Quality Through Consensus Standards

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In the surface finishing industry today, regardless of the facility size, technical standards play an essential part in developing the manufacturing process for the processing of parts. Standards can be used to learn the "standard" way to prepare the part, to identify the deposits and thickness required to meet the required service condition, and to determine the required tests to ensure a quality part. By utilizing recognized consensus standards, companies benefit from the proven state-of-the-art technology contributed by the combined experience of recognized experts. Quality, processing costs, buy vs. make decisions, import/export requirements, ISO 9000, and liability exposure are a few factors influenced by the use of standards.

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Standards, They Affect Our Everyday Lives

Examples are often given to help demonstrate the importance of standards in our everyday lives. One that uses parts produced with the help of the surface finishing industry is about a commercial airplane trip from the US to South Africa. A new American built airplane is flying over Central Africa when the pilots noticed that they were running low on fuel. Suspecting a fuel leak, they radioed to the nearest airport for clearances to make an unscheduled landing. They landed at a small airport that was not on the route of any American built planes of this type. However, within a few hours, a new gasket and several bolts were placed on the plane to stop the fuel leak. They were then refueled and left safely on to their destination.

Most people would not think that this incident was very unusual. There are enough unscheduled landings that people think that they are almost routine. However, without standards, this would never be routine. Even though this was the first time this type of airplane ever landed at this airport, standards made it appear routine. Standards allowed the pilot to communicate in English and be familiar with the landing procedure at this airport. Standards also guaranteed that the plated replacement bolts would fit and meet the strict performance and safety requirements for airplanes. And finally, they were confident that the fuel would meet the requirements of their particular airplane engines. Of course, the example could have started even earlier by mentioning the standards that controlled the quality of every component used to produce the airplane and train the crew and airport personnel.

A more down to earth example of the use of standards, or in this case the lack of standards, takes place in North America during the 50s and 60s. During this period, decorative exterior bright trim on automobiles and trucks reached its high point. Consumer demand increased as the number and complexity of nickel-chromium plated bumpers and body trim increased. However, within a few years at the end of the 60s, the use of decorative exterior automotive trim almost disappeared. This rapid decline can be contributed to many factors such as aerodynamic designs to improve fuel economy and consumer's complaints of rapid corrosion. A SAE Technical Paper (number 900766) reported some of the factors that contributed to accelerated corrosion of the plated parts:

1. Many of the part designs were too complex to plate to specification without expensive racking and auxiliaries.
2. Production requirements outstripped the ability to produce quality products within the price contracted with some of the automotive companies. Many parts were put into service with thin deposits that had poor physical properties produced from electrolytes that would be considered out of specification today. (Some of the problems associated with the physical properties of the deposits were unknown during the 60s.)
3. The corrosive nature of the environment was increasing due, in part, to acid rain and the increased use of sodium and calcium chloride on snow/ice covered streets. Even if parts were produced to the existing specification, the standards were not sufficient to protect against the increased corrosive nature of the environment.

Insufficient or unapplied plating standards contributed significantly to the demise of decorative plated parts on North American automobiles in the 70s. Decorative trim was no longer considered a sign of quality. It was not until the 90s that the consumer again started to prefer automobiles with OEM decorative trim. The increased use of aftermarket decorative trim accelerated the reintroduction of OEM parts. In 1997, ABPA, a trade organization with a goal to encourage automotive bright trim, sponsored a consumer survey to determine the preferences for bright automotive trim. The survey estimated that 44% of the consumers would prefer bright trim on their next vehicle. With 23% undecided, the survey predicts that over 50% of new vehicles will be purchased with bright trim. The survey determined that the consumer again considered that bright trim was a sign of quality for the part and the vehicle.

Between the 70s and the 90s, many things changed that helped the automotive consumers regain their perception that decorative bright trim implies quality:

1. Through better designs and electroplating practices, bright automotive trim parts were produced with adequate deposits to meet service requirements.
2. Suppliers and platers developed a better understanding of the technology that is required to produce corrosion resistant deposits. Improved standards and tests were developed to ensure this information was utilized.
3. The corrosive nature of the environment stabilized or even improved making it possible to determine what was required to eliminate base metal corrosion over the survive life of the part.

Standards Help Ensure Quality – Among Other Things

Many standards are developed to helps ensure quality results. They also help improve production efficiency and reduce production costs. They can be used to expand the market for parts by producing them to meet the service conditions required by a variety of potential purchasers. Following internationally accepted standards eases the barriers to international trade. They help meet performance requirements such as ISO 9000 and contribute to reduced liabilities. New technology can even be transferred through the use of standards.

When choosing the appropriate standards to obtain these benefits, it is usually best to use recognized standards that are based upon established, state of the art technology. They should contain or reference all the information to consistently produce parts with the stated performance. The aerospace and automotive companies produce many of their own Company Standards based upon their experience and the expertise of their suppliers. They many times reference or incorporate Government Standards. They also use Consensus Standards produced through the collective experience of a broad-based group of experts. These experts represent all phases of the technology combining expertise from inside and outside the industry.

Organizations such as ASTM and ISO provide the unbiased mechanism to produce Consensus Standards through the collective knowledge of many, many times competing, experts. To ensure impartiality and to further the technology, organizations such as ASTM independently corroborate the experts' information through experimentally designed test programs.

To ensure that Consensus Standards reflect the state of the art, organizations such as ASTM require that their standards be technically reviewed and balloted at least every five years. A major technical revision of ASTM B 456 (Specification for Electroplated Coatings of Copper Plus Nickel Plus Chromium and Nickel Plus Chromium) is currently underway. B 456 addresses the requirements to produce nickel plus chromium electroplated decorative parts on most commonly used substrates except plastic. Through the practice of B 456, quality parts can be consistently produced.

B 604 (Specification for Decorative Electroplated Coatings of Copper Plus Nickel Plus Chromium on Plastics) covers the same technology for plastic substrates. B 604 is just starting to be technology reviewed.

Quality Parts Through the Teachings of B 456

ASTM B 465 and its ISO counterpart 1456, contains or references most of the requirements to produce a decorative copper-nickel-chromium plated part. They contain 5 Service Conditions, Table 1, that cover the typical uses of decorative electroplated parts. Once the appropriate Service Condition is determined, the standard specifies the thickness and properties of the deposits along with the testing required to ensure that the parts meet the requirements of the Service Condition.

Table 1 – ASTM B 456 Decorative Service Conditions

SC 5 – *Extended Very Severe* – likely damage from denting, scratching, and abrasive wear plus exposure to corrosive environments where long-term protection of substrate is required – e.g. exterior automotive parts
SC 4 – *Very Severe* – slightly milder then above – e.g. boat fittings for salt water and automotive
SC 3 – *Severe* – occasional to frequent wetting, exposure to strong cleaner and saline solution – e.g. lawn furniture, bicycles, and hospital fixtures
SC 2 – *Moderate* – indoors with moisture – e.g. kitchen and bathroom fixtures
SC 1 – *Mild* – warm, dry indoor air with minimal wear or abrasion

ASTM B 456 references or contains the factors that combine to establish the manufacturing procedure for electroplated parts, Figure 1. B 456 does not specify how the part is manufactured prior to electroplating except for offering suggestions through B 507 on how to design the part for easier electroplating, Figure 2. Figure 3 lists the referenced ASTM standards that detail how to prepare the substrate prior to electroplating copper or nickel. Other preparation methods are permitted within B 456 to prepare the part for electroplating as long as it is established that the alternative methods perform at least as well as the referenced methods.

The electroplating section of B 456, Figure 4, contains the plating specifications for the different Service Conditions. The standard addresses steel, copper & copper alloys, zinc alloys, stainless steel, and aluminum substrates. The purchaser's requirements are permitted as long as they meet the minimum thickness specifications for the specified Service Condition. The minimum deposit thickness was determined by industrial experience and a series of corrosion programs conducted by ASTM dating back to 1945. Table 2 lists some of the major programs including two 2001 programs that are ongoing.

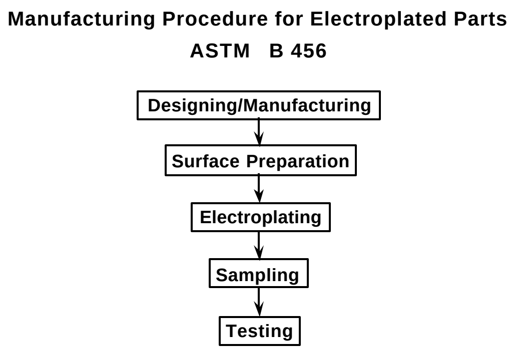

Figure 1 – Electroplating Standard

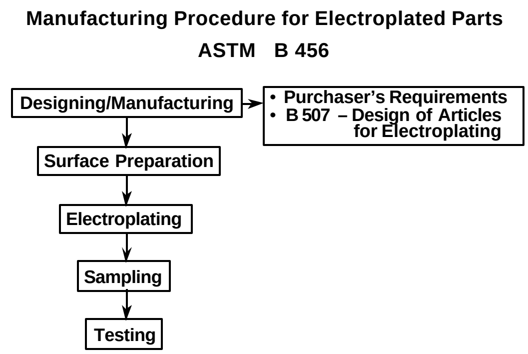

Figure 2 – Design Criteria

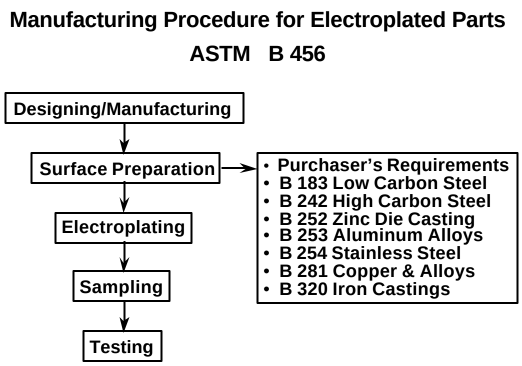

Figure 3 – Substrate Preparation

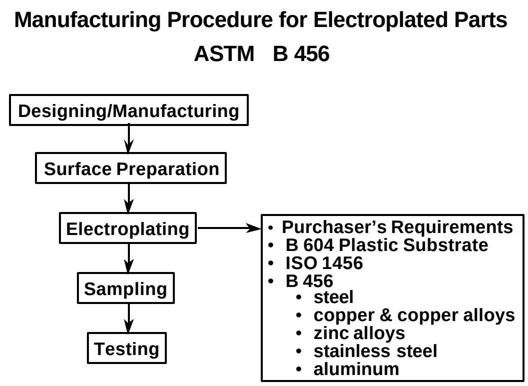

Figure 4 – Requirements to Meet Service Conditions on Different Substrates

ASTM Corrosion Programs Used to Develop B 456

In 1945 a corrosion program, Table 2, was established to determine if increasing the thickness of nickel improved the corrosion resistance of the deposits. This is obvious today but this corrosion program was deemed necessary at the time to quantify this relationship. It also demonstrated that a copper deposit offered little to the overall corrosion resistance of the system. Copper deposits do offer an excellent substrate for the subsequent nickel deposits.

The 1956 program investigated the effect of copper and nickel strikes under nickel deposits. The results showed that they offered no corrosion resistance but could help with adhesion. This program also indicated that some bright nickels resist corrosion better than others. This helped start an investigation into which nickel compositions and other factors influence corrosion resistance, stress, and ductility. The benefit of Duplex nickel, a specified thickness ratio of semi- bright nickel under bright nickel, was confirmed in a 1958 program. This program also helped initiate many studies that improved the understanding of the properties of nickel deposits. The 1962 and 1966 programs investigated the preferred deposits over aluminum and zinc die casts. They also reestablished the ineffectiveness of copper deposits in improving corrosion resistance.

The benefit of micro-discontinuous chromium was investigated in 1968. The results from this program and one in 1970 program were used to establish the requirements for Service Condition 4. SC 4 was set at a minimum of 25 microns of Duplex nickel under micro-discontinuous chromium. Appearing that the effect of copper needed more investigation, the 1970 program and another program in 1974 again established that copper offers no protection of the substrate from corrosion. Service Condition 4, designed to meet the requirements of decorative exterior bright automotive trim, was developed after bright trim had almost disappeared from North American automobiles. Even though it initially had limited use, it did increase the level of understand of the requirements for decorative finishes that could resist severe corrosion conditions.

In 1980, a corrosion program was started to investigate Service Condition 5. SC 5 was required to meet the automotive need for decorative exterior bright trim that could resist base metal corrosion for over 10 years in a very severe corrosive environment. Parts close to the ground such as bumpers and wheels experience this type of service condition. The 1980 program helped establish that 30 to 40 microns of Duplex nickel under micro-discontinuous chromium was required to meet these requirements. No plating system was established for chromium that was not micro-discontinuous. Without micro-discontinuous chromium, the nickel thickness would have to be much thicker. Service Conditions 4 and 5 established specifications for today's decorative exterior bright automotive trim that consumers perceive as quality.

The use of micro-discontinuous chromium required a compromise between extended protection from base metal corrosion and the development of a slight dulling of the surface due to the formation of surface pits during corrosion. Chromium without micro-discontinuities maintained its reflectivity longer but develops large surface pits that develop into based metal corrosion. Figure 5 shows a magnified surface of corroded micro-porous chromium. The micro-pores enlarge during corrosion and account for the dulling of the surface. Figure 6 shows the magnified surface of a micro-cracked chromium surface after corrosion. Both systems were exposed to 12 years of an industrial environment containing salt, sulfur, acid rain, and alternating hot and cold temperatures. The large surface pit depicted in Figure 6 was created as the small "islands" of chromium flaked off during corrosion. When enough adjacent "islands" flake off, pits large enough to be seen with the eye causes the surface to become dull and gray. Because of the loss of appearance with micro-cracked systems and the slightly less corrosion resistance, the North American automotive companies have specified that only micro-porous chromium may be used. The 1981 corrosion program also saw the difference in appearance and the slightly less base metal protection of micro-cracked systems.

The 1981 program established that trivalent chromium deposits could be with all Service Conditions that specify micro-discontinuous chromium. Trivalent chromium deposits are micro-discontinuous as plated. This corrosion program along with the two started in 2001 were plated outside of ASTM's direct control but are rated annually for performance during ASTM corrosion inspections. This was necessary because of the difficulty of raising enough money within ASTM to pay for these expensive corrosion programs. One of the 2001 programs is investigating the optimum thickness for the particle nickel strike and the high sulfur nickel strike deposits. The automobile companies are using both of these strikes. The other program looks at different nickel thicknesses for satin nickel deposits under Service Conditions 4 and 5. Satin nickel is receiving a lot of attention today by the automotive companies but very few corrosion studies have been reported that determine the optimum thickness of the semi-bright, bright, satin nickel, and particle nickel deposits. ASTM might include the results of these studies in future technical revisions of B 456.

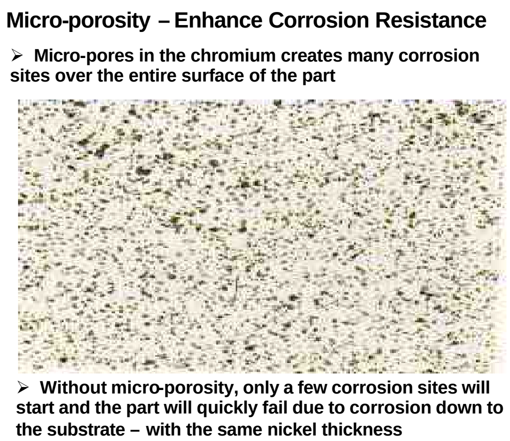

Figure 5 – Magnified appearance of micro-pores after 12 years of industrial corrosion

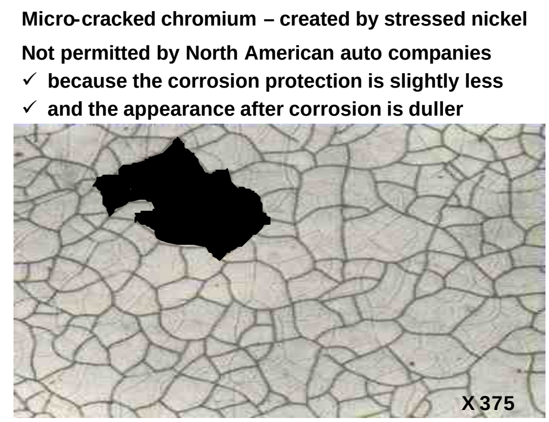

Figure 6 – Magnified appearance of micro-cracked chromium after 12 years of industrial corrosion

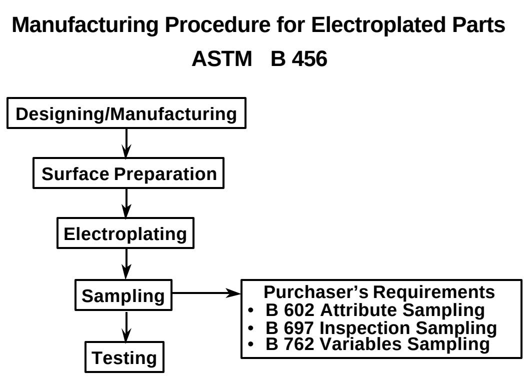

Figure 7 – Sampling Standards

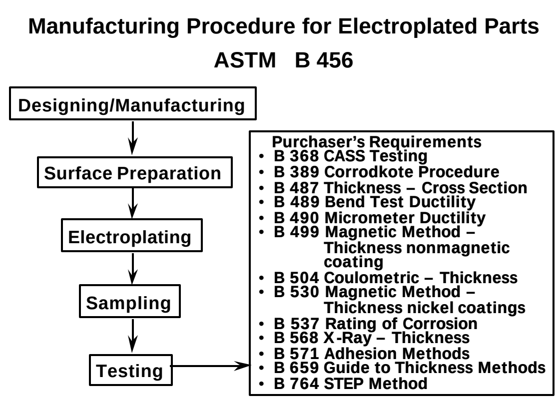

Figure 8 – Testing Standards

Sampling and Testing

ASTM B 456 requires that certain tests be conducted to insure that the electrodeposits meet specification. Figure 7 lists three sampling standards that can be used if the purchaser does not specify one. Figure 8 lists the tests methods referenced within B 456. ASTM B 456 and the automotive companies specify that the deposits meet thickness, ductility, adhesion, micro-porosity of the chromium deposit, percent weight of sulfur in the nickel deposits and STEP requirements. These properties have a direct influence on the ability of the part to resist base metal corrosion for the specified time. CASS accelerated corrosion testing is conducted to help determine if the part is plated to specification. A relatively new parameter, active sites, determines the actual corrosion sites after the required number of CASS cycles. Every micro-pore, as determined by the Dubpernell test, does not develop into an active site. Active sites are defined as the actual corrosion sites formed within the bright nickel deposit during the CASS test.

Table 2**
ASTM Corrosion Programs Used to Develop B 456

Date	Objective	Observed Effect
1945	Nickel-chromium vs. Copper-nickel-chromium	Nickel thickness important – two layers of nickel better – copper adds little to corrosion resistance
1956	Effects of copper and nickel strikes	Nickel and copper strikes no help with corrosion resistance – different bright nickels performed differently
1958	Effects of single and double layers of nickel	Duplex nickel (semi-bright nickel under bright nickel) is superior to buffed Watts and single layer bright nickel
1962	Performance of nickel over aluminum	Duplex nickel superior to buffed Watts – performance improved with nickel thickness – increased copper no benefit
1966	Performance of copper-nickel-chromium on zinc alloy die castings	Duplex nickel out performed single layer nickel – increased nickel helped – copper replacing semi-bright nickel detrimental to the corrosion protection of the substrate
1968	Effect of nickel thickness under micro-discontinuous chromium	25 microns of Duplex nickel under micro-discontinuous chromium minimum requirement for SC 4 – designed for exterior automotive bright trim applications
1970	Substitute copper for nickel in SC 4	Nickel replaced with copper detrimental – micro-discontinuous chromium required for SC 4 using ASTM B 456 nickel thickness
ASTM B 456 SC 4 nickel thickness established	Steel > 30 microns Duplex nickel with mp or mc Steel > 15 microns copper + 25 microns Duplex with mp or mc Zinc > 5 microns copper + 30 microns Duplex nickel with mp or mc Copper > 20 microns Duplex with mp or mc Aluminum and stainless steel substrates not in standard at this time	
1974	Effect of reducing semi-bright nickel thickness	Decreasing thickness or substituting copper detrimental to substrate protection from corrosion
1980	Single vs. Duplex nickel with and without copper	30 to 40 microns Duplex nickel required for 10 years without red rust, data for SC 5 – STEP must be correct
1981*	Confirming ASTM B 456 SC thickness – effect of trivalent chromium	Service Conditions meet minimum requirements with proper STEP – trivalent chromium equivalent to micro-porous hexavalent chromium
2001*	Thickness of particle nickel and high-sulfur-nickel deposits	Program started to determine effects of different thickness of the particle nickel and high sulfur strikes on overall corrosion resistance and appearance after corrosion
2001*	Satin nickel for SC 4 and SC 5 conditions	Program started to determine required thickness and type of additional nickel deposits required for SC 4 and 5

* Programs plated outside an ASTM program but rated during ASTM inspections.
** Table information obtained from ASTM B 08 files and personal information

Technical Revision of ASTM B 456

Early in 2002, a technical revision of ASTM B 456 was initiated. Several changes were made to reflect current practices, mostly within the automotive industry. At the time this paper was written the balloting on these changes was not complete and so some of the following changes might not be approved and additional ones may be added.

Ductility

The current B 456 standard requires that the copper and semi-bright nickel deposits have a minimum elongation of 8 %. This requirement was maintained for the copper deposit but, to reflect current practices, the ductility of the nickel deposits has replaced the elongation measurement. Using the micrometer ductility test, ASTM B 490, the semi-bright nickel deposit must have a ductility of at least 67 %. The bright nickel deposit has a minimum of 11 %. Figure 9 shows this test being conducted. It is very operator dependent but once learned it is dependable enough to fulfill this requirement.

Nickel Ratios

Table 3 lists the current and revised thickness ratios for the semi-bright, high sulfur, and bright nickel deposits. These relatively minor changes reflect the findings of corrosion programs and the specifications currently used by the automotive companies and others.

Figure 9 – ASTM B 490 Micrometer Ductility Test Method

Thickness Ratios for Duplex and Triplex Nickel Systems

Type of Nickel deposit	Current			Revision	
	Double Layer		Triple Layer	Double Layer	Triple Layer
	Steel*	Other*	All**	All**	All**
Semi-bright	75% min	60% min	50-70%	60-80%	50-70%
High- Sulfur			10% max		10% max
Bright	10-25%	10-40%	30% min	20-40%	30% min

* Substrate,
** Copper, zinc, stainless steel, and aluminum substrates

Table 3 – Current and Revised Thickness Values Relative to total Nickel Thickness

CASS Testing

Service Condition 5 currently requires 44 hours of CASS testing. This was changed to 66 hours in the revision reflecting the actual corrosion resistance capable of the deposits required for SC 5. Service Condition 2 was changed from 4 hours to 8 hours for the same reason.

The CASS Test standard, B 368, is also being reviewed to address concerns from people using the test procedure. A round robin is being conducted to look at the rate of corrosion of the nickel standard used to calibrate the CASS Box. There as been a change in the design of the boxes since the standard was written which might require a change in the method used to calibrate and operate the chamber. This ASTM conducted round robin should be completed during the first half of 2003.

Removal of Service Condition Options

The current standard permits a single deposit of dull or semi-bright nickel that has been polished to full brightness to replace Duplex nickel. This option has been removed in the revision. Dull and semi-bright nickel deposits do have a low corrosion rate because they should contain less than 0.005 % by mass sulfur. Prior to the introduction of the STEP requirement in B 456, this low activity nickel could have been equivalent to Duplex nickel that had a low STEP value. However, in the current standard, the STEP value is recommended to be between 100 and 200 mV. With this STEP, Duplex nickel is much more resistant to corrosion than the single polished nickel deposit.

The STEP Test, B 764, is also being technically reviewed at this time. Several changes are being balloted but the most significant one is the "typical-idealized" STEP curve shown in the standard. There is enough corrosion data today to specify that the STEP value of the particle nickel deposit must be nobler than the bright nickel deposit. Prior to the revision, the STEP Test curve in the standard, Figure 10, shows the particle nickel to be more active than the bright nickel. This was permitted when the curve was placed in the standard but not today. By making the particle nickel deposit nobler than the bright nickel deposit, the corrosion takes place under the particle nickel in the bright nickel deposit making it invisible on the surface of the part. One of the 2001 corrosion programs listed in Table 2 might help determine the optimum thickness of the particle nickel deposit.

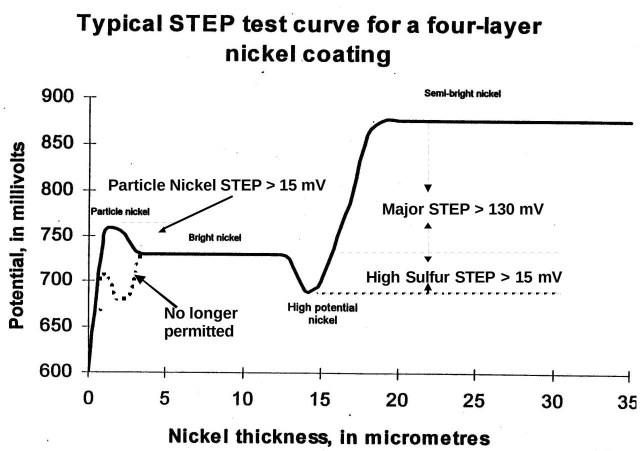

Figure 10 - STEP Curve

.... *Current Curve*

________ *Revision Curve*

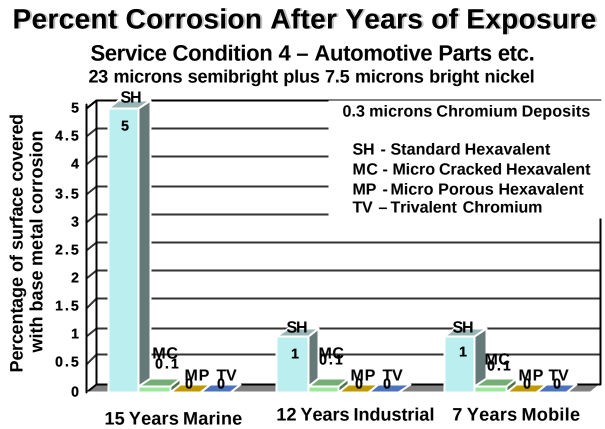

Figure 11 – Service Condition 4 Data from 1981 Corrosion Program

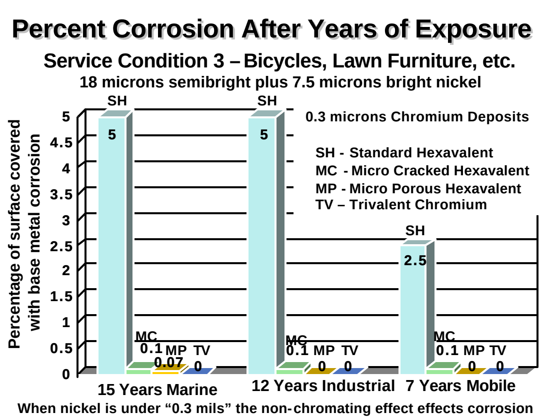

Figure 12 – Service Condition Data from 1981 Corrosion Program

Under Service Conditions 3 and 4, non micro-discontinuous (regular) hexavalent chromium has been removed as an option, even with thicker Duplex nickel deposits. Corrosion data has demonstrated that regular chromium does not perform well enough to meet the Service Condition requirements since it permits faster corrosion to the substrate than micro-discontinuous chromium. Figures 11 and 12, obtained in the 1981 corrosion program, present some of this corrosion data. The figures also contain some trivalent chromium corrosion data showing that it performs as well as micro-discontinuous hexavalent chromium deposits. Micro-cracked chromium is permitted in B 456 even though many companies do not permit its use on their parts. It remains as an option for those who want to use it and to keep B 456 in line with ISO's comparable standard, ISO1456.

Standards Help Ensure Quality

The factors that contribute to a quality product change as consumers' expectations change. They expect the product to keep meeting the conditions for which they are produced even if the conditions keep changing. Standards must also change with time as new information is obtained and as the environment changes. ASTM B 456 and some of its referenced standards are undergoing technical revisions to reflect these changes. The objective of B 456 is that, if it is practiced as written, the decorative copper-nickel-chromium part will meet the requirements of its expected Service Condition. Meeting the Service Condition is one factor that imparts quality in a manufactured part.