Defluxing for New Assembly Requirements

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Abstract:
Consider defluxing at the design stage. This involves determining how product design may impact the assembly process. It also involves selecting the most effective, rugged defluxing option relative to the assembly design. The reward is reliable, competitive, and profitable electronics assembly. Selecting the right defluxing process must take into consideration not only performance requirements and costs but also miniaturization, component configuration, as well as local, national and international regulatory constraints. Changes in product design and the increase in highly-populated assemblies may impel modification of the defluxing process. Changes in the defluxing chemistry and in the defluxing process can benefit product quality and performance.

Supply Chain

Increasingly, those who fabricate electronics assemblies are part of a complex supply chain, one where electronics assemblies are themselves part of even more complex assemblies. Understanding and anticipating the requirements of your customers will make the product even more valuable. Developing techniques to evaluate current and future product lines in terms of design and choice of materials as well as materials compatibility is essential to remain competitive, especially with high-value and mission critical assemblies. This involves selectively evaluating the offerings of equipment and cleaning chemistry suppliers to achieve a rugged defluxing process.

Defluxing and Cleaning Review

In the past, most electronics assemblies were defluxed. Rosin fluxes, traditionally used in military and other high-reliability applications, had to be cleaned with CFC-113 or trichloroethane. In most instances, ultrasonic cleaning was considered unacceptable.

The production phaseout of ozone depleting chemicals (ODC's) required the development of defluxing processes that did not involve chlorofluorocarbons (CFC's). The replacement efforts, beginning in the late 1980's, were arduous and challenging. In retrospect, however, it was a productive experience that benefited industry and the environment. Defluxing options increased. Aqueous, semi-aqueous, and advanced solvent processes grew in availability and acceptance. Even more important, the soils (fluxes) changed. RMA fluxes were supplanted by water-soluble OA flux or low-residue (no-clean) flux, even for many high-reliability applications. Manufacturers who had been in the electronic assembly field for many years saw cleaning problems vanish, because the need to clean was eliminated. Ok, maybe the no-clean flux requires a bit of cleaning. However, water or dilute aqueous cleaners did the job.

Over the past few years, technical performance requirements, new design, and safety/environmental regulations have again made design of defluxing processes important.

Defluxing *is* cleaning

Defluxing is a cleaning process. Cleaning is the removal of soil; soil is matter out of place. In most instances, the cleaning or defluxing process consists of three stages: washing, rinsing, and drying. The wash step removes soil from the surface while avoiding soil redeposition. Rinsing removes residual cleaning agent, and may also continue removal of fluxes and other soils. Drying removes water or solvent (in cleaning, *solvent* usually means organic solvent). In all three steps, materials compatibility problems must be avoided. That is, the steps must be accomplished without unacceptable surface or product modification.

Especially with close-packed or low standoff components, pressure spray alone may not adequately deliver cleaning chemistries or rinse to the region to be defluxed. A guideline developed by Bill Kenyon for electronics defluxing is the "wetting index," a measure of how easy it is for a chemical to get into tight spaces. The index is proportion to density and inversely proportional to viscosity and surface tension. The physical parameters and wetting index of a few defluxing and cleaning chemicals are shown in Table 1.

Table 1. Physical parameters and Wetting Index

Cleaning Agents	Density g/ cm3	Surface Tension Dynes/cm3	Viscosity Centipoises	Wetting Index
CFC-113	1.57	17.3	0.65	140
1,1,1-trichloroethane	1.32	25.6	0.79	65
HFE-569sf2 (HFE 7200)	1.43	13.6	0.61	172
n-propyl bromide	1.35	25.9	0.49	106
Acetone	0.79 (20 C)	23.3 (20 C)	0.36 (20 C)	94
Isopropyl alcohol	0.78	21.8 (15 C)	2.4 (20 C)	15
d-limonene	0.84	25	1.28	26
H20	1.00	72.8	1.00	14
H2O w/ 6% ethanolamine-based saponifier	1.00	29.7	1.08	31

Final assembly requirements, military and aerospace

Military and aerospace assemblies require careful evaluation of the end use requirements. For example, when an electronics assembly is incorporated into a weapons system, cleaning requirements and anticipated cleaning techniques of the initial electronics assembly must be considered in the context of the final assembly. This is true even if traditional solders rather than lead free are used. In addition, materials of construction must be evaluated in terms of anticipated contamination requirements.

Physical Barriers to Contamination

The initial electronics assembly may pass tests for ionic contamination with flying colors. However, it may have to withstand potential contamination from other product. For example, anodized materials vary in process quality. We see batch to batch variability, where one lot of anodized material visibly discolors the process bath. In a way, such an obvious problem is good, in that there is a clear, immediate indication of a problem. On the other hand, one manufacturer recently complained about a "dulling" of anodized parts. Is this "dulling" or "discoloration" corrected by a change in the cleaning process? Perhaps. However, there is the nagging suspicion that in the process of forming discoloration, a contaminant may be generated that could migrate to the electronics assembly.

One solution is to apply a potting compound or a conformal coating to protect the assembly. Of course, there are issues of using the correct coating, applying it as per instructions, and using the correct curing protocol. Before applying the coating, the surfaces to be coated must be both defluxed and cleaned of other contaminants, or the results can be analogous to repainting a wall that is covered in grease. Adhesion may not be optimal. Flaws in the coating can allow contaminants released during subsequent assembly and handling to contact and contaminate your electronics assembly. Careful control means you are not part of the problem. Certainly, part of this control can involve monitoring the fabrication and cleaning processes used by suppliers of electronics assembly components. However, consideration of complete cleaning as well as defluxing during assembly helps assure that your contribution to the final assembly is rugged.

Contamination Levels – More than Conductive Contamination

The *final*, final assembly (the one that includes both your product and many other materials of construction) may have requirements for low particulate and thin film residue, requirements that encompass both conductive and non-conductive residue. Examples of such requirements are found in IEST-STD-CC1246D [1]. This specification, derived from an older Military Specification of the same number, is rather general. For example, while the residue level is listed, how you determine that residue, including extraction techniques, are not specified. Extraction may be performed by rinsing, refluxing, or, increasingly, using ultrasonics. Water or any of a number of organic solvents may be called out. Electronics components that are damaged or modified by ultrasonics or where potting and conformal coating are not adequately controlled may yield spuriously high particulate and/or non-volatile residue (NVR) levels.

Residues that are not detected by ionic analysis techniques may still compromise assembly performance. Capacitive coupling from residues may become important at high frequencies, thus affecting triggering circuits or communication applications [2]

Ionic or non-ionic contamination may have many sources. Table 2 lists a number of soils that may contaminate a product.

Table 2 Examples of Soils

Solder flux (rosin, organic acid, low residue)
Oils, greases
Metal working fluids
Lapping, polishing compounds compounds
Particles (metal fines, chips, skin flakes, polishing grit)
Acids
Water
Solvent
Product Assortment
Residual product/breakdown (in processing equipment)
Deposited cleaning agent residue
Rust-preventative
Bacteria, mold, life-forms (alive or dead)

Medical Devices

Designing rugged electronics assemblies for use in medical devices is particularly challenging. Many of the issues of concern in military and aerospace applications also hold for medical devices. However, the issues for medical devices are even more complex.

For one thing, there tends to be a very high level of secrecy on the part of the final assemblers, perhaps more so than in military and aerospace. Competitive sensitivity certainly plays a role. However, the level of secrecy can be so high that, within a given facility, the processes and practices of one group may be kept secret from another group. This makes process integration a challenge, to say the least.

In addition, the phrase “regulatory issues” carries a connotation for medical devices beyond that of, say the Environmental Protection Agency, OSHA, or REACH. Specifically, the Food and Drug Administration (FDA) requires that device manufacturers demonstrate safety to the patient, particularly if there will be direct contact with the body or if the devices will be implanted. Because there are so many different materials of construction, configurations, and uses, obtaining regulatory approval is often accomplished on a case-by-case basis. Required testing may include Total Organic Carbon (TOC), biocompatibility, and risk analysis of the nature and potential consequences of leachable residue such as outlined by ASTM method F-2459-05 [3] and ISO Standards 10993-17 [4] and 10993-18 [5]. Leachable residue is often more complex in medical devices in that the device manufacturer has to consider not only the level of residue and impact on reliability of the device but also, in some cases, the impact on the patient. This means that the steps in the defluxing and cleaning processes, including not only washing but also rinsing and drying have to be carefully defined. Even process chemicals that have a fairly benign worker safety profile can have catastrophic effects on the host. Catastrophic effects come with liability implications for the final, final assembler of the device.

In addition, the FDA may respond by issuing advisories against using the cleaning agent in question, certainly without proof that all of the cleaning agent residue has been removed. The device manufacturer is left to ponder and justify what "all" means. Alternatively, another cleaning or defluxing agent may be selected, perhaps one with less well-defined information about the consequences of use.

This regulatory complexity and the potential liability concerns can have unfortunate societal implications. Some manufacturers refuse to knowingly sell electronics assemblies to device manufacturers. Others, justifiably, explain that the final device assembler has the responsibility for demonstrating lack of contamination Suppliers of cleaning agents may have similar provisos, even if those cleaning chemistries are regularly used in device manufacturing. The associated level of secrecy on the part of device manufacturer can result in a lack of communication on the part of the final device manufacturer with the supplier of electronic assemblies and vice versa. This means that the desired levels of contamination and desired manufacturing practices may not be clearly communicated. As a supplier of electronic assemblies to be used as part of medical devices, setting quality standards and observing GMP would be of value in these critical applications, even where the final device assembler has the ultimate responsibility.

Regulations and Performance Requirements
(Safety and Environmental)

Certainly, REACH has added a level of complexity to many global operations. Even within North America, the impact of regulations, primarily environmental regulations, but also some worker safety issues, has potential impact on assembly performance and long-term reliability.

Aerospace and aeronautic electronics assemblers must cope with restrictions on air toxics and on volatile organic compounds (VOCs). Where assemblies are purchased infrequently and intermittently and where they are required to a certain test specifications, we may run into unanticipated problems. That is, the type of flux and the associated defluxing process may be modified; and the assembly may meet the specifications. However, especially where many variables have changed, it must be determined whether or not those specifications cover the anticipated performance needs.

There is also the issue of finding appropriate suppliers. Some assemblers will not accept contracts where defluxing is required; or they will accept projects that use either water alone or water with low levels of cleaning chemistry.

In effect, environmental requirements impact product performance standards.

Suggestions toward Future Quality Development

We need more comprehensive performance standards that include conductive and non-conductive residue.

Process options have to be considered, and perhaps reconsidered. There is a general concern with using appreciable levels of additives; and many groups have an aversion to using organic chemicals. While cleaning under close-spaced components is possible using water or water-based chemicals, the surface tension, density, and viscosity or water, alcohol, and other process chemicals limits their utility. The level of required process control is such that as rugged defluxing process is not readily achievable. In addition, while ultrasonic cleaning is gaining some acceptance, other groups have a concern with product damage. Certainly, there is such a potential; and we have seen ultrasonics used inappropriately. [6]. At the same time, we have also observed component damage due to high-pressure spray. The potential for component damage from physical and chemical cleaning forces must be considered.

References

1. "IEST-STD-CC1246D: Product Cleanliness Levels and Contamination Control Program," Institute of Environmental Sciences and Technology, http://www.iest.org/i4a/pages/index.cfm?pageid=3845.
2. H. Schweigart, "Contamination-Induced Failure of Electronic Assemblies," in *Handbook for Critical Cleaning, Second Edition*, B. Kanegsberg and E. Kanegsberg, editors; CRC Press (2011).

3. "ASTM F2459 - 05 Standard Test Method for Extracting Residue from Metallic Medical Components and Quantifying via Gravimetric Analysis," ASTM International, http://www.astm.org/Standards/F2459.htm .

4. "ISO 10993-17:2002 Biological evaluation of medical devices -- Part 17: Establishment of allowable limits for leachable substances," http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=23955

5. "ISO 10993-18:2005 Biological evaluation of medical devices -- Part 18: Chemical characterization of materials," http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=41106

6. B. Kanegsberg & E. Kanegsberg, "Parameters in Ultrasonic Cleaning for Implants and other Critical Devices," *Journal of ASTM International*, April 2006, Vol. 3, No. 4.

Defluxing for New Assembly Requirements

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Wednesday, April 13, 2011
Las Vegas, NV

BFK Solutions
Cleaning Consultants, est. 1994

- **Experience, expertise, common sense**
- **Barbara Kanegsberg, "*The Cleaning Lady*"**
  - Biochemist, clinical chemist, manufacturing process
    - IPC revision, electronics cleaning handbook
- **Ed Kanegsberg, *"The Rocket Scientist"***
  - Physicist, engineer, process evaluation
  - Multiple patents
- **"Clean Source" eNewsletter**
- **Editors, "Handbook for Critical Cleaning," CRC Press,** 2 volume 2nd edition, 2011
  - now available

Defluxing for New Assembly Requirements

- Cleaning basics
- Population and defluxing
- Regulatory and assembly challenges
- What’s next

Soil: matter out of place

Cleaning:

Removing matter out of place

Soils

Solder flux (rosin, organic acid, low residue)
Oils, greases
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Lapping, polishing compounds compounds
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Cleaning & Energy

- Cleaning
  - 1. Disrupt forces holding soil to substrate
  - 2. Remove soil from vicinity of substrate
- Disrupting forces involves energy
  - Chemical
    - Reactivity
    - Solvency
  - Impact (momentum)
    - Temperature
    - Directed matter
- Cleaning Processes not always called “cleaning”

Facets of cleaning systems

- Cleaning chemistry
- Force
- Temperature
  - Rule of thumb
    - 10 degree Centigrade increase in temperature doubles reaction rate
- Time

Steps & Functions of Cleaning System:
Think About Cleaning Agent and Cleaning Process Together

- (1) Wash
  - Deliver cleaning agent to surface
  - Provide cleaning action to remove soil without damage to surface
  - Remove soils from proximity of surface (i.e. leave a clean surface)
- (2) Rinse
  - Remove residual cleaning agent
  - Continue cleaning process
- (3) Dry
  - Remove water, adsorbed solvent
- Separate, distinguishable operations
  - Allocate $$$ and design time appropriately
- Restore cleaning agent for subsequent operation (Optional, but often desirable)
- All steps: avoid product damage

Importance of Physical Properties: Wetting Index

- Guideline, teaching tool
  - W.G. Kenyon
- Wetting index =

  density x 1000/surface tension x viscosity
- Higher wetting index, better penetration close-spaced components
- Data from published, reliable sources
  - Please reconfirm with manufacturer

Physical Properties of Cleaning Agents—Wetting

(Data @ 25C except as noted)

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A defluxing study

long long ago

Presented

1997

On Planet Nepcon

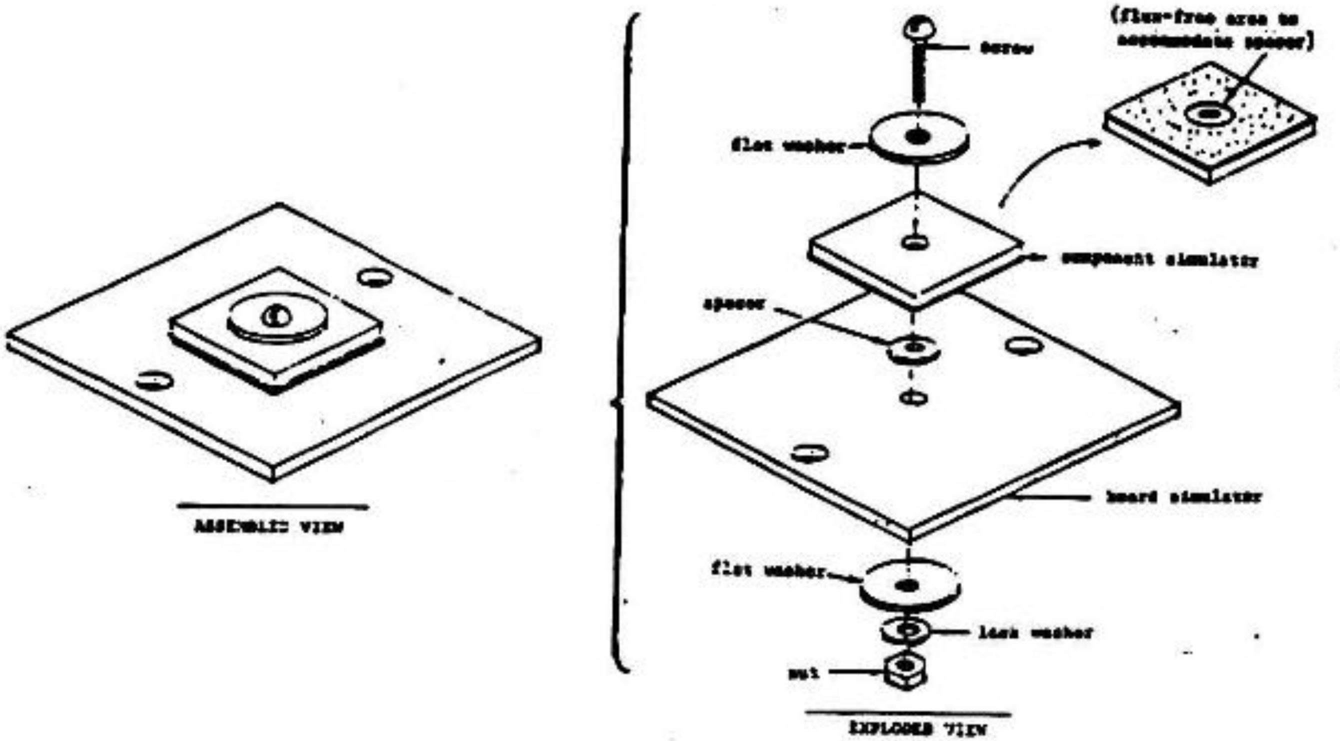
Standoff

Defluxing of Electronics Assemblies, Military Application, Effect of Standoff - circa 1990

(W. Machotka, C. Knapp, B. Kanegsberg)

- Leadless 1 inch square simulators
  - No surrounding components
- Compare effect of spacing on flux removal
  - 0.003 inch
  - 0.005 inch
  - 0.008 inch
  - 0.015 inch
- Test in operating cleaning systems
  - Travelling "reflow oven" – adapted toaster oven
- Batch & in-line
- Various cleaning agents – solvent, aqueous, semi-aqueous
- Estimate removal RMA flux
  - Gravimetric

Component Simulator



% Defluxing Relative To Standoff, Component Simulators

		Per Cent Flux Removed			
Process	**Cleaning agent**	**3 mils**	**5 mils**	**8 mils**	**15 mils**
1 in-line	**1,1,1-trichloroethane azeotrope**	**98**	**100**	**100**	**100**
2 in-line	**HCFC 225**	**88**	**100**	**100**	**100**
3 in-line	**orange terpene A, semi-aqueous**	**79**	**100**	**100**	**100**
4 batch	**orange terpene A, semi-aqueous**	**69**	**100**	**100**	**100**
5 in-line	**hydrocarbon blend, semi-aqueous**	**56**	**100**	**100**	**100**
6 in-line	**aqueous/ saponifier A**	**79**	**93**	**100**	**100**
7 batch	**aqueous/ saponifier A**	**65**	**96**	**94**	**100**
8 in-line	**aqueous/ saponifier B**	**71**	**100**	**100**	**100**
9 in-line, vintage 1980’s	**aqueous/ saponifier A**	**26**	**38**	**63**	**73**

RMA Flux Removal, 1990's & Defluxing 2011+

- Adequate standoff improves cleaning
  - 0.005 inches standoff or greater
    - Aqueous, semi-aqueous, solvent options
  - Under 0.005 inches standoff
    - Solvent options likely to be more successful
- Suggestion: involve design engineers on your process change team
- Dense population = defluxing challenges

Current & Near-Future Defluxing and Cleaning Issues

- Increasing regulations
- Costs, competition
- Cleanliness testing largely restricted to ionics
  - Non-ionics not adequately considered
    - Conformal coating
    - Outgassing
    - Parasitic capacitance (affects high frequency performance)
- Education, training, creativity
  - Over 50% designers have < 5 years experience
  - Lost: what NOT TO do
    - As useful as what TO do

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- Cleaning basics
- Population and defluxing
- **Regulatory and assembly challenges**
- What’s next

Supply Chain and Regulations

- Interconnected issues for electronics assemblers
- Complex supply chains
  - Multiple uses of product
  - Electronics assembly is not final assembly
- Safety and Environmental regulations
  - Local, regional, national
  - Restrict process chemicals that can be used
    - Moving target
    - Catch 22
- FDA

SCAQMD Headquarters

Diamond Bar, CA

Will EPA Compel States to Adopt SCAQMD Regulations?

- Aerospace presentation, IPC/SMTA cleaning conference, Nov. 2010
  - Assertion: EPA will require adopting SCAQMD Rulebook
- South Coast Air Quality Management District (SCAQMD)
  - Southern California
  - Poor air quality, volatile organic compounds an issue
  - 25 g/L VOC maximum for most cleaning operations
    - Airless/Airtight Systems required for most high VOC applications
  - Most low VOC chemicals don't clean effectively
- You should be concerned
- Effective cleaning/defluxing agents would be limited
- Audience requests to Barbara: "*Do something!*"

Barb Response: "*Take two aspirin, I'll call the EPA in the morning.*" So, I did ….

- EPA can't force states to adopt SCAQMD rules
  - Would probably require Congress to act
- Rules for ground level ozone (bad, smog-producing ozone) tightening
  - more areas non-compliant
  - States must propose stronger State Implementation Plans (SIPs) for better air quality
- Net effect - "voluntary" moves by states to adopt/adapt SCAQMD rules
  - It's expeditious
  - SCAQMD has much larger staff than most state agencies
  - Assertion: California does it, so it must be ok

Connecticut Regulation-- VOC's, Industrial Hand-wipe Operations

- Cleaning chemicals no higher than 50 g/l VOC or 8 mm Hg @ 20^{O} C
  - Effective Jan.1, 2011
  - 50 g/L was older SCAQMD limit
  - Are some exemptions (eg. Aerospace)
  - Sec. 22a-174-20

Regional Regulation - OTC

- “The Ozone Transport Commission (OTC) is a multi-state organization created under the Clean Air Act (CAA). We are responsible for advising EPA on transport issues and for developing and implementing regional solutions to the ground-level ozone problem in the Northeast and Mid-Atlantic regions.”
- http://otcair.org/

OTC Members

- Connecticut
- Delaware
- District of Columbia
- Maine
- Maryland
- Massachusetts
- New Hampshire,
- New Jersey
- New York
- Pennsylvania
- Rhode Island
- Vermont
- Virginia

OTC Model Rule for Solvent Degreasing (2011 082710B GMP)

- Draws heavily from (cut & paste from)
  - SCAQMD Rule 1122 (2009)
- Voluntary compliance date, January 1, 2014
- BFK Solutions listed as “interested people”

OTC Limitations

- Air toxics could have lower controls
  - VOC's, not HAPs per Congressional mandate
- Model rule, findings not binding on states
- Limited staff, limited money
- OTC presumption: SCAQMD is correct, has expertise
- Adopted most of SCAQMD Rule 1122 verbatim
  - 25 g/l limit
  - Definition of Airless/Airtight system
- ***OTC assumption: if there were problems with Rule 1122, someone would have complained***

Response, Southern California Electronics Assembly Job Shops

- Do not complain
  - Fear of regulatory citations, fines
- Avoid defluxing
- Deflux with water
- Case study: response to SCAQMD regulations
  - Accept only electronics assembly projects where water removes the flux
  - Decline projects using cleaning chemicals

Lubricants, SCAQMD Rule 1144

- Metalworking Fluids and Direct Contact Lubricants
  - Adopted July 9, 2010
- "The purpose of Rule 1144 is to reduce volatile organic compound (VOC) emissions from the use of metalworking fluids and Direct-contact lubricants at industrial facilities."
- Independent Lubricant Manufacturers Association (ILMA)
  - Two-year involvement, test method development
  - Why? Strong potential for Rule adoption, other areas

Overall Impact 1144

- Metalworking fluids restricted to less evaporative materials
- Less evaporation -> more residue - > potential impact on hardware
- Cleaning agents/processes may not be adequately effective

Rule 1144: VOC levels (g/l) Metal working fluids, Effective date

Fluid	1/1/2010	1/1/2011	1/1/2012
Vanishing oil	50		
Metal forming			75
General metal removal			75
Precision metal removal			130
Metal treating			75
General metal protecting	300		50
Military specified preservative		340	
Direct contact lubricant			50

Will the lower VOC levels have an impact on cleaning (beyond defluxing)?

- YES– BFK
- NO– Some ILMA members in SCAQMD process
- VERY LIKELY– Other chemists, evaluation experts producers of metal working fluids
- Disconnect between people who formulate metal working fluids and people concerned with soil residue
  - *Why would anyone ever want to remove our wonderful metal working fluid*? - Formulator perspective
- Some suppliers suggest veggie oils as lubes
  - Observation – can be exceedingly adherent

Regulatory: FDA

- Food and Drug Administration is global
  - FDA regulates imports
  - FDA has international presence
- Overwhelming concern - patient safety
- Residue concern
  - Total Organic Carbon (TOC)
    - Traditional issue
  - Biocompatibility
  - Leachable residue
  - Toxicity of residue

Newer standards, medical devices

- Extraction and Gravimetric Quantification
  - ASTM F2459-05
- Standard Practice for Reporting and Assessment of Residues on Single Use Implants
  - ASTM F2847-10
- Biological evaluation of medical devices
  - Establishing allowable limits for leachables
    - ISO 10993-17
    - Risk analysis
    - Decision tree
  - Chemical characterization
    - ISO 10993-18

Challenges, Medical device assembly

- Diverse materials & chemicals
- Complex international supply chain
- Must prove to FDA you are assembling correctly
  - There can be no single test for “correctly”
- If problems are found, FDA requires removal to “no detectable level”
  - Test method usually is not provided
  - “Low residue” may not be acceptable
  - Chemicals with effective wetting may leave a leachable residue

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Challenge: Outreach to Final Product Assemblers

- Informal survey at MD&M West
  - Feb., 2011
  - Numerous contract device manufacturers
- Asked approx. a dozen electronics technical people about IPC/ APEX
  - Only 1 planned to attend
- Important responses
  - Not aware of IPC
  - Concerned with final assembly, not defluxing

Successful Electronics Assembly for the Next Decade

- Understand Cleaning/defluxing
  - Cleaning is removal of soil (matter out of place)
  - Cleaning challenges will grow - small spaces
  - Non-ionics impact performance
- Be aware, stay aware of regulations
  - California regulations are being copied elsewhere
    - Speak up!
  - The application defines the regulations – know your customer requirements
- Design for defluxing
    - Complex designs are more complex to deflux
    - Be aware of final assembly requirements (post-defluxing)

Defluxing & Cleaning

- **Find the optimum process to remove the soil**
  - without harming the worker
  - without harming the environment
  - without harming your pocketbook
  - Without harming the product itself

- **Consider all the options**
  - Aqueous
  - Solvent
  - Non-chemical
  - Other

Don’t be afraid of the molecule