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New Progress on Application of NEUI400kA Family High Energy Efficiency Aluminum Reduction Pot ("HEEP") Technology

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Key words: Aluminum reduction pot; NEUI400; high energy efficiency; new application progress

Abstract

NEUI is the first to have successfully developed *NEUI400kA Family High Energy Efficiency Aluminum Reduction Pot ("NEUI400 Family HEEP") Technology* by incorporating the numerical simulation technology with the experiences on developing high amperage aluminum reduction pots. And the first 230kt/a potline adopting NEUI400(I) HEEP technology in China has been put into commercial operation in Aug., 2008. At present, the operating amperage of the potline is 415kA, average pot working voltage is less than 3.85V, DC energy consumption is less than 12500kWh/t-Al, and the anode effect frequency is less than 0.015effects/pot·day.

On the basis of summarizing experiences on developing NEUI400(I) HEEP and analyzing the measured physical field results, NEUI has optimized the physical field of NEUI400(I) HEEP by using its proprietary "Physical Field Numerical Simulation and Analysis Software Package for Aluminum Reduction Pots". Meanwhile, NEUI has also developed some new technologies such as sub-section high level gas collection technology and compressible pot lining technology, etc.

NEUI has successively developed NEUI400(II-IV) high energy efficiency aluminum reduction pot ("NEUI400(II-IV) HEEP") technologies which have been used in Linfeng Aluminum and Power Co., Ltd., Shandong Nanshan Aluminum Co., Ltd. and Jinning Aluminum Co., Ltd respectively. The design capacity of the three potlines is respectively of 250kt/a, 250kt/a, and 300kt/a. The operating amperage has respectively reached 430kA, 440kA, and 460kA. And more excellent techno-economic indices have achieved such as average pot working voltage less than 3.85V, DC energy consumption less than 12500kWh/t-Al, anode effect frequency less than 0.01effects/pot·day and current efficiency up to 94%, etc.

1. Introduction

The aluminum output of China has been No.1 in the world for years. And aluminum industry technologies are also galloping ahead. At present, 300-400kA family aluminum reduction pot technologies have become the main pot technology in China's aluminum industry. China has made great break-through on pot design, fabrication, reduction process and technical innovations of the aluminum reduction pot, which have brought the continuous improvement of the techno-economic indices for aluminum reduction.

As an important technology supplier and service provider in China's aluminum industry, NEUI has made great contribution to the rapid development and improvement of the technological level of China's aluminum industry. By incorporating the numerical simulation technology developed by itself with the experiences on developing high amperage aluminum reduction pots, NEUI is the first to have successfully developed NEUI400(I) HEEP technology and first applied it to aluminum industry. China's first 400kA reduction potline with capacity of 230kt/a adopting NEUI400(I) HEEP technology has been put into operation in Aug., 2008, and excellent techno-economic indices were obtained. With successful application of NEUI400(I) HEEP technology, the situation has been terminated that high amperage aluminum reduction pots have to be developed by industrial test and intensify amperage step by step. The development approach has greatly reduced the cost and time for developing high amperage aluminum reduction pot technologies. At present, the actual operating amperage of the NEUI400(I) HEEP potline has reached 415kA, the average pot working voltage is less than 3.85V, DC energy consumption is less than 12500kWh/t-Al, and anode effect frequency is less than 0.015effects/pot·day. At 2010 TMS held in Seattle, NEUI has presented the main technical features, start-up

and operation conditions of NEUI400(I) HEEP which can refer to the reference [1] and [2] for detail.

On Aug. 11th, 2008, NEUI400(I) HEEP technology successfully passed the appraisal during the *Scientific and Technological Achievements Appraisal Meeting* held by China Non-Ferrous Metals Industry Association. All experts at the meeting have the common comments that the overall technologies and equipment of NEUI400(I) HEEP has reached the world leading level.

Fig. 1 and 2 are respectively the potroom and average pot working voltage of NEUI400(I) HEEP potline in Henan Zhongfu Industry Co. Ltd.

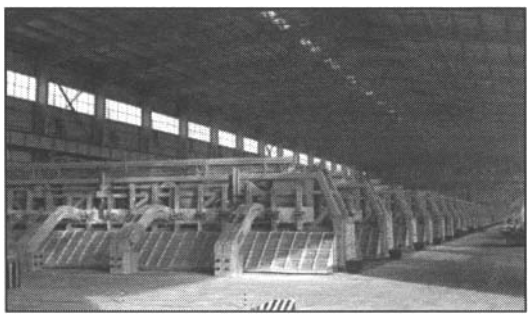

Fig. 1 NEUI400(I) HEEP Potline of Henan Zhongfu Industry Co., Ltd.

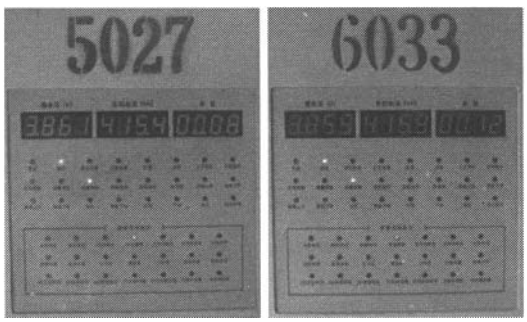

Fig. 2 Pot Working Voltage of NEUI400(I) HEEP

2. Recent Progress of NEUI400 Family HEEP Technology

Based on overall analysis of the physical field measurement results and the operation status of the pots, NEUI has optimized NEUI400(I) HEEP by using the proprietary *"Physical Field Numerical Simulation and Analysis Software Package for Aluminum Reduction Pots"*, which has not only further optimized the key technologies including MHD stability, thermal balance and steel structure, etc., but has also developed some new technologies such as sub-section high level gas collection technology and compressible pot lining technology, etc. By integrating the new technologies above, NEUI has successively developed NEUI400(II-IV) HEEP technologies which have already been put into commercial application respectively. The following will mainly introduce the technologies of sub-section high level gas collection, compressible pot lining and MHD stability.

2.1 Sub-section High Level Gas Collection Technology

NEUI has developed the sub-section high level gas collection technology by using *"Simulation Software for Negative Pressure Balance of Pot Gas Collection System"* which is redeveloped by NEUI based on the CFD (computational fluid dynamics) software platform. Comparing with the traditional hooding structure, the new hooding structure was lifted above the horizontal cover board, and the new hooding structure has the following advantages:

- The spaces within the superstructure and inside members can efficiently be used;
- After lifting of the pot hood, not only the negative pressure generated by the hot fume can be fully utilized, but also enough operation space can be provided for process operations such as anode change, etc.;
- More uniform distribution of negative pressure, flow velocity and temperature inside the hood can be obtained, which is in favor of improving the hooding efficiency.
- Effective gas collection can be achieved through using the new hooding structure. Then the fume exhaust volume and the load of the scrubbing system will be reduced obviously.

The simulation results of the sub-section high level gas collection structure of NEUI400kA Family HEEP are shown in Fig. 3 to 6.

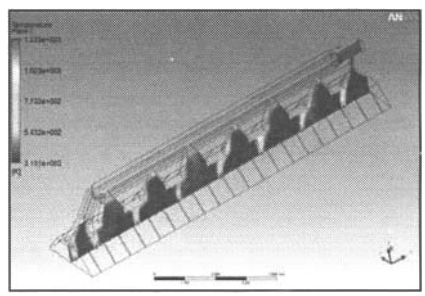

Fig. 3 Sectional View of the Temperature Distribution by the Sub-section High Level Gas Collection Structure

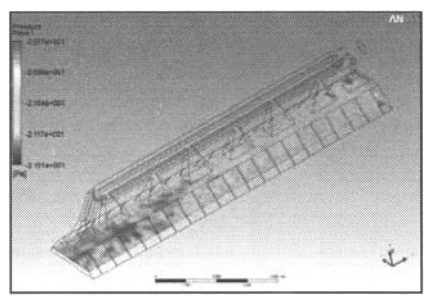

Fig. 4 Sectional View of Pressure Distribution by the Sub-section High Level Gas Collection Structure

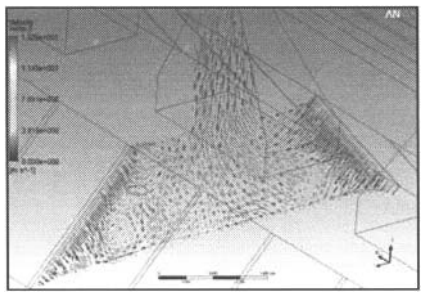

Fig. 5 Sectional View of the Velocity Vector Distribution by the Sub-section High Level Gas Collection Structure

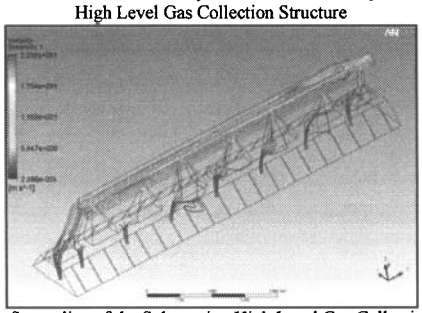

Fig. 6 Inlet Streamline of the Sub-section High Level Gas Collection Structure

The simulation results showed that the distribution of negative pressure, temperature and velocity inside the pot hood are more uniform. The total resistance of the system was only 75Pa. When the negative pressure at the gap was maintained at -20Pa, the outlet negative pressure was only required to be 100Pa, which has significantly reduced the outlet negative pressure of the pot. The hooding efficiency will be no less than 99% when the gas exhaust volume is 9150Nm^3/h. The technology has already been applied to the operating potlines which adopting NEUI400(III) and NEUI400(IV) HEEP technologies, and excellent application effect was obtained.

Fig.7 is the overview of NEUI400(III) HEEP potline in Shandong Nanshan Aluminum Co., Ltd. which adopted the sub-section high level gas collection technology. From the picture, we can see that the air environment inside the potroom was quite good, with almost no fume emission. Fig. 8 is the reduction pots in the potline when the pot hood at the tapping end was opened. From the picture we also can see that there was no fume escaping even when the side hood at the tapping end was opened. All above indicated that the use of the sub-section high level gas collection structure has effectively captured the fume and significantly reduced fugitive emissions, the hooding efficiency has reached 99% or above. The measurement results of negative pressure at the branch ducts showed that excellent gas collection effect can be achieved if the outlet negative pressure was kept at 100-150Pa. Comparing with the conventional outlet negative pressure of 300Pa, the operating load and cost of the scrubbing system have been reduced significantly.

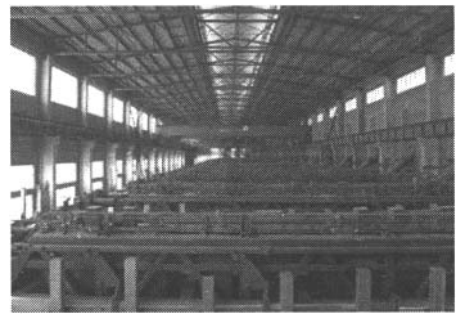

Fig. 7 Overview of NEUI400(III) HEEP Potline of Shandong Nanshan Aluminum Co., Ltd.

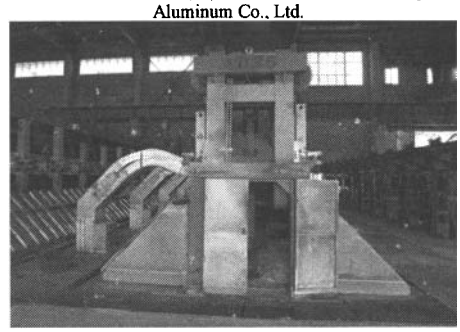

Fig. 8 Status of NEUI400(III) HEEP When the Side Hood at the Tapping End Was Opened

2.2 Compressible Pot Lining Technology

The compressible pot lining structure has been applied to NEUI400(II-IV) HEEP. In the design of the side lining at the lower part of the pot, the cathode paste, high strength castables, and heat resistant calcium silicate boards (or ceramic fiber boards) are organically combined to form the compressible structure, which can effectively absorb the thermal expansion stress and reduce upheaving of the cathode. When the NEUI400(II-IV) HEEP reached the start-up temperature during baking and before the liquid bath was filled in, the cathode upheaving was no more than 2cm, which was quite low comparing with the maximum 15cm upheaving of the traditional high amperage aluminum reduction pots. The application of compressible pot lining technology is benefit to prolong pot life of NEUI400 Family HEEP.

2.3 Optimization of the Magnetic Fluid Stability and Busbar Arrangement

Aiming to gain more excellent distribution of the magnetic field, the non-symmetry magnetic field compensation method of *"Strong Compensation at the Short Side and Multipoint Weak Compensation at the Bottom"* was used for busbar arrangement of NEUI400(II-IV) HEEP. The main characteristic of the compensation is most of current on upstream will go around the end head of the reduction pot, and less current will pass through the bottom of the reduction pot. In the process of creating the electromagnetic field model, in order to be more close to the actual conditions, the whole potline was brought into the boundary conditions for calculation, and the current balance calculating

results were used as the busbar current data, for the iterative calculation of the magnetic field and the current balance.

The calculation results indicated that no matter under normal operation condition or during short circuit period, the current ratio between upstream and downstream, current deviation ratio of each side, current density in each single flexible busbar, as well as the difference between current inside the riser busbar and the theoretical value, etc. can be all controlled within the reasonable range. For the vertical magnetic field value, no matter the maximum, average, or changing gradient, are more ideal than that of NEUI400(I) HEEP. Even when the potline's amperage was intensified by 15%, the busbar was still not overloaded, which indicated that the busbar system was more safe and reliable.

In Jul. 2010, Materials & Metallurgy School of Northeastern University tested the MHD stability of NEUI400(III) HEEP and 300kA reduction pots in Shandong Nanshan Aluminum Co., Ltd. Fig. 9 is the working site for this job. Fig. 10-13 show the measured anode current fluctuation of two type pots. The measured results indicated that at the same location (center or corner), the anode current fluctuation of NEUI400(III) HEEP was obviously lower than that of 300kA family aluminum reduction pot, which indicated that the interface stability of NEUI400 Family HEEP has been greatly improved than that of 300kA family aluminum reduction pot.

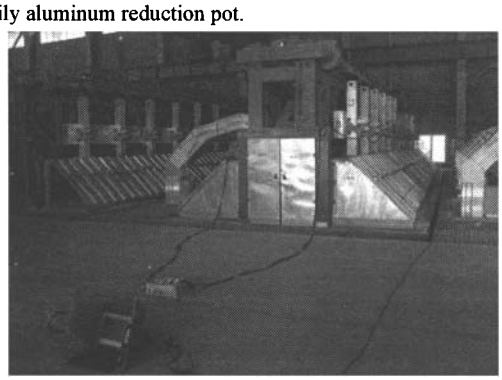

Fig. 9 Measurement of MHD Stability of Aluminum Reduction Pot

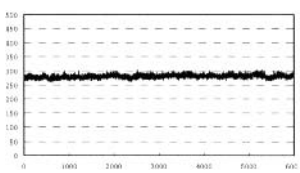

Fig. 10 Anode (A6, center) Current Fluctuation of NEUI 400(III) HEEP

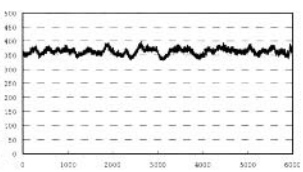

Fig. 11 Anode (A5, center) Current Fluctuation of 300kA Family Aluminum Reduction Pot

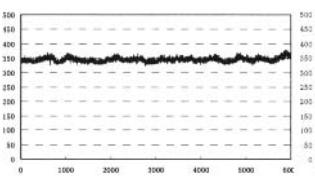

Fig. 12 Anode (A12, corner) Current Fluctuation of NEUI400(III) HEEP

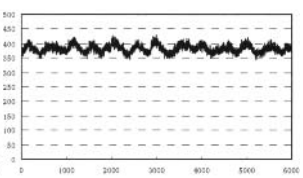

Fig. 13 Anode (A10, corner) Current Fluctuation of 300kA Family Aluminum Reduction Pot

In May 2010, the research people from Auckland University came to Henan Zhongfu Industry Co. Ltd to test the control software for automatic extinguishing anode effect on NEUI400(I) HEEP potline. They found that the aluminum reduction pots still run smoothly and stably when the pot voltage drops to 3.6V. MHD stability of the improved NEUI400(II-IV) HEEP is more excellent than NEUI400(I) HEEP. The high MHD stability of NEUI400(II-IV) HEEP was also proved through the liquid aluminum pouring quantity during the start-up, when 5-10t liquid aluminum was filled in, the pots showed rather high stability. The more advanced MHD stability design created favorable conditions for NEUI400(II-IV) HEEP to run under even lower pot working voltage and higher amperage.

3. Expanded Application of NEUI400kA HEEP Technology

The optimized NEUI400(II-IV) HEEP technologies have been respectively applied in Linfeng Aluminum Co., Ltd, Shandong Nanshan Aluminum Co., Ltd., and Jinning Aluminum Co., Ltd. Table I gives the detail.

Table I. NEUI400(II-IV) HEEP Potlines in Commercial Operation

Main Technical Parameters / Item	Current Intensity of Potline (kA)		Capacity (kt/a)		Remarks
	Design	Actual	Design	Actual	
NEUI400(II) HEEP potline of Linfeng Aluminum and Power Co., Ltd	400	440	250	275	Without the sub-section high level gas collection technology; The construction of the potline began in Jan. 2008, and the potline was put into operation in Aug. 2009.
NEUI400(III) HEEP potline of Shandong Nanshan Aluminum Co., Ltd.	400	430	250	270	The construction of the potline began in Apr. 2008, and the potline was put into operation in Nov. 2009.
NEUI400(IV) HEEP potline of Jinning Aluminum Co., Ltd.	400	460	300	350	The construction of the potline began in Nov. 2009, and the potline was put into operation in Jun. 2010. At present, the operating current intensity is the highest and the capacity of the single potline is the largest in China.

3.1 NEUI400(II) HEEP potline

NEUI400(II) HEEP technology has been used in the 250kt/a potline of Linfeng Aluminum Co., Ltd. The new technologies such as the double-anode, pipe truss girder superstructure, and compressible pot lining, etc. have been used in the design of the

pot. Besides, in order to further improve MHD stability and intensify the current of a reduction pot, the busbar arrangement has been further optimized.

The construction of the potline began in Jan. 2008, and been put into operation in Sep. 2009. Now, the amperage of the potline is 440kA, average pot working voltage is less than 3.8V, and DC energy consumption is less than 12500kWh/t-Al. Fig. 14 is the picture of NEUI400(II) HEEP potline of Linfeng Aluminum Co., Ltd.

Fig. 14 NEUI400(II) HEEP Potline of Linfeng Aluminum and Power Co., Ltd.

3.2 NEUI400(III) HEEP Potline

NEUI400(III) HEEP technology has been used on the 250kt/a potline of Shandong Nanshan Aluminum Co., Ltd. The construction of the potline was started in Apr. 2008, and the potline was put into operation in Nov. 2009. The double-anode, triangle plate anode lifting device, as well as the sub-section high level gas collection technology and compressible pot lining technology, etc. newly developed by NEUI have been used on this potline. Now, the amperage of the potline is 430kA, average pot working voltage is less than 3.95V, and current efficiency is up to 94%. Fig. 15 is the picture of NEUI400(III) HEEP potline of Shandong Nanshan Aluminum Co., Ltd.

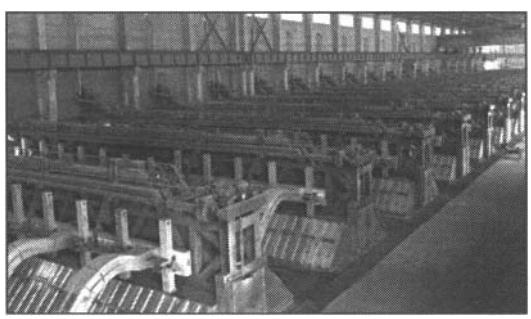

Fig. 15 NEUI400(III) HEEP Potline of Shandong Nanshan Aluminum Co., Ltd.

3.3 NEUI400(IV) HEEP Potline

NEUI400(IV) HEEP technology has been used for 300kt/a potline of Jinning Aluminum Co., Ltd. The construction of the potline began in Jun. 2009, and the potline was put into operation in Jun. 2010. The potline also adopted the sub-section high level gas collection technology and compressible pot lining technology. The busbar has further been optimized in order to further increase the current intensity. At present, the actual operating amperage of the potline has reached 460kA, and the actual capacity has reached 350kt/a. It is the only aluminum reduction potline in China which has the largest single potline capacity and the highest operating amperage. Additionally, average pot working voltage is stabilized under 3.9V within three months after it was put into operation. Fig. 16 is NEUI400(IV) HEEP potline of Jinning Aluminum Co., Ltd.

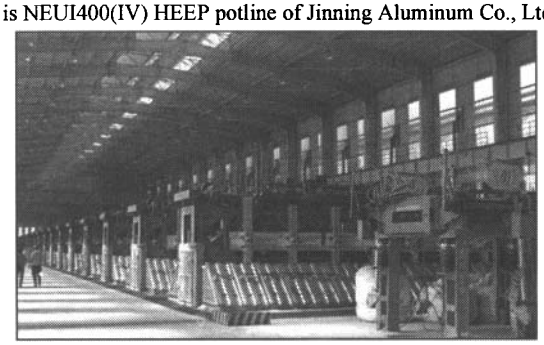

Fig. 16 NEUI400(IV) HEEP Potline of Jinning Aluminum Co., Ltd.

4. Excellent Operating Indices

After NEUI400(II-IV) HEEP potlines were put into commercial operation, all potlines have achieved excellent techno-economic indices. Refer to Table II for detail.

Table II. Main techno-economic Indices of NEUI400(II-IV) HEEP

Potline	Date of Operation	Potline Amperage (kA)	Average Pot voltage (V)	DC energy Consumption (kWh/t-Al)	Anode Effect Frequency (effects/ pot·day)
NEUI400(II) HEEP potline of Linfeng Aluminum Co., Ltd.	08. 2009	440	<3.80	<12500	<0.01
NEUI400(III) HEEP potline of Shandong Nanshan Aluminum Co., Ltd.	11. 2009	430	<3.95	<12500	<0.01
NEUI400(IV) HEEP potline of Jinning Aluminum Co., Ltd	06. 2010	460	<3.90	—	—

From Table II, we can see that with the NEUI400 HEEP technology, the amperage of the operating potline has reached 430-460kA, the amperage is increased by up to 15% comparing with the designed value, which means the actual capacity is increased by up to 15% too. It also indicated that NEUI400 Family HEEP can surely run stably at the current density above 0.8A/cm^2. This has also laid the good foundation for the development of NEUI500 Family HEEP.

Utill Sep. 2010, four potlines adopting NEUI400 Family HEEP technologies have been put into commercial operation, and the total actual capacity of them has reached 1,150kt/a. Now, six NEUI400 Family HEEP potlines with the total design capacity of 1,100kt/a are under construction, and will be put into operation successively by the end of 2010. Besides, there are six NEUI400 Family HEEP potlines with the total design capacity of 1,230kt/a are under detail design. So, it is obvious to see that NEUI400 Family HEEP technologies have become the main aluminum reduction pot technology in China's aluminum industry.

5. Comprehensive Evaluation and Conclusions

As the physical field are further optimized, NEUI400(II-IV) HEEP showed more stable than NEUI400(I) HEEP. All the NEUI400(II-IV) HEEP potlines are running stably at the amperage above 430kA. Even when the amperage of the NEUI400(IV) HEEP potline in Jinning smelter reached 460kA, the reduction pots still run stably and efficiently.

The sub-section high level gas collection technology and the compressible pot lining technology which are newly developed by NEUI have been applied on NEUI400(II-IV) HEEP, and gained very good effect. The sub-section high level gas collection technology has helped to realize a more effective capture of the fume and reduce the fume exhausting volume, the hooding efficiency can reach 99% or above. The application of the compressible pot lining technology has greatly decreased the cathode upheaving during pot start-up. The measured upheaving was less than 2cm, which is in favor of prolonging the pot life.

The pipe truss superstructure developed by NEUI continues to be used on NEUI400(II-IV) HEEP. The advantages of the structure including the high strength, less material consumption, good ventilation and heat radiation effect, as well as easy fabrication, installation and maintenance, etc. are brought into full play during their actual application.

Comparing with NEUI400(I) HEEP, the optimized NEUI400(II-IV) HEEP has achieved more excellent techno-economic indices, including average pot working voltage less than 3.8V, DC energy consumption less than 12500kWh/t-Al, anode effect frequency less than 0.01effects/pot·day, and the current efficiency up to 94%, etc. The optimized NEUI400(II-IV) HEEP technologies have made great contribution to the energy saving & emission reduction target of the China's aluminum industry.

Now, NEUI has become an important technology supplier and service provider for the aluminum industry both home and abroad. Based on the specific conditions of each project and the needs of the customers, by following the development mode of incorporating the numerical simulation technology developed by NEUI with the experiences, NEUI is able to provide customers with further optimized NEUI400 family HEEP technologies or even higher amperage HEEP technologies and equipments, as well as all-around technical support and service, etc.

Acknowledgement

The project is jointly completed by NEUI's aluminum reduction technology R&D team. The project is organized by Mr. Lu Dingxiong, Mrs. Mao Jihong, Mr. Qi Xiquan and Mr. Yang Qingchen, etc., who are also the technical advisors of the project. The development of the busbar arrangement and MHD stability technology is mainly completed by Mrs. Mao Jihong and Mr. Mao Yu; The thermal balance calculation of aluminum reduction pots is mainly completed by Mr. Ban Yungang; The ventilation structure design and simulation are mainly completed by Mr. Chen Gaoqiang and the design and simulation of the pot superstructure are mainly completed by Mr. Dong Hui and Mr. Huang Kuisheng. Thanks for the technical data they have provided for the project.

Reference

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[2] Yungang Ban, Xiquan Qi, Yu Mao etc. "Baking Start-up and Operation Practices of 400kA Prebaked Anode Pots", Light Metals 2010, TMS (The minerals, metals & materials society) 2010, 369-373.