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TECH 2 TECH Technical Article

pH Employment in Electronic Cleaning

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UNDERSTANDING pH

The terms "acidic", "alkaline" and "neutral" refer to positions on a scale of pH ranging from 1 to 14. A solution can have a pH below 1 and above 14. However, this range is most used. A pH of 7 is neutral, while numbers less than 7 are acidic and greater than 7 are alkaline or basic. A neutral pH of 7 is thought of as being desirable because the fluids of a human body are close to this value. Consequently, if skin meets a solution, either above or below 7, the skin may become irritated. A neutral pH does not indicate whether a liquid is safe to drink or not. If one was to ingest dish soap, the individual will likely become sick even though most mild dish soaps have a pH of 7-8.

Alkaline solutions are better at cutting through dirt, grease, proteins, oils, and other organic items. Acids are better for removing 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 end of the pH scale are not recommended for electronics assembly cleaning for multiple reasons. Solutions that have a pH at the extreme ends of the spectrum will react with metals. Depending on the solvents used, they may negatively interact with certain plastics, epoxies, and coatings.

As technology continued to advance, so did the aqueous cleaning agent, more towards the neutral range. A pH neutral cleaning agent sounds great! With the apparent disadvantages of acidic and alkaline cleaners, neutral cleaners would be an ideal solution. This, however, depends on several factors. A cleaning agent in the pH neutral range, even with a pH of 7.0 may also interact with metals, plastics, epoxies, and coatings under production conditions. In some applications, there can be a more significant negative reaction of a pH 7 cleaning agent over a mildly alkaline cleaning agent. A strictly neutral formulation may not have very good cleaning power. Some reactivity is desirable, especially to remove the latest generation of flux residues.

The best neutral range of cleaning agents are balanced. This means that the ingredients are formulated together so that they provide a high level of cleaning activity, very low toxicity, with acceptable cleaning performance in normal production conditions. This balance needs to stay consistent from the start of a fresh bath to the end of that bath. Making a truly informed choice requires knowledge of soil and surface conditions, and the cleaning agent. Some understanding of cleaning technology will at least lead to a more informed choice.

Just as there are advantages to staying near a pH of 7.0, there are just as many, if not more, advantages to being slightly alkaline. Mild alkalinity enables saponification. This results in faster cleaning with less exposure time and energy, better soil loading which enables longer bath life, and more stable compatibility through the life of the bath when buffered to keep pH in balance. Additives can be engineered into the formulation to enhance inhibition of the sensitive metals and coatings, rather than relying on pH alone. In the early 2000s, cleaning agent pH began to shift from high alkalinity toward more neutral. Today, most modern cleaning agents consist of:

- Solvency package to solubilize non-polar residues
- Aqueous Package to dissolve polar soils
- Functional Additives: These are de-foamers, buffers, corrosion inhibitors, wetting agents, and other minor ingredients to improve compatibility, bath life, and loading

Most CM's today use Bi-Phased cleaning agents. Bi-Phased cleaning agents have both a solvent phase and an aqueous phase, which allows the solvent to be sprayed without safety concerns. These are typically partially soluble in water. The solvent phase allows the cleaning agent to target the non-polar residues, such as resins and rosins, oils, and greases. The aqueous phase targets polar soils. This will remove the ionic residues such as fingerprints and minor ingredients of the paste, flux activators, and salts.

Cleaning agents are also multi-material compositions using both hydrophobic (oil-loving) and hydrophilic (water-loving) components. A solvent (neutral pH by nature) is less capable on polar residues and tend to be higher molecular weight molecules, making it more challenging to rinse, becoming a contaminant itself. Effective removal of all residues requires a combination of both (like dissolves like). A good cleaning and good rinsing require a balance of both phases to produce a reliable product.

The early aqueous based pH 7.0 cleaning agents were engineered with high solvency, obtained a very short bath life, required higher concentration, exposure time and temperatures to achieve a satisfactory level of cleaning. Aggressive cleaning conditions failed to remove some flux residues fully. In addition to inefficient cleaning, these early products proved to be more difficult to rinse than mildly alkaline solutions. Even though the pH reduced the degradation of metals, the temperature increase became a problem with the other materials such as labels and plastics, higher chemical losses, and non-user-friendly product. As the temperature is increased evaporative losses dramatically increased. There was also a concern to employees as the solvent in early chemistries put off an odor that caused headaches, nausea, and eye irritation to the operator. The solvents used in the early aqueous cleaning agents frequently lacked compatibility with plastics. Fortunately, the leading chemical manufacturers have worked to improve cleanability on the wide range of the latest fluxes and increasing material compatibility and providing a more environmental and user-friendly product. Cleaning is a process, not only a cleaning agent. The process can be complex and dynamic. Success is achieved by understanding how the cleaning agent behaves in the wash tank while it is doing its job of removing residues. There are three important areas to understand:

1. Mechanical Energy
2. Flux loading impact on the wash
3. Rinsing

Mechanical Energy will vary from machine to machine. If a machine has low mechanical energy, the solution is often to increase the exposure time, temperature and even the concentration. While the focus is typically on the wash side of things, it is equally important to do the same on the rinse side. Dialing in a process takes understanding your soils, the cleaning agent, and the equipment.

Electronic assemblies require solder masks, components, part marking, substrates, assembly materials, alloys, coatings, bonding and stacking materials. Assemblers identify components by using markings, labels, or other identifiers. These components and markings may have damage from exposure to the cleaning agent and mechanical energy needed to clean the part.

Compatibility can be impacted by the cleaning material, temperature, impingement from spray at the board level and exposure time to the product. Some product may be cleaned multiple times. All these factors are especially challenging today with the much wider availability of different materials. Traditional saponified cleaning agents (high pH/alkalinity) can attack specific metal types such as Aluminum, Copper, and even Lead.

There are cleaning agents which are designed to effectively remove flux residues and provide a wide compatibility range. They are also easily rinsed and safe for the environment. If a cleaning agent is designed with a balance of solvency, buffers, and inhibitors, it will be compatible with a wide range of metals over time. The solvent, buffers and inhibitors widen the process window which also enables a long bath life and promotes good rinsing. When a cleaning agent is engineered correctly, success is achieved even with the harshest of conditions.

Bath behavior is defined by how a cleaning agent behaves inside the wash tank, taking into consideration exhaust, flux absorption, and concentration fluctuations over time. Due to the dynamics of the wash tank, it is essential to understand the influencing factors and their impact on the entire process. How the flux is absorbed into the wash solution is a critical component in how the bath behaves. Too much flux loading 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 shifts toward the acidic range. This is when wash bath starts to attack sensitive metals, such as copper and aluminum and cleaning may become challenging. The attack is far less frequent with today’s pH neutral chemistries. There is still a big difference in how a pH neutral chemistry reacts and pulls in the flux, vs mild alkaline chemistry.

A cleaning agent engineered with mild alkalinity performs better on polar/ionic residues than a pH neutral chemistry. Mild alkaline cleaning agents remain stable throughout the life of the bath requiring no process adjustments, which validates cleanability with a new bath as well as a bath in the production environment. The pH of a cleaning agent will directly influence how the bath behaves as flux loads. Careful monitoring of wash bath concentration and overall production conditions is critical to ensure reliability.

BATH LIFE

Adding an acidic flux to a wash solution has the potential to lower the pH. When cleaning PCBs in typical production conditions, acidic flux is continuously added to the bath. To avoid the pH shift, some cleaning agents are formulated with materials to help stabilize the pH over an extended period of time. The addition of buffering agents in the formulation allows the cleaning agent to hold more acid/flux for a longer bath life while protection sensitive components. The amount of acid a bath can hold and still do its job is dependent on the pH of the material and the buffering design. A poor-buffered wash solutions, with a starting at a pH of 7.0 to 8.0, will quickly decline in pH as it absorbs the acid. However, a well-buffered wash solution with pH of 9 - 10.5 will be able to absorb more acid and maintain stability.

As flux loads the wash bath, a drop in pH occurs. If the pH drops to a point where the wash solution no longer cleans, it has reached its end of life. pH absolutely affects bath life, as well as potential compatibility risks. Even products that are designed with buffer materials to hold a stable pH will decrease over time which correlates to a shorter bath life, versus a cleaning agent in the 9-10 pH range. The potential for compatibility issues also drastically increase when the pH falls below 7.

When a wash bath solution is near the end of its life, there will be signs the bath has been spent. Early signs can be:

- Drop in surface tension on the substrate
- Flux/soil redeposition
- Insufficient rinsing
- Compatibility issues concerns
- Foaming in the wash bath

While pH fluctuation is an indicator of flux loading, it is also related to concentration. The combination of a lower pH and flux load, depending on flux components, can lead to compatibility on sensitive metals. This shift happens much quicker at lower concentrations. Cleaning agents in the 7-8 pH range will be able to clean at a lower concentration initially. However, they often require process adjustments, such as an increase of concentration, time, and/or temperature in order to maintain the same level of cleanliness as in the beginning. A buffered pH cleaning agent with a pH in the low 9's (mildly alkaline) will remain more stable over a longer period of time and flux load. Additionally, this cleaning agent is able to achieve the same level of cleanliness at lower concentrations and temperatures throughout the life of the bath. This extends the bath life, reduces waste, and diminishes potential compatibility issues attributed to low pH. When a cleaning agent is part of a manufacturing process, there are different challenges to overcome. On the other hand, reliability risk can be greater if no cleaning is used. This is the reason most assembly manufacturers are either required or choose to clean. It is all about balance.

CONCLUSION

Cleaning is a dynamic process. No one single facet can be studied on its own. Soil loading (flux, and other assembly contaminants), temperature, exposure time, mechanical energy, and the cleaning agent all react together within the wash process. These interactions affect the entire cleaning process, wash, rinse, and the environment. The pH of a cleaning agent affects the entire cleaning process.