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Anodizing Racks: Understanding Your Options Helps in Making Design Decisions

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Among the most difficult decisions an anodizer must make is one which must be made almost every day: selection of the right anodizing rack for each job. If the selection is wrong, the surface finish suffers, resulting in rejected parts, delayed deliveries and costly reworking.

Good rack design techniques have given rise to a set of guidelines for rack selection. These have been developed and proven over the past 20 years, working with anodizers to design and fabricate racks for an almost infinite variety of aluminum parts in every conceivable size and shape. The information is, however, far from absolute. As with most rules, there are exceptions. As with most situations involving technology, there are shades of gray. Accordingly, it is suggested that you use these guidelines to help focus your thinking and streamline the decision making process.

MAKE RACK DESIGN THE FIRST STEP

Precise deposition of anodic film is the ultimate goal of every aluminum finisher. The process has always been thought of as involving three steps: cleaning, anodizing and sealing; however, to assure the integrity and success of the process, a fourth step—rack design and selection—should be included as the first step. Ironically, this step takes into account the actions and requirements of each of the three steps which follow. If a rack is properly designed and built, cleaning, anodizing and sealing efficiencies will be optimized.

For example, achieving good drainage is necessary to assure that solution chemistries are not contaminated. Electrical requirements must be considered so that coating thickness and consistency can be maintained throughout a load. Mechanical design must be concerned with fast, efficient material handling and the customer's concern for rack marks. And, let's not forget critical cost issues.

Racks have got to be affordable, not just useable.

RACK DESIGN CRITERIA

There are five criteria which must be considered when evaluating rack design options. They are:

1. Current flow.
2. Drainage.
3. Rack marks.
4. Material handling efficiencies.
5. Rack economics.

Each criterion will be reviewed to better understand how it affects rack design and, ultimately, the anodized finish.

CURRENT FLOW:

Current flow forms the core of the anodizing process. Aluminum parts are immersed in an oxidizing environment, most often sulfuric acid, and an electric current is applied to the parts. The standard recipe calls for 10 to 15 Amps per square foot with higher current flows required for the thicker hard coat processes as well as other special surface treatments.

Rack material is the major factor affecting current flow. For more than 45 years, aluminum has been used in building racks. For the past 25 years, anodizing with titanium racks has increased in popularity. Each of these metals has its own design advantages and limitations (See Table I).

Table I. Characteristics of Basic Rack Materials

Aluminum	*Titanium*
Lowest initial cost	Lowest cost in use
Higher conductivity	Better strength
Easy to fabricate	Corrosion resistant

Aluminum is often used because of its low initial cost, its high conductivity and its ease of fabrication. Because aluminum costs are relatively low versus titanium, finishers tend to maintain larger inventories of racks and rack components. This can add important flexibility when responding to customer demand for short lead time deliveries. Any delay in assembling the appropriate racks for a "hot" job can adversely affect the finisher's ability to be customer responsive.

Aluminum is also easily fabricated. It can be cut and bent using basic metal shop equipment, and welded far easier than titanium. Thus, should a finisher need to create racks for a particular job, he can usually do so with minimal cost, semi-skilled labor, and little investment in capital equipment.

On the down side, aluminum racks will become anodized along with the parts they're designed to carry. As such, extra maintenance work is required to strip the racks of their conductivity inhibiting oxide coating. Aluminum is also subject to vigorous attack by corrosives such as sulfuric acid. Ensuing corrosion can consume most racks after only a few months in active service, and aluminum sulfate builds up in etch and anodize tanks.

Titanium is long lasting and inert in most chemistries used by anodizers as long as the metal is kept anodic (connected to a positive power source). Its corrosion resistance precludes etch and anodize tank contamination and its longer service life can actually result in a lower total cost in use than for aluminum racks, especially for long running jobs and when the rack design is flexible enough to allow its use with a variety of basic part shapes. Finally, titanium is stronger than aluminum, thus less prone to damage in normal use.

On the down side, titanium will not conduct current as well as aluminum.

A designer's rule of thumb suggests that aluminum can carry 1,000 Amps per square inch of cross section (A/in^2) while titanium can carry only 350 Amps per square inch of cross section. As a result, care must be taken when using titanium to design racks of sufficient cross section so as to enable them to carry required current loads without becoming overheated.

In the last 15 years, a new "hybrid" material has gained acceptance as a preferred material for rack splines (vertical or horizontal members onto which clips, tips and clamps are affixed). It combines the high conductivity of aluminum with the corrosion resistance of titanium. Titanium covered aluminum can be designed to comfortably carry up to 850 A/in^2.

Good rack design is as much an art as a science. As such, the ideas and guidelines being discussed are not absolute. A titanium rack designed beyond 350 A/in^2 can work, as can an aluminum rack designed beyond 1,000 A/in^2; however, in both cases unwanted heat will be added to the anodizing tank and it may not be effectively removed by the cooling system. Thus, for best current flow, the best rack designs often include larger cross sections, especially above solution level where air cooling may not be as effective in solution cooling.

Good rack design for optimum current flow requires that vertical splines be designed to carry the total current output of the rectifier. Titanium, aluminum, or titanium covered aluminum splines can be selected by the anodizer based upon his own preferences. When splines are properly designed, one need only count the drops and multiply times the rated capacity of each spline to determine the current carrying capacity of these vertical members. (Fig. 1). In general, good design assumes generous current carrying capacity in each spline as part of the design process.

Once the vertical splines have been designed to satisfy current flow, the balance of the rack design work can begin. The first order of business is to assure that there are no bottlenecks in the current flow which can result in uneven coating thicknesses and flaws in the surface treatment. If clips, tips and clamps won't carry ample current, resistance heating can occur. This localized warming can create rainbows, inconsistencies in color, and even serious burning due to arcing.

Good design guidelines call for 8 Amps per point contact, 15 Amps for a line contact, and up to 60 Amps for a clamp contact when using titanium racks. Triple these current flow numbers for aluminum racks.

In Fig. 2, example "C" shows a questionable application of a clip style. Though the line contact style will carry current as well as the two-point contact style in example "B", it may not hold as firmly or exert enough pressure to cut through the natural oxide film found on all aluminum parts.

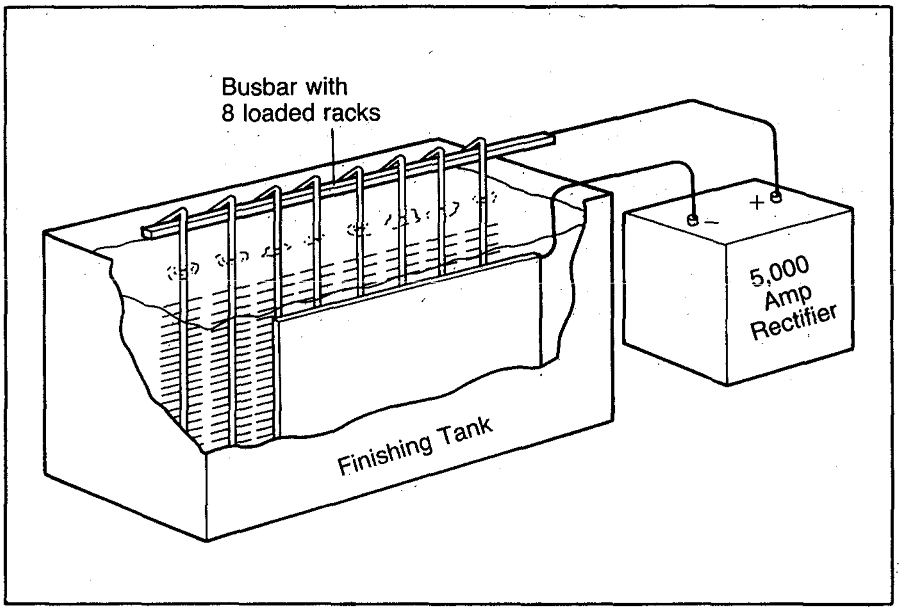

Fig. 1. 5,000 Amps of rectifier output requires that each of the eight splines must carry at least 625 Amps.

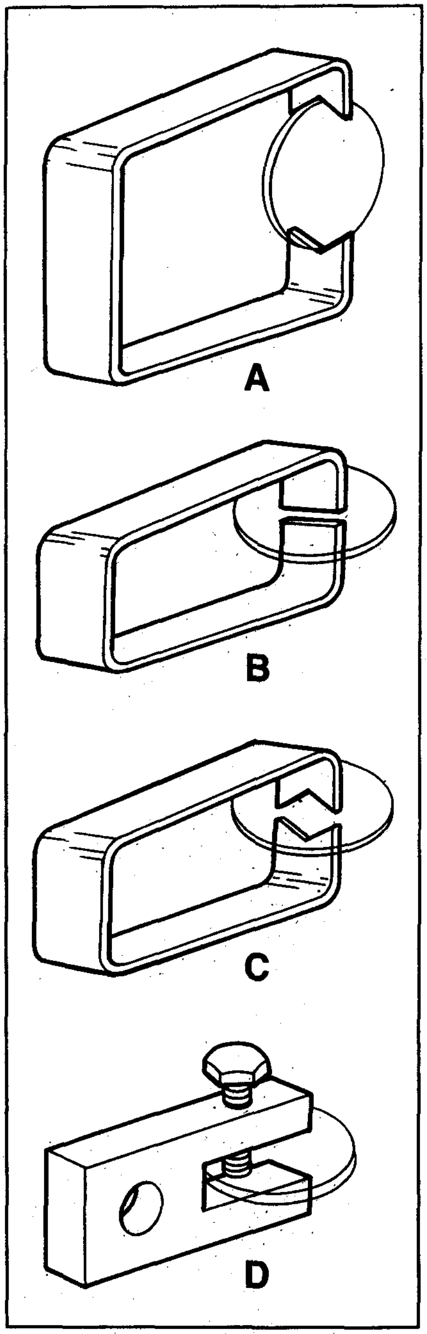

Fig. 2. Design clips, tips and clamps to carry ample current. (A) 8A (Ti)/25A (Al) for each of two point contacts. (B) 8A (Ti)/25A (Al) for each of four point contacts. (C) 15A (Ti)/45A (Al) for each of two line contacts. (D) 60A (Ti)/180A (Al) for a clamp contact.

Designing for optimum current at the tip of a clip or clamp is only half the battle. Good design also requires that ample current will flow through the clip or clamp. This means designing for the proper cross section. For example, at 8 Amps per contact, the minimum size of a two-point contact titanium clip must be 0.050 gauge x 1/2". These requirements often pose problems for rack designers not used to working with titanium. A standard aluminum clip is often 0.080 gauge x 3/4″ and will carry 60 Amps through each leg. This provides plenty of capacity and makes electrical design a secondary issue when working with aluminum.

DRAINAGE:

Good rack design must also consider how solution will drain from the parts and, less often, the rack. It's rare that drainage problems occur due to poor rack design. More often, it is a function of part geometry.

Most rack induced drainage problems are easily remedied with a few strategically placed holes to allow fluids to drain from rack surfaces as the racks pass from tank to tank; however, if parts are poorly oriented on the rack, they can easily trap and retain fluids, or worse yet, finish quality can be adversely affected.

When working with single cavity parts as in Fig. 3, drainage problems are easily spotted and managed. More complex parts, with multiple cavities, can pose very difficult design problems. Often no viable solution is available through part orientation. Rather, finishers use masks that close thread parts, or they may include an extra step between tanks that tips the entire rack to pour off extra solution caught in part cavities.

It is a prudent and money saving idea to build a test rack and run trials to confirm rack and part drainage before investing in a full rack inventory.

RACK MARKS:

Among rack designers, the ability to hide racking marks is what separates the big league players from the minor leaguers. What anodizer hasn't picked up an aluminum part in the hardware store looking for telltale rack marks as a clue to how—and how well—the part was racked?

In fact, good anodizing needs rack marks. They show the spots where the rack made positive contact with the underlying aluminum base metal. If it is a firm contact, the contact area can be kept small, but because the anodic film is not growing under rack contact, there will have to be a small breech or hole in the anodic film.

Superior rack design precludes any sign of rack marks in designated critical areas. This usually means areas where the marks would be visible on the part as it is normally viewed. Rack designers prefer to work with part designers to identify acceptable surface areas on which rack marks can appear.

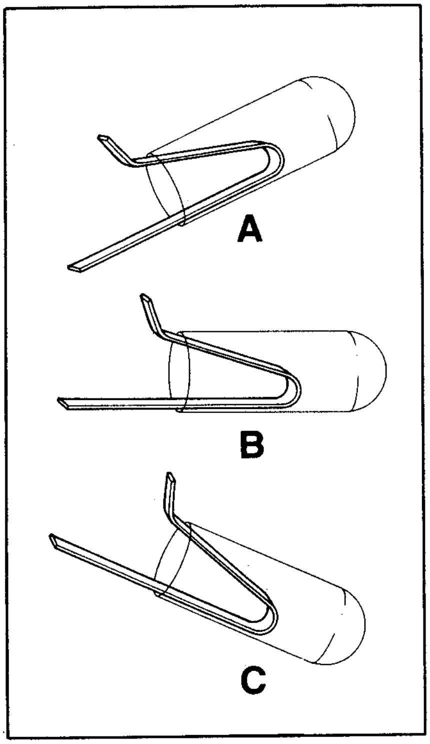

Fig. 3. Part orientation affects drainage. (A) No drainage problem here, but trapped air may prevent complete anodizing inside. (B) A level cavity allows both fluid and air to drain well. (C) The part will anodize well, but proper drainage can't occur.

Figure 4 is a typical example of inside racking options. In all cases, the marks will not be highly visible as they will be located on the inside of the cylinder. Were the cylinder to be a solid bar, outside racking would be required and options might include making contact on either end, on the edges of the ends, or on the surface of the bar. Each part demands its own racking solution to assure minimum marking and best mark location.

MATERIAL HANDLING EFFICIENCIES:

Competitive pressures and profitability goals are moving finishers to process greater numbers of parts per load. This phenomenon has created a relatively new rack design criterion: material handling efficiency, or the efficient loading and unloading of parts on racks and racks on bus bars. Efficiency usually embraces three issues: 1. Part density, or number of parts per tank load. 2. Speed of racking. 3. Desire for and availability of mechanical racking assistance.

In general, it is rarely a problem to design a rack to maximize the number of parts per load. Often, it's a simple matter of "reverse engineering". Rectifier capacity ultimately limits the number of parts which can be processed per load. Thus, dividing rectifier capacity by the required current flow per square foot of surface area yields the maximum square feet of surface permitted per load. By dividing the surface area per load by the surface area per part, an accurate measure of the maximum number of parts per load is attainable.

Putting all those parts on the rack quickly is usually a bigger problem. Any number of design solutions are available. For example, larger parts such as moldings or extrusions can be racked using twist racks, stack racks or clamp racks (Fig. 5).

An ideal rack design for smaller loads is one which can be loaded "one-handed", increasing the efficiency of racking personnel. Most push on type racks (Fig. 6) fall into the "one-hand"

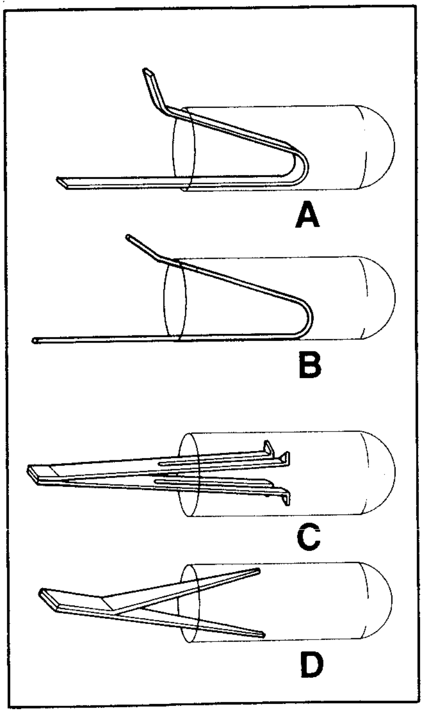

Fig. 4. Good rack design can manage placement of rack marks. (A) Sheet metal U-bend clip leaves marks over a large area. (B) Wire U-bend clip leaves two thin line marks. (C) Split finger clip leaves four small marks and reduces part rocking. (D) Pointed tip leaves two very small marks, but may allow rocking and cause burning.

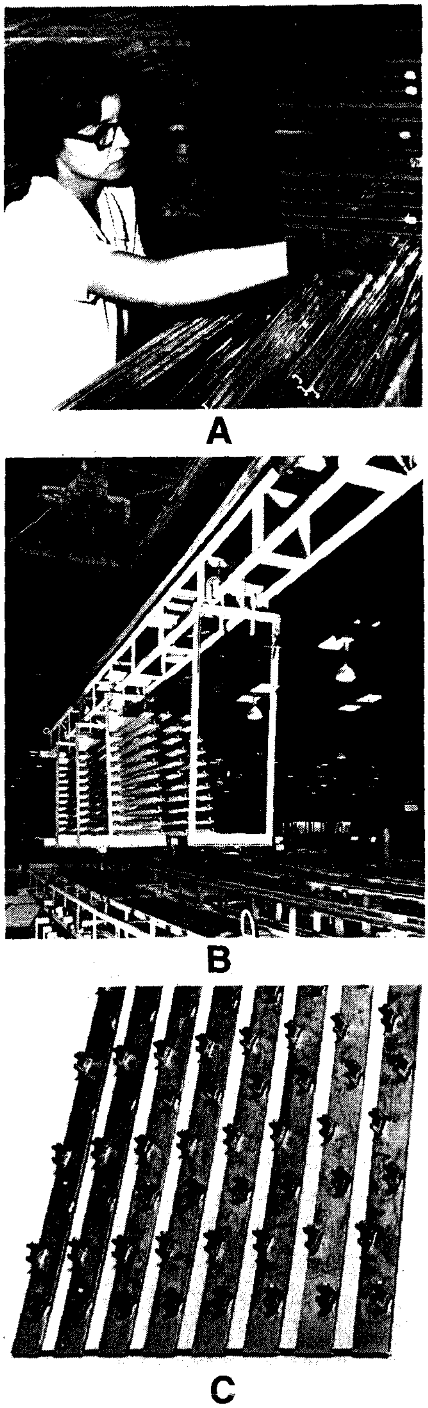

Fig. 5. Larger parts require special racks. (A) Twist rack. (B) Extrusion layer rack. (C) Clamp rack.

category.

Added racking speed is being achieved through the use of mechanical devices (Fig. 7) to automate much of the manual process, particularly where two-handed loading is required. In a two-handed situation, the loader is required to pinch close or spread open a rack clip before the part can be racked.

A normally two-handed racking procedure is reduced to a quicker one-handed task when entire sections of a rack are closed or opened by the equipment. The loader is only required to insert parts and remove the loaded rack from the device. By reversing the process, the same device can be used to drop parts from a rack, en masse.

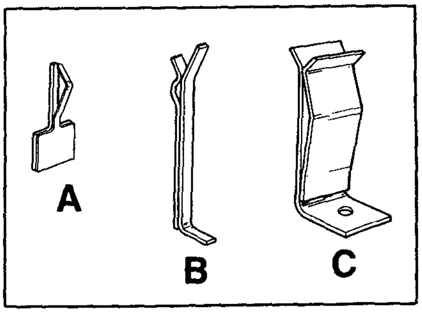

Fig. 6. Push on type racks load "one-handed". (A) For inside racking. (B) For outside racking. (C) For flat sheeting racking.

RACKING ECONOMICS

Anodizing racks are no different than other production related equipment in the plant. They must provide a suitable return on investment. The problem is that calculating the R.O.I. on an anodizing rack would be next to impossible. So, why not settle for the next best thing. Do whatever you can to optimize R.O.I. and assume that the efforts will pay handsome dividends, because they will.

Here are a few ways to optimize R.O.I. If some of them ring familiar, it's because we've already touched upon them in reviewing the previous four rack design criteria.

1. Choose rack material wisely. Use titanium in racks designed for long runs of the same part, and in multi-purpose utility racks. Use aluminum for shorter runs.

2. Consider titanium covered aluminum for splines. This material gives the current carrying capacity of aluminum and the corrosion resistance of titanium. It's less costly than solid titanium and lasts hundreds of times longer than solid aluminum.

3. Watch rack maintenance carefully. Aluminum racks must be stripped regularly; however, if they're stripped too aggressively, they'll wear out sooner than necessary.

Titanium racks should be adjusted regularly to restore their spring tension. Users of aluminum racks are accustomed to bending them back into position to return original spring tension. Bending can damage titanium racks.

Occasionally, titanium racks will require stripping to remove a deep blue or purple coloring that indicates a heavier than normal build up of oxide film. Careful immersion into your nitric acid tank (without an applied current), or into a caustic etch, will usually remove the film.

4. Invest in racks on the basis of their cost in use. This is not a new concept, but it's very valid. Cheap racks, like any type of cheap equipment, can wind up costing more over time, while good rack design and fabrication can improve productivity, decrease maintenance and labor costs, and provide a longer useful service life. Quality may have a higher initial price, but over time you'll realize a lower cost in use.

5. Recognize that racks can affect finish quality. There's nothing economical about rejected parts, no-charge reworked parts, and unhappy customers. Today's manufacturing environment demands output consistency. Anodizers who readily accept a "reasonable" rejection rate in their production process are missing an important signal. Something's not working right!

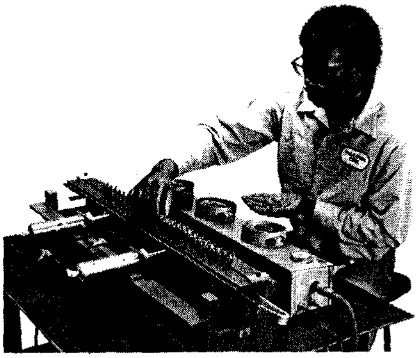

Fig. 7. Automated racking devices improve efficiencies.

A well designed rack should yield a full complement of high quality parts from every run. Zero defects isn't just a buzz word. It's an achievable goal if you want it badly enough. **MF**

Biography

Richard E. Leopold is president of Vulcanium Corp., a Northbrook, IL based designer and manufacturer of titanium anodizing racks, corrosion resistant heat transfer equipment and titanium anode baskets. He holds an MBA from the University of Chicago and an engineering degree from the University of Michigan.

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H.K. Srivastava discusses the effects of formamide, dimethylformamide and diethylformamide on grain refinement in plating from a nickel chloride bath.

Richard Leopold addresses five factors in the design of anodizing fixtures including current flow, drainage, rack marks, efficient loading and rack economics.

M.F. Shaffei et al show how spectrophotometry can be used in matching color tones and derive a color rate equation.

Benjamin Yaffe provides an overview on the various methods of sealing such as organic, steam, hot water, nickel acetate, dichromate and others.

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A montage of anodizing racks representing a variety of styles. Photo courtesy Vulcanium Corp., Northbrook, IL.