

# INDSIM

technology and innovative equipment for induction  
heating of spherical metal products



### PURPOSE OF THE PROJECT

**Commercialization** of R&D results of technology and equipment (induction heating plant, hereinafter - IHP) for high-quality heating for heat treatment of spherical metal products with the achievement of a rare paired effect "price-quality" of the final product.

### WHAT IS THE INNOVATION

**Innovation** - a new class of induction heating plants for metal products with a discrete cross-sectional area has been created, combining stimulation to free rotation of spherical metal products (a new construction of the transport profile) and a device for maintaining power for heating fast-moving workpieces at any time.

The result is direct controlled heating for heat treatment of spherical metal products to a given depth and temperature, in-line mode in seconds before the quenching temperatures, ensuring the level of axisymmetry in 95-97%.



### CURRENT STATE

#### 2021 year

A fully functional IHP – prototype was manufactured on a pilot production line, the performance of the equipment was confirmed in real operating conditions (TRL\* 7).

#### 2020 year

The project team with the support of the Skolkovo Foundation initiated work towards the creation of a complex model for induction heating of spherical metal products for its integration with the developed IHP – prototype with a diameter (spherical metal product) of up to 40 mm.

#### 2018-2019 years

With the support of the FASIE\*\*, MVP\*\*\* - an innovative installation for induction heating of spherical metal products with a diameter of up to 20 mm - was developed and tested.

#### 2017-2021 years

The solutions were patented in the Russian Federation, under the PCT (Patent Cooperation Treaty) procedure - a report from the International Patent Office (Geneva) was received, an application for patenting was filed in Germany as part of the transfer of the international patent application to the national stage.

TRL\*— technology readiness level — international technology readiness assessment scale.

FASIE\*\* — Foundation for Assistance to Small Innovative Enterprises (the Federal foundation for innovative development in Russia).

MVP\*\*\* — minimum viable product — a product that has a minimal but sufficient set of functions to satisfy the first consumers.

## 04 THE PROBLEM

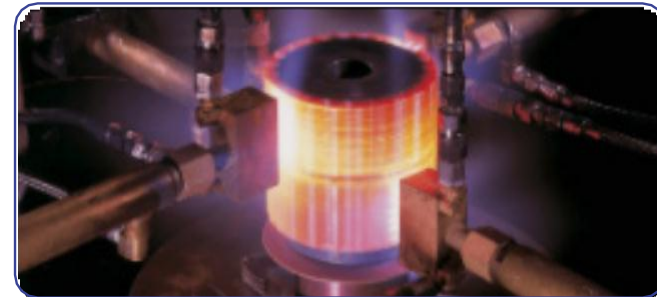


**The low level of quality of steel balls** produced by enterprises of the Russian Federation (and other countries), as a result-a short service life, which leads to an increase in TCO\*.

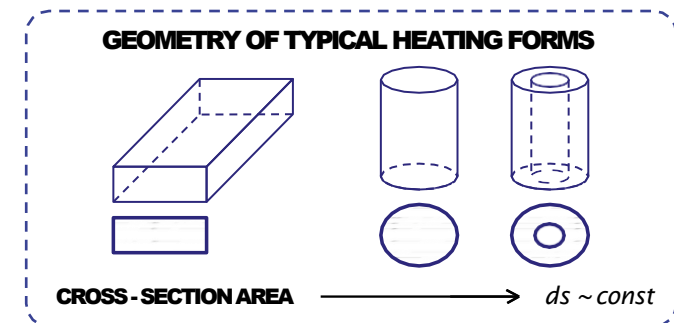
**The reason** is obsolete production technologies (primarily metal heat treatment) and equipment.

In the USA and the EU (Germany, Austria, etc.) in the last 15 years induction heating technologies for heat treatment of metal products have become widely used, which have a number of advantages:

- **direct heating** - conversion of electromagnetic field energy into thermal energy directly in the volume of metal;
- **easy control of temperature** and depth of heating (achieving volumetric hardness);
- high-speed heating process (seconds) – very weak of decarburization and oxidation.



However, despite all advantages of this method (induction heating technologies for heat treatment of metal products), **it is only applied to produce articles of a continuous or near-continuous cross section with ensured symmetry of heating in the world practice.**



## 05 THE SOLUTION

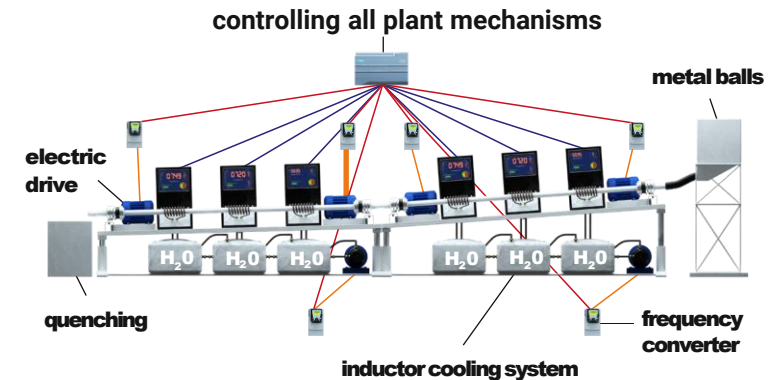


Creation energetically efficient continuous-action equipment for symmetric rapid heating of spherical metal products to a given depth for heat treatment without oxidation and decarburization.

Induction heating with direct high-rate (several seconds or fractions of a second) conversion of electric energy into heat energy meets these industrial heating requirements best of all. This method of heating is characterized by simple temperature and heating depth control, which makes it possible to obtain the optimum combination of a high surface hardness (back-to-back endurance) of products with a relatively plastic core (anticracking) after quenching and tempering.

The kinematics of ball motion along the guide profile in the work-coil (free motion) is characterized by three-dimensional (or the motion trajectory of the center of ball mass), stimulation to changing the axis of ball rotation from the entrance into the work-coil to the exit from it. This fact implies the possibility of creating continuous IHP that provides **density-uniform interaction of the entire ball surface with the electromagnetic field in the work-coil and, correspondingly, the possibility of reaching symmetric heating to a given depth**. This heating is direct, high rate, and energetically efficient with very weak oxidation and decarburization, with the exception of the cost of expensive radiant heating elements (heating elements) and high-inertia gas heating furnaces.

### PRINCIPAL DIAGRAM OF THE EQUIPMENT



MVP\*

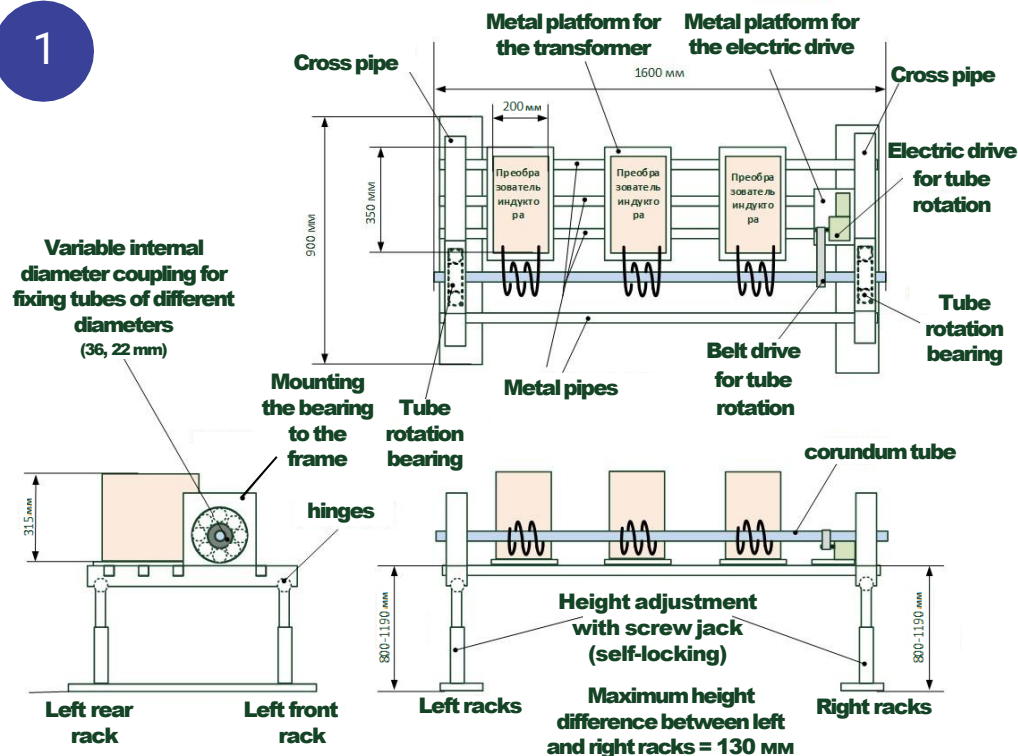
induction heating of spherical metal products  
(diameter up to 20 mm)



\* MVP (diameter up to 40 mm) to be completed in the first quarter of 2021



1



The solution to the voiced problem of high-quality heating of spherical metal products for heat treatment is achieved through the following innovations:

1

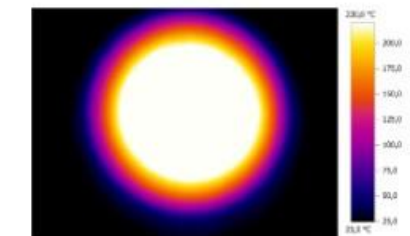
technological complex of equipment for stimulation to changing the axis of spherical metal products rotation into the work-coil in the electromagnetic field of high-frequency currents (patent of the Russian Federation No. 2691354 of 11.06.2019, international application for the PCT\* No. PCT/RU2019/050223 of 21.11.2019, patent application in Germany No. 112019000202.3 of 22.06.2020);

2

density-uniform interaction of the entire spherical metal product surface with the electromagnetic field in the work-coil and, correspondingly, the possibility of reaching symmetric heating to a given depth and temperature (volumetric heating);

3

device for maintaining a set power for induction heating fast-moving workpieces at any time (patent of the Russian Federation No. 172183 of 30.06.2017).



2

thermal image after heating spherical metal product with a diameter of 18.2 mm



3

the high-performance controller used

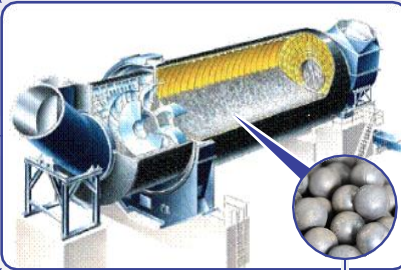
The technical result of the innovation is energetically efficient continuous-action equipment for symmetric rapid heating of spherical metal products to a given depth for heat treatment without oxidation and decarburization.



# 07 THE MARKET (PART 1)



## Beneficiation of iron ore in metallurgy (grinding metal balls in ball mills)



grinding metal balls



**The construction industry** - production of silicates, cement (grinding of clinker with grinding metal balls in ball mills).

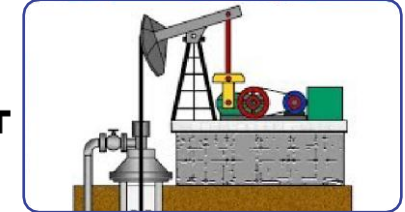
## Balls for rolling bearings



## Heat Treatment

High-tech methods for imparting specified properties to metal spherical surfaces by symmetric thermal diffusion alloying (chromium, titanium, boron, etc.)

**Oil production** (valves in hydraulic systems, and wear-resistant balls in the backwater gates of deep-well pumps)



## Potential consumers of the project are companies:

I  
stage

- Oskol Electrometallurgical Plant (Russian Federation),
- TENOVA LOI Thermprocess GmbH (Germany),
- MAGNATECH GmbH (Austria),
- IHK Saarland GmbH (Germany),
- EUROCEMENT group (Russian Federation).

II  
stage

other metallurgical enterprises in the Russian Federation (EVRA3 Group, Severstal, NLMK, MMK), enterprises of «RosTec» state Corporation, enterprises of «RosAtom» state Corporation and industrial enterprises abroad (EU, USA, Japan etc.).

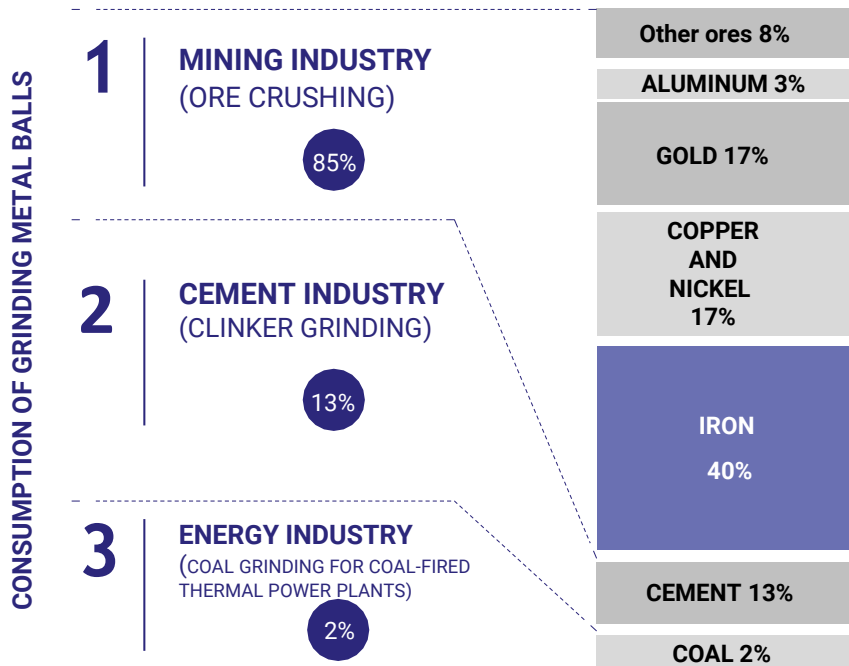
## 08 THE MARKET (PART 2)

# ANALYTICS ON THE EXAMPLE OF THE GRINDING METAL BALLS MARKET\*



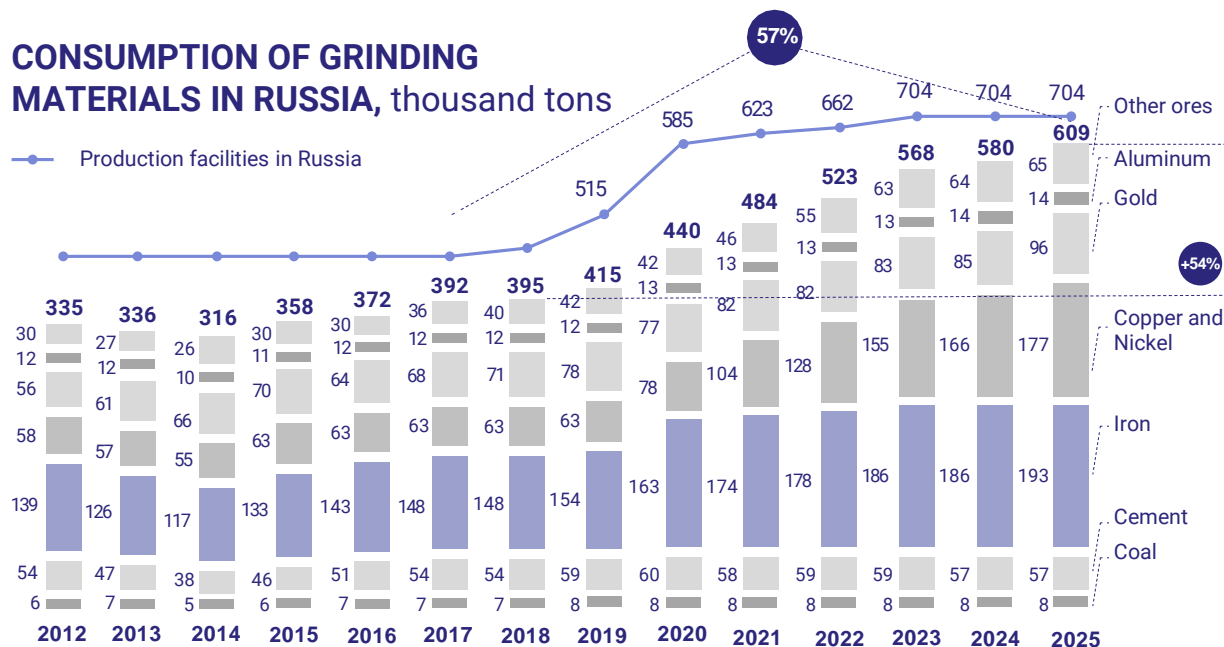
Considering a number of large projects in copper, iron and gold, the market for grinding balls can be expected to grow ~ 1.5 times by 2025.

STRUCTURE OF CONSUMPTION OF GRINDING BALLS IN THE RUSSIAN MARKET (2020, %)

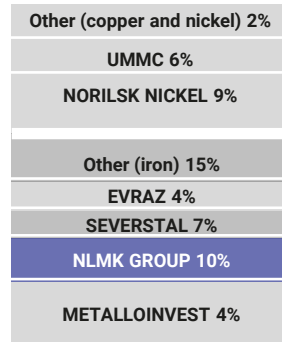
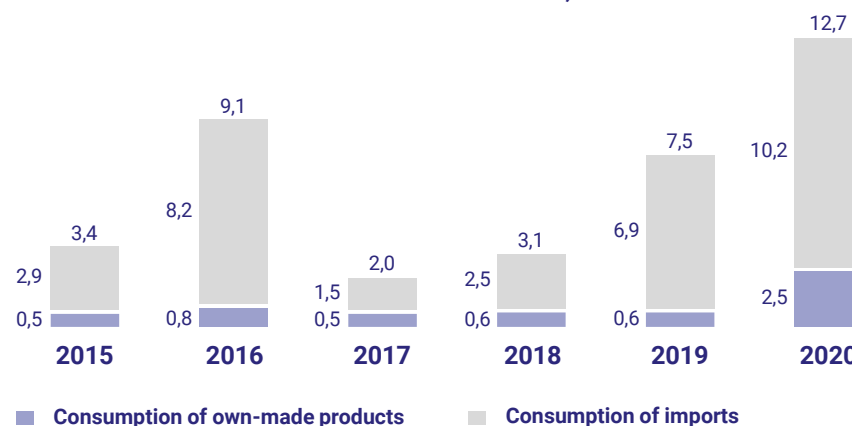


\* on the example of the Russian Federation market

CONSUMPTION OF GRINDING MATERIALS IN RUSSIA, thousand tons



STRUCTURE OF CONSUMPTION OF EQUIPMENT FOR THE PRODUCTION OF GRINDING METAL BALLS IN RUSSIA IN 2015-2020, billion rubles



NLMK GROUP CONSUMES ~10% GRINDING BALLS ON THE RUSSIAN MARKET





Parameter to compare	Manufacturer name of 40mm Ball Bearing (world industry Leaders)				
	Project	SKF (Sweden)	Nachi-Fujicoshi (Japan)	Schaeffler Group (Germany)	SPZ***** (Russia)
Induction equipment manufacturer name	LLC «SPE System48»	Emag Eldec Induction GMBH	Denki Kogyo Co.	Inductoheat Europe GMBH	VNIITVCH named after V. P. Vologdin
Model of induction equipment	IHP 1	Custom Line MF	PTG Type 100	Inductoheat SP 11	-
Level of heating asymmetry, %	95-97 *	90-92	90-92	90	88-90
Heating speed, C/sec	up to 125	100-150	90-160	90-100	80-100
Control range of the output current of the induction converter, A	400-2000	1000-3000	up to 2500	up to 2400	up to 3000
Heating depth control channel (operating frequency of the inductor current, kHz)	30-60	8-20	0,3-80	5-200	8
Surface hardness (up to), HRC	62-67	62-67	62-67	62-67	58-62
Volumetric hardness, HRC	GOST standard 7524-2015 **	GOST standard 7524-2015	GOST standard 7524-2015	GOST standard 7524-2015	GOST standard 7524-2015
Heating temperature of metal balls, C	up to 1000	850-900	850-900	800-950	850-930
Diameter of the heated metal balls, mm	at the first stage up to 40	up to 80	up to 96	up to 80	up to 90
TCO reduction***, %	up to 25***	up to 10	up to 10	up to 10	-
Cost of equipment, million \$ (including installation and NDT)	1,4 (at the rate of 03.2020 without service)	2,1 (at the rate of 03.2020 without service)	2,7 (at the rate of 03.2020 without service)	2,37 (at the rate of 03.2020 without service)	-*****
Cost of a ton of metal balls, cu.	1 130****	1 650	1 930	1 720	1 250
Prospect of import substitution	yes	global exporter	global exporter	global exporter	Russian market

\*- the advantage is achieved due to the equipment patented by LLC «SPE Sistema48»; \*\* - V hardness group; \*\*\*- TCO - Total Cost of Ownership; \*\*\*\*- estimated amount including costs for adjacent areas; \*\*\*\*\* - there is a rare paired effect: an increase in the quality of the product while reducing its cost to the consumer due to the applied innovations (efficient heating technology, equipment for axisymmetric heating); \*\*\*\*\*- a number of plants in the Russian Federation that have adopted the production capacities of enterprises of the USSR: GPP-2, GPP-10, GPP-11, SPZ-4.9 and others that use standard heating technologies for quenching; \*\*\*\*\*- evaluation is difficult due to the depreciation of the equipment and its long service life.

Sources : [https://cdn.eldec.net/fileadmin/user\\_upload/user\\_upload/Dateien/produkt\\_prospekte/eldec\\_generator/eldec\\_generators\\_russian\\_2017.pdf](https://cdn.eldec.net/fileadmin/user_upload/user_upload/Dateien/produkt_prospekte/eldec_generator/eldec_generators_russian_2017.pdf); <https://www.denkikogyo.co.jp/en/business/hf/product/induction/ptg.html>; <https://inductoheat.eu/products/statipower-sp11-radio-frequency-induction-power-supply/?lang=en>; report №2889/19 from 17.10.2019 year on the assessment of the market value of an intangible asset, performed by LLC «Aprais».



Parameter to compare	Manufacturer name of 40mm grinding balls (world industry Leaders)						
	Project	Arrium (Australia)	Gerdau Ameristeel (Brazil)	AIA Engineering (India)	ME Elecmetal (USA)	Vitkovice (Czech Rep.)	OEP (Russia)
Induction equipment manufacturer name	LLC «SPE System48»	Danieli (Italy)	There is no information in open sources	Irrelevant comparison (foundry production)	Sauer Austria GMBH (Austria)	KOCH H&K (Germany)	Wisdril (China)
Level of heating asymmetry, %	95-97 *	80-85	90	90	80-85	80-85	70-80
Heating speed, C/sec	up to 125	up to 135	90-130	foundry production	up to 100	up to 140	up to 120
Control range of the output current of the induction converter, A	400-2000	610-2700	700-2500	-	-	350-4000	1000-2000
Heating depth control channel (operating frequency of the inductor current, kHz)	30-60	2,3-2,9	4	-	2,5	3	2,2
Surface hardness (up to), HRC	62-67	62-67	62-64	58-62	62-65	62-67	48-54
Volumetric hardness, HRC	GOST standard 7524-2015 **	GOST standard 7524-2015	-	-	GOST standard 7524-2015	GOST standard 7524-2015	GOST 7524-2015
Heating temperature of metal balls, C	up to 1000	1000-1200	1050-1170	-	1020-1200	1040-1200	1050-1150
Diameter of the heated metal balls, mm	at the first stage up to 40	up to 120	up to 180	up to 180	up to 120	up to 120	up to 120
TCO reduction****, %	up to 30****	up to 20	up to 10	up to 10	up to 20	up to 20	up to 20
Cost of equipment, million \$ (including installation and NDT)	1,4 (at the rate of 03.2020 without service)	2,1 (at the rate of 1997 including 3 years of service)	There is no information in open sources	Irrelevant comparison (foundry production)	..*****	4,2 (at the rate of 2009 including 5 years of service)	16,1***** the planned cost of the project is the beginning of construction in 2020
Cost of a ton of metal balls, cu.	781***	1 150	1 221	1 300	1 170	1 070	1 070
Prospect of import substitution	yes	global exporter	global exporter	global exporter	global exporter	global exporter	yes

\*- the advantage is achieved due to the equipment patented by LLC «SPE Sistema48»; \*\* - V hardness group; \*\*\*- there is a decrease in the proportion of alloying components in the workpiece, direct heating to a given depth instead of indirect heating through the protective atmosphere and through pre-rolling; \*\*\*\*-TCO- Total Cost of Ownership; \*\*\*\*\* - there is a rare paired effect: an increase in the quality of the product while reducing its cost to the consumer due to the applied innovations (efficient heating technology, equipment for axisymmetric heating); \*\*\*\*\*- it is planned to build a production facility for balls with a diameter over 40 mm.

Sources : [http://www.infomine.ru/files/catalog/28/file\\_28.pdf](http://www.infomine.ru/files/catalog/28/file_28.pdf); <http://www.asms.ru/upload/iblock/57f/57f11461880499f5fcd7e58ba7d43671f.pdf>; report №2889/19 from 17.10.2019 year on the assessment of the market value of an intangible asset, performed by LLC «Aprais»; <http://www.metalloinvest.com/media/press-releases/423943/>

# 11 ADDITIONAL BENEFITS (NOT INCLUDED IN THE TABLES)

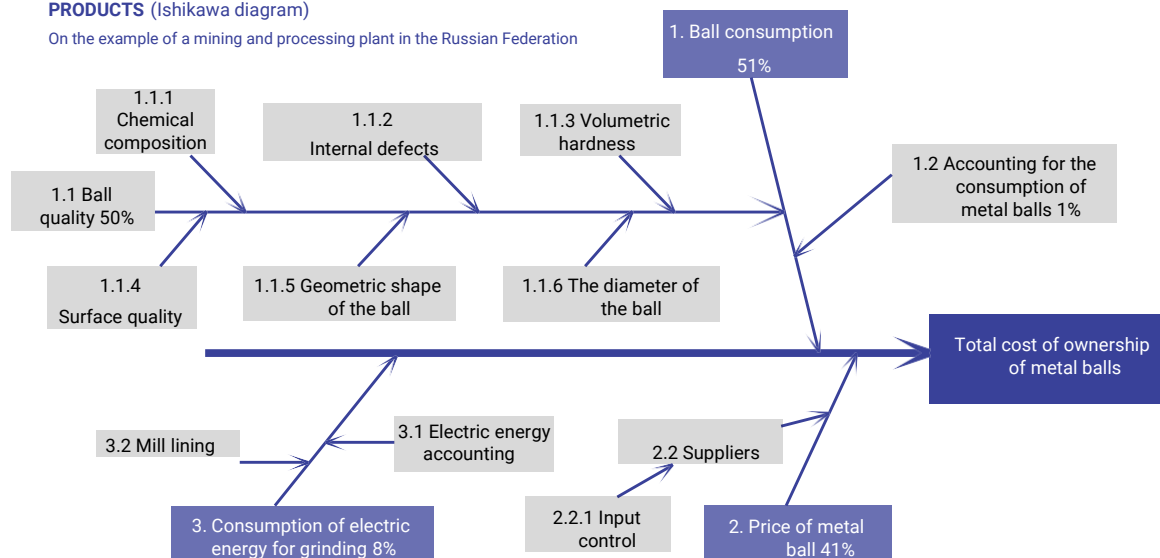


The main competitive advantages of the proposed heating technology and equipment are:

- increasing the service life of spherical metal products by **1.3-2 times** (the optimum combination of a high surface hardness (back-to-back endurance) of products with a relatively plastic core (anticracking) after quenching and tempering);
- reduction of alloying components in the workpiece by **7-11%**;
- reduction of energy consumption for heating the workpiece up to **28%**;
- reducing the total cost of ownership of spherical metal products by **15-27.5%** (depending on the industry);
- heating rate - **about 125 ° C / sec** (very weak oxidation and decarburization of the metal ball material due to the rapidity of the heating process);
- **the technology of high-speed heating** of steel for quenching, which excludes overheating and the growth of austenite grains, determines the dispersion of the final structure of the formed martensite with a minimum amount of austenite residual, which affects the increase in the hardness of the ball and reduces the likelihood of significant quenching stresses;
- «flexibility» of parameterization of the unit settings due to **sectioning** (for example, 9 sections are provided for a ball diameter of 40 mm) of the heating zone and the ability to control the heating mode of each section;
- **eco-friendly** heating method.

## ANALYSIS OF FACTORS INFLUENCING TCO\* OF SPHERICAL METAL PRODUCTS (Ishikawa diagram)

On the example of a mining and processing plant in the Russian Federation



## Decrease in TCO\* of the metal ball by 27.5 %

cost reduction  
up to 11%

Reducing the content of alloying  
components in the workpiece

Increasing the efficiency of the equipment  
(direct heating of the ball material by the  
energy of the electromagnetic field)

Surface heating of the metal ball to a given  
depth (no energy consumption for heating  
the core of the product)

High-speed heating  
(no need to expend energy for hours)

increase the  
service life up to 2  
times

AXISYMMETRIC  
heating of the ball material to a given depth

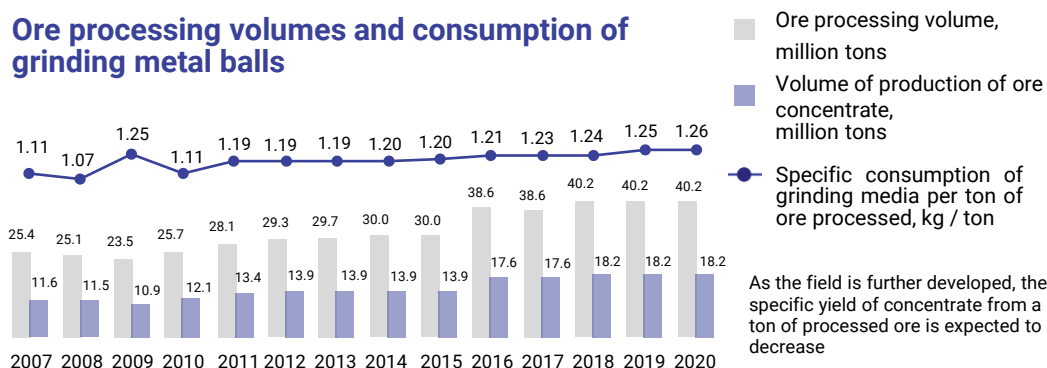
ANTICRACKING:  
high surface hardness  
(back-to-back endurance)  
of products with a relatively plastic core

Very weak oxidation  
and decarburization due to the high heating rate

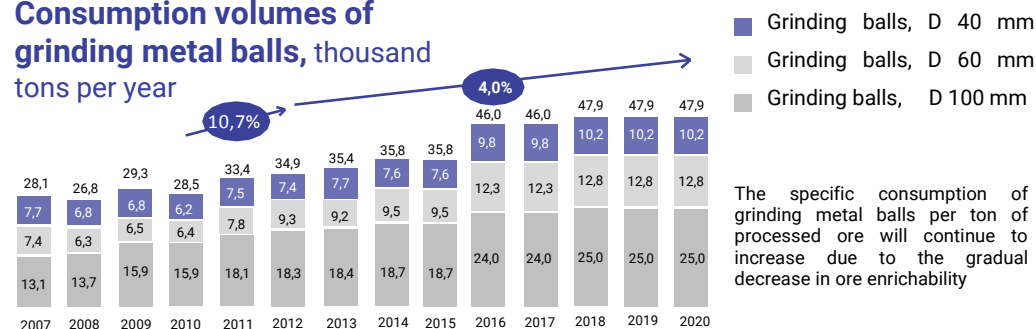
# 12 EFFECTS FOR INDUSTRIES \*



## Ore processing volumes and consumption of grinding metal balls



## Consumption volumes of grinding metal balls, thousand tons per year



## TCO OF SPHERICAL METAL PRODUCTS

(data analysis of the Ishikawa diagram - previous slide)

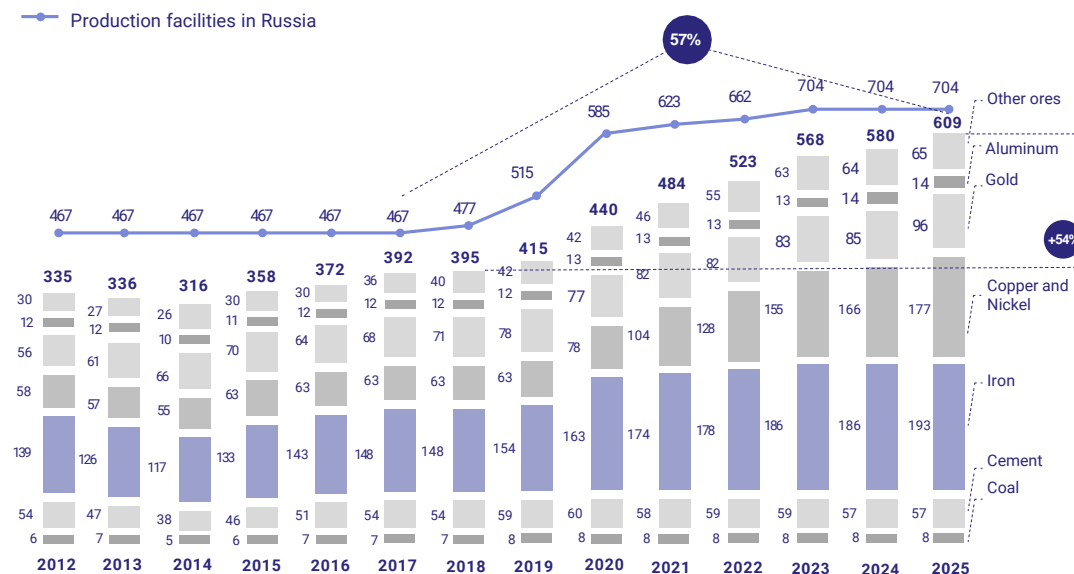
Metal balls consumption **51%** (low quality of metal balls)

High cost of metal balls **41%**

Electrical energy consumption for grinding **8%**

Considering a number of large projects in copper, iron and gold, the market for grinding balls can be expected to grow ~ 1.5 times by 2025.

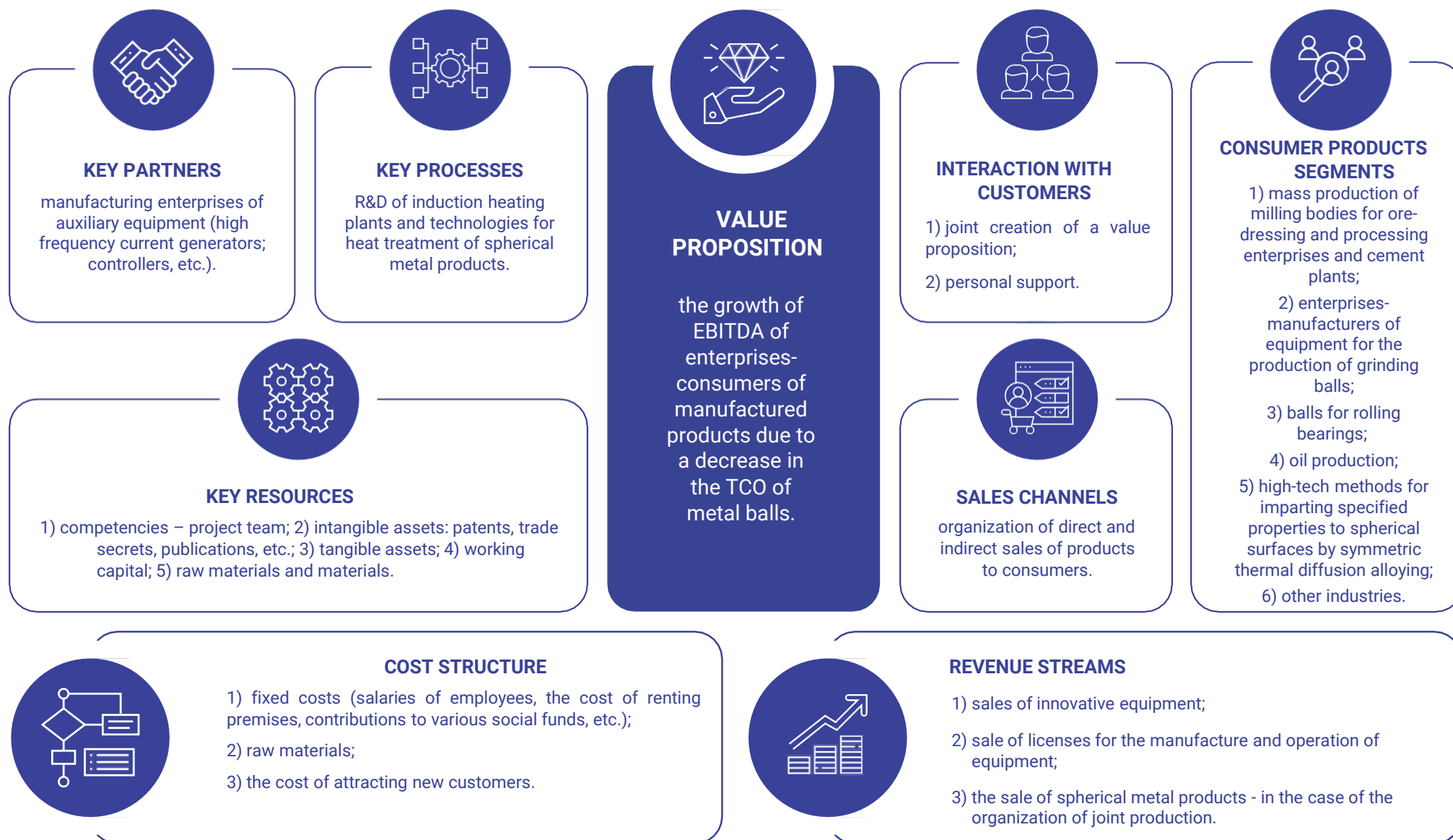
## CONSUMPTION OF GRINDING MEDIA IN THE RUSSIAN FEDERATION, thousand tons



Annual parameters	On the example of a mining and processing plant in the Russia	Russia by 2025
Consumption, thousand tons	47,9	609
Costs, million rubles	1 916	24 360
TCO, million rubles	4 673	depends on the industry
Loss of benefit by 1% decrease of TCO, million rubles	46,7	depends on the industry

\*On the example of a mining and processing plant in the Russian Federation

# 13 THE BUSINESS MODEL OF THE PROJECT \*



\* accordance with the methodology of A. Osterwalder



# 14 AUDIT OF RESULTS IN THE PROCESS OF PROJECT DEVELOPMENT



## Publications in peer-reviewed journals (including international)

Development of technology and equipment for induction axisymmetric hardening of grinding steel balls // Chernye Metally. – Moscow – 2020 - №6. – p. 11-16 (Russia)

Research on the heat condition of spherical metal bodies in the process of induction flow heating // Journal of Chemical Technology and Metallurgy. - Vol. 2020, No. 1. – p. 163–170 (Bulgaria)

Induction Heating Plant for Heat Treatment of Spherical Metal Products // Russian Metallurgy (Metally). – Vol. 2015, No. 12. – p. 985–992 (Germany)

Research of the heating process of metal balls in an innovative induction plant // Izvestiya SPbGETU «LETI». - Saint Petersburg - 2020 - №6. - p. 92-104 (Russia)

Calculation and development of an experimental induction installation for symmetric hardening of grinding metal balls // Chernye Metally. – Moscow – 2019 - №4. – p. 51-57 (Russia)

Development and investigation of a symmetric induction heating unit for spherical shape metal ware // Journal of Chemical Technology and Metallurgy. - Vol. 2018, No. 5. – p. 1009–1016 (Bulgaria)

Analysis of the effect of electromagnetic forces on the kinematics of a spherical metal product in axisymmetric induction heating // Electrical systems and complexes. – Magnitogorsk – 2017. – №2. – p. 67-73 (Russia)

## Intellectual property

International Patent Application under the PCT procedure No. PCT / RU 2019/05023 dated 21.11.2019

The application for patent in Germany, №112019000202.3, 22.06.2020

Patent of the Russia 2691354 dated 11.06.2019 «INSTALLATION FOR IN-LINE INDUCTION AXISYMMETRIC HEATING OF BALL-SHAPED ARTICLES»

Patent of the Russia 172183 dated 30.06.2017 «Device for controlling the inductor»

## The project is supported by the leading development institutions of the Russia



## Expert recognition of the project at specialized competitions

I place the Startup tour 2019  
(Skolkovo)



II place in the energy-efficient technologies  
section of Startup Village 2019 (Skolkovo)



IHK Saarland GmbH (Germany)

 **Saarland**

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**Besuch einer Delegation aus dem Gebiet Lippek in der IHK Saarland am 27.06.2019**

Auf 27. Juni 2019 hat der Generaldirektor der Gesellschaft mit beschränkter Haftung (GmbH) „NPF Sitemals®“, Sergei Sergeevich Tlov, das Projekt „Entwicklung der Technologien und innovativer Ausrüstung für achsensymmetrische Induktionserwärmung von Metallergüssen mit einer diskontinuierlichen Querschweißung“ im Rahmen einer Arbeitskonferenz mit anschließender Unterzeichnung einer Absichtserklärung für eine weitere Zusammenarbeit zwischen der Industrie- und Handelskammer des Saarlandes und des Gebietes Lippek, die in Saarbrücken (Deutschland) stattgefunden hat, präsentiert.

Selbsts der deutschen Delegation der Industrieunternehmer wurde bemerkt, dass die Einführung dieser Innovation in die bestehenden technologischen Verfahren zur Herstellung von Metallgüssen ein großes Potenzial besitzt. Außerdem wurde Interesse an der Zusammenarbeit bei der Umsetzung des Projekts in der deutschen Märkte, einschließlich der technologischen Partnerschaft und der weiteren Förderung innovativer Produkte von OOO „NPF Sitemals®“ bekundet.

Director of International Department IHK Saarland  Oliver Groß

## Lipetsk Region Administration (Russia)



**ГЛАВА  
АДМИНИСТРАЦИИ  
ЛИПЕЦКОЙ ОБЛАСТИ**

2004 г. Липецк, ул. Ленина, Соборная, 1.

№ 01-2048/с от 10.04.2004

10.04

Президенту  
Некоммерческой организации  
Фонд развития Центра  
разработки и  
коммерциализации новых  
технологий  
В.Ф. Новоселову

Уважаемый Виктор Фёдорович!

Настоящим письмом сообщая, что в Липецкой области реализуется инновационный проект «Разработка технологии и инновационного оборудования исследуемого осесимметричного нагнетателя металловедущей с дисперсной фазой порошечной системы» компании ООО «НПТ Системы» - участника проекта создания и обеспечения функционирования Инновационного центра «Сколково».

Администрация Липецкой области отмечает высокий потенциал положительных эффектов от коммерциализации указанного проекта в регионе вследствие наличия прототипов в разрабатываемом продукте со стороны промышленных предприятий РФ и ЕС (в т.ч. Германии), а также расположения в Липецкой области основной проектной площадки Группы компаний ИЦМ и одного из центров знаний международного промышленного Холдинга «Европротект» - потенциальных потребителей продукции ООО «НПТ Системы».

Проект создан при участии (в т.ч. материальной) поддержке разрабатываемого инновационного проекта ООО «НПТ Системы» на со стороны Некоммерческой организации Фонд развития Центра разработки и коммерциализации новых технологий.

Со своей стороны администрация Липецкой области продолжает оказывать всестороннюю поддержку ООО «НПТ Системы» в направлении коммерциализации разрабатываемого инновационного проекта.

  
И.Г. Артюхин

Глава администрации  
Липецкой области

МФ № 01-2048/с



**TITOV SERGEY**  
**Founder CEO**

Project leader, PhD (candidate of Technical Sciences); author of the project idea; leads the project team, which won the Startup Tour 2019, took the second place in the Startup Village 2019 section and other innovation competitions. Developer of the strategy for organizing sales of the first batch of products in 2019 – a batch of balls with a diameter of up to 20 mm reinforced by the developed technology. He was trained under the guidance of McKinsey&Co specialists (including in Germany). Responsible for the development and implementation of the company's strategy; general management of the company's production and economic activities; interaction with external contractors; organization of the company's work in order to achieve effective interaction of all functional areas of the company; other issues.



**BEZDENEZHNYKH DANIEL**  
**CTO**

PhD (candidate of Technical Sciences); responsible for the comprehensive management of the technical part of R&D for the project; development of technical tasks for R&D; development of design, working, executive documentation; search and development of technical solutions within the project; carrying out calculations to assess the cost of technical aspects of the project implementation; commissioning of equipment.



**MESHCHERYAKOV VICTOR**  
**CRO**

PhD (doctor of Technical Sciences); he led more than 17 R&D projects, authored more than 70 Russian and foreign patents, and published more than 350 scientific papers. Responsible for consulting on issues in the technical field of R&D; search and analysis of information on relevant scientific and technical issues; analysis of the obtained practical results, etc.



**KOFANOV ALEXANDER**  
**CMO**

Responsible for information on trends in the relevant product market (benchmarking); searching for potential counterparties; analyzing presentation materials for interaction with potential counterparties in the field of product sales, etc.; organizing business meetings with representatives of administrations at different levels.



**KOVALENKO OLEG**  
**TO**

A specialist in materials science, including metal physics. Responsible for the technological of heat treatment of metal products with a discrete cross-sectional area. Author of more than 15 scientific and technical publications in the leading specialized peer-reviewed publications of the Russian Federation.



**SYSTEM<sup>48</sup>**

innovation as a style of thinking