NLMK Group

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Environmental Strategy

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NLMK DanSteel participates in improving constructions of offshore wind turbines

NLMK DanSteel, Denmark's only manufacturer of plates, has joined the European research and development program aimed at improving the construction of foundations for offshore wind turbines in order to reduce their weight and cost, as well as raise the investment appeal of wind generation.

The research project is carried out by the UK Carbon Trust, Offshore Wind Accelerator programme (OWA).

NLMK DanSteel will supply thick plates of special dimensions made from high-strength steel to be made into piles used in the foundations for new-generation turbines.

Igor Sarkits, NLMK Europe Plate CEO, said:

"NLMK DanSteel is a leading supplier of thick plates for North European wind generation. We view this segment as the most prospective and strategically important not only in terms of business development, but also as part of NLMK Group's policy aimed at promoting advanced environmental technologies."

The Research has shown that the current geotechnical design for the foundations of offshore wind turbines is very conservative. Oxford University, Imperial College London and University College Dublin have developed a new progressive method. To implement it, a series of experiments needs to be performed using large-dimension steel piles under lateral load. Experiments will be held in the coastal waters of Dunkirk (France) and Cowden (Great Britain). At the end of 2014 it is planned to use the results of the experiments to develop an industrial prototype for the new type offshore wind turbine foundations.

NLMK upgrades the electrical steel delivery system

NLMK Group increases container exports of electrical transformer steel rolls

The company has launched a pilot project at the Lipetsk production site to develop a new logistics system: export of rolls of electrical steel in large capacity containers. This will allow NLMK to cut its transportation costs in half.

In the past, VIZ-Steel (Yekaterinburg) was the only NLMK production site which exported rolls of electrical transformer steel in large capacity containers.

"The developed system and a new, more convenient organizational logistics structure are aimed at improving our client experience. NLMK Group's key goals are to further increase the operational and commercial effectiveness of its logistics, produce the highest synergistic effect, and ultimately improve the company's overall performance," says Vice President for Logistics Sergei Likharev.

Our custom rolled stock for Samsung's consumer electronics

NLMK Group has begun deliveries of its polymer-coated rolled stock for consumer electronics manufactured at the Kaluga Region plant of Korean giant Samsung.

This has allowed NLMK to introduce its new premium metal products, previously produced exclusively for export, to the Russian market.

This type of rolled stock was developed especially for Samsung's consumer electronics division. The NLMK metal features exceptional cold stamping features, a smooth polyether finish, and an underside polyurethane coating that is highly resistant to corrosion.

The Lean Manager

Vice President for Logistics at NLMK, Sergei Likharev, on laziness, and the "snags" and grains of sand which get in the way of business.

Interview: Yulia Taranova

The timber industry, airport management, aircraft engineering, telecommunications, and even a meat processing plant – your CV is impressive! How is it that you have worked in so many different sectors?
Nowadays that is not such a rare thing. The thing is that strategic challenges to development and the ways they are resolved are much the same whatever the industry, particularly in the real economy. Of course, you have to be able to quickly come to grips with the specifics of a particular business, but after moving on once or twice that's not so difficult. That aside, my recent moves have not been all that unusual – since 2004 all of my work

Bio

Born in Moscow in 1964.
Holds a Doctorate in Physics and Mathematics from Moscow State University, and
an MBA from Cornell University.
From 1990 to 1993 -- a researcher at Moscow State University.
From 1993 to 1997 -- a strategy consulting project manager at Cannon Associates and Coopers & Lybrand.
From 1997 to 2004 -- held senior positions at Interros, Ostankino Meat Processing Plant, and Golden Telecom.
From 2004 to 2007 -- CEO at Aviacor Aviation Plant in Samara.
From 2008 to 2012 -- CEO of the Basel Aero airport group.
From 2012 to 2013 -- Aviation Business Director at Russian Machines and Chairman of the Board of the Aviacor aviation plant.

"Strategic challenges to development and the ways they are resolved are much the same whatever the industry" has been linked one way or another with transportation.

What general working principles, applicable to a wide range of business sectors, do you rely on?
Firstly, you must make the best possible use of your own past experience. A shift into a new sector means that you can look at the problems it faces with fresh eyes: for example, it seems that the methods of so-called queuing theory used to calculate loading in telecommunications systems can also be effectively used to work out the throughput capacity of airports and to calculate the optimum dimensions for warehousing space. Secondly, you must know how to listen to people and to learn from them. Despite the fact that around 80% of the challenges at any business are relatively straightforward, you must quickly get to know the remaining 20% which are particular to that sector. To do so, you must, on the one hand, be able quickly to grasp information from print and electronic sources and, on the other hand, simply listen to people, ask the right questions, and be able to analyze and compare things with your own past experience. That is what business consultants do – and that is what makes them successful in developing such a variety of businesses.

So do you see yourself as a specific kind of business consultant who has been brought into the system?
No, of course not. I am simply a manager who uses their methods to good effect.

If you were asked to come up with some sort of universal principle for success or efficiency, what would you say?
You have to be completely involved in the business so that you will intuitively, so to speak, get a feel for its problems. This is where lean management methods can help a lot. Sometimes they are called lean production. This system teaches you how to find the losses, imperfections, unnecessary variations, unpredictability, etc. that exist in any business. And these losses for the business process are like grains of sand in the gears of a clock: small though they may be, they slow the overall work noticeably. You must get inside a business to the point that you can see these problems at first glance and learn how to eliminate them quickly. But the most important thing is not to lose interest in everything that you do. When there is an inner drive, every problem is solved "on the fly."

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NO ONE CAN REALLY REMEMBER WHICH PAPER SITS IN THE EIGHTH PILE, FIVE LAYERS DOWN

"The work must be extended to raise the efficiency of internal logistics"

One of the steps you undertook in the airport project was to transfer the office from Moscow to Krasnodar. How did people react to that?
When I arrived at Basel Aero it became immediately obvious that having the company's headquarters in Moscow, while all of the airports were in Krasnodar Territory, was just nonsense. One of the main principles of lean management stipulates that leaders must work not in offices but at the so called genba – on the manufacturing floor – that is to say, where the surplus value is created. The devil, as everyone knows, is in the detail, and it is these details that will determine the success or failure of any business. In an office you can look at the figures, you can read the reports, but a complete sense of what actually makes a business tick will only come about if you live on the manufacturing floor, as it were.

Was the transfer from Moscow not a problem for you personally?
It was a completely natural decision. Although I am a native Muscovite, I've hardly lived in Moscow since 2002. I worked in Tashkent, then Samara, then Khabarovsk, then Krasnodar... For me, the principle that you must be where the business is has been evident for a long time. But by no means did everyone at the airport company take to this idea. In fact, hardly anyone took it well. No one had given any thought to efficient management; they were simply concerned with day-to-day issues. They said: what do you mean? We are Muscovites and you expect us to move to the sticks? Basically, as well as changing offices we had to change the staff. Forty were boiled down to two – one of whom was me.

That's pretty drastic.
Well, there's no point in crying over spilt milk. And in fact it turned out best for the company: the snobbery you often find in Moscow can often damage things, but we put together a new team focused not on going clubbing, but on getting the job done. People came from Moscow, St Petersburg, Rostov, the Urals, and Siberia to join us in Krasnodar. We ended up with a Russian national team which, in just four years, took the business to a whole new level.

What changed?
Productivity increased by 150% and profits by 250%. New airports were established in Gelendzhik and Sochi. But the main thing was that our people were working for the fun of it. In four years, not one person from this new team left of his or her own accord.

How about now? Where do you spend most of your time?
About 80% of the time I'm in Lipetsk, and the remainder in other cities. There is also work to be done in Moscow, of course. This is where our main partners' headquarters are: Russian Railways, the marine ports, as well as state authorities.

It's not so easy to catch you in Moscow.
Well, look: next week I have to be at four different group locations. Then I'll have a week in Lipetsk, and then I have to go to the ports in Novorossiysk and Tuapse. So yes, there's not much time left for Moscow.

Which site do you prefer to work at?
Lipetsk, of course. That's where both half the production, and half the company personnel are. That is the engine – that is where the main reserves to improve efficiency are to be found.

What do you have to get done for the group in the near future?
First of all I have to support and build upon what my predecessor, Alexander Sapronov, achieved. Mainly, these were improvements to external logistics, and understandably so: that is where the main logistical costs were, and he managed to reduce these significantly. Now the work must be extended to raise the efficiency of

THE MAIN THING IS TO AVOID SNAGS, TO WORK STEADILY AND TO MAINTAIN AN EVEN RHYTHM

"I hardly ever work with paper documents"

internal logistics and improve the whole logistics chain.

So, your main projects at the moment deal with internal logistics?
Yes, there is a lot to be done there. For automobile transport, we have to perfect the servicing and repair system, improve capacity take-up both of cargo volumes and driver time, improve operational speed, and reduce expenditure on fuel and lubricants. For railroad transport, we must unify the stockyard and increase the turnaround of the rolling stock, extend the usage of bimodal technology (both for field engines and railcar movers), and reduce the cost of track maintenance. Additionally, we are faced with the tasks of optimizing the whole logistics chain, reducing the stocks of shipped products at ports, cutting expenditure, and so on.

Are you also faced with the task of optimizing personnel?
I am. Labor efficiency must be increased – this is one area where we are significantly behind the best in our industry.

Oftentimes, increased labor efficiency is taken to mean staffing cuts.
Yes, that can be the case. Many think that increased productivity means mass redundancies for some and sweatshop practices for the remainder. People think that they'll be worked to exhaustion, health and safety will be thrown to the wind, and that generally they'll all have nervous breakdowns, just like in Chaplin's *Modern Times*. But it's nothing of the sort. The point is not to squeeze your workers dry, but to make sure that they waste less time on non-productive tasks and that there is an even tempo to the work. All too often the following happens: everyone's rushing about, doing something really quickly, bustling about and shouting at one another, and then there's a half-day smoke break. The results are just so-so, and yet fatigue is extreme. It's not physical fatigue, but mental, and people suffer all the more from it. So the main thing is to avoid snags, to work steadily and to maintain an even rhythm.

How?
This is where you have to switch on your own lazy streak and your brains. Don't be surprised, it's not so strange! Laziness, with the right approach, is in fact a very positive quality. What is laziness, after all? It is the desire to do what is required of you with a minimal amount of effort. And that means to think up a way to make the outcome the same, but reduce the effort involved. How can such a miracle be achieved? Simply by stopping doing what doesn't have to be done: remove the needless actions, the needless moves, the lost time. Work should be standardized and planned accurately, in terms of what you are going to do and when. And once you hit your stride, then you'll get your second wind just like in a long-distance race: at the start it's hard and you get a stitch in your side, but later you can easily run a marathon. The main thing is to get rid of the waste, get rid of the snags.

Does that mean not getting distracted?
It means not getting distracted but also planning and organizing your work. Lean management involves the use of a tool called 5S. The point of this is that there should be nothing around you in your workspace that you do not need, and that the things you actually do need are neatly and properly organized. You can go to some people and find a heap of papers or tools on their desk, and they say to you: look how much work we have! But in fact all that means is that the work is inefficient. No one can really remember which paper sits in the eighth pile, five layers down, and he or she must forever be mentally jumping from one thing to another and losing his or her concentration. A messy workplace eats into your consciousness and creates a messy mind.

But we all have masses of incoming mail to deal with – how can we manage that?
I hardly ever work with paper documents and receive most things in electronic format. And there is a very simple way to deal with the avalanche of emails. I never delete an email from my inbox until I have dealt with it: I must consider it, make a decision, and write to someone. I have set up Outlook so that my inbox window shows me exactly twelve messages. If there are more, then some of them drop out of sight and the scroll bar appears, do you see? So every day I make sure that I do not leave work until that blasted scroll bar has disappeared – that is, until I only have twelve emails left to deal with. Then my email does not develop that same "build-up of unproductive stock" against which we are struggling in logistics. Some evenings when I am very tired I have to kick myself to get on with it. I won't lie to you – sometimes I don't manage it. But on the whole, the system works.

Tell us of how you were accepted by the team.
In my view, we got on well. We communicate actively and discuss how to work more efficiently. The main thing here is that changes are not rejected out of hand, which happens all too often in large organizations, particularly those with a tradition, a history. Of course, some ideas have to be justified and fought for. You might have to run a kind of boot camp on some matters, but that is normal. When changes are introduced it's always like that.

What are your overall impressions about the company?
From the point of view of management organization and business processes optimization, the interaction between employees at the different NLMK businesses are significantly better than at other places I have worked. Plus there is a significant – you could say simply enormous – possibility for development: for example, labor productivity in logistics could be raised by no less than 15–20%, and the level of shipped product reduced by 10–15%. In established markets, people struggle for single-figure percentages and consider them to be great achievements, but here we could get into double figures! That's very inspiring. Overall I like it here a lot!

Occupational Health and Safety in Denmark

The head of occupational health and safety for NLMK DanSteel, Irina Volovik, has been on a familiarization visit to Lipetsk. In an interview with ***NLMK Magazine*** she shared her impressions of the Lipetsk site and told us how health and safety is managed at the group's Danish operation.

Natalia Sviridenko

"If the director is directly involved in this matter then health and safety is certainly taken very seriously"

Irina, a single group of companies would imply that there is a shared view of occupational health and safety. But clearly the differences in scale of production, as well as between various countries and their legislations will have an impact on health and safety policy. Tell us how this is managed at DanSteel.
At DanSteel there is an occupational health and safety committee which is headed by the plant's director. This is, of course, very rare and a very positive thing. If the director is directly involved in this matter then health and safety is certainly taken very seriously. The entire plant is divided into sections, and each of these has their own working group. Usually these include the head of the section and an authorized representative from the workforce. The workforce elect their own representatives. It is a voluntary position, and there is no pay attached to it. It is these working groups which carry out all of the work associated with occupational health and safety.

What can you tell us about what you have seen at Lipetsk?
I took part in a seminar which was run for the Dolomite plant management by Victor Togobetskiy, the Director of Occupational Health and Safety for NLMK Group. I found it to be a positive experience. Above all, it gave me the opportunity to talk to the people working here: both with the management and the workforce.
I myself took part in hazard assessments and putting up progress sheets. We don't do this yet, but I liked the idea because it is a tool which allows workers to see the final result, and they can judge for themselves what has been done and what hasn't. After all, it's not enough to just uncover the risks: they must be eliminated as well.

I also had the chance to visit the Novolipetsk production floor, where I was pleasantly surprised by its cleanliness and tidiness. I saw the cleaning schedule which lists who is on duty and who is in charge. We don't yet have such a strict regime and structure in place. We have a lot of work ahead of us.

What are the accident statistics at DanSteel?
I am happy to say that we have had no fatalities in recent years. As for injuries, there were twenty-four accidents in 2011, eleven in 2012 and six in 2013. This reduction in accidents was even noted by the state inspectorate. But I am not convinced that we have done anything in particular to bring down the number of accidents.
Of course, we have an active policy with regard to health and safety: we have specific aims and plans, and we are developing projects to improve things. That said, I'm sure you understand that any project to reduce accidents needs time.

We are also running a variety of courses to train staff: practical courses on firefighting, first aid, and so on.

Which type of employee is most likely to be involved in an accident? Those who have been working for, say, 10 years, or those who have just started with the company?
I do not think accidents are linked to age or experience. Of course, sometimes when someone has been on the job for a long time, that person thinks that they know it all and have nothing to learn.

"The hardest thing is to overcome people's inertia, and to involve them"

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ACCIDENTS ARE NOT LINKED TO AGE OR EXPERIENCE. OF COURSE, SOMETIMES WHEN SOMEONE HAS BEEN ON THE JOB FOR A LONG TIME, THAT PERSON THINKS THAT THEY KNOW IT ALL AND HAVE NOTHING TO LEARN

What type of injury is most common?
We have carried out an accident analysis and the results showed that the most common is falling over after a stumble or a slip. We investigate every accident. Generally, the injuries result from inattentiveness. The person knows it all, has passed through a particular place a thousand times, but, evidently, there is a lapse in attention or they are simply in a hurry. This never happens because one is under pressure to work faster.

What projects are you working on now?
I must say that our programs are far more modest than those at Lipetsk. For example, we need to set up walkways so that people only walk where permitted, so we are working on a specific project to improve the walkway surfaces.

Now we are facing the task of developing a points system which will help us to measure and see the results of our work.

People must be able to see how the work is progressing and what we have achieved.

Do attitudes to health and safety differ here in Russia from those in Denmark? What is the main difficulty when working with people?
The hardest thing, in my opinion, is to overcome people's inertia, and to involve them. If people see that the management is not interested in something, then nothing will be done about it.

This is totally regardless of nationality, and innovations are very rarely taken to straight away here in Denmark. As a rule, you have to infect people with your own attitude.

I can certainly say that in Russia, the workforce is generally better prepared. People are quicker to see and understand something and put it into action. I even think they are quicker to change their attitudes.

NLMK Launches Environmental Program 2020

NLMK Group has launched Stage 3 of its Environmental Program, which will take the company through to the year 2020

Andrey Kazantsev

NLMK's 2013 emission levels per tonne of steel were the lowest in history

The program, part of the company's development and investment strategy, is designed to further minimize its environmental footprint and reach the highest global environmental standards in steel production.

NLMK Group has earmarked RUB 10.6 billion (~USD 300 million) for investment in environmental protection initiatives and projects by 2020, RUB 5.5 billion (~USD 160 million) of which will be invested at the Lipetsk site.

MORE METAL, WITH FEWER EMISSIONS

Environmental initiatives implemented at the company's main production site in Lipetsk have yielded noticeable results. The Environmental Program 2020 will also serve as a new impetus for the company's environmental operations at the Novolipetsk site.

In 2013, as NLMK's steel production grew by nearly 220,000 tonnes, the company managed to not only keep its gross emissions at the same level, but actually lowered them by 461 tonnes

Investments in environmental initiatives and projects – RUB 10.6 billion (~USD 300 million)

Yuri Larin,
Vice President of Technology Development and Operational Efficiency:

"NLMK Group achieved impressive results in implementing previous stages of our environmental program by applying the latest technology and by launching environmental protection initiatives. It is crucial to note that these results are even more commendable if we take into account the fact that the company significantly lowered its environmental footprint while nearly doubling its production volumes. Stage 3 of the company's Environmental Program is grounded in decades of experience amassed by its environmental experts and scientific research, and was developed hand in glove with the Group's production plan.

Our goal is to become an environmental leader in Russia and on the global stage."

NLMK's goal is to become an environmental leader in Russia and on the global stage

NLMK has completely stopped waste water discharge since 2009

compared to 2012, reaching the lowest emissions level per tonne of steel in the company's history, at 22.3 kg per tonne. By way of comparison, the lowest emissions level in the world for an integrated production facility is 18.9 kg per tonne of steel. "That's our target", they say at the plant.

THE WORK BEHIND THE RESULTS

NLMK's longstanding positive emissions trend is due to the systematic implementation of the company's environmental protection policies. In 2013 alone, NLMK undertook 69 measures to improve air quality. One of the most significant of these was the complete restoration of the sintering plant's central dedusting system No. 2, which reduced dust emissions by nearly 2,000 tonnes per year. The refractory plant also reduced its dust emissions by 50 tonnes per year by replacing electric air filters in rotating furnace No. 5. In 2013, the company installed over 1,000 filter sleeves made of cutting-edge materials inside the dedusting systems of its BOF plants, refractory plant, cold rolling and coating mill, and the shape casting, reinforced concrete, and ferroalloy plants. This effort lowered dust emissions by another 85 tonnes per year. Measures implemented at the blast furnace plant lowered carbon monoxide emissions by 5,226 tonnes per year and lowered hydrogen sulfide concentrations in the gas emissions.

Although NLMK completely stopped waste water discharge since mid-2009, it continues to plan and implement water protection initiatives. Today, these measures are focused on lowering pollutants in household sewage. Last year, the plant implemented four water protection initiatives, including the removal of surplus ferruginous slag waters from the cold rolling and coating mill and their storage in slag reservoirs, as well as cleanup of blast furnace gas condensate from seven of the most actively used condensate extractors.

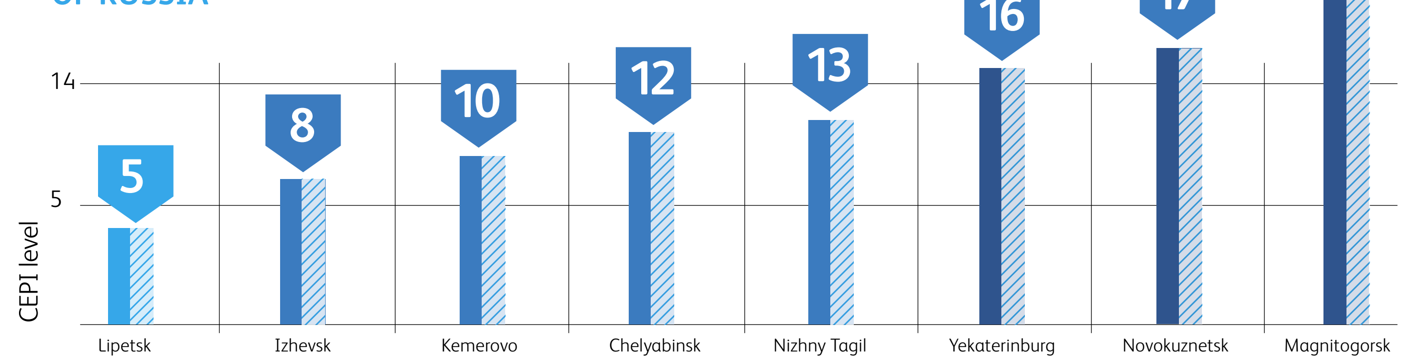
In 2013, the company processed and reused 95.7% of waste produced by its facilities and lowered its solid production waste output by 230,000 tonnes. NLMK launched a total of 24 waste treatment initiatives in 2013.

THE CLEANEST STEELWORKS TOWN

The Comprehensive Environmental Pollution Index is currently the most scientifically sound air pollution evaluation method. The CEPI calculates five pollutants most common in a given region as a total ratio of average annual pollutant concentrations to the maximum allowed concentration, taking into account the toxicity level of each pollutant. This measures long-term, chronic levels of air pollution. According to the Federal Service for Hydrometeorology and Environmental Monitoring of Russia, the Lipetsk CEPI decreased to 5 points in 2013, reaching the margins of low air pollution.

Five points on the CEPI scale is an unprecedented level for an industrial town. That same year, the Federal Service for Hydrometeorology and Environmental Monitoring reported a

LIPETSK IS ONE OF THE CLEANEST STEELMAKING REGIONS OF RUSSIA



Source: Federal Service for Hydrometeorology and Environmental Monitoring of Russia

Key Stage 3 projects:

- construction and restoration of dust collecting systems;
- modernization of the blast furnace slag cooling assembly at the main production site in Lipetsk;
- restoration and modernization of dedusting systems at the Stoilensky and Altai-Koks sites;
- construction and restoration of waste and rain water treatment facilities, including for treatment of oil-contaminated water from NSMMZ and NLMK Europe (La Louvière) rolling operations;
- reclamation of the Novolipetsk slag dump site and VIZ-Steel industrial waste disposal site, and elimination of the NSMMZ slag dump site;
- use of mill tailing in the construction of tailing dump compartments at the Stoilensky site.

score of 26 points for Magnitogorsk: five times that of Lipetsk. The score in Novokuznetsk was three times higher than that of Lipetsk, while Chelyabinsk and Nizhny Tagil scored 2.5 times higher, and Kemerovo and Izhevsk scored 2 and 1.5 times higher, respectively.

Even compared to its closest non-industrial neighbors, Lipetsk finds itself among the top three cleanest towns. Today, the only town in the Central Black Earth Region rated cleaner than Lipetsk on the CEPI scale is Gubkin in Belgorod Region.

Environmental Program 2020 performance targets:

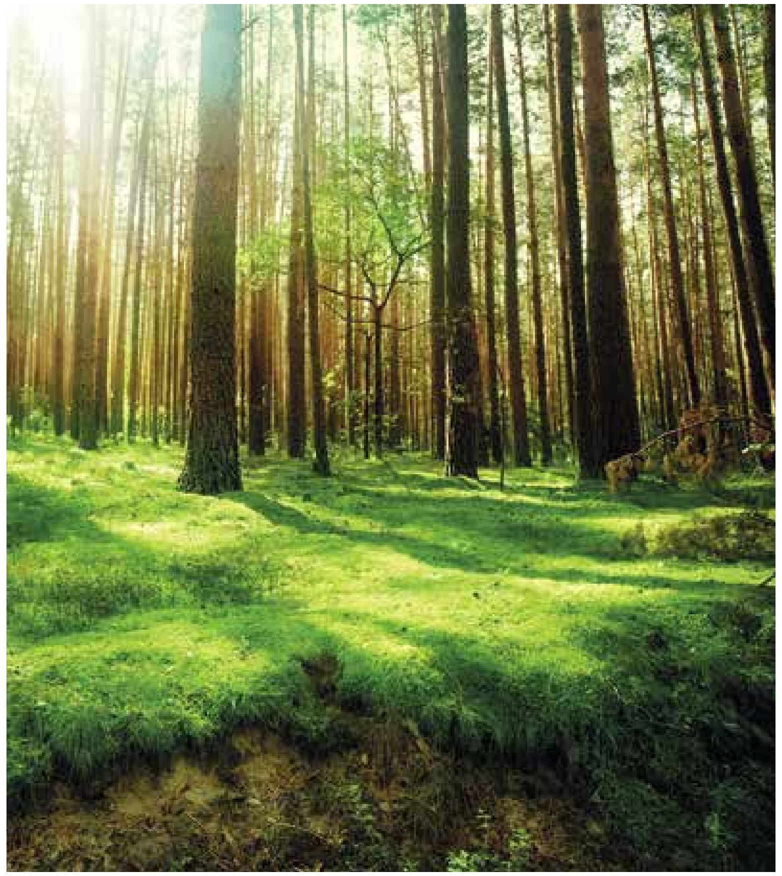
- to ensure that all NLMK Group sites meet all environmental regulations;
- to lower emissions from 21.9 to 19.4 kg per tonne of produced steel (an 11% reduction) across all Russian NLMK Group sites;
- to completely eliminate water dumping throughout the company;
- to increase waste recycling levels from 5% to 25%.

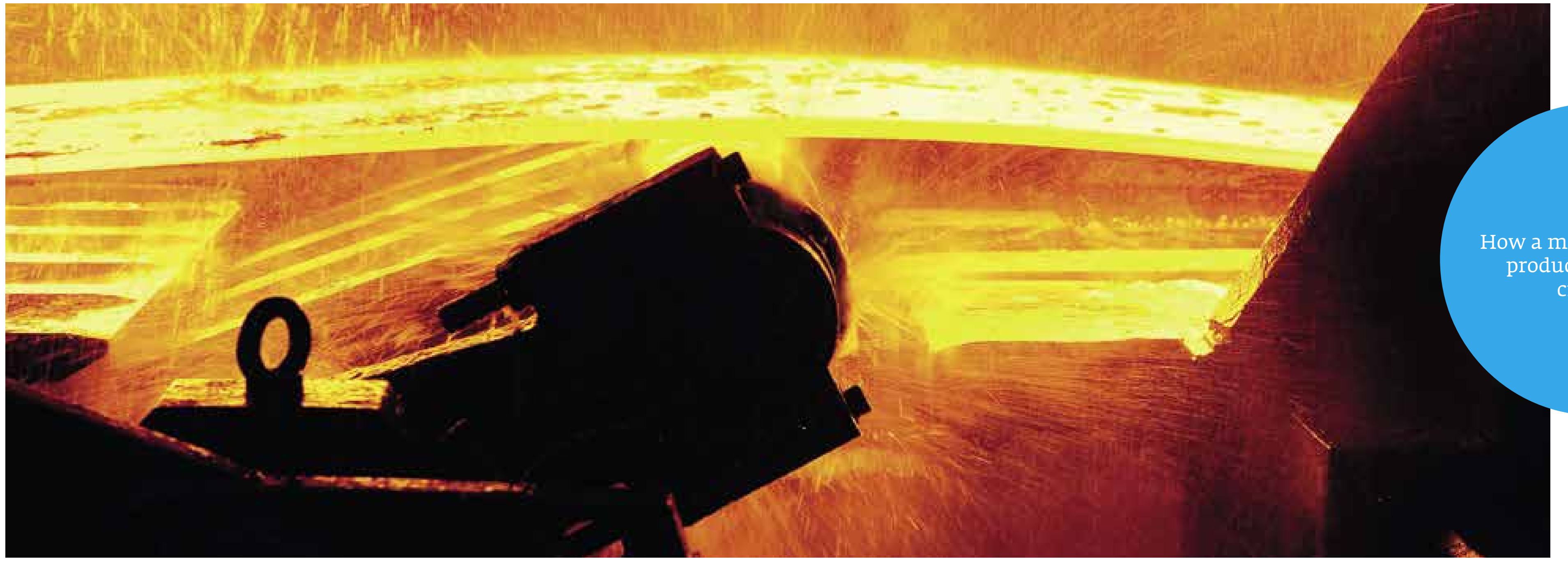
FUTURE PLANS

The Environmental Program 2020 will serve as a new impetus for the company's environmental operations at the Novolipetsk site.

The next step is to modernize the blast furnace waste cooling system by 2015, which will allow the company to lower hydrogen sulfide concentrations during the waste cooling process to the lowest possible levels. A number of measures are designed to lower dust emissions.

By 2020, NLMK plans to completely overhaul and restore blast furnaces Nos. 4, 5, and 6; replace BOFs Nos. 2 and 3 and the corresponding gas ducts; and build a fugitive emissions recovery and purification system. In the same period, the company also plans to fully capitalize on its industrial waste reuse program. One part of this initiative involves the construction of an ore slag briquetting plant, which will turn waste into blast furnace fuel. By 2020, the Novolipetsk site will eliminate its slag dump site and reclaim the site it currently occupies. By 2020, NLMK Group plans to lower emissions from 21.9 to 19.4 kg per tonne of produced steel (an 11% reduction) across all of its Russian sites. All NLMK industrial sites will completely eliminate water dumping, and increase overall waste recycling levels from 5% to 25%.





How a method to mass produce steel was created

Man of Steel

We live in a world made of solid steel: from bridges and skyscrapers to railroads and pipelines. All of this has become possible thanks to the invention of one man – Henry Bessemer

Dmitry Mamontov,
Scientific Editor, Populyarnaya Mekhanika (Popular Mechanics) magazine

Bessemer, of course, was by no means the first to work out how to smelt steel. Moreover, he was neither a chemist nor a metallurgist, possessed by the abstract dream of a new construction material. However, he was most definitely a brilliant inventor and businessman who knew how to make good money from his inventions. He was just the man to create something without which the industrial revolution would not have been possible – a method to mass produce steel.

THE GENETICS OF INVENTION

It's unclear whether an aptitude for invention can be hereditary, but Henry Bessemer, born January 19, 1813, clearly did take after his father. Anthony Bessemer, a native Londoner, had moved to Paris at the age of 21 and married a Frenchwoman there. He spent five years working at the Parisian Mint, where he contributed a number of very useful innovations. As a result, he was accepted as a member of the French Academy of Sciences at 26. Having amassed a respectable fortune, he returned to Britain, where he settled in Hertfordshire.

Anthony had four children, but he doted especially on his only son. Although Henry's formal education ended when he was 14, the boy read a great deal, and by 17 had absorbed the basics of engineering physics, law, and finance, and was an experienced draughtsman. It was at this age that he came up with his first serious invention – he devised a needled punch for revenue stamps so that they could not be used a second time. Later he came up with a more simple and elegant solution – to print dates on the stamps, which rendered his first invention useless and completely profitless. Bessemer's career in the civil service came to an end at that point and he resigned.

A few years later Bessemer obtained a patent for a way to make graphite pencil leads. However, he encountered brazen attempts at piracy from other manufacturers and, deciding not to become involved, sold all of the rights for 200 pounds. Consequently, for his next invention he decided upon a completely different financial model. He selected a product which at that time was growing in demand throughout Europe and devised a method to mass produce it. He chose gold paint, a product solely manufactured in the 1830s by a German company in Nuremburg. Bessemer applied what is nowadays known as reverse engineering: he carefully studied the composition of this paint, discovering that it contained brass powder, and then devised a way of producing a far finer powder in a completely different way. The production cost of Bessemer's paint was less than 10% of the German product.

> A captain in the French army complained that cast iron cannons were insufficiently durable. This was a challenge, but Bessemer accepted it, since he well understood the potential of steel production

A STEELY CHALLENGE.

In the 1840s Bessemer set up a foundry in the London borough of Camden where he produced metallic paints, powders, wires, foils, and other metal products, and where he also experimented with new materials and processes. There he developed more than thirty highly successful inventions. After the end of the Crimean War, Henry Bessemer looked at weapons manufacturing and devised a new type of shell which was stabilized by rotation. The British military were not interested in this development; however, the French were. A captain in the French army, Claude Étienne Minié, inventor of the minié ball, complained to the British inventor that cast iron cannons were insufficiently durable. This was a challenge, but Bessemer accepted it, since he well understood the potential of steel production.

At that time metallurgical science was already aware of how carbon content could influence the properties of ferroalloys. If there is too little carbon, less than 0.1–0.2%, then the alloy is too soft and it is impossible to temper it. If there is too much carbon, over 2%, the resulting iron is hard but brittle and not ductile, and therefore useful only for casting. At the same time, it is precisely cast iron which was the result of recovering iron ore with the use of coal, since during this process the iron became saturated with carbon.

In the 1850s cast iron was already a popular product, with an annual production volume of around 1.3 million tonnes. But steel, containing from 0.2 to 1.8% carbon, which was amenable to being both forged and tempered, was at that time made, if not quite piecemeal, certainly only in small quantities – the annual worldwide output of forged steel was only 70,000 tonnes in total. This was because it was difficult to produce: cast iron was turned into steel through the process of puddling, devised by the British metallurgist Henry Cort. Molten cast iron, isolated from contact with fuel (ordinary coal) in a stove, was mixed by hand with the aid of a metal rod to which the steel mass got attached. The mass was then broken up and melted, resulting in malleable steel.

A LUCKY ACCIDENT.

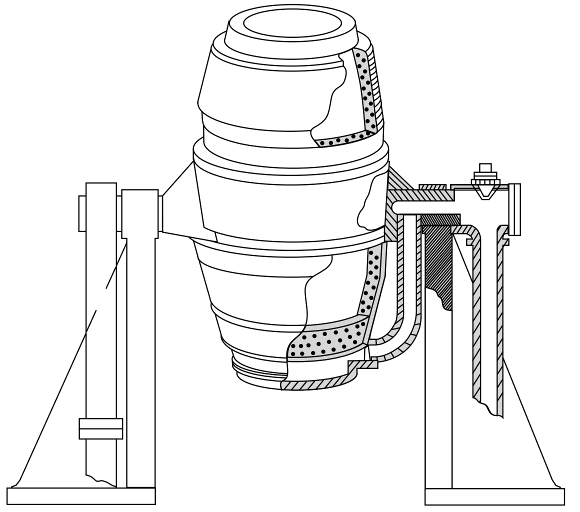
Experimenting in his laboratory in Camden, Bessemer noticed during one smelting session that a piece of cast iron had not melted, and in order to raise the temperature, increased the airflow to the furnace. But half-an-hour later, and even an hour later, the piece still did not want to melt. At the end of the smelting session Bessemer studied the stubborn piece and to his surprise discovered that it was covered with a fine crust of decarbonized, forged steel. That was when he realized that blowing air onto the molten metal could speed up the process of puddling. And in order to make the process even more efficient, Bessemer decided to increase the area of contact between the air and the metal, blowing it directly through the molten metal. He had already designed a large furnace with pipes to bring air to the molten metal, but modifications would take time. The inventor was impatient so he decided to experiment on a smaller scale and without a heat source, simply blowing air through the molten metal. As it happened, this action saved his life.

He added six pipes attached to some bellows to a vessel which held around 300 kg of molten iron, and began to pump in air. For the first ten minutes the molten metal seemed to do nothing (much later it became clear that during this period silicon was being burnt out of the composition of the molten metal), and despite the skepticism of some of the workers in the workshop (the vessel had no firebox or fuel), it did not cool down. Bessemer was already convinced that all was going according to plan, when suddenly... bursts of sparks flew up from the mouth of the vessel and a series of loud explosions threw a fountain of molten metal up into the air. Bessemer and his assistants managed to jump back to a safe distance. Before a serious fire could start the reaction stopped of its own accord. Once they had poured the metal into molds and let it cool, Bessemer discovered that all of the carbon had been burnt up and virtually pure iron was the result, malleable and ductile.

RISE AND FALL.

After a series of experiments, on August 11, 1856, Henry Bessemer presented his paper, “The Manufacture of Iron without Fuel,” at a meeting of the British Association (since 2009 the British Science Association) in Cheltenham. The very title had a whiff of the absurd about it, and those present almost mocked the speaker – common sense dictated that if one did not use fuel and blew cold air through metal it could lead only to metal cooling down. But all Bessemer had to do was display his specimens, obtained as a result of his experiments, and the laughter died down. The audience realized that this was a revolution in the making.

Bessemer added six pipes attached to some bellows to a vessel which held around 300 kg of molten iron, and began to pump in air



A Bessemer converter

Competitors

The Bessemer process was to be improved upon more than once in subsequent years. In 1879 Sidney Thomas developed the theory further and understood the connection between the phosphorus in the charge and the material composition of the furnace lining. From that time it became possible to use virtually any ore (not only low-phosphorus ore), which made it even easier to produce in quantity. Bessemer also had direct competitors. At the end of 1856 the German-born British engineer Carl Wilhelm Siemens created the regenerative furnace, using the waste-gas heat to warm the air and the gases entering the furnace. Based on this construction, the French metallurgist Pierre-Émile Marten devised, in 1864, a furnace using the Siemens-Marten process. It was these Marten furnaces which, by the 1920s and 1930s, had squeezed the Bessemer process out of the steel industry (and by 1970 they had given way to basic oxygen furnaces and electric arc furnaces). Nevertheless, the Bessemer process will always be known for brilliantly achieving its aim of supplying the world with cheap and reliable steel.

Within a month four major metallurgical companies had paid Bessemer GBP 27,000 (nowadays this would be the equivalent of tens of millions of pounds sterling) for the right to use the process. Nonetheless, the inventor still had major problems ahead of him. Trying to reproduce all the stages of his process in the workshops of the metallurgical companies, time and again, Bessemer ended up not with the malleable steel that he wanted, but a brittle and therefore completely useless alloy.

TRIUMPH ONCE MORE.

Trying to find out where he was going wrong, Bessemer hired a number of metallurgists and chemists who, step by step, variable by variable, searched for his mistake. And at last they found it. It was all down to the quality of the original materials. For his experiments in Camden, Bessemer used iron smelted at Blaenavon (Wales), which contained virtually no phosphorus. At the same time, no one had paid any attention to the lining of the converter (the name given by Bessemer to the vessel in which the process took place). A limestone lining had remained after a previous experiment, and it had simply not been removed. Later it became clear that the fired limestone, dolomite, or magnesite combined with phosphorus in the form of phosphates, and now this principle bears the name of the alkaline Bessemer process.

> Step by step, variable by variable, they searched for his mistake

There was one other problem of which Bessemer was unaware. The almost total absence of carbon in the molten metal after it had burnt off and the excess oxidation as a result of the passage of the air made the steel brittle. Stopping the process at the point where the carbon content had reached optimum levels (0.1–1.8%) was quite complicated. Bessemer himself focused on the full completion of the exothermic reaction (with a considerable discharge of heat) of the carbon burning off. Robert Mushet, managing the family metalworks at Darkhill, guessed how to overcome this limitation: he proposed to initially burn off the carbon, adding it back in the necessary quantity. Mushet used manganese to eliminate the excess oxygen. These were both added in the form of “mirror iron,” a molten metal which went under the German name spiegeleisen.

The first steel smelting businesses to use Bessemer converters were Mushet's factory in 1857 at Darkhill in Britain and Göransson's factory at Edsken in Sweden. From the beginning of the 1860s this technology began to be used by virtually all producers of steel. And although Bessemer's monopoly did not last long, it did provide a very significant technological step forward. The production of malleable steel – one of the cornerstones of the Industrial Revolution – could be done quickly, at high volumes, and cheaply. The Bessemer process allowed the smelting of steel by the tonne instead of by the pound, thousands of times quicker and at a tenth of the cost, creating the steel skeleton of today's world.

Printing the Future

The technology to make three-dimensional metal objects using 3D printing technology has the potential to change the face of the industrial market. Eventually, "home-based factories" producing household necessities will probably render mass production unnecessary. But for now, 3D printing remains only a fascinating experiment.

Ivan Shipnigov

3D printing can help slash production costs

One-off instead of mass production

A ONE-OFF PRIORITY. Print on Demand is a new publishing technology that allows anyone to print a book for any circulation volume, even as small as a single issue. The fast-growing 3D prototyping method offers similar functionality, although it is designed to create a unique product, rather than save on costs. However, both of these print on demand technologies follow the same recent trend: a return to forms of consumption that existed before the Industrial Revolution introduced mass production in the late 18th century. But the future might still belong to one-off production.

With 3D printing, one-off production might become so cheap that the cost of an individually produced item might fall below that of its mass-produced counterpart. This would rob one of the Industrial Revolution's crowning achievements – the economy of scale – of its significance. If 3D prototyping technologies continue to advance,

Craftspeople in ancient China developed a method of making decorative boxes and other objects out of varnish. The secret behind this method is that the entire object consists of nothing but varnish: it is layered onto a base that is carefully removed once the varnish dries their impact could equal that of the first mills and factories. Ironically, it may sound the death knell of actual mills and factories.

PROTOTYPING AND CUSTOMIZATION

Although 3D printers have been around for quite some time, they have traditionally been used mainly in car manufacturing and the aerospace and medical fields. The technology is chiefly used to create a template for conventionally mass-produced components. Today, 3D printing is beginning to compete with the conveyer belt, which no one would ever use to produce a single, unique object. A 3D printer crafts every object as if for the first time, instead of churning out copies of the same template. This creates vast potential for customization: the process by which each object is created and adjusted to fit the needs and tastes of a specific person.

UP IN THE AIR.

How is 3D prototyping used in metalwork?

Researchers from the Joris Laarman Lab in Amsterdam designed a unique 3D metal printing (for lack of a better term) technology.

This Dutch technology creates objects without using any supporting structure: the "printed" metal objects literally hang in mid-air.

Their 3D printer consists of two parts: a welding device, which smelts and arranges the metal, and a robotic arm. The machine uses a process called extrusion: it pushes thin threads of smelted metal through small extruder openings. For a brief time the threads hang in mid-air, while new threads are layered on top of them. Gradually, the threads crisscross to form the future object.

This daring technology, called the MX3D-Metal 3D printing initiative, can use stainless and regular steel, bronze,

The process is called "printing" for lack of a better term

But how soon will average consumers be able to afford 3D metal printing?

Currently, industrial metal 3D printers cost tens of thousands of dollars

aluminum, and copper to create three-dimensional objects without the use of supporting structures. The designers are working on expanding the list of metals that can be used in their machine by developing new extruders with different smelted metal extrusion openings. The company is also developing 3D printer software that will allow users to set more precise parameters for the desired object.

The layered metal deposit technology is called additive manufacturing. The metal additive manufacturing method offers a number of advantages over traditional conveyor production: it does not involve any production line maintenance costs and reduces harmful emissions. Most importantly, 3D printing is extremely flexible in terms of object design, allowing the user to create any number of new shapes. This is especially useful in the aerospace, medical, and other high-tech fields.

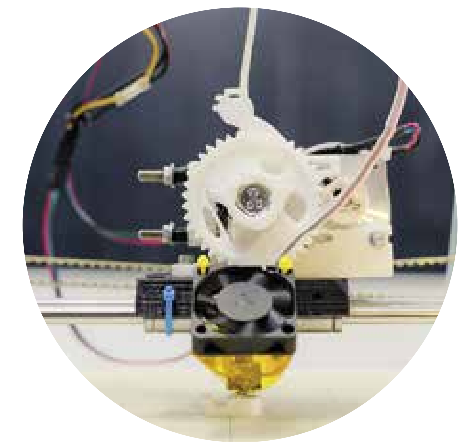
HIGH-TECH, LOW PRICE.

But how soon will average consumers be able to afford 3D metal printing? Currently, industrial metal 3D printers cost tens of thousands of dollars, while printers available for around USD 1,000 can only use plastic.

American entrepreneur and engineer David Hartkop designed a Mini Metal Maker printer which will retail for just USD 750. Hartkop's printer creates 3D objects using so-called metal clay, invented in Japan in 1990. This hybrid material consists of very fine metal powder mixed with water and an organic, viscous emulsion. Metal clay is designed to create virtually anything using various casts, just like ordinary clay. After the object is "cast" by the printer, it is dried and fired, again much like potter's clay. Once a given pot or plate leaves the firing kiln, it is ready for use and has certain well known properties. Similarly, metal clay allows the user to create a metal object. The organic emulsion burns up in the fire, while the metal powder is smelted into a completely metal article.

Metal clay is widely used in jewelry making to model and sculpt three-dimensional art. This material combines the flexibility of clay with the durability of metal. It can be made using virtually any common metal and alloy: copper, gold, bronze, brass, silver, iron, and steel

Metal clay products created using this 3D technology can be fired using a regular gas stove. After firing, the end product loses the layered structure typical for 3D printed objects. Metal powder forms a very dense homogenous mass, possessing a durability that is virtually indistinguishable from that of solid metal. The resulting objects can be treated in much the same way as their regular counterparts: they can be drilled, polished, and sawn.



THE PRINTER VS. THE CONVEYOR.

Still, despite its promising potential across a range of areas, metal 3D printing technology has two clearly defined uses. The first, which could tentatively be termed "home-based use" is not yet advanced enough to allow consumers to create necessary household items in all shapes and sizes using a personal 3D printer. Meanwhile, industrial application in component manufacturing will remain tied to mass production for some time to come. Someday, individually produced items will replace their mass produced counterparts, especially in areas such as computing and medicine, where the quality of a product and its components are of the highest priority.

For now, companies seem unlikely to reject the cheap and convenient conveyor belt. Nevertheless, metal 3D printer technology is guaranteed to bring about one major change.

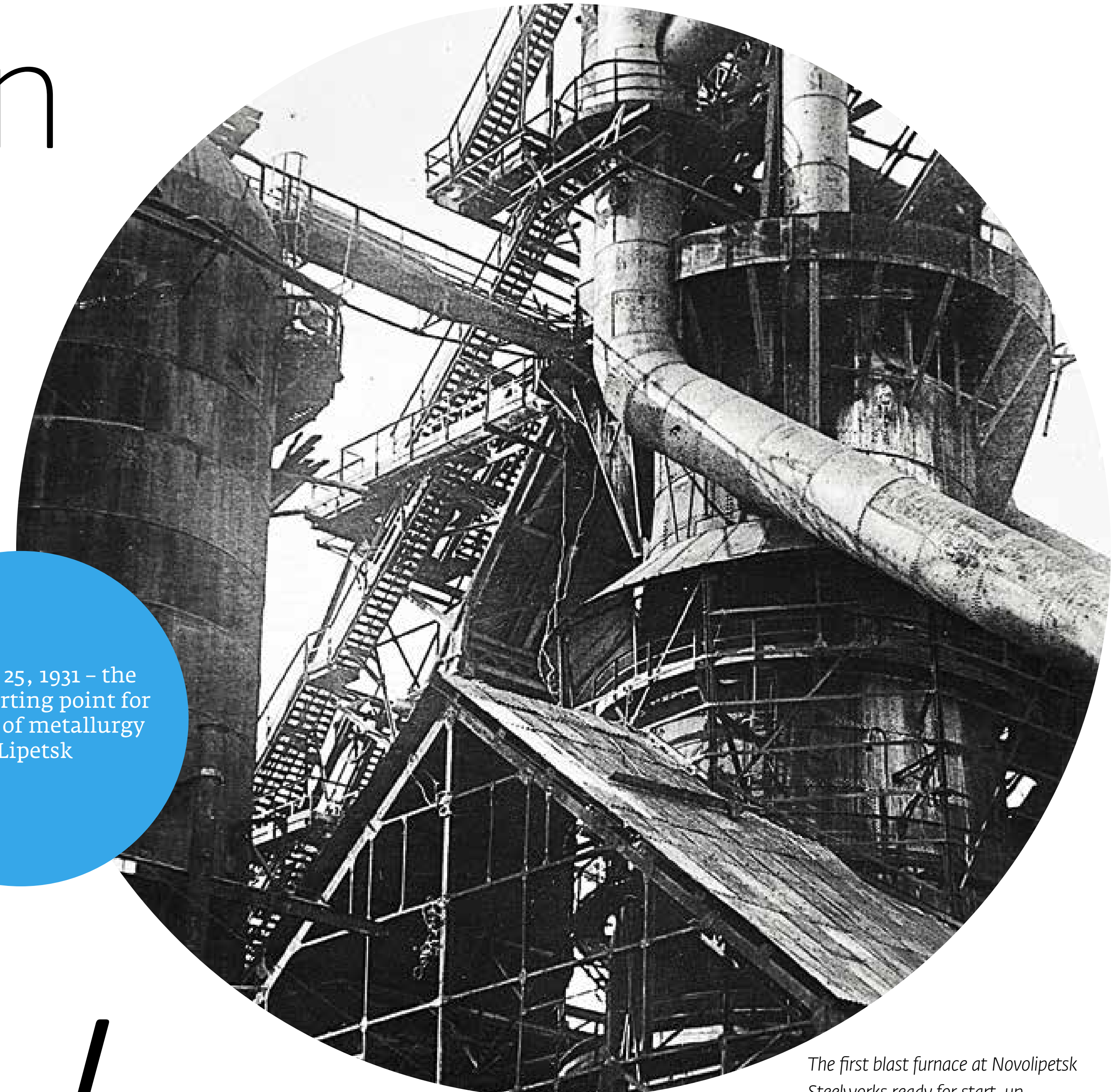
This technology will herald the return of the lone craftsman, all but extinct since the Industrial Revolution. Back in the day, people hand-produced items in small quantities because they had no other choice. This new class of craftspeople will print, use, and sell their unique products because they want to.

The Construction Project of the Century

Construction of Novolipetsk Steelworks commenced during the first Soviet five year plan, when the foundations for the country's heavy industry were laid and the country's industrial giants such as the Magnitogorsk, Kuznetsk, and Kryvyi Rih plants came into being. The reasoning behind construction at Lipetsk was its convenient geographical location, and the presence of iron ore and limestone in the locality.

Olga Schurova, Head of the NLMK Museum

February 25, 1931 – the official starting point for a new era of metallurgy in Lipetsk



The first blast furnace at Novolipetsk Steelworks ready for start-up

We have already talked about how, even in the time of Peter the Great, there were ironworks here. A thread runs from that distant past to the present day.

It is February 25, 1931 which may be seen as the official starting point for the new era of metallurgy in Lipetsk: it was on that date that the order was issued by the Council of People's Commissars of the USSR to construct an iron foundry in Lipetsk, which was later to bring world renown to the city. The Leningrad design institute, Gipromez, drew up a design for the facility, including in it the latest technological achievements of the time. The blast-furnace shop consisted of two 930 m^3 furnaces, each capable of producing 250,000 tonnes of cast iron per year. A site was chosen for the plant on the left bank of the Voronezh river. Soon the place was bustling with work on a scale and at a speed hitherto unknown in the region. In order for the plant to be built in the quickest possible time, a special department was set up called Lipetskstroy, which was headed by Jan Andreevich Berzin. It is he who became the first director of Novolipetsk Steelworks.

Construction of the facility was declared a top priority project. Country folk from surrounding villages were brought in to help, many of them lacking any technical education. Thus, alongside the plant under construction, an educational complex was set up to provide training for the construction workers and metallurgists. As we know from contemporary documents, by launch of the first blast furnace 460 foremen, technicians, and skilled workers were trained; 1,525 people studied in groups togain the minimum technical knowledge required and some of the workers underwent internships at cast iron foundries in Ukraine and Tula. Experienced specialists were also transferred to the new factory from facilities in the Urals and western Siberia.

The NLMK museum houses priceless relics in form of memoirs by its first construction workers and metallurgists about the progress of the plant's construction and the challenges they encountered along the way.

Yakov Rostovsky, *senior land-surveyor and head of the general plan for the construction site:* "In 1929 students and teachers from the Voronezh Agricultural Institute came to the construction site. Their task was to carry out a geodetic survey and draw up a plan of the future factory's site. All of the geodetic work and plan drawings were carried out under the leadership

The place was bustling with work on a scale and at a speed hitherto unknown in the region

Woodcutting brigade

"If you're not involved in agricultural work, come and build the Novolipetsk plant!"

of Professor Petrenko. This material served as the basis for Leningrad Gipromez to design all of the buildings and communications for the BF No. 1 complex, and made it possible to have part of the construction drawings on-site by the second quarter of 1931. A Lipetsk geological survey group was organized and entrusted with discovering and documenting the iron ore, flux, and fireclay for the plant as it was being built.

"The office was situated on Lenin Street (across from Verkhny Park), in a small wooden building. A dense forest covered the site of the future plant. Just to the right of the forest stood a row of timber sawhorses in a small field. Here, logs were sawn by hand with large, long-frame saws into planks, which were then and there used to enclose the framework of the hut, before being caulked with turf and sawdust."

Vladimir Kondratyev, *construction worker:* "In March 1931, when my brother Alexander and I were assigned to join the engineers and technicians from Azovstal for the construction of the metallurgical plant in Lipetsk, we had to literally start from scratch. There wasn't even a design for the complex. That is what we had to start with. The first task that the construction director, Jan Berzin, assigned us was to design... a stable for 75 horses. Does that seem like a joke? Now, it certainly does. But back then, it wasn't at all. The horse was the main 'working unit' on the site. We even won a prize for this, our first design. At that time there were few draftsmen and copyists. We had to do everything ourselves."

Yakov Rostovsky: "In May, deliveries of construction materials increased. Everything was unloaded at Kazinka station and delivered to the site by horse along a dirt road. The station was piled high with construction materials. There was an urgent need to build a rail link to the construction site... There was no time to draw up a plan. It was decided to devise a draft plan and put it into action bit by bit, following it by laying the railway tracks."

"The first task was to design... a stable for 75 horses. The horse was the main 'working unit' on the site".

Sergei Parshin, *a veteran of NLMK, spent most of his life working in the blast furnace shop:* "I remember that in 1931 I read an appeal to young people in the paper: 'If you're not involved in agricultural work, come and build the Novolipetsk plant!' Our village, Varvarinka (now part of Lipetsk District), was visited by a local man, Alexander Korolev, who gathered together the young people and the Komsomol members and gave a speech about the construction of the metallurgical plant. He said, 'The Novolipetsk plant will have several top class sections, including a blast furnace shop which will smelt 1,000 tonnes of cast iron a day.' Many of us did not believe that. A thousand tonnes! Maybe he meant 1,000 poods? (A pood weighed just over 16 kilograms). I was among those who didn't believe it. All the same, after the meeting many of us wanted to get involved in the construction project. I too asked for my name to be added to the list. In the summer of that same year we came to the site... I have to say the work was not the easiest; there was not enough equipment and everything had to be done by hand. We lived in wooden huts and the food was not very good. But we didn't lose heart, especially the younger among us: in the evenings we organized dances, went to the cinema or Nizhny Park, held propaganda meetings, amateur talent nights, and sports competitions."

Yakov Rostovsky: "The construction workers had no experience, knowledge, or qualifications. But there was no shortage of keenness or enthusiasm to acquire a specialization. From the earliest days of construction, a training complex was set up on site."

Efim Karpachev, *electrical worker and subsequently foreman of the ferroalloy shop:* "The students of the training complex often helped out the construction workers. The youngsters dug foundation trenches, leveled the ground, performed site clearance, and unloaded wagons."

Yakov Rostovsky: "Pouring of the foundation for the first blast furnace shop began in August 1931. Loading crushed stone, cement, and sand into the concrete mixer and the concrete casting were both done by hand. The concrete was delivered to the concrete casting site in wheelbarrows and handbarrows.

"Assembly of blast furnace No. 1 started in June 1932. The work was carried out in the toughest of conditions; there were no mechanical hoists. Goods, equipment, and hardware were all lifted using hand winches. It was particularly hard assembling the BF shells, stoves, and frames, all of which were riveted by hand. Tens of thousands of rivets were heated up in portable furnaces, and once white-hot were passed to the riveters who set them in the holes of the two metal sheets where they were to be joined, and held them in place with their chests while the rivet was driven in from the other side.

"Erection of the inclined bridge was also difficult, as it was delivered in individual parts which had to be put together. It was decided to put the bridge together on the ground and then lift it in one piece, weighing more than 75 tonnes. This was a very great weight for that time, and the first time that lifting such a piece at a construction site was attempted. The assembly was planned by construction workers from the technical department and fitters.

"Out of all the buildings for the BF No. 1 complex, constructing the hoppers, made by hand of cast-in-situ reinforced concrete, was the hardest and most complicated. For the first time in the history of construction, the equipment was assembled before the concrete casting of the walls to which they would subsequently be fastened."

Ivan Ivanisov, *a leading light in blast furnace production, and honored metallurgist:* "At the beginning of July 1934 I was sent to the Novolipetsk metallurgical plant to commission the first blast furnace.

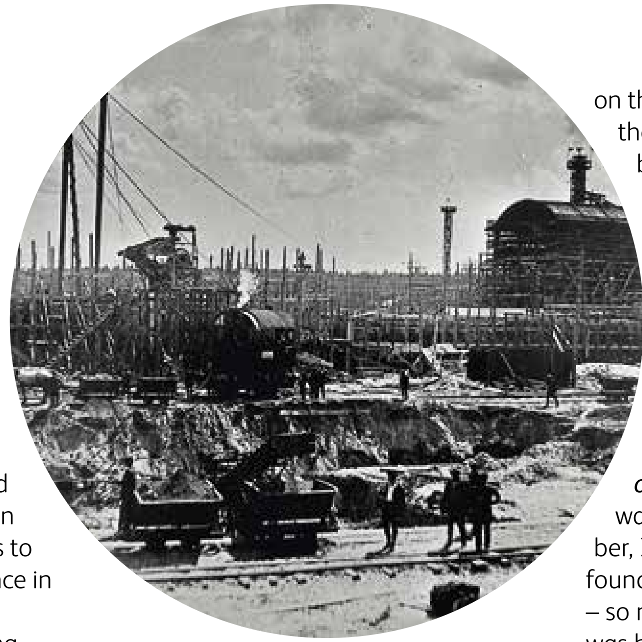
The office of Lipetskstroy. March 1931

From the earliest days of construction, a training complex was set up on site

"Before me I found a construction site that was enormous for those times. Almost the entire area, carved out of the deep pine forest, was gouged with trenches for the foundations of future workshop buildings. The first blast furnace was almost ready. A second furnace was going up alongside the first. The furnaces had a capacity of 930 m^3, and their technical equipment amazed me.

"I began work on July 7. With the construction workers I began assembling the units and the individual component parts... My joy knew no bounds when I saw the new, modern equipment for the furnaces and sufficient amounts of instrumentation. I worked as gasman foreman in team No. 3. We approached the new technology with great enthusiasm. Vitaly Kaporulin, assistant head of the BF machine shop, helped us enormously with this.

"Our shift leader, Grigory Shabanov, was an engineer with a thorough understanding of furnace work. He knew very well that people who had only just come to the plant from various parts of the country, from very different facilities, had to be put together into an efficient team, 'to give everyone such practical skills that team members would understand each other without having to say a word.' And this had to be done



The Lipetskstroy site, 1932.

in the shortest possible time. Just before the blast furnace was put into operation, he frequently had us role-play training games during his shift to prepare us for the activities involved in producing cast iron, imitating the time and conditions of producing cast iron in every detail. He set up games to eliminate any elements of chance in various sectors."

On November 3, 1934, testing of the furnace equipment began. A government commission approved the loading of the charge into the blast furnace.

And on November 7, 1934, at 7:30 in the evening, the furnace produced the first cast. The first 64 tonnes of cast iron were made. This date became Novolipetsk Steelworks' birthday. The first cast was managed by engineer Shabanov and furnace-man Ivan Schmidt, who had earlier launched all four blast furnaces at Magnitogorsk.

Ivan Ivanisov, *who at that time was a gasman, gave the following description:* "On November 6, 1934, blast furnace No. 1 was prepared for blow-in. The honor of starting her up was given to our Komsomol youngsters' No. 3 shift. At 3:15 in the afternoon, Grigory Shabanov gave the 'Start her up!' command, which was then proudly carried out by the gasmen of our shift."

Zinaida Paramonova, *analysis laboratory assistant (graduate from the chemistry department of the Lipetsk metallurgical technical school in 1932):* "On that day I was working

A government commission approved the loading of the charge into the blast furnace

as shift leader in the laboratory. And here, in my hands, was the first cast iron. What was it like? How good was it? In a word, I felt like a mother looking her first newborn in the face for the first time."

Sergei Parshin: "On November 7, 1934, I finished my army service, and on that day I heard on the radio that the first blast furnace at Lipetsk had been commissioned and had produced its first cast iron. I shouted 'Hooray!' so loudly that all the barracks heard me."

On November 4, 1935, blast furnace No. 2 produced its first cast iron.

Nikolai Sobolev, *foreman of the gas supply facility, participated in the launch of five of the plant's blast furnaces:* "It was all so very new to us. I remember, I got to the pumping station and found such enormous engines turning – so many different machines – that it was hard to believe that all of this was under human control. Well, of course, it was hard for me to believe, since I'd not even seen a steam engine before!"

Grigory Shabanov, *shift-man for BF No. 1:* "We commissioned the blast furnace at Lipetsk without any help from foreign specialists. American technology was not news to us. The blast furnace was brought online without a hitch, in an orderly and elegant manner."

In an article about the plant's 30th anniversary, **Vladimir Vinishenko,** *Novolipetsk Steelworks' director from 1962 to 1967, explains:* "All of the equipment was made at our machine shops. Towards the end of the five-year period our plant gave the country almost twenty times what it had in its first year of existence, and in 1935 the Lipetsk metallurgical plants produced significantly more cast iron than all of the plants in Poland, Hungary, and Italy put together."

During the years of Novolipetsk Steelworks' construction, life in the small provincial town of Lipetsk also changed beyond recognition. The town grew alongside the plant. In 1933 alone, 40,000 square meters of residential accommodation were built, along with a new bread factory; a broadcasting network was developed and libraries were opened.

The first cast was managed by engineer Shabanov and furnace-man Ivan Schmidt, who had earlier launched all four blast furnaces at Magnitogorsk

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