-82

When melting this type of product by the same furnace before upgrading and as-upgraded the following results have been achieved:

Before upgrading: dotted non-homogeneity 3-4, segregate zones, centerline weakness, cluster of non-metallic inclusions, microstructure 4-5 number.

As-upgraded: dotted non-homogeneity 1, no segregation, no weakness, disconnected non-metallic inclusions, stable microstructure 6-7 number.

The following data has been resulted from the examinations applied to ACAF-20 and GPDCAF-20 melts by the Central Laboratory of JSC “TAYZHPRESSMASH”:

- Chemical composition deviations less by 35%;
- Improved conformity of mechanical properties for cast steel by 35%;
- Improved conformity of ultrasonic inspection requirements for all as-US inspected forged pieces by 15% and export shafts by 45%;
- Higher stability of mechanical testing results, namely:
 1. Less data spread by 20%;
 2. Improved precision of measurements by 40%
- Improved mechanical properties for steel:
 1. 25L: σ_B – by 5%; δ - by 7%; α_K – by 10%;
 2. 35L: σ_T – by 9%; σ_B – by 10%; δ - by 7%; α_K – by 15%;
 3. 45L: σ_T – by 18%; σ_B – by 15%; δ - by 11%; ψ – by 15%;
 4. 20ГЦЛ (foundry steel): σ_T – by 5%; σ_B – by 12%;
 5. 35ХМЛ (construction foundry steel): σ_B – by 14%;
 6. Steel 20: σ_T – by 8%; σ_B – by 4%; δ - by 6%; ψ – by 9%;
 7. 40ХМА (construction high quality steel): σ_T – by 9%; σ_B – by 13%; δ - by 20%; α_K – by 20%;
 8. 40ХН2МА (carbon steel): σ_T – by 11%; σ_B – by 6%; δ - by 8%; α_K – by 11%; ψ – by 4%

Non-conformities in mechanical properties for forged pieces and castings have been reduced:

1. Yield strength by 90%
2. Ultimate strength by 60%
3. Tensile strain by 45%
4. Contraction – no changes
5. Impact elasticity by 80%

Annual economical benefit from the upgrading totals about **52 mln. RUB**, there is about **3600 RUB** savings for 1 ton of liquid metal for separate steel grades. Payback period is 10 months.

The main cost-casting items are:

- Replacement of carburizer of pig iron with steel scrap and graphitized chips – about **12 mln.RUB**;
- Charge materials cutting – about **13 mln.RUB**;
- Ferroalloys consumption decrease – about **3 mln.RUB**;
- Power consumption decrease – **2,2 mln.RUB**

Figure No.1 shows the economical benefit structure:

**Main shares of economical benefit thanks to GPDCAF-20
(for 10 months in operation), RUB/ton**

- Power consumption
- Graphitized electrodes
- Technology
- Steel output increase
- Refractory materials and lining works

The above structure of the economical effect confirms the fact that power consumption saving can not be the main task of upgrading. The base of any performance characteristics is the costs of raw and other materials. It is also proved by Figure No.1 that new furnaces to get the output higher have a very quick payback period. Ecology cost savings are not taken into account but they are also very significant.

JSC “TAYZHPRESSMASH”, Rayzan city

25 ton capacity direct-current arc furnace for steel melting made by switching ACAF into direct current

Production Association “IZHSTEEL” [3,4] Upgrade of ACAF-25 to DCAF-30. The furnace was in operation for mass production of tool steel P6M5 (high-speed steel). The upgrading has made the level of dust and gas emissions less by 7-10 times, noise level conforming to the sanitary code, graphitized electrode waste decreased down to 1,5 kg / ton of melting, specific power energy consumption when full-power operation decreased down to 12MWatt for melting – 420-435 kWatt h with the melting time of 60-70 minutes. The main cost-saving item is reduction of melting materials which include the following savings (kg/ton of metal):

- Alloyed charge materials – 30-40;
- Ferrotungsten – 0,3-0,8;
- Ferromolybdenum – 0,3;
- Ferrochrome – 1,5;
- Ferrovanadium – 7,5.

The upgrading costs have had a 7 months payback period.

Production Association “IZHSTEEL”, Izhevsk city

25 ton capacity direct-current arc furnace new generation for high-alloyed and tool steels melting. The upgrading ACAF-25 to DCAF-30

JSC “Electrosteel”. Upgrading ACAF-5 to GPDCAF-6. The furnace is intended for production of high-alloyed steels and heat-resistance alloys. All the advantages typical to GPSCAF-NG have been achieved. High-quality materials are manufactured by using advanced technology and new technical solutions. There are no problems with nitrogenization. Mastered technology allows melting about 250 high-alloyed steels and alloys.

JSC “Electrosteel”. Electrosteel city

6 ton capacity direct-current arc furnace made by switching ACAF to direct current

GPDCAF-24, Ahmedabad city, India. The furnace system is intended for producing nickel less stainless steel connected up with converter. Charge materials from metallized pellets and briquettes as well as high-carbon ferrochromium are melted in the furnace.

Electrotherm Ltd., Ahmedabad, India. 25 capacity direct-current arc furnace for steels

Grade steels are produced in converter. The furnace is intended to make a melt with carbon content of up to 4,5% for further processing. The furnace is equipped with water-cooled roof, wall panels, and bottom discharge facilities. The furnace is successfully mastered. Melting technology is different from accepted ones being in use. Charge materials in the form of pellets and briquettes are loaded into the furnace in one dose. With the metallization level of briquettes, reduced metal goes to a melt in full, the output against the weight of briquettes totals 93% thanks to reduction of unreduced ferric oxide in charge materials. The furnace in operation demonstrates a very low level of powder and gas emissions, very high quality of charge materials at the end of melting process, power energy consumption being low for such melting types – 610kWatt h/t. Production costs for steel have been turned out to be by 25 USD cheaper in comparison with the costs when producing by ACEAF (electric arc furnace) equipped with a stove-basket and of 150 ton capacity converter.

The melt as an iron alloyed with copper and chromium is passed on from the furnace to converter with oxygen-argon blow where the alloying is completed or directly to continuous casting block machine.

As required by Indian customer, the stove-basket was added to the technological process. Our position that it does not make any sense has been further confirmed.

Iron Production

JSC “KURGANMASHZAVOD” [1,5] Iron melting in direct-current arc and alternating-current arc furnaces has been mastered. Melting productivity in GPDCAF-6x2 is much higher than in alternating-current furnaces.

Production of synthetic iron without using pig iron and foundry iron has been mastered at the furnace. The furnace melts 5 ton of metal with design content of 2,2% carbon in metallized charge materials. Carburizer is graphite crumbs of crushed electrodes, 3-10mm in fraction, carbon content of 96%, which are loaded onto the bottom after a previous melting has been discharged. Carbon recovery is 75%, the time of melting, heating, carbonization, and element finishing is 80 minutes; power energy consumption when operation in two shifts and long idle times are occurred is 630 kWatt h/t. Pig foundry iron in charge materials has been replaced with steel scrap 2A to GOST 2787-75. Costs of such charge materials are more than by **4000 RUB/t** lower compared with that having pigs. Other charge materials are own production returns.

The final chemical composition of synthetic iron tested as follows: C-3,60%, Mn-0,96%, Si -2,18%, S- 0,027%, P – 0,086%. In respect to carbon and silicon content the iron is in line to CЧ15 (grey iron) grade to GOST 1412-85. But its mechanical properties - $\sigma_B = 11,0 \text{ kg-force/mm}^2$, HB=229 correspond to CЧ20 (grey iron) grade. Such high improved properties are provided by technological possibilities of GPDCAF-NG.

Production of grey irons in grades from CЧ15 to CЧ30 (grey iron) and high-strength irons in grades from BЧ40 to BЧ70 (high strength iron) in ACAF and GPDCAF-6x2 has been also mastered by the company.

Starting iron for high-strength grades is melted in a furnace having the basic lining. Active slag processes and melt mixing is provided for a sulfur content to be not higher than 0,001% that allows reducing the consumption of magnesium alloys down to 1,0-1,2%. Mechanical properties are noticeably improved. For an example, iron having such element contents as C-3,58%, Si-2,13%, Mn – 0,68%, S-0,007%, P-0,06%, Cr -0,17%, Ni-0,05% gives the ultimate stress of 68 kg-force/mm², tensile strain of 12%.

JSC “GAS” GPDCAF-12. The furnace is mounted at a steel-casting foundry having no funds to produce iron castings. After rise in prices for pig iron and foundry iron, the furnace was re-oriented to produce charge blanks from syntethic iron for cupola-furnaces.

JCS “GAS”, Nizhnjy Novgorod city

12 ton capacity direct-current arc furnace for melting steel and iron

Full set supply

Iron with carbon content of upto 3,6%: is produced by melting briquettes from steel sheets and coke in small fraction fines when melting the charge materials and heating the melt. The melting time is 80 minutes, weight of melt is 12 tons, economical benefit is **3000-4000 RUB/ ton**.

JSC “KOSTROMAMOTORGETAL” GPDCAF-3x2 [6] Melting system consists of two furnaces with capacity of 3 tons each and operates with a 5,5 ton load for turn-by-turn operating furnaces. The system melts iron with chips loose due to cooling liquid. Iron is melted in induction crucible furnaces of 10 tons capacity, which receive the melt from DCAF. The productivity of DCAF is 1000 ton/month. This is the first time when the equipment has allowed industrial processing the chips with no further wastes and resolved the serious problems with recycling the iron.

Availability of large quantity of contaminating components of cooling liquid, sand, and others in the chips does not allow determining the output by weighting. But it can be evaluated by comparison of final chemical composition with the technical requirements for metal from which the chips was done. Table No.4 demonstrates the comparison data.

Melt primary element chemical composition Comparison against the technical requirements

Table No.4

Name of values	C	Si	Mn	S	P
Values to technical requirements, %	3,10-3,30	1,80-2,00	0,30-0,80	≤0,05	0,11
Actual values, %	3,63±0,8	2,28±0,13	0,4±0,04	0,007	0,11

Actual content of C, Si, Mn being higher than designed by the technical requirements is obviously resulted from reduction of cooling liquid materials and sand from slag. Low sulfur content is sequent from the classical desulfurization in GPDCAF-NG. The difference between the price of chips – about **2000 RUB**/ton and slag costs for iron melting – about **12000 RUB** / ton totals the economical benefit.

Installation of second power supply unit to replace induction crucible furnace and transfer the iron production to GPDCAF-NG is currently under discussion.

[JSC “MOTORGETAL”, Kostroma city](#)
[Furnace system for melting iron chips](#)
[Full set supply](#)

Melting of aluminum-based alloys and addition alloys

Technology and equipment for melting aluminum alloys in arc and plasma furnaces had first been successfully mastered in the USSR in 1986-1987. (Development and investigation of arc melting of aluminum alloys. The All-Union Science & Research Institute of Electrothermal Equipment Report 1986. Scientific and Technical Head – Malinovsky V.S., candidate of technical science). The objective of the works was to master the production of quality foundry from secondary aluminum alloys. That objective had been successfully achieved. Currently many processes connected with quality foundry melting, aluminum alloys waste recycling including chips, slag removals, charge materials having steel and other small size ferrous metals in Al charge, various aluminum and deoxidizer-based addition alloys melting have successfully been mastered in GPDCAF-NG. Their construction and operation principals do not differ from those that used for melting steel, iron and other metals in GPDCAF-NG. Possibilities of melting aluminum alloys have been demonstrated by industrial application of melting systems GPDCAF-0,5x2. Such a system is possible to be supplied in two set options:

- First option - power supply unit S=0,84 MBA, one melting pot
- Second option - power supply unit S=0,84 MBA, two melting pots

The prototype of the furnace was plasma-arc furnace induction steel melting furnace-06\07 developed in the process of works stated by the above said report. It was installed at the Kovrov Electro-Mechanical Factory (Kovrov city) to replace four furnaces induction

aluminum melting-0,4 thanks to its high productivity. Service time of rammed lining is 13-14 years, a furnace roof is replaced in 6-8 months. End-to-end power energy consumption for foundry production was 2800 kWatt h/ton when using the induction furnace for Al melting-0,4 and have been improved down to 800 kWatt h/ton after the new furnace was run. The high power energy savings were provided thanks to sharp decrease of rejects when producing complex castings, significant time improvement for aluminum melting in the whole production cycle – 20 min melting time in furnace, low energy consumption - 340 kWatt h/ton when melting directly in furnace.

GPDCAF-NG melting ensures metal of high quality. For example, AK7ч alloy (aluminum alloy with silicon) being in mass production corresponds to the requirements of GOST 1583-94 in its chemical composition and even higher in its mechanical properties. Reference standards from this alloy cast in metallic forms as-cast heat-treated condition demonstrate ultimate stress being not less than 216 MPa, tensile strain being not less than 2%, Brinell hardness being not less than 94,9 BA; at that a silicon varies from 6,15 up to 7,15%, magnesium – 0,25-0,4%, ferrous – 0,1-0,3%, structure is notable for higher dispersity of nonmetallic inclusions. Hydrogen content is 0,1-0,2 sm³/100 gr of metal, and final castings always give the porosity level meeting 1 number to GOST 1589-93.

High quality of aluminum alloys can be demonstrated by the example of АЛ9 (aluminum foundry alloy). The alloy was subjected to four-step melting process and the holding time during the last melting was 40 minutes (mixing mode). All the processes of melting and holding did not practically change the chemical composition of the alloy. The metal had Si-7,1-6,9%; 0,25-0,23%; Fe-0,43-0,41%. After the 40 minutes holding, Fe content became less down to 0,32% . No other actions to improve the quality of metal had been taken. The alloy was in line with the requirements of GOST 2685-75 in respect to its chemical composition and mechanical properties level and its structure represented higher dispersity of non-metallic inclusions. Its tensile strength as-cast was 160 MPa (16kg/mm), tensile strain -2%, hardness -50 HB; hydrogen content – 0,2-0,4 sm³/100gr of metal.

GPDCAF-NG is the only system where intensive removal of hydrogen and non-metallic inclusions goes during the melting process. Fast speed of the melting process allows producing a melt as-ferrous-unsaturated when melting the aluminum having steel small size parts. The melt always give the porosity level meeting 1 number to GOST 1589-93 with hydrogen content, as a rule, 0,1-0,2 sm³/100gr of metal (for a number of alloys as-cast conditions it can reach maximum 0,4 sm³/100gr of metal). All of this makes it possible to produce quality foundry from secondary aluminum with much less costs. Thanks to exception of many technological operations [5] and quality improvement of alloys, technological process costs go down:

- by 5 times compared with induction melting costs;
- by 15 times compared with gas melting costs

At that aluminum losses are cut down by many times.

JSC “ZAVOLZHSKY MOTORNY ZAVOD”s specialists conducted a number of trial melts in DCAF-0,5 at the Kovrov Electrical Mechanical Factory. The subject of the trials was an alloy resulted from melting AK7ч returns left from casting production at the JSC “ZAVOLZHSKY MOTORNY ZAVOD” where induction channel furnaces were in use and dramatic quality deterioration happened after repeated melting. The DCAF-0,5 load weight of the returns with no steel elements removal totaled 427,3 kg. Melting and short-time holding resulted to 398,3kg of aluminum alloy. Losses as slag, waste of metal, and steel elements sludge on the furnace bottom were 6,8%. The final alloy after the trials was

fully in line with the requirements of GOST 1583-93. Samples taken from the trials demonstrated the following mechanical and technological properties:

Alloy properties	GOST	Top sample	Bottom sample
1. Tensile strain, %			
2. Point of maximum load, kg-force/mm ²			
3. Hardness, HB			
4. Hydrogen content, sm ³ /100gr of metal			
5. Gas porosity, number			
6. Castability, mm			

GPDCAF-0,5 for “Aluminum Alloys of Estonia AS” The furnace is intended for melting aluminum alloys from secondary aluminum, including chips and slag. Capacity of the furnace was increased up to 1000kg. Among the aluminum alloys, there was production of addition alloys and deoxidizing agents. The bottom lining made from magnesite that allows heating a melt up to 1720°C has lightened the works. There is production of addition alloys: AlSi (10-60); AlFe (10-80); AlTi (5-70); AlSr, AlMn and others. This project had not been completed. That was supposed to install GPDCAF melting furnaces and mixer with capacity of 9 tons. The operations were designed to be performed by the furnace: scrap sorting to separate steel small size parts off and remove the non-metallic inclusions and hydrogen in the process of melting. Followed by fast speed 15 minutes melting, the melt had to be poured into a ladle which the chemical analysis was conducted in. If the alloy was in line with the requirements of chemical composition in part of impurities, than the ladle had to be poured into a mixer. If there were significant deviations from the chemical requirements, then the metal was used as a material for special orders for alloy with such a chemical composition. The mixer heated by arc discharge with melt mixing had to hold the alloy to get the designed chemical composition and to pour into ingots. Large capacity of the mixer would have lightened the task of averaging-out the composition. The possibility of full discharge from the mixer would have provided for an easy alloy change. As a further step, a mechanical device with smaller capacity of bath could be connected to power supply unit of the mixer to produce small volume orders or special properties alloys. It took about 1 hour to produce the alloy in the furnaces with no mixer; 15-20 minutes from the above period took the melting process. The balance of the time was required to obtain the designed chemical composition in the furnace. However, the process demonstrated high characteristics even with the above conditions. The alloys were of high quality level normal for GPDCAF-NG, power energy consumption totaled 350-400 kWatt hour/ton: 290-310 kWatt hour/ton – for melting process, 170 kWatt hour/ton was required when melting heavy-oiled charge materials with use of “hot” oxygen.

The produced alloys as cast into charge blanks were in full line with the technical requirements in respect to their chemical composition and mechanical properties, had a high density and hydrogen content not more than 0,4 sm³/100 gr. If there was foundry equipments available, they could have been used for production of casting blanks of high quality.

[“Aluminum Alloys of Estonia AS”, Tallin city, Estonia](#)
[Furnace unit for melting aluminum alloys and addition alloys](#)
[Full set supply](#)

GPDCAF-0,5 for JSC “STUPINKAY METALLURGICAL COMPANY”

There is the stage of mastering a number of technologies. It confirms high characteristics when producing high quality castings in aluminum alloys.

JSC “STUPINSKAY METALLURGICAL COMPANY” GPDCAF-0,5

General-purpose direct-current arc furnace for melting steels, irons, alloys based on aluminum, copper, nickel, cobalt and other metals.

Capacity range from 0,5 to 1,2 tons.

DIRECT CURRENT ARC MIXERS

GPDCAF-12x2 JCS “YAROSLAVKY MOTORNY ZAVOD”

It is installed for heating and holding iron melted in cupola furnaces. It has two mechanical parts connected up to the same power supply unit with power of 4,5 MBA. The mechanical parts are of 12 tons each in capacity and of 40 tons in hour productivity when heating 100°C. The power of energy unit allows melting metal in case of its freezing and provides operating two mixers at the same time. The mixer can be also used to melt steels and alloys based on aluminum and copper.

According to the conception of the NTF EKTA, two mechanical parts are supplied. It also supposes the possibility to apply technological processing to a melt in mixers – desulfurization, dephosphorization, hydrogen content control, alloying, chemical composition adjustment, refining with use of active slag processes. These possibilities allow producing high-quality metals from regular charge materials as-melted by low technological level equipment or when recycling scrap materials pre-sorted when pouring from GPDCAF-NG of smaller capacity. The mixers are very simple in their construction and do not have any problems with lining materials and lining works. They are economical and safe and provide for full discharge of metal.

New method of heating can be applied to distributing furnaces and pouring units. They can repeat the technological possibilities of induction heating units but thanks to the use of arc heating they can be more general-purpose and safe.

The NTF EKTA is ready to supply mixers of various capacities and power ranges as specified by customers and cooperates for equipping foundries with the advanced engineering solutions.

It follows from the above examples that:

Equipping foundries with GPDCAF-NG allows producing high-quality metals from regular cheap scrap and widely spread refractory products. Using the equipment makes it possible to avoid:

- organizing mass production of special refractory materials or importing them from other countries
- industrial processing scrap to separate off metals higher in quality, more pure in chemistry and others acceptable for induction melting
- heat treating or other processing for organic fertilizer and moisture removal
- organizing complicated system for out-furnace metal processing.

In respect to AC arc electric furnace + slove-basket processes, the use of GPDCAF-NG provides foundries with favorable conditions to fulfill the kiot agreements and the requirements for protection of labor, to resolve the energy savings solutions at the high

technological level, to organize easy-change production with any work schedule, to agree between the melting processes and castings production and to ensure technological general purpose approach, with significantly cutting down capital assets costs and operation costs.

JSC “YAROSLAVSKY MOTORNY ZAVOD”

General-purpose direct-current arc mixer for melting iron, steels, and alloys based on aluminum and copper. It is used for iron. Capacity is 12 tons. Hour productivity when overheating of 100°C is 40 tons. It makes the dephosphorization and desulphurization possible.

FORWARD-LOOKING STEEL PRODUCTION PROCESSES

The perspective application for mixers is decarbonization and refining processes for iron poured in the mixers from blast furnace. Ore concentrate, ore pellets, metallized pellets with low metallization degree can be used for oxidation of hydrogen.

The technology makes it possible to perform melting with intensive magnetohydrodynamic mixing and to obtain a slag-melt with advanced surface thanks to the mixing process. It also allows continuing a blast-furnace process with a full use of carbon and getting up to 40% ore concentrate involved into the process, in particular in forms of metallized pellets with metallization degree not higher than 60-70%. Independent heating makes it possible to conduct the process within the designed temperature limits that permits to oxidation of iron additions such as magnesium, silicon and others at not high temperatures of the reaction and hold them in a melt at the process temperature higher than 1600°C. The process can be realized in mixers of any capacity with energy supply sources of limited power. For example, 25MBA power unit would be enough for a mixer with 100 ton of technical ferrous in hour productivity. DCAF can also be used to energy supply a mixer or converter to produce synthetic iron by steel scrap carbonization. Such a method was introduced at JSC “GAS” when melting a synthetic iron in GPADCAF-12 for further loading into cupola-furnaces. Steel melting when liquid condition loading from a mixer is also possible in DCAF of low power equipped with addition alloys feeding system. GPDCAF-NG’s technological process to produce synthetic iron or blast-furnace – mixer oriented to ferrous recovery process by iron carbon - GPDCAF-NG for steel production – based on furnaces having already been in industrial use where it was realized by parts (see JSC “GAS”, “ELECTROTERM” (India), JSC “KOSTROMAMOTORGETAL”, JCS “TAYZHPRESSMASH”). New technological process is possible to give the productivity not less than equipment being now in metallurgy has given but using the new technological process will have much higher performance characteristics and atmospheric emissions lower by hundred times.

As an option, GPDCAF-NG can be applied for processing steel scrap into synthetic iron to supply a converter with power energy. This would significantly improve the process costs thanks to full or partial replacement of pig iron by synthetic one. Such process giving the annual productivity of 100 ton was realized by the NTF EKTA for Mardia Steel, India. There were used metallized pellets and briquettes, steel scrap, carburizer, ferroalloys as charge materials to produce nickel-less stainless steels.

2. GPDCAF-NG Technological Conception

As an alternative to the current melting systems, the NTF EKTA's specialists have developed a range of general-purpose DC arc furnaces of new generation (GPDCAF-NG) which have been applied to master the melting of steel in any grades such as Steel 3, Steel 40, XMJ1, 5 XHM, 4X5MΦC, 110Г13Л, P5M5, P16, stainless chrome-nickel steels such as 10X17H13M3T, 06X20H14C2; nitrogenated steels such as 03X17ГДАМБ; nitrogen-free stainless steels; die steels such as 4X5P2ΦC; high-chrome steels such as 95X18, special steels and alloys such as 14X20H25B5МБ-Π and other similar alloys; grey irons of such grades as CЧ15 to CЧ30 with grade increase from Π45, Φ55 up to Π in CЧ30, high strength irons BЧ40-BЧ70 and others, aluminum-based alloys such as АЛ-9, АК7ч, АК12-18 and other master alloys based on aluminum such as АlSi 20-60, АlMn and others; deoxidizing agents such as FeAl20Ti, FeAl30Mn30 and other alloys based on copper; reducing melting processes for nickel, cobalt, magnesium, and others. General-purpose mixers have been developed for iron, steel, alloys based on aluminum and copper.

The technological conception of the new furnaces have been based on the condition that they would be able to perform all the classic operations known from the metallurgical process theory under the conditions as near as possible to the ideal that is the melting process must be free from such events as any local overheatings of metal, gas exchange between furnace environment and ambient space, melting loss. Controlled melt mixing, temperature and chemical composition of slag having the advanced interaction surface – slag-metal – thanks to the mixing provides for such advantages as the homogeneity of the chemical composition and temperature during all the periods of the melting process, no ingress of materials from heating sources into melts, the possibility of reducing and oxidizing processes, metal aeration suppression such as nitrogen and hydrogen, active dephosphorization and sulphur removal when melting iron and steel, removal of non-metallic inclusions and solute gases from the melt, dispersion of residuary non-metallic inclusions, and other processes. All of the above listed has resulted into a high-quality metal melted in our furnaces in industrial operation that will be below proven by particular examples.

To realize the accepted technological conception, general-purpose DC arc furnace of new generation (GPDCAF-NG) has been developed.

3. Basic DC arc furnace of new generation

The mechanical system is based on typical construction of AC arc furnaces including: steel case lined with refractory materials which are selected depending on the requirements of a particular technological process; a water-cooled roof lined with refractory products; a case opening that is closed by a door for slag discharge and other technological operations; a graphitized electrode move mechanism; tilting mechanisms to pour a melt out and discharge a slag, to move the electrode, to lift a roof or roll out a bath for charge loading; a door opening mechanism. The construction of the furnace had been worked through well for many years when ACAF being in operation. It does not have water-cooled elements under and around a melt that is frame safety one. Any refractory products without special requirements can be applied for lining. The construction is easy, long-lived, and reliable in operation. It allows for performing the reducing and oxidizing processes, cold and hot maintenance and does not take a long time for overhaul. The charge materials melting and

melt heating processes are performed by arcs burning between a graphitized electrode and melt.

Bottom electrodes are located at the bottom of DC arc furnaces to conduct the current to charge materials and melt. Three roof electrodes do through the roof of ACAF, there are no bottom electrodes in ACAF's construction. ACAF normally makes a full melt discharge and allows for producing steel (iron) in high quality with the use of cheap scrap and inexpensive high-carbon ferroalloys. Apply of overheating to scrap in or out of a furnace improves the melting performance characteristics but gives a rise to ecology problems.

4. Disadvantages of ACAF

In spite of the advantages of ACAF, they and DC arc furnaces which are produced by many companies have very grave disadvantages. They result from the fact that the problems of melt mixing, energy transfer from arc into the melt, arc discharge control are not solved at the ACAF. All of the above said causes a 4,5-6% high charge materials and ferroalloys loss, 4,5-17,0 kg/ton graphitized electrodes loss, local overheating of melt under arcs, and narrow application field: for an example, the ACAF cannot be used to melt aluminum alloys, high gas and dust emissions and high noise level, a drastic variable loading of power supply system, flicker, high energy consumption 650-900 kWt hour/ton, low productivity, need of manual labor.

In spite of the above listed disadvantages, ACAF are currently in operation at many Russian factories giving the output (in particular, for steel foundry) which is much higher than the output of modern induction melting furnaces thanks to their technological activity to melt high-quality metal from cheap charge materials. The ACAF's profitability is dramatically cut off when performing the ecology requirements to the preservation of the environment and when installing new power supply systems to improve the electrical energy quality. The costs for gas and dust cleaning systems and filter compensation followed by installation and further maintenance works increase production costs. Just a transfer of ACAF to direct current supply is not repaid because its only result of the transfer requiring significant costs is reduction of flicker and graphitized electrodes consumption.

With all this going on, DC arc furnace designed with taking no attention to interaction between arc discharge and metal can give a rise to a sharp increase of rejects due to nitrogen saturation from furnace atmosphere. For an example, there have been plasma and DC arc furnaces in operation at Joint-Stock Company "MECHEL" (Chelabinsk city) at which more than 240 grades of special steels and alloys had been mastered with the assistance of the author. The reconstruction performed with the factory's specialists together with the Joint-Stock Company "AKOND" was unsuccessful and resulted to almost complete loss of all the furnace technological possibilities and dramatic increase of rejects due to nitrogen saturation.

5. Modern foreign and domestic trends of ACAF reconstruction

At the present time when developing and upgrading the ACAF technological processes the foreign and domestic companies follow the direction of duplex-process that supposes the charge materials melting in combined ACAF and steel production in a bucket with using

the arc heating. Such a technology, to my opinion, is disputable to be used in metallurgy and is unsuitable for machine-building metallurgy.

The material set forth in [8] is under consideration to understand this point of view. A general article describes the most modern electric arc furnaces (EAF) designed to produce a melt for stove-baskets. The article describes a high-capacity steel melting furnace but smaller capacity furnace is based on the same principles offered to the machine-building. The furnace capacity is 160 tons, melt weight is 120 tons, the balance of metal in furnace is 40 tons, the output is 90-91%, and transformer power is 170 MBA. To melt at higher speed, to protect the walls, to reduce heat losses, and to save power energy the furnace operates with four 3,6 MWt lance burners; two gas-oxygen burners 3,6 MWt are used for charge materials heating; three oxygen lances to burn up CO in furnace gases with oxygen consumption of 400 m³/hour, three lances to blow carbon powder in – 70 kg/min.

Consumption of materials and energy for 1 ton of liquid steel (more precisely, technical iron, the steel will be done in stove-basket): technological energy – 340 kWt hour/ton, electrodes – 1,2 kg /ton, oxygen – 35m³, natural gas – 5m³, carbon containing materials in charge – 10kg, coal powder blown in for frothing of slags – 7kg, lime – 40kg, charge as fuel – 90-100kg.

It is very important to make the right choice of charge materials to melt steel in electric arc furnace due to the fact that 70% of costs are taken by metallic charge materials. As stated by the authors, it is not obligatory that cheap slag guarantees low costs for production stages due to the fact that change in technological energy costs depending on the slag quality has to be taken into account. From this point of view the best charge materials are as shredder-processed. When melting the metal with low additions, the charge materials are metallized pellets and briquettes with carbon content desirable to be of 5% and having a high degree of metallization. When melting in electric arc furnace, up to 20% of energy put into the furnace is lost with waste gases as chemical and physical heat. This among with much larger amount of waste gases in comparison with ACAF causes the ecology and heat utilization problems. As stated by [8], electric arc furnace shall be equipped with a mine reheater for charge materials including briquettes to utilize the heat of waste gases and to arrest the dust.

Strained heat conditions of the furnace operation and gas outlet sections make it necessary to widely use water-cooled elements with picking of heat.

The gas and dust cleaning system must be equipped with filters, lined chamber for burning waste gases up, hardening chamber, absorber for removal of toxic impurities in waste gases filled with activated coal of 0,3kg /ton of steel. The successful operation is possible only when using the advanced auxiliaries and industrial control. That is to say that the only process that can be performed in electrical arc furnace is oxidizing one. The other technological processes are taken place in stove-basket and require such supplies as gas – oxygen, argon; slag-making additions or synthetic slag; powder-like slag-making materials; deoxidizing agents including aluminum wire; ferroalloys. Such processes as slag materials and graphitized electrodes loss, energy and refractory products consumption happen at the stove-basket as well but with all this going on the real high quality of metal are achieved when using vacuum processing.

6. Disadvantages of electric arc furnace + stove-basket process in machine-building metallurgy

The authors of the above-mentioned article [8] do not cite any data concerning the power energy costs required by auxiliary operations such as gas and dust removal system operation and stove-basket operation which, by the most conservative estimate, are 100-150 kWt hour/ton making the total power energy consumption equal to 440-490 kWt hour/ton; but the equipment does not make it possible to melt steels without duplex-process and powerful gas and dust cleaning system. Wide use of chemical reactions heat is in contrast with the Kyoto agreements increasing the atmospheric emission of CO₂ by many times. The authors did not cite any data in respect to noise level which being higher than 100 dB.

The equipment taken for comparison by the above-mentioned article is actually the most effective for its equipment group and any variance from its technical solutions would make worse the performance characteristics.

Let's suppose that you want to modernize the factory where ACAF is in operation. In this case it would be necessary to purchase electric arc furnace, stove-basket, mechanization and automation facilities, to build oxygen station, chemically treated reused water cooling station, to supply natural gas, to solve noise-proofing problem, probably to improve the power energy system, to revise the requirements to crane equipment, to match the furnace operation with foundry equipment (because the electric arc furnace can not be used at intermittent mode), to solve the slag removal problem (the output is 90-91%, and practically all the alloying additions including toxic elements are passed on from charge materials into slag). All the above and many other costs must be taken into account when calculating the capital assets.

The above costs are much higher when replacing open-hearth furnaces.

If the conditions are such that the replacement is necessary and you are offered to purchase a stove-basket as a first, the offer shall include further purchase of electric arc furnace.

With applying GPDCAF-NG it is not necessary to purchase a stove-basket and what is more that its use may deteriorate the quality of metal.

Electric arc furnace and stove-basket are connected in consecutive line. Let's suppose that one of the elements of high-productivity equipment line would be out of action, and such sometimes happens, all the production process would stop.

There are a lot of grades of iron and steel in production for machine-building metallurgy. The required availability of the liquid metal in furnace makes it difficult to transfer from one grade to another one.

Foundry production is accompanied with a large amount of domestic returns (up to 40-60%) from which 10% will burn when melting at electric arc furnace including all the main alloying elements that is all the production shall be oriented to purchase fresh ferroalloys.

Charge materials has to include a large amount of carbon for operation of oxygen lances that is they shall be alloyed with significant quantity of iron that costs much higher than steel scrap does.

When calculating the production costs, it is necessary to estimate how much are: auxiliary materials – oxygen, natural gas, lime, water; gas cleaning system maintenance; burned-out charge materials, and others. If all the above is evaluated in power energy costs, then it can be cleared up that the costs of burned-out charge materials to produce carbon low-alloyed steel with its loss of 10% and even if the charge materials costs are less than their fair value and are **8,000 RUB/ton**, then if the power energy costs **1 RUB/kWt hour**, are 800

kWt hour in addition. It is evident from the above that this melting method is of high resource and energy costs, particularly when melting high-alloyed steels and irons.

When producing cast products, the metal is poured out into molds, and further pressure processing in contrast to metallurgical production does not take a place. Under these conditions, the possibility of high-quality steels at electric arc furnace + stove-basket gives rise to doubts. Besides, other types of furnaces are used for these purposes in the world.

7. Induction furnaces

Induction crucible furnaces have a melt being inside of water-cooled coil and isolated from it by lined crucible. Induction channel furnaces have a melt being in crucible and heated in lined channels inside of water-cooled induction coils. Any damage in quite a thin lining can always result in water ingress under the melt. In such a case, intensive slopping of melt from the furnace or explosion may happen.

Companies manufacturing induction furnaces has developed special lining leakage diagnostics to prevent from the damage but the principle of induction furnace construction is based on such a potential risk of damage.

The attempts to use induction furnaces for hot slag processes which always promote the lining attack and larger capacities of induction furnace make the risk of negative consequences higher.

The second source of danger when melting at induction furnaces is that the main part of charge materials has to be loaded into a melt. This is due to the fact that induction furnace chamber volume comes near to a melt volume by the end of the melting, and density of charge materials is few times lower than a melt density. Ingress of moist charge materials, pieces of ice, any capacities filled up with water into a melt can also cause the explosion. The problem can be fully improved by use of additional equipment, as a rule, thermal one, to heat charge materials before induction melting but the principle possibility of damages still takes place. That is why induction furnaces are highly explosive by their basic principle but in spite of the fact they are widely used thanks to their possibility to melt and hold a wide range of metals and alloys when any alternative equipment is not available.

Currently induction furnaces are the heart of production activity of the leading foreign and domestic companies. There have been developed and mastered a lot of technologies, special foundry equipment has been developed with taking their use practice into account; significant funds have been invested into improvement and upgrading activities. Competition between the biggest manufacturers of induction melting systems induces putting in heavy expenses for advertising and public opinion making. The danger risk when induction melting has been got into the habit.

Against this background this is of a great importance to develop and master alternative and principally safe equipment which is not second to the induction melting but even much better and exceeds it. If there is any chance that heavy consequences may happen from any processes and events, then it is necessary to go away from them. The more so as induction furnaces have very serious disadvantages concerned with the performance characteristics.

Being technologically passive, induction furnaces make it impossible to perform almost all the technological procedures of metallurgical processes. Induction furnaces are able to melt or re-melt metals with some degradation of starting charge materials in properties. The quality of end metal is fully depending on the quality of starting stocks. This is in respect to chemical composition of charge materials. The induction melting does not allow

any pollution of organic compounds, the presence of moist charge materials. To make the induction melting relatively safe, specially developed refractory products must be used and exacting lining and operation requirements must be followed. There is a special charge materials preparation and quality refractory materials production system designed and mastered in the market-economy countries. It does not present at full in Russia. Scrap must be definitely sorted in the process of charge materials preparation; it also to be cleaned by detergents or thermal-treated that is far to be ecologically safe and takes heavy expenses. In many cases other types of melting furnaces are used for production of special stocks for further induction melting.

Another trend is technological outside processing to be applied to a melt after induction melting to remove all injurious additions and with the purpose of refining. A lot of types of equipment and materials that are expensive as a rule and harmful to the environment have been developed for the above processes. That is why when calculating the performance characteristics for induction melting all the above listed and other factors such as feed stock costs, its melting preparation expenses, and non-furnace treating costs should be taken into account.

Power costs when induction melting having mains or higher frequency are not of great importance against the others. However, there had been a great amount of mains frequency induction furnaces produced in the USSR for mass production purposes which stayed idle due to a lack of orders under the market conditions after the Soviet period's collapse. Due to long idle times the need of holding some liquid metal had resulted to heavy specific power energy consumption of 1500-2500 kWt hour/ton when producing an iron, for an example. Replacement with higher frequency induction furnaces eliminates the defect but when looking for new equipment other alternative possibilities should be taken into attention.

When calculating the capital funds it should be paid attention not only to the price of furnaces but to other auxiliary equipment costs as well such as charge materials preparation facilities, auxiliary materials expenses, non-furnace treating equipment, cooling system, ecology costs, in particularly for before and after melting production arrangement. But the main thing is to make your production safe.

8. DC Arc Furnaces New Generation Conception

Developed and patented system of engineering solutions which are base for the performance characteristics significantly exceeding the main characteristics of modern melting equipment give prove actually only for the NTF EKTA's equipment performance characteristics.

It was above said that the base construction of GPDCAF-NG is ACAF, all the merits and demerits being typical for ACAF were listed; the technological conception of GPDCAF-NG was stated. The below is our new engineering solutions developed and mastered by us to arc furnaces which made it possible to rank them to new generation equipment.

Metal heating sources – electric energy without attracting any other heat sources.

Furnace safety – the base is ACAF's construction without water-cooled elements under the bottom lining. Bottom electrodes in form of steel sheets located in the depth of the lining and welded to copper-steel base are used to lead the current to charge materials. The copper-steel base is cooled behind the bottom's case. To protect the bottom electrode from

flash arc, the active anti-flash arc system is mounted on the furnace case between the bottom electrode and the case and connected with the alarm system and with power supply unit cutoff. Temperature sensors of the bottom electrodes are installed inside the base. Any explosion is impossible if metal leakage through the furnace bottom happens [9, 3].

The furnace capacity makes it possible to feed charge materials by one load. If any additional loads are required, they can be added into the furnace as heated but not into a melt. The metal is poured out at its full amount at the end of the melting. Under these conditions any availability of water, ice, and other materials in the charge will not result in melt slopping.

Local metal overheating suppression [10]. The melting is started at high voltage and low current arc. Anode spot of the arc becomes attached to pieces of charge materials, melt drops flow down as soon as their weight is more than surface tension force. At the same time a melt is accumulated on the bottom, and any overheating is impossible. The melting is further running at higher current and voltage that is proportionally declined by power supply unit in the ratio of reduced power in the arc and in its basic spot - 80-90% and 20-10% accordingly. The furnace bath is fed with significant amount of a melt; magnetodynamic mixing is applied to a melt under the arc spot. Further melting, melt heating, technological operations are performed with keeping the power thanks to the magnetodynamic mixing system. The ratio of energy given directly to a melt by the arc is 80-90%, a cold metal runs under the arc at high speed and goes inside the melt. Any local melt overheating risk is eliminated.

Melt magnetodynamic mixing [10]. It is achieved thanks to the current spreading from basic spot of the arc to the bottom electrodes located at the periphery of the bath. At the same time, the interaction between horizontal and vertical components of the current with the current developed by electromagnetic field gives rise to toroidal mixing in a vertical section and rotating move in a horizontal section. The mixing is unstable and results in the generation of vortices under a graphitized electrode and the bottom electrodes; with all this going on, the balance of melt stops moving. Special program to control the arc current and SCR converter keeps the mixing in constant form, adjusts its intensity, eliminates vortex flows above the bottom electrodes (Fig.1).

Fig. 1 Scheme of magnetodynamic mixing in GPDCAF-NG: a) mixing of melt in its cross-section; b) mixing system is on; c) mixing system is off.

Patent No. 2104450 “Electric melting method and arc furnace to make it performed”

Bottom electrodes

a) b) c)

TOP VIEW

Dust and gas emission suppression [10]. Magnetodynamic mixing and charge materials melting arrangement eliminates the local melting overheating that is to say the evaporation. The current stabilization by SCR converter and the above described melting modes suppress the arc power variations. In accordance with $PV=nRT$ when the furnace capacity is the same, the gas pressure variations inside the furnace giving rise to gas exchange with the environment depend on the gas temperature variations. If electric mode is stable, then the furnace gas temperature variations are suppressed, and oxygen is prevented to go to the furnace. With all this going on the composition of furnace gases depends on melting products, mainly CO , C_nH_m , N_2 which go out from the furnace being

of high concentration and of high temperature. When interacting with oxygen in the air, the gas emissions ignite and burn up to completed oxides CO_2 , H_2O . Because the oxygen is almost absent and the furnace gases are of high temperature, all of these prevents from the metal oxidizing, the generation of nitrogen oxides, cyanides, furans, other harmful elements, and intensive dilution of small amounts of furnace gases with a large amount of air, when entering the dust and gas removal system, and provides for hardening (quick cooling) to off-gases preventing from repeated generation of harmful compounds. If this is technologically required, the furnace atmosphere can be replaced with nitrogen, argon, oxygen, other gases forcibly feeding into the furnace including when they are fed through a hole of graphitized electrode at the high temperature. This is not reasonable to perform the off-gases heat utilization as well as charge materials cleaning from organic and other contamination in special equipment for the purpose of melting at GPDCAF-NG because the first process takes much less % from the input energy, and the second is conducted during the melting process of charge materials.

Slag mode control. The main part of slag-making additions is fed into a furnace together with charge materials. It allows protecting the metal from the furnace atmosphere during the whole melting process. Metal oxidizing suppression when melting process prevents from the generation of first slag that is why the composition and properties are designed by burdening and changed under control. Other types of furnaces do not offer such possibilities. After a metal has been melted, a slag can be removed, for an example, for the purpose of steel dephosphorization, at the same time on a new slag is formed for 2-3 minutes after slag-making materials have been added. The ratio in temperature of metal and slag can be changed by the arc modes. The magnetodynamic mixing allows keeping the effective surface “slag-melt”, providing the melt with transporting to the area of interaction with a slag, keeping the melt homogeneous in its temperature and chemical composition. It makes it possible to perform all the ACAF’s technological operations – oxidation-reduction and refining processes but much deeper and faster. For an example, when ore kip occurs the decarburization speed of steel is 0,1% for three minutes, and the carbonization of steel when producing synthetic iron is combined with melting process. The possibilities of slag processes had an influence on the choice of construction type for GPDCAF-NG. Because a slag keeps a high refining ability up to the end of the melting process, it does not make any sense to cut it from a melt to organize the bottom discharge, and it would be reasonable to pour it out into a basket when a furnace is tilted. The refining process is going on in the basket when further melt is poured out. Advanced possibilities of GPDCAF-NG offer especially high effectiveness including the possibility to produce high-quality metal when the whole production process for steel, iron and other metals can be performed at it. That is to say that there is no need in a stove-basket, and it even is harmful from the point of steel quality. At the same time non-furnace treatment of melt is not denied including if it takes place in a basket by argon, ammonia, for an example. Vacuum treatment to obtain the designed properties or to remove copper can also be applied to steel. But all the processes are of low energy and can be performed thanks to the reserve of the melt temperature which losses when pouring out into a basket are very low because the melt temperature in furnace is homogeneous. The redistribution of energy flow during the melting from the arc and heat transfer from the arc to a melt has made it possible to avoid using the frothing of slag to improve the heat losses and keeping the slag at the same active level thanks to its temperature reduction by wide use of water-cooled walls and roof.

As it mentioned before, the GPDCAF-NG can be well applied for effective production of aluminum alloys. This is resulted from the elimination of local metal overheatings during the melting which may give rise to the structure heredity deterioration. When melting aluminum alloys, especially from second feed stocks, it may face some problems in respect to high oxidability of metal surface and the presence of non-metallic inclusions and solute hydrogen in charge materials. High temperature gradient limited by some exceed of the melt temperature is formed on the surface of pieces of charge materials when melting. Under these conditions the hydrogen actively goes away from a metal, melt drops are filtered from non-metallic inclusions going through natural slag generated from charge materials. When aluminum recycling these processes provide for the production of quality aluminum alloys with minimum loss and do not require the preparation of charge materials and non-furnace treatment. Aluminum recycling costs to obtain quality cast products in GPDCAF-NG are 5 times less compared with induction melting and 15 times less compared with gas furnaces [11].

Power energy supply system arrangement. GPDCAF-NG is offered as a general-purpose machine for producing quality metals. The energy is supplied from typical three-phases AC mains with voltage 6, 10, 35 kV and 0,38 kV for small capacity furnaces. With sharply variable loads and flicker being almost absent, the margin of power for dynamic stability of power energy equipment can be reduced. This fact allows making the power of GPDCAF-NG's power supply system greater by 20-30% when reconstructing or replacing ACAF; the works will not require filter compensation system to be installed.

The GPDCAF-NG's power unit consists of transformer with a few three-phase secondary windings and three sections of SCR converter with switches for serious mode, parallel-serious mode, and parallel mode, smoothing chokes, heat exchanger to cool thyristors, control cabinet. This scheme allows conducting the whole melting process at the same power matching the current and power supply unit voltage with the operate requirements of arc heating by switchings. Under these conditions a position high-speed circuit-breaker and voltage switching regulator is not installed in transformer. The power supply units and furnace control boards include the overvoltage protection system, static and dynamic current protection, magnetodynamic mixing control and startup system, parasitic arc protection system, bus bars fuse protection, bottom electrodes protection [10,12], arc current and voltage stabilization and control system, automatic arc firing after fault, input energy melting control [10], water flow control, electric equipment status control. Currently the works on development of the intelligence melting control system with self-adjustment of mode are being completed.

When making a choice in respect to the power of supply unit, its operation conditions at a customer's cite and power supply system facilities should be taken into attention. The minimum specific power of furnace to melt iron and steel is 0,25-0,3 kBA/kg, the maximum one is not limited. The melting time depends on the specific power and can last 25-30 minutes at $S=1$ kVA/kg and can reach 80-90 minutes at $S=0,25$ kVA/kg. With all this going on, the specific energy consumption for melting is not much changed and is within 410-450 kWt hour/ton but power supply equipment costs will be significantly increased. The time of technological melting period for steel including dephosphorization, desulfurization, carbonization, decarbonization, chemical composition development, refining do not exceed 20 minutes, and extra energy consumption is not greater than 70-100 kWt hour/ton but the technological time and energy consumption strongly depends on work process arrangement – load time and additional loads time, slag discharge time, slag-

making additions feed time, test volume and time for chemical analysis, ferroalloys preparation and loading, possibilities of charge materials and sorting aisles, one-two-three shifts operation mode. When the works are arranged at the high level, the time can be down to 10-15 minutes, and in such a case it does not have any influence on the specific energy consumption and it makes sense to force the melting by powerful power supply units to improve the melting time up to 60-70 minutes. Actually, with applying no changes to a steel-melting shop with ACAF, we have succeeded to cut off the specific energy consumption by 150 kWt hour/ton as minimum and the melting time by 1,5-2 times just by switching the furnace into the direct current; the power supply system was not changed in that case.

Reliability. We have been faced no claims for GPDCAF-NG operation reliability from our customers. The product is granted with the European Certificate and manufactured by joint manufacturers having great domestic and foreign authority.

A number of customers have faced some difficulties in maintaining the bottom at the very beginning when mastering the equipment. With being in normal operation and meeting all the instructions, the bottom with bottom electrodes runs much more reliable in comparison with ACAF's bottom. The first melts required a few simple patented procedures [13] to be done which prevent from any loss of electric contact with charge materials that may give rise to troubles at the beginning of melting and alarm events and furnace off due to bottom electrodes overheating. After the bottom is metallized in a few meltings, there will no need in paying special attention to the bottom electrodes. If any breakdown of the bottom happens due to melt overheating, the bottom electrodes are subjected to "hot" or "cold" repair without replacement; such works technologically do not differ with ACAF. The bottom life when melting steels with ore kip and oxygen blowing is 1,5-3 years, when melting aluminum-based alloys exceeds 10 years. When the bottom is under overhaul, the electrodes are subjected to repair and re-mounted in the bottom. The reliability of GPDCAF-NG and ACAF in mechanical parts does not have any distinctions. The service-life of water-cooled cables and power supply unit elements is many times greater for GPDCAF-NG thanks to a lack of dynamic loads.

Conclusions

It can be concluded from the experience of GPDCAF-NG being mastered that:

1. The furnaces strongly take stands in foundry in Russia.
2. The performance characteristics of the furnaces are mainly determined not by power energy consumption and the possibility for fast-speed meltings but by material researches saving, end high-quality metal produced from cheap regular charge materials, the capital funds value cutback thanks to a lack of need in additional, in particular, chemical types of energy and additional facilities, use of refractory products mastered in Russia, reduction in technological operations necessary to obtain the end metal of high quality, refusal from many harmful substances, providing the foundry with such a type of equipment which sharply reduces harmful emissions followed by significant ecology problems costs saving. The advantages given by GPDCAF-NG in meeting the performances are obvious.
3. Technologies and equipment of GPDCAF-NG are based not on the art but on the most complete use of metallurgy theory, a rich experience gained in production and

operation of other types of furnaces, the technical progress results in electrical engineering, and other fields of technology and science.

4. The high performance characteristics of equipment are achieved not by switching to DC arc heating but by developing the conception of interconnected system and its use, technical solutions developed and patented by us when creating the GPDCAF-NG. Therefore, attempts to reduce furnace costs thanks to famous more simple solutions make switching furnaces to DC senseless.

The intellectual property rights for our equipment and any relative processes are patent law protected.

More detailed information about DC arc furnaces to melt steels, irons, aluminum and copper-based alloys can be asked from the NTF EKTA's specialists at the following address: Russian Federation, Moscow, P.Romanova Street, Building 7, offices 410, 505. Tel: (495) 679-48-81, 679-48-43, or at www.stf-ecta.ru.

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