

## The Anatomy of an International Cartel: Cyanide, 1897–1927

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**ABSTRACT** *The development of a new product or a new process, if adopted by the market, may generate a number of economic processes including secondary innovations to promote the exploitation of the new discovery. Such technological advances may also promote new industrial ventures which may exist over many decades, enhancing economic development. The history of the adoption of the cyanide process for the extraction of gold from its ores exemplifies such developments. One outcome was the formation of an international cyanide cartel.*

**Keywords:** technological advance, cyanide manufacture, industrial competition, international business, international cartel.

### Introduction

Until the late 1880s the world demand for (potassium) cyanide, confined as it was to its use by electroplaters, photographers, and pharmaceutical producers, had restricted the production of the chemical to just under 200 tonnes a year, most of which occurred in Germany.<sup>1</sup> But a new and important use for it was about to emerge.

In 1887 in Glasgow, three researchers led by John Stewart MacArthur discovered that gold in its raw state, in tailings, or when mixed with base metals could be dissolved and recovered by the use of a dilute cyanide solution. This method yielded a high gold extraction rate with a relatively low production cost. It was covered by two English patents, numbers 74174 of 19 October 1887 and 10223 of 14 July 1888. When gold miners used the process in its simplest form as discovered by the three Scots or in one of the hybrids that were developed over time to meet varying conditions, they extracted the metal from all kinds of ores much cheaper and more efficiently than when alternative methods such as chlorination were used. Its low cost per ton of gold-bearing material treated very quickly enhanced its popularity on the gold-fields. After the success of trials conducted in several countries by MacArthur for his employers, the Cassel Gold Recovery Company,<sup>2</sup> the cyanide method of gold extraction spread throughout the world. As a result, the demand for potassium cyanide grew, slowly at first and then very rapidly.

A programme of selling the cyanide process to the overseas gold mining companies was implemented by the Cassel Company and soon South Africa became an important cyanide market when its use became a boon to the miners there.<sup>3</sup> As a result, cyanide production became a secondary activity associated with the spread of the cyanide process and a string of new patents emerged.

### **Growth of the Cyanide Manufacturing Industry**

The Cassel Company began to build up its cyanide production as if it alone produced the chemical and was determined to maintain its position on the gold-fields.<sup>4</sup> The German cyanide producers did not accept the monopsonistic attitude of the Scottish upstart which had even begun to purchase some of its raw materials from the German prussiate producers.<sup>5</sup> While they played a wait-and-see game in the beginning, by 1891 they were ready to compete in the South African market and gain some of the spoils available in the rapidly growing market. In mid-December 1891, the Cassel board received an unexpected surprise when MacArthur returned from a meeting in London with Hugo Andreae, the London agent of DEGUSSA.<sup>6</sup> The latter suggested that Cassel should close down its cyanide works and purchase all its requirements from DEGUSSA, thus reducing the former to an intermediary between the German cyanide producers and the increasing numbers of cyanide users overseas. But this German move had come too late: Cassel was already producing cyanide and was investing in new equipment. The Cassel board considered the proposal entirely unacceptable, not only because of its assumed claim to the market that Cassel had created for itself but also because the company could see the potential for further growth. It also argued that it desired to maintain a uniform quality in the cyanide its customers received.<sup>7</sup>

Despite further negotiations, relations between the Scottish company and the German producers became strained and, in January 1892, MacArthur went to Frankfurt to confer with DEGUSSA. He returned with the news that the Germans were about to attack the South African market in earnest. While maintaining friendly relations with DEGUSSA, Cassel began to reduce its price in South Africa to 'keep control of the market'. The possibility of a future price war was recognised in Glasgow, but there was more to the Cassel approach at that time, and this also appears true of the Germans. Hesitancy in negotiations resulted from the fact that Cassel did not want to bind itself to firm commitments at the time because it was developing an ammonia-based method of making cyanide (the Beilby process) which was not, however, ready for commercial use.

Beilby's cyanide came on stream in mid-1894 and the Germans' brands soon after.<sup>8</sup> Even at this early stage in the development of cyanide manufacture, there was a great emphasis on advancing technology to steal a march on competitors. As a result of the intensive research undertaken by several companies on both sides of the North Sea, at least four new methods were soon found. The more advanced companies embraced the ammonia-based method while other firms developed such alternatives as the use of prussiate of potash obtained from the residues of gasworks, the use of beet-sugar residues (the *schlempe* method), and the direct use of gas (the Bueb method). We do not know the precise costs associated with each method but it appears that the 'schlempe' method was to become the cheapest because it produced sulphate of ammonia as well and the total manufacturing costs could be shared between the two products. In addition, it is known that the use of prussiate obtained from gasworks was a high cost method.<sup>9</sup>

From the mid-1890s, there were several new entrants into cyanide manufacturing including, in Britain, the British Cyanides Company, Johnson Brothers, May and Baker, the London Gas, Light, and Coke Company, Blagden and Waugh, and the North British Chemicals Syndicate. These firms largely produced prussiate, at first mainly from the wastes of gasworks.<sup>10</sup> The low cost of the raw material at the time allowed them to make cyanide generally more cheaply than using prussiate obtained by the initial method. In Germany, the main cyanide companies after 1895 were DEGUSSA, Vorster and Grüneberg (from 1897 the Stassfurter Chemischen Fabrik) at Stassfurt, the Chemische Fabrik Schlempe at Taucha, and the Chemische Fabrik Residua, which produced prussiate from gas at Dessau.

Then began a third development from the initial Scottish discovery, a change in business organisation. Throughout 1894 the DEGUSSA agents were persistent in their attempts to persuade the Scots to set up an international cartel but all attempts were resisted. In July, the company rejected the suggestion that it should accept a 240 tons quota under cartel arrangements. It notified the Germans it would want at least 25% of the group production. By the end of that year no concrete agreement had been reached, but DEGUSSA and its associates also needed time to develop their new methods of producing cyanide. Their approaches to Cassel throughout 1894 were thus exploratory at most.

By 1896, Cassel had concluded that the unsatisfactory situation in the cyanide market had to be addressed. Having reduced its costs considerably by using its new synthetic process, it decided that the time was right to come to grips with its rivals. It began a price war by discounting its new cyanide. As this product was close to 100% purity, its use not only reduced the production costs of the mining companies but it also improved their productivity by increasing the gold extracted per ton. But, while DEGUSSA followed suit and other producers fell by the wayside, the latter were not forced out of the industry completely, for most of them were multi-product firms, able to continue production of their other chemical lines after, temporarily, relinquishing their position in the cyanide trade.

### **The Establishment and Operation of the Cyanide Cartel**

Out of the price war emerged the inevitable cartel. This occurred in 1897, when Cassel and DEGUSSA agreed on the change. It was very clear in the industry that these two firms would control the cartel operations, but not that this should be resented for the larger firms stood ready to help the smaller ones if they overproduced or if they could not fill their quotas profitably.

Quotas were allotted on an annual basis and their sizes depended upon the projections of the total demand for the following year. As demand was rising until 1900, when the Boer War adversely affected African demand, few cyanide producers wished for larger shares of the total output than those allotted to them. Some, unable to fill their quotas without recording financial losses when prices declined, bought cyanide from the larger firms (at a discount) to meet their customers' needs. In addition, the larger firms dealt with unusually high stocks at times when one member temporarily overran its quota.

Thus, the aim of the cartel became the restriction of supply—to set a price high enough to ensure 'satisfactory' profits for the established, highly efficient firms, but low enough, it was hoped, to keep the smaller producers in check and to impede other companies from entering the industry.

The cartel market consisted of all gold mining countries other than the United States which, it seems, was omitted by Cassel to appease the German producers and to maintain a high quota within the cartel. In practice, the United States market remained largely the province of the German manufacturers and Roessler and Hasslacher, the DEGUSSA American subsidiary.<sup>11</sup>

Except for the duration of the Boer War, 1899–1902, the market was an expanding one. Thus, the individual quotas of cartel members tended to rise from year to year. DEGUSSA was able to ensure that German manufacturers generally did not exceed their quotas but, at times, was able to alter quotas to solve specific problems presented to it. As an example, DEGUSSA and Cassel were able to limit the production of the French Société d'Électrochimie de Paris when in 1900 it began to produce sodium cyanide at Les Clavaux.<sup>12</sup> The two companies also prevented a German firm (the Stassfurter Chemischen Fabrik) from establishing a subsidiary in the United States by granting it a higher quota under the cartel arrangements and by jointly reimbursing it for its financial outlays in America. Cassel even persuaded a British cyanider to refrain from recommencing production by paying him enough on an annual basis to remain outside the industry. Indeed, the Cassel Company was able to extend its production beyond its quota at times by supplying cyanide to other British quota-holders when the price fell below their production costs, with May and Baker and with Blagden and Waugh in 1900 and often in the following years.<sup>13</sup> In addition, Cassel and DEGUSSA occasionally swapped quantities of cyanide. In many ways there were very close and flexible relations among cartel members and with their suppliers of raw materials.

By 1900, several producers had begun to shift from potassium to sodium cyanide, a move which would ensure higher extraction rates per unit of cyanide used. The primary consideration of cartel members then was to find reliable sources of metallic sodium. This involved DEGUSSA and the Aluminium Company (later to become the Castner–Kellner Alkali Company) establishing a German firm to produce sodium at Rheinfelden in southern Germany, close to hydro-electricity; Cassel establishing close links with Castner–Kellner for the supply of sodium from Wallsend in north-east England; the Société d'Électrochimie, aided financially by Cassel and DEGUSSA, setting up its sodium works at Martigny in Switzerland; and DEGUSSA, the Aluminium Company, and Roessler and Hasslacher constructing a plant at Niagara Falls. Cheap electricity was an essential requirement for sodium manufacture. Cassel was associated financially with each of these developments, and profit-sharing and the exchange of information became important features of the companies involved.<sup>14</sup> The existence of the cartel facilitated the changeover to sodium cyanide which became predominant by the middle of the 1900s. For gold and silver miners this meant a reduction in costs per unit of output, and a better quality product.<sup>15</sup>

The prolonging of the Boer War to May 1902 reduced cyanide production in 1901 and 1902 but some producers stockpiled quantities above their quotas. In addition, it was clear by 1902 that potential supply was greatly in excess of potential demand even when the estimated demand from South Africa after the war was taken into account.<sup>16</sup> At the end of October 1902, the Cassel board, realising that a rationalisation of the industry was required to prevent over-production, gave the required 2-weeks notice to the cartel for breaking the price agreement, thus setting it aside for a time. Prices fell from around 9–10 pence a pound in late-1902 to as low as 6.5 pence in December 1903. By the end of 1904, however, the cartel arrangements had been re-negotiated and prices were set at around 7–8 pence a

pound. These levels were maintained until 1914. A greater degree of stability was possible in the cyanide industry as several of the smaller, high-cost, producers vacated the field at the time, while others were just able to cover their costs at the new prices. When the price of prussiate, the major raw material of some producers, began to rise in 1906, their positions as cyanide producers became more tenuous.

Such was the situation of the cartel during the 1900s. The potential for over supply was ever present, and the two leaders ensured that production did not expand unduly. While *schlempe* cyanide was the cheapest to make, its output in Germany fluctuated from year to year depending on the size of the beet-sugar crop and the demand for cattle cake, also obtained from the beet residues. If the latter was high, the raw material tended to be used for that purpose. The cartel was also affected by a number of factors. While the production of gold and silver rose in this decade, and while there were several improvements in the use of cyanide at the mine site, it was found that reducing the strength of cyanide solutions increased the efficiency of the process and reduced the cost per unit output of the gold producers.

Many of the old firms remained in production mainly because most of them could switch to other products if cyanide production became unprofitable. Moreover, they held on to their cartel quotas because they were able to purchase any shortfall in their production from the leading producers. Production surpluses could be unloaded but not without a penalty. Control over cyanide production by Cassel and DEGUSSA, except in the United States, ensured that the mining community did not experience further price reductions during these profitable years. Nevertheless, the virtually constant cyanide price, the economies in cyanide usage, and increases in other costs, ensured that the share of total mining costs taken up by cyanide declined over time.

While the cyanide cartel was a method used by the two dominant firms to control the activities of other producers, the 'big two' could keep prices so low that some high-cost small firms, including those using the wastes of gasworks, could only operate on the margin. It is clear from the evidence that once the cartel was firmly established, the price of cyanide did not depart much or often from what the dominant firms considered the *right* price. The cartel arrangements then consisted of setting the quotas from year to year.<sup>17</sup>

Operations were smooth for a number of years and may have continued to be so for many more if World War I had not occurred. From 1904 to 1914, the long-run average cost curve of each would have virtually been flat or, at most, very slowly rising. Increasing the size of plant generally meant adding to the number of productive units rather than a complete replacement of the given plant with a new larger integrated one which would have been more efficient than the one it replaced. In addition, there was little change in the cost of inputs over this period. The cartel worked successfully because there were no outside producers (no free riders), or no potentially new entrants who could not be incorporated easily in the arrangements or who could not be kept out. A continuously rising market undoubtedly contributed much to the cartel's stability during this period.<sup>18</sup> Still, the cartel arrangements undoubtedly favoured the dominant, efficient producers. The financial returns of the Cassel Company clearly demonstrate the profitability of that company for, between 1900 and 1914, it paid annual dividends of 25 to 80%, generally after placing thousands of pounds into reserves every year. The ties of the company with its major suppliers of raw materials were very strong and Cassel's

profits were shared by these suppliers, Castner–Kellner, through the profit-sharing arrangements between the two companies, and Brotherton of Leeds, the ammonia supplier to Cassel, also the largest shareholder in the Cassel Company. The estimates available for DEGUSSA<sup>19</sup> suggest that that company paid regular dividends of up to 50% by the end of this period and added to its capital by retaining large amounts of its annual profits in reserves. Undoubtedly, the company had similar arrangements with its suppliers also.

Despite the large returns to the shareholders of each company, mining companies also gained considerably. While, by the end of the 1900s, the price of high quality cyanide had fallen to around 7 pence a pound weight, the gold miners were still unhappy about having to pay so much. Nevertheless, by that time, the total cost of extracting gold from 1 ton of ore, for cyanide, power, and labour could have amounted to only 11 pence.<sup>20</sup>

During the 1900s the inter-connections between pairs of operators in Britain and in Germany became complicated, despite the appearance of reasonable calm within the cartel. But uncertainty still prevailed. Almost every year the Cassel Chairman warned of potentially poor dividends in the following year, whether the concern of a one-product firm or a general stance by each cyanide producer is not known.

### **The Post-World War I Problems**

Attempts to renew the combination's pre-war agreements in the 1920s became difficult, principally because of the weaker competitive position of the German companies and by the appearance of a new dominant producer. The interloper, the American Cyanamid Company, could have been accommodated under the old cartel arrangements except for two facts. This company produced cheap, lower quality, cyanide from cyanamid and many cyanide users were willing to forgo the small additional output which could be obtained using the high quality product. They purchased the cheaper one. The new cartel agreement, therefore, was looser than its pre-war counterpart for it covered quotas only and they were set with no common prices in mind. Concessions to the American company, which aimed to become the major producer in the world, had to be made from year to year by the previously dominant firms, especially Cassel. At this time, German production was much lower than before the war.

To illustrate the prices situation in the 1920s, the average prices of sodium cyanide imported into the United States in 1923 (in which year, 11,180 of the total 14,335 long tons—78%—came from Canada), from Germany, Canada, and France, were respectively 14.1, 6.8, and 19.7 cents a pound weight. The average imported price was 8.9 cents.<sup>21</sup> The poor quality Canadian cyanide<sup>22</sup> was favoured in the United States over the dearer, higher quality product from other sources. Also in 1923, exports from the United States were valued at an average 11.6 cents a pound, reflecting the price of the cyanide produced by Roessler and Hasslacher.

Nevertheless, the presence of American Cyanamid in the industry, its aggressive stance at cartel meetings, and its constant demands for a higher proportion of the world market eventually led to the demise of Cassel. In 1927, confronted by a declining quota under pressure from American Cyanide and the possibility of the entry of a large German chemical company into cyanide manufacture, it accepted the take-over proposals of the newly established Imperial Chemical Industries (ICI)

with a view to consolidating its efforts. With Roessler and Hasslacher being absorbed by Du Pont, the cartel became the province of giant chemical firms: DuPont, ICI, DEGUSSA, and American Cyanamid, firms which continued to play the cartel game for several years.

### **Theoretical Difficulties**

The relevant economic theory concerning the operations of an international cartel over time assumes that the aim of establishing and maintaining a cartel is to maximise joint profits by equating the marginal revenue of the cartel with the marginal cost of each member firm. Thus the price is fixed and the total output can be carved up among the participants. The cartel acts as a monopolistic firm, the costs of production are the same for all members and production functions are identical. But such assumptions are unrealistic for the cyanide-making industry of this period. There were several methods of producing cyanide and thus several production functions with high- and low-cost firms. But a low-cost firm could expand production beyond its quota if another (high-cost) member desired to cease production because of potential short-term losses arising (say) from a temporary increase in raw material prices, and to purchase the amount of its quota from the low-cost member at an agreeable discount (as noted above). The theory would suggest that the low-cost producer would act in this way if its quota output was below that of maximum profits.

In addition, whereas the theory deals with a one-product firm, in reality, most cyanide-makers were multi-product chemical firms. Cyanide production was often only a small part of their operations. If raw materials prices rose enough to make cyanide manufacture unprofitable, such firms could run down their cyanide output, until it was once again profitable, transferring their energies to their other lines of production. They could maintain faith with their gold-mining clients during such difficult times by purchasing their needs from other producers. Also, if the raw materials of a firm had important alternative uses such uses could at times supplant cyanide in the firm's production. For example, it was sometimes more profitable for one cartel member to produce oilcake instead of schlempe cyanide, as noted above.

Much of the long-run cartel theory is directed towards the three great problems capable of rendering a cartel inoperative, namely, the movement of customers to near substitutes, the possibility of cheating and the potential entry of a large producer to the industry. There were no close substitutes to cyanidation. Chlorination was very effective in recovering gold but it was more expensive. Flotation was used towards the end of the period but, for gold, it eventually formed part of the whole extraction scheme of which cyanidation was the major process. In the case of cheating, the exchanging of sales information among members and good information channels ensured that any attempts at cheating would be squashed very quickly and effectively. The third was that of the entry of a new, low-cost, large firm, able to sell its output at a large discount below the established cartel price. Up to 1914, no such devastating entry occurred. The entry into the cartel of the French firm with the aid of the two dominant firms shows another side of the cartel operations—their flexibility. Flexibility was also evident when one of the German members attempted to begin production in the United States, a move contrary to the wishes of DEGUSSA. Cancellation of operations and compensation were possible because of the large resources of Cassel and DEGUSSA. The most

difficult problem occurred in the 1920s with the entry of the American Cynamid Company although it could be argued that its product was, in effect, a close substitute to the better products of the other members, a product which could not be used in all circumstances.<sup>23</sup> But it was the entry of American Cyanamid into the cartel and its constant demands, which led to the rationalisation of the organisation and the assumption of leadership by three dominant firms. In addition, the 'free rider' problem was of a new producer taking advantage of the high cartel price without being bound by the cartel's rules and remaining a non-member. The operations of the United States producers tended to assume the appearance of a totally independent market, as far as the European cartel was concerned, but, because of the prevailing import duties up to 1913, were almost wholly confined to Roessler-Hasslacher.

A number of features of the cartel could have been unique in international cartel history of the pre-World War I period. The combination was virtually restricted to two countries in which cyanide production was controlled by two major firms that set the rules for the international operations—for the price and the determination of quotas. The major problem for members was that the production potential of the industry exceeded the demand from customers at all realistic prices. An alternative to the setting of prices would have been the establishment of a free market price by a competitive system as in 1896 and 1902, which would ensure the elimination of most of the firms, and a reduction in profits of those efficient enough to maintain operations.

An important point to note is that the establishment of cartel arrangements did not stifle research and development. The tremendous research activities on both sides of the Channel in the 1890s in the endeavours of the industrial chemists of chemical companies to find new and cheaper methods of making cyanide were noted above. Such efforts did not cease.<sup>24</sup> A well-funded research and development team was maintained by Cassel under Dr Thomas Ewan, who was developing a new and presumably cheaper method of production of cyanide, until its absorption by ICI, and certain German firms were acting in the same way. Even in 1927, when Cassel was negotiating with ICI, two new methods of production were patented by large German chemical firms. Stealing a march on cartel rivals played an important part in such activities but, perhaps more importantly, it was a defensive activity—to prevent other firms from adopting revolutionary methods without having some answer to such advances.

The consequences of the discovery of new technology can be very important in the development of an economy and can be very diverse in their nature. As the above illustrates, industrial organisation can also be substantially affected but even if the structure of the world industry appears to be highly restrictive, technological progress can still advance substantially because of the underlying competitiveness among the members of the industry.

## Notes and References

1. In reality, a German cyanide cartel had existed before 1887 but its output was highly restricted by the size of the market. Production was controlled by the group's selling agent, DEGUSSA (see note 6 below).
2. In 1906, it was renamed the Cassel Cyanide Company.
3. At this time, potassium cyanide was a dirty grey product, around 72% pure. Its manufacture was very primitive, using animal refuse: hides, horn clippings, old shoes, and blood solids,



along with potassium carbonate and iron filings. See A. Loughheed, 'Technological advance in the manufacture of chemicals: the case of cyanide, 1888–1930', *History of Technology*, 18, 1996, pp. 81–94.

4. Much of the detailed information contained in this study comes from the *Board Minutes* of the Cassel Company, housed in the Cheshire County Record Office, Chester, England.
5. Prussiate of potash was the material from which potassium cyanide was made at that time.
6. The Deutsche Gold und Silber Scheideanstalt (DEGUSSA) of Frankfurt was the selling agent for the German cyanide producers. On DEGUSSA and the other German producers, see Anon, 'Deutsche Gold und Silber Scheideanstalt, 1873–1923', *Die Chemische Industrie*, 46, 1923, pp. 99–104; and H. Meyer-Wegelin, 'Marktreisungen in der chemischen industrie', *Die Chemische Industrie*, (new series), 4, 1952, pp. 745–48.
7. This was rather a pretentious claim for cyanide quality was low at around 72% purity at this time even if the price was quoted for 100% quality.
8. This would not have taken long. The details of Beilby's process were published in the *Journal of Society of Chemical Industry*, 11, 1892, p. 747, recording the registration of English patent No 4820 of 18 March 1890. A little industrial espionage would have revealed his involvement with Cassel. Also, a similar process in Germany involving the use of ammonia may have preceded Beilby's. Its details were outlined in the *Journal of Society of Chemical Industry*, 9, 1890, p. 860, under an English patent No 13697 of 30 August 1889, obtained by H. Grüneberg of Cologne, and two other industrial chemists. Vorster and Grüneberg was a German cyanide producer located at Stassfurt.
9. See A. Loughheed, *op. cit.*, for a description of each of these methods.
10. Johnson Brothers was absorbed by May and Baker in 1896, and the North British Chemical Syndicate was liquidated in 1900. Blagden, the cyanider at the Gas, Light and Coke Company, left in 1899 to form Blagden and Waugh, which was granted a cartel quota. The Gas, Light and Coke Company was producing some prussiate at this time but no cyanide.
11. This US firm was set up by two DEGUSSA ex-employees. DEGUSSA provided much of the capital and, by 1914, held 51% of the shares. In 1894, the company began to manufacture cyanide from prussiate at a plant at Perth Amboy in New Jersey.
12. The Société obtained a licence from DEGUSSA allowing it an annual quota under the cyanide cartel (400 tonnes), to which arrangement Cassel acceded.
13. For example, the Cassel *Board Minutes* of 13 June 1899 record a sale of 200 tons to the latter company at 10.75 pence a pound over 1900. Further sales were negotiated in later months as was a sale of 180 tons to May and Baker at 10.375 pence over 1900. There were many instances of discounted sales in the period.
14. For example, the Cassel Board Meeting of March 1904 was informed that, through its agreement with Castner–Kellner, it had received £2373 as its share of the profits of the Niagara and Rheinfelden operations for the previous year.
15. There is a greater proportion of available cyanogen (the active element in cyanide) per weight of cyanide in sodium cyanide than in the potassium variety. See A. Gordon Salamon, in discussion of Arthur C. Claudet, 'The relation of the chemical industry to metallurgy', *Journal of Society of Chemical Industry*, xxix, 1910, p. 1427.
16. On this point, see G. T. Beilby, 'State of the cyanide industry', Paper read at the International Congress of Applied Chemistry, Berlin, 1903, cited in the *Journal of Society of Chemical Industry*, 22, 1903, pp. 766–67.
17. While we are accustomed to note that a cartel cannot set prices *and* quotas simultaneously, the evidence suggests that the setting of price was of first consideration to the cyanide cartel, a reasonably good estimate of potential demand was then calculated, with any shortfall or increase in the demand at the set price leading to adjusted quotas during the year. In addition, increases or decreases in total production could be initiated at any time during any calendar year. Close monitoring occurred. The market was a dynamic one subject to changing conditions from time to time.
18. In the United States especially, increasing cyanide usage occurred in other industries, including the Californian citrus industry, the hardening of steel, and electroplating. By the

1920s, its use in the mining industry had declined relatively every year. Sheltered behind a tariff wall, Roessler and Hasslacher supplied most of the increased demand from the other sources.

19. See Anon, *op. cit.*, 1923.
20. See Arthur C. Claudet, *op. cit.*, p. 1424. He also suggested that, without the cyanide process, the gold obtained from the Rand would have been 20–30% below the ‘present’ extraction.
21. See US Bureau of Foreign Commerce, *Foreign Commerce and Navigation of the United States*, various issues.
22. The American Cyanamid Company operated on the Canadian side of the Niagara Falls where electricity was cheaper at this time. Furthermore, by this year, the import duty on cyanide had been reduced considerably.
23. This was evident at some Canadian mines, especially at Cobalt, where the lime contained in the *Aero* brand of American Cyanamid had to be removed by the use of soda ash, a cost which ensured that the higher priced cyanide was at little disadvantage relative to *Aero* in some circumstances.
24. In the first quarter of the twentieth century more than a dozen new patents were registered in England, some of which could have been used successfully.