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Fully Automated, Clean Manufacturing Environment For High Yield Ultra Fine Line (UFL) Production

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Abstract

- Machine Technology designed for the manufacture of Ultra Fine Line product
- Machine design provides clean production environment
- Latest State of the Art, Horizontal Wet Processing Equipment
- Intelligent Machines with high levels of automation, self cleaning
- Reliable process control and dosing systems that can maintain demanding production tolerances
- Bar-coded panels automatically adjust machines processing parameters
- Reel to Reel production for thin material
- A totally integrated production system

It's all the numerous single details which when combined, in the end, make a highly capable and effective production environment.

Cleanliness, Control and Automation in Horizontal Wet Processing Machines

Any skilled company can make samples with 1-mil lines and spaces, but to produce these circuits with high yields, requires much more.

Modern production operations adapt their whole environment starting with process equipment, including automation, materials and trained people. In order to go this one step further in technology, they set up a Totally Integrated Production System of horizontal Ultra Fine Line (UFL) wet processing machines (Figure 1).

Figure 1 - Totally Integrated Production System

Demands and features for modern UFL production lines are:

- Advanced Automation - production parameters automatically adjusted and monitored
- Advanced Automation - better yields
- Advanced Automation - faster throughput
- Advanced Automation - higher productivity

Modern Production Machines Provide Clean Room Environment

Clean Room Basics:

- A medium human hair has a diameter of more than 3 Mils.
- Line widths on UFL panels are down to 1 Mil.
- Customer's specs typically allow a track-reduction of 20% maximum, which is 5 µm.

This means that 5 Microns is the maximum allowed production tolerance on 1 Mil UFL work!

The Clean Room Class 1,000 Spec allows per cubic foot a maximum of:

- 7 particles with a size of 5,0 µm and 1000 particles with a size of 0,5 µm.

The Clean room Class 10,000 Spec allows a maximum of:

- 70 particles with a size of 5,0 µm and 10,000 particles with a size of 0,5 µm.

This is the specification for the environment in which we have to produce our circuits, if we want to achieve acceptable production yields!

Example: Clean Room Conditions in Pre Clean Lines

In order to meet these specifications, we have filters down to 1 µm in the final rinsing cascade of our lines. We connect the air input of our pre-clean line dryers to the customers clean room of the photo/mechanical coating area.

This makes sure, that we always have identical clean room conditions in the dryer and (covered) output of our pre-clean lines, as we have in the following coating room.

Clean Water

The final surface cleanness can only be as good as the quality of the cleaning water. For ultra clean panels we need ultra pure filtered water.

The dirtiest part in our production is the panel. This is being cleaned during each individual wet processing step. Therefore filters in each module are very essential (see Figure 2).

Figure 2 – Filters in each Module

Water is an important chemistry. Its cleanness, softness, PH, temperature and all parameters are extremely process relevant.

Water Cost

In Germany the drinking water costs vary from approx. 2.20 to 5.60 US$ per 1 m³ (265 Gal). This gives a prospect of major savings.

To waste a flow of only 1 m³ (265 Gal) per hour would cost a company 20,000 to 50,000 US$ per year.

The cost for every additional cascading rinse will amortize in less than ¼ of a year! Additionally, longer rinsing time considerably improves rinsing quality. It leaves more time for Ion exchange.

We achieve a much higher cleaning effect by running the water in a right-to--left overflow manner (Figures 3 through 6).

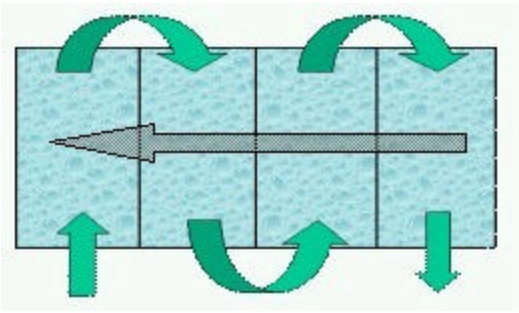


Figure 3 – Right – Left Overflow Manner

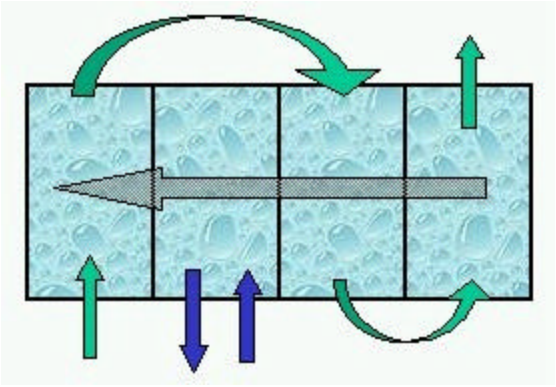


Figure 4 - Separated Chemical Process Section For Detarnish, And Surface Conditioning

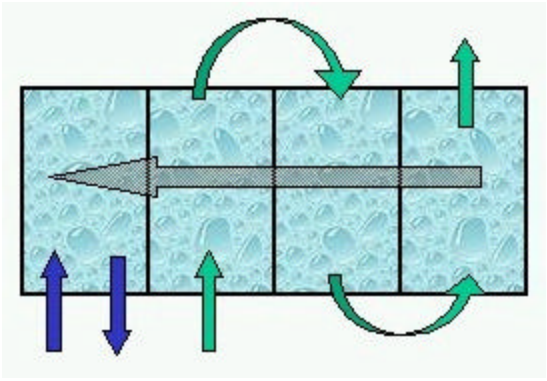


Figure 5 - Separated DI- Water Rinse Last (Final) Rinse

Separated Concentrate rinse. First rinse after chemical process for extra waste treatment.

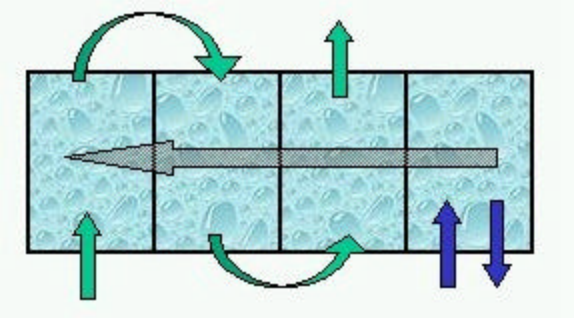


Figure 6 - Separated Concentrate rinse - First Rinse after Chemical Process for Extra Waste Treatment

Cascading Rinse

Cascading Rinses can be Equipped with: (Figure 7)

- Spray bars for surface processes
- Example: Etching developing stripping etc.
- Tsunamis for hole cleaning
- Example: Replenisher, Plating processes etc.
- Typhoons for hole cleaning with air injection
  Example: Solder Mask, SES lines etc.
- Ultra sonic for high micro-flow-activation

- Example: Particle loosening and removal etc.
- Hi-pressure (Hammer)-Rinses for surface and hole
- Example: Deburr, High power cleaning processes

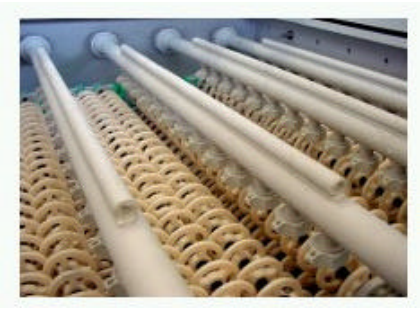


Figure 7 - Cascading Rinse with Spray Bars
Example: Micro etch developing stripping

Cascading Rinse with Tsunamis Holes (see Figure 8).

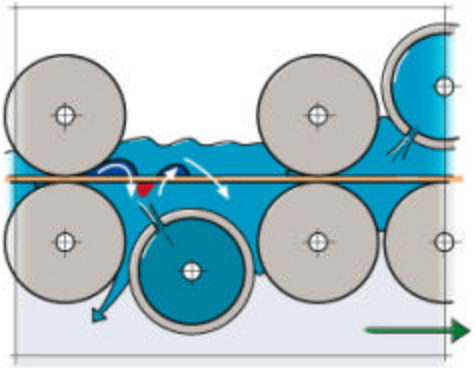


Figure 7 - Rollers Build a Trap and Make the Fluid Go Up and Down (Push – Pull) Through the Holes

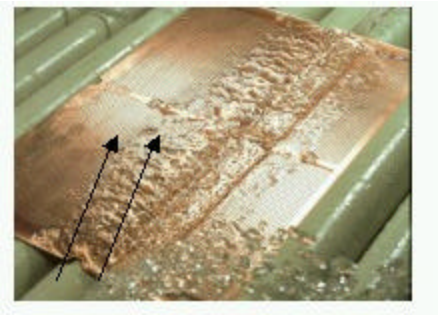


Figure 8 – Strong Push-Pull Action

Tsunamis for hole cleaning, minimize drag out.
Example: Replenisher, Plating processes.

Cascading Rinse with Typhoons
Typhoons for strong hole cleaning with air injection. (see Figures 9 and 10).

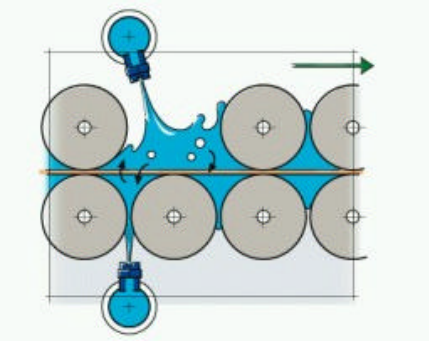


Figure 9 – Cleaning with Air Injection

Figure 10 - SES Lines Including Tin Stripper, Solder Mask

Cascading Rinses with High Pressure
High Pressure (Hammer)-Rinse
For surface and intensive powerful hole cleaning as seen in Figure 11.

Example:
Panel: A:R ≅ 20:1
Hole size ≅ 10 mil

Pump Features:
Pressure: 600 psi,
Flow rate: 20 gpm,
Pulsing beam

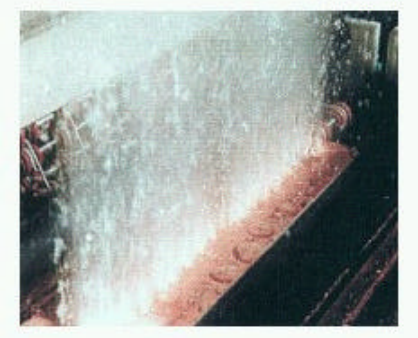
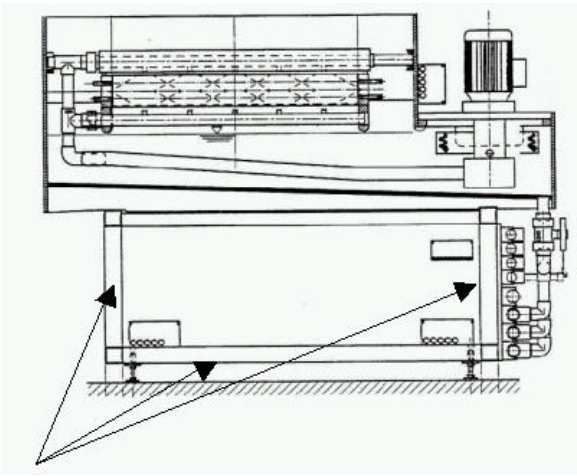


Figure 11 - Perfect Rinse for Hole Cleaning Prior to Desmearing and PTH

Basic Module Design for Clean Room Production
Production machines can be well closed up and fulfill clean room specifications. They need to be easily accessible (double Glass Lids from top).



Sturdy frame / closed module body
Carries fixture for tubing
Equipped with good direct filtration
Non degrading Materials
Easy to clean,

Figure 12 – Production Machine

Clean Room Feature: Central Tubing
Fixture for tubing attached to base- frame of module. Nothing fixed to floor (Figure 13).

Figure 13 – Base Frame of Module

Rear side of machine can be hosed down and spray cleaned easily underneath tubing and module

Smooth Conveyor for UFL
Mechanically rounded, polished roller surface for delicate UFL surface and rollers staggered to prevent shielding, color coded. (Figures 14 and 15).

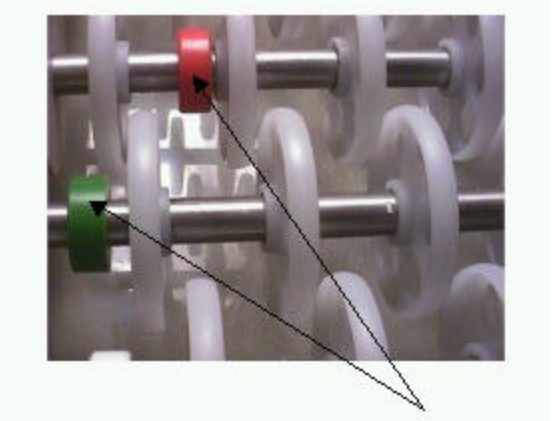


Figure 14 – Roller Surface

Figure 15 - Rollers staggered

Soft rollers for liquid coating and non-degrading, non-abrasive heavy duty materials for bearings. Sturdy smooth conveyor drive (Figures 16 and 17).

Figure 16 – Soft Rollers

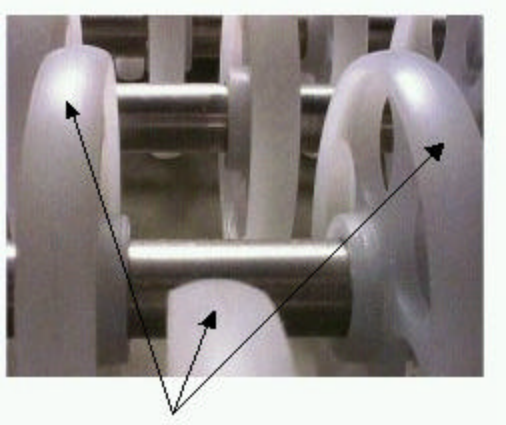


Figure 17 – Non-Degrading, Non-Abrasive Heavy duty Materials

Easy Access makes Clean Machines
Pumps which can be plugged allow for quick and easy replacement. Machine sumps not on the bottom, but on a solid ~2 feet high frame for better access and easy maintenance (Figure 18).

Figure 18 – Pumps Which Can Be Plugged for Quick and Easy Replacement

Process Control and Dosing Systems
Reliable precise control and dosing systems provide tight process tolerances.

For UFL product, much smaller production windows have to be maintained.

The full performance of an integrated production system can only be achieved, by minimizing all individual process control and dosing tolerances (Figure 19).

Figure 19 - Conductivity Control/Flow Meter with min/max Alarm

All machine parameters like temperatures, pH, SG, RED-OX, Conductivity etc. of process chemicals as well as rinse water quality are fully controlled and monitored. If any parameter like the flow rate of a spray bar is getting out of tolerance (clogged nozzle), the machine will give an alarm.

The previous times, when operators had to watch the machine functions, are over. Operators today are responsible for more than one production line. They have to take care of the finished product.

The machine has to notify the operator if any parameter is getting out of tolerance or the operating limits (Figure 20).

Flow control

Figure 20 - Laser Sensor for Precise Panel Width Determination

Flow controls and automatic flow rate adjustment must be set according to panel thickness and hole size. Pump invertors adjust the pumps and hold the proper specified flow rate on desmear and PTH lines.

Different Process and Production Steps

- Integrated line details
- UFL machine technology
- Monitoring and dosing parameters
- Process control devices

Pre-clean for Micro - Etch
Pre-clean lines are prior to Coating. An extremely clean surface is needed for liquid resist coating.

Fine Filtration, is essential. Liquid resist is only a few Microns thick. For the rinsing water in the final cascading rinse 1 µm Filtration is being used (Figures 21 and 22).

Figure 21 - For Best Surface Uniformity We Use High Speed Oscillation

Figure 22 - Double Glass Lids are Used for Security and Cleanness

The air input of the dryer will be connected to the clean air supply of the coating room.

The panel, which comes through the pre-clean line and into the coating room, goes through a 1µm filtration of the final rinsing cascade. The following dryer automatically, and at no cost, has the same air conditions as the following coating area.

High Resolution Exposure Machines
A high level of UFL exposure quality is being achieved with fully automated lines. These lines have high precision alignment and a rotating parabolic reflectors for parallel light. (see Figures 23 and 24).

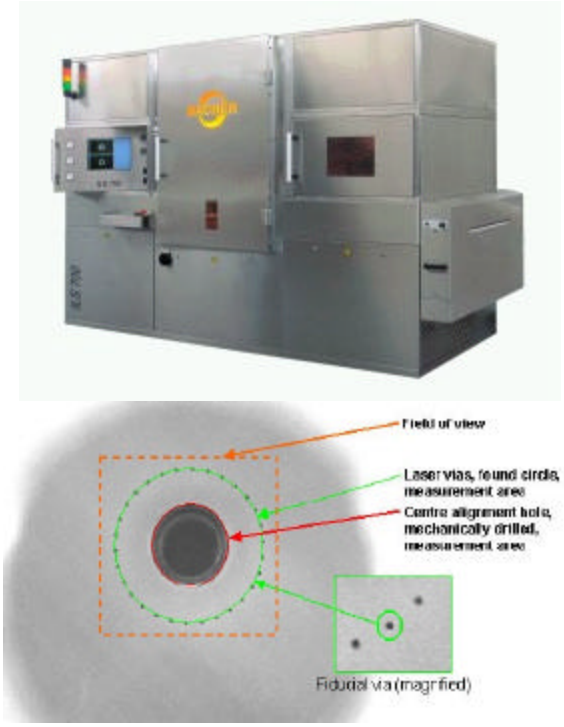


Figure 23 – Machine with High Precision Alignment

Figure 24 – Rotating Parabolic Reflector

The entire unit has to be temperature controlled within a few degrees, in order to hold tight tolerances. These closed systems are water-cooled and use HEPA fine filtration for extreme cleanness (Figure 25).

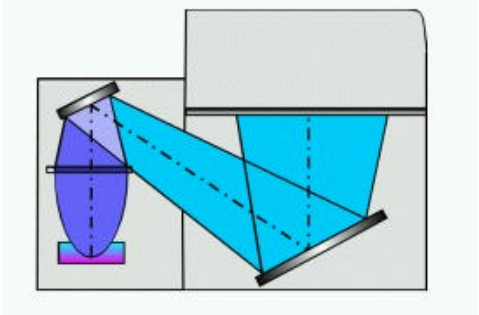


Figure 25 - Cold Light Schematic

Photo Resist Developers
They need fine filtration (10 µm), and the proper impact in order to maintain highest uniformity and resolution including side walls (Figures 26through 28).

Figure 26 - Hi pressure Pumps and Filters for High Resolution - Hi Speed Oscillation

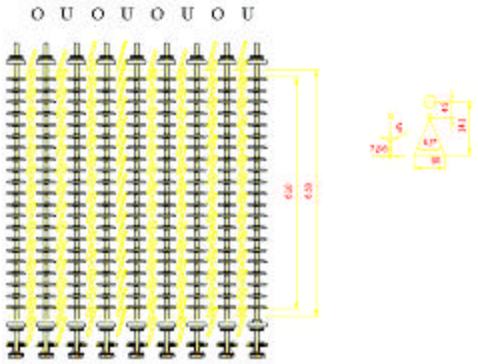


Figure 27 - Spray Between Conveyor Rollers - Slim (45°) Spray Angle - High Impact for Straight Side Walls

Figure 28 - SEM Lines 40 µm - Very Straight Sidewalls

UFL Etchers
The UFL- Etcher spray pattern is similar to the one of a developer. The difference between these etchers is, that they have to compensate for uneven copper thickness as well as etching effects. Therefore etchers have to be able to control, adjust and vary flow rates of the individual spray bars in working (X) direction and cross working (Y) direction (Figure 29).

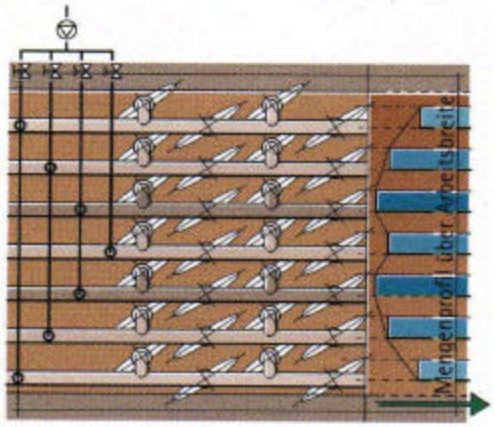


Figure 29 - Flow Control and Adjustment of Individual Spray Bars in Working Direction

An enhancer module at the end of the etcher chambers with spray bars cross working direction can compensate the copper thickness in Y-direction (leading and trailing edge) (see Figure 30).

The etcher has flow sensors and motor adjustment valves for each individual spray bar. These etchers can run different programs with fixed, low flow rates. If a spray nozzle gets clogged, the etcher will indicate it and give an alarm.

The etchant is controlled within very tight chemistry tolerances and temperatures (± 1°F).

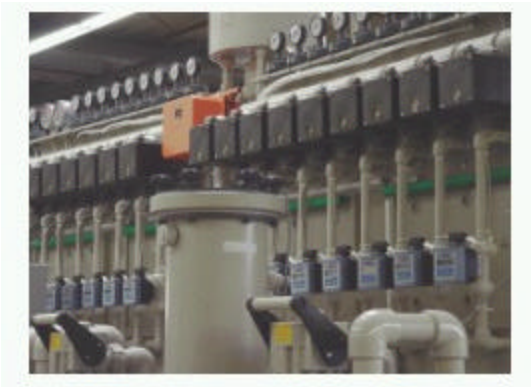
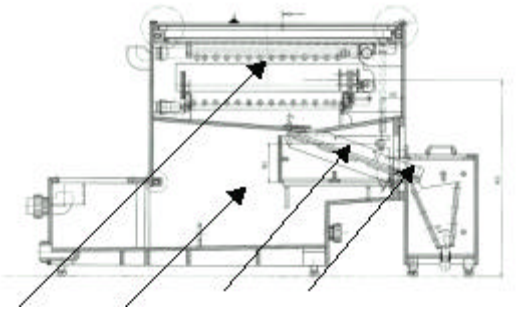


Figure 30 - Enhancer Module

Resist Stripping Technology Including Filtration
UFL Stripping has to be very effective and reliable. The resist filtration has to be perfect. The separation between stripper spray area and the sump has to be 100% (Figure 31).



Spray area / Sump / Filtration / Resist Sludge

Figure 31 – Separation between Stripper S pray area and Sump Has to be 100%

Black Oxide / ~Replacement

Figure 32 - Extremely Clean Surface Required, Very Fine Filtration and Very High Rinse Water Quality

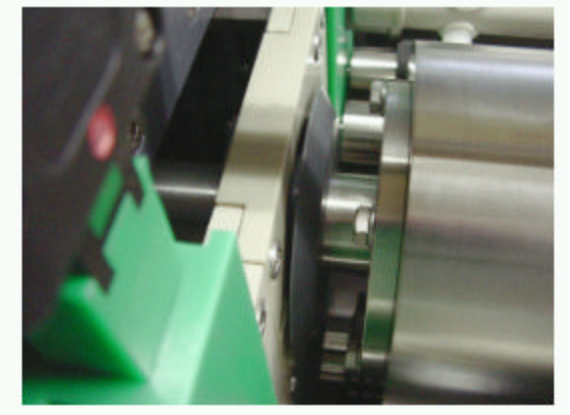


Figure 33 - Brush, Deburr, Nodule Removal

For Precision deburring and similar brushing processes, machines with massive construction such that they are vibration- free, are needed.

They have beltless, direct drive and can be universally used for all types of brushes.

Horizontal Desmear / Electroless Copper

The big advantages from horizontal machines are:

- Direct filtration – High cleanness
- Small sumps, frequent replenishment
- Perfectly controlled flow rates
- Forced Flow elements for smallest holes and vias. (See Figure 34)
-

Figure 34 – Horizontal Machine

Flow rates can be nearly perfectly adjusted in an automatic manner, monitored, repeated and saved in different programs, for the various panels (Figures 35 through 37).

Figure 35 - Low Flow

Figure 36 - Medium Flow

Figure 37 - High Flow

Figure 38 - 2 Fully Integrated Lines: Deburr / Desmear / Electroless

Horizontal – Electro Plating

Horizontal Plating System with: (Figure 40)

- Ultra high flow rates for high aspectratio (A/R)
- Fine filtration
- Insoluble Anodes and Pulse Plating

Figure 39 – Horizontal Plating System

Extremely high and fully controlled flow rate is possible. Also, the contact system is very reliable and uncomplicated.

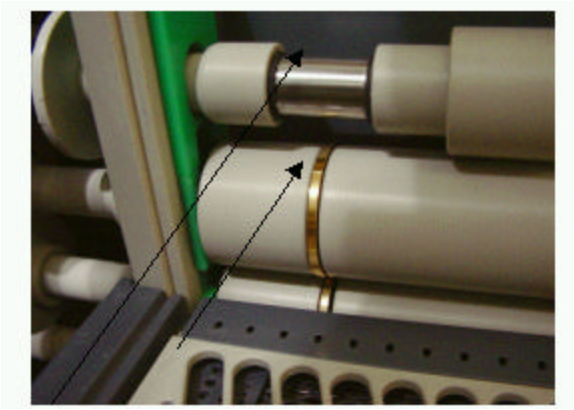


Figure 40 - Insoluble Anodes with Fluid Guide Elements

(Deplate / Gold plated Contact Ring top and bottom)

Automatic Handling

- **For optimized production flow and maximum output:**
  - **Handling units have to be reliable and precise;**
  - **Integrated lines need to have buffers; and**
  - **Automated batch change must be present.**

Figure 41 - Advanced Technology with Integrated Control and Automation Improves

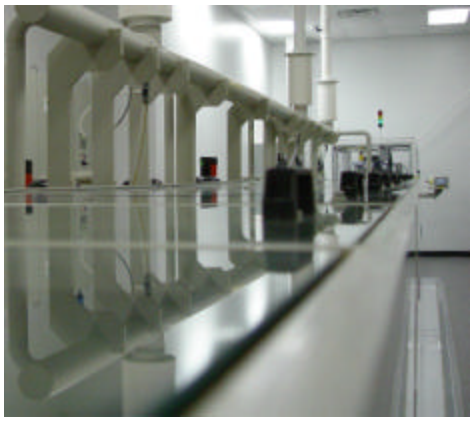


Figure 42 - Uniformity, Cleanness