INTRODUCTION

Accounts of 15th and 16th century copper metallurgy include references to roasting and matte smelting, refining by oxidation, and final reduction by charcoal. Oxide and carbonate ores were recognized as useful for reaction with copper and iron sulphides, and there was extensive retreatment of slags and fume. In some cases the copper and iron sulphides were separated from the gangue as a first step, but in others there was a preliminary roast. Fluxes capable of forming liquid slags were known under the description of 'stones which melt easily in the fire'. Some copper was produced by repeated 'roasting' of matte, but there are indications that most was made by smelting dead-roasted ore or matte in a shaft furnace with charcoal. Stirring with green wood was practised in order to remove oxygen and produce malleable copper at the end of the oxidation refining operation. Where necessary, silver was removed by alloying with lead and then liquing out the lead-silver alloy. The unit size of charge was a few hundred pounds and refining was carried out on about 250 lb of blister copper. Repeated treatment, depending on the appearance of samples, was necessary for production of satisfactory material. Whilst certain slags must have been rich in copper, there is evidence from Rio Tinto that much of the waste slag contained as little as 0.2%–0.6% Cu.

COPPER IN SOUTH WALES

The earliest reference to copper smelting in Swansea mentions a furnace near the castle in 1479. This was either extremely small or had gone out of use by the time the Mines Royal Society decided to establish a copper smelting works in South Wales in about 1580. This Mines Royal Society was the result of collaboration between German miners and smelters who had come to Britain in 1561 by invitation, to assist in the development of the indigenous copper industry. They had formed the Society of Mineral and Battery Works in 1565 and were smelting copper at Keswick and in Cornwall before coming to South Wales. Grant Francis states that the first furnace was at Melincryddan on the eastern side of Neath, and there is certainly a local tradition that this was so, but later evidence appears to support more firmly the view that the furnaces were at Aberdulais, some two miles up the Neath Valley from the centre of the town. Contemporary correspondence indicates that the scale of operation was large, by the standards of the times, and that a reverberatory furnace was used to smelt about 24 cwt of ore a day. The move to South Wales resulted from a realization of the economies possible if the ore was taken to an area where coal was mined, since several tons of coal were required for the production of one ton of metal. Because of irregular deliveries of ore, this smelter was forced to close after a few years and by about 1580 there was virtually no smelting of copper in Britain.

COPPER IN SWANSEA

The discovery of substantial deposits of copper ore in Cornwall and the abolition of the monopoly of the Society of Mines Royal resulted in a rapid expansion of the British copper industry from about 1680, and smelters were established at Melincryddan in 1695 and at Neath Abbey before 1700. The first copper smelter to be built in Swansea at this time was the Llangafelach works at Landore in 1717, and this was quickly followed by the Swansea Copper Works, on the site of the old Cambrian Pottery, in 1720. The total British production at this time was about 1000 tons a year and by 1750, when it was about 4000 tons, half of this was produced in the Swansea area. At the peak of the Swansea copper industry in about 1890, 90% of the British output came from this area. This concentration and continuing growth over a long period certainly originated in the availability of large quantities of cheap coal of superior burning characteristics. It was assisted by the availability of fireclay and limestone, and especially by the local development of high-quality 'Dinas' silica bricks from about 1790 onward, but the principal reason was the development of the Welsh process of smelting, whereby a high efficiency of metal recovery was combined with large capacity and less use of fuel than was previously the case. Viewed from the present day, it can be seen as a synthesis of the principles established at least two centuries earlier, with those of counter-current operation and utilization of chemical information which are still being developed in contemporary smelting.

THE WELSH PROCESS

This process was normally carried out in six stages, all of which were intended to remove impurities by oxidation. In two of the stages solid material was exposed to air at elevated temperature and in the other four the charge was molten at the end of the treatment. The final product was tough pitch copper, containing such precious metals as were originally present and those base metals like nickel which could not be eliminated by oxidation.

The ores used in the heyday of the Welsh Process were those which are found very rarely in the 20th century: 'Some of the Australian ores reaching Britain in 1945–46 yielded 40% copper and those of Chile from 20–60%. Even Cornish ores contained 8–10% Cu, and these were considered poor stuff when compared with Cuban ores containing 27% Cu. (The 19th century smelters would not welcome the ores containing 0.3–0.5% Cu which are now being treated at a profit).'

Process control in the early stages was by making sample trials of each batch of ore and then calculating furnace charges and treatment times on the basis of the results. As chemical analysis developed, so the need for trials was eliminated. The basis of treatment was the production of blister copper at the end of the fifth stage of the process. This depended on the material from the fourth stage having a high copper content and being substantially free of iron. Attainment of this composition depended upon oxidation of iron and sulphur in the first four stages by a combination of oxygen from the air and from copper oxides in the slags recycled from later stages. The final waste slag only left the system after contact with matte rich in iron sulphide and so was free from chemically combined copper oxide. That which was present was in the form of very small globules of matte or metal which had not had time to settle out. The flowsheet shown in Fig. 1 is based on a drawing made in 1777.

The number of stages required for the production of refined copper depended on the copper and iron sulphide contents of the original ore.

The first stage for pyritic ores was calcination to remove sulphur to the extent that the residual amount was sufficiently...