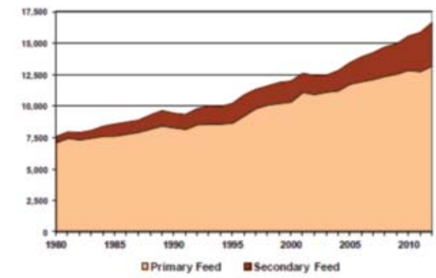
New copper smelters boost capacity to meet demand

Amongst the newest primary copper smelters in the world are the Jinchuan Fangcheng 400,000 t Cu/year plant in Guanxi Province in Southern China (commenced operations in November 2013) and the Kazzinc smelter in Kazakhstan (commenced operations in July 2011). Dr Phillip Mackey takes a detailed look.

The two technologies employed at these plants are the leading copper smelting technologies in the world today - Outotec flash technology for the custom smelter at Fangcheng and ISASMELT™ at Kazzinc - a captive smelter treating polymetallic concentrate from the local Kazzinc mines. Together with the Mitsubishi Process, Ausmelt, the Noranda and El Teniente Processes, these represent the main technologies in use around the world today. The newly emerging SKS process in China is now making inroads as a competing technology, and this process is already producing significant tonnages of copper in China. This article provides an update on copper smelting technologies in 2014.



Source: ICSG, 2014
Figure 1 – World copper smelter production, 1976 to 2012

World copper smelter production was 16.7 Mt of copper in 2012, with 13.5 Mt produced from primary concentrates and the balance - 3.2 Mt - produced from secondary scrap copper at smelters, as Figure 1 shows. From a technology perspective, world smelter output is close to being split between flash and bath smelting plants, as illustrated in Figure 2. This provides the distribution of world copper smelter production by the various technologies.

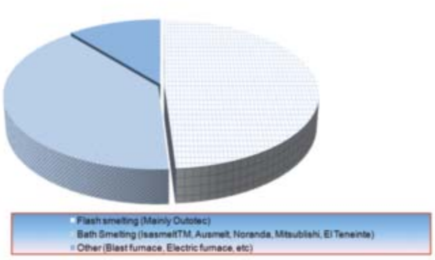


Figure 2 – Proportion of world copper production in 2011 by the three technology groups – flash smelting, bath smelting and other.

The capacity of individual primary smelters varies - from somewhat under 100,000 t of Cu/year up to 800,000 t of Cu/year. The general trend is that more and more copper is now smelted in larger and larger plants. Typically the new larger plants are custom smelters, largely based in China, and generally these are treating 'clean' custom copper concentrate supplied from Chile and Peru. Based on a survey of 60 smelters, it is seen that of this total number, 37 plants or 62 % of plants had capacities of 200,000 t of Cu/yr and above. These 37 plants accounted for about 80 % of copper smelting capacity. Some 12 % of plants, representing about 25 % of smelting capacity, were plants with capacities over 400,000 t of Cu/yr. Plants at or below 100,000 t of Cu/year accounted for only about 4 % of world smelter capacity.

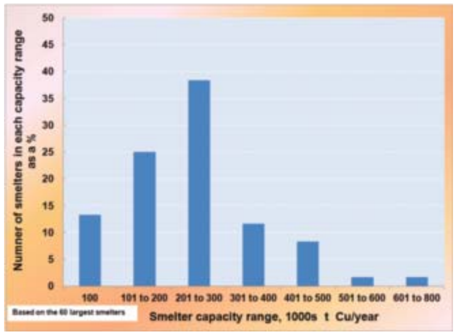


Figure 3- Distribution of the number of world copper smelters as a percent by plant capacity range

Figure 3 shows the distribution of the number of plants given as a percentage of the total number of plants in each capacity range. Interestingly, the new Kazakhstan ISASMELT™ plant, located in Ust-Kamenogorsk, which is home to a multi-smelter metallurgical complex handling a wide range of polymetallic feeds, has a design capacity of 70,000 t of Cu/yr treating a complex copper-lead-zinc concentrate. A schematic diagram of this plant is shown in Figure 4. By contrast, the new, large Tongling complex designed to treat over 1.6 Mt of clean, imported concentrate is illustrated in Figure 5. This plant commenced operations in December 2012.

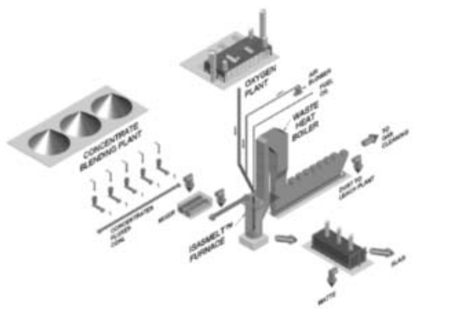


Figure 4 - Schematic diagram of the 70,000 t of Cu/yr ISASMELT™ plant at Kazzinc in Kazakhstan (2)

The even newer Jinchuan Fangcheng plant mentioned above (November 2013) has a similar plant arrangement and capacity as Tongling. These new smelters each had effective start-up programs and reached design capacity corresponding to - and sometimes exceeding - the "Type 1" start-up profile based on the well-known McNulty curves. Smelter technology today has a solid performance record and all new plants have full sulphur capture.

Today's successful smelting technology can be traced back more than 75 years to when flash smelting was first developed and commercialised. It was sometime later that the bath smelting technologies in use today were introduced. At the time of development, all these technologies were well piloted during the initial testing phase, and the first commercial plants were modestly scaled-up from the pilot plant capacity (Figure 1).

Figure 5 – Conceptual view of the new Tongling 400,000 t Cu/year copper smelter and refinery, China

Interestingly, the scale-up from pilot to the first commercial plant in each case was found to be a factor of about 10 for the technologies illustrated in Figure 6. Later, by careful process development, big gains in plant capacity were subsequently achieved in each of these examples, leading to the mega-scale plants seen today. As an example, within less than eight years of start-up, the ISASMELT plant at Mt. Isa Australia had doubled capacity. This trend continues today, and the technology can now achieve smelting rates in excess of 170 tonnes concentrate/hr.

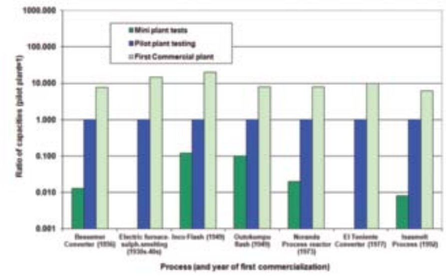


Figure 6 – Relative capacity of the first commercial plant for a number of processes (Right hand bar for each process) compared to the nominal capacity = 1 (middle bar) of the main pilot plant used in development, and that for the initial mini plant used in laboratory test work (left hand bar).

Under development since the early 1990s, the SKS technology in China now boasts three operating plants in China, with at least four new plants presently under design (Figure 7). There is also one SKS plant in Vietnam. Inspired in part by the well-known Noranda and El Teniente vessels and using special high pressure shrouded tuyeres (somewhat akin to the Savard-Lee Canadian injectors), the SKS process represents the newest copper smelting technology in the world. The

Figure 7 – The SKS reactor vessel (4.4 m diameter by 16.5 m long) at the Dongying copper smelter in China.

present SKS plants in China are relatively small by world standards, but plans include design tonnages of over one million tonnes of concentrate per year for a single unit.

The smelting mechanisms in flash and bath smelting are different - and this can influence one way or another the ancillary aspects such as dust make, slag chemistry, off-gas volumes and so on. In flash smelting, bone dry concentrate plus the required amounts of flux and any finely ground reverts are injected into the vertical reaction shaft through the concentrate burner, along with highly oxygenated air. Sulphide particles quickly react with the oxidising gases producing smelting heat. The reacted particles fall to the furnace hearth where the process is completed with separation of matte and slag. Upon tapping, typically this slag is slow cooled and milled for copper recovery. The off gases are cooled in a waste heat boiler, cleaned and treated in the acid plant. The tapped matte is converted to copper.

On the other hand, in bath smelting, filter cake concentrate, flux and reverts are introduced to the surface of the slag bath where due to the stirring action of the injected gases, smelting occurs within the bath. In the Top Smelting Lance system, typified by the ISASMELT™, reaction gases are introduced via the top mounted lance. In the Noranda and El Teniente vessels, oxygen enriched air is introduced via submerged tuyeres. Cooled and cleaned off-gas is treated in the sulphuric acid plant in each case. Smelting slags are treated either by slow cooling and milling, or by cleaning in an electric furnace. The tapped matte in each case is converted to copper.

A variation of this provides for submerged injection of bone dry concentrate through submerged tuyeres as in the continuous smelting reactor at Altonorte in Chile. Lance injection of bone dry concentrate is employed in the Mitsubishi process.

Converting

At the present time, the Peirce-Smith converter remains the dominant technology for copper matte converting. A typical large plant today producing over 300,000 t of Cu/year with matte grades in the range of 60 to 68 % Cu would operate four Peirce-Smith converters (typically sized approximately 4.5 m dia. by 13.4 m long). There would be two vessels blowing at any one time. Modern multi-stage hooding captures all process and fugitive gases. The new Kazzinc plant noted above employs two Peirce-Smith converters treating about 400 to 450 tonnes/day of 55-58 % Cu matte. The three new flash furnace plants in China treating custom feed - Xiangguang Copper, Tongling Jinguan and Jinchuan Fangcheng – each utilise a single Kennecott-Outotec flash converting furnace for converting.

Environmental aspects

The environmental performance is a key factor influencing the choice of smelter technology. All modern technologies reach high standards, and each of the flash and bath technologies discussed above have demonstrated that a very high environmental performance can be achieved. Complete environmental performance data on the SKS plants is not yet available, hence it is difficult to do a detailed assessment, however it is expected that performance should match that of other technologies.

The important environmental parameters to be considered are the following:

- Low plant gaseous and particulate emissions (process and fugitive emissions)
- Low effluent discharge levels
- High sulphur fixation
- Low noise levels.

These are considered plant wide parameters and as such apply to all areas of the plant, not only as related to the smelting unit itself, including areas such as the converters, anode furnaces, slag treatment and acid plant, as well as auxiliary plant functions such as the oxygen plant. Control of fugitive emissions requires expert design of hooding, ducting and related equipment, and perfection of such designs can often take some time.

Energy requirements

In former times, when the large, fuel-fired reverberatory furnace dominated copper smelter production, large amounts of fossil fuel were consumed in the production of copper. Thus a typical reverberatory furnace operated at firing rates of around 4,000 litres of heavy oil per hour. This alone represented a specific energy consumption of the order of 18,000 MJ/tonne of copper. With modern flash and bath smelting technologies operating at high levels of oxygen enrichment, the major energy requirement at a smelter today is electricity, with fossil fuel at a minimum.

The average estimated energy requirement for producing anode copper from concentrate in one of the modern flash or bath smelters is given in the following table. It is seen that relative to the older reverberatory furnace, the fossil fuel requirement alone has dropped by a factor approaching seven times.

Item	Energy requirement
Electricity	917 kWh/t of anode copper
Fossil Fuel	2,712 MJ/t of anode copper

Note: The electricity requirement corresponds to 8,690 MJ/t anode copper assuming a fuel-fired power plant at 38 % efficiency

Table 1. Energy requirements in modern copper smelting processes

Future demand

Future copper demand is seen as increasing, driven in large part by growth in Asian markets. World demand for refined copper from all sources is expected to grow to just under 30 Mt per year by 2025, or roughly by three-quarters of a million tonnes of copper each year on average. Meeting this growth rate would require at least one new 400,000 t of Cu/year smelter each year. Modern copper smelting technology - whether by flash or bath processes - is well able to meet future demands with energy efficient, environmentally safe plants.

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