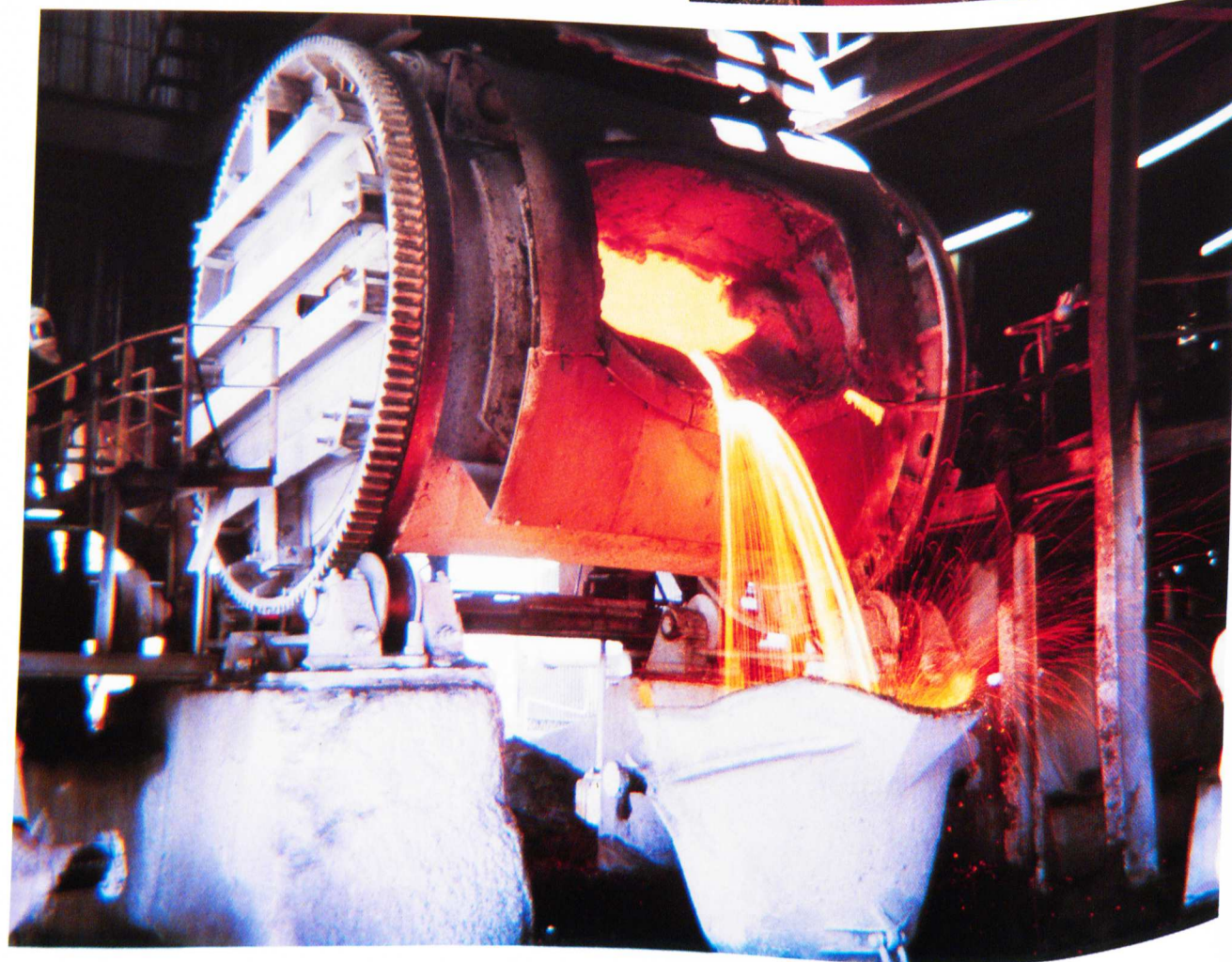


Tapping 'green' matte from the furnace
(courtesy Gold Fields of South Africa Ltd)



Pouring slag from a converter
(courtesy Lonrho SA Ltd)

the rhodium sulphate is dissolved in water and any insoluble residues are separated. The rhodium is then precipitated by the addition of sodium hydroxide, and is separated from any other hydroxides formed by the addition of hydrochloric acid and subsequent treatment with sodium carbonate and sodium nitrite. This treatment precipitates the base metals and leaves the rhodium in solution as the nitrite. Addition of ammonium chloride causes the precipitation of a complex ammonium rhodium nitrite salt, which can be redissolved in hydrochloric acid to form rhodium chloride. Rhodium metal is recovered either from this solution by reduction with formic acid, or reprecipitated repeatedly as an ammonium rhodium chloride salt followed by a reduction with hydrogen gas at 1000 °C to produce a pure rhodium metal powder.

- (f) *Iridium recovery.* The insoluble residue from the sodium bisulphate fusion is smelted with sodium peroxide and sodium hydroxide, which converts the osmium and ruthenium to water-soluble sodium hyperosmate and sodium ruthenate respectively. The iridium is converted to its dioxide, which is insoluble in water, then treated successively with aqua regia and ammonium chloride to produce ammonium hexachloroiridate, which is purified by solution reprecipitation, and then reduced by hydrogen gas at 1000 °C to the pure iridium metal.
- (g) *Ruthenium recovery.* The solution from the peroxide fusion is treated with alcohol, which reduces the ruthenate to insoluble ruthenium dioxide, leaving the osmium as the soluble osmate. This is then converted with the addition of hydrochloric acid to soluble ruthenium tetroxide, which can be separated from any remaining osmium by boiling with nitric acid, which volatilizes the osmium as its tetroxide. Treatment with chlorine gas converts the ruthenium to its tetroxide, which is distilled and absorbed in hydrochloric acid. This solution is treated with ammonium chloride to precipitate an ammonium ruthenium chloride salt, which is collected and reduced to pure metal by hydrogen gas at 1000 °C.

- (h) *Osmium recovery.* The soluble sodium osmate is converted to osmium tetroxide by treatment with nitric acid. The tetroxide is distilled and absorbed in methanolic sodium hydroxide. The reformed sodium osmate is then reduced to osmium metal with sodium formate or hydrogen gas. Since the metal reacts slowly with moist air to form the poisonous tetroxide, it is generally best to isolate and store the metal as the insoluble potassium osmate.

The above is a very broad review of the classical chemical refinement of the precious metals. Many of the intricate chemical techniques involved have merely

been glossed over, and detailed textbooks on the techniques should be consulted by anyone interested in greater detail.

(2) *Modern Methods of Precious-metal Refining*

Modern methods have decided advantages over the older techniques because of their continuous operation, the cleaner separations and the improved yield of the precious metals, the reduced recycling of the residues, and the higher overall metal recoveries. The various refineries may use different orders of separation, as well as different reagents to separate the precious metals. The design and operation of modern refineries are aimed at minimizing losses of the valuable precious metals, and all liquid and solid residues are carefully analysed on an ongoing basis for their PGM content before they are discarded. This continual monitoring of the process not only accounts for losses of metal inherent in the process, but also prevents any losses due to theft. Instrumental analytical methods, such as atomic absorption, inductively coupled plasma, or emission spectroscopy are usually employed. Emission spectroscopy is particularly important for the analysis of the final products with low impurity levels. Analytical instruments require frequent recalibration using reliable standards. Replicate samples of plant or refinery products are commonly collected and are submitted to separate instrumental analytical circuits, the results being subjected to rigorous statistical analyses.

The trends in modern plants are to improve the working conditions of the employees, as well as improving the environmental conditions in and around refineries. Certain platinum salts cause allergies such as asthma and severe skin rashes. Nickel compounds in base-metal refineries can also impact on the health of personnel.

The extraction, beneficiation, and refining of the PGM is a long process, but attempts are being made to speed up their processing. For example, process fluids are now pumped rather than fed by gravity; the hold-up of metals in the process is being shortened, and labour requirements reduced. Moves are also afoot to increase efficiencies and reduce metals inventories at refineries. As the demand pressure increases, even greater efficiencies in extracting the PGM will be required.

The input to refineries from the concentration plants on the mines consists mainly of the gravity concentrates of high-density ore minerals, as well as the high-grade precious-metals concentrates derived from the converter matte. At the refinery, the gravity concentrate is roasted in air and leached with hydrochloric acid to remove any remaining base metals (mostly iron, copper, and lead). The leached concentrate, together with the concentrate derived from the matte, is then leached with chlorine under pressure and hydrochloric acid to dissolve the precious metals. The resulting solution is