Batch Semi-Aqueous Emulsion Cleaning
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Abstract
Recent development and work with water immiscible Semi-Aqueous solvents at 5%-20% concentration have led to a process that offers significant advantages over full strength Semi-Aqueous, saponification and water-soluble processes. This process uses less solvent, is safer, requires no nitrogen inertion for spray-in-air applications, significantly reduces the cost of rinse water treatment, and lowers equipment costs. This paper examines the effect of process parameters surrounding the emulsion cleaning process and reveals a piece of cleaning apparatus that optimizes the advantages that this process offers.

What is Controlled Emulsion cleaning?
Controlled emulsion cleaning is similar to the 100% or full semi-aqueous cleaning system in that it uses a water-immiscible (gravity-separable) solvent wash followed by water rinsing. Controlled emulsion cleaning uses a 5-20% solvent-water mixture instead of washing with 100% or full-strength solvent. Solvents such as Axarel®-32, Envirosolv® KNI-2000 or Petroferm Bioact®-EC7R are ideal for this process.

The beneficial effect of an emulsion rinse following a full semi-aqueous wash is well documented in in-line cleaning system. The solvent concentration in an in-line emulsion rinse is not controlled, but is simply a byproduct of product flow and drag-out from the wash stage. In the emulsion cleaning process, concentration is carefully controlled.

The batch spray cleaning system is particularly suitable for the controlled emulsion process. Another advantage of the batch spray process is that it does not over-emulsify the mixture thus allowing quick separation on removal of spray emulsifying energy.
Major advantages of Controlled Emulsion Cleaning

Total solution....Wash, Rinse, Dry and Waste Treatment

One of the chief benefits of the controlled emulsion process is that it allows washing, rinsing, drying and waste treatment in one small footprint. The operator does not need to transfer product from the wash to the rinse and dryer modules as required by full semi-aqueous batch equipment. Of course higher throughput can be accomplished with a companion dryer. For safety reasons this companion dryer should be suitable for drying flammable solvents.

Safer....requires no nitrogen

The full semi-aqueous process has two potential safety issues, the fire potential due to flash point and the explosion potential due to the organic mist induced by spraying in air. The controlled emulsion process, if operated at low concentrations with water, obviates the mist explosion potential. However, the flash-point fire potential still exists and washing and rinsing should be done at temperatures below the flash point of the solvent.

IMPORTANT NOTE: Consult your semi-aqueous solvent vendor for proper and safe operation temperatures.

Low process costs

In addition to not requiring expensive nitrogen, the emulsion cleaning process wastes considerably less solvent due to dragout. This means you use less semi-aqueous solvent overall.

Lower waste treatment costs

Lower wash solvent concentration means lower rinse solvent concentration. As there is less solvent in the rinse water, less carbon is required to remove it. Carbon use can be as low as 10% that of full semi-aqueous systems.

Lower equipment and labor costs

The “one chamber” construction of the emulsion cleaning system not only lowers equipment costs, but reduces labor. It is no longer necessary to move product from rinse to wash to drying module.
Total cost savings of the controlled emulsion system are compared to other cleaning alternatives in figure 1. The data in this figure is based on 10 loads per day, 20 square feet per load. The two processes on the left are open-loop saponification. The saponifier re-use process re-uses the wash solution 10 times. The most expensive process is the full semi-aqueous process. This is a 3-module wash, closed-loop rinse and dry. On the right is the water-soluble closed-loop rinsing process. In comparing the full semi-aqueous with the emulsion process, you can see that in addition to the savings in nitrogen costs, carbon and chemistry (solvent) costs are significantly reduced. DI resin use in the saponifier processes is in the treatment of the incoming rinse water. It is interesting that it requires less DI resin to remove the salts from the rinse water in the closed loop processes than to clean up the incoming water in the open loop processes. As you can see, the closed loop controlled emulsion process compares favorably with the open loop saponifier processes.
Advantages compared to other Cleaning Options

Controlled Emulsion Advantages Compared to Full Semi-Aqueous

One of the chief advantages of emulsion cleaning compared to full semi-aqueous is the fact that a complete system can be built with one spray chamber. In the full semi-aqueous system, the wash and rinse stages required two separate chambers, as dragout losses from the wash stage to the rinse were too costly. Another advantage with 5-20% emulsion is the reduction in flammability potential, to the point that nitrogen purging during washing is not required. Of course with lower wash solvent concentrations, the amount of waste solvent in the rinse is greatly reduced, thus reducing treatment costs. Lastly, the “one-chamber” cleaning system can be produced at lower cost than the separate wash and rinsing systems.

Controlled Emulsion Advantages Compared to Saponifier

One of the chief advantages of emulsion cleaning vs. saponifier cleaning is that the organic solvent does not “dull” solder joints like some alkaline saponifier formulations. Another significant advantage is that if rosin removal is not complete, the boards can be re-cleaned. With Saponifiers, if the process is not complete, re-washing is almost impossible due to hydration of the rosin residues. Alkalaline Saponifiers can be difficult to rinse, especially at lower temperatures. If Saponifiers are not adequately rinsed, harmful and corrosive residues can be left on boards.

From a waste treatment standpoint, the emulsion rinse solution is much easier to treat. With gravity-separation (decanting) and carbon adsorption, rinse waste can be economically and simply treated. On the contrary, organic Saponifiers are highly polar and are difficult to remove from the rinse water stream.

From an air pollution standpoint, the typical solvent has a lower vapor pressure than most Saponifiers, thus lowering VOC emission levels.
Controlled Emulsion Advantages Compared to Water Soluble Flux

Possibly the most significant advantage of the controlled emulsion cleaning process is that it works with rosin flux and does not require the user to change his process.

Water soluble flux residues can be corrosive and cause equipment failures if not properly removed during cleaning. Semi-aqueous solvent residues are mostly volatile and evaporate from assemblies.

From a waste treatment point, rosin flux followed by a semi-aqueous cleaning process results in lower rinse water heavy metals content. This lower metals content reduces DI resin requirements in closed-loop rinsing and increases life.

Another advantage of the controlled semi-aqueous process is that organic soils such as finger prints and oils are removed during the rinse process.
What testing says
Phase II Testing

Preliminary IPC/DOD TR-580 test protocol data is shown above in figures 2 and 3. As can be seen, the emulsion process was as good or better than comparable 100% Semi-Aqueous Phase II test results. This data is especially comparable, as the Axarel®-38, Envirosolv® KNI-2000, and Petroferm Bioact® EC7R products were tested in essentially the same batch spray cleaning equipment.
Comparing 5%, 20% and 100% emulsion cleaning efficiency

In order to compare the effect of emulsion concentration on cleaning efficiency, B-36 coupons were wave soldered with RA flux, cleaned and tested. Wash times, rinse times and temperatures were kept the same for the testing. Two solvents were tested. Figure 4 above illustrates the results. For comparison purposes, the data in this fig for the 20 and 100% concentrations was normalized to the 5% Omegameter values. Figure 4 shows that the 5% is very close to the 100% performance of Solvent “A” and is considerably better than the performance of Solvent “B”.

Figure 4.
In order to compare the effect of emulsion wash temperature and water rinse temperature on cleaning efficiency, B-36 coupons were wave soldered with RA flux, cleaned and tested. Wash temperatures for the emulsion were 100F and 140F, rinse temperatures were 100 and 140F also. Wash and rinse times were kept constant at 10 minutes each. Figure 5 illustrates the results. For comparison purposes, Figure 5 data was normalized to the 5% Concentration test Omegameter values.
Figure 6.
Equipment and Process (continued)

An implementation of an emulsion cleaning and waste treatment system is shown in figure 6. A typical daily operation sequence would be as follows:

1. Before the first wash of each day, the machine mixes precise levels of new solvent and re-used water, creating a wash solution in the heated wash holding tank, where sensors control temperature and solution levels automatically.

2. During the wash cycle, the wash solution is continually pumped through a particle filter to the wash chamber, and then back to the holding tank, where this closed-loop cycle continues. The solution in the wash chamber is continuously emulsified and recirculated at 60 GPM over the PCB assemblies with a separate pump.

3. After the wash cycle is completed, the emulsion wash solution flows back to the wash holding tank and slowly separates, with the emulsion collecting at the top.

4. During the rinse cycle, water is continually pumped through a particle filter and a series of carbon/DI filters to the wash chamber, through a decanter and back into the holding tank, where this closed loop cycle continues. The rinse water in the wash chamber is recirculated at 60 GPM over the PCB assemblies with a separate pump.

5. After the rinse water is drained from the cleaning chamber, assemblies are automatically dried by a built in dryer. The machine is now ready to continue it’s production.

6. At the end of each work day, the machine automatically cleans up the wash solution, removing used solvent to a separate holding tank. The machine is now ready to recharge itself at the start of the next work day.

Conclusions

Controlled emulsion cleaning has many advantages over other cleaning alternatives used for rosin flux cleaning. The process is capable of “Better Than” PhaseII cleanliness levels, it provides clean boards with shiny solder joints and has significant waste treatment advantages. The controlled emulsion cleaning process is safer and easier to operate than “Full” Semi-Aqueous. Finally, the controlled emulsion process offers significant cost savings over other rosin removal processes, when cost of waste water treatment is included.