DuPont Teijin Films

Cleaning Of Polyester Films Prior to Vacuum Coating

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Cleaning Of Polyester Films Prior to Vacuum Coating

- Problem of contamination on surfaces during vacuum coating
- Pinhole defects and the problems they can cause
- Web cleaning
  - Experimentation
  - Results and data handling (statistics)
- Conclusions

Polyester Film and Vacuum Coating

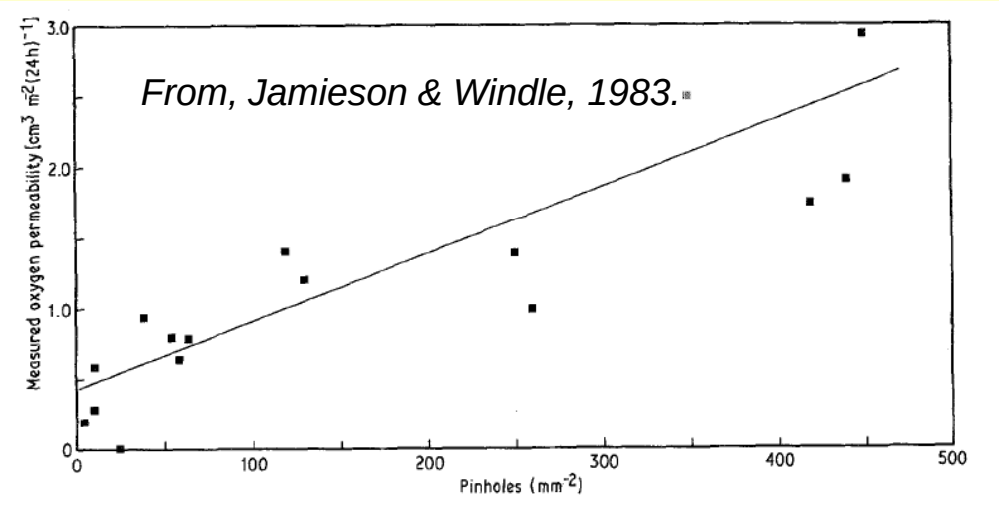
- Polyester is one of the most widely used substrates in R2R vacuum deposition:
  - Mechanical strength
  - Thermal stability
  - Optical Clarity
  - Surface smoothness
  - Can be tailored for application
- However, like any substrate it presents an available surface on which unwanted particulate debris can deposit and interfere with the vacuum coating process
  - This is a problem
    - Coat quality
    - Product performance
    - Cost

Cleaning Polyester Film

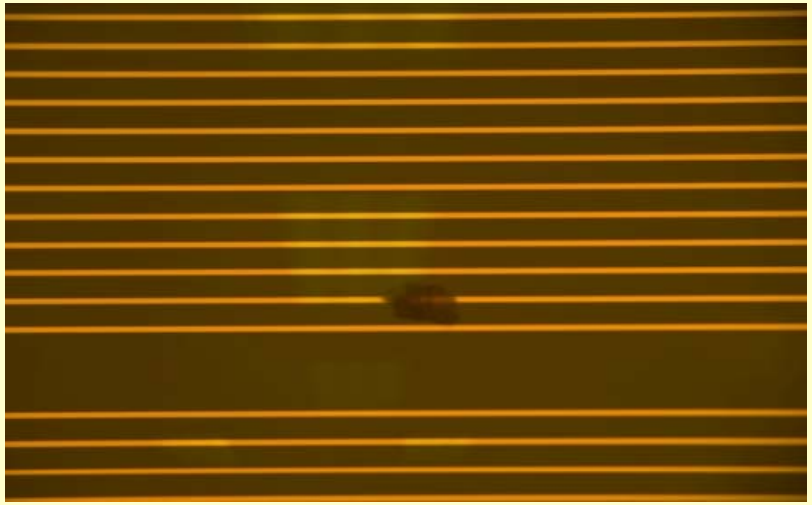
- Surface of a film is of paramount importance
  - Printing
  - Overcoating
  - Food contact
  - Optical properties
- Surface contamination (particulate debris) can lead to *pinhole defects* in vacuum deposited layers which are detrimental to the properties described above
- Pinhole range from <1μ to >50μ in size*

* *E.H.H. Jamieson & A.H. Windle, 1983, Structure and Oxygen-Barrier Properties of Mettalized Polymer Film, Journal of Materislas Science,18, 64-80*

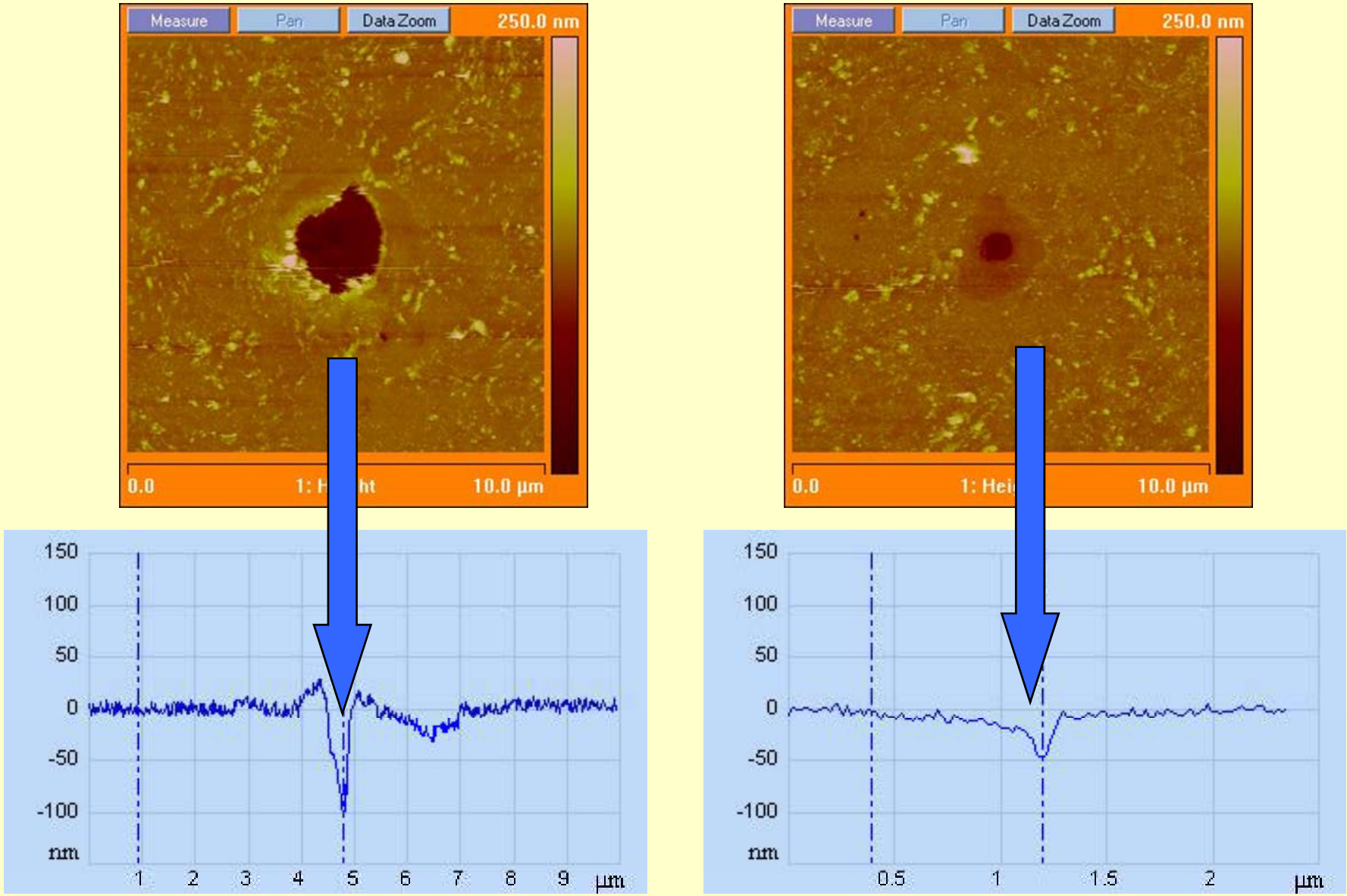
Problems Caused by Pinhole Defects



Example 1. Reduces effectiveness of a gas barrier layer; i.e. provides a channel through which small molecular species can migrate. V. important in packaging films and encapsulation for OLEDs



Example 2. Can cause electrical defects ('open circuits') in masked circuitry. V. important in display microelectronic and display applications.


Measure
Pan
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250.0 nm
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Measure
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Data Zoom
250.0 nm
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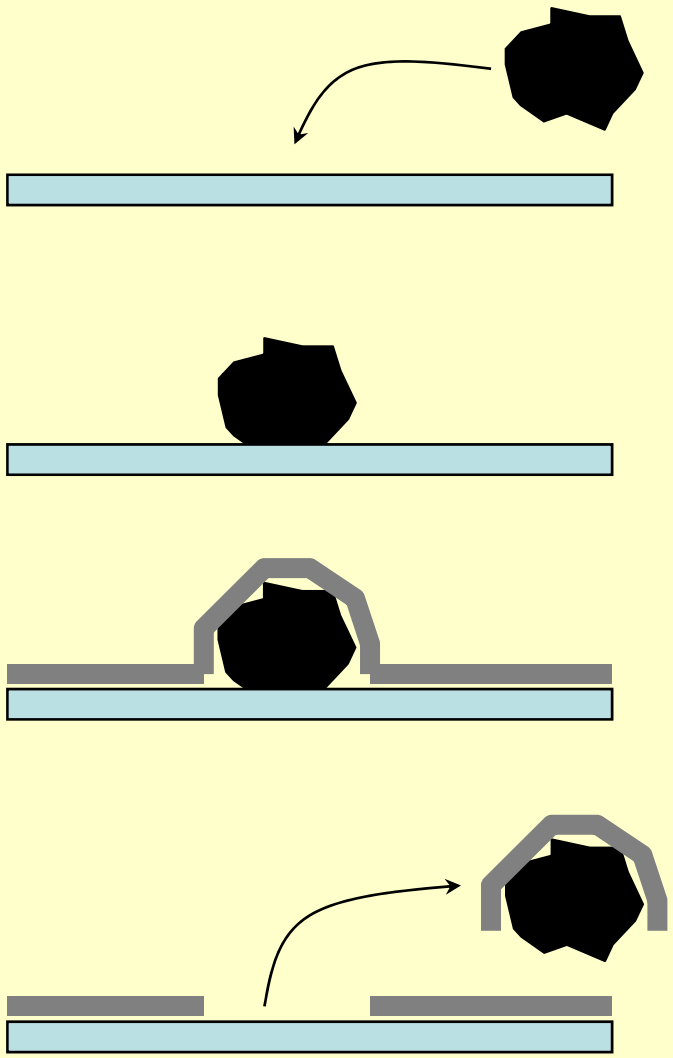
Pinhole Formation



Step 1. Particulate is deposited on substrate.

Step 2. Particulate is held on on surface by electrostatic, Van der Waals and boundary layer forces.

Step 3.Substrate, including particulate, is coated

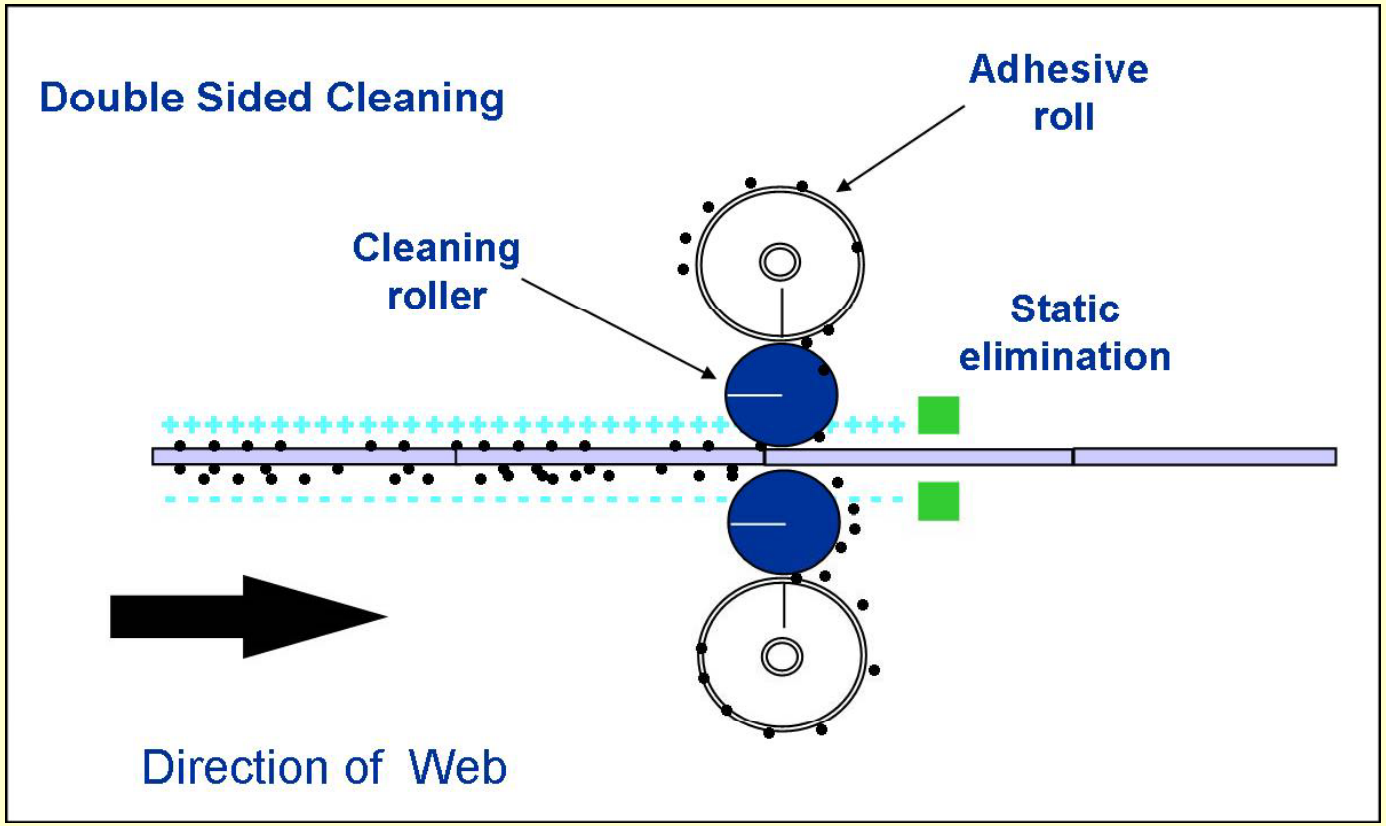
Step 4. Particulate is knocked off surface by mechanical or other energetic means.

Cleaning Methods

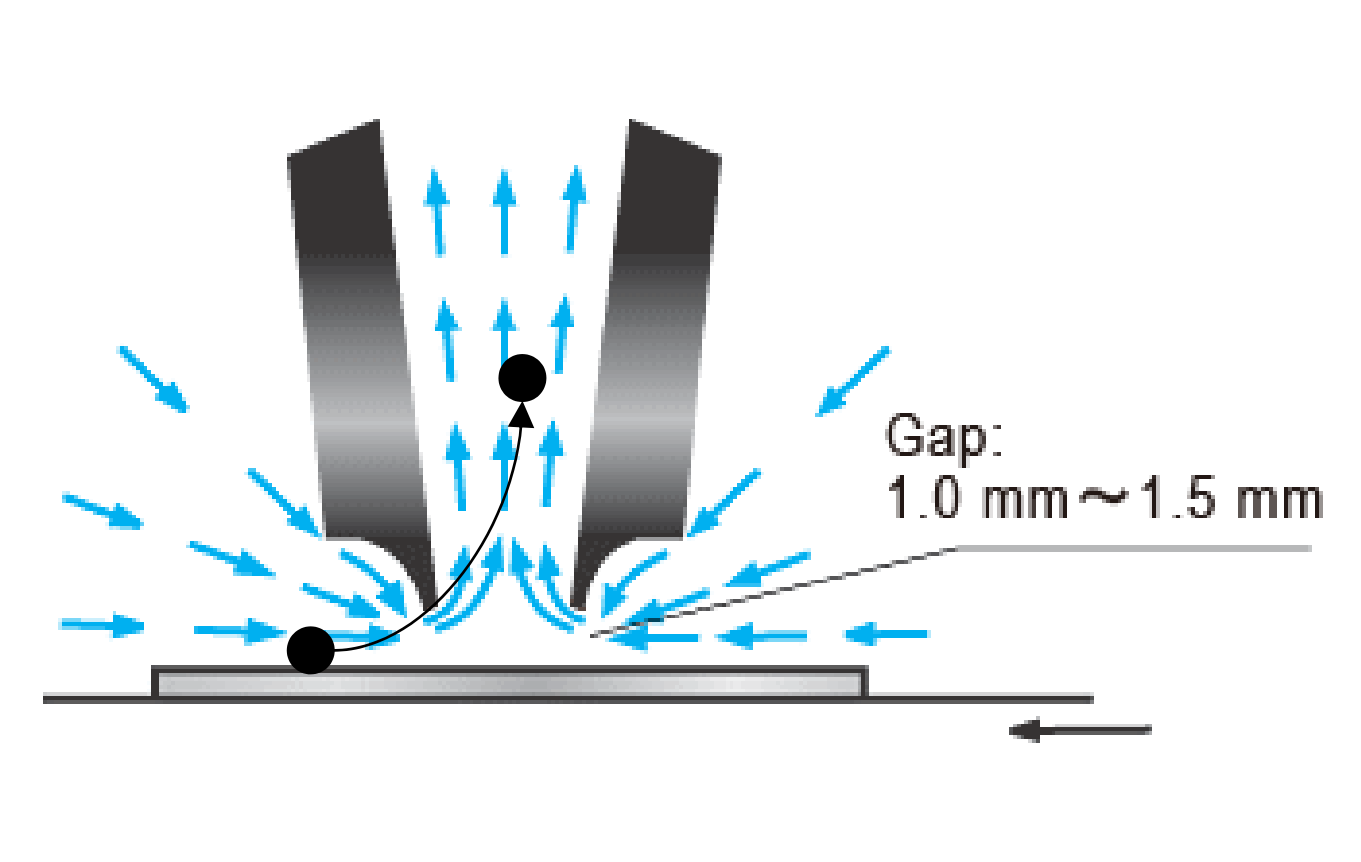
- Contact Roll Cleaning
- Vacuum Web cleaning
- Air Knife
- Tacky Rags
- Brush Cleaners
- Laser cleaning
- Dry Ice
- Washing…etc…etc

Comparison between a Contact and a Non-Contact cleaning technique!

Cleaning Methods – contact roll cleaning



Cleaning Methods – Vacuum cleaners



What we need to know….

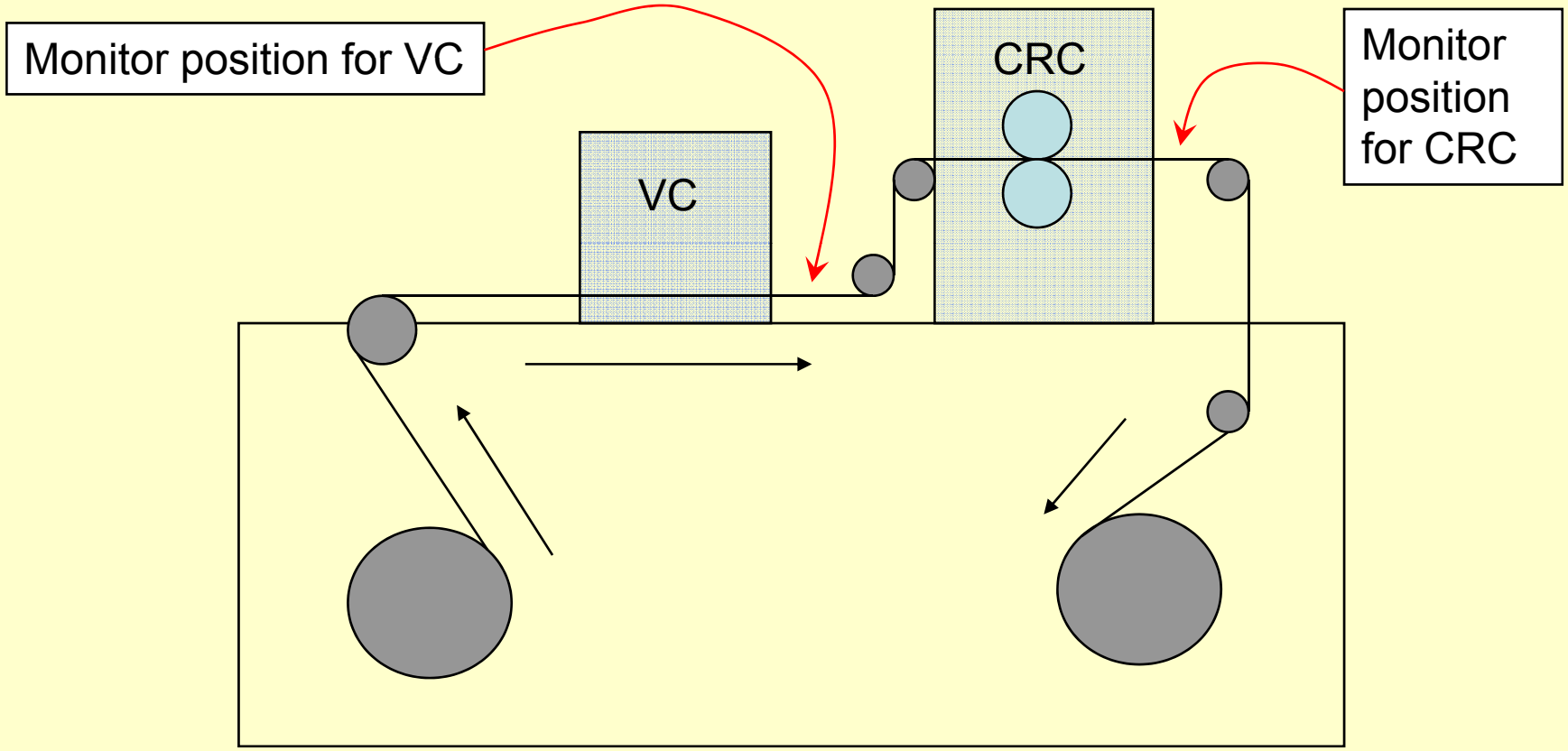
- Need to optimise (maximise) cleaning of polyester film.
- Key Parameters for CRC
  - Roller Type (Hardness)
  - Adhesive Roller Type (Film based or Paper based)
  - Position of static eliminators
- Key Parameter for Vacuum Cleaner
  - Air pressure differential
- Is there a synergistic effect ?

Experimental Detail

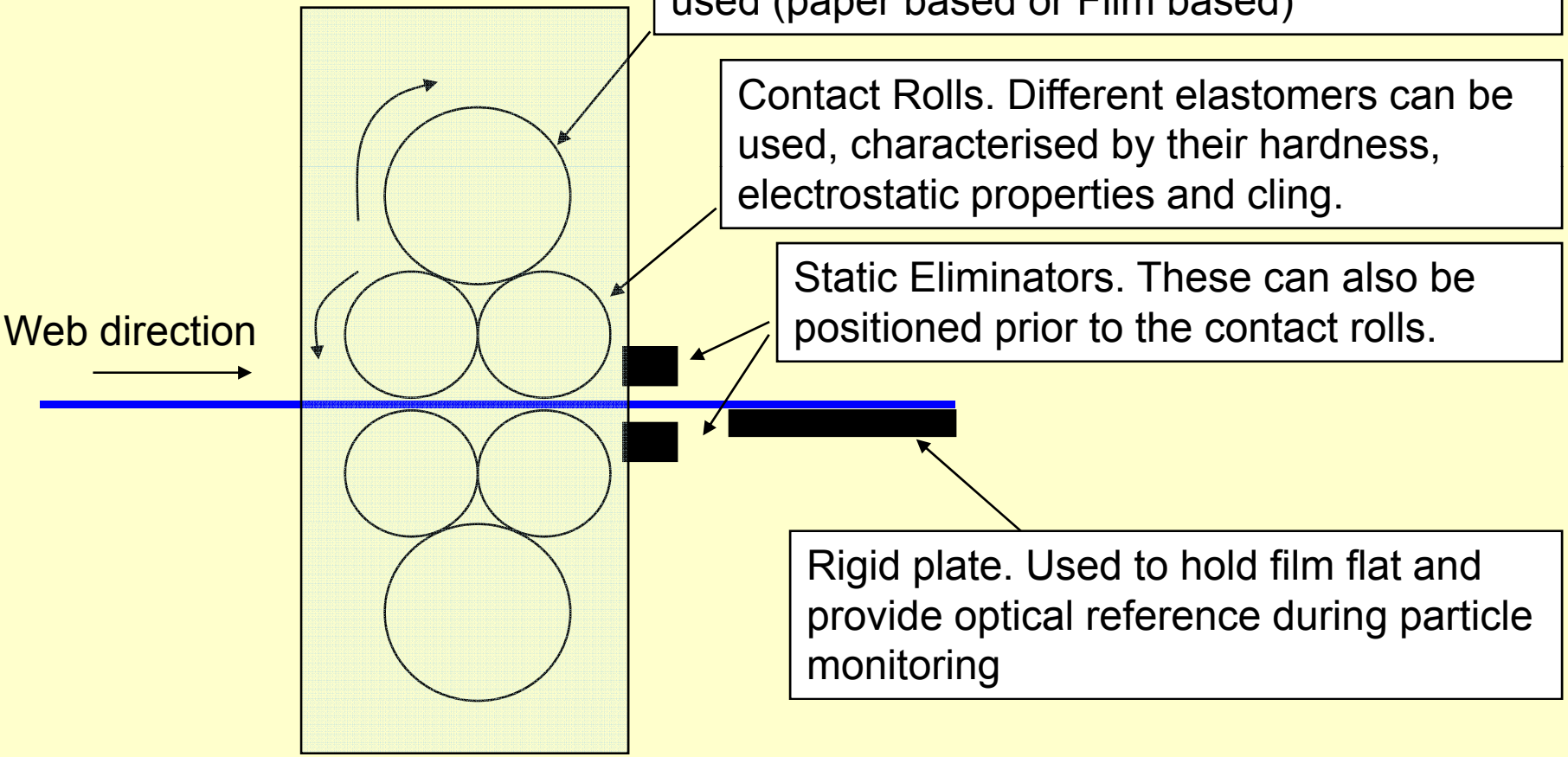
- Clean room
  - Class 1000 (CPI, Flexible Electronics Substrate Facilty, Wilton, UK)
- Film
  - Various grades of Mylar Film (DTF UK Ltd)
- R2R machine
  - Doel Engineering Ltd. (Kent, UK)
- Contact Roll Cleaner
  - Teknek Ltd (Glasgow, UK)
- Vacuum Web Cleaner
  - Shinko Co. Ltd, (Osaka, Japan)
- Particle Counter
  - Particle Guard (ACP Technologies, Stuttgart, Germany)

R2R Web Cleaner

Cleaner Schematic and measurement positions



Details of contact roll cleaner



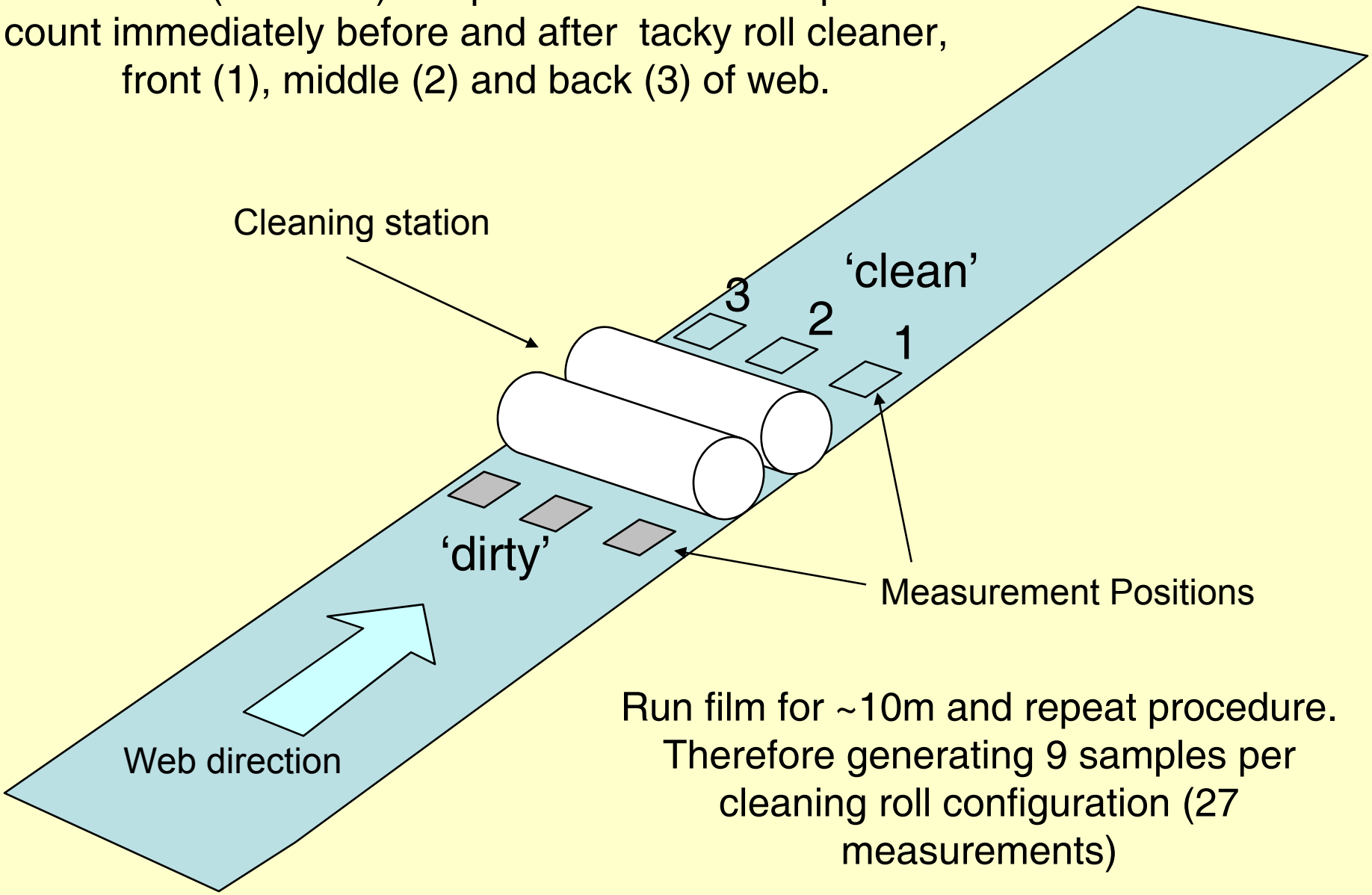
Contact Roll Types (Teknek Ltd, UK)

Contact Roll Type	Hardness 'Asker C'	Comment
'ESD'	~18	'ESD' = 'Electrostatic discharge'
'Film'	~32	Designed for flexible substrates
'F3'	~39	
'Panel'	~43	Designed for cleaning rigid panels such as circuit boards

Vacuum Web Cleaner Conditions (Shinko Co. Ltd, Jpn)

Vacuum Condition	Inlet Pressure (mbar)	Outlet Pressure (mbar)
'Low'	4	120
'Medium'	6	150
'High'	10	170

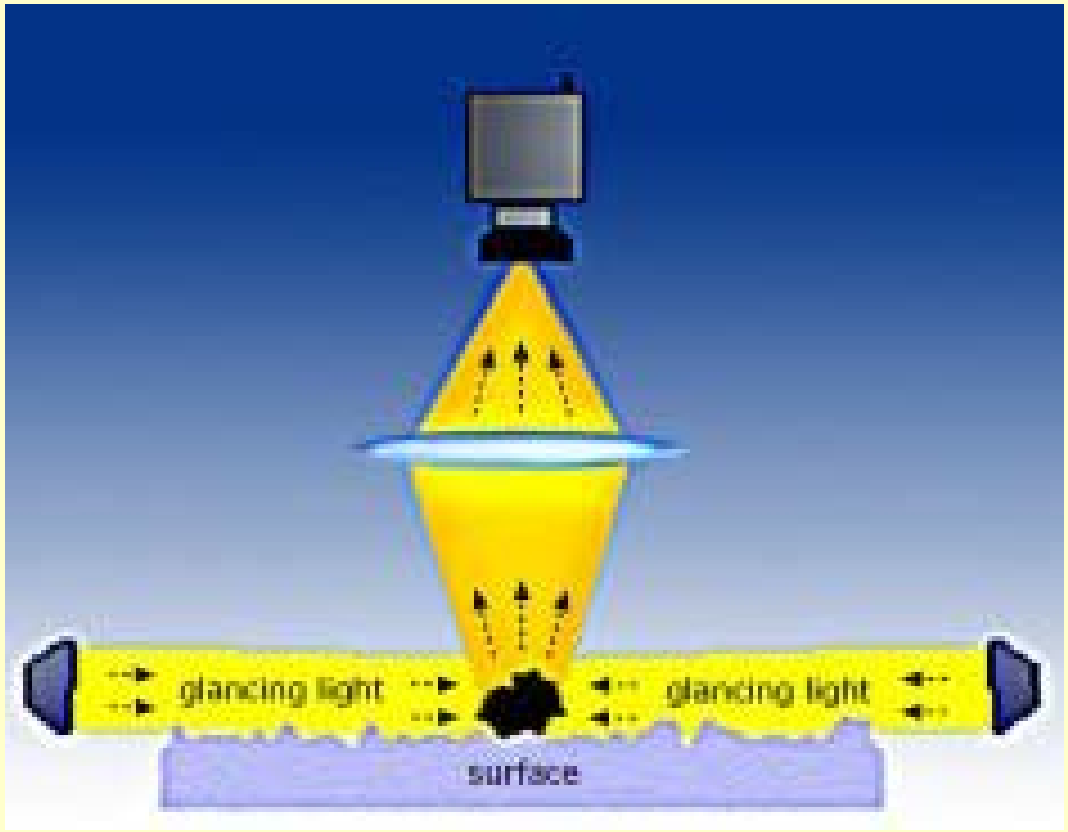
Run film (10m/min). Stop film and measure part. count immediately before and after tacky roll cleaner, front (1), middle (2) and back (3) of web.



Run film for ~10m and repeat procedure. Therefore generating 9 samples per cleaning roll configuration (27 measurements)

Some notes on surface particle measurement and data handling (statistics)

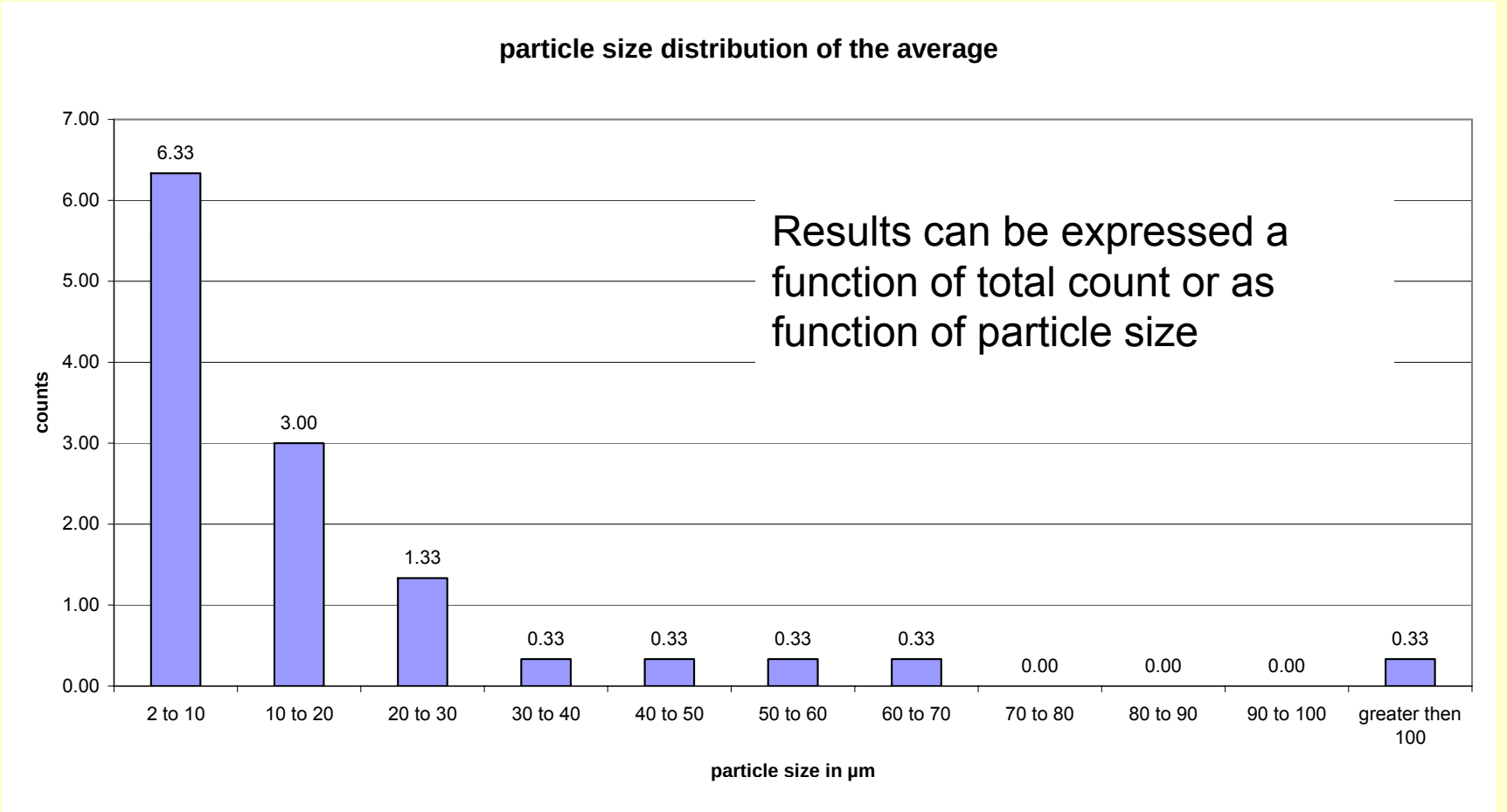
Measurement and Imaging



Measuring Principle

- Light Scattering
- Digital CCD detector normal to the surface
  - Scattered light detected by CCD is ‘seen’ as contamination.
  - Software counts total ‘particles’ and sizes each count
    - Min ~5µ, Max ~4000µ
  - Will count anything which scatters (not necessarily external contamination)
    - Substrate roughness could interfere with measurement

Particle Guard Measurement Output.



Count Statistics

- Surface contamination counting has been of interest for many years in several important areas of industry
  - Semi-conductors
  - Pharmaceuticals
  - Lens making and optical materials
- The counting of surface particulate debris or defects in general is based on some simple mathematical principles*
  - Poisson statistics
  - Count distribution
  - Non-normal distributions

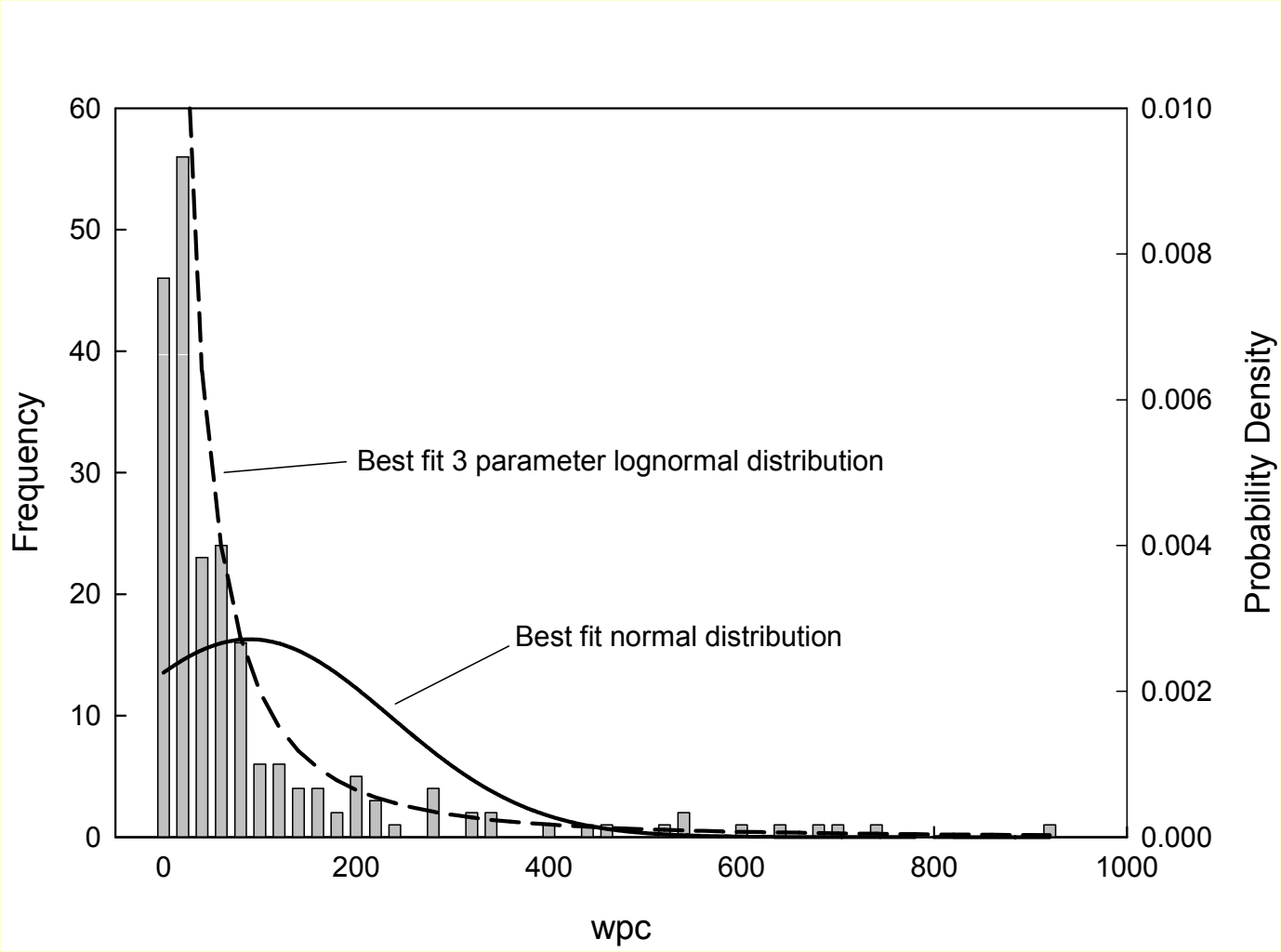
**C.H.Stapper, F.M. Armstrong, K. Saji, 1983, Intergated Circuit Yield Statistics, Proceedings of the IEEE, 71:4, 453-469*

Rare Event Data

- At low particle concentrations
  - Zero, or very few particles will be found and therefore, theoretically particle counts should be distributed according to the Poisson distribution or a derivative thereof.
- It is unlikely that a free surface has a constant and uniform surface particle concentration*
  - σ can be ~ μ; Poisson or normal distributions are inappropriate models under these circumstance
  - Other distribution models need to be used
    - e.g. lognormal models
  - ..or use non-parametric testing to ascertain cleaning efficiencies
    - Mann-Whitney U Test is appropriate

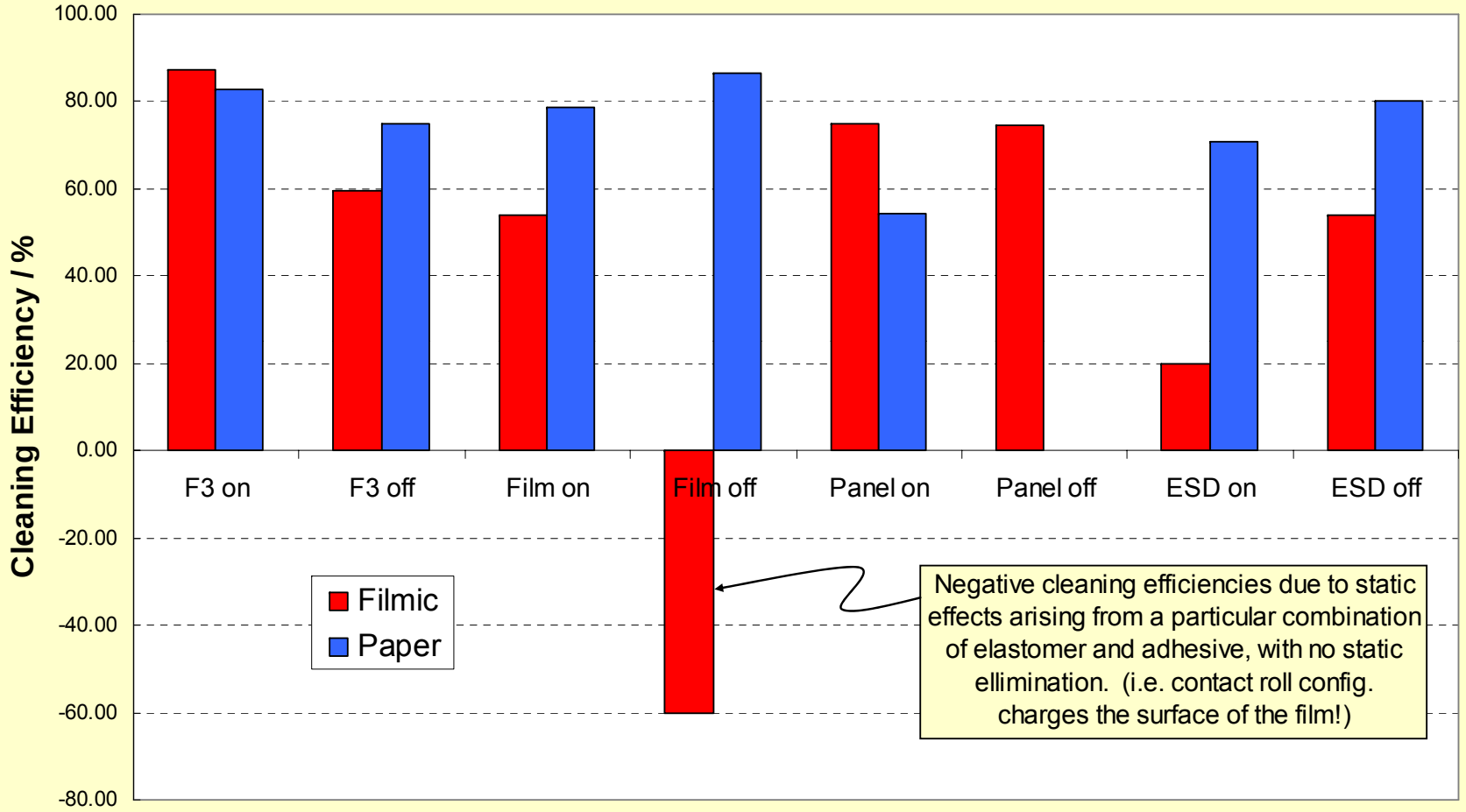
**Douglas W. Cooper, 1986, Particulate Contamination and Microelectronics Manufacturing:An Introduction. Aerosol Science & Technology,5:3, 287-299*

Typical Count Distributions

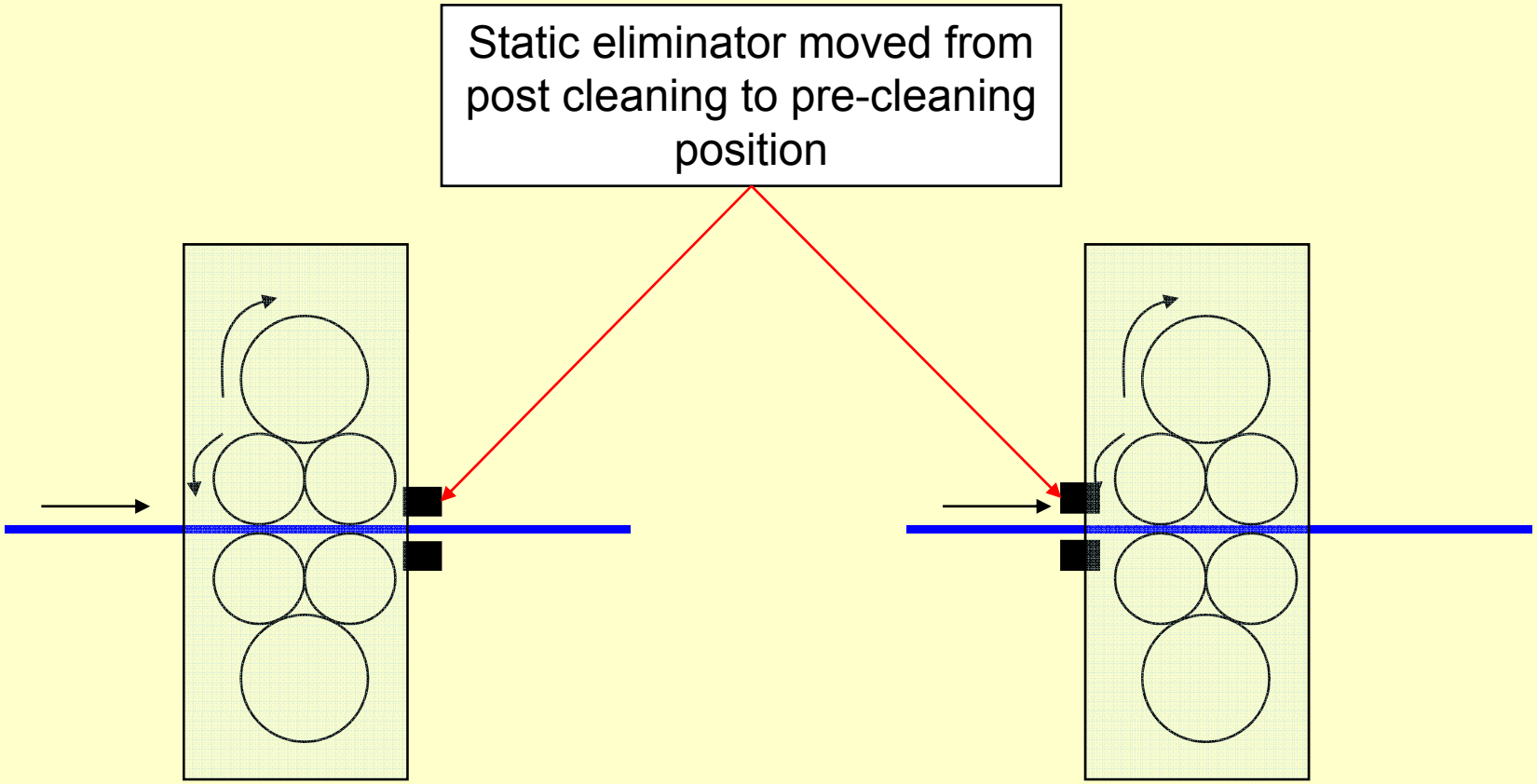


Results For Contact Roll Cleaner (Based on Total Particle Count)

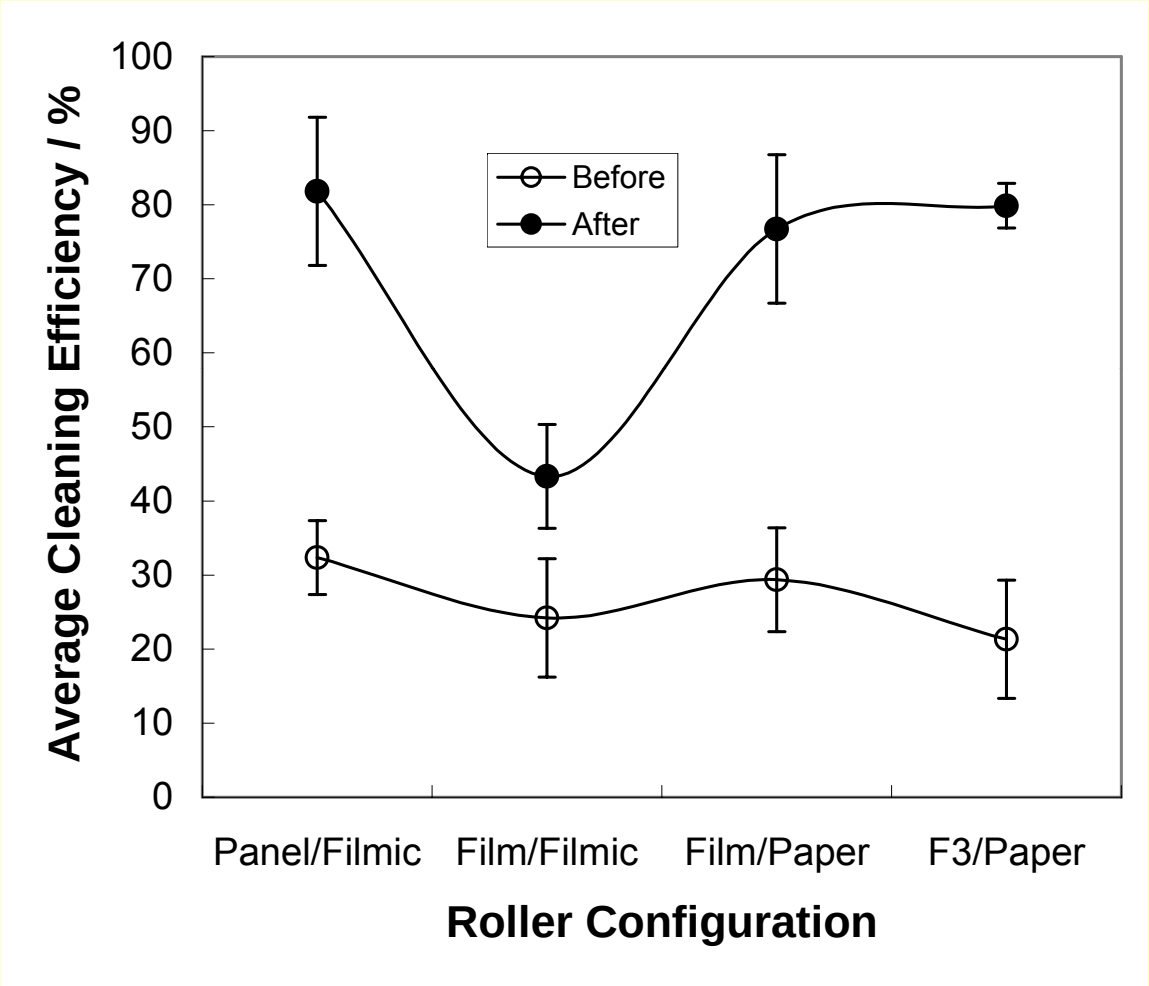
Average Cleaning Efficiency For CRC Configurations



Effect of Static Eliminator Position

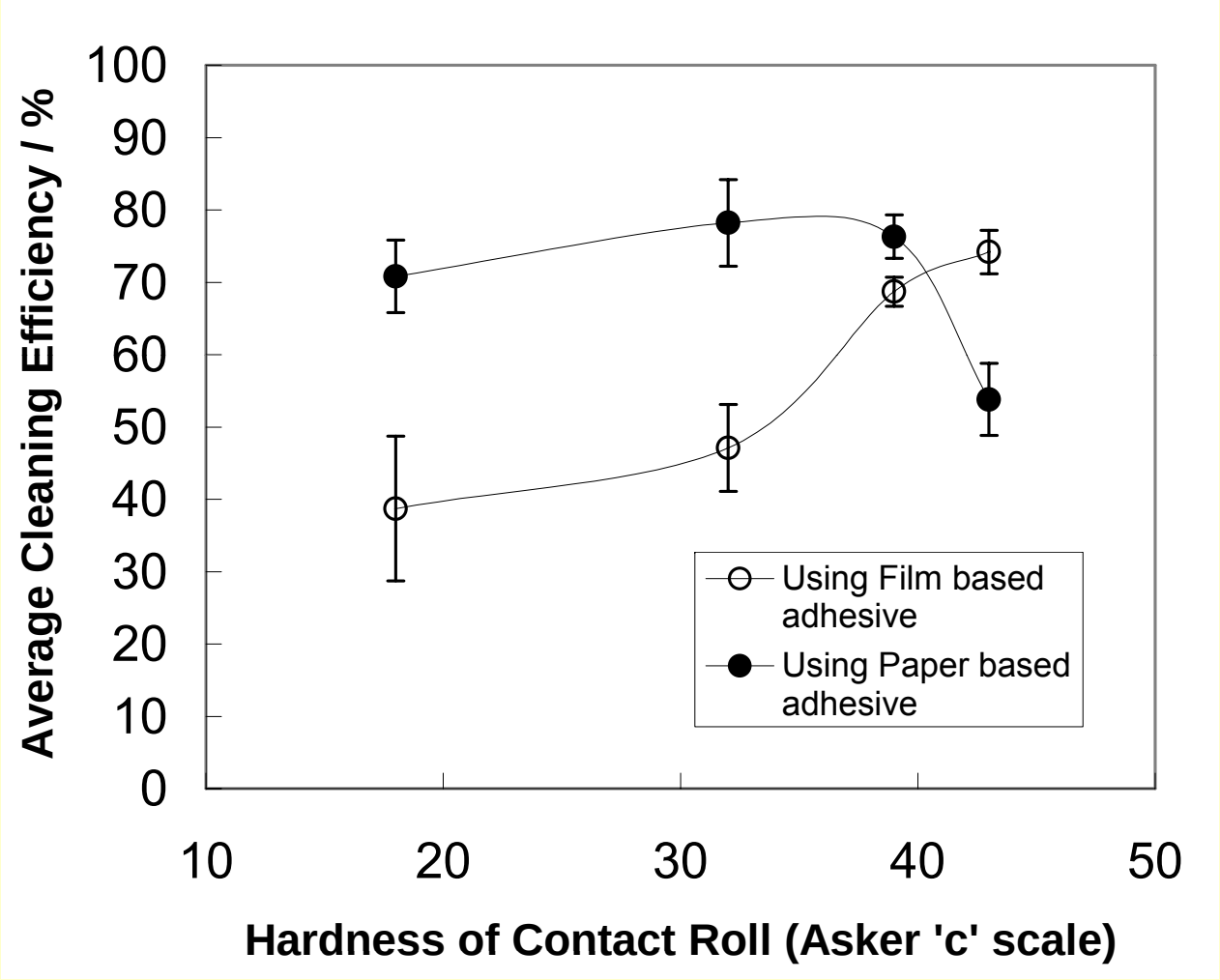


Re-positioned Static Eliminator



When film goes through the CRC it gains charge due to surface contact with the elastomer rolls. This charge is then removed by the SE, hence surface of film has little or no static charge. When SE is in 'pre' position, charge is eliminated but then film gains charge due to contact in the CRC, and atmospheric particulates are immediately attracted to the surface , hence surface is re-contaminated

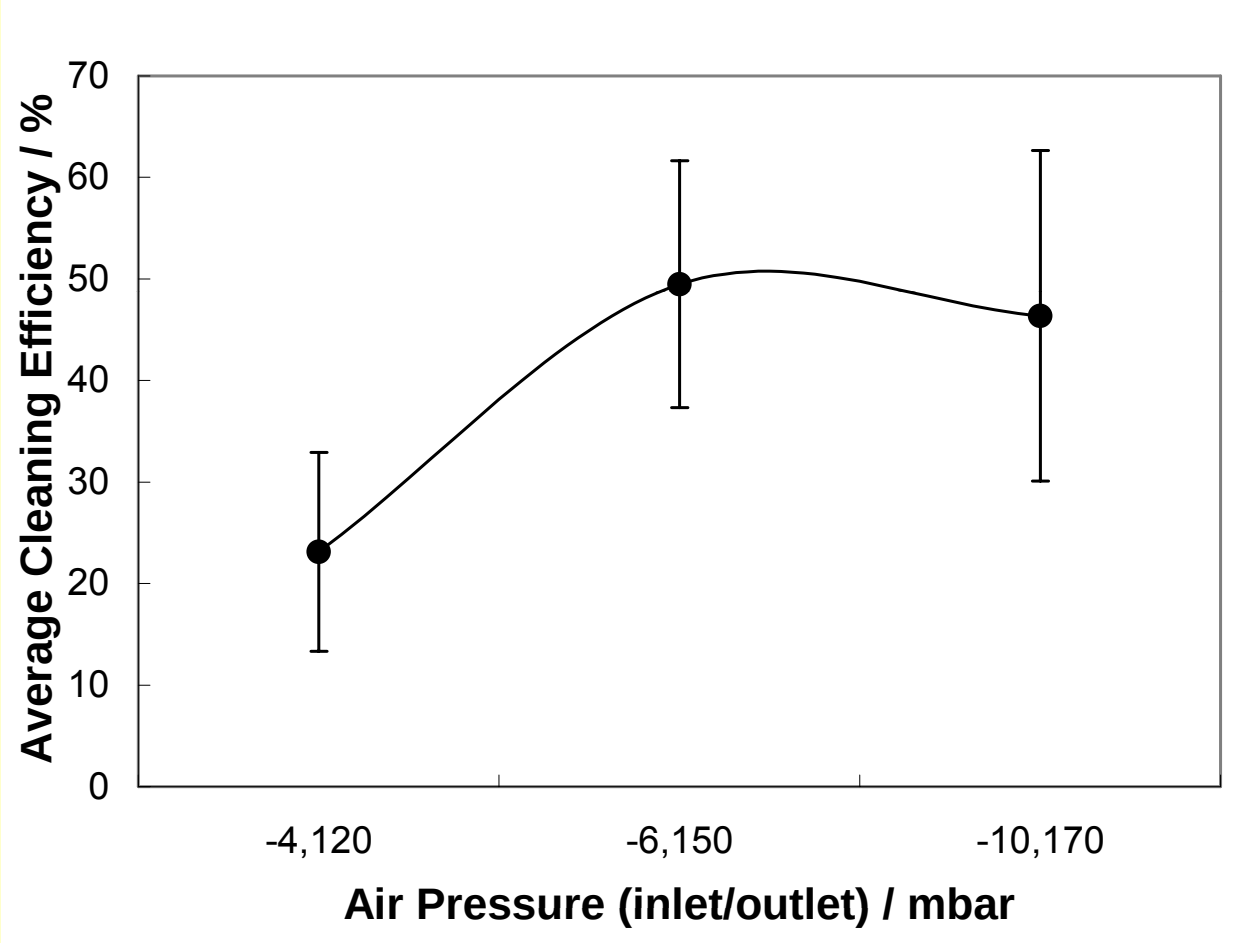
Cleaning Efficiency as a Function of Contact Roll Hardness



Result show marked dependence on roll hardness when 'Filmic' adhesive roll is used. When 'Paper' based adhesive roll is used only the hardest roll ('Panel') shows a marked difference.

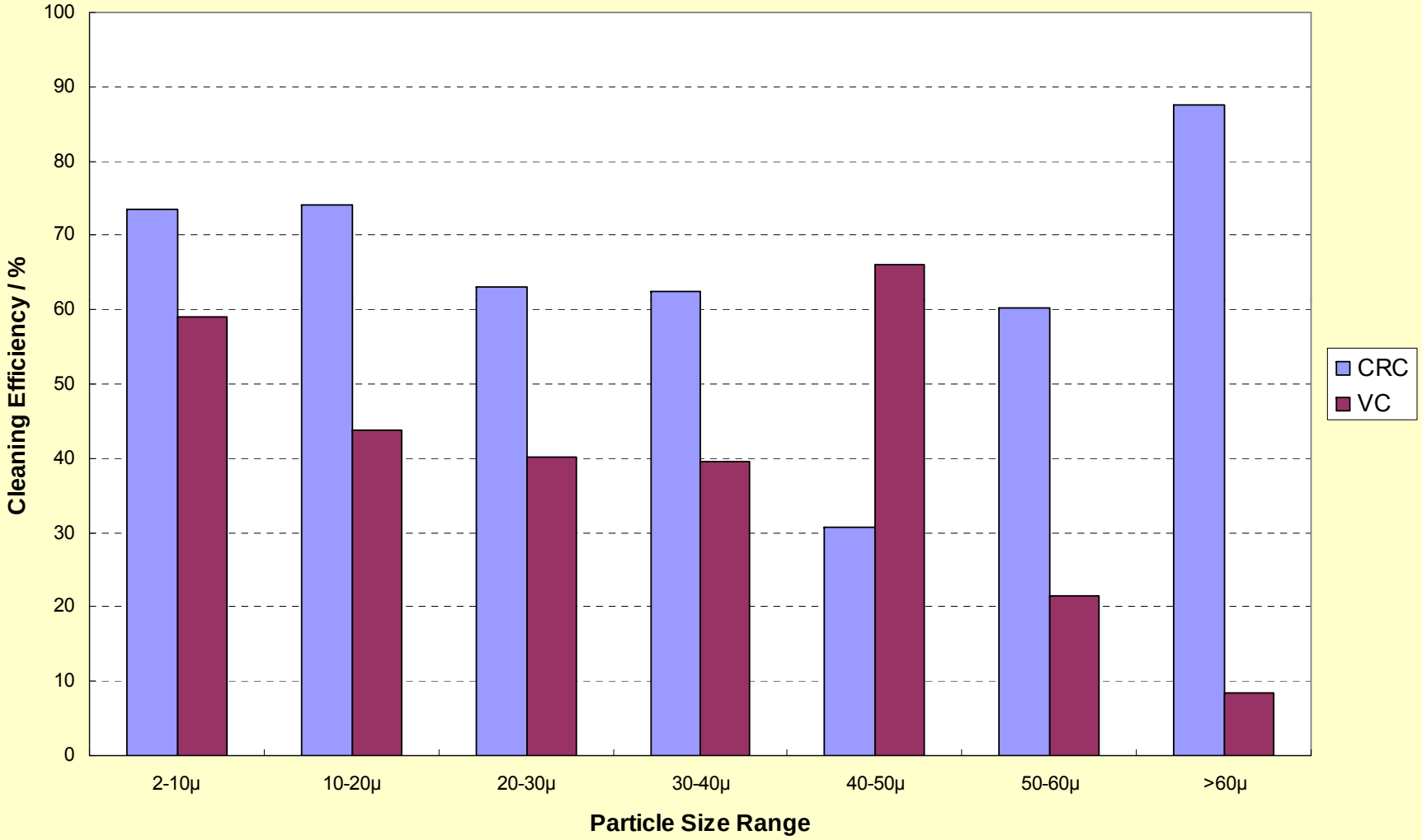
Results For Vacuum Web Cleaner (Based on Total Particle Count)

Cleaning Efficiency For Vacuum Web Cleaner

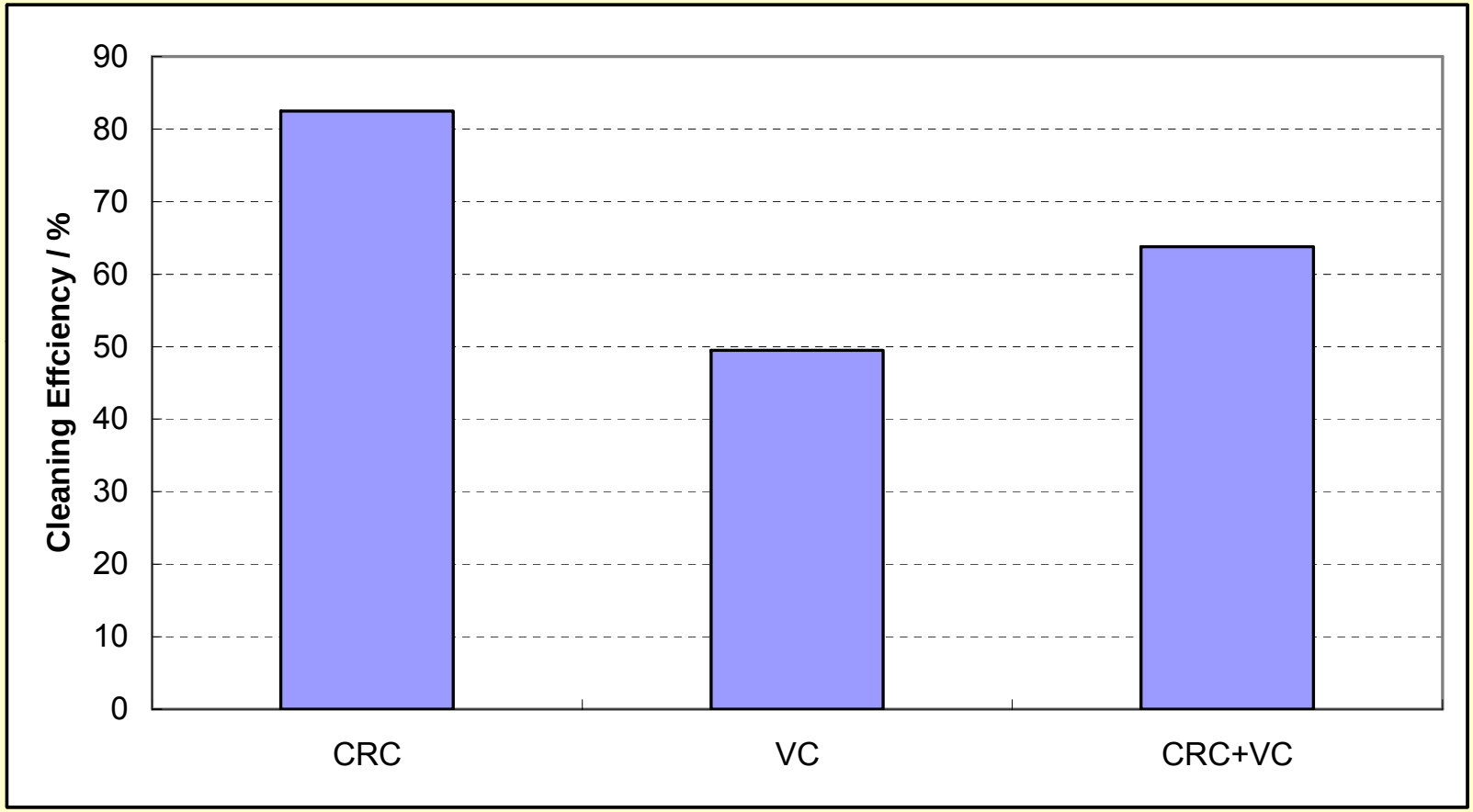


As expected the larger the pressure differntial (harder vacuum) the greater the cleaning effect. However, it is noticeable that the best cleaning efficiencies are lower than those for the CRC (~50% vs ~80%)

Cleaning Efficiency as a function of particle size: Averaged results (all data)



Comparison of best observed cleaning efficiencies for CRC, VC and combination

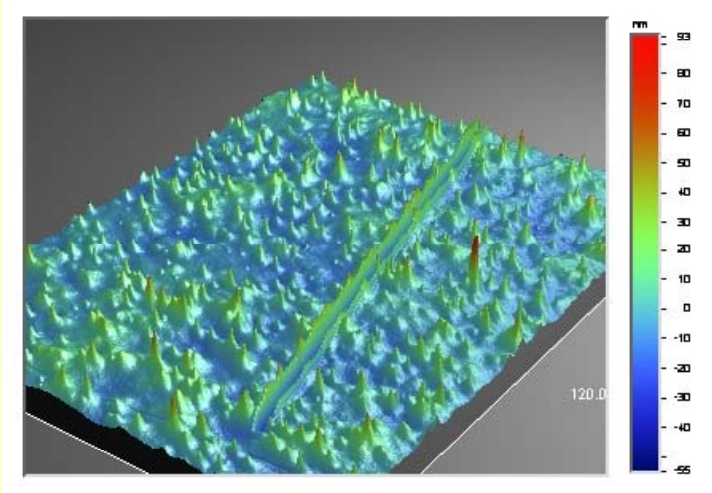


No observed benefit in combining CRC and VC!

However, a word of caution…

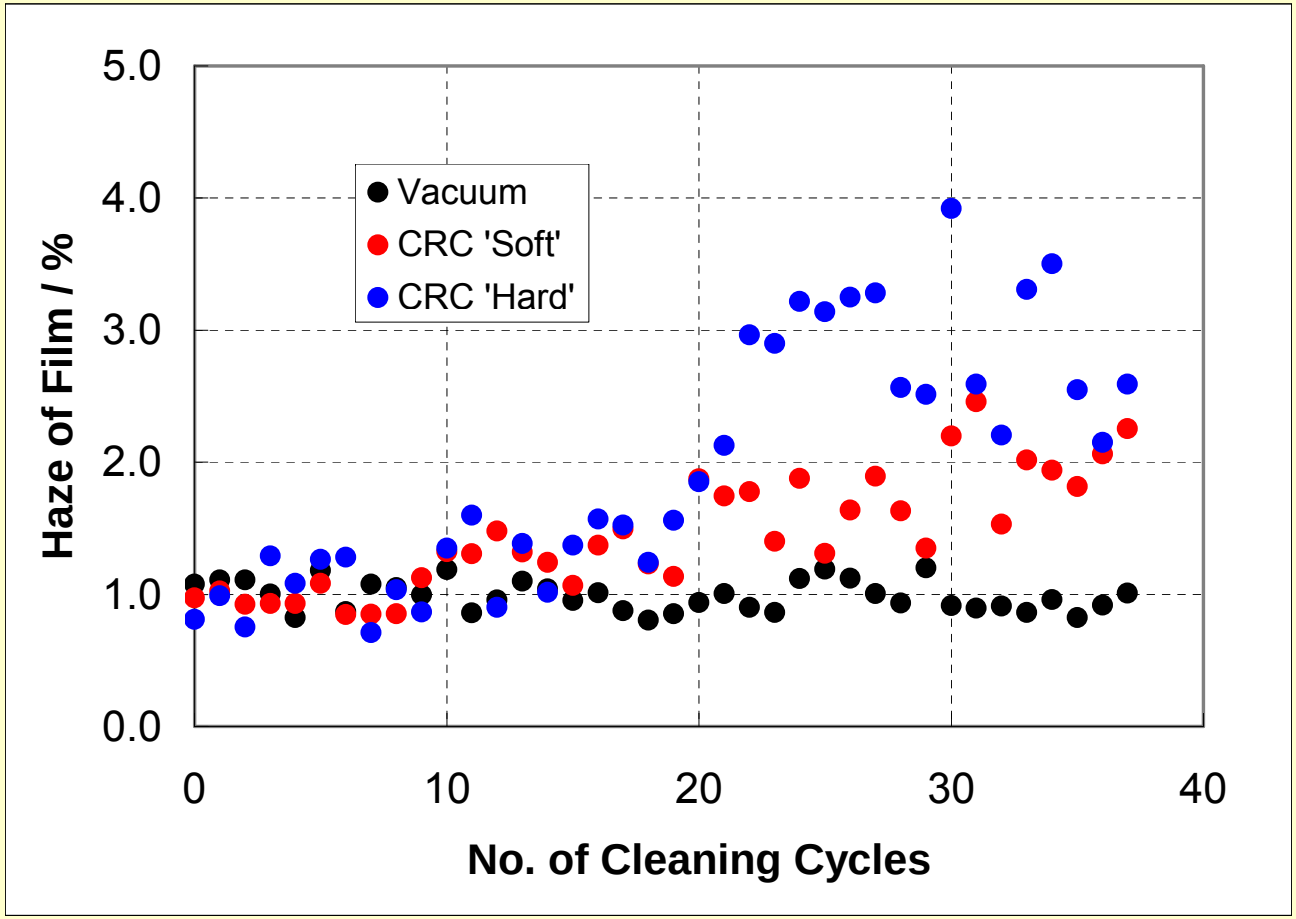
CRC is a contact technique…VC is non contact…!!

- Analysis of cleaned film reveals some surface scuffing, (also visible as an increase in light scattering)
- Measured % haze as a function of cleaning cycle for 2 configurations of CRC and for VC
- Measured over ~30 cycles

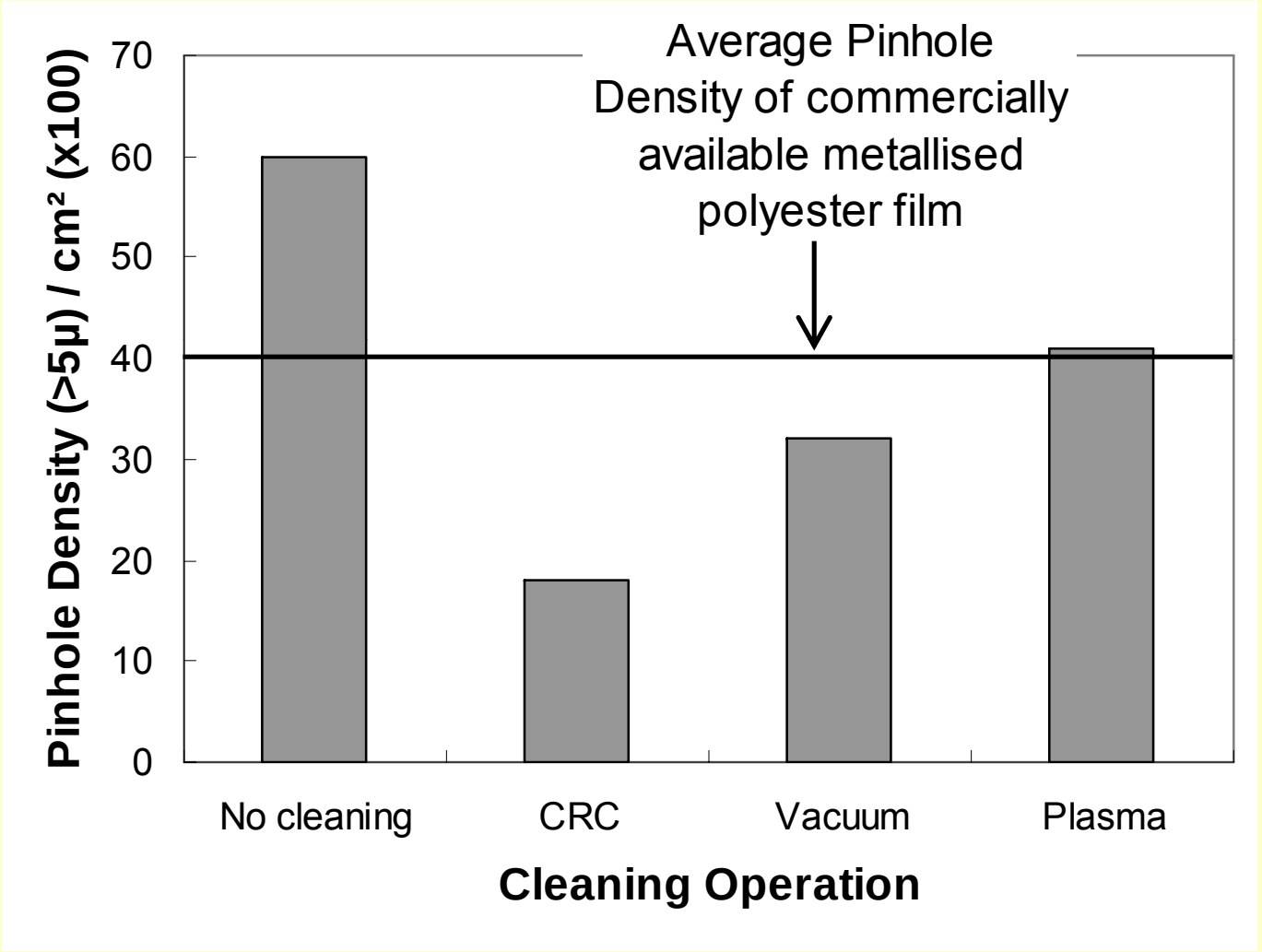


Surface Scratch approx. 5µ long , 100nm deep

Scuffing and scratching of polyester film due to different cleaning operations



Measured Pinhole Density For Different Cleaning Operations



What we need to know….

- Need to optimise (maximise) cleaning of polyester film.
- Key Parameters for CRC
  - Roller Type (Hardness)
  - Adhesive Roller Type (Film based or Paper based)
  - Position of static eliminators (post>pre)
- Key Parameter for Vacuum Cleaner
  - Air pressure differential
- Is there a synergistic effect ?

Summary

- Polyester Webs can be cleaned at high efficiencies by contact roll cleaning and vacuum cleaning
- CRC cleaning efficiency is dependent on the specific combination of contact and adhesive roll and static eliminator position
  - Generally Using ‘Paper’ based adhesive yields highest cleaning efficiency (~80%)
  - Static elimination is most effective when employed ‘post’ contact
- Vacuum cleaning has a lower cleaning efficiency than CRC (~50%) but has the advantage of being non-contact and therefore is seen to impart less damage to the film surface
- No observed benefit in combining CRC and VC
- Correlation between efficacy of cleaning method and measured pinhole density in Al sputtered polyester film has been demonstrated
- Robust statistical methodologies need to be used when dealing with particulate concentration data which tends to be highly disperse

Acknowledgements

- Damian Tuffin (DTF)
- John Flett (DTF)
- CPI clean room staff

Thank You for your attention!