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SUMMARY OF SUBSTRATE CLEANING OVERVIEW

Cleaning methods

There are a variety of methods available for cleaning webs and sheets. We will not discuss aqueous ultrasonic, mega sonic or CO2 cleaning systems since these are batch systems.

Cleaning methods range from hand powered rags to sophisticated systems capable of cleaning to the micron level.

Air knives
Fixed brushes, with or without vacuum
Rotating brushes
Semi-contact rotating buffs
Vacuum only
Pressure and vacuum
Pneumatic ultrasonic and vacuum
“Tacky” rolls

Note that any of these cleaning methods will have advantages and disadvantages depending on the results that are desired, and of course, the budget available to achieve these results.

How clean do you want to get it?

The most difficult question to answer is “how clean do you want the substrate to be.” For one application, “as clean as possible” may mean removing particulate matter no smaller than 10 mills (250 microns). In another application, this particle size may represent a boulder, especially for food and pharmaceutical packaging or in the manufacturing of video displays.

For perspective, a 40 to 50 micron (2 mills) particle is at the lower end of the visible scale.

The table below provides some typical applications, and the particle sizes to be removed. Note that this is a general summary, and your specific requirements will be different. Nothing is carved in stone.

Remember that all of these cleaning systems will “clean.” You must determine which one best meets your requirements and budget.

How clean can you get it?

For in-line process cleaning, 3 microns is about the smallest particle that can be consistently and efficiently removed. And this is extremely process dependent. By efficient removal, we mean at least 99% the particular particle size.

Some tacky roll cleaning systems do claim to remove 1 micron particles, and there is no reason to dispute this. But in general it is very difficult to achieve these levels and it requires very expensive equipment to verify this level of removal.

The typical “proof of the pudding” is the effect of cleaning determined at the critical down stream process point.

Decreased reject rates due to contamination

No more voids in the bar codes

No more “tents” in the coating

No visible particles in the potato chip bag

Here are some typical particle removable goals. This is only a guide and please do not consider it to be the final word. Your application will determine the requirements.

TYPICAL APPLICATION	MATERIAL	PARTICLE SIZE
REMOVE SLITTER DUST	PAPER/LABELS FILM	> 40 MICRONS > 25 TO 40 MICRONS
PRE COATING	PAPER/LABELS FILM MEDICAL	> THAN 40 MICRONS > 5 TO 20 MICRONS > 10 TO 25 MICRONS
PRINTING	PAPER/LABELS FLEXIBLE PACKAGING	> THAN 40 MICRONS > 25 TO 40 MICRONS
DISPLAYS	GLASS FILMS	< 3 MICRONS OR SMALLER

Remember that no cleaning system can remove 100% of all particles of all sizes. There are a multiple of variables that prevent us from achieving this

state of cleaning Nirvana.

Detriments to effective cleaning

Static attraction:

Static attraction forces between the particles to be removed and the substrate can be very high. Such an attraction will prevent any cleaning system from removing these particles. For this reason, we recommend that static be reduced to less than 100 volts prior to cleaning. In some critical applications, such as displays and very thin coatings, the static must be reduced to even lower levels, in the low double digits. There are a variety of static control systems available that can easily meet these requirements.

Boundary layer

When air moves across a surface, such as a high-speed web, a boundary layer is formed. This layer can build to substantial thickness, trapping and carrying particles with a diameter less than the boundary layer thickness. A web moving at 1500 ft/min, for example, can form a layer thicker than 1 inch, allowing even large particles to remain trapped. These trapped particles are then very difficult to remove.

Impressed & embedded particles

Impressed or imbedded particles, “squished” is the technical term, are very difficult to remove with any cleaning system. The energy required to remove these is extremely high and not available with any of the non contact systems we are discussing here. The most difficult “particles” we have been asked to remove were insects on a PET film, post nip roll! Partially imbedded particles or the short fibers from recycled paper or board are removable with the proper cleaning system, typically one of the contacts.

Particle density

As previously mentioned, no cleaning system will remove 100% of all particles of all sizes. For example, assume you have a particle density of 100,000 per square foot, not unreasonable for some dirty recycled board. A 99.9% efficient cleaning system will still not remove 100 particles. In some cases, dual pass cleaning or multiple different systems may be required.

Pros and cons of various cleaning systems

Most cleaning systems do an effective job of particle removal. However, the sizes they are capable of removal does vary greatly.

SYSTEM	PRO	CON
Air Knife	Inexpensive	Removes gross particles only
Fixed Brush	Low cost	Damage/Recontamination
Rotating Brush	Moderate cost	Damage/40 micron and larger

Rotating Buff	No damage/moderate cost	40 micron and larger
Tacky Roll	1 – 3 Micron removal	Not many/Recontamination?
Simple Vacuum	Low Cost	40 micron and larger only
High Velocity Vacuum	30 Micron removal/Low cost	Not many
Pressure and Vacuum	Moderate cost	20 micron and larger
Ultrasonic and vacuum	3 micron or smaller removal	Higher Cost

Fixed and rotating brush cleaners

Fixed and rotating brush cleaners will break through the boundary layer by the fact that they are in contact with the web. However, because they are in physical contact with the web, the risk of substrate scratching or damage is high. If the system does not incorporate sufficient vacuum to quickly and efficiently remove particles, then there is the additional problem of recontamination. This is most likely with fixed brush systems. Both of these cleaners are also susceptible to trapping partially dried coatings and increasing the probability of substrate scratching.

Rotating buff cleaners

An alternative to fixed and rotating brush systems is a “kissing contact” rotating buff cleaner. Instead of utilizing physical contact with the substrate and depending on coarse or stiff brushes, this system utilizes a combination of high velocity airflow and ultra-soft cotton buffs rotating at high speeds.
High-speed rotating buffs generate strong air currents that remove the particles. The buff is manufactured in a series of special cotton discs, which are raked to form a series of soft “fingers.” Because of the high rotational speed, only the end of the fingers contacts the substrate.
A vacuum carries the dirt, dust and other contaminates away into a dust collector. This cleaning is accomplished without any damage to the substrate. A built in beater bar continuously cleans the buff to prevent recontamination of the substrate.
This system will remove partially imbedded and impressed particles, especially the short fibers so common in recycled board or paper.

Vacuum Systems

For non-contact cleaners, the only way to effectively remove smaller particles is to utilize some method to disrupt or penetrate the boundary layer. Typical low flow, low vacuum systems do a poor job, and thus cannot accomplish this.
A unique aerodynamic nozzle accelerates the vacuum air to 300 plus mph. This high velocity air partially disrupts the boundary layer and lifts particles off the web surface.
Mounting the cleaning head on a back up roll maintains consistent substrate gap and insures repeatable cleaning results. Unlike many other systems, this mounting does not induce any web flutter and hence possible substrate damage.

Dual Ultrasonic

To remove fine particles, in the 5 to 10 micron range, more energy or agitation is required. The dual ultrasonic nozzles of the Ultra Cleaner superimpose high frequency pulses over a high pressure, high velocity flow to impart very high energy levels to the substrate. These pulses knock the trapped particles out of the boundary layer so the vacuum can remove them without any damage to the substrate.

Cleaning Systems and their effects on the clean room environment

There are special considerations when utilizing cleaning systems in a clean room:

Airflow disruption

Heat generation; on substrate and the environment

Noise

Physical room

Other? Specific to process

Let's examine some of the previously mentioned systems and how they may affect the clean room environment. Note that it is always possible to utilize systems that are not appropriate for use inside the clean room, prior to entry into the room. For example, initial cleaning with a brush system, fixed or rotating, may be performed prior to the substrate transfer into the clean room. Or the systems may be isolated inside the room to prevent flow disruptions or particle generation.
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Tacky Roll: Minimum effect. Basic "bolt on"

Simple Vacuum: Requires additional plumbing to recirculate air back to room. External blower mounting required.

High Velocity Vacuum: Requires additional plumbing to recirculate air back to room. External blower mounting required.

Pressure and Vacuum: Noise suppression may be required. External blower mounting may be required. Possible heat generation on substrate and environment.

Ultrasonic and vacuum: Noise suppression required. Intercooler for heat suppression may be required. External blower mounting usually required.

How do I pick one?

- Make an honest assessment of your cleaning requirements.
  - Define your "clean as possible."
  - Please don't ask for cleaning to 1 micron in your class 10,000 clean room.
  - Try to determine the type of particles to remove. Optical analysis, "tape pulls".
- Consider your substrate and process limitations:
  - Heat sensitivity

  - Surface sensitivity
  - Surface temperatures at proposed cleaning points
  - Web tension
- Determine your cost/cleaning criteria.
  - Do you really want to pay the extra premium to clean those extra 10 microns?
- “Try before you buy”
  - Most companies have test facilities, evaluation units or other methods to help you determine their systems’ capabilities for your requirements.