Nitric vs. Citric Acid Passivation

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Our customers often ask about the advantages and disadvantages of citric acid passivation compared to nitric acid passivation and which they should choose. While both effectively passivate stainless steel and other alloys, the one you select depends on the alloy itself and benefits your value the most.

Citric and nitric acid passivation is effective for stainless steel parts and is detailed in ASTM A967 and AMS 2700. However, alloys such as titanium should only use nitric acid passivation per ASTM F86.

The Importance of Citric and Nitric Acid Passivation
While stainless steel has natural corrosion resistance, free iron may remain on the part surface after machining and fabrication. This free iron can corrode, so removal is necessary. The citric and nitric passivation process removes these contaminants and promotes the growth of a protective oxide layer which adds another layer of corrosion protection to the surface.

Nitric vs. Citric Acid Passivation
Before diving into nitric and citric acid passivation, we've summarized the key points in the table below.

	Nitric Acid	Citric Acid
Handling	Special handling required	Safer to use
Hazards	Toxic and corrosive gases Special disposal required Dangerous at high temperature	No toxic gas emissions Easier disposal No dangers at high temperature
Ventilation	Required	Not Required
Process Time	20+ minutes	5 - 20 minutes
Temperature	High temperature is required for most applications	Room temperature for many applications

Effects on Equipment	Corrosive degradation of non-stainless steel metal or polymer-based equipment	No corrosive degradation
Cost	Low chemistry costs High disposal costs High maintenance costs	High chemistry costs Low disposal costs Low maintenance costs

Citric Acid Passivation
Citric acid passivation is the newer of the two processes and was initially developed by the Coors Brewing Company to passivate the inside of its beer kegs. Since citric acid is GRAS (Generally Recognized As Safe) by the Food and Drug Administraton, manufacturers can use it in food and beverage applications.

Citric acid is the same non-toxic, biodegradable natural acid found in oranges and other citrus fruits, making its use in passivation an environmentally friendly alternative to nitric acid. It also has fewer handling concerns than nitric acid. Unlike nitric acid, citric acid can typically be disposed of with minimal waste treatment.

Citric acid passivation can passivate a wider variety of stainless-steel alloys than nitric acid passivation. A citric acid passivation bath also takes far less time than nitric acid, speeding up the cleaning process considerably.

However, for all these benefits, citric acid passivation is considerably more expensive, which is why many choose nitric acid.

ASTM A967 details five different citric acid passivation methods:
Citric 1: 4-10 w% Citric Acid, 140-160F, 4 Mins minimum
Citric 2: 4-10 w% Citric Acid, 120-140F, 10 Mins minimum
Citric 3: 4-10 w% Citric Acid, 70-120F, 20 Mins minimum
Citric 4: Other combinations of temperature, time and concentration of citric acid with or without chemicals to enhance cleaning, accelerants or inhibitors capable of producing parts that pass the specified test requirements.
Citric 5: Other combinations of temperature, time and concentration of citric acid with or without chemicals to enhance cleaning, accelerants or inhibitors capable of producing parts that pass the specified test requirements. Immersion bath to be controlled at pH of 1.8-2.2.

Nitric Acid Passivation
Nitric acid passivation is the traditional method of passivation and is also the most used. It has been used since the 1960s, when the U.S. military first detailed specifications in QQ-P-35. However, lower grades of stainless steel risk etching during the passivation process, also known as a "flash attack." This can be limited by adding sodium dichromate to the nitric acid, using a higher nitric acid concentration, or heating the nitric acid to a higher temperature.

Nitric acid chemistries with high oxidizing potential are best, as the passive film formed on the surface forms faster and is more effective, reducing the potential for etching.

While nitric acid passivation is cheaper to run, environmental hazards exist. Nitric acid is naturally hazardous and emits toxic fumes. It also requires special handling and disposal, making it more expensive than using citric acid passivation in some situations.

ASTM A967 details five different nitric acid passivation methods:

Nitric 1: 20-25 v% Nitric Acid, 2.5 w% Sodium Dichromate, 120-130F, 20 Mins minimum
Nitric 2: 20-45 v% Nitric Acid, 70-90F, 30 Mins minimum
Nitric 3: 20-25 v% Nitric Acid, 120-140F, 20 Mins minimum
Nitric 4: 45-55 v% Nitric Acid, 120-130F, 30 Mins minimum
Nitric 5: Other combinations of temperature, time and acid with or without accelerants, inhibitors or proprietary solutions capable of producing parts that pass the specified test requirements.

Nitric vs. Citric Acid Passivation
From a purely environmental standpoint, citric acid passivation is a far better option. There are fewer handling concerns and less to worry about when it comes to disposal. But there are cases where nitric passivation works better.

The risk of flash attack is elevated with nitric acid, however, taking the precautions mentioned earlier lessens your risk. Flash attack can occur with citric acid too, but there's far less of a risk. Early citric acid formulations suffered from organic growth and mold issues, but today's formulations include biocides that have solved that issue. Citric acid removes only the free iron on the surface, whereas nitric acid removes some metals on the alloy itself.

However, citric acid is far more expensive since it is naturally derived and can't be created in a laboratory. This results in higher chemistry costs, even as it saves money in just about every other area, including labor, equipment, maintenance and disposal costs.

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We find that citric acid passivation is often the better choice for various reasons. In precision applications such as aerospace and medical, proper passivation is vital for performance and durability.

Since citric acid only removes the free iron without altering the alloy, it is the better choice. And since citric acid is easily disposed of, it has enabled some companies to bring their passivation processes in-house rather than depending on a third-party shop.

Switching over to citric acid is recommended. While chemistry costs will rise, the long-term savings of using citric acid and the environmental and disposal advantages make it a wise decision.