# Injection Mold Design Guidelines

*EIGHTH IN A SERIES*

# Maximizing Performance Using Copper Alloys

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*for the Mold Marketing Task Group of the Copper Development Association*

**Protecting Copper Alloys With Plating**
Frequently various coatings or platings are used in injection molds to prevent corrosion or erosion from the plastics attacking the mold. Coatings can reduce mold maintenance intervals while extend mold life. Copper alloys, C17200, C17510 and C18000 utilized for their high thermal conductivity properties to improve part quality and reduce cycle times, are no different than tool steels when protection is desired.

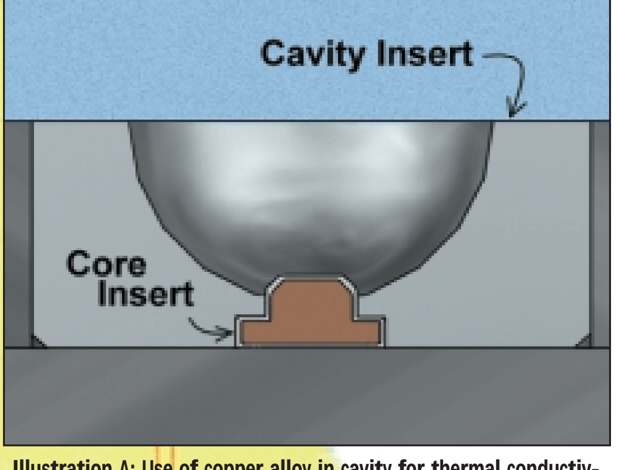


Illustration A: Use of copper alloy in cavity for thermal conductivity and plated to isolate it from the steel cavity.

Copper alloys in the presence of some plastic residues will react with mating steel components and create an electric current flow, similar to a battery. Isolating the copper- to-steel contact, Illustration A, with plating eliminates the galvanic action between the two materials and prevents the formation of small amounts of tarnish that could transfer to the plastic part. Typically the insert is completely covered with the plating.

**Preparing Surfaces for Plating**
The desired SPI surface finish, A-1 through D-3, should be applied to the copper alloy prior to shipment to the plating source. The plating will generally duplicate the surface where it is applied. A very rough surface finish will improve slightly when plated and a smooth highly polished surface will appear less polished. The plating process will not cover scratches, nicks and surface imperfections. Any mold defects must be removed prior to plating.

While it is a common and acceptable practice to sample a mold prior to plating, it is necessary to remove all traces of plastic from the component and notify the plater that the mold is used. Mold drawings, indicating the molding surfaces to be plated, should accompany the components to the plater. Masking surfaces where the plating is not desired can and should be noted on the mold drawings, if there is a good reason for not applying plating. However, masking can be a time consuming and expensive operation and it is normally a better choice to plate the entire component when it will not interfere with the molding process.

**Choices for Protecting Copper Alloys**
A wide variety of platings and coatings are available to protect your mold components. Some are more effective than others and individual choices will vary depending upon the application and experiences with your type of applications. Additionally, the quality of a given plating or coating may be very dependant upon the company that did the work.

Based on studies taking place at Western Michigan University two types of platings are showing the most promise depending upon

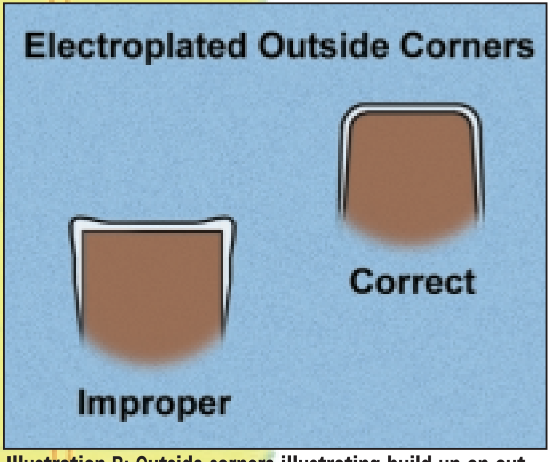


**Illustration B: Outside corners illustrating build up on outside sharp corners along with the correct application of radii.**

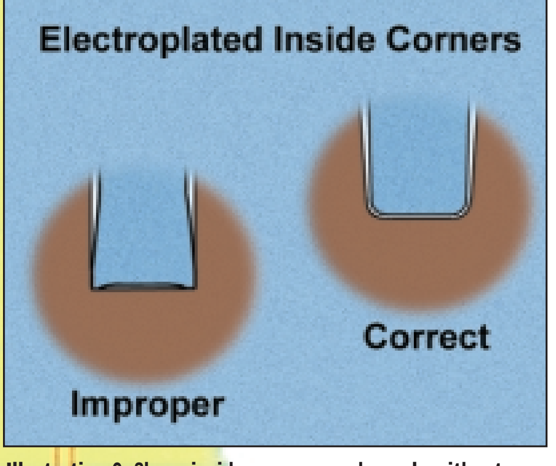


**Illustration C: Sharp inside corners on channels without draft results in uneven plating. Draft on the walls and radii on the inside corners allow for an even build up of chrome.**

the specific application, chrome electroplating and electroless nickel. The first and most effective protection against wear caused by impingement of glass filled nylon against cores is a variety of electroplated chrome platings. These chrome platings fall into one of four categories; standard industrial hard chrome, industrial hard chrome with its structure filled with a polymer, densified chrome platings and chrome composites like Armoloy's XADC a nodular chromium containing nano-composite of diamond.

**Chrome Electroplating**

The electroplating process uses electrical current to deposit the chrome on the mold component surface. Both ferrous and non-ferrous materials conduct current around the outside of the component and as a result the process attracts more chrome to outside sharp corners than flat surfaces. However, the copper alloys are such great electrical conductors that corner build up is accentuated over comparable steel components. See Illustration B. To reduce the build up, sometimes referred to as chrome trees or dog bones, the use of generous outside radius is recommended on the components outside corners. Obviously, the plastic part and its function must be able to accept the radius without detrement. Normally a generous radius, outside edge on the mold component and inside edge of the plastic part, adds great strength to the part and is typically a great benefit.

This electroplating process also creates problems on sharp inside corners of the mold component, see Illustration C. A sharp corner, due to current flow, will be starved of chrome. A generous radius on the inside corners allows for a more even build up and will prevent chipping at the corners. Channels cut into mold components (for forming ribs on the plastic part) create problems in electroplating. When the depth is greater than one half the width, plating thickness will vary considerably and diminish on the sides of the walls as the depth increases. Illustration D shows a typical condition encountered in molds. The sharp outside and inside corners, coupled with the depth of the channels prevents the chrome from building up evenly. Illustration E exhibits a more ideal construction method using an insert eliminating the channel depth-to-width problem. Additionally, the generous outside radius eliminates the problem of excessive outside corner build up, while the inside radius reduces corner starvation. When mold components can not be modified to optimize the electroplating process then anodes have to be built to get the plating down into deep channels.

**Benching of Electroplated Mold Components**

Mold components must be benched after electroplating. Any overhanging chrome deposits must be removed prior to sampling the mold or the plastic will form around the build up and the results will either be sticking of the plastic part or the chrome tree breaking off or chipping exposing the parent material. Illustration F shows chipping of chrome in a gate area. Two methods are normally used to remove the chrome build up. The first is with a hard 600 grit stone and carefully stoning the surface in the direction of draw, removing any chrome build up which would create an undercut.

The second method, performed by a skilled mold maker, uses a nylon brush mounted in a rotary tool operating at a slow speed with light pressure and a chrome polish. The surface is gently worked, carefully removing only the overhand so as not to destroy the intended plating thickness or reducing adhesion to the mold component. Caution has to be used, as to much pressure and/or high removal rates can cause chipping and exposure of the parent material.

**Electroless Nickel**

The second category of protection is electroless nickel



LHP MODERN PLASTICS, Issue date, Folio #, Date, Time
Version #/Filename:
BLACK CYAN MAGENTA YELLOW
PMS ID
5% 25% 50% 75% 95%

applied by an auto catalytic (without current) process. The advantage of electroless nickel is that the surface is covered to a uniform thickness compared to most of the electroplating processes. As the deposition is applied uniformly and without current due to the electroless process, special draft angles are not necessary and the process is forgiving on both inside and outside corners. The disadvantage is that the hardness of nickel is in the 50 Rc range, a lower hardness than many of the other platings available. Additionally, nickel is not a great bearing material and it should not be used in applications with moving parts.

**Plating of Holes**
Electroless nickel has the advantage of covering side surfaces of holes or channels with large aspect ratios. Sharp inside corners on blind holes are difficult to cover and a radius is recommended on any blind hole. On holes up to .125 inch in diameter the depth is limited to about .750 inch due to problems associated with getting the gases out of the hole. There is no practical limit to the depth of plating electroless nickel in holes greater than .125 inch on conventional molds. (Table 1)

Electroplating chrome into holes is more difficult than applying nickel. Frequently, anodes have to be built to assist in the application process. The cost of constructing the anode can be a significant additional cost not encountered with electroless nickel. Maintaining the proper position of the anode also adds difficulty in the plating process. Not withstanding the cost and difficulty, one plater uses the information listed in the following table as a guide to maximum depths of chrome plating into blind or through holes.

**Deposition Thickness**
The best thickness to apply a coating to a mold component is an age-old question and opinions differ widely. Experience and extensive testing at Western Michigan University shows that a thin layer of protection is extremely effective. The first consideration has to be to insure that the plating will adhere to the patent metal. This favors a thin layer over a thick layer. The second consideration is to the reason why the plating was applied in the first place and if a thicker layer will provide better protection.

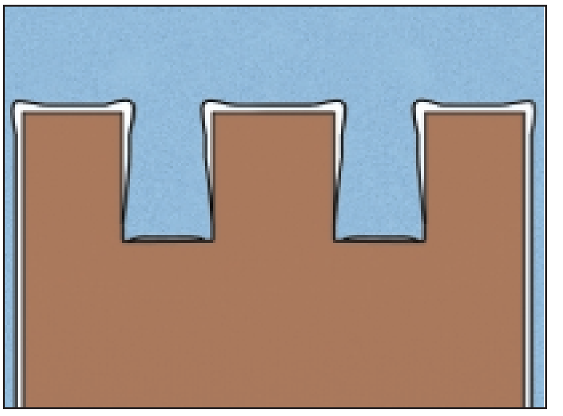

**Illustration D: Illustration shows the uneven plating build resulting from typical mold construction practices. Chrome build up is thick on the outside corners and thin to non-existent in the channels.**

Table 2 lists plating thickness, which have proven to be effective in protecting copper alloys used in plastic forming applications.

**Deposition Temperatures**
Care must be taken to avoid exposing all materials used in mold construction to excessive heat which could stress relieve or anneal the component. The copper alloys should not be exposed to temperatures above recommended manufacture specifications, typically around 400 degrees F. The electroless nickel process is typically less than 200 degrees F. Chrome electroplating usually has a process temperature of 185 degrees F or less. PVD or CVD process can run up to and sometimes exceed 400 degrees F. Considerations must to be given to the use of processes that expose copper alloys to temperatures approaching 900 degrees F, such as those found in some titanium nitride processes. Exposing copper alloys and some other mold alloys to high temperatures for extended times can be detrimental to their properties.

**Reasons for Plating Mold Components**
Copper alloys are plated to extend periods between maintenance or component replacement intervals and to improve part quality. Most plating is applied to protect plastic forming components from erosion and premature failure resulting from running glass or mineral filled plastics. Testing underway at Western Michigan University, using 33% glass filled type 6 nylon in an eight cavity mold, has shown that copper alloy cores protected with some of the chrome processes have extended component life up to 20 times longer when compared to non-plated P-20 cores.

The second reason is to protect against corrosion. The copper alloys are naturally resistant to attack from most plastics. However, to prevent tarnish and the transfer of residue created by the interaction with steel, plating of copper alloys is an effective prac-

**TABLE 1. Depth of Electroplating Chrome in Holes**

| Hole Diameter | Blind Hole | | Through Hole | |
|---|---|---|---|---|
| | Typical Range | Maximum Depth | Typical Range | Maximum Depth |
| .125 | 0.00-0.75 | 1.00 | 0.00-1.50 | 2.00 |
| .250 | 0.00-1.50 | 2.00 | 0.00-3.00 | 4.00 |
| .500 | 0.00-6.00 | 8.00 | 0.00-12.00 | 16.00 |
| .750 | 0.00-12.00 | 18.00 | 0.00-24.00 | 36.00 |
| 1.00 | 0.00-24.00 | 36.00 | 0.00-48.00 | 72.00 |
| *All dimensions are in inches | | | | |

**TABLE 2.**

| Plating Process | Ideal Thickness | Maximum Thickness |
|---|---|---|
| Electroless Nickel | .0005-.0007 | .001 |
| Flash Chrome | .0001-.0003 | .001 |
| Thin Dense Chrome | .000050-.0005 | .0005 |
| Thin Dense Chrome with Diamond | .000050-.0005 | .0005 |
| *All dimensions are in inches | | |

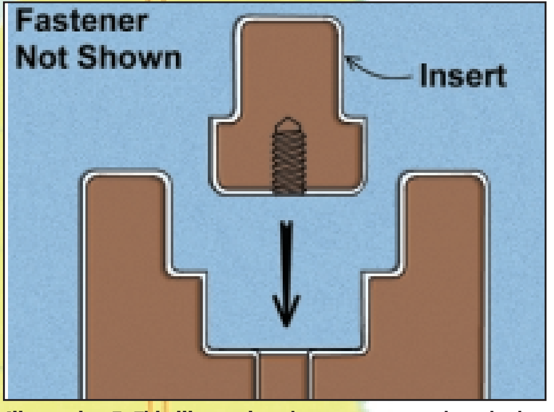


Illustration E: This illustration shows a suggested method of manufacture that results in a component that can be plated to an even thickness.

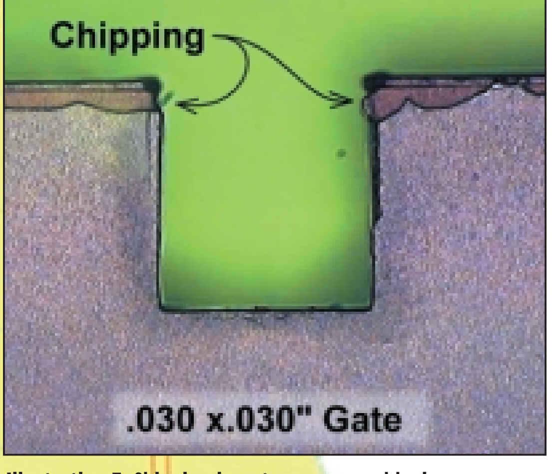


Illustration F: Chipping in gate area caused by improper removal of chrome build up at the corners.

tice. Nickel is recommended over chrome when molding polyvinyl chloride, as hydrochloric acid will strip chrome from the component surface. Chrome works well with most other plastics.

Another reason for applying plating is for wear associated with stripping abrasive plastic parts from cores. As chrome has a higher hardness level, it proves to be more effective than nickel. In mold areas where components are in moving contact, the nodular chromes tend to work best. The sliding coefficient of friction of non-lubricated nodular chrome against nodular chrome is around 0.14. This compares to a rating of 0.20 of steel against steel. Nickel does not hold up as well in rubbing applications.

The last reason for plating is to improve mold release. Nickel and chrome with impregnated polymers are offered by a number of companies as a solution in reducing friction and improving part release. Other companies offer wide ranges of platings and coatings in which they claim success in resolving release problems. Due to the wide range of mold conditions and plastic part design, it is difficult to qualify what process works better. However, if is safe to say that the first priority has to be to allow adequate draft angles and provide proper ejection mechanisms as a first step to insure part release. Next, the mold component must be benched properly. This includes removing all machining marks and stoning or polishing in the direction of draw with the proper grits, prior to applying the desired surface finish.

The plating should only be applied after the plastic forming mold surfaces have the proper finish. A coating or plating will not resolve all release and ejection problems; especially those created by improper mold finishes.

### Affect on Thermal Conductivity of Copper Alloys

Extensive laboratory testing on the affect of nickel or chrome plating on thermal conductivity is scheduled by the CDA. At this time the experience gained in running thermal studies indicates that there is no measurable loss in cooling effectiveness when comparing the same plated and non-plated mold cores. Similarly, no significant change in cycle time, have been reported in situations where molds are sampled without plating and then plated and run in production. One theory is that the high thermal conductivity of the copper alloy overcomes any reduction in heat flow from the plastic part that the thin layer of plating could create.

### Allowing for Plating Thickness

In certain situations the thickness of the plating has to be taken into account in mold design. Fits of inserts, for example, should allow for the increase in size due to plating thickness insuring proper mold function. These allowances are typically in the range of tenths to a few thousands of an inch. ■

### Acknowledgements

The injection mold design guidelines were written by Dr. Paul Engelmann, Associate Professor, Western Michigan University and Bob Dealey, Dealey's Mold Engineering, with the support of Dr. Dale Peters, for the Mold Marketing Task Group of the Copper Development Association. Kurt Hayden, graduate research assistant, WMU, generated the illustrations. Research conducted by WMU plastic program students.

### Disclaimer

These guidelines are a result of research at WMU and industry experience gained with the use of copper alloys in injection molding. While the information contained is deemed reliable, due to the wide variety of plastics materials, mold designs and possible molding applications available, no warranties are expressed or implied in the application of these guidelines.

### Contact Information

Information on copper alloys is available from the Copper Development Association, at 800-232-3282. Technical clarification of the guidelines can be made by contacting Bob Dealey, Dealey's Mold Engineering at 262-245-5800

For more information about the use of copper alloys in tooling, please circle 675 on the reader service card.