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YUNNAN COPPER CORPORATION'S NEW SMELTER

CHINA'S FIRST ISASMELT™

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Abstract

In 1999 Yunnan Copper Corporation (YCC) decided to modernise their copper smelter and change the existing sinter plant / electric furnace process to a combination of ISASMELT[i] and electric slag cleaning furnace. The main aim of the project was to improve the environmental performance and decrease energy consumption.

Generally the project has been successful, partly attributable to the selection of a reliable and fully demonstrated technology. The design capacity for the ISASMELT furnace is 600,000 tonnes of dry copper concentrate per year. The furnace has been running smoothly since heatup in May 2002. YCC expended considerable effort in the preparation for plant operation. An extensive training program for key YCC personnel at the Mount Isa Copper Smelter improved their understanding of the process significantly and ensured successful hand-over of the technology. This paper describes the project history and summarizes initial operating results.

Introduction

The Chinese metallurgical industry is facing a number of challenges as it enters the twenty first century. First there is a desire to increase industrial efficiency and this is starting to be achieved through the privatization of state owned companies. Secondly the government is committed to reducing the impact of heavy industry on the environment. It is therefore encouraging those companies that are selected for privatization to modernize the existing metallurgical complexes, replacing outdated technology with modern technologies, either developed within China or imported from overseas. YCC is one company that chose to import new smelting technology from outside China.

Yunnan Copper Corporation

The YCC copper smelter is located in the Western Hills District of Kunming, Yunnan Province, China. It is a company with 44 years of copper manufacturing history. Annual production is 200,000 tonnes of high purity copper cathode, 450,000 tonnes of sulfuric acid, 200 tonnes of silver, 2 tonnes of gold and 60,000 tonnes of copper rod for use in electrical applications. YCC was listed on the stock market on June 2, 1998, and was subsequently selected to be part of the American Dow Jones Composite Index on April 1, 1999 and to be part of the Shenzheng Composite Index on October 8, 1999.

[i] ISASMELT™ is a registered trademark of Xstrata Technology

Prior to listing on the stock market a smelter modernization project was started. Process modifications were identified and evaluated from 1993 to 1996 with the aim of saving energy and improving the environmental performance of the plant. The ISASMELT process was identified as the most suitable process for the upgrade and work related to process selection was completed during 1997-1998 culminating in the signing of an ISASMELT copper smelting technology licence agreement with MIM Process Technologies (MIMPT) on March 21, 1999. The project Kick-Off Meeting was held from September 28 to October 8, 1999. Construction and equipment installation began in 2001. The furnace heat up commenced on May 9, 2002 and feeding of raw material commenced on May 15. From the start of production to September 30, 2002, production availability was 75.8%, or 87.1% once scheduled shutdowns and shutdowns attributable to other plant areas were allowed for. A successful start-up was achieved from day one.

ISASMELT Process

The copper ISASMELT process used at YCC is a bath smelting process developed by Mount Isa Mines in Australia over approximately 20 years. The process has been described in a number of technical publications.[1-7] Oxygen enriched air passes down the specially designed lance into the molten slag, producing a highly turbulent bath that expedites chemical reactions and uses the heat produced by oxidation of sulfur and iron contained in concentrate for smelting, producing a high grade matte and a fayalite slag. Coal is used as additional fuel if the heat of reaction from the concentrate is insufficient to maintain the heat balance.

The design capacity of the YCC ISASMELT furnace is 600,000 tonnes of dry concentrate per year. The process flowsheet for the plant is shown schematically in Figure 1. A number of different concentrates, mostly from mines within China, are blended with flux in a blending plant. The majority of the coal required for the process is added to the blended mix after it has passed through a squirrel cage crusher to remove large lumps. This feed mix is pelletised on up to four disc pelletisers. A further small amount of coal and silica is added to the pelletised mix before it is fed into the ISASMELT furnace. Oxygen enriched air is injected into the bath through the ISASMELT lance. Oil is also added through the lance to fine tune the bath temperature. The molten slag-matte mixture produced by smelting is tapped intermittently from the ISASMELT furnace into an electric settling furnace. The slag and matte separate by gravity in the settling furnace. Matte is subsequently transferred to Peirce-Smith converters for further processing. Slag is granulated and removed for disposal. The process offgas is directed to a sulfuric acid plant after passing through a waste heat boiler and electrostatic precipitator to lower its temperature and remove the dust. The dust collected in the waste heat boiler is crushed and returned to the electric furnace. The dust collected in the electrostatic precipitator is conveyed to the electric furnace.

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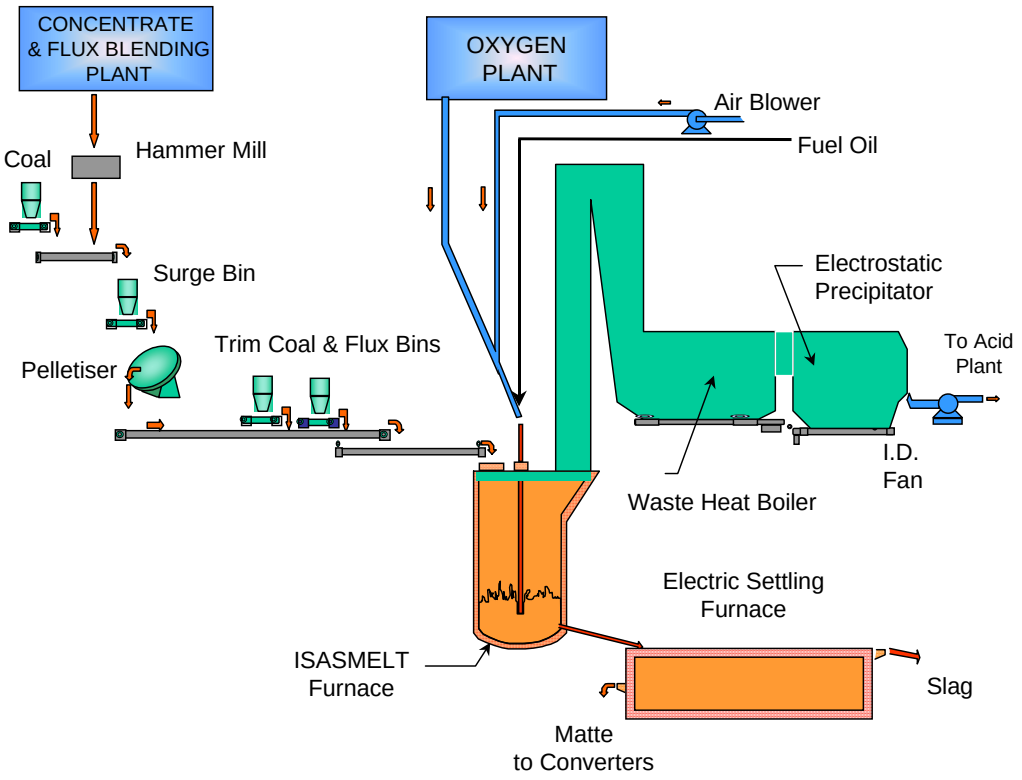

Figure 1: Process flowsheet

Engineering and Construction Management

The modernization project commenced in early 1999. YCC had a number of associated plant modifications in addition to the ISASMELT plant itself. In order to coordinate direction and speed up plant construction, YCC divided the project into four project areas according to the various fields they belonged to: smelting, sulfuric acid, oxygen production and power.

In smelting the main focus was the ISASMELT Furnace. MIMPT was responsible for the basic design of the ISASMELT plant and related interface design, as well as the detailed design of the core items associated with the ISASMELT Furnace. Oschatz from Germany was responsible for the design of the Waste Heat Boiler associated with the ISASMELT Furnace, while the remaining engineering design was undertaken by the Beijing Engineering & Research Institute for Non-ferrous Metallurgy (ENFI). YCC coordinated the design work of all parties. The engineering design was essentially complete following the basic engineering review meeting held in April 2000 in Brisbane and the detailed engineering review meeting held in August 2000 in Kunming.

Project construction was executed by local Chinese construction companies. The piles of the ISASMELT Furnace main building were installed by Kunming Non-ferrous Foundation Engineering Company, and the piles foundation test was performed by the Science and Technology Development Company of Kunming Prospecting Institute. The ISASMELT Furnace foundation and related civil work was completed by No. 14 Metallurgical Construction Company.

Yunnan No.1 installation company was the contractor for the ISASMELT Furnace installation, their work including manufacturing of the furnace shell, ISASMELT building steelwork, ISASMELT furnace system equipment, piping work, electrical components and instrumentation. This work was effectively complete by March 2002. The ISASMELT furnace bricking was completed by the No. 14 Metallurgical Bricking Company under the supervision of site service personnel from RHI Refractories of Austria. Anti-corrosion work was undertaken by Yunnan Smelter Construction Company in April 2002. It included sand-blasting for rust removal, followed by application of chlorinated rubber primer and surface coating.

Subsidiary projects that related to the ISASMELT furnace system included the smelting vessel itself, feed preparation, control room and staff facilities, emergency flux and coal bins, lance and lance handling equipment, heat up burner, holding burner, dip bar, clay gun and tapping machine, molten matte and slag tapping area, air conditioning systems (slight positive pressure ventilation), hygiene ventilation systems (pollution-free venting), reverts handling, pulverized coal, brick unloading, after-burning air, air and oxygen piping, oil piping, cooling water circulation, plant water and potable water supply and draining, cranes and personnel elevator.

The projects related to the waste heat boiler system included the waste heat boiler, boiler water supply, forced circulation, natural circulation, steam piping, emergency cooling, drag chain conveyors (dust removal), crusher, dust conveying, offgas discharge and heat preservation.

Further projects included electrical power supply, instrumentation, ISASMELT Distributed Control System (DCS) and waste heat boiler DCS, and building structures.

Plant Design

As with any “brown field” project, the construction of the plant resulted in a number of unique challenges, because of the location. The ISASMELT furnace and waste heat boiler had to be installed in a very restricted area surrounded by existing plant facilities. It was necessary to construct the furnace adjacent to the existing electric furnace, so that it could be used as a settling furnace once the new plant started operation. The available space was restricted by the converter aisle on one side and the electric furnace offgas bag filter on the other. One of the advantages of the ISASMELT process is that it could be constructed within such a confined space. Figure 2 shows the limited space available for the plant once unnecessary buildings and equipment had been demolished.

Figure 2: Plant site

Construction was made more complicated by the fact that Kunming is in an earthquake prone region, and as a result the foundations had to be designed with particular care. MIMPT provided data on the static and dynamic loads that would be expected during operation and the foundation and furnace support were designed based on that data.

Feed mix was brought to the plant from the existing feed preparation plant that had previously been used for feeding the sinter plant. A new conveyor bridge was constructed to the ISASMELT building. The ISASMELT Furnace is located as close as possible to the electric furnace and two tapholes and two launders are used for tapping the molten products. The waste heat boiler is installed on the opposite side of the furnace. The boiler comprises a radiation section, with uptake above the furnace offgas outlet and downcomer, followed by a convection section. A new duct was installed to convey the cooled gases to a pair of existing electrostatic precipitators, that were upgraded for use with the new plant.

The ISASMELT Furnace has an internal diameter of 4.4 metres. It is lined with high quality chrome-magnesite refractory bricks. The roof of the furnace is made of boiler tube and forms part of the waste heat boiler. The ISASMELT lance has a diameter of 400mm and is lowered and raised in the furnace on a specially designed lance carriage. Figure 3 shows an elevation of the ISASMELT building.

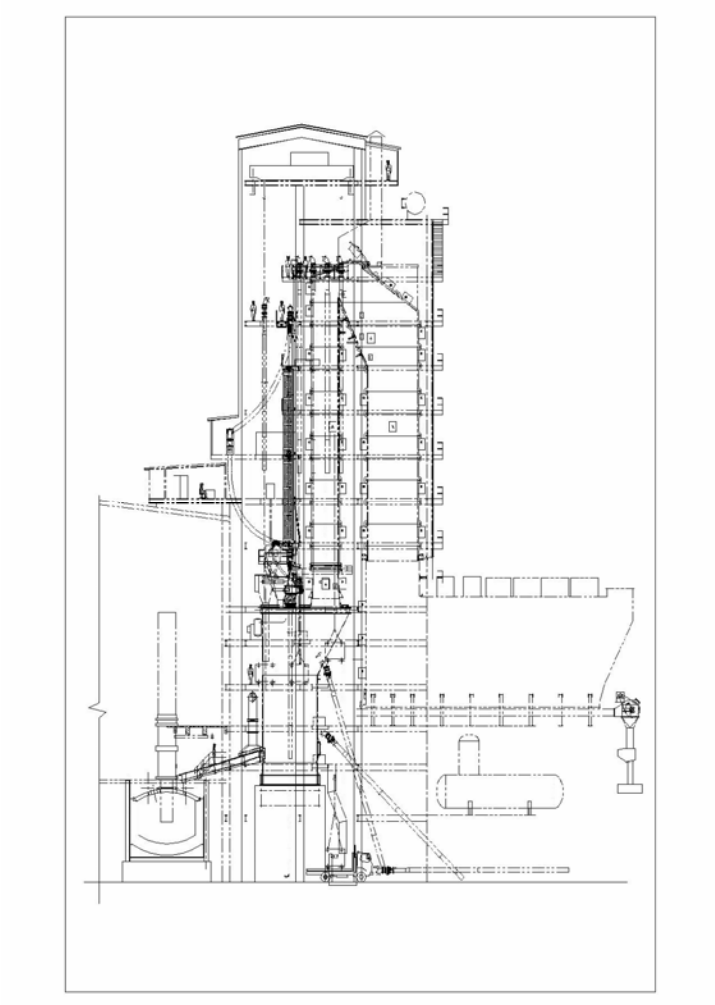

Figure 3: ISASMELT building elevation

Preparation for Production

An ISASMELT process team was established in 1998 to commence preparation for production. This group participated in selection of the best technical solution for the YCC upgrade. Additional technical personnel joined the team to prepare for the procurement of equipment, plant installation and plant commissioning. YCC set up a special management team for preparation of production, with the task of coordinating all work around the ISASMELT plant. One key issue that was identified was that effective training and preparation of personnel would be the most important means for minimising risks to the project and future production. YCC management therefore decided to accept MIMPT's proposal for an extensive training program to take place at the Mount Isa Mines copper smelter.

Personnel Training

An ISASMELT process team was established in 1998 comprising metallurgical engineers who concentrated on learning about the ISASMELT process. They gave instructions to the staff of

the existing smelting plant on ISASMELT process principles from 1999 to 2001. The total tuition time was about 430 hours with about 200 smelting plant employees being involved. YCC management then chose a group of reserve staff for the heatup of the ISASMELT Furnace based on the competency demonstrated.

YCC management used a more detailed selection process for nominating metallurgical, electrical, instrumentation and mechanical engineers, control room operators and tapping operators who would go to Mount Isa for training. The successful candidates gained further profound understanding of the ISASMELT process, equipment, safety and related management issues during the training program in Mount Isa. This training, arranged and supervised by MIMPT, took place over a 7-month period during 2001. Tutorial sessions were held on a wide range of issues and the trainees gained extensive “hands-on” experience as part of the regular shift crews. By the end of their training on the Mount Isa plant, YCC personnel were able to operate the ISASMELT Furnace under supervision of MIMPT staff. They were then ready to put the theoretical and practical training into practice on their own plant.

Figure 4: YCC training in Mount Isa

On their return from Mount Isa to Kunming, new operations personnel from the reserve staff were recruited for heating up and operation of the ISASMELT plant. Further training occurred on site and all reserve persons joined in the installation and commissioning of equipment in order to become as familiar as possible with the equipment before heat up.

Personnel training also occurred on the waste heat boiler. Thirteen staff took part in the training during 2000. Engineers and operators participated in the installation, inspection and commissioning.

The end result demonstrated that YCC reaped many benefits from this comprehensive training program.

Compilation of Operating Procedures

The compilation of the operating procedures for the ISASMELT plant commenced in May 2001. The related safety and management procedures were compiled in July. The operating procedures were translated for MIMPT personnel to review. After modification according to MIMPT's recommendations, YCC organized new training sessions based on the modified procedures to unify the understanding of operations personnel.

Risk Analysis, Planning and Training

YCC analysed the predicted list of possible risks during heating up and production in the ISASMELT plant based on questions that had arisen during preparation from January to February in 2001. The final HAZOP and risk analysis plan was completed with the assistance of MIMPT site service engineers and was distributed to all operators.

Preparation of Equipment Inspection Sheets

Inspection sheets were prepared for everyday running and maintenance indicating the inspection requirement for equipment.

- The requirements of inspection content, range and method
- The requirements for inspection personnel and training
- The requirements for inspection frequency
- The requirements for recording and handling

Participation in Installation and Commissioning

YCC set up teams to monitor progress on site for specific disciplines such as process engineering, mechanical engineering, instrument and control engineering, electrical engineering, thermal engineering, and water reticulation systems. Their tasks included learning about the plant and process, inspecting, feedback, presentation of proposals and recording of progress.

The inspections were divided into two steps. The team members carried out the first pass inspection. The team leader carried out the second inspection or so-called general inspection. If there were any problems different groups became involved. Related groups exchanged ideas, cooperated and found solutions to complex problems.

To minimize the impact of the language barrier on project progress YCC established a special translation group to complete translation work parallel to the establishment of the project. Two groups of ten young employees received English tuition during 2000 and 2001. These employees became the site interpreters, having dual roles of engineer and interpreter. This initiative decreased the difficulties arising from the language barrier.

Cold Commissioning and Modifications Required Based on Problems Encountered

YCC's strategy for commissioning was that the startup should occur smoothly and efficiently, all items should be commissioned completely and hot commissioning should lead to stable operation as quickly as possible. Commissioning represented the final stage of the long road to implementation of ISASMELT technology at YCC. Issues resolved during the cold commissioning included:

- Some problems on the feed system such as the conveyor belt drift, feeding port blockage, final conveyor belt modification.
- Some problems with imported equipment and their installation such as the tapping machine drill bits that could not drill to the design drilling depth**,** rotation of swivel joints, a malfunctioning load pin and lance replacement difficulties related to dimensional problems with expansion joints.
- Some problems with domestic equipment and their installation such as oil pumps not supplying the required oil flow rate and pressure, and some domestic belts support structure not meeting requirements.
- Modification of items that were not compliant with production and safety requirements such as the relocation of a burst disc and some thermocouples, removal of ramming material under the splash block.
- The number of vents on the lower furnace shell was increased to allow moisture to escape from the refractory lining during furnace heatup.

Preparation of Operating Tools and Equipment

Preparation of operating tools and equipment had commenced at the end of 2001 and included personal protection equipment, tapping floor material and tools, other special tools, production material, spare parts, stationery, and rain and dust protection equipment.

Figure 5: YCC ISASMELT plant

Heatup and Commissioning

Arrival of MIM Operations Personnel

A team of experienced operations personnel from the Mount Isa Mines copper smelter arrived at YCC site just prior to furnace heat up. These specialists assisted YCC personnel on shift roster throughout the first weeks of operation of the plant. In accordance with YCC's requirements, the MIM personnel assumed an observation role, allowing YCC personnel to take charge of the operation, and only stepping in to assist when necessary.

Preparing the Heatup Schedule

YCC sent the primary heat up and production schedule to MIMPT for review in March 2002 and then modified it based on MIMPT's suggestions. Further amendments occurred to the heat up program through discussion between MIMPT site service engineers and YCC. A layer of granulated slag was placed in the base of the furnace. Initial heating occurred with a wood fire together with an oil-fired heat up burner, with subsequent secondary heating by holding burner. This method allowed precise control of refractory temperature through the critical range up to

operating temperature. Temperature monitoring allowed confirmation of the heat up curve and heat up speed, with recording of heatup data on spreadsheet software.

Start of Shift Operation

YCC decided to adopt a 12 hour shift roster for the commissioning period, similar to that practised at the Mount Isa copper smelter. Personnel were appointed to the shift work crews, including foremen and control room operators. All of the foremen, main control room operators and some of the tapping floor operators had been to Mount Isa for training. The shift crews commenced shift work one month in advance of furnace heat up.

Issue and Performance of Safety Regulations Around ISASMELT Plant

YCC set up special safety regulations for the ISASMELT plant at YCC based on safety regulations supplied by MIMPT. These regulations included executing the requirement for wearing personal protection equipment, danger tagging, label usage and field isolation regulation for controlling the production area.

Management of Heatup of ISASMELT Furnace

According to the heating up schedule team members inspected the heat up progress around the ISASMELT plant. Each member reported progress to his supervisor. The management team was responsible for general coordination and control.

Initial Production Data

Following heat up the plant quickly increased production to satisfactory levels. During initial operation the furnace operated in parallel to the existing sinter plant, and the matte grade was maintained at lower levels to allow converter operations to gradually become used to operating with the higher matte grades. Once YCC felt satisfied that the new ISASMELT furnace was operating stably the sinter feed to the electric furnace was stopped and the new plant increased throughput up to design capacity.

Table 1 summarizes key operating data for the first few months of operation. The data demonstrate the speed at which the process came under control, with operation stabilizing as plant personnel became more familiar with the process.

Table I – Key operating data

Month (2002)	May	June	July	August	September
Average Feed Rate (dry t/h)	61.8	70.6	70.3	61.9	58.8
Average Oil Consumption (L/d)	7,184	4,285	2,016	2,078	1,846
Average Matte Grade	48.4	55.7	64.3	60.1	58.6
Average SiO_2:Fe	0.98	0.84	0.88	0.88	0.92
Average Lance Life (days)	1.4	2.0	3.7	6.6	10.5

Commissioning Problems

As with any new plant, a number of problems occurred during plant commissioning. The main problems, and the respective solutions, are described briefly below.

Heatup Burner

A heatup burner was used for the initial heat up of the furnace from ambient temperature to operating temperatures. This oil-fired burner was capable of very precise control to ensure that the refractory heat up curve could be followed throughout the heating period. During the latter stages of the heatup, however, the burner tip was damaged. YCC shift operators removed the burner from the furnace and the heatup continued using the holding burner. YCC and MIMPT agreed on actions required to ensure the problem would not occur in future heatups.

Lance Operation

During the first few weeks of operation lance life was relatively short and the lances tended to bend during operation. Over time the YCC operators became more experienced with operating the furnace, and as a result the furnace temperature became more stable. Stable operation has reduced lance bending and increased the lance life significantly.

Some problems occurred with the oil nozzles and oil pipes dislocating from the lance body in the first couple of weeks of operation. MIMPT established that the cause was a minor design error that was corrected and the existing lances were modified, thus alleviating the problem.

Feed Surges

Initial problems were encountered with surges in the feed to the ISASMELT Furnace. These feed surges led to difficulties controlling the furnace operation, with wide swings in the air and oxygen rates and resulting variations in the bath temperature. The solution was to enhance the monitoring and control of the feed system and modify the control logic in the DCS.

Refractory Brick Wear

Some refractory bricks were spotted by tapping operators during the first weeks' operation of the furnace. Although this is a normal occurrence with a new lining, as the refractories bed in and exposed corners spall off, operators were nevertheless concerned about ongoing refractory wear. The control room operators therefore focused on lowering the operating temperature and stabilizing the furnace temperature control in line with the operating practice learned at Mount Isa.

Conclusion

The engineering design, construction and commissioning of the first Chinese ISASMELT copper smelter has been carried out smoothly and successfully as a result of the cooperation between YCC and companies inside and outside China including MIMPT, Oschatz and ENFI. YCC has shown that its decision on technology selection was correct. The decision to choose a smelting technology provider with operations experience and to take full advantage of access to the operations at Mount Isa for the extensive training program has paid significant dividends to YCC.

This novel bath smelting technology has been implemented successfully at YCC, with stable operation achieved within the first five months of production. YCC looks forward to a secure future, in the knowledge that it is set to take full advantage of this efficient, modern smelting technology.

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