1950 THE GOLDEN AGE OF ELECTRONICS 2000

OR

"A WONDER-FULL HALF-CENTURY!"

(Made possible through the efforts and inventions of members of The American Electroplaters and Surface Finishers Society)

As reported by
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It's been a half century since, like most platers, I accidentally became one. The year was 1956 and back then fifty years seemed a tremendously long time. Now it seems little more than fifty weeks. It's said time flies when you're having fun. It also flies when you're working hard. During that almost half century, especially the first twenty five years, I, as did most platers in or on the fringes of the electronics industry, had a lot of fun working very hard. For us time flew by at warp speed. (Very fast)

After World War II ended in 1945 (we won that one) scientists set about finding new and better ways to do things. They were enormously successful, particularly in the field of electronics where they invented such miracle workers as the transistor (1947), the printed circuit (1948), silicon semi-conductors (1950), the light emitting diode (1956), integrated circuits (1958) and lasers (1960). These and many other discoveries rapidly led to the invention, development and proliferation of the plethora of electronic devices we've come to rely on today for just about everything.

You may not believe this, but trust me. In 1956 electroplating was still widely regarded as an art. A sort of "black art" actually. Platers were frequently called magicians and asked to make things bright and shiny by "dipping" them in their witches' brews. As I recall, even the Constitution of the American Electroplaters Society contained the phrase "*electroplating and its allied arts*!" However, by the early 1970s electroplating had become accepted as an industrial *science*! A very important industrial science. Why the difference? Because by then few could deny it was electroplating and its allied *sciences* which enabled that plethora of new and wonderful electronic devices and electrical products to: (a) function, (b) be affordable, (c) be reliable and (d) be long-lived.

Whether they were remarkably shrewd or remarkably ignorant, most inventors and designers at the onset of what was to become known as "The Golden Age of Electronics," (GAE) failed to consult with platers regarding the "platability" of their handiwork. Platers, in-house (captive departments) and "out-house" (job shoppers), were abruptly confronted with having to plate heretofore "unplateable materials." They were also expected to process parts with geometric shapes and configurations heretofore deemed "unprocessable." And it didn't stop there. The plated deposits on these unplatable and unprocessable parts were required to pass physical and chemical tests which were heretofore regarded ridiculous (at least by platers).

By the way, I suspect most "platers" reading this know to whom I'm referring when I use the word, "plater." In case you don't, *any person directly or indirectly associated with the production of plated and/or otherwise surface finished parts is a plater*! The list includes, but is not limited to:

- All employees of process, equipment and chemical manufacturers and suppliers
- All employees of plating companies and
- All employees in or functionally associated with captive plating departments.

Chemists, engineers, technicians, superintendents and forepersons, tank persons, quality control folks, sales persons, whoever. Oh yes - and even plating consultants.

It's important to understand this since these were the "*platers*" who had no choice but to discover procedures for successfully cleaning and activating unplatable surfaces. These were the *platers* who had to design the kind(s) of equipment which could successfully handle unprocessable parts. These were the *platers* who had to formulate plating solutions that deposited coatings capable of passing the new ridiculous chemical and physical specifications.

These were also the platers who were so successful that they were immediately confronted with another formidable challenge: producing enough of those heretofore unplateable things fast enough to meet rapidly soaring production requirements. An example: IBM's monthly requirement for gold plated connector pins jumped from about one million to more than fifteen million in less than two years. Platers now had to have high speed cleaning, activating and striking solutions; much better solution agitation systems; way improved filtration equipment; more efficient formulations; "high speed" plating solutions and high volume production equipment. Plus the quality assurance programs to go with them.

Gold deposits from cyanide solutions were no longer suitable due primarily to staining, porosity and slow plating rates. Neither was tin from stannate solutions suitable, primarily because of solderability problems. Electroless copper and electroless nickel solutions had to be upgraded from a sort of "hope for the best" type of process to reliable workhorse solutions, and deposits of predictably good quality. It's likely that had not bright acid gold, bright acid tin and bright acid tin/lead processes been introduced and if electroless copper and nickel solutions had not been made more productive "user friendly," the Golden Age of Electronics would have fizzled in just a few years.

As for equipment, the list of inventions during the first half of the Golden Age of Electronics is a big one. A few of the items which come immediately to mind (mine) are: port-hole barrels, button contact barrels, mesh lined barrels and bottom contacting oblique barrels; PVC and polypropylene tanks and liners; in-tank filters and carbon cartridge filters; vibratory platers; low ripple and pulse-reverse rectifiers; platinized tantalum and titanium anodes; automated plating lines which could be (mechanically) programmed to deal with more than one process at the same time; and Beta ray thickness testers. The latter was a Godsend to precious metal platers since it superseded the woefully time consuming and equally woefully inaccurate (really) microscopic cross-sectioning technique.

It was about 1973 when product requirements began to plateau. By then, the Sylvania plating department in Warren, PA was consuming at least twenty pounds (Avoirdupois) of gold every twenty four hours plating formed contacts, connector pins and continuousl (reel-to-reel) plating stamped contacts and lead frames. Whether bought from Sylvania or any of the other electronics parts manufacturers, most of the gold cost (at least we so believed for a costly period of time) was passed on to the buyers, the Western Electrics, IBMs, Signetics, Westinghouses, Motorolas, Hewlitt Packards, etc.

Until about 1973, productivity was the force driving electronics manufacturers, resulting in "damn the expense, full speed ahead" production activities. When production requirements began to plateau, the bill payers of the major electronics firms - presidents, comptrollers and such - began to fret about gold plating being so costly, sometimes doubling the manufacturing cost of an electronic part. They asked their employees responsible for the plating specs questions such as, "What is there that's as good as gold but a lot cheaper?" "How come we need such thick gold coatings?" and "How come we have to have to plate the whole damned contact or lead frame instead of just where it's actually needed?"

The last question was referred to the plating industry, and it wasn't long before platers had come up with a variety of clever controlled depth, stripe and spot selective plating systems. These were followed by equally unique equipment capable of selectively plating contacts already molded into plastic connector blocks and electronic devices. Another innovation was "Loose piece parts platers" featuring vibratory feeding systems which inserted individual contacts into especially designed masking belts or into stainless steel belt fixtures.

Platers had much to do with the rapid and huge growth of the printed circuit industry. Especially designed and automated equipment, improved electroless nickel and copper solutions and numerous technical innovations facilitated high production rates and successful through-hole plating. A 1987 thesis, "Plating in a Tight Spot," published in *Circuits Manufacturing* magazine said this about that problem: "In through-hole plating a number of physical laws seriously inhibit the deposition of acceptably uniform and functionally reliable coatings. Ironically, the same laws enabling conventional metal deposition are those which tend to prevent it from occurring in the restricted spaces within small holes. Laws pertaining to fluid flow, surface tension, gravity, friction, molecular

TABLE 1—GOLD USAGE STATISTICS (1970-1980)

Year	Metric tons (Electroplating)	Production Factor*	Usage**	Tons Saved	Annual Avg. $/Troy oz.	$$Saved (Millions) (32.159 T.O./metric ton)
1970	44.8	1.0	Base year		$36.41	
1971	42.8	0.97	43.5	(0.7)	$41.25	$(928,330)
1972	51.2	1.1	49.3	(1.9)	$58.60	$(3,579,581)
1973	61.6	1.3	58.2	(3.4)	$97.81	$(10,691,611)
1974	44.0	1.2	53.7	9.7	$159.74	$49,815,718
1975	24.9	1.3	58.2	33.3	$161.49	$172,890,387
1976	27.7	1.4	62.7	35.0	$125.32	$141,016,330
1977	31.4	1.5	67.2	35.8	$148.31	$170,700,361
1978	36.4	1.6	71.7	35.3	$193.55	$219,658,927
1979	39.7	1.7	76.2	36.5	$307.50	$360,864,563
1980	38.3	1.8	80.6	42.3	$340.20	$462,653,289

* Production Factor: an estimate of the increase in plating through-put relative to 1970.

** Usage is determined by multiplying the Production Factor by metric tons used in 1970.

attraction, electron transfer and chemical and electrochemical reactions each complicate the job of successful through plating to various degrees." The article goes on to say that to obtain the required copper thickness of 0.001" in a through-hole 0.015" in diameter and 0.062" in length, the solution must be replaced 300 times. Considering the aforementioned physical, chemical and electrical factors, the job is, in theory, impossible.

I doubt if anyone ever thought (or really cared) about trying to quantify the degree to which platers, that is the plating industry, effected the overall USA economy and/or the GNP - particularly during the Golden Age of Electronics. I know if anyone were to do so the answer would be, in a word, stupendous! To bolster that claim, consider the accompanying chart, a comparison of gold usage for plating from 1970 to 1980.

The usage figures in Table 1 are those reported in *Gold Statistics and Analysis: J. Arom and Gold 1981, 1983, and 1986: Consolidated Gold Fields, Ltd*. It is estimated that the electroplating industry consumes about 75% of the total metric tons of gold reported sold each year.

The decline shown in 1971 was due to a recession. From 1972 to 1973 there was a period of rapidly increasing production of gold plated parts. The negative savings indicated for those three years were because of inadequate gold control, *i.e*., overplating and excessive dragout. Beginning in 1974 gold control programs began to take effect and selective plating of contacts and strip was getting underway. From 1975 through 1980, production requirements climbed steadily but gold usage per year did not. The "Production Factors" are my estimates based on Sylvania's productivity during those years. They are conservative numbers since from 1970 to 1980, the production of electronic parts far exceeded the 1.8 times stated on the chart.

Those parentheses around "Tons Saved" for years 1971, 1972 and 1973 indicate more gold was purchased for plating than could be accounted for on plated parts. About 2% was unaccounted for in 1971, 4% in 1972 and 6% in 1973, and this increase reflects the approximate rise in numbers of parts being plated. The records indicate six metric tons of gold either went down the drain, out the door on over-plated parts, or wherever, in those three years. The records also show that from 1974 through 1980 a total of 227.9 metric tons were **not** purchased by platers despite increasing production throughput, the primary reasons being selective plating, thinner deposits and conservation programs.

While focusing our efforts primarily on production, that is to say, getting parts out the door, not much attention was paid to the proper utilization of our raw materials. Unfortunately one of these raw materials was gold. We didn't realize how much gold we were giving away by overplating, poor plating distribution, poorly designed equipment and inadequate solution maintenance. We believed we were not allowing gold to go down the drain. We were very wrong. Nor did we understand how much gold was given away by not having the slightest idea how much gold was in the solutions and on scrap materials sent out for refining.

In a manner of speaking, we allowed a total of about $15.2 million dollars worth of gold to slip through our fingers during 1971-1973. Big deal? Yes and no; fifteen million dollars is a fair amount to be sure, but when comparing that amount to the $227.9 million dollars saved in years 1974-1980, it's a rather paltry sum. So much for the big numbers. The rest of this essay illustrates, via words and pictures, a few of the necessity-inspired inventions and developments that fostered and sustained the Golden Age of Electronics.

GTE Sylvania's Parts Division located in Warren, PA was whereas I said, I accidentally became a plater. There were four separate but integrated manufacturing facilities in that location, producing plated wire, formed wire, wire leads, welded wire components and contacts, nickel plated strip materials and stamped parts, plastic components and connectors and bases for incandescent and fluorescent light bulbs. In addition to other Sylvania divisions these products were sold to customers such as General Electric, Western Electric, RCA, Motorola, ITT, Westinghouse and a fledgling IBM.

In 1956 the major equipment in the plating department included, in addition to conventional horizontal and oblique barrel plating lines, two unconventional wire/rod Kenmore continuous platers (Fig. 1), one unconventional "vertical" continuous strip plater (Fig. 2) and one very unconventional continuous gold plated (small diameter) wire line. The latter three were systems designed and built by Sylvania "platers" to overcome costly quality and production problems.

Before about 1953, 100-lb. coils of 0.100"-diameter steel or copper wire to be nickel plated were spread out on a three-foot wide "plating bar." During the cleaning and nickel plating steps a rubber gloved employee had to continuously move and spread the coils to (try to) obtain a uniform a 0.002" plating thickness. After plating, the wire was drawn to diameters as small as 0.020" and, due to non-uniform plating thickness and intermittent poor adherence, scrap and lost time added greatly to production costs.

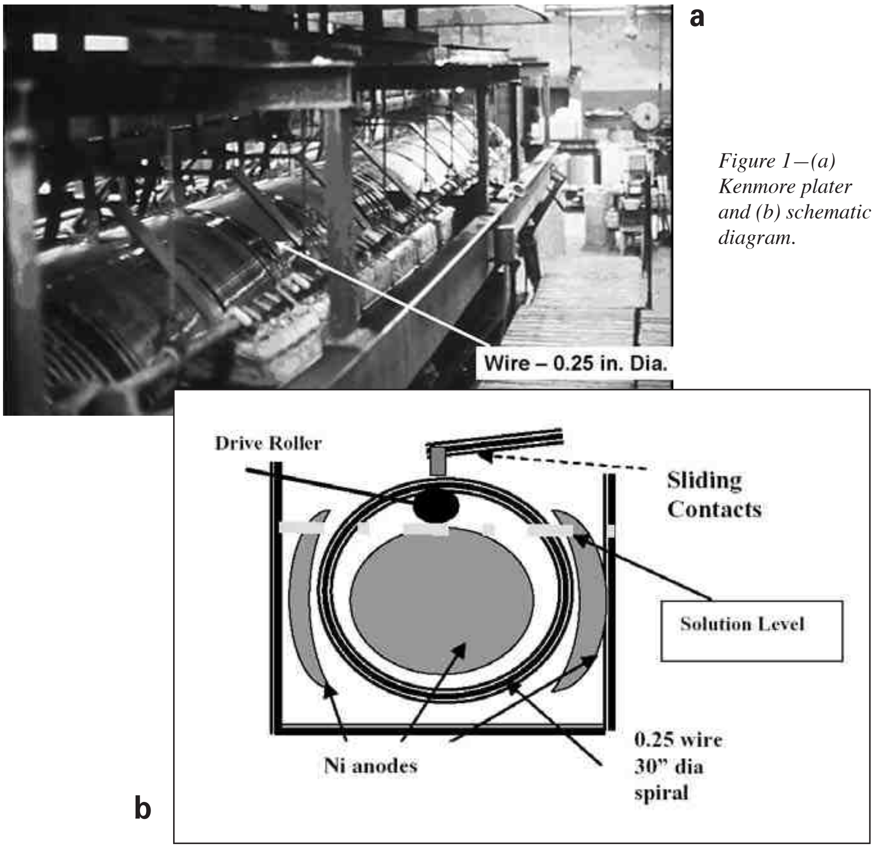


Figure 1—(a) Kenmore plater and (b) schematic diagram.

It was about 1953 when the "batch" wire plating system was replaced by what came to be known as the Kenmore Process (Fig. 1). It is an ingenious continuous plating system in which 0.250" diameter wire is spiraled through the cleaning and plating tanks. Invented by a Sylvania employee, the plating tank features conforming OD and ID anodes and individually contacted loops of wire. This process increased the plating rate from about 125 lb./hr to about four hundred while dropping the 10 to 15% scrap rate to virtually zero.

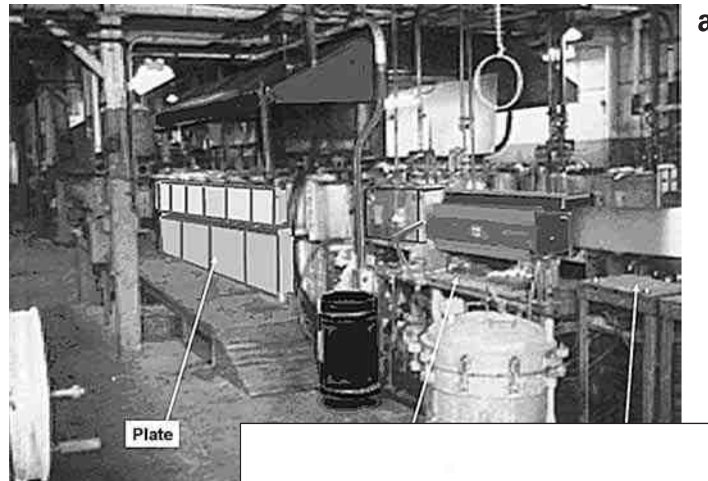
The vertical strip plating line (Fig. 2) was also developed by another Sylvanian about 1954 to resolve a major procurement and cost problem. In those years, tons of nickel plated steel strip, typically eight inches wide and 0.005" thick, were needed each day to produce the functioning components of electron tubes. About 50% of these components required a black surface to obtain a "black body effect" or heat absorbing capability in the tubes. The black surface was created when the nickel plated strip was continuously "carbonized" (the pyrolytic reduction of nickel in a hydrocarbon gas) in towering furnaces. Carbonizing was a hypersensitive process and thus the nickel thickness could not vary more than 0.000025" on either side of the typically eight-inch wide strip.

Until the vertical plating equipment was developed, only the center eight inches, called the prime cut, of horizontally plated thirty-six inches wide could be carbonized. By continuously plating the strip vertically, as seen in the picture, it was possible, via anode placement and shielding, to maintain the plating thickness to within plus or minus 0.000010".

It can be deduced from the sketches in Figs. 3 and 4 that from 1865 and 1952, a span of 87 years, there was little progress in the technique used for continuously gold plating small diameter wire. That is, except for solution heating (wood fire vs. electric immersion), and source of DC (battery vs. rectifier.) Oh yes, and the matter of pulling the wire through the plating lines: in 1865 it was accomplished by an unknown person who hand cranked the take up spool; in 1954 the spool was hand cranked by a man named Bill. That is, until a mechanical engineer named Bob had the bright idea of hooking up an electric motor from his son's Gilbert Erector Set to a level winding Shakespeare fishing reel.

The reason why, during those 87 years, there were few changes made is there was no need, but the onset of the Golden Age of Electronics fixed that. Requirements for gold plated fine diameter wire soared, as they did for silver, tin and solder plated wire. Since strand plating lines were not a "shelf item" in plating equipment supply stores, Sylvania, and their competitors, had to design and build what they needed (Figs. 5 and 6).

Sylvania's Parts Division was among the first of major manufacturers of contacts stamped from strip plated strip and of lead frames, stripe or overall plated after stamping. As in the case of wire plating, strip plating equipment was not yet commercially available, so again Sylvania platers, plating technicians and plating chemists, teamed with Sylvania equipment designers, plating process vendors, suppliers selling ancillary equipment, *i.e.*, filters, heaters, tanks and pumps, to build what was required (Figs. 7 and 8).



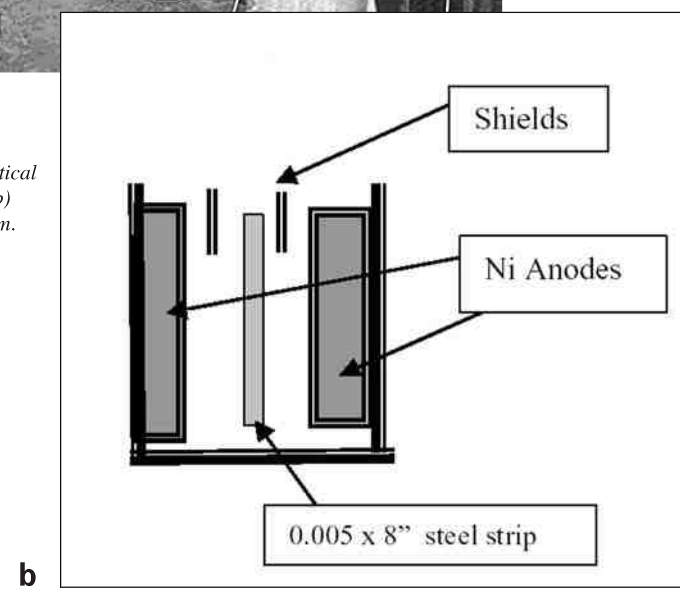


Figure 2—(a) Vertical strip plater and (b) schematic diagram.

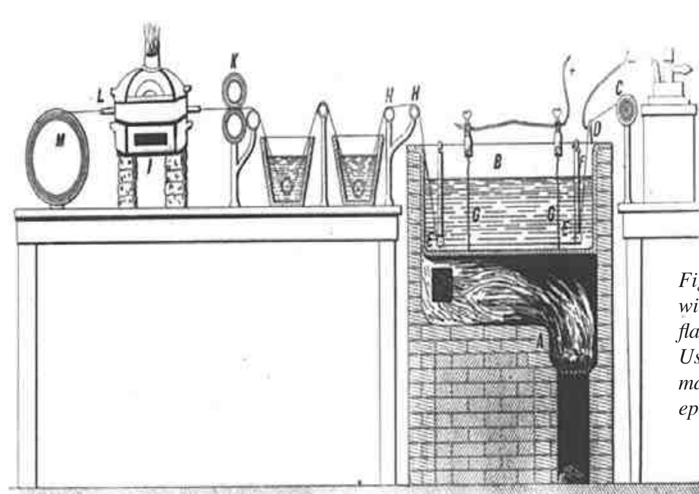


Figure 3—Circa 1865 wire plater. Gold flashed 0.007" copper. Used as thread to make U.S. Army epaulettes.

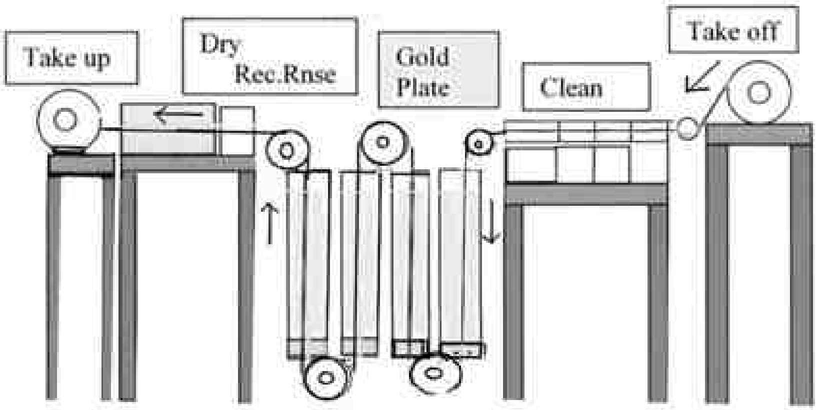


Figure 4—Gold plating on nickel-plated 0.015" copper wire; gold cyanide, 130°F; plating thickness, 0.000030"; plating speed, 10 ft/min (Designed by two Sylvania chemists about 1953).

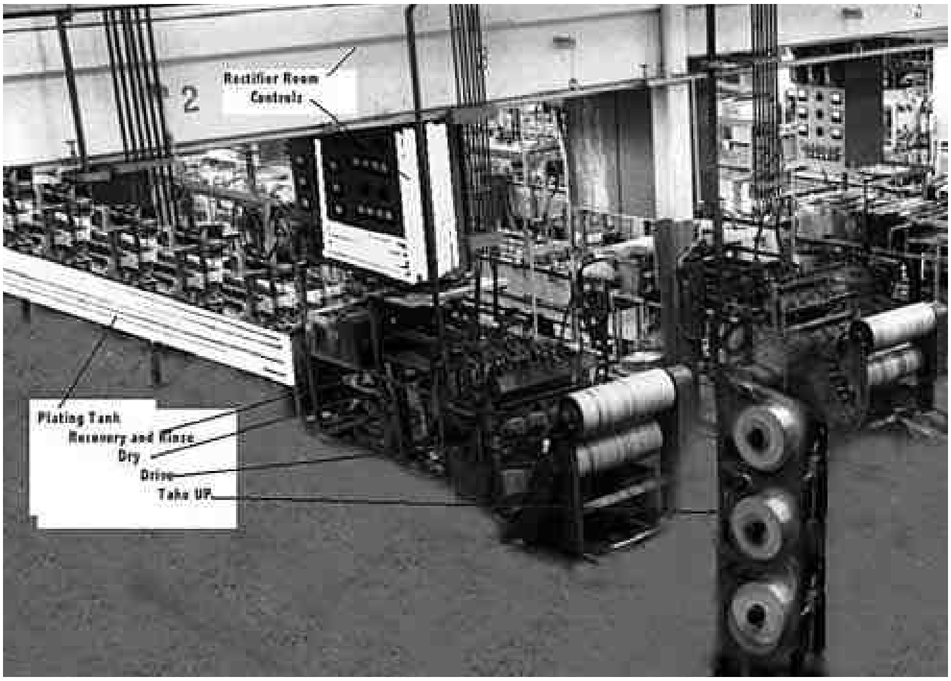


Figure 5—This six strand gold plating line is capable of plating wire from 0.010" to 0.40" and at speeds from 10 to 150 ft/min. The newly marketed acid gold solution at 1.0 oz/gal heated to 120°F could be operated up to 50 A/ft^2. In-tank filters and quartz heaters were used. Copper and/or nickel underplates were deposited in preceding tanks (The gold tank and control panel are accented via light shading in this B&W photo).

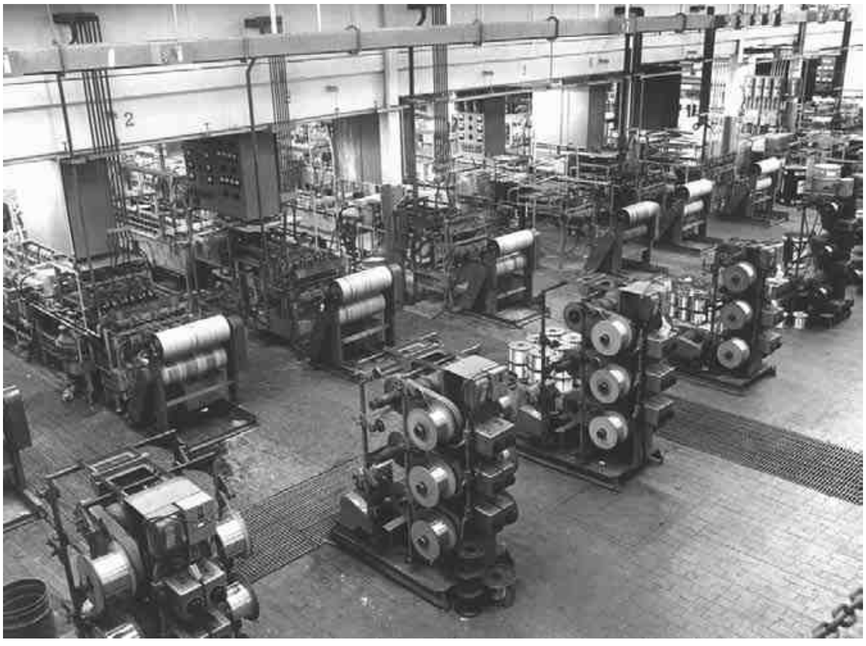


Figure 6—By 1972, ten 6-strand plating machines were in operation, plating gold, silver, reflowed tin and reflowed 60/40 solder onto wire diameters from 0.008" to 0.040" at rates from 15 to 200 ft/min. Rectifiers were located in an overhead air-conditioned room. Except for the rectifiers, take-up spoolers, tank heaters and solution filters, all of the equipment was designed and built by Sylvanians.

In a preceding paragraph I said had not "platers" been able to successfully design equipment and develop processes to do the (practically) impossible, there could have been no Golden Age of Electronics. This I honestly believe! Here's another thing I honestly know! ***Had it not been for the then American Electroplaters Society, "platers" would have been far less successful and timely with their designs and formulations.***

Before the early 1950s, when platers got together they talked mostly about door handles, hubcaps, faucets, crescent wrenches and silverware. They also talked about crankshafts, periscope tubes, radiators and outboard motors. And they talked a great deal about how to plate bumpers so they wouldn't rust while cars were still in the showroom. To check this out leaf through some of the AES Convention Proceedings published before, say 1955. You'll learn that way less than 10% of the papers presented had anything at all to do with electronics, which is understandable since probably way less than 10% of the AES members had anything at all to do with electronics.

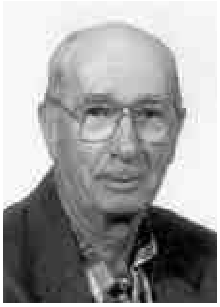
Then came the influx of all those inventions of electronics-related products which couldn't work, couldn't last, wouldn't be affordable and/or wouldn't be reliable unless plated. Plating for electronics suddenly became a new, unexplored facet of plating endeavor. The AES (AESF), via symposia, publications, forums, technical conferences, illustrated lectures and the like, allowed its members to collectively explore this new facet. The thing is that while two heads are better than one, a lot of heads are much better than two.

Figure 7—Continuous or reel-to-reel strip plater. Pre-formed or stamped strip sizes from 0.005" to 0.015" thick by 0.75" to 2.75" wide overall, or stripe plated with gold, silver, tin or solder over a nickel underplate. This and three similar lines were required.

Figure 8—Spot plater for lead frames, providing continuous gold or silver spot plating of from four to forty lead frames. By means of stepping and repeating, ten to twelve spots were plated simultaneously through specially designed masking "shoes." Four spot lines were required.

Recognizing what the AES could do for the electronics industry, most of the key electronics manufacturers encouraged their platers to join and become actively involved in AES programs and committees. Many companies - Western Electric, General Electric, ITT, GTE, GTE Sylvania, IBM, Westinghouse, Signetics and Motorola come to mind - had from five to ten employees belonging to, and dedicated to, the Society. Collectively they addressed the long list of complex challenges confronting "platers for electronics" and collectively they resolved them successfully and expeditiously (despite many of them falling into the "impossible" category).

While it's unlikely there will ever be a repeat of the fun and busy years of the Golden Age of Electronics, it's predictable that there will be another era of discovery and invention. Due to the grossly inefficient modes of transportation we have today, whether in the air, in space or on the ground, it may be the next Golden Age will be that of "Getting There." And whatever changes are in store, it's a good guess that, as it was in electronics, electroplating and its allied sciences will make these changes (you guessed it) (a) function, (b) be affordable, (c) be reliable and (d) be long-lived. That is, providing there is still an AESF or similar organization around to "beam us up" in a manner of speaking.



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