Measurement of Particle-Shedding from Different Wiper-Materials

A Comparison of Wet and Dry Measuring Methods

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Most of the methods for testing cleanroom-wipers do not take the practicalities of wiper applications into account. In this paper three new test methods and a new general and optionally expandable classification for cleanroom-wipers are introduced. A test report containing numerous tests of different wiper constructions with f ive different test methods is given.

An Introduction
There have been quite a number of publications refering to the particle-release of *cleanroom garments* suggesting various methods of causing the release of particles from the garment with subsequent measurement. Thanks to the 1988 publication by Ehrler and Schmeer* we have also a comprehensive synopsis about the state of the art in this field of technological activity.

The other important textile-product used in a cleanroom is the cleanroom-wiper. This textile, an which more exacting demands are made than an any other cleanroom auxiliary product, deserves our technological attention. In this connection it should be kept in mind, that in a large ULSI-cleanroom every year between 50 and 100 000 sqm of wipers are being used. Considering this as 100 to 200 000 sqm of contaminating material highlights the importance of this product fo many users.

In recent years numerous ways and recommendations of testing cleanroom-wipers for particle release have been published but nearly all of these methods are more of theoretical value than of practical application. This is because the practicalities of the wiper-handling in a cleanroom, which should be the starting point of considering a test-method, have not been carefully studied prior to the Invention of test-methods.

It is the purpose of this paper to review the situation pertaining to the use and testing of cleanroom wipers with the aim of arriving at solutions based an the realities of this product's practical application. Moreover the attempt is made to establish a new generally acceptable classification comprising all kinds of cleanroom-wipers, their possible uses and the various kinds of surfaces to be wiped.

The Application of Cleanroom-Wipers
In view of the above the passages of possible contamination by a wiper into the cleanroom can be easily marked:

- *1. from the point of removal out of the package to the point of storage (i.e. in wiper-trays);*
- *2. from the point of storage to the point of moistening;*
- *3. from the point of moistening to the point of use;*
- *4. from the point of use to the point of disposal.*

It should be noted that wipers only an two passages of four during their travel of application are in a moist condition. They are predominantly yet, not entirely in a moist condition during their application. They are almost never in a wet condition.

The moistening of a wiper:
- can be purposely applied before the removal of an undesired contamination in form of a solvent or
- it can happen in the course of the wiping application as a side-effect of the removal of wetted contaminants.

It must be recognised that more than 80 % of all cleanroom wipers			
1. are manufactured, supplied and stored in their package or place in dry condition;	2. are then taken manually in dry condition to their point of use;	3. are wetted and used in damp or wet condition;	4. are finally disposed of in wetted condition.

No doubt, a test-specification for cleanroom-wipers will have to take these realities into account. Therefore the dispute whether a wiper should be tested by dry- or by wet-testing methods is absurd - it should be tested in accordance with its practical application - this means, dry as well as wet testing methods should be applied.

The basic denomination for cleanroomwipers can be divided into three groups:

1. **Quality of surface to be wiped;**
2. **Construction of the wiper;**
3. **Criticality of application.**

Table 1 contains the list of surfaces and obj ects to be cleaned in a cleanroom. Based an the information contained in Table 1 it should be possible to attribute the various surfaces mentioned to a few common features relative to their cleaning by wiping methods (Table 2).

This in turn will then permit a coordination between the characteristics of wipers (Table 3) and the so obtained surface-characteristics.

Taking this model of coordination one step further, the introduction of three classes of criticality in application might be helpful (Table 4). This is because of the different requirements in cleaning e.g. the surface of a shaft encoders disc or the outer surface of a cleanroom-wall. Both surfaces are of a smooth nature but remaining particles or fibers affect the performance of the final product in a different order of magnitude.

In order to establish a practicality-based classification for cleanroom-wipers, the consideration of the objects to be regularly cleaned in a cleanroom manufacturing process should be the first step of observation. This is realised below (Table 1):

List of objects in a cleanroom to be regularly cleaned by wiping methods:
The Product during Manufacture and Repair (i. e. Winchester-drives, precision- potentiometers, shaft-encoders, optical glasses, liquid crystal displays, printed circuit boards, solar-cells etc.)
The Cleanroom Furniture surfaces of plastic materials, metallic surfaces, trays, trolleys with circular blanks, sinks and drains
The Cleanroom Outfit doors, door-handles, windows and floors, lamp-covers, electrical components like light switches, metal-pipes
The Cleanroom Equipment interior of machines, outer machine-surfaces, keyboards, glass-surfaces, masks, optical instruments

Table 1

List of various surfaces in cleanrooms
S 1 - Smooth surfaces without blanks
S 2 - Smooth surfaces with blanks and / or edges
S 3 - Surfaces with increased roughness but without blanks and / or edges
S 4 - Surfaces with increased roughness with blanks and / or edges
S 5 - Window-glass-surfaces
S 6 - Optical glass-surfaces

Table 2

List of various cleanroom-wipers by construction
W 1 - Polyester + Cellulose / Viskose-Nonwoven in different mixes
W 2 - Polyester-Nonwoven. Fiber-Diameter is 10 micron or more
W 3 - Polyester-Polyamide Microfiber-Nonwoven. Fiber-Diameter around 3 µm or below
W 4 - Polyester-Nonwoven with microporous Elastomer-Coating
W 5 - Polyester-Knitware Std-Fiberdiameter. Possible additional features: Particle washed and edge-seales
W 6 - Polyester-Knitware Microfiber. Diameter around 3 micron or lower. Possible additional features: Particle washed and edge-sealed
W 7 - Polyurethane-Foam-Wipers

Table 3

The contents of Table 1 to 3 are combined in Table 4, so that a practicality-based classification for cleanroom-wipers emerges. This can be applied to test methods and recommandations for the use of wipers.

Various Methods of Collecting Particles
In order to obtain the numbers of particles counted after their release - following various kinds of stress application - a large number of counts have been taken and scheduled in Table 5.

The particle counts of five different test methods applied to various wiper- constructions can be compared. An attempt has been made to obtain some particle counts under conditions particularly selected to be very close to reality-based stresses an a wiper.

The purpose of this is to show how the particle counts of the different test methods differ from the „reality counts“ and if some kind of correlation between the methods can be found.

Of course, to take a sufficient number of particle counts for statistical evidence is a troublesome and very time-consuming task. This in particular for the wet-testing methods, where each count takes about 30 minutes until completion. For this reason Table 5 does not yet contain all the counts needed. However, from the material available conclusions can be drawn without the danger of a large deviation. Continued efforts are going an to complete this Table 5 so that during 1991 full information an the subject shall be available.

The Various Mechanics of Stressing the Wiper

The Labuda-Ball-Head-Impactor
The wiper is mounted and fixed like a membrane. A ball headed hammer freely falls 60 times during one minute

Cleanroom wipers: Classification based on surface-quality, wiper-construction and criticality of application

Surface	Quality of Surface to be cleaned	Criticality of application		
		Low (L)	Medium (M)	High (H)
S 1	Smooth surfaces without blanks	W 1	W 2	W 5 / W 6
S 2	Smooth surfaces with blanks and / or edges	W 5	W 4	W 4
S 3	Surfaces with increased roughness but without blanks / edges	W 2 / W 7	W 7	W 4 / W 5
S 4	Surfaces with increased roughness with blanks / edges	W 4	W 4	W 4
S 5	Window-glass-surfaces	W 1	W 1	W 5
S 6	Optical-glass-surfaces	W 6	W 6	W 3

Table 4

Particel Counts on different wipers applying various kinds of stress (all data has been based on wipers with standard size of 200 x 200 mm)

Reference-Letter	Description of tested material	Application of stress based on various test methods					application of reality-based stress		
		Dry counting		Wet counting			Dry counting		Wet counting
		Labuda-Ball-Head-I-Impactor	Labuda-Colander-method	Modified F51-method	A3-Fluid-Laser-counter	Hoechst-surface-friction-method	Removal out of package (Aerodynamic counter)	Putting wiper aside (Aerodynamic counter)	Removal of 20 ml fluid Surface-friction-method
A	Polyester-Viskose-Nonwoven *No of samples taken* *Std.-Var.*	5524 *25* *2280*	98826 *25* *39910*	na	92400 *10* *21200*	nt	4955 *25*	nt	nt
B	Polyamide-Nonwoven *No of samples taken* *Std.-Var.*	2542 *25* *606*	23767 *25* *11089*	231000 *8 x 20* *1006000*	70740 *010* *34200*	10300 *5 x 20* *17200*	nt	504 *25* *799*	3450 *2 x 20*
C	Mikroporous Elastom. on Nonwoven *No of samples taken* *Std.-Var.*	2988 *25* *837*	2425 *25*	144000 *10 x 20* *53900*	364300 *10* *66300*	3600 *5 x 20* *4600*	nt	nt	nt
D	Particle-washed Knitware *No of samples taken* *Std.-Var.*	7676 *40* *8105*	35522 *25* *13065*	25750 *4 x 20* *15399*	20445 *10* *4854*	nt	nt	nt	nt
E	Polyester-Nylon-Mocrofiber-Knitware *No of samples taken* *Std.-Var.*	5631 *25* *2286*	24908 *25* *14385*	nt	113900 *10* *24900*	nt	nt	nt	nt

Table 5 na = not applicable nt = not yet taken onto the wiper. Under the wiper the probe of an Aerodynamic Laser-counter is fixed, so that particles, which are freed from adhesion by the impacts of the hammer find the way into the probe (Fig.1).

The Labuda-Colander-method
The wiper is fixed onto the base of a cylindrical body of a defined weight. The cylindrical body with the wiper is being rotated an the surface of a metal- colander of selected construction. Because of this particular kind of stress, particles and fibers fall through the holes of the colander. Under the colander the probe of an aerodynamic Laser counter has been fixed, so that particles are collected. To determine the ratio between particles and fibers a modfied ASTM-F51-68 method can be applied for microscopic analysis instead of the Laser-counter-probe (Fig. 2).

Modified F-51-method
This method derives from the well known Method ASTM-F51-68. The wiper is immersed in minimum 250 ml of clean fluid. Multiple immersions or agitation of the wiper by a biaxial-shaker increase the number of particles released from the wiper. The fluid is then soaked through a micropore filter. The remains an the filter can be counted by microscopical methods. This is the maj or advantage of the method. Another aspect is the high amount of measuring safety rendered by this method.

Fluid-Laser-counter
This method is similar to the Modified F-51-method, only that a probe is taken from the fluid after agitation. The counter automatically displays number and size of particles. The advantage of this method lays in its ease and speedy operation. However, fibers cannot be detected and the method does not permit any qualitative assertion as to the contaminants, like in the previous method (Fig. 3).

Hoechst-surface-friction-method
The not yet so popular test-method deserves more attention because it resembles the reality-stresses having an effect to the moist wiper very well and is therefore often more truthfull in its evidence than other methods.

A clean tray with a slightly roughened surface is being wiped 5 times with a wetted wiper. The quantity of fluid in the wiper can be determined by its total absorption (i.e. 50 % or 100 % of it).

Subsequently the tray is rinsed with 250 ml DI-water and the water is then analysed by Method F 51.

One of the problems with this method is the relatively low number of particles counted in many cases, so that statistical evidence is only arrived upon after microscopically viewing a large number of filters.

Application of reality-based-stress
In order to determine the resulting contamination from reality-based-stresses an a wiper the following tests have been performed (Fig. 4):

- *Removal of a wiper from a package:*

The full package of 50 wipers was fixed onto a small stand. The stand was positioned in a clean-bench. The top edge of the pile was located 6 cm above and in 8 cm distance of the opening end of an aerodynamic Laser-counter-probe. One after the other wiper was removed from the package while the count was taken. The surface of the probe fits 65 times into the surface of the wiper. There-

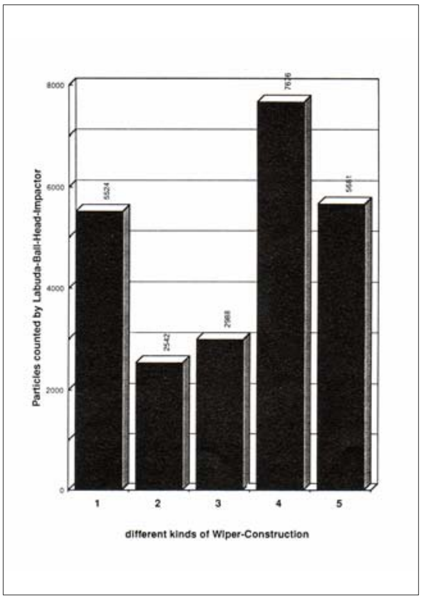

Fig. 1 Particle counts on different wipers with Labuda-Ball-Head-Impactor

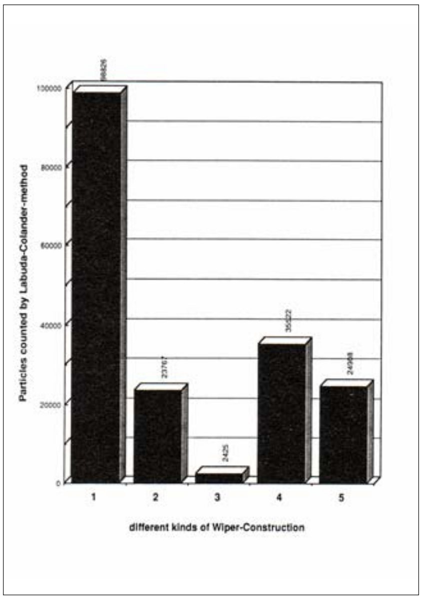

Fig. 2 Particle counts on different wipers with Labuda-Colander-method

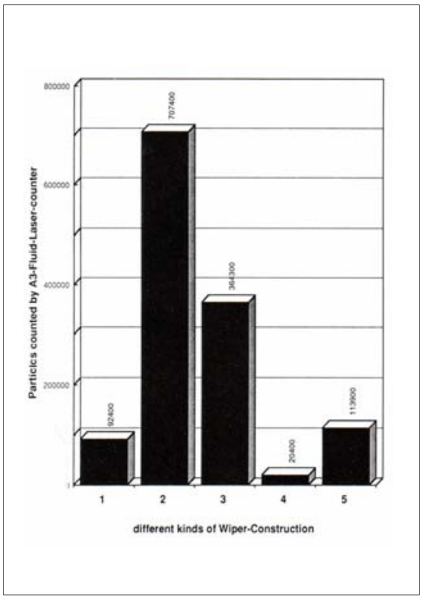

Fig. 3 Particle counts on different wipers withA3-Fluid-Laser-counter

fore the counts were multiplied by a factor of 65 times.

- *Putting wiper aside:*

A ring-stand standing an three supports was arranged in a clean bench so that 6 cm under the ring of 15 cm diameter the opening end of an aerodynamic Lasercounter probe was fixed. 35 times when the count was taken a wiper was placed an the ring.

- *Removal of 20 ml fluid:*

20 ml DI water was given into a clean-bowl and this water was subsequently taken up with a folded wiper, rubbing only as much as necessary for the removal of fluid.

Labuda-Ball-Head-Impactor
The test equipment for particle shedding of sheet materials such as textiles, nonwovens, foils and paper is shown in Figure 5.

The test equipment was invented and many times improved upon within the German VDI-Panel 2083-4 *Surface Cleanliness*. The author expresses his thankful appreciation to his colleagues for their continuous advice.

This equipment makes it possible to carry out particle tests an sheet materials such as textiles, nonwovens, gloves, foils and paper. Higher particle counts are registered using this method rather than other particle counting methods, e.g. the„Flex“ method known in the USA. To carry out the tests described in this paper, the following equipment is necessary:

1. an aerodynamic particle counter of 1 cft/m;
2. an isokinetic probe of 38 mm diameter with connecting hose;
3. a Labuda-Ball-Head-Impactor.

The construction of the equipment was based an a number of fundamental considerations:

A. In various methods of counting

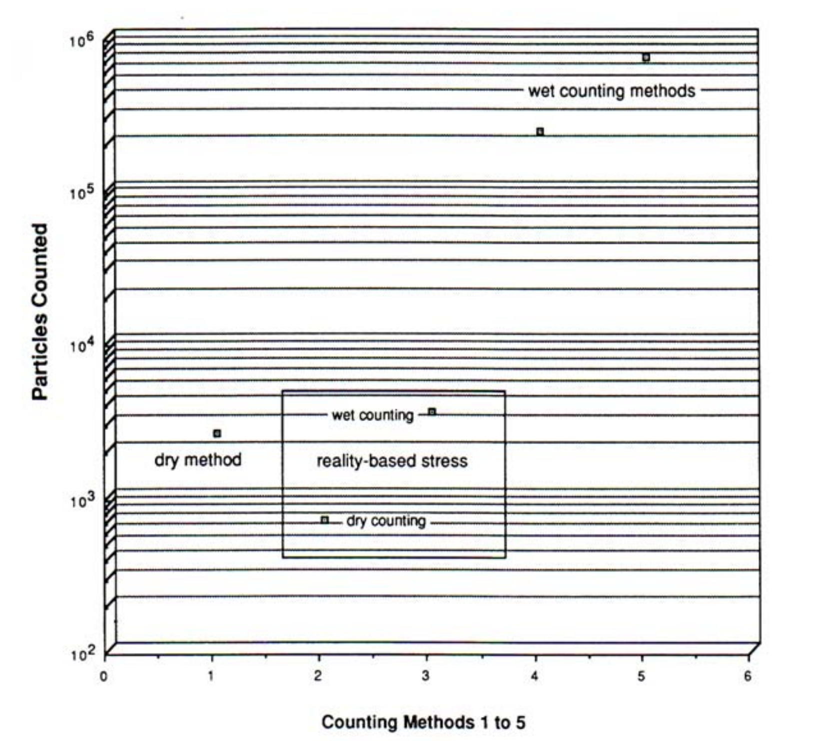

Fig. 4 Reality-based-stress counts (relative to wet and dry counting-methods). Dry-counting-methods: 1. Labuda-Ball-Head-Impactor; 2. Putting wipers aside. Wet-counting-methods: 3. Removal of 20 ml water; 4. Modified F-51-method; 5. A3-Fluid-Laser-counter.

particles from e.g. textiles the agitation energy used to release those particles is applied to the total surface of the specimen (e.g. of a wiper of approximately 200 x 200 mm) whilst only a fraction of the particles can find their way into the opening of the probe. The actual circular area, within which a stream of particles can be measured using an isokinetic probe of 30 mm diameter, is roughly 33 mm diameter, this being mechanically determined by the distance between probe and specimen. The mechanical agitation to the specimen had to be restricted to a circle of about 30 mm diameter.

B. To avoid measuring errors caused by lateral shearing of fibers when inserting the specimen into the equipment, the specimen had to be secured against lateral movement before and during the test, using a specially designed clamping device, allowing insertion with relative ease.
C. During the metering any air flow through the specimen had to be avoided to prevent the familiar defects of method F 51 as well as allowing tests an materials such as foils, gloves etc. where a passage of air through the material is not possible.

D. Testing to be accomplished without specially skilled and trained personnel.

Description of the equipment (Fig. 6)
The test equipment basically consists of two horizontal platforms, one of which can be moved vertically by electrically operated motion. The specimen may be securely clamped between these platforms. In the middle

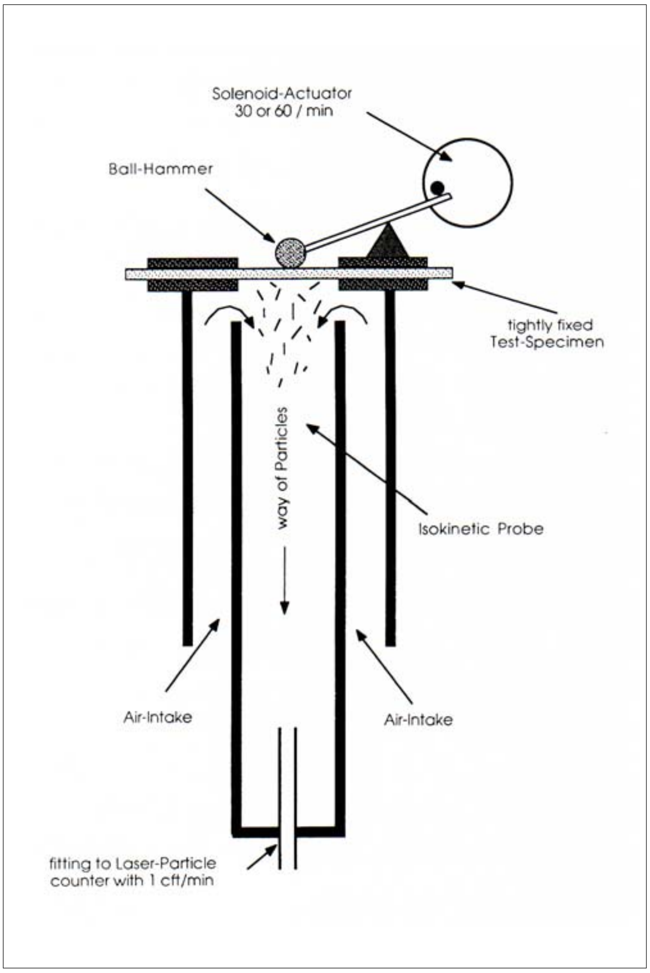

Fig. 5 Labuda-Ball-Head-Impactor. Test-Equipment for particle-shedding of sheet-materials such as textiles, nonwovens, foils and paper.

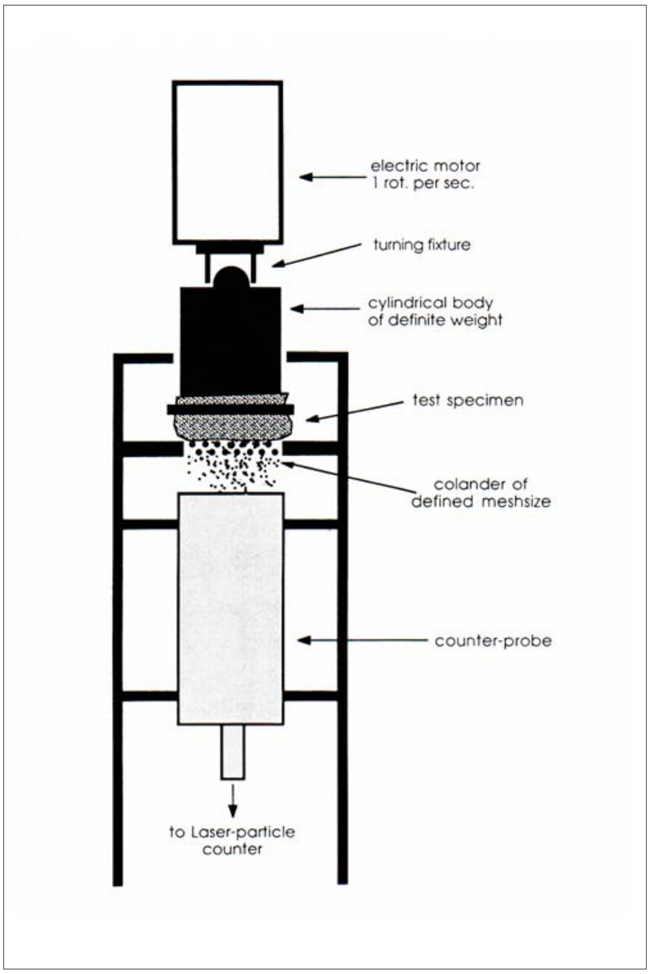

Fig. 6 Labuda-Colander-Test-Euipment

of the platforms there are circular holes, across which the specimen is mounted free like a membrane. One of the holes is surrounded with a rubber ring. When the specimen is placed between the holes to clamp it, this ring presses it into a groove around the hole in the opposite platform thereby stretching the material and providing nearly constant tensioning of the specimens. Above the platform is an impact generator with a ball head which, pivoted and falling freely, gives 60 Impacts/min onto the specimens. Through these impact forces particles are released from their location. To avoid rebound impacts an the specimen, the ball head is caught mechanically after each initial impact. At a slight distance centrally below the platform is an isokinetic probe connected by a pipe to a Laser particle counter for airborne particles with a flow rate of 1 cft/min (e.g. Climet 6300). With the Impact of the ball head an the specimen particles are forced out of it. Therefore to obtain an Optimum count, suction air flow of the probe and are thus counted by the particle counter.

Surrounding the isokinetic probe is an air-intake cylinder preventing air from passing through the specimen, because this can lead to considerable falsification of the test results. The air-intake cylinder also serves to keep away floating particles falling from above, which would influence the results, too.

Suggestions for testing procedures

In their essay „Optimal Test Methods Wanted“, published in Reinraumtechnik 1 / 1988, Ehrler and Schmeer rightly point out the interesting fact, that the results of particle counts an textiles are influenced by electrostatic phenomena when the tests are performed using aerodynamic methods. According to this statement discharging in particle size ranges from 0.3 to 0.5 µm and 1.0 to 2.0 µm lead to higher particle release in electrostatically decharged specimens. In three tested specimens and averaged out for all size ranges, the decharging causes an at least 27 % higher particle release. This increase, however, is almost exclusively confined to the ranges 0. 3 to 0.5 µm, 0.5 to 1.0 µm and 1.0 to 2.0 µm. In certain materials and size ranges this increase can be as much as 180 %. In tests run by the author it was noticed that the results of particle counts an materials were not influenced by static when the relative humidity of the surrounding air was kept around at least 50 % and the specimens had been kept in these conditions for at least 24 hours beforehand. If that is not possible, the specimens can easily be decharged of static shortly before testing using an electric antistatic film dusting device.

Selection of specimens to be tested for particle levels e.g. gloves, wipers and papers, frequently causes problems. In this context the following suggestions for testing procedures are to be observed:

1. Specimens should be selected evenly from the delivered product. Thus, if the delivery is of 100 cartons and 200 specimens are to be taken.

2. Specimens for particle testing should only be unpacked in the cleanroom, otherwise they would be contaminated in normal atmosphere which contains 250.000 to 500.000 particles > 0.2 µm.

3. Specimens should only be handled wearing cleanroom gloves to prevent contamination from skin rub off.

4. The specimens should not be pulled from the pile because this can loosen particles; they should be removed carefully and without friction.

5. Particle counts arrived at thus are only comparable with tests carried out in the same test unit and under the same conditions. Until such time as uniform specifications and test equipment exist everyone will be using his own test methods; data in brochures or particle counts made an other testing equipment are therefore useless for purposes of comparison.

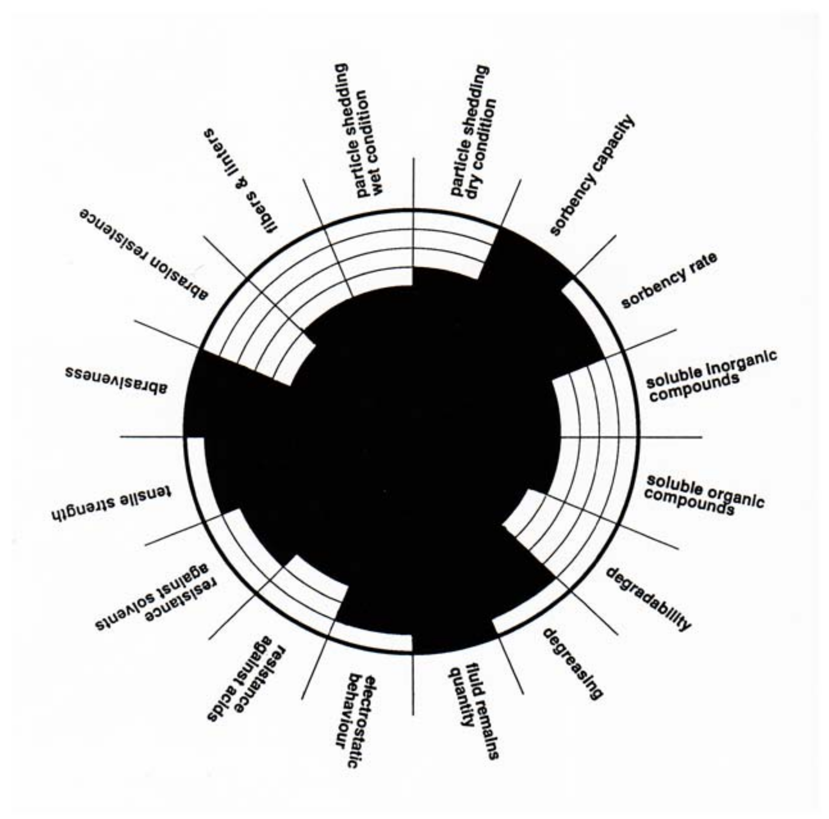

Fig. 7 Hi-Tech-wiping-products. Profile of performance (example)

The profile of performance for Hi Techwiping products is displayed in Figure 7. This is a polarographic distribution of all parameters pertaining to the application of wiping products. This kind of presentation permits a particular ease in the selection of wipers to specific requirements (Fig. 7 is an example).

This paper is dedicated to Ed and Florence Paley in recognition of their prior contamination-control-research.

* Testing procedures for the valuation of functional properties of cleanroom garments. Nov 1988 ITV Denkendorf.