Web Cleaning: How Process Parameters Impact Cleaner Selection

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Keywords: web cleaning, dust removal, print quality, contact cleaning, remove contamination

Abstract

With increased usage of recycled materials and "less than clean" substrates, converters and packagers find an increase in defects, and process downtime, due to dirt and contamination. There are numerous solutions for dealing with this contamination, all with varying degrees of success. The converting and packaging industry, as a whole, has very little quantifiable data to determine success with regard to cleaning. The general consensus is that if the customer does not complain, then the product is clean enough. Manufacturer's measure success based on the number of customer complaints versus actual metrics of particle counts and print defects.

Customers generally view all web cleaning methods as equally effective, but this is not reality. In this paper we will explore different types of web cleaners, the best application for each type and selection criteria for choosing the best solution for a given set of parameters.

Parameters
Industry of Use
Web Substrate Makeup
Size of Contamination
Amount of Contamination
Width of Web
Speed of Web
Web Tension
Total Cost of Ownership

Web Cleaning Methods
Tack Cloth
Non-Contact Vacuum
Contact Vacuum
Rotary/Moving Brush
Contact Cleaning (Tape)
Contact Cleaning (Traversing Wash)

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General web cleaning concepts have changed very little in the last 30 years. However, the design, selection and implementation practices based on process specifications and experience has furthered the effectiveness of web cleaning.

Introduction

Customers looking for web cleaning options generally view all web cleaning methods as equally effective. However, this is not the case. The most appropriate solution for your web cleaning application is dependent on a variety of factors. Polymag® Tek recommends a four step approach to determining the best web cleaner for your process.

1. ***Know your process contamination standards based on the industry***
2. ***Identify variables and operating parameters that impact cleaner selection***
3. ***Analyze the parameters versus the operational principles; identify advantages and disadvantages of known cleaning technology***
4. ***Analyze the total cost of ownership***

The goal of this paper is to outline the process and criteria to select the best cleaning technology for a particular process.

Selection Procedure

Know your process contamination standards

Throughout much of the industry, there is little or no standard for web contamination. The general consensus is that the web must be clean enough to not adversely effect any follow-up operations or final usage. Certain industries tend to have more stringent quality requirements with quantifiable standards (medical, food, pharmaceutical, electronics, aerospace). Ask yourself, "Why Web Cleaning?"

- Is web cleaning necessary on your product lines?
- Does the customer or product specification require web cleaning? Is it required to keep equipment clean from substrate contamination to minimize downtime, waste, maintenance and operational cost?
- What contamination needs to be removed? What is the particle size?

Identify variables and operating parameters that impact cleaner selection

There are many sources of contamination within a process, including Air (Atmospheric), Substrates, Equipment and People. Different processes also create contamination. Processes like slitting, shearing, die cutting and stamping, along with general debris created from conveyance, can all create contamination. Before selecting a web cleaner, consider the following variables:

- Type of converting process
- Sources of contamination and their relative location in the process
- Substrate composition, sensitivity, thickness and width
- Web speed and tension
- Is the process continual with flying splices, or intermittent
- Dimensions of idlers and machine frame (space available)
- Cleanroom, solvent, or aqueous environment

Industry of Use–

Different industries have different standards for cleanliness of substrates. For example, if you are printing cereal boxes, your standards may be less stringent than if you are producing medical packaging. Each industry has tribal knowledge for expected levels of cleanliness, but there is little recorded in the form of quantifiable standards. Perhaps the most well recorded standard is ISO 14644 Part 9: Classification of surface cleanliness by particle concentration.[1](ISO,2012) This standard is applicable to cleanrooms, but is somewhat translatable to surfaces or substrates produced in cleanrooms. This standard specifies levels of cleanliness based on particle size and count within an area. For optical films, semiconductors or medical products, manufacturers may take aim at quantifying desired results using the ISO 14644 chart for particles between 1um and 5 um. For the packaging industry, the general policy is that in order to prevent contamination of product, protective wrappings shall be as clean or cleaner than the cleanliness of the product it is being used to protect.

There are also regulations involving the materials that are used to manufacture the web cleaner itself. These regulations can impact the design considerations and price of the web cleaner. For instance, if a web cleaner is being used in a clean room, the metal framework may need to be constructed from stainless steel or anodized aluminum to prevent surface shedding.[2](Gyork, 2000) If a web cleaner is being used in a Hazardous environment, like C1D1, all sensors and switches must be intrinsically safe and the Controls Enclosure must be located in a general-purpose area.

As you can imagine, there is a lot of variation in the expectations. Because of the variation,
this is where one typically starts when determining the best web cleaner for the process.

Web Substrate Makeup–

The composition of the substrate is important in selection of the proper cleaning method. The main types of substrates Polymag® Tek is asked to clean are Papers and Films. What is good for one substrate may not be good for another.

Virgin Paper/Paperboard coated or uncoated– Virgin paperboard is generally cleaner than recycled paperboard. The substrate is still viewed as a high contamination substrate. The main contamination is dust from the slit edge and storage of the master rolls. In most Virgin Paperboard applications, Polymag® Tek recommends a contact web cleaner with either a high capacity, large OD adhesive tape roll for collection of the contaminants, or a Traversing Wash Web Cleaner that utilizes a robotic cleaning head to continuously clean the contact cleaning rolls. Tack cloth, Vacuums, or brushes may be effective depending on speeds and other process parameters.

Recycled Paper/Paperboard– Very high level of contamination from slit edge and micro-cracking of the substrate as it passes over the rollers. Recycled papers are some of the most difficult to clean because the contamination removed can often overwhelm the collection mechanism. At slow speeds, contact vacuums may work effectively. A Traversing Wash Web Cleaner is really the only cost effective option for this level of contamination.

Film- Films tend to be cleaner than papers, but the expected cleanliness is higher. PE and PET films are great candidates for standard nip contact web cleaners, non-contact cleaners may work at slower speeds and larger particle sizes.

Thin Film– Thin films are generally the most difficult substrates to clean. The relative sensitivity of the product, high-speed processing and low tensions make cleaning thin films harder than the thicker substrates. Care must be taken to avoid damaging the substrate surface or changing the properties. In very sensitive applications, utilizing an S-Wrap vs a Nip in contact cleaning may provide better results. The cleaning efficiency is reduced, but the substrate remains intact and is cleaner than before. Other methods of non-contact cleaning tend to be unsuccessful because the speeds greater than 100fpm create a boundary layer air, holding contamination to the web.[3](Polymag, 2009)

Laminated Films and Pouches– with laminated films and pouches, the contact surface of the substrate is critical. Cleaning this surface to prevent particles within the layers or pouch prevents contamination of laminates or packaged products. Single sided contact and non-contact cleaners may work in this environment. An important constraint in these processes may be the stop and go nature of many pouch lines. The cleaner must be able to endure intermittent cycle based operations. Metals and Metalized films- Metals tend to have oils deposited on the surface. This does not work well with contact polymer rolls. A brush or fabric based cleaner that can absorb oils may be a better solution. Metalized Films are similar to thin films. Care must be taken to not damage the substrate surface. Contact and non-contact cleaning can work in most scenarios.

Foam– Many foams can be cleaned with Adhesive Tape placed directly against the substrate. The amount of contamination removed depends on if the surface cells are open or closed cell. Otherwise, vacuums or contact cleaning is an option.

Nonwovens– The surface of nonwovens can be porous and contamination may reside in these pours. Contamination levels tend to be higher. Any method for cleaning needs to be able to overcome the textured nature of the product to remove particles without overwhelming the collection system.

Size of contamination particles–

The nature of what you are trying to remove plays an important role in the selection of a web cleaner. "The thin film of air attached to all moving webs is known as boundary layer air. Small particles (<50um) on the web surface are trapped in this air layer. High velocity air knives and ultra-sonic devices can be used to remove this layer of air at low web speeds (<100fpm). For small particles at higher web speeds, non-contact methods of web cleaning are not effective."[4](Polymag, 2009) Particle size determines the type of cleaner that is best for the process. For instance if your particle size is greater than 40um, a non-contact or contact system may be effective. However, if the particle size is less than 3um, contact cleaning has been shown to be the only effective method.

Typical Application	Material	Particle Size
Remove Slitter Dust	Paper/Labels Film	>40 µm 25 µm to 40 µm
Pre-coating	Paper/Labels Film Medical	>40 µm 5 µm to 20 µm 10 µm to 25 µm
Printing	Paper/Labels Film/Flexible Packaging	>40 µm 25 µm to 40 µm
Optical Films	Glass Film	<3 µm <3 µm

Table 1: *Removal Target Particle Size[5](Zuments, 2015)*

"The ultimate goal of the cleaning procedure is to remove all particles prior to the contamination sensitive production process. The requirements can vary between particle sizes of bigger than 50 micron for the printing and packaging applications down to particle sizes of less than 2 microns for the film, foil or clean room applications. Unfortunately is it not economical to develop a system that meets all requirements. A label printer will not invest in a non-contact cleaning system, which can clean down to 2 micron in particle size. The return of investment cannot be justified comparing the cost/necessity for this sophisticated technology."[6](Hildebrand, 2017)

Amount of Contamination–
The amount of contamination plays a significant roll in the selection of the appropriate web cleaner. This is particularly important when exploring the particle collection method. Simple web cleaning devices, like Tack Cloth, will accumulate the contamination on the surface of the cloth. This surface can quickly become overwhelmed if the contamination level is high, leading to more frequent change out and missed particles. Contact Cleaners with adhesive tape can become quickly saturated if the substrate is very dirty as well. Additionally, the concentration of particles in one area, like the edges of the substrate, can overload the collection device and lead to higher consumable costs and ineffective cleaning. There are some available countermeasures to mitigate this as well as web cleaners that are made to address this problem. In some cases, customers choose to employ oscillation or a multi-layered approach to web cleaning that integrates non- contact and contact systems together to increase efficiency. Continuous web cleaners also exist. These cleaners allow the operator to change out or refresh the consumable while the press is in operation, preventing the need for shutdown.

Substrate Width–
Web cleaning is needed for a large variety of applications, from narrow web label printing to large format, wide web film lines. For narrow web applications, the substrate width has minimal impact on selection. The cleaner should be sized slightly larger than the substrate in order to account for increased debris on the edge of the product. Polymag® Tek typically matches the cleaner size to the size of the idler roll on the press.

For wide web applications, many times the limiting factor for web cleaner selection is the size of resources. For instance, if you have a 120” wide web, it may be difficult to find a single vacuum system motor that can maintain the airflow across that distance, that isn’t a jet engine. Conversely, when using a contact web cleaner, the wider the system, the larger the brush or cleaning roller OD becomes in order to combat deflection of the roll and maintain consistent contact with the web surface. This may create a problem with available space for the cleaner. And of course, as size increases, so does price.

Consumable size also plays a roll in system selection. Adhesive tape for contact systems generally come in lengths less than 60”. This requires multiple offset rolls to span the width, or in some instances, a traversing tape head.

Processing Speed–
The speed of the moving web impacts the effectiveness of the different web cleaning methods. As discussed earlier, the boundary layer air needs to be broken in order to successfully remove the particles. Particles smaller than the thickness of the laminar flow boundary layer stay on the surface of the web as it moves. Moving webs exhibit this boundary layer air at speeds as slow as 60ft/min. Web cleaning

companies have various methods to disrupt the boundary layer air. Contact cleaning companies utilize a nip with two rollers to squeeze the boundary layer. Many non-contact companies use high velocity air knives or rotating brushes to disrupt the boundary layer of air. There are some drawbacks to each method.

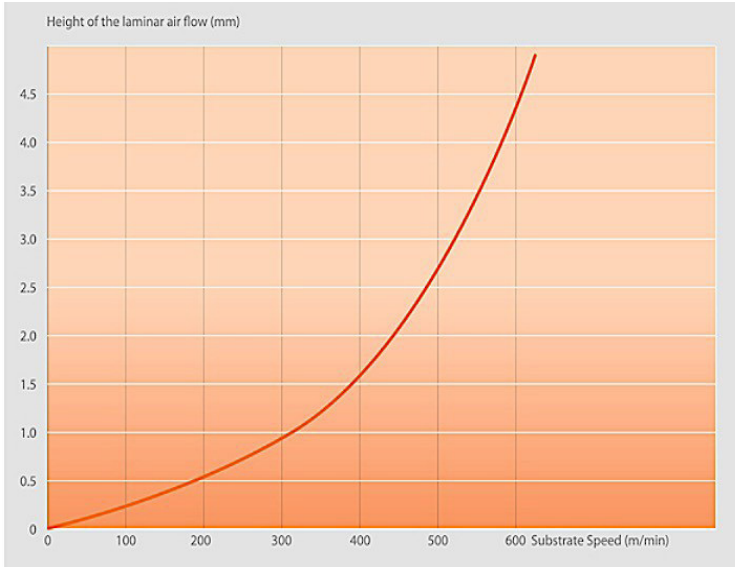

Table 2: *Height of laminar air flow with respect to substrate speed[7] (Hildebrand, 2017)*

One drawback for vacuum systems is as Hildebrand Technology states, "Dust removal systems, which are working with a geometrically simple slot in a vacuum tube are very inefficient as soon as higher web speeds are reached. This small vacuum force cannot break the boundary layer."[8] (Hildebrand, 2017) Additionally, non-contact devices designed to break through the boundary layer need to be within 1mm of the web surface.[9] (Meech, 2016) This can cause problems if web tensions are lower or if there is web flutter.

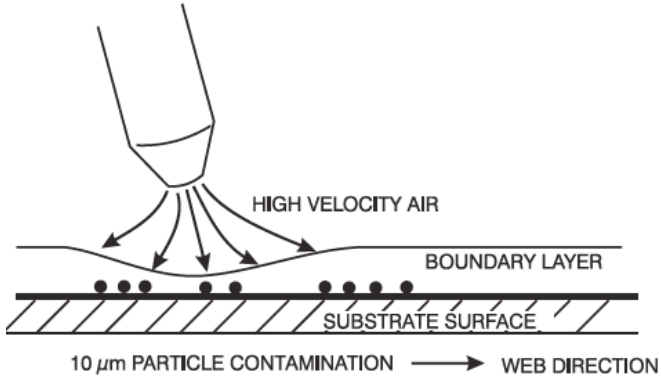

Figure 9. *TVI conformity between TVI method (left) and device link method (right) (Courtesy Andrew R. Gutracker, clean room consultant)[10] (Polymag, 2009)*

For contact cleaning, when speeds are higher than 800 feet/min the contact rolls may need to be driven and with a web speed match feature to prevent web conveyance issues.

Tension–

Tension impacts cleaning efficiency in coordination with the speed of the web, particularly with contact web cleaning. There are multiple configurations of contact cleaning. End users that implement contact cleaning in a S-Wrap or Turret configuration need to maintain high web tensions to ensure consistent contact with the cleaning roller. Even with high-tension levels, unless the cleaner is forming a nip, there is a tendency for the boundary layer air to cause the web to float on the surface of the cleaning roller. This reduces the contact area, and thus the cleaning efficiency. A nip style arrangement squeezes out the boundary layer air so the cleaning efficiency is not reduced at higher speeds.[11] (Polymag, 2009)

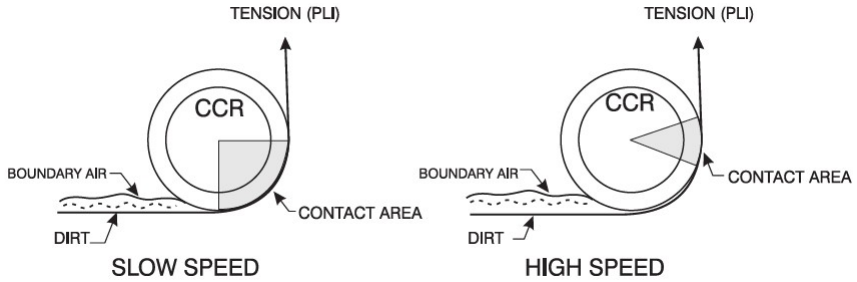

Figure 2: *Contact area with respect to speed*

The amount of air trapped between the web and the roller can be calculated based on the process parameters. In general terms, as tension increases, air gap decreases. Also, as web speed increases, air gap increases. Calculators for this air gap are available online[12](Abbott, 2017).

Some substrates operate at such low tensions that conveyance is compromised by a nip and cause wrinkles. Based on empirical testing at Polymag® Tek, pull tests revealed that a gravity nip configuration web cleaner creates less than 0.04 pli web tension loss. Although this is very low, some sensitive substrates cannot handle the tension loss. Under these circumstances, an S-wrap configuration is preferred even though the efficiency is reduced by 30-40% for 10um sized particle removal.[13](Polymag, 2009) This configuration can handle thin, sensitive, low-tension substrates at fast speeds.

Analyze the parameters versus the operational principles; identify advantages and disadvantages of known cleaning technology

Once you have determined the quality standards, the source of the contamination, and the process parameters, you can compare web-cleaning methods to find the right fit for your process.

When comparing methods, it is important to consider what holds dirt and contamination on a moving web.

1. **Tack cloth**– a rudimentary web cleaning method where a cloth with an applied adhesive contacts the surface of the web. Tack Cloth is very cost effective if you have a narrow web, "stop and go" process that does not have strict quality standards. This is generally only used for single side cleaning. Disadvantages are that the cloth cannot capture small particles and may break apart, adding more contamination to the process. The process relies on operators to identify when the cloth is saturated and change if needed. Tack cloth should not be used on thin substrates or substrates sensitive to contact.

Parameter	Notes/ Usage
Industry of Use	Industries without strict quality standards, converting
Substrate	Papers, non-sensitive films.
Particle Size	Large, Greater than 50um
Particle Amount	Particles can quickly saturate the surface, so lower levels of contamination preferred
Web Width	Narrow web; generally hard to make a wide web tack cloth apparatus with consistent contact
Web Speed	Slow; even at 200fpm, webs cut into cloth creating more debris
Web Tension	Higher tension works better
Total Cost of Ownership	Very low. Cost is approximately $0.66/SF, but if you use new cloth every changeover, you might spend $5-$10/Day

2. **Non-Contact Vacuum Systems** are an effective non-contact web cleaning method best utilized on large particle contamination at slow speeds. The disadvantage to non-contact vacuums is the inability to break through the boundary layer of air. Claims of being highly effective on particles > 20 microns with speeds up to 100mm/sec (20fpm).[14] Some systems claim to break through the boundary layer of air by using air knives or high speed rotating brushes that come close to web surface, but do not contact it. In theory this may work, but tight tolerances on position require little to no web flutter.

Parameter	Notes/ Usage
Industry of Use	Almost all. Does not work well in removing particles less than 40um, so medical and optical films may not be the best fit.
Substrate	Papers, Films, Foams, good for sensitive substrates
Particle Size	Large, Greater than 40um ideally
Particle Amount	Vacuums work well with large concentrations of contamination as long as the particle size is large enough and the speed is slow.
Web Width	Up to 10 meter width
Web Speed	Speeds up to 2500m/min but may see particles carried past by boundary layer air. Less than 20m/min is ideal.
Web Tension	No tension loss. High tension better to reduce web flutter to keep web at consistent distance from vacuum
Total Cost of Ownership	Low to Moderate initial investment, filter and collection consumables and electricity

3. **Contact Vacuum Systems–** a web cleaning method that utilizes brushes, static elimination and/or air knives to release particles from the surface of the substrate and then vacuum them up. Claims of being effective on particles > 2 microns with speeds up to 1600m/min (5249ft/min).[15] Brushes are often retractable for use with sensitive substrates. Contact vacuums represent a moderate investment price. A disadvantage is determining how to clean the brushes to avoid cross contamination.

Parameter	Notes/ Usage
Industry of Use	Almost all. Does not work well in removing particles less than 40um, so medical and optical films may not be the best fit.
Substrate	Papers, Films, Foams, nonwovens. Brush contacts substrate, so not great for sensitive substrates
Particle Size	Some suppliers claim down to sub micron level at speeds up to 1600m/min. Verifiable data from other suppliers indicate 92% removal of particles greater than 30um at 20ft/min
Particle Amount	Vacuums work well with large concentrations of contamination
	as long as the particle size is large enough and the speed is slow.
Web Width	Up to 10 meter width
Web Speed	Speeds up to 2500m/min but may see particles carried past by boundary layer air. Less than 20m/min is ideal.
Web Tension	No tension loss
Total Cost of Ownership	Moderate initial investment, filter and collection consumables and electricity

4. **Moving Brush Systems–** a web cleaning method that utilizes a spinning brush to remove contaminants, then collect by using a "flicker blade" and vacuum. There are also products that rotate a brush in the transverse direction to remove particles. This method can be effective in removing large particles from highly contaminated substrates. This method can also be used on irregular surfaces. Disadvantages include potential issues of removing contaminants from the brushes, causing cross contamination, high equipment and operational cost, not for use on sensitive substrates, and does not perform well on small particles.

Parameter	Notes/ Usage
Industry of Use	Automotive, Furniture, Metals, Converting
Substrate	Papers, Films, Foils, Metal Coils, Thermoformed Blanks (Sheets), 3D surfaces. Sensitive thin films may not be a good fit due to potential abrasion from brush.
Particle Size	Large, Greater than 40um ideally
Particle Amount	Brush can loosen adhered particles. Vacuums work well with large concentrations of contamination as long as the particle size is large enough and the speed is slow.
Web Width	Up to 3200mm(126in) width
Web Speed	Speeds up to 600m/min
Web Tension	Unknown
Total Cost of Ownership	High-brushes, vacuum, controls and pneumatics, filter, collection consumables and electricity

5. **Contact Cleaning–** Tape Systems- a contact web cleaning method that uses a specially formulated polymer roll (Contact Cleaning Roll) to nip the substrate between another contact cleaning roll or idler. Since the contact cleaning roll nips the surface of the substrate, it breaks through the boundary layer of air. The contact cleaning roll collects the contaminants from the web and transfers them to an adhesive tape roll with every revolution, continually cleaning the roll. Single "nip" configurations remove 96.9% of contaminants from the web, down to 1 micron. Contact web cleaners carry a moderate investment price. Disadvantages are that the adhesive tape needs to be manually checked and maintained. High contamination levels may make the tape consumable costs prohibitive. Contact cleaning creates static. Active static elimination is often incorporated with this method to neutralize the charge created by contact cleaning.

Parameter	Notes/ Usage
Industry of Use	Converting, Flexible Packaging, Medical, Nonwovens, Electronics
Substrate	Papers, Films, Foils, foams, non-wovens, plastics
Particle Size	Down to sub micron level (documented)
Particle Amount	Moderate contamination levels acceptable, as long as amount of
	contamination does not overwhelm adhesive tape collection in determined time period. .
Web Width	Generally up to 180 inches
Web Speed	Speeds up to 800 ft/min, >800 ft/min with speed match
Web Tension	Usually not critical. Nip tension loss is minimal. Configurations vary. Higher tensions preferred.
Total Cost of Ownership	Low initial investment. Consumables cost vary by contamination level.

6. **Contact Cleaning – Water Wash–** a contact web cleaning method that uses a specially formulated polymer roll (Contact Cleaning Roll) to nip the substrate between another contact cleaning roll or a nip roller. As the web transports over the nip roller, a CCR provides lay-on contact with the web surface, thereby eliminating the loose contamination present on the web surface. The dirty CCR is then retracted as a water wash and drying cycle are performed on the dirty CCR. After the cleaning and drying cycle is complete (approximately every 5-7 minutes), the retracted CCR is speed-matched with the web line and nipped into the lay-on position. The previously in-service and dirty CCR is then retracted for a wash and drying cycle. The two CCRs continually cycle between the lay-on web cleaning and the retracted water washing positions. The automated washing head uses a roll of fabric to collect and hold the contaminants removed from the web's surface by the CCR. Water never comes in contact with the substrate, only the retracted CCRs. Water wash systems are generally used for substrates with high levels of contamination and fast speeds. Single nip cleaning is 96.9% effective at removing contaminants. Water wash systems are the only web cleaner capable of cost effectively cleaning recycled CRB, URB or virgin- coated board stocks due to the low annual consumables cost. The disadvantage is the high investment price, although ROI is typically less than 1 year.

Parameter	Notes/ Usage
Industry of Use	Paperboard Converting, Nonwovens
Substrate	Papers/Paperboard (recycled), Films, non-wovens
Particle Size	Down to sub micron level (documented)
Particle Amount	Very high contamination levels acceptable
Web Width	Theoretically infinite with traversing wash head. Generally up to 180 inches
Web Speed	Speeds up 2500 ft/min with speed match
Web Tension	Usually not critical. Configurations vary. Higher tensions preferred.
Total Cost of Ownership	High initial investment. Consumables cost is low.

Analyze the total cost of ownership (Beware of the Hidden Costs!)

When analyzing the best option for your process, consider not only the initial equipment investment, but also the cost of consumables, maintenance and man-hours. Additionally, contrast these costs with the level of cleaning efficiency.
For instance, when comparing Vacuum systems vs Tape Contact Cleaning systems

- Initial Investment prices for Vacuum systems and Tape Contact Cleaning systems are comparable.
- Electricity is a Vacuum system's consumable. Electricity consumed by the vacuum pump and compressed air on Vacuum systems, can equal or exceed the consumable costs (Pre- Cut, Sheeted, Adhesive Tape) of a Tape Contact Cleaning system.
- Vacuum systems have a lower cleaning efficiency and particle size effectiveness than Tape Contact Cleaning systems.

Make the appropriate selection for your process

Analyze the selection criteria to choose the system that works best for your process. Please feel free to contact Polymag® Tek if you have any questions of you would like a more in-depth explanation of this article.

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