Technical Article

How pH Cleaning Agents Affect Production Performance

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INTRODUCTION

Over the last few years, there has been a significant focus on the pH of cleaning agents. This movement has been driven by the notion of pH and its influence on the environment and material compatibility on the assembly. The challenge is to find the right balance between cleaning agent design, performance and the environmental impact of the entire cleaning process.

UNDERSTANDING pH

The terms "acidic", "alkaline" and "neutral" refer to positions on a scale of pH ranging from 1 to 14. A pH of 7 is neutral, while numbers less than 7 are acidic and greater than 7 are alkaline or basic. pH is a measure of the comparative amount of free hydrogen and hydroxyl ions in the water. It is important to recognize that unlike the temperature scale, the pH scale is logarithmic. In other words, each number is 10 times more powerful or less powerful than the next, and so on. For example, the pH of 9 is 100 times more alkaline than a 7pH, and the pH of 5 is 100 times more acidic than the pH of 7, and so on.

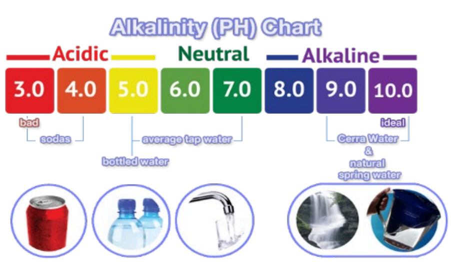

Image courtesy trubalanceh2o

Figure 1: pH scale with everyday liquids

This does not automatically mean pH of 5 or 9 is bad, but rather it is an indicator of how the ions in the water has changed. We use products with pH of 3 like carbonated cola, to expensive water, with a 10pH in our every day lives. The impact pH has on a person or the environment is only piece of the picture.

Alkaline solutions cut through dirt, grease, proteins, oils, and other organic items, while acids remove calcium, rust, and other minerals. Highly acidic products (below pH 3) are referred to as corrosive, and those that are highly alkaline (above pH 11) are considered caustic. Products with pH values between 6 and 9 are found to be within the pH neutral range. Products that measure at either edge of the pH scale are not recommended for electronics assembly cleaning because of probable negative reactions.

SOLVENT CLEANING AGENT pH

In the early days of electronics cleaning, solvents were the most commonly used products. Solvents that do not contain water will not have a measurable pH. Freon and n-propyl bromide (nPB) were favored products for their ability to clean quickly. However, neither are environmentally friendly. Freon was banned due to its ozone depletion properties, and nPB is a known carcinogen. In 1987, with the Montreal Protocol, industries started moving towards semi-aqueous materials that were engineered from modified alcohols, terpenes or hydrocarbon-based materials. The water content of these semi-aqueous blends gives them a neutral range pH. Such products are still used for assembly cleaning today, although due to the evolution of assemblies, they are no longer considered the leading cleaning technology. These materials are much less effective on today's flux formulations, especially if they are lead-free.

Manufacturers found these products compatible with most metals. However, most semi-aqueous products contain limited to no buffering capacity. Therefore, as soon as the acidity of the flux reaches a certain level of saturation in the wash bath, the pH becomes acidic, creating a compatibility issue with sensitive metals. The other challenge is many solvents tend to be aggressive towards plastics and similar materials often used on assemblies. In addition to the limits in cleaning performance with solvents, the mechanical energy in a solvent cleaning system is not as effective on removing residues underneath modern low stand-off devices.

AQUEOUS CLEANING AGENT pH

As technology evolved, assemblers moved towards aqueous-based sprayable cleaning agents, which were perceived to be more environmentally friendly. The early aqueous chemistries tended to be high in alkalinity (above 11) to help with cleaning but they had short bath life, poor compatibility on devices and were harsh on equipment.

As technology continued to advance, so did the aqueous cleaning agent, more towards the neutral range. At first glance, a pH neutral cleaning agent sounds great. A cleaning agent in the pH neutral range, has the potential to interact with metals, plastics, epoxies, and coatings under production conditions. In most applications, there may be a more significant damaging reaction of a pH 7 cleaning agent than a mildly alkaline cleaning agent. Neutral formulations tend to have limited cleaning power. Balanced and controlled reactivity is desirable, especially to remove the latest generation of fluxes.

Staying near a pH of 7.0 may be desirable, however there are many advantages to being slightly alkaline. Mild alkalinity enables saponification. This saponification results in faster cleaning with less energy, better soil loading (enables longer bath life) and more stable compatibility through-out the life of the bath when buffered to keep pH stable. Functional additives are engineered into the formulations to enhance compatibility of the sensitive metals and coatings, rather than relying on pH alone.

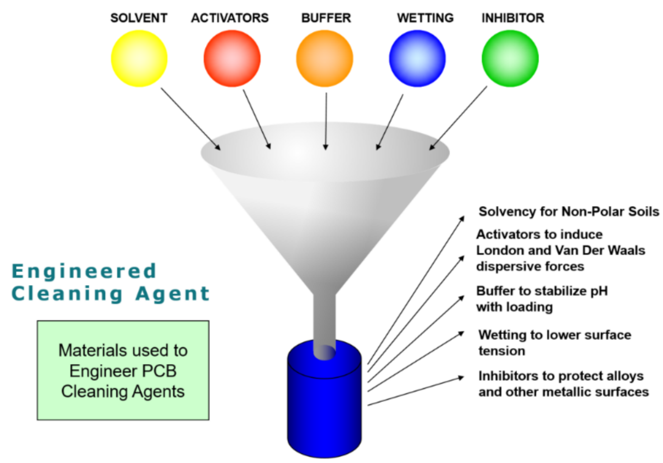

Figure 2: Aqueous Cleaning Agent building blocks

Modern balanced aqueous cleaning agents allow for the complexity of modern assembly processing. Solder paste being a combination of organic and inorganic ingredients, is most effectively removed by a combination cleaning agent. The solvents target the non-polar/inorganic residues, such as resins and rosins, oils and greases, and the activators dissolve the polar/organic residues, such as fingerprints and minor ingredients of the paste, flux activators, and salts. These chemistry blends are frequently a Bi-Phased solution, allowing the solvent to be sprayed without safety concerns. These are naturally partially soluble in water and effectively dissolve all the flux residues.

DYNAMIC CLEANING PROCESS

Cleaning is a complex and dynamic process. Success is achieved by understanding how the cleaning agent contributes or inhibits this multifaceted process.

Mechanical energy will vary from machine to machine. If a machine has limited mechanical energy, the solution is frequently to increase the exposure time, temperature and even the concentration. While the focus is usually on the cleaning, it is likely more important to allow equal focus on the rinse.

BATH BEHAVIOR

Bath behavior is defined by how a cleaning agent behaves inside the wash tank, taking into consideration exhaust, flux loading, and concentration fluctuations over time. Due to the dynamics of the wash tank, it is essential to understand the reasons and their impact on the entire process. How the flux loads into the wash solution is a critical component in how the bath behaves. Excessive amounts of flux can lead to foam in the wash, irregular concentration measurements, compatibility shifts, and poor rinsing. Traditionally, the higher the alkalinity, the more flux it can absorb. With semi-aqueous solutions, once a wash bath reaches a certain flux load percentage, the pH drifts toward the acidic range. It is at this point the wash bath starts to attack sensitive metals (ie. copper and aluminum). Today, with modern balanced aqueous chemistries, metal attack is far less frequent. However, there is a distinct difference in how a pH neutral chemistry reacts and pulls in the flux vs. mild alkaline chemistry.

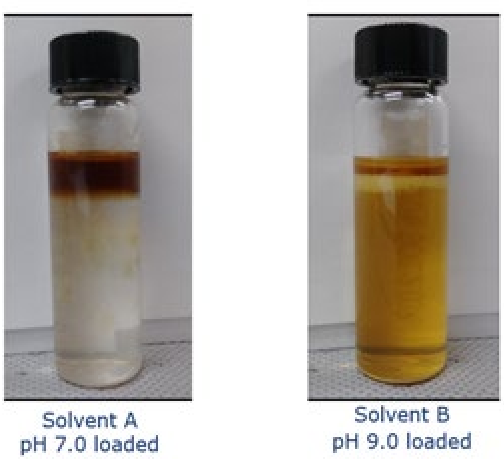

Figure 3: Flux absorption based on pH

Images above show the flux loading reactions in different solvent solutions. Solvent A shows the reaction of flux absorbed into the solvent phase, where it forms a layer that does not mix well with the aqueous phase. In Solvent B, the flux disperses in both the aqueous and solvent phases, with no hydrophobic reaction.

Unfortunately, process qualifications or evaluations are most often conducted under pristine conditions; fresh bath, optimized machine, and test vehicles carefully assembled, not taking into consideration production influence on the final product. During qualification, cleanliness is measured by Ion Chromatography (IC) and/or Surface Insulation Resistance (SIR). There is little consideration for the dynamics of a wash bath in production conditions, influence of flux, and the changes that may occur over time. Not only does the wash solution go through a visual physical change from removing soils from assemblies, the flux-loaded wash solution affects the ability to completely rinse the substrate substantially. Wash bath behavior and conditions influence final product quality and final product reliability.

COMPATIBILITY

The pH of a solution is one factor that can impact a surface. Frequently pH neutral “7” products are considered to desirable/good, mostly because the human body fluids are close to 7pH and it is viewed to not cause irritation or harm to any surface. Numbers on either side are often viewed negatively for both humans and/or surface compatibility. However, compatibility is also influenced by the chemical characteristics of the cleaning material, cleaning temperature, impingement energy and exposure time to the cleaning process, including rework cycles. A product which contain high levels of solvents to help remove the inorganic soils, may lead to plastic or metal attack. They may also give off fumes that are intolerable, creating corrosive or caustic mixtures and can also be air quality threats. The potential interactions between these factors are especially challenging today with the broad range and use of different materials.

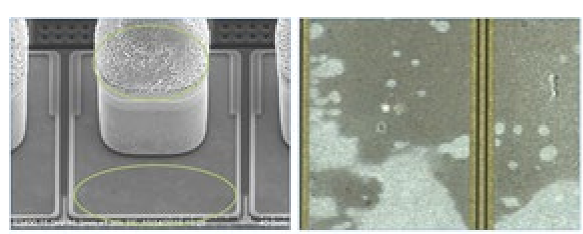

Figure 4: Component after cleaning with CA #1

The crucial factor is to design a cleaning agent which is balanced. For example, take the 7 cleaning agents below. The cleaning agents range from pH 7.6 to 11, with various solvency and builders' levels.

Cleaning Agents	pH	Solvency	Buffer	Wetting	Corrosion Inhibition
DI	4.7	None	None	None	None
CA #1	7.6	High	Low	High	Low
CA #2	9.0	High	High	High	High
CA #3	10.1	High	High	High	Medium
CA #4	11.0	Medium	Medium	Medium	Low
CA #5	11.0	High	High	High	High

Figure 5: Building blocks of 7 cleaning agents

If a cleaning agent is designed with a balance of solvency, builders (buffers) and inhibitors, it will be compatible with a wide range of metals and plastics over the life of the bath, as shown in below.

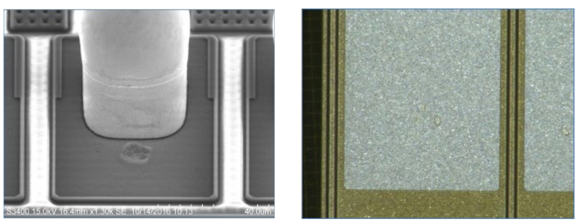

Figure 6: Component after cleaning with CA#2

With the correct balance, the cleaning agent can effectively remove no-clean flux residues, provide a stable and wide compatibility range, rinse easily, and be environmentally friendly. Too much or too little of one ingredient can meaningfully affect compatibility.

ENVIRONMENTALLY FRIENDLY

For a cleaning agent to be environmentally friendly or "Green" it should minimize the burden to the cleaning process AND the environment. This means the entire fingerprint of the cleaning process, not solely the cleaning agent, but the machine energy consumption, VOCs emissions and waste streams produced by the cleaning process. If a cleaning agent is effective at lower temperature and concentration, there is less chemical consumption, less waste produced, less VOCs emitted, and less energy expended to run the cleaning process. Being "Green" should include the entire cleaning process, not pH alone.

CONCLUSION

When a cleaning agent is part of a manufacturing process, there are various challenges to overcome vs. a "true" no-clean process. Conversely, reliability risk can be greater if no "cleaning" is used. Most Class 3 manufacturers view the risk of not cleaning to be greater than the challenges of cleaning. As a result, cleaning is either required or chosen. It is all about balance.

Cleaning is a dynamic process; no one single facet will provide all the answers. Only by balancing the flux loading, temperature, exposure time, mechanical energy, and the cleaning agent can you achieve a stable and reliable process. All these interdependent variables affect the entire cleaning process: wash, rinse and the environment. The pH of a cleaning agent impact on the entire cleaning process, both negatively and positively is only part of the story. Establishing a reliable cleaning process requires a good understanding of all influencing factors and defining the right balance to meet final product reliability.

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