The Technical Characteristics of the Chinese Submerged Arc Furnace

Guo Hongfa and Ye Zheng
CERIS, Beijing 100053, China

SUMMARY

China is a large ferroalloy producing country equipped with submerged arc furnace sizing from 2 MVA to 50 MVA. China processes rich experience on the design and manufacturing of submerged arc furnace particularly for the small and medium furnace. This paper reviewed the progress on technical development of submerged arc furnace. Moreover, the paper introduced the characteristics of equipment systematic structure to the various furnaces such as electrode assembly, furnace cover or semi-enclosed hood, charging device etc.

It was proved by practice that the Chinese designed and manufactured submerged arc furnace has the advantages of better metallurgical performance, simplified equipment structure and practicable, which is the ideal installation for the production of ferrosilicon, high carbon ferromanganese, MnSi alloy and high carbon ferrochromium.

1 PREAMBLE

China is a large ferroalloy producing country with capacity of installation up to approximately 5 million tons per annum, ranking number one over the world. I would say that the submerged arc furnace and other special equipment such as the furnace rammer, the charger as well as the tap hole driller and the stopper are mainly manufactured in China except that have learned from the import items. The above mentioned equipment played an important role in the ferroalloy production in China. Beijing Central Engineering and Research Incorporation of Iron and Steel Industry (CERIS in short) has undertaken the design of submerged arc furnace for the most domestic ferroalloy plants. It is known that the submersed arc furnace is the core of the ferroalloy plant. The paper is aiming to introduce briefly the technical characteristics of CERIS designed ferroalloy submerged arc furnaces to enable our international friends to have a basic understanding on the Chinese submerged arc furnace.

2 TECHNICAL DEVELOPMENT ON THE CHINESE FERROALLOY SUBMERGED ARC FURNACE

The technical development of Chinese ferroalloy submerged arc furnaces passed three stages.

The first stage should date back from 1942 to 1964 (mainly 1956 to 1964). All submerged arc furnaces designed in that time are equipped with high hood for fume exhausting, the electrodes lifted by winch, electrode releasing realizing on manual operating brake by releasing a section of steel sheet, then descending of electrode by its own gravity. The electrode holders are composed of two half copper bushes pressed tightly by some large bolts and the connecting pressure is adjusted depending on the manual turning force to the bolts. The manual charging pipe is arranged out of the furnace and lower mechanical level for the furnace operation. The generated fume from the arc furnace is exhausted to the atmosphere and scattered in the plant.

The second stage may be calculated from the year of

1965 to 1984. During this stage, the Chinese ferroalloy industry developed to a certain extent and possesses a special technical team for design of the enclosed submerged arc furnace having higher mechanical level. The action of press and releasing of electrode holders are hydrauliclly driven so as to realize the mechanized electrode action and sequential operation. These impovement may create the necessary conditions to the normal operation of the submerged arc furnaces. In the meanwhile, we made the intensive study on the charging system to the enclosed type submerged arc furnaces to guarantee the trouble free operation of the furnaces. The typical products of the two 9 MVA submerged arc furnaces exported to Albania.

We are now standing on the third stage since 1985. Our ferroalloy industry was rapidly developed to form a technical stage with our own characteristics. More than 20 sets of new furnace rating 10 to 30 MVA and more than one hundred sets furnace rating 3 to 10 MVA were put into operation in this period.

During this period, We also enlarged the export to the foreign clients with ferroalloy plant and completes set of equipment for submerged arc furnace.

The typical product is the three 12. 5MVA furnace to Philippines and two 12. 5MVA furnaces to Iran.

3 STRUCTURAL CHARACTERICTICS ON THE CURRENT CHINESE SUBMERSED ARC FURNACE

The current designed submerged arc furnace is shown as following fig. 1.

3. 1 ELECTRODE ASSEMBLY

The electrode assembly is consisting of three parts, i. e. eletrode regulating device, elerctrode slipping unit and the holder.

The elecrode regulating device is mainly of hydraulic driven type. The hanging structure is adopted for the connection between two regulating cylinders and the electrode slipping platform and the suporting platform is fixed on the plant platform. The top of regulating cylinders are connected to the electrode slipping platform by the four hanging rods. With the oil charging or discharging of the cylinder, the cylinder will move up or down along with the electrode slipping platform. As a result, the electrode will relatively move up or down accordingly. Comparing with the old design of supporting cylinder, the new design will provide the advantages of beneficial to guarantee the verticality of the electrode assembly easier for maintenance and reduce the side pressure to the eletrodes. Comparing with the hanging type cylinder, the new design is capable to lower the loading point of the electrode resulting in better civil engineering conditions.

The electrode slipping unit is composed of upper and lower clamp rings and slipping cylinders. The upper and lower clamp rings are pneumatic driven using the compressed air as medium. When the clamp ring is boosted with compressed air, the clamp ring is expanded to transfer the equal pressure to the electrode shell so as to holding up the electrodes. This type of slipping device is beneficial for assembly, maintenance and providing the better metallurgical performance as well as lower cost. It is obvious that the pneumatic clamp ring is much better than that of hydraulic one. In order to obtain the reliable slipping amount, the device is equipped with a mechanical limiter along with the limit switch to realize the quantitative slipping. The small and medium size furnace will be equipped with cone-shaped ring type holder, which is composed of a lifting ring with incline surface and some copper contact clamp with incline surfaces. The lifting ring is hanged by 2 to 4 cylinders. When the lifting ring is lifting up, the contact clamp will press tightly to the electrode through the function of incline surface to enable the power transmitting to the clectrode in a better way. When the lifting ring descending, a clearance is formed between the incline surface of copper contact clamp and the lifting ring so as to relieve the electrode. The moving up or down of the lifting ring is depending the force of spring and hydraulic pressure. With the regulation of hydraulic pressure, the pressure of copper contact clamp to the clectrode is changed accordingly. Owing to the cylinder is far from the high temperature zone, the electrode holder will work for a long time.

As to the large size furnace, the ovality of electrode may be increased by the enlarged size of electrode. If we still use the cone-shaped ring type holde, insufficient connection of individual copper contact

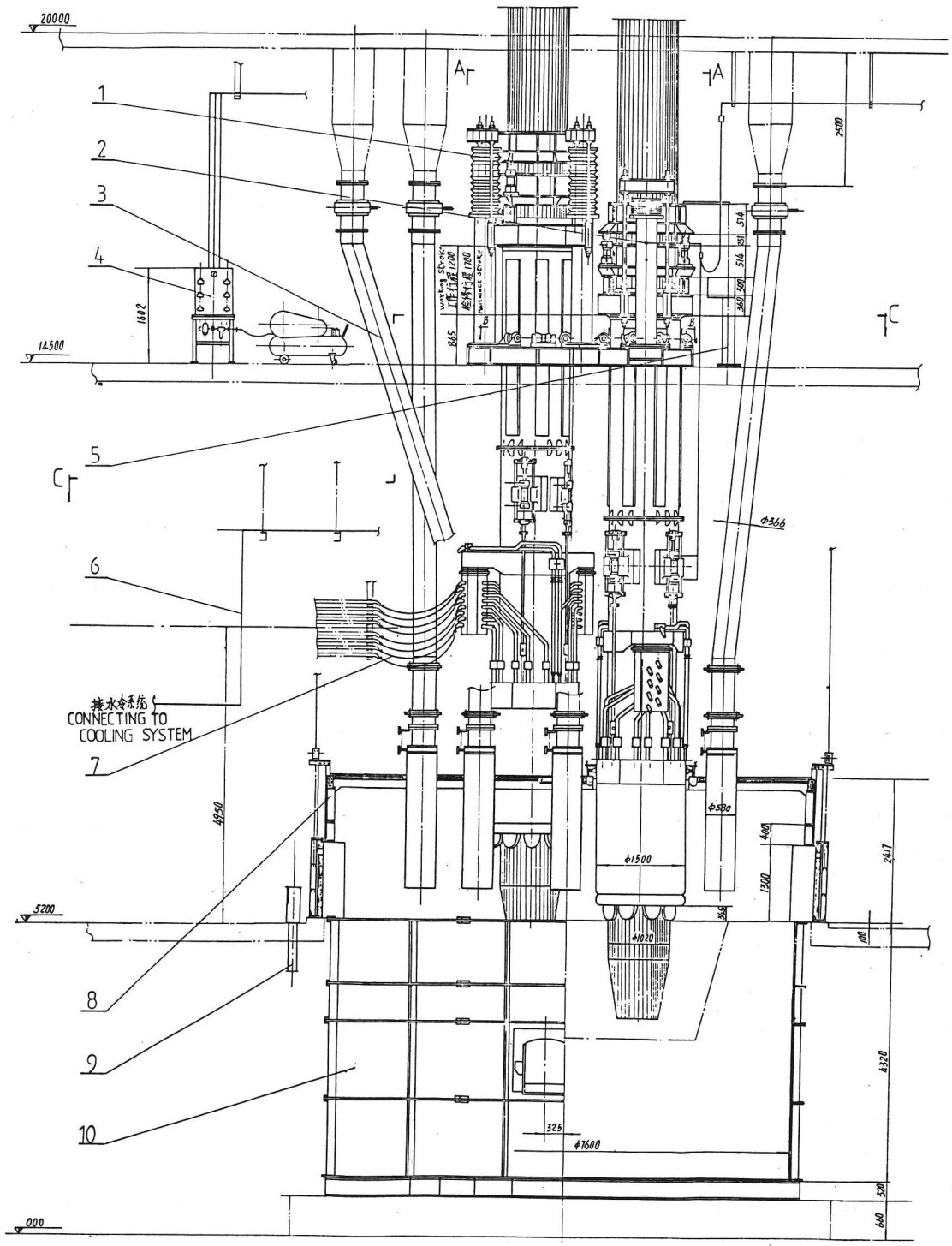

Fig. 1. 1. Electode system 2. hydraulic system 3. Charging system
4. Compressed air system 5. Electrode position indication
6. Elecctrode and charge tube water-cooling system 7. Large current bus bar
8. Fume hood 9. Furnace hood water-cooling system 10. Furnace shell

clamp will be occurred. Therefore, for the large furnace we will adopt the design of each contact clamp with individual pressing gunit to ensure better power transmintting to the eldectrode.

3. 2 FURNACE COVER AND HOOD

During smelting of ferrosilicon, a great amount of fume is geneated along with the reaction of SiO, resulting in calcining on the burden surface.
It is known that the permeability will effect on the normal operation of the furnace. Sequentially, the requirement to the burden surface shall be very high. For instance, furnace door operation like furnace ramming and burden pushing are required frequently. In that case, the semi-enclosed type furnace is recommended for production of ferrosilicon. As to the high carbon ferromanganese, MnSi alloy and high carbon ferrochromium, they are capable to be produced in the enclosed furnace in case the burden conditin is appropriate. However, if fine ore is in high percentage or with high moisture, then they may only be produced in the semi-enclosed type furnace. The semi-enclosed type furnace is equipped with a hood with operating door over the furnace and the enclosed type furnace is equipped with a furnace cover over the furnace. The furnace hood may be of round shape or polygon shape consisting of side wall, frame and top plate.
The side wall is laid with refractory and the steel frame and top plate are water cooled and painted by refractory inside. Three lifting doors are equipped in the side walls for operatioon of furnace ramming and burden pushing. Needless to say, sometimes, the auxiliary material are charged from these lifting doors, If possible, three small doors may be equipped opposite the electrode so as to meet some special operation requirement.
At the top plate of the hood, there are three holes for electrode, two holes for fume exhausting and some holes for charging pipe accessing. In order to prevent the fume scattered, the air curtain is installed at the furnace door for the large and medium size furnace. The refractory laid inside the hood may protect the steel structure free from the local overheat and/or burn out so as to ensure the long service life of the furnace.
The enclosed type furnace cover with function of to provent the furnace fume (with 60 to 80% of CO) burning is consisting of water cooling frame, water cooling cover and refractory cover. Three elecrtrode holes, one vent hole and some charging pipe holes as well as the anti-explosion hole are set on the cover, All seam should be sealed by stuffing to avoid the air breathing in or the fume breathing out.
The water cooling frame and steel cover are laid with refractory for prolong their service life. It was proved by the practice, that this type of furnace cover are able to work under the pressure of 50 Pa.

3. 3 CHARGING SYSTEM

The furnace charging system is consisting of storing bins. discharging pipe and its extension end inserted into the furnace. Each pipe is equipped with the gates or feeder for controling the charging speed or charging quantity and for the requirement of maintenance. As to the semi-enclosed type furnace, the lower part may be opened for furnace ramming and burden pushing. Moreover, a certain amount of air shall be breathed in to avoid the fume breathing out from the burden pipe. The type and location of the charging gate is the key technical points for the semi-enclosed type furnace.
The main technology for charging system of enclosed type furnace are the location and type of the pipe extension end. Owing to the whole pipe is full with burden, therefore, the locations and type of the pipe extension end will govern the profile of burden surface and the exhausting routing of the reaction gas. As a result, the inner furnace heat exchange and reaction as well as the operation performance are affected. We are proud to say CERIS have rich experience on the charging system design.

3. 4 LARGE CURRENT BUS BAR

The furnace large current bus bar includes the water cooling bus tubes, water cooling cables and the feeding copper tube to supply the power to the copper contact clamps. Two direction arrangement is adopted for water cooling copper bus tubes. Isolating measures are taken to the copper tubes of the same phases and different phases. The good isolation will ensure the safe operation of the furnace.
The water cooling cable is used to connect the bus

tubes end and the copper tube on the copper contact clamps. This type connection will realize the principle of one feeding line from the transformer connecting to one copper contact clamp so as to prevent the problem of uneven current distribution basically.

With regard to the arrangement of water cooling cables. the attention should be paid to the point of avoiding to connect the copper circuit where smaller value of inductance/reactance are involved, to the bus tubes, where inductance and reactance value are larger usually. As a result, the unbalance of inductance and reactance shall be minimized.

The kind of large current bus bar structure has advantages of to ensure no unbalance on the current distribution and avoid the circuit overheat or burning out by the current unbalance. Meanwhile, these bus bar will minimize the bolt connecting points and minimize the connecting resistance. Comparing with the traditional bus bar, it has advantages of larger reliance, saving on copper material and minimize the eccentric current to be occurred. In addition, water supply and power supply to the electrode in one unit will simplify the piping arrangement, hence to save a lot of steel and let larger space is available over the hood resulting in beneficial to the maintenance.

3. 5 POWER AUTO-REGULATING DEVICE

The powere auto-regulation device may be installed for the furnace with higher automation requirement, The power auto-regulating device for submerged arc furnce not only higher control precision and stability, but less number of eletrode action and ideal electrode speed responsibility. We would say CERIS designed power auto-regulating device is able to work under either constant current or constant resistance. When the furnace is operated under constant current, the furnace is controlled by the difference between actual current and the preset value. On the contrary, when the furnace is operated under constant resistance, the furnace is controlled by the difference between measured resistance and the preset value. One should bear in mind that the prerequisite is to measure the actual phase voltage and actual current to the electrode so as to reflect the actual furnace situation.

The zero line installed under the furnace bottom will provide the better condition for measuring the real of phase voltage. The current transformer shall be installed on the appropriate location for obtaining the electrode current. Under the condition of available real phase voltage and current. the power auto-regulating shoukd be realized along with the appropriate software.

In the submerged arc furnace supplied to the Philippines, the power auto-regulating device is operated under constant current. The result is that the electrode will ascend 0. 35 times per minute and descend 0. 32 times per minute. In other words, the control precision, i. e. the difference between the actual value and preset value within 5% meeting the requirement of ferrosilicon production is realized. After installation of the power auto-regulating device, the furnace is capable to introduce larger power and improve the labor intensity.

3. 6 INSTRUMENTATION

In order to let the submerged arc furnace to be operated free of trouble, the furnace should be equipped with instruments with following functions.

1) Measuring and control to the inlet/outlet temperature and pressure of cooling water system.

2) Measuring and display on the electrode position.

3) Measuring of lining and fume temperature.

4) PC system for the furnace control and record.

4 CONCLUSION

During 1985 to 1990, the domestic ferroalloy market is very firm and the domestic power tariff is relative lower and not so harsh terms on the environmental protection. A number of new furnaces or new plants were mushroomed. For example, the ferroalloy plant in Datong, Emei, Tianjin, Jiangyin, Danjiangkou, Zunyi and Guizhou Qingzhen installed the furnace with capacity of 6MVA, 12. 5MVA respectively to produce ferrosilicon, MnSi alloy and high carbon ferrochromium. Moreover, we have exported totaling 5 sets of 12. 5MVA furnaces to Metro Alloy of Philippines and Faryab Mining Co.

of Iran, where CERIS has undertaken the plant engineering work and design of furnace equipment. The normal operation from these plants and furnaces were reported after commissioning. Needless to say that except CERIS, other engineering companies, research institutes and ferroalloy producers had contributed their effort to the design of submerged arc furnace and its auxiliary equipment. We would like to say that in the field of small and medium size submerged arc furnace, China has owned and improved their technology for the modernized furnace or for the furnace with lower installation level. We are now developing the large size submerged arc furnace and their relating technology. It is expected that in the near future, we are able to provide much more and better equipment and technology for the ferroalloy production.