Smelting

Smelting is the process of reducing mineral ores and concentrates to metal. Most methods involve heating the ore/concentrates with carbon to effect reduction with additional refining to produce metal in a high state of purity ready for sale.

Tin ore (cassiterite) is relatively easy to reduce to metal. Evidence of very early smelting suggests that the process was carried out in a simple furnace, often no more than a shallow pit dug into the ground. Here the tin ore was added to a charcoal fuelled fire, perhaps assisted by a blast of air from a bellows, and reduced to metal This collected on the floor of the furnace, and when cool, recovered from the ashes.

Out of this very early process developed the “Jews’ House” These furnaces comprised a bowl shaped lower section sunk into the ground between 0.5-1.0 metres in diameter and made from clay and stone. A dome shaped structure with an opening at the top covered the furnace. A passage communicated with the lower section that was either positioned to funnel the prevailing wind or to convey a blast of air from a bellows to assist burning. The ‘black tin’ concentrate was added to burning charcoal in the furnace, and as the temperature increased, was reduced to tin metal. The molten metal collected in the lower part of the furnace or may have been discharged via a small opening to flow into a mould to cool and solidify.

By the 14th century the ‘blowing house’ was well established as the means of smelting tin concentrates. The blowing house furnace or ‘castle’ was constructed from granite blocks tied together with iron rods and cemented with clay. It measured about 6-9 ft in height and about 4 ft square, the interior chamber was clay lined and took the form of a double cone, the lower section tapered downward to a sloping floor that communicated, via a channel, with a stone trough, called the ‘float’, situated at the base of the exterior of the furnace. The upper section tapered towards a chimney flue. A large piece of wrought iron called the Hearth-Eye was fitted in the furnace wall about ten inches above the level of the floor. The nozzles of two large bellows (driven by a waterwheel) were fixed to the hearth eye so that a blast of air was directed into the lower part of the furnace. The furnace was filled via a charging door near the top.

The furnace was filled with alternating layers of charcoal and tin concentrate and ignited. The blast of air from the bellows raised the temperature of the burning charcoal to over 1000 degrees centigrade reducing the cassiterite to metal. The molten tin collected at the bottom of the furnace and flowed to the float. Most of the cassiterite smelted in the blowing houses came from alluvial deposits and was mostly free of contaminating metals and required no further refining, thus the tin from the float was ladled into smaller moulds to cool and solidify ready for sale.

If further refining was necessary the tin from the float was ladled into an iron cauldron or ‘kettle’ with a small fire burning beneath to keep the tin molten. Two or three large pieces of charcoal were soaked in water and pushed beneath the surface of the molten tin. The water absorbed in the charcoal instantly boiled and the steam carried any remaining slag and impurities to the surface as dross. This was skimmed off and the remaining clean tin ladled into moulds to cool and solidify ready for sale.

Blowing houses remained in use from the 14th century to the 19th century; the last one, at St Austell, closed in the 1860's. The later furnaces were constructed from firebrick and the bellows replaced by blowing cylinders (still driven by waterwheels) but they were inefficient and consumed huge amounts of charcoal. One major disadvantage of using a blast of air to force the fire was that the cassiterite concentrate was in a fine state and easily blown out of the furnace by the air blast. Many blowing houses had long sloping flues, often with arresting chambers, to catch the fine cassiterite. It is recorded that the thatched roofs of the early blowing houses were periodically burned to recover cassiterite dust.

The blowing houses were suited to small scale smelting of clean alluvial cassiterite using charcoal. By the 18th century the output of cassiterite from underground was steadily increasing. The cassiterite produced from these mines contained residual iron, arsenic and sulphide minerals and better smelted using a reverbatory furnace.

In 1702 Robert Lydall was granted a patent for the smelting of tin in a reverbatory furnace "without the help of bellows". Lydall was probably not the originator of the process as reverbatory furnaces had been used to smelt lead at the end of the 17th century. Lydall took out a second patent in 1705 that specified the use of "Culm and Sea Coal" in a blast furnace to smelt tin. It was the use of culm (anthracite) as a fuel that was the key to the process. The rights to exploit Lydall's patent was taken up by a partnership of merchants led by Francis Moult. Within the year they had acquired a site alongside the Truro River at Newham and built their furnaces.

Pryce, around 1770, described the furnaces as being built from granite blocks bound together with iron plates and tie-bars and lined with brick and fire clay. The furnace was about 6ft long by 3ft wide, the roof of the furnace chamber was arched and extended from a firebox at one and lowered towards the chimney flue at the opposite end. The furnace floor sloped towards a tap hole and was built of firebrick resting on slabs of slate supported by iron bars that spanned the furnace walls. Small iron doors gave access to the firebox and furnace chamber for tending the fire, charging the furnace and rabbling (raking the charge during smelting).

The smelting process commenced with mixing the black tin concentrate with around 20% of 'culm' (clean burning anthracite coal with a high carbon content). A small amount of slaked lime or fluorspar was often added as a flux and the whole mix dampened with water to prevent fine particles being carried away by the draught. The mix or 'charge' was shovelled onto the furnace bed, via the charging door, and levelled out by raking. The furnace doors were sealed and a coal fuelled fire made up in the firebox. As the fire burned the flames swept over the charge on the furnace bed and within two or three hours the whole mass was in a molten state, further amounts of culm were added if needed and the temperature kept up, after about six hours the whole charge had been reduced to tin metal. When ready the furnace was tapped by the withdrawal of the 'clay stopper bar' (a short iron bar embedded in clay blocking the tap hole). The molten tin and slag (known as glass) flowed from the furnace into a stone or cast iron trough (the float) adjacent to the furnace. As the melt cooled the glass solidified on the surface of the tin and was removed.

The residual, still molten, tin was left to stand in the float for some hours and any dross that rose to the surface was skimmed off. Finally the molten tin was ladled into smaller moulds called ‘tappings’ to cool.

At this stage the tin was still in an impure state and needed to be refined. This was done by re-melting or ‘liquating’ the tappings by gently heating them on the bed of second reverbatory furnace. As the tin melted it flowed away from the, semi-solid, contaminating metals that remained on the furnace bed as ‘hardhead’. The molten tin flowed from the furnace to a kettle where it was ‘boiled’ or ‘poled’ by plunging a log of green wood beneath the surface of the molten tin. This produced a rapid stream of steam and gas that erupted from the surface throwing the molten tin into the air as if it were boiling. The contaminating metals were oxidised and rose to the surface as dross. This was removed by skimming the surface, and after several hours when the tin was judged to be pure it was ladled into moulds to cool. The uppermost layer of tin in the kettle, about one third of the total, was the best quality or ‘refined tin’ whilst the layer beneath was slightly inferior and termed ‘block tin’. The remaining tin was of poor, often unmarketable, quality and returned, along with any tin recovered from the slag and dross, for re-smelting.

Over the next two centuries smelting operations were modified and improved. Later furnaces were larger, up to 30ft long and 12 ft wide, with an 8-12 tonne capacity, and built entirely of firebrick. By the 1920’s many furnaces were fuelled by pulverised coal or oil and condensing systems were installed to recover tin lost as ‘fume’. Refining was improved by the introduction of steam injectors in the boiling process.

By the early 19th century the blowing houses were in decline and by the 1860’s most Cornish smelting works used reverbatory furnaces to reduce tin concentrates. Records show over fifty ore smelting works in Cornwall and most towns had one or more smelters. During the 18th and 19th centuries much of the output from the St Just mines was smelted in the Penzance area. The Trereife Smelter was established before 1732 in a valley to the west of Penzance. It was latterly operated R. R. Michell and closed in 1896. On the eastern side of Penzance the Bolitho family operated the Chyandour Smelter. In the 1880’s this was described as the largest smelter in Cornwall with an output of 2,700 tonnes of metal a year. This was the last smelter to operate in west Cornwall being closed by the Consolidated Tin Smelting Co in 1912. Other notable Cornish smelting works included the Williams, Harvey’s Mellanear works at Hayle, The Calenick works at Truro and The Cornish Tin Smelting Co at Sellegan, Carnkie near Redruth.

During the first decades of the 20th century the surviving Cornish smelters were amalgamated. The Cornish Tin Smelting Co at Sellegan, Redruth, became part of Consolidated Tin Smelters Ltd. This holding company also controlled the Eastern Smelting Co, Penang, Williams, Harvey & Co Ltd, owning smelting works at Bootle, near Liverpool and the Penpoll Tin Smelting Co. with substantial interests in N V Hollandsche Metallurgische Bedrijven owning tin smelting works at Arnhem, Holland. Consolidated Tin Smelters marketed their tin as English Lamb and Flag, Cornish, Mellanear and Penpoll. In the 1920’s the Sellegan works was thriving and employed over two hundred people, but by 1932 had closed, being the last smelter to operate in Cornwall. With the closure of the Sellegan works the output from the Cornish mines was smelted by the remaining U K works notably Capper Pass & Sons at Bristol or Williams, Harvey at Bootle.

Copper ores were also smelted in Cornwall. It is recorded, in 1584 that under the guidance of Ulrich Frosse a German master miner copper concentrates from Treworthie were smelted. Later in the same year Frosse was asked to supervise a new smelting furnace at Neath, close to the port of Swansea and the S. Wales coalmines. Frosse took with him experienced men from Cornwall and by 1585 the smelter was fully operational and sourcing copper ore from Cornwall. Copper smelting required large amounts of coal and it proved to be more efficient to ship the ore to S. Wales than to bring the coal to Cornwall, thus by 1600 Copper smelting in Cornwall had ceased.

For much of the 17th century only a small amount of copper was mined in Cornwall but by the end of the century, in 1693, an attempt was made to revive the smelting industry by Sir Clement Clark. The venture was short lived but increased copper production from local mines saw small scale smelting at St Ives just before 1700. By 1710 Gideon Cosier of Perranzabuloe erected a copper-smelting house at Penpol, Phillack, this venture was more successful and remained in business until 1735. Other smelters were built at this time but were mostly unsuccessful. Around 1750 a copper smelter was being operated at Dolcoath, Camborne by Sampson Swaine an engineer with ideas for improved furnace design. Swaine was soon joined by others and formed a partnership with the intention of buying and refining Cornish copper ore, and by 1755 had erected furnaces at Carn Entral, north of Camborne. In 1756 the smelting operation was relocated to a site close to the port of Hayle this greatly reduced the cost of transporting the large amounts of coal need for smelting. Thus the Cornwall Copper Company was born. The smelter thrived for the next sixty years and in the 1820's the business was expanded with the building of an iron foundry. By this time the copper smelter was no longer viable and closed, but the foundry and ancillary business continued and were to survive until 1870. A small town, Copperhouse, grew up around the works and is now part of the present town of Hayle.

From the 18th through to the early 20th centuries most Cornish copper ores were smelted in the S. Wales and Bristol based works, during the late 18th and 19th centuries there was a thriving trade shipping coal to Cornwall and copper ore to S. Wales.

By the time Geevor was producing tin concentrates the Penzance smelters had closed. Much of Geevor's output went to the Williams, Harvey Smelting works at Bootle. The high-grade tin concentrate was packed into lined hesian sacks of 1cwt capacity (latterly 50kg) and sold in 15-ton lots being delivered to the works by road. Williams, Harvey also smelted Nigerian and Bolivian concentrates and Bolivian tin sacks were often returned to Geevor for re-use.

The lower grade concentrates were sent in 15-25 tonne lots, sometimes by rail, but mostly by road to Capper Pass & Sons. They specialised in the smelting of low-grade non-ferrous metal concentrates and were originally located at Bristol. During the 1950's they relocated to Ferriby on Humberside.

The Williams, Harvey works moved from Bootle to Kirkby, south of Liverpool, in the 1960's and continued to smelt Geevor high grade until their closure in the late 1980's. In the last few years of Geevor's operation the high grade concentrate was packed in 50 kg bags (400 bags comprised a 20 tonne lot) and loaded into containers for transportation via road and sea to various, usually Malaysian, smelters. The lower grades continued to be smelted by Capper Pass & Sons at Ferriby - which finally closed in the 1990's.

The small amount of copper concentrates produced at Geevor (around 600 tonnes per year @15% Cu) were stockpiled on the mine and periodically sold in 3000- 5000 tonne lots to various copper smelters (latterly the Outokumpu Works in Finland).

During the 19th and early 20th centuries small scale smelting was attempted on some mines notably Wheal Vor at Helston and, experimentally, at Tolvadden near Camborne, a portable smelter was also developed that could be driven from mine to mine but was not a success.

At Geevor from 1926- 1930 an attempt was made to produce tin metal from low-grade concentrates without smelting. An experimental plant was built to convert cassiterite into tin chloride by heating a mixture of low-grade concentrate and carbon in an atmosphere of hydrogen chloride. The tin chloride was volatilised and collected in a condenser. The solid tin chloride was then dissolved in water and the solution passed to and electrolytic cell where the tin was recovered as metal. The process was problematic and later modified to recover the tin as volatile tin sulphide, this was oxidised to produce a concentrate of clean tin oxide that could be smelted in the normal way. The plant was abandoned in 1930 but some of the processes developed are in use today in modern smelting works to recover tin from low-grade concentrates and slag etc.