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# The Leading Edge Guide to Top Quality Anodizing using the Complete Spectrum Approach with a Universal Type I – II – III – (123) Mixed Electrolyte

by

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#### ABSTRACT

This paper discusses a new advanced problem solving anodize technology for processing Types I, II and III anodize (A123) in a universal mixed electrolyte. This new chromium-free formulation will activate pore structure development, producing excellent Type IC and Type III hard anodize at lower voltages. The following technical areas will be discussed: (1) new anodize bath parameters in service, (2) simplified electronic power supply requirements and (3) slow pulse-step-ramp-dwell procedures. Data logger graphs presented will prove quality, efficiency and energy savings on critical alloy parts (2024, 2219, 7050, etc.) and actual leading edge configurations.

#### Background

Environmental considerations and other problem solving situations have necessitated ATS to develop a non-chromated polycarboxylic acid anodize electrolyte for Brush Type IC and II anodize which could also be used in larger Type II and III hard anodize process tanks on the line. This "greener" electrolyte has already been used successfully as a Type IC alternate at a time when nothing else was available (1991-92). In 1996, we also developed a modified oxalic acid anodize using tartaric acid, which was also used for hard anodizing on a Silicon Valley project. Due to red tape, their approvals were held-up in the aerospace arena because of structural concerns, even though the pore structure criteria did meet critical requirements. Some qualified technical people feel this has been ignored by the aerospace industry for far too long. Meanwhile, the present chromic acid anodize facilities have been so very busy meeting process deadlines, that hexavalent chromium pollution continues to escalate.

Because of RoHS requirements, European aircraft facilities have adopted a tartaric acid process as a Type IC alternate on commercial aircraft, which is similar to our Silicon Valley modified process. This indicates it has met their approval on structural aircraft assembles. In addition, Sikorsky Aircraft is pushing to use Type IC alternates exclusively for all of their helicopters.

At ATS, we have proceeded to integrate tartaric acid as the primary electrolyte in addition to our amino polycarboxylic formulation, along with further modifications for Type IC, Type II-23 and Type III hard anodize. Also, we have investigated polycarboxylic acid combinations for greater efficiency during the complete ramp cycle, which is most critical for Type I anodize, particularly on leading edge configurations.

It is important to remember that the problem-solving data which we are sharing has been a major part of our research and development work at ATS and PAC for well over 50 years. Our recent papers submitted since 2003 have led up to this paper, including the information we share, which serves to remind us how important the exchange of information is for both present and future production.

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This innovative chemistry will become very important for all future anodizing in order to meet more demanding pore structure, coating weight and hardness requirements and should be controlled between minimum and maximum units as follows:

- Polycarboxylic acids controlled between 1 25% (or 25 1%), while we control...
- Sulfuric acid between 25 1 % (or 1 25%), to this we make calculated additions of...
- Amino-complex ion and inorganic/organic bonded groups from 2 10%

Specific control of this chemistry from a 1:25 ratio (or 25:1) has been key to our research and development on a practical basis. It is the ultimate determinant in attaining a complementary balance of pore structure, coating weight and wear resistance properties.

#### Introduction - moving forward

Our ultimate goal was to practice the best leading edge technology possible on all production part and leading edge configurations, using all organic based electrolytes. This meant getting rid of both the chromic and sulfuric acid. However, we also needed to present a powerful formulation, which could be added to all existing production sulfuric anodize tanks as a superior accelerator and modifier for Type II and Type III hard anodize, which would pass all applicable aerospace, military, medical, automotive and other commercial specifications.

The final chemistry presented here is not just leading edge from a basic technology standpoint, but also leading edge in expanding our complete spectrum package, which includes:

- Chemistry: Amino polycarboxylic complex ions
- Electronic power package: Slow pulse-step waveforms
- Procedures: Slow pulse-step-ramp-dwell (throughout the entire anodize cycle)

New, improved procedural developments have further enhanced leading edge pore structure development by pushing the envelope in eliminating burning on 2000 and 7000 series alloys.

This leading edge technology starts at 2 to 3 volts, with early pore structure development, which is completed at low final voltages and energy levels. The pore structure is improved at the very base nanostructure and then continues to build at a lower exothermic electrochemical energy level. This means less energy usage while producing higher quality anodize. This higher quality anodic pore structure allows for better sealability and promotes longer in-service quality performance.

The leading edge technology presented herein comes with priorities, some of which have to do with our commitment to the industry. There are specific commitments which the customer needs and/or wants, depending upon his particular facility. Regardless of the motivations, they should all be based around the following factors:

- Quality
- Efficiency (anodize time)
- Energy savings

Always bear in mind, the leading edge technology for the top quality anodize presented in this paper is integrated into our complete spectrum approach as a total package. This entire package must be considered as one, for optimum results. To better explain the technology, this paper has been divided into the following seven sections:

- 1. Chemistry: process tank electrolyte
- 2. Electronic power package requirements
- 3. Slow anodic pulse control discharge
- 4. Process procedure ramp and run requirements
- 5. Data logger graphs
- 6. Air agitation requirements
- 7. Conclusions





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Chemistry: process tank electrolyte

The aim was to develop a single complete universal electrolyte for Types IC, II, IIB, 23 and III hard anodize coatings. The Type IC formulations were reviewed by people who know and understand aircraft structural and leading edge requirements. The choice of organic acid used as a base had to be compatible with and enhance or improve sulfuric acid anodizing to satisfy specification requirements and organic dye pore structure considerations. The ATS Group wanted the organic acid formulation to include at least two different polycarboxylic acids for better efficiency and compatibility with existing organic, sulfuric acid and phosphoric acid electrolytes. Finally, we also wanted this electrolyte, as a concentrate, to perform as a super additive or modifier when added to any existing sulfuric acid anodize tank and stand alone as a superior brush anodizing solution for all MIL-A-8625 types.

Since 1961 we have studied and reviewed more than 160 carboxylic acids as potential useful anodize electrolytes. Over 30 of these have been used as basic anodize electrolytes in laboratory and/or production tanks. We have integrated three of these acids into the concentrated amino polycarboxylic electrolyte/accelerator (ACEA) for one good scientific reason - they absorb heat at different energy levels which one organic acid such as tartaric will not do by itself. This heat absorption is very important to pore structure development as related to sealability, hardness and process time and is equally important to eliminate burning of difficult-to-anodize alloys.

The high concentration of amino, dicarboxylic and polycarboxylic groups (ACEA) are very beneficial in three different applications. First, when added to a basic preferred electrolyte (tartaric and/or oxalic), the resulting electrolyte has much greater efficiency as related to anodize time and potential structural bonding. Second, this concentrated mixed organic electrolyte activator (ACEA) will also increase the efficiency of any sulfuric acid anodize electrolyte, even when the aluminum is controlled in the 10-20 g/L range. In fact, when a sulfuric anodize tank is maintained with 5-10% of this mixed organic electrolyte, the free sulfuric acid can be lowered to 7-12 vol% with no burning on 2000 series alloys, producing a superior hard anodize which passes Taber abrasion tests at 0.8-1.8 wear index on 1000-3000 A production loads. Third, the mixed organic activator formulation also works as an excellent brush anodizing electrolyte. We have even touched up scratches on existing chromic acid anodize panels with an exact grey visible match to the existing anodize.

Through exhaustive testing, we have established that this highly concentrated universal electrolyte can be used by itself or with other basic acid electrolytes to meet applicable specifications. The basic organic and inorganic electrolytes which we have used in activation, anodize and brush anodize/electropolish applications are as follows:

Organic:	Tartaric acid Oxalic acid	Inorganic:	Sulfuric acid Phosphoric acid
	Citric acid		Boric acid

The amino carboxylic electrolyte/activator (ACEA) presented in the anodize tank operation ranges shown in Table 1 is a 75% active concentrate. Amine complex ion chelates are also included in the remaining 25% aqueous part of the formulation. All formulations are presented as they have been tested in laboratory and production tanks up to 1000 A loads at this time.

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	Type IC / IIB / 23	Type II / 23 / III
Basic organic electrolyte (tartaric / oxalic / citric)	2.0 / 5.0 vol%	2.0 / 4.0 / 6.0 vol%
Basic sulfuric acid	0.0 / 5.0 / 7.5 vol%	5.0 / 10.0 / 12.0 vol%
ACEA (75% conc.)	2.5 / 5.0 / 10.0 vol%	5.0 / 10.0 / 20.0 vol%
Voltage	5.0 / 24.0 V	10 / 25 / 50 V
Current density	2.0 / 25 A/ft <sup>2</sup>	10 / 25 / 50 A/ft <sup>2</sup>
Temperature	85 / 105°F	35 / 60-80 / 105°F
Air agitation	1.0 / 3.0 ft <sup>3</sup> /min	3.0 / 5.0 / 7.5 ft <sup>3</sup> /min

Table 1 - Operating conditions for the ACEA universal mixed electrolyte.





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The Type IC and Type 23 anodic coatings have been excellent in the following three areas which have traditionally presented quality issues/problems:

- Excellent pore structure development (for adhesive bonding)
- Good bright microfinish maintained (for structural applications)
- Superior wear resistance on Type III hard anodize (all 2000 series including 2219)

Electronic power package requirements

#### Power supplies

The standard power supply (rectifier) is the full wave type with constant voltage (CV) and constant current (CC) controls for all Type IC, II, II B and III hard anodizing with one universal electrolyte. From here on, the electrolyte will be referred to and labeled "Type 123." Secondary SCRs (silicon-controlled rectifiers) are preferred in a center-tap full-wave wiring configuration to perform both rectification and control. The voltage requirements for Type 123 anodizing are typically as follows:

0 - 20V
10 - 18V
0 - 10V
0 - 24 - 30V
0 - 50 - 75V

Most notable here are the lower voltage ranges needed when using the Type 123 universal electrolyte.

Special half wave rectifiers have also been used successfully for all Type 123 high-speed anodizing. However, filtering is preferred during the ramp cycle for Type IC until further testing on production parts is completed. The panels submitted in this paper have all been processed with both full-wave and half-wave rectification in order to substantiate the completeness of this technology. The current density requirements are also considerably lower when anodizing with the universal Type 123 electrolyte. As we have explained, this is due to the combination of dicarboxylic, polycarboxylic and amino acids which promote higher conductivity at different energy levels during the ramp cycle

Type IC - 123	2 - 5 - 10 A/ft <sup>2</sup>
Type II - 123	10 - 20 A/ft <sup>2</sup>
Type IIB - 123	5 -10 A/ft <sup>2</sup>
Type II - 123 Hard	15 - 25 A/ft <sup>2</sup>
Type III - 123 Hard	15 - 50 A/ft <sup>2</sup> +

Extremely low current density ranges are now attainable for Type IC and II B anodize. In addition, finer microfinishes are maintained throughout the complete anodize cycle for all types.

#### Slow pulse ramp

Extensive research and production dating back to a 1968 U.S. patent (#3,418,222) has proven that slow pulse always gives the best results. The pulse cycle ranges can vary from 1.0 cycles/sec to 3.0 cycles/min, depending on the alloy and specification requirements. Pulse parameters are also centered around slow pulse turn-on and turn-off times (depending on the load, 1000-3000 A), so that one can take advantage of both relaxation and recovery times during the pulse ramp cycle. In addition, we have added anodic pulse control capacitance discharge (APCCD) which has proven to be very important by allowing higher current densities at lower voltages when anodizing with the universal organic/inorganic Type 123 electrolyte. APCCD (and/or APCD) will be presented in detail in the next section. Basic slow pulse specifications are listed in Figure 1.





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Figure 1 - Basic slow pulse waveforms and specifications.

#### Slow anodic pulse control discharge

As we have presented in previous papers, basic anodic pulse discharge makes it possible to pull more current and anodize at lower voltages. Capacitance reactance at the anodize surface is pulsed discharge using a network of special resistors and/or inductors. Slow anodic pulse control discharge truly gives amazing results when using with the universal mixed electrolyte. For ease of explanation, the new improved and practical slow anodic pulse controlled capacitance discharge will be abbreviated "slow APCD" or simply "APCD." APCD was first introduced in 2008. However, slow APCD was not economically practical at the





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time. Due to recent advances in solid state technology, we are now able to pulse the discharge more economically on 3000-A rectifiers. This makes higher current density pulsing possible.

Using APCD and an initial anodize current density reached at 2 - 5 V at the very beginning of the pulse-step-ramp cycle make this truly leading edge technology in two areas:

- More functional on actual leading edges of aircraft structural assemblies.
- · More economical for the entire highly competitive commercial anodize industry.

Slow APCD gives superior results with both organic and inorganic electrolytes as related to anodize microfinish, voltage and time. These results are evident because of two phenomena that occur using APCD with the universal electrolyte:

- The effective anodizing current starts at a potential of 2 5 V where it simply does not exist without APCD.
- Higher amperages (500-1000 A) are produced on the anodize load with no change in anodizing voltage at the tank.

All anodizing is completed at lower voltages and reduced time with better quality and efficiency in every case due to lower total kilowatt-hours per tank load. The results are so good that people are amazed when they see it operate. Some have been known to say "OK, where is the other power supply?" We say there is no other power supply. We are taking advantage of capacitance discharge during the anodize run cycle. It is in reality a free energy return, and takes advantage of otherwise lost energy.

Complete specifications for the pulsed resistance inductance discharge banks are available. Please note the basic specifications below and how they differ from those noted in a NASF 2008 SUR/FIN technical paper.

APCD:	Pulsed 6 - 30 sec at 0 - 15 V Max. ) 20 × 1.0 $\Omega$ resistors per bank 2 × 20 resistors per bank = 40 resistors 0.100 $\Omega$ total resistance
APCD:	Fixed CSD; no pulse at 0 - 30 V Max. ) 42 resistors series / parallel 0.21 $\Omega$ total resistance

We have created different systems for using slow APCD during the anodize process. Some are more expensive due to the number of resistors, inductors and the anodize cycle time. Regardless of cost, the system should always be used from the beginning of the anodize cycle during the pulse-step-ramp to 15 - 20 V.

The most economical slow APCD with the best payback should be used during the pulse-step-ramp, because it will initiate anodize at a very low voltage. This can be seen in the data logger graphs in Figs. 2(a) and (b). A production load is shown in the pulse-step-ramp mode to 20 V with no APCD connected [Fig. 2(a)]. Please note that anodizing did not start until 15 V was applied to the load. When the voltage reached 19 V the current increased to 140 A or 7.5 A/ft<sup>2</sup>.

Another identical size load of the same production parts were run [Fig. 2(b)]) with the APCD connected. Anodize was initiated at only 5 V. Please note that at 16.7 V, the current on the load was 308 A or 16.7 A/ft<sup>2</sup> after subtracting discharge current.

This represents a significant increase in current density at the same voltage. Remember that only amperes produce anodize. The current density was over 100% higher at the same voltage. This particular anodize cycle reached a peak of 1000 A and the total cycle time was reduced by 20 - 25% with lower total kilowatt-hours.





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Figure 2 - Comparison of anodize current-voltage-time characteristics for (a) a standard slow pulse-step-ramp to 21 V and (b) an anodic pulse control discharge (APCD) slow pulse-step-ramp-dwell to 20 V.





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#### Process procedure ramp and run requirements

The process procedure requirements for anodizing with the universal electrolyte (Type 123) just may be the most important part of our technology. We have developed this problem solving technology and methodology over the past 50 years or more and it has been the basis for continuing chemistry and electronic pulse improvements. Since they have already been presented in previous papers, we will only reference strategic data and critical factors as they relate to Type 123 anodizing. These critical requirements are listed below in order of precedence:

- Activation: voltage, current density
- Pulse-step-ramp / slow APCD PSR
- Dwell times
- · Current-voltage spikes or deviations
- Amperage decay or drop-off (ADO)
- Constant current density ranging (CCDR)
- Process time vs. ampere-hours
- Real time graphic observation (monitoring and reproducibility)

#### Activation

Activation is important for all anodize types because it leads to better pore structure development, improved sealability and final improved corrosion resistance. It is accomplished by ramping to an initial voltage and/or amperage within 10 to 30 seconds after positive bus bar contact in the anodize tank. The voltage should then be held constant while the amperage (current density) is allowed to drop off (decay).

Type IC-123	1.5 - 3.0 V	2 - 4 min
Type II-123	5 - 10 A/ft <sup>2</sup>	1 - 3 min
Type III-123	10 - 15 A/ft <sup>2</sup>	2 - 5 min

Pulse should not be used for Type IC during the activation period. Slow pulse-step-ramp including APCD should always be used for Type II and III anodize whenever available.

#### Pulse-step-ramp

Slow pulse-step-ramp technology can be used on all Type II-23, III-123 anodizing as it has been specified in past papers (2009, 2010). It should not be used for Type IC. APCD should be integrated into the pulse system as slow APCD pulse-step-ramp whenever possible for maximum efficiency. This is due to initial anodize development at lower voltages (2 - 3 V). As a reminder, please note the slow APCD pulse turn-on and turn-off times are longer (6 - 12 sec). Also, please do not forget this statement which I have always been known to preach:

*"All of the good or the bad is done During the first few minutes of the run."* 

Basic pulse-step-ramp procedures were first introduced in 1968, proven successful in 1978 and published in 1983-85. APCD was introduced as CSD in 2005 and proven successful in production through 2008 with improvements made in 2009-10. We now introduce APCCD and will continue with a revised APCD designation.

#### Dwell times

Successful slow-pulse-step-ramp and run procedures require proper dwell times for all Type II and III anodize. However, these dwell times or periods should not be used for Type IC-123 after reaching maximum voltage because Type IC will be controlled by maximum voltage and time, not by current density. The dwell times listed here should be used for Type II, III-123 difficult-to-run alloys when anodizing in the Type 123 electrolyte:

2000 series	1 - 3 min dwell
7000 series	30 sec - 2 min dwell





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#### Current-voltage spikes and deviations

Current-voltage spikes and deviations are usually a malfunction within the electronic power package. They can cause potential burning problems and/or poor quality dull coatings. An experienced anodizer can detect them and final verification can be made with an oscilloscope. SCR radical misfiring leading to voltage spikes has been found in many rectifiers. We have located circuit boards in SCR systems that should have been replaced long before the serious burning started. A simple oscilloscope check by the meter certification technician could have detected the problem early during routine calibrations. Remind your maintenance department or certification agency of this important procedure.

#### Amperage decay or drop-off (ADO)

Amperage decay or ADO should always be used for all Type II, III and 123 anodizing during pulse-step-ramp and constant current density ranging to the end of the anodize cycle. The power supply (rectifier) must be operated in the voltage mode when increasing amperage and most importantly to allow the amperage to decay (ADO). When ADO is observed, the anodic coating is building in a proper nanoscale fashion.

There is only one continuous ADO for Type IC-123 anodize after reaching the maximum ramp voltage. The anodic coating is simply allowed to build and fill-in pore structure for the remaining anodize time or end of cycle as in Type I chromic anodize.

#### Constant current density ranging (CCDR)

Constant current density ranging has been pioneered and developed by the ATS group since the 1980s. It has since been the major solution to numerous problem solving situations. It should only be used on Type II and III anodizing with the Type 123 electrolyte. It most likely can be used for Type IC anodizing when further testing at low current density has been completed. A steady constant current should never be used for Type II or III anodizing. The amperage must be allowed to drop off by 5 - 10% after reaching constant current and then increased (reset) by increasing voltage. Hence, the code name CCDR – constant current density ranging.

#### Process time vs. ampere-hours

There are at least three ways to process anodize. These include time, final voltage and ampere-hours. Most anodizers run by time. However, ampere-hours should be used if we are to take advantage of slow pulse-step-ramp, dwell times, ampere decay (ADO) and CCDR. We have had to use ampere-hours in numerous aerospace applications where the final coating thickness was critical, including brush plating/anodizing. Ampere-hour meters will no doubt be used on more anodize tanks in the future.

#### Real-time graphic observation (monitoring and reproducibility)

It cannot be over-emphasized how important real time graphic data loggers are for improving quality, efficiency (reduced time) and energy saving (reduced kilowatt-hours). They can be a real educational tool when anodizing difficult alloys such as 2024, 2011, 2219, 7075 and 7050. A potential burn can be detected early during the ramp cycle. With early detection, the part may be saved for evaluation and rework. Expensive aerospace parts can be monitored on a continuous basis for ADO during dwell periods with calculated current density changes made while the real time graph is observed during the entire process run. My personal graphic data logger equipment has been an extremely useful tool for training and problem solving situations which could not be replaced by any other equipment available.

With data loggers, there is a permanent record for future evaluation and a means for continuous improvement. Anodizing with one universal electrolyte can now be done for leading edge, structural, salvage and brush anodize applications that were not possible in the past. Use of data loggers will consistently lead to improved quality, efficiency and energy savings in all of these applications. One prime example is Type IC where the ramp voltage is recorded and now exactly repeatable. This will be directly related to structural bonding and corrosion resistance properties on aerospace assemblies.





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#### Data logger graphs

The data logger graphs presented in this section in Figs. 3 thru 6 include the latest slow APCD pulse-step-ramp-dwell technology when anodizing in the universal Type 123 electrolyte. Three perfected major developments are evident:

- Effective anodize current is initiated at lower voltage
- APCD increases current density with no voltage increase
- Effective lower wattage pulses are evident during the pulse ramp cycle



Figure 3 - Type IC-123 voltage ramp to 15 V then to 20 V; 0.00005-0.00010 in. anodize at 15 V; 0.00015-0.00025 in. anodize at 20 V. Note running CD hold @ 5.0 A/ft<sup>2</sup> max.



Figure 4 - Type II-123 hard ramp to 40 - 44 A/ft<sup>2</sup> @ 20 V; 20 A/ft<sup>2</sup> (73% higher CD with APCD, lost when APCD disconnected) at 15 V; 30% higher CD with APCD, lost when APCD is disconnected at 20 V (10:48); 38 A/ft<sup>2</sup> (25% higher CD with APCD, lost when APCD is disconnected) at 20 V (10:50).





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Figure 5 - Sonabuoy Oceanographic Tubes, 6061 alloy: PSR - 52 min.; slow pulse-step-ramp and run cycle, 1.0 - 1.5 mils.



Figure 6 - Sonabuoy Oceanographic Tubes, 6061 alloy; APCD - 40 min.; slow APCD + PSR ramp and run cycle, 1.2 - 1.5 mils; slow APCD bank #1: PSR: 0 - 17 V; slow APCD bank #2: PSR: 17 - 30 V; Note: 100% increased CD with APCD at 15 V; 33% increased CD with APCD at 30 V.

This graphic procedure was used on seven production runs with two tubes in each tank load. The hard anodize in the interior of each tube proved to be of superior quality and finish. A 10 - 15 min. reduction in process time using APCD and the Type 123 electrolyte was also evidenced.





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Air agitation requirements

We have been involved in the design, redesign and installation of numerous air agitation systems since 1960. We would estimate that 50 to 75% of all agitation systems in use today still need modifications. There must be sufficient, even air in the form of tiny bubbles and/or micro-bubbles. In many cases, insufficient air has been the main cause for burning and/or powdering and uneven rack / tank loads. Most often, unfortunately, this becomes evident when the operator checks the rack location of burned parts in the anodize tank. The improvements in efficiency with proper agitation can be seen visually right after the installation. The operator will witness a better amperage decay or ADO with better agitation. A small current density probe is available which will detect poor air agitation areas as will time lapse photography. These voids / dead spots can initiate unwarranted burning. Insufficient air can be the real problem in many problem solving situations where solution chemistry has been blamed.

There are many types of agitation. In most cases however, air or a combination of air and solution pumping has proven overall to be the most successful. After years of observation, we have arrived at the following basic design data, including some italicized additions and revisions for tanks up to 10 feet long. Low pressure, high volume air from a regenerative blower supplies air to a manifold which feeds riser pipes in all four corners of the tank. The vertical riser pipes connect to a network of ½ in. schedule 80 airlines fabricated and drilled according to the following specifications:

- Hole size, 0.020 0.040 diameter (min., 1/32").
- · Holes drilled horizontally, 1" apart.
- 24 holes per foot (180° both sides of pipe).
- Air lines 6" to 10" apart along the length of the tank.
- Air lines should be 1/2" schedule 80 PVC.
- Outside envelope lines must be <sup>3</sup>/<sub>4</sub>" schedule 80.
- Riser lines must be <sup>3</sup>/<sub>4</sub>" schedule 80.
- Air pressure to manifold, 1.0 1.5 psi greater than that calculated for solution depth and specific gravity requirements.
- Air to tank, 3 5 ft<sup>3</sup>/min per square foot of solution surface.

Air pressure is critical and depends on the solution depth and specific gravity along with the total ft<sup>3</sup>/min needed and total pipe length from blower to the tank, including any 90° elbows and obstructions along the main supply line.

#### Conclusions

- 1. Type IC, II, IIB and III hard anodize can be accomplished more successfully with a universal mixed organic polycarboxylic electrolyte. This represents true leading edge technology.
- The universal organic electrolyte (Type 123) increases the quality and efficiency of three basic carboxylic anodize processes.
- 3. The preferred organic electrolyte used in this paper contains 5% tartaric acid and 5% amino polycarboxylic electrolyte/accelerator (ACEA).
- 4. The mixed electrolyte and/or amino ACEA is positively effective when added to existing Type II and III sulfuric acid electrolytes. Anodize wear resistance is increased and anodize time is reduced.
- 5. With the exception of Type IC, slow APCD pulse-step-ramp should always be used when anodizing with the Type 123 electrolyte for maximum wear resistance and shortest anodize time.
- 6. Structural aircraft parts meet all applicable pore structure / coating weight requirements when processed in the Type 123 electrolyte as specified.
- Slow APCD pulse-step-ramp (PSR) initiates effective anodize amperage at a very low voltage (2 5 V) which is a key factor necessary for proper pore structure development when anodizing with one universal anodizing electrolyte (Type-123).
- 8. All 2000 series and 7000 series alloys including 2219 and 7050 can be anodized with no burning or powdery coatings.
- 9. It cannot be overemphasized how important it is to use all of the data presented in this paper as one complete spectrum package.
- 10. Brush anodizing with the universal electrolyte (123) for all Type IC, II, III touch-up applications is a reality.





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#### About the author



Fred C. Schaedel started anodizing and plating at Hudson Plating Works & Harshaw Chemical Co. (Cleveland, Ohio) in 1957. He has developed specialized anodize additive modifiers, pulse ramp systems including waveform technology, and established training programs (one on one) in the anodize industry dating back to 1962. His early research work on complex ions and chelating agents at Drake University and Schaedel Laboratories led to the development of his first process (Patent issued 1968) for hard anodizing-specific critical alloys, including 2024 and 7075. He has held special certifications for testing and processing anodize for the Apollo Program (NASA), YF17 (Northrop) later F/A18 Hornet (1975-1999) and MK48 Torpedo (US Navy NUWS). He has also developed commercial, high speed, continuous anodize systems

for heavy production in diversified areas including automotive, hydraulics and medical equipment. His additive modifiers and pulse ramp systems have been continuously upgraded through R&D and problem solving on the process line. Fred Schaedel continues to spend all his available time integrating his chemical formulations and electronic waveform technology together with pulse-step-ramp procedures to cover the complete spectrum for aluminum and titanium anodizing.