Equipment Selection Considerations

Key to Low Standoff Cleaning

Presented by Steve Stach
1. Fluid Flow Theory

2. The Problems
   1. Existing Limitations in Fluid Flow.
   2. Surface Effects in Tight Spaces.

3. Solutions
   1. Energy/Solvency Balance
   2. Batch Cleaners
      1. Vapor degreasing
      2. Spray under-immersion
      3. Ultrasonics
      4. Spray in air
   3. Inline Cleaners
      1. Three Steps to Clean Fully Blocked Gaps.
      2. Progressive Energy Dynamics.

4. Summary and conclusions
Cleaning Equipment Selection Considerations

The Fluid Flow Theory
Fluid Flow Theory:
Penetrating Small Gaps Is Dependent on The Following Properties

1. Physical Properties of the Cleaning Agent

   1. Surface Tension
   2. Density
   3. Viscosity

2. Higher Energy Fluid Delivery

   1. Flow Rate
   2. Impact Velocity

Energy Delivered is Dependent on the Following Equation for Kinetic Energy:

\[ \text{Kinetic Energy @ Surface} = mV^2 \text{ @ the Surface} \]
Fluid Flow Theory: How Much Energy Does It Take to Clear Tight Spaces?

Interfacial pressure differential calculation

Planar

\[ \Delta p = \frac{2\gamma \cos \Theta}{R} \]

Cylinder

\[ \Delta p = \frac{\gamma \cos \Theta}{R} \]

NOTE:
If \( \theta \) is greater than 90˚, as with water on waxy surface, the force becomes negative or repulsive. If surface is wetted, force pulls the fluid into the gap.

\( \gamma \) Surface Tension
\( \Theta \) Contact Angle of Liquid at Surface
\( R \) Radius Meniscus

Fluid Flow Theory: How Much Energy Does It Take to Clear Tight Spaces?
Fluid Flow Theory: Small Unfilled Gaps

Relationship between gap size and capillary force for water on glass.

- Relationship between gap size and capillary force for water on glass
Cleaning Equipment Selection Considerations

The Problem
The Problems:  
Existing Limitation in Fluid Flow

- Space under components is shrinking.
- Interconnect densities are increasing.
- Performance requirements are increasing.
- Lead-free & no-clean are harder to clean.
- Fluxes are fully filling small gaps.
The Problem:
Surface Effects in Tight Spaces Retard Fluid Flow

Computer model of flow in 50 micron gap.
The Problem:
Fully Filled Gaps Prove Increased Resistance to Cleaning

Resistors, Capacitors, LCCs, and QFNs
Cleaning Equipment Selection Considerations
The Solution:
3 Steps To Cleaning Fully Blocked Gaps

1. Outer solvent depleted zone softened.

2. Liquid jet with sufficient energy forms flow channels.

3. Bulk residue is eroded & dissolved by fluid flow.

*Steps 2 & 3 Require Substantial Energy.*
Selecting Your Cleaning Equipment
1st Step Narrow the Choices

Aqueous or Solvent
Batch or Inline
Open or Closed Loop
Special Requirements
Selecting Your Cleaning Equipment

2nd Step Document

Document what is important to you

- Process Performance
  - Clean what?
  - How clean?
  - How fast?
- Process Cost Estimates
  - Labor
  - Chemicals
  - Equipment
  - Facilities
- Environmental
  - No Drain
  - VOC’s
- Product Testing
  - Delicate circuits
  - Adhesives, markings, labels
**Batch Cleaners**

Many Choices

- Dip Tanks
- Degreasers
- Immersion Agitation
- Ultrasonic
- Spray in air
- 3D
- Planar
**Batch Cleaners**

Many Choices  
Dip Tanks  
Degreasers  
Immersion Agitation  
Ultrasonic  
Spray in air  
3D  
Planar

---

<table>
<thead>
<tr>
<th>Energy Sources</th>
<th>Heat Brushes</th>
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<tbody>
<tr>
<td>Dip Tank</td>
<td>Advantages</td>
</tr>
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</table>
Batch Cleaners
Many Choices
Dip Tanks
Degreasers
Immersion Agitation
Ultrasonic
Spray in air
3D
Planar

Energy Sources
Heat Spray

Vapor Degreaser
Advantages
Low to Medium Cleaning Energy
Clean/Rinse/Dry
Water Free
Closed loop

Disadvantages
Limited Solvents
Operator Safety
Waste Disposal
VOC’s, ODC’s
Batch Cleaners
Many Choices
Dip Tanks
Degreasers
Immersion Agitation
Ultrasonic
Spray in air
3D
Planar

Energy Sources
Spray UI
Centrifugal
Ultrasonic
Heat

<table>
<thead>
<tr>
<th>Agitation under immersion</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Low to Medium Cleaning Energy</td>
<td>Clean/Rinse/Dry Multi-Solvent Closed loop Low VOC Emissions</td>
<td>Limited Throughput</td>
</tr>
</tbody>
</table>
Batch Cleaners
Many Choices
- Dip Tanks
- Degreasers
- Immersion Agitation
- Ultrasonic
- Spray in air
- 3D
- Planar

Ultrasonic Cavitation
Energy Sources

<table>
<thead>
<tr>
<th>Ultrasonic</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Low to Very High</td>
<td>Water Based or Solvent Compatible</td>
<td>Can damages wire bonds &amp; glass seals</td>
</tr>
<tr>
<td>Cleaning Energy</td>
<td></td>
<td>Operator Safety</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Waste Disposal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limited Process Control</td>
</tr>
</tbody>
</table>

Ultrasonic Advantages
- Low to Very High Cleaning Energy
- Water Based or Solvent Compatible

Ultrasonic Disadvantages
- Can damages wire bonds & glass seals
- Operator Safety
- Waste Disposal
- Limited Process Control

Energy Sources
- Ultrasonic Cavitation
- Heat
## Batch Cleaners

### Many Choices
- Dip Tanks
- Degreasers
- Immersion Agitation
- Ultrasonic
- Spray in air
- 3D
- Planar

### Energy Sources
- Air Spray
- Heat

<table>
<thead>
<tr>
<th>Spray in Air</th>
<th>Advantages</th>
<th>Disadvantages</th>
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</thead>
<tbody>
<tr>
<td>Medium to High Cleaning Energy</td>
<td>Clean/Rinse/Dry Water Based Closed loop</td>
<td>Through put Waste Disposal</td>
</tr>
</tbody>
</table>
Air Spray Nozzle Design Data

<table>
<thead>
<tr>
<th>Spray Type</th>
<th>Typical pressure @ 2&quot;, 50 psi man. /Pressure loss/in</th>
<th>Indicated use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fan/Delta</td>
<td>2 psi / ~50% drop/inch</td>
<td>Wide coverage, overlap for high impingement or close work distance</td>
</tr>
<tr>
<td>Conical</td>
<td>0.4 psi / ~75% drop/inch</td>
<td>Widest coverage area, lowest kinetic energy, flooding applications</td>
</tr>
<tr>
<td>Coherent</td>
<td>10 psi / ~10% drop/inch</td>
<td>Smallest coverage, highest energy density over longest distance</td>
</tr>
</tbody>
</table>
Inline Cleaning Considerations

Progressive Energy Dynamics

*Key to Low Standoff Cleaning*
### Designing High Energy Inline Cleaning Manifolds

**Coherent Jet .075”**

<table>
<thead>
<tr>
<th>Manifold Pressure</th>
<th>Flow Gpm</th>
<th>Spray coverage 1.5”</th>
<th>Spray coverage 4.0”</th>
<th>Impingement lbs/insq 1.0”</th>
<th>Impingement lbs/insq 2.0”</th>
<th>Impingement lbs/insq 4.0”</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 psig</td>
<td>0.6896</td>
<td>0.6</td>
<td>0.7</td>
<td>15</td>
<td>6.5</td>
<td>10</td>
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<tr>
<td>40 psig</td>
<td>0.8243</td>
<td>0.6</td>
<td>0.7</td>
<td>17</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>50 psig</td>
<td>0.8877</td>
<td>0.6</td>
<td>0.8</td>
<td>19</td>
<td>9.5</td>
<td>13</td>
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<tr>
<td>60 psig</td>
<td>0.967</td>
<td>0.6</td>
<td>0.8</td>
<td>20</td>
<td>11</td>
<td>15</td>
</tr>
</tbody>
</table>

**Manifold Flow Velocity**

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Gpm</th>
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**Spray coverage**

<table>
<thead>
<tr>
<th>Diameter</th>
<th>1.5”</th>
<th>4.0”</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5”</td>
<td>1.5</td>
<td>1.7</td>
</tr>
<tr>
<td>2.0”</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td>4.0”</td>
<td>3.25</td>
<td>4</td>
</tr>
</tbody>
</table>

**Impingement lbs/insq**

<table>
<thead>
<tr>
<th>Diameter</th>
<th>1.0”</th>
<th>2.0”</th>
<th>4.0”</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0”</td>
<td>3.2</td>
<td>4.4</td>
<td>7.2</td>
</tr>
<tr>
<td>2.0”</td>
<td>1.6</td>
<td>1.8</td>
<td>2.5</td>
</tr>
<tr>
<td>4.0”</td>
<td>0.2</td>
<td>0.3</td>
<td>0.5</td>
</tr>
</tbody>
</table>
The Solution:

High Impingement Jets and Progressive Energy

- Static Dissolution
- Concentric Stripping
- Channeling

Optimum Impact Pressure Delivers a 2-D Spread

Too High Impact Pressure Delivers a 3-D Spread

Progressive Energy Provides Greater Impingement Force Eliminates Puddling
The Solution: 
Research Leading to PED
The Solution

*Inline Progressive Energy Dynamics Approach (PED)*

- New Approach to Inline Design
- Involved Manifold Design with Increased Pressures at Each Manifold

![Diagram showing the process of Pre-Wash, Wash 1, Wash 2, and Wash 3 with different energy levels.](image)

- **Pre-Wash**: Low Energy Jet Heat and Wet Surface
- **Wash 1**: Medium Energy Jet Penetrate Outer Layer
- **Wash 2**: High Energy Jet Form Flow Channels
- **Wash 3**: Highest Energy Jet Erode Flux
The Solution

*Inline Progressive Energy Dynamics Approach (PED)*

PED Works in a Standard In-line Configuration

*MicroJet FC Shown in Diagram*
The Solution

*Inline Progressive Energy Dynamics Approach (PED)*

1. Soften Outer Shell
2. Create Flow Channels
3. Erode Flux Residue
The Solution

*Inline Progressive Energy Dynamics Approach (PED)*

**Progressive Energy Dynamics Is:**
- A Fluid Delivery System.
- Recognizes The 3-Step Process
  Required to Clean Flux-Filled Spaces.
- Delivers Only What is Needed at Each
  Step.

*961 I/O “Glass on Glass” Flip Chip*
EQUIPMENT SELECTION
SUMMARY

Remember, Fluid Flow Theory

Cleaning Rate Theory
Static Rate + Dynamic Rate = Process Cleaning Rate

Types of Cleaning
Dissolution – Low energy
Erosion – High energy

Cleaner performance comes down to Solvency and Energy
EQUIPMENT SELECTION SUMMARY

Decide what is important

- Aqueous or Solvent
- Batch or Inline
- Open or Closed Loop
- Special Requirements

Life is full of choices
EQUIPMENT SELECTION SUMMARY

Research and Document

1. Equipment Spec
2. Environmental Needs
3. Cost Model
4. Qualification Protocol
5. Quality Standards

Do your homework & document findings
EQUIPMENT SELECTION SUMMARY

Shop systems that match your needs

- Production Throughput
- Solvent/Machine compatibility
- High Energy Systems
- Small foot print
- Low operating costs
- Environmental Compliance
- Employee Health Safety
EQUIPMENT SELECTION SUMMARY

Start-up Check list
- Equipment buy-off (at vendor or on site)
- Ready facility
- Train Operators & Support Staff
- Perform Environmental Checks
- Set Process Control Limits
- Establish maintenance schedule
Ask your Boss for a salary increase