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A Retrospective View of Nickel Plating

by

W. Wallace Sellers

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The fascinating story of nickel plating is characterized by resourceful individuals and companies responding to industry needs.

A chronicler's view is seldom completely objective. It is colored by his perspective. My 38 years in the nickel-plating industry causes me to view it differently than would one writing not from involvement but solely from facts garnered in a library or from interviews. His story might well be more objective than mine. And developments I see as most significant may not be those the reader would have chosen. This, therefore, is not a complete history of nickel plating over these past 75 years but only a citation of salient developments that, in my view, brought the industry from its infancy in the early 1900s to its maturity today. Fascinating things happened along the way.

Dr. Isaac Adams is credited by George Dubpernell with being the father of nickel plating in the U.S.[1] From the days of Adams, who reputedly spent more time with plating baths than with medicine, to the comprehensive work of O.P. Watts, progress in the industry inched along. The main patent on Adams' bath and process, issued in 1869,[2] served as a cornerstone on which subsequent researchers built. But it was not until Watts reported his work in 1915[3] that nickel plating really began to grow. An investigation by H.T. Kalmus and coworkers dealing with cobalt as well as nickel was summarized in the *Transactions of the Electrochemical Society* of 1915. This work led the authors to the opinion that nickel could not be plated under commercial conditions at current densities as high as those possible for cobalt.[4] Accepting the challenge, Watts did further work that led to his famous paper of 1916,[5] in which he suggested the formula known the world over as the "Watts bath." This laid the foundation for modern nickel plating. Although the merits of Watts' formula were not immediately recognized, acceptance grew steadily. By 1924 it was used to plate automobile bumpers.[1,6] According to Watts' personal survey, 200,000 gallons were in use in 1931.[1] The bath was on its way to becoming the basic electrolyte of the nickel-plating industry.

Watts' formula was an aqueous solution of nickel sulfate, nickel chloride and boric acid. Although these continue to be the basic ingredients of the majority of nickel-plating baths used in industry, the amounts and their ratios have varied significantly, so that a more precise name for such baths is "Watts-type." These baths yield soft, ductile deposits that are easily buffed to an appealing bright finish. If deposited over a bright surface to a thickness not exceeding 1 mil, the coatings usually exhibit a degree of brightness without buffing. But to achieve the luster demanded by a discriminating buyer, the object being coated must be polished and the coating must be buffed. Both are costly. With the development of automatic polishing and buffing, costs were reduced. But this was not enough. Hence, the simple Watts-type bath is used today for non-decorative, or functional, plating. Other electrolytes were developed for decorative coatings. Most of these used some modification of the Watts-type formula as the basic electrolyte.

Bright nickel

Even before Watts published his work, the possibility of producing bright coatings without polishing and buffing tantalized researchers. Several reported and some patented bright baths early in this century.[7,8,9] Being difficult to control, however, they provided little utility to the commercial plater. The first practical bright nickel bath was developed by Max Schloetter in the early 1930s.

Schloetter, who had established a plating supply house in his native Germany in 1912, was reported to have 73 patents by 1930 dealing chiefly with tin, iron, copper, lead and zinc plating.[10] Having successfully used aromatic sulfonates in some of the processes, he decided to try them in a nickel bath. The result was his U.S. patent of 1934[11] claiming use of unsubstituted aryl poly-sulfonates with two to three sulfonic groups. Schloetter's patent was preceded in 1931 by one granted to G. Lutz and L.R. Westbrook for use of other brighteners in this class.[12] The alkyl naphthalene sulfonic acids of Lutz and Westbrook, however, proved less useful than Schloetter's compounds.

Following the Schloetter patent, fruitful research netted a succession of processes. In 1936 and 1937, L. Weisberg and W.B. Stoddard were issued a patent in the U.S., Canada and the United Kingdom on an application filed in 1935.[13] To cover their inventions, E.D. Vries and B.C. Case were issued a U.S. patent in 1938 and another in 1939.[14,15] Also in 1938, W.J. Harshaw and K.E. Long were granted a patent suggesting diphenyl sulfonates[16] and H.V. Waite was granted one covering the use of naphthalene disulfonic acids.[17]

The Weisberg-Stoddard bath contained cobalt and, under certain conditions, a small amount of ammonium ion. In a succession of technical papers, Weisberg promoted cobalt-nickel plating.[18,19,20] In 1936, a leading plating supply house, Hanson-Van Winkle-Munning, made bright cobalt-nickel plating a commercial reality and announced the process with at least two ads in the technical press.[21,22]

Competing supply houses quickly followed Hanson-Van Winkle-Munning: Harshaw Chemical Company in 1935, 1936 and 1940;[1] The Udylite Company in 1938;[1] Seymour Manufacturing Company in 1938[1] and the McGean Chemical Company in 1938 and 1939.[1]

Some problems

Although real progress had been made, there were still problems. Pitting, failure of thick deposits to be fully bright, and high internal stress were among them.

Tendency for deposits to pit was a common fault, but one that proved easy to correct through the use of anti-pitting compounds. An effective one was sodium lauryl sulfate, use of which was patented in 1941 by V.H. Waite and V.P. Martin, with assignment to McGean Chemical Company.[23]

Deposits from baths using Schloetter-type compounds were highly stressed and therefore easily cracked. There was also a problem with brightness. Although benzene disulfonate and naphthalene trisulfonate were dependable brighteners and could be used in substantial quantities without harmful effect, rate of brightening tended to decrease with thickness.

Fortunately, the advantages of bright nickel processes impelled researchers to spend money and effort to overcome the deficiencies. Their work uncovered other effective brighteners that were compatible with the Schloetter type and that could be added in small amounts to give decided improvements. But confusion followed their discovery. Some called the Schloetter type "secondary brighteners" and the newly discovered, more powerful compounds "primary brighteners." Others used a different nomenclature. Their importance, though, lay not in what they were called but in what they did. Together with suitable wetting agents to control pitting and other additives to reduce stress they made nickel plating an outstanding industrial development of the period.

Here we digress to note other developments without which decorative nickel plating may never have achieved its dominant position.

Top coatings

Although a few products are plated only with bright nickel, the majority have a top coating of another metal. This may be a precious metal, gold, silver, brass and even lacquer. There is neither time nor space to discuss when and how they came to be used, but their contribution to bright nickel plating is acknowledged.

Bright chromium

Far more significant, however, was the discovery of bright chromium. Even though it remains for another to tell this story, its importance to nickel plating should not be ignored. For the combination of a thin layer of bright chromium over a layer of bright nickel came to be the preference of many designers and manufacturers seeking inexpensive ways to add beauty and corrosion protection to many useful and ornamental objects of our daily lives.

Several scientists are credited with the discovery of bright chromium plating. A German chemist, E. Liebreich, disclosed his invention in a series of patents issued in 1925, 1926 and 1927.[1] Colin G. Fink and C.H. Eldrich invented a similar process about this same time.[24,25] Although significant changes and some improvements have been made, this early work was the foundation for commercial bright chromium plating, particularly in the U.S. Without bright chromium, much of the work that followed in the field of decorative nickel plating may have been only of academic interest. Or it may not have occurred at all.

Semibright nickel

Bright chromium over a layer of bright nickel did not prove to be completely satisfactory for objects subject to impact (*e.g.*, automobile bumpers). Bright nickel deposits were brittle and readily cracked under impact. Hence, the industry sought an economic alternative, a coating that would reduce the high cost of buffing, essential with matte nickel deposits, and would have the required degree of ductility. The obvious choice was semibright nickels. These ductile, easily buffed deposits, often produced with only a single organic additive, offered a significant savings in the cost of buffing and proved sufficiently ductile to withstand reasonably high impact (Perhaps it should be noted for clarity that here we are using the word "ductility" loosely to imply not only elongation but lower internal stress.). Such coatings were used with considerable success on automobile bumpers until the advent of multilayer coatings. Opinions differ about the role of semibright nickels, particularly those produced with coumarin as the sole brightener. There are those who recall that this "class" of semi-bright nickels was the only one used on automobile bumpers until about 1958. There are others who would assign the coumarin semibright nickels a slightly less important role.

But to debate this is to quibble unnecessarily. The key points are: (1) good semibright nickel coatings were an important bridge between the development of early bright nickels and the multilayer coatings to come later; (2) many skilled people in the automobile industry as well as in the plating supply houses contributed their talents and time to bring semibright nickels to the stage where they would be a dependable base for the multilayer coatings that were to follow.

Multilayer nickel

Electrodeposited nickel-chromium quickly became the accepted coating for automobile bumpers. The coating was also used on trucks, which were fast replacing railroads as the preferred way to haul. As autos congested city streets, buses replaced trolleys; bus bumpers were also plated. The automobile industry grew and carried nickel plating along. Soon nickel plating bumpers became the largest single application. With more vehicles and more industry came a more corrosive environment, aggravated in cold winter weather by salt and sand spread on streets and highways. Recognizing that nickel-chromium coatings were not providing adequate protection for bumpers and other automobile trim, enterprising investigators developed multilayer coatings (Those who prefer this term recognize that most multilayer coatings consist of only two layers: semibright under bright. But since there are systems comprising more than two layers, they prefer "multilayer" to "double layer." The role of copper, frequently used as an initial coating in nickel-chromium systems, must also not be discounted, but "multilayer" refers here only to more than one layer of nickel.).

Accuracy would be violated by an attempt to set the precise date for the commercial introduction of multilayer coatings. Although dates on patents may be an indication, they do not tell when the claims in the patents became a commercial reality. We, therefore, must approximate a time. As we shall discuss later, growth of the nickel-plating industry has been stunted by periods of imbalance between supply and demand. A severe imbalance spanned the years of 1950 through 1956. In the U.S. all civilian nickel-dependent industries had to eke out on less than was needed. Plating was no exception. Coating thickness was often reduced to little more than enough to cover the surface. Lacquers applied to help stave off the ravages of corrosion did not keep objects from quickly losing their bright, good looks. Automobile bumpers looked sad. Automobile owners looked sadder. Nickel-chromium coatings lost much of their respectability. When in 1958 it became clear that the crises had passed, developers of multilayer systems and The International Nickel Company, Inc. (Inco), the leading supplier of nickel anodes whose research between 1945 and 1955 had demonstrated the efficacy of multilayer coatings in enhancing corrosion protection of plated nickel, concurrently and independently set out to improve the reputation of decorative nickel-chromium. The processes, which had been shelved or used ineffectively during the imbalance, were zealously promoted. This was truly a turning point. For without multilayer coatings it is doubtful that nickel-chromium would have remained the only coating used on steel bumpers for so many years.

Leveling nickel

Among the effective means of avoiding or reducing the high cost of polishing and buffing was the discovery of ways to make the plating baths do part of the work. G.E. Gardam appears to have been one of the first to recognize that certain solutions deposited more nickel in recesses than on points of a surface.[26] In this process, which came to be called "leveling," compounds appear to be deposited along with nickel on microscopic peaks of the surface being plated, thus retarding deposition of nickel in those locations. The result is a smoothing or leveling of the surface that often reduces the amount of polishing required and frequently eliminates buffing. Today most good, decorative nickel systems perform some leveling. Leveling saves the industry thousands of dollars each year and thus ranks among the significant developments in nickel plating. Many papers have been written on the subject, particularly between 1956 and 1961. In 1959, E.R. Letter and H. Leidheiser Jr. published a comprehensive review.[27]

Satin nickel

Although one sees little satin or brushed nickel today, it was a popular finish in the 1960s, when it was widely used on furniture and on traffic and major appliances. At the peak of its popularity this finish, which has since yielded its place to paint, colored plastics and enamel, consumed many tons of nickel. It was so important, in fact, that Inco devoted a series of ads to promote it. An illustration from a typical ad is shown in Fig. 1.

Figure 1 - Built-in oven with nickel-chromium - the fashionable finish of the 1960s.

To achieve this finish some platers polished the basis metal, usually steel, so that the coating would look brushed instead of bright. Others brushed the nickel coating. Still others did a little of both. And it is a tribute to the ingenuity of the plating supply houses that some devised processes for depositing a satin finish directly from the plating bath. This was achieved by adding finely divided, inert particles to the solution.

Economics and changes in fashion contributed to its decline. But the pendulum swings. Perhaps this attractive, functional coating may once again be favored by designers and consumers.

Industrial nickel plating

Industrial nickel plating in the U.S. dates from 1865, when Isaac Adams first plated gas tips for a Boston dealer. Although its share of the market is small (estimated to be 5-10 percent in the 1950s, about 15-20 percent today), it has continued to be an important part of the industry. There are four major processes: that which we may call conventional; those which do not employ electric current; and brush plating. The fourth, which uses conventional electrolytes, but at times unconventional techniques, is electroforming, which belongs in a class by itself.

Conventional plating

Conventional, non-decorative plating is used to impart certain desired properties not possessed by the object being plated. They protect objects from corrosion. When plated on vessels for processing foods, they maintain product purity. They inexpensively salvage worn and mismachined parts of mechanical equipment. They impart wear resistance. There have been noteworthy advances in baths to achieve these ends since Dr. Adams' discontent with his success in plating gas tips.[1] Dr. Adams improved his process, but Watts, whose work has already been noted, laid the foundation for modern industrial nickel plating. Others who followed varied the amounts and ratios of ingredients, changed operating conditions, and thus composed baths yielding deposits that offered good corrosion protection. But tensile strength was around 55,000 psi and hardness around 140 to 160 Vickers, characteristics which moved researchers to seek further improvements.

One innovation was an electrolyte composed solely of nickel chloride and boric acid. In 1935, W. Blum and K. Kasper described a bath operated at boiling point.[28] In 1939, W.A. Wesley and J.W. Carey introduced a composition operated at lower temperature.[29] Deposits were harder and stronger than those from a Watts-type bath. Internal stress was between 40.000 and 50,000 psi and ductility was lower. Operated under proper conditions, the bath gave deposits as hard as 400 Vickers. There were other advantages, but a tendency for deposits to crack spontaneously limited the bath's usefulness.

In 1942, W.A. Wesley and E.J. Roehl described a bath of nickel sulfate, ammonium chloride and boric acid that could be operated at high pH to produce deposits with hardness in the range of 350-500 Vickers and tensile strength around 150,000 psi.[30,31] Although ductility was relatively low and internal stress was high, the good abrasion resistance of the deposits made the bath useful in salvaging worn and mismachined parts.

Then, in 1945 and 1946 came the sulfate/chloride baths of W.L. Pinner and R.B. Kinnaman[32] and the version by G.A. Hogaboom and P.J. Lalonde.[33,34]

In 1950, the technical press carried the work of three pairs of researchers with nickel fluoborate processes, which had characteristics making them attractive to the electrotyping and stereotyping industries.[35,36,37] High initial cost of the electrolytes, however, has tended to limit their use.

Baths in which nickel sulfamate is the dominant salt and boric acid the usual buffer have been more successful. Although M.E. Cupery was granted a patent for the use of sulfamates as early as 1943,[38] nickel sulfamate baths did not attain commercial importance until 1949, when R.C. Barrett introduced his composition.[39] Following this, nickel sulfamate received notable attention from electrochemists. Among them were Myron Diggin in 1954,[40] W.L. Pinner, B.B. Knapp and Diggin in 1963,[41] R.J. Kendricks, who described a high-current-density bath in 1964,[42] and Knapp again in 1971.[43]

The early baths, to ensure low internal stress in deposits, omitted the halide ion, thus mandating the use of specially depolarized anodes. Later small amounts of chloride (or bromide) were added to many baths to obviate this dependency

Electroless nickel plating

Electroless plating, in which a chemical replaces electrical current to reduce nickel ions to metallic nickel, has played an important, if small, role in the nickel-plating industry. Credit for the discovery belongs to The National Bureau of Standards' Abner Brenner and Grace Riddell, who described their work with nickel and cobalt in two papers in 1947.[44] Since then technical literature has been replete with papers on electroless nickel plating. No less than 90 patents and papers on the subject were found in what appeared to have been the most fruitful period, 1947-1971.

An outstanding commercial application was the General American Transportation Corporation's patented and trademarked Kanigen process for plating the inside of car tanks.[45] In 1959 George Gutzeit, one of the inventors of the Kanigen process, presented a comprehensive discussion of the chemistry of the catalytic nickel process.[46]

Because many of the electrolytes used sodium hypophosphite as the reducing agent, phosphorus, in amounts ranging from 2 to 15 percent, was codeposited with the nickel. Properties were therefore not those of nickel but those one would expect in nickel-phosphorus alloys. Where these properties were not desired, the presence of phosphorus proved to be a detraction. This provoked a search for other reducing agents. To cite a few examples: In 1965, D.L. Levy patented a bath using hydrazine.[47] In 1967, a patent was issued to T. Berzins for a process using amine boranes,[48] and J.W. Dini and P.R. Coronado discussed a hydrazine formula.[49]

In 1977, Inco published an excellent summary, giving data on physical and mechanical properties of deposits and important references. Thus, it summarized the state of catalytic nickel deposition up until that time.[50]

Other processes

Through the years, other industrial processes have come along to serve special needs. An interesting one, patented in 1925, was a type of electroless plating involving high-temperature reduction of nickelous oxide and dibasic ammonium phosphite. Another was a process, which first came into prominence in the U.S. in the 1950s, for applying metal coatings with a swab or applicator dipped into a suitable electrolyte before being "brushed" over the surface to be coated. Still another was black nickel plating, the origins of which were not uncovered and which has proved to be of limited utility.

Applying coatings to steel by electrochemical displacement is one of the simplest and oldest forms of nickel plating. This process, in which the object to be coated is immersed in an aqueous solution of nickel salts so that ions of the metal being coated go into solution and are replaced by metallic nickel, is self-limiting and can only be used where thin layers are desired. The enameling industry is an example. Perhaps the best discussion of the process was by W.A. Wesley in 1950.[51]

Electroforming

The versatile technique called electroforming by most and cold casting by some has come a long way in the last 50 years. The date of its first commercial use was not uncovered. But George Hogaboom wrote on electroforming in a publication by Inco in 1937,[52] thus signifying it had achieved some prominence by that time. Several papers between then and 1949 discussed interesting applications.[53,54,55] William Blum and George Hogaboom, however, in the third edition of their classic text of 1949 devoted most of their chapter on electroforming to electrotypes with little more than passing reference to other uses of the process.[56] The other major use at this time was the making of matrices and stampers for phonograph records.

Prior to 1949, Watts-type baths were commonly used. With them, skilled, meticulous platers produced many products of intricate shape: hypodermic needles, molds for toys, industrial dies and molds, Venturi tubes, cams, radar fittings, reflectors for large search lights, precision tubing, sizing screens and wave guides ranging from a few ounces to several tons in weight.

Electroforming with Watts-type baths was not easy; hence, perfection of nickel sulfamate solutions in the years following 1949-1950 gave the technique a needed boost. Sulfamate processes offered economical ways to make textile printing rolls and seamless belts and proved to be the optimum way to meet the demands of a rapidly growing high-fidelity phonograph record industry.

It is obvious, then, that many industries were employing electroforming in the 1940s and 1950s to produce a variety of items. But collectively consumption of nickel was small. Therefore, Inco devoted sizeable effort in the years between 1960 and 1966 to promote nickel electroforming for the production of consumer items. They attempted to spark the imagination of manufacturers by showing prototypes of specially designed consumer products ranging from electric switch plates to bathroom lavatories. One, which enjoyed some commercial success, was an electric coffee maker.

Anodes

The discovery and production of good anodes were vital to the success of nickel plating. I should love to tell this fascinating story, but I shall refrain and limit these comments to those developments that have been most influential. First, there was the discovery by Isaac Adams, who described his invention about 1869 and who must be credited with the first practical nickel anode, even though W.H. Remington patented a less useful one in 1868.[1,57] Then came the high-iron anodes, which dissolved readily, but caused trouble in low-pH electrolytes. The Watts bath made additional improvements possible. Consequently, the high-iron anode was followed by ones of much higher purity containing as much as 99 percent nickel and varying amounts of carbon, which prevented loose nickel from falling into the bath by forming a film on the surface of the anodes as they corroded. An anode containing oxidized pitch enjoyed modest success, but it was difficult to cast. By the 1920s, the use of anode bags had become common, and electrolytic nickel was available at reasonable prices, thus tempting platers to try using electrolytic strips for anodes. But pitfalls were legion; most attempts to overcome the disadvantages had only isolated success. Nickel anodes had come a long way by the end of the 1920s, but the industry still did not have a consistently reliable product.

The need was met in stages. In 1930, Harshaw, Savage and Bezzenberger patented a rolled anode depolarized with oxygen (and other elements). Inco acquired the patent, commenced production at its rolling mill in Huntington, WV, and thus established a milestone in the history of nickel plating. The industry now had a dependable anode with consistent, reproducible chemistry and physical properties and which corroded at high anode efficiency over a wide range of operating conditions and bath compositions. It was ideal in many applications, but caused roughness with some bright nickel solutions.

In bright nickel baths, anodes containing carbon and silicon were much better. But all were cast, and although some performed satisfactorily, large grain size and variations in the quality of castings made most far from ideal. With what may have been a mixture of foresight and luck, Inco once again stepped up to the need and introduced in the early 1930s a rolled anode containing carbon and silicon with traces of other elements. The anode performed ideally in bright nickel baths and in many other electrolytes. Quality of cast carbon anodes improved; these were offered by a few leading suppliers. The rolled carbon anode, however, remained for more than a quarter of a century the quintessential anode of the industry.

Its preeminence was shattered in 1962, when A.G. Sleeker and V.J. Cassiday revealed the use of anodes composed of titanium baskets filled with squares of electrolytic nickel to plate automobile bumpers.[58] Titanium baskets did not lessen the electrochemical deficiencies of electrolytic nickel. But they overcame the physical limitations. Baskets could be as long, as wide, and as thick as the plating tank and the work required, and to maintain a constant anode area, the plater had only to add more nickel squares to the baskets as the nickel corroded. Later that year, a group of platers met in Chicago to discuss plating with baskets and some of them, eager to save money, decided to try them. Use spread; the anode industry was never the same again.

Knowing the disadvantages of electrolytic nickel as an anode and realizing baskets were here to stay, Inco, in 1963, introduced a new electrolytic nickel containing just enough sulfur to enable it to corrode smoothly and efficiently over a broad range of conditions. The product proved to be even better electrochemically than the carbon anode. This was followed a few years later by another Inco innovation, the same excellent depolarized electrolytic nickel in a round, or button, shape with obvious advantages over the squares.

About 1980, both Falconbridge Nickel Company and Inco introduced round forms of pure electrolytic nickel for those platers who preferred that type despite its deficiencies. The anode industry had come a long way since the days of Isaac Adams.

Supply-demand imbalance

What I choose to call an imbalance the reader may term a shortage. Regardless of the name, there have been two protracted periods in my memory when civilian industry, particularly in the U.S., has had to make out with less than adequate supplies of nickel. The plating industry was no exception. These periods choked the industry, sent designers, manufacturers and platers clamoring for substitutes, and thus profoundly affected growth.

One such imbalance began in 1950. In that year demand for nickel soared to what was then an all-time high. The U.S. government was buying nickel for stockpile; supplies held by consumers were dwindling. The world's largest producer was in the process of converting some mines from open-pit to underground operations. Imports from Norway declined. Overall world production was down. Before the year was half gone, two of the world's major suppliers, realizing demand would exceed supply, instituted "voluntary rationing," which gave way to stricter controls supervised in Washington, DC. Along with other civilian users of nickel, most of the plating industry had to squeeze by on less than was needed. Plating thickness was drastically reduced so that nickel-chromium coatings failed miserably in all but the most benign environments. Nickel coatings were designed out of many products. Substitutes were found, and markets were lost. Thus, this period of imbalance, which lasted through part of 1957, dealt the industry a mighty blow.

From 1958 to 1965, the industry recovered much of its loss and grew at a healthy pace. Demands of a healthy economy joined with military requirements for the Vietnam War to cast a rosy hue over nickel-consuming industries. Consumption and production reached record highs. But the rosy hue turned dark gray in 1966 with the onset of another imbalance, which endured for the next 3½ years. Once again the plating industry suffered a crippling blow. Whether the industry has ever fully recovered is debatable. But it is reasonably clear that this imbalance was a factor in hastening the maturity of nickel plating, if we can accept the word to mean that stage in which growth no longer exceeds, and at times fails to keep up with, the increase in gross national product.

Consumption

Table 1 shows sales of "anode" nickel to the plating industry for the years 1945 through 1982, based on figures published by the Bureau of Mines in the *Minerals Year Book*. With all due respect to the bureau for their excellent work, I must point out that these figures - if not properly interpreted - can be misleading. First, they are sales (not consumption) and cannot take into account what fraction of sales went into inventory. Second, they do not include nickel sold as nickel salts, which for many years was a sizeable fraction of nickel sold and consumed. Third, the ratio of nickel consumed as salts to that consumed as anodes was much higher in the days before strict regulations of plating effluent. Fourth, accuracy of the statistics depends on cooperation of suppliers to report their sales. Gathering these statistics, therefore, may have been easier in the days when 90 percent of nickel anodes was sold by a handful of suppliers than it has been since the advent of titanium baskets. Hence, the chief value of Table 1 is as an indicator of the trend in consumption.

Perhaps the most cogent point the table can make is that consumption more than doubled from 1945 to 1949, hit its peak in the 1970s following the second major imbalance, and has dropped appreciably in the last three years. Actually, if we average sales in that fairly normal period of 1959-1966, we get a figure of 33.632 million lb. - just 2.5 percent less than the 34.481 million lb. average for 1980, '81 and '82. Averaging several years tends to even out the effects of inventory and should yield figures approximately equivalent to consumption. Admittedly, the argument is open to challenge, but the evidence is strong that growth peaked in the 1970s and the industry has now reached a state of maturity [by 1984].

Table 1 - Sales of nickel to the plating industry*

Year	Millions of pounds	Year	Millions of pounds
1945	12.736	1964	38.892
1946	17.059	1965	38.900
1947	17.975	1966	27.656
1948	28.426	1967	47.442
1949	27.621	1968	43.822
1950	38.848	1969	32.974
1951	11.967	1970	42.048
1952	13.799	1971	37.132
1953	26.548	1972	50.702
1954	26.920	1973	53.066
1955	29.258	1974	49.246
1956	31.904	1975	35.606
1957	46.708	1976	53.566
1958	15.386	1977	39.612
1959	29.288	1978	51.484
1960	31.694	1979	49.858
1961	31.474	1980	31.494
1962	33.906	1981	37.550
1963	37.242	1982	34.700

*As reported by the U.S. Dept. of the Bureau of Mines. Figures have been converted to pounds from those published in the *Mineral Year Book*.

A final word

This is not to say the industry is dying. Far from it. The combination of bright nickel and chromium remains an attractive, economical tool for imparting beauty and durability to hundreds of objects and one of the most practical ways to upgrade inexpensive materials. People have ever been fascinated by brightness and perhaps always will be. An exciting chapter, and one we must pass with this fleeting note, is the one by leading designers who brought nickel-chromium out of the kitchen dining nook into the most elegant drawing rooms and offices in today's world. Wherever we go, we find nickel-chromium used with good taste and style.

In our haste, we have skipped too quickly by without nodding to the contributions of automatic and programmed plating machines, improvements in cleaning and pretreatments, advances in filtration, reclamation of plating salts, control of plating effluent, and the general and steady transformation of nickel plating from an art to a science. We have also failed to pay tribute to a host of dedicated scientists whose pioneering research made nickel plating what it is today. My head is filled with illustrious names. But since I may fail to name them all, I refrain from naming any save those whose particular work has been cited. And so, we close with a bit of envy for those whose privilege it will be to fashion the coming years of an industry whose past has been exciting and whose future promises to be far from trivial and dull.

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About the author (as written in 1984)

W. Wallace Sellers spent 38 years as an electrochemist, supervisor of electroplating research, plating specialist, general sales manager and assistant to the executive vice president at the International Nickel Company, Inc. He has since retired. Mr. Sellers has written a number of papers on electroplating and related subjects and received the AES Gold Medal, Silver Medal and George Hogaboom Award. He has also been an invitational lecturer on electroplating in Australia, Japan, Taiwan and Korea. Mr. Sellers holds a B.S. degree from the College of William and Mary and an M.S. in physical chemistry from Vanderbilt University. He is a past member of the AES, ASTM and other societies, and a fellow of the American Institute of Chemists.