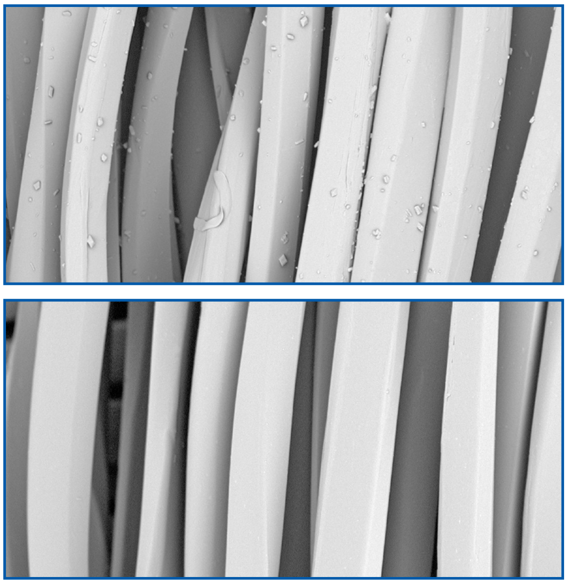

Fig. 1 HiTech cleaning wiper, type Sonit®-MDM section, SEM photo 2500x, image width 107 µm, above: not decontaminated, below: aquatically decontaminated (no particles)

Win Labuda

New ISO Standard for Clean-room Consumables - Commentary

DIN EN ISO 14644-18:2022 draft (ISO 14644-18 abbreviation) Evaluation of the cleanroom suitability of consumables: HiTech cleaning wipers product group

Clear & Clean - research laboratory, as of 06.2023
Version 1.2 E

Content

Introduction

In November 2022, the 2-month appeal phase for the above standard and thus also the cleanroom consumables have now been formally incorporated into the international standard system ISO. From now on, the standard should be a recommendation for how all these cleaning wipers, mops, swabs, gloves, special papers, notebooks, adhesive labels, plastic bags and - last but not least - items of clothing, can be selected, tested and used to the advantage of the user. A great accomplishment considering the many small items, without which a modern cleanroom would not properly function.

So, studying the 50-page draft ISO standard with due care, we are initially impressed by its scope and wealth of detail. Yet questions and concerns still arise. We shall deal with some of them below. For reasons of necessary limitation of scope, from the above range of consumables, we exclusively concentrate on the HiTech cleaning wipers and their cleanliness suitability, application and metrology.

Unlike *standard household* or general commercial cleaning wipers, *HiTech cleaning wipers* address the need for reduced particulate, fiber and chemical release into the cleanroom environment. In particular, the highly decontaminated synthetic cleaning wipers are expected to absorb/remove particulate and filmic contaminants from the object surfaces to the wiper surface and then be entirely removed from the cleanroom environment. The HiTech industries include, above all, the *biotechnology*, *semiconductor*, *laser* and *pharmaceutical industries* as well as *precision optics* and not least the *aerospace industry*. The air and surface cleanliness of clean production environments recommended in accordance with specifications (see DIN EN ISO 14644-1, EG-GMP, VDI 2083 9.1 and 9.2) forces users to use consumables of high application purity [1, 2].

1- Explanation of product-specific standardization issues

Standardization should generally be determined by the expectations of users. Now, in relation to the product *HiTech cleaning wipers*, there is not one user, but many, and they have very different technical requirements regarding the cleaning wiper product. If we look for common ground, there are three criteria that apply to every HiTech cleaning wiper: This is the desire for optimal:

- *solvent absorption,*
- *contaminant retention and*
- *cleaning effectiveness*

With their current technical status and when used effectively, HiTech cleaning wipers are *precision tools of modern manufacturing*. The wiper (size 230 x 230 mm) with the finest structure to us known consists of 470,000 individual meshes with a filament diameter of 4 µm. Some knitted synthetic microfilament yarn wipers are designed to completely remove submicron contaminants from object surfaces in the laboratory or manufacturing environment.

During almost all wiping agent based HiTech cleaning procedures, the cleaning wipers are soaked in a solvent. Partially soaked wipers can be problematic in terms of particle and fiber scattering but also triboelectric sparking (risk of ignition!). A mixture of analytically pure 2-propanol and DI water has proven itself as a standard solvent in cleanroom technology. Alcohol concentrations of 9, 30 and 70%, depending on the respective needs, have become established. However, a not insignificant proportion of the commercially available HiTech cleaning wipers is already soaked in solvents when delivered and is offered packed in a resealable polybag or in a carrying bucket with a sealing lid.

The *cleaning effectiveness* of a certain HiTech cleaning wiper for different surface types or roughnesses and under the influence of different solvents can be determined gravimetrically within the *scope of cleaning procedures* by comparing the *surface contamination* status **before** and **after** a wiping cleaning procedure by precision thickness measurement such as ellipsometry or according to Labuda rotational wipe simulator using laser fluorescence in mass units. The *contamination reduction* (*cleaning effectiveness* taking into account the *cleaning time*) results from the quotient of the two metrologically determined cleanliness states as the most important technical parameter of a cleaning procedure. The surface cleanliness as well as how it is achieved, maintained and reduced are, in *principle, surface-related phenomena* for which the following technical parameters are important for the success of a cleaning procedure:

- Contaminant mass - viscosity [cSt]
- Solvent absorption of the wiping agent [ml], [ml/min]
- Material moisture of the wiping agent [mw|mtr]

- Wiper contact pressure [g|cm^2]
- Average roughness of the object surface [Ra µm]
- Kurtosis of roughness distribution [Sku]
- Relative speed between object surface and wiping agent [m/s]
- Number of surface contact points (papillae) per unit area [number-conc.]
- Tearing strength of the specimen [N]
- Chemical composition of the solvent [example= C_3H_8O]
- Response sensitivity of the measuring devices, example [ng]

In order to *simulate* a wiping cleaning procedure in practice, to determine its process suitability and to determine the cleaning effectiveness of the HiTech cleaning wiper under test, there are certain technical requirements. There are four prerequisites of central importance in terms of simulation technology:

- realistic contamination or a combination of contaminations
- a realistically simulated object surface
- compliance with the uniform relative movement between object surface and specimen with constant contact pressure and not least:
- metrological systems with sufficiently high detection sensitivity for determining filmic and particulate surface contamination.

The prerequisite for the suitability for international standardization of technical components, devices and systems is, among other things, their parameterizability and the international availability of suitable measuring systems. These often reach their physical and technical limits when it comes to measuring surface cleanliness.

In view of the complexity revealed above, it is questionable whether standardization is at all feasible at the limits of the technology, given this multitude of variables. In principle, standardization becomes absurd if the standard state cannot be achieved at a reasonable cost and therefore cannot be appreciated by the professional world. However, standardization also becomes meaningless if the measurement methods specified within its scope demonstrably fail to lead to the desired objective. In this respect, standardization also represents an arbitrary intervention in the design freedom of developers and manufacturers. Every standardization project should therefore be scrutinized by the standardization bodies themselves and with due contact with the interested user groups, also with regard to its necessity, for example to determine from the user‘s point of view whether the regulatory advantage brought about by the standard is lower than with the standardization associated with the manufacturers’ and users’ restrictions and hardships.

The draft standard ISO 14644-18 is - as far as the measurement technology is concerned adopted from an IEST application recommendation - partly burdened by conceptual errors of the former and current American colleagues from the IEST (Institute of Environmental Sciences and Technology - USA). In October 1987, this panel formulated a first practical recommendation for "*Wipers used in cleanrooms and controlled environments, IES-RP-CC04-87-T2*" [3]. With the conceptual errors eliminated, a revised ISO 14644-18 standard would require a changed parameter and different test technique, namely *surface cleanliness after the wiping cleaning procedure*. This is complex to carry out in the lower micrometer and nanometer particle range, but in the mid range of 2.5-10 µm, for example, it is justifiable in terms of cost (see section *Surface-oriented particle measurement technology*, p. 7). That the responsible German standardization body, the working committee (NA 041-02-21 AA Reinraumtechnik SpA CEN/TC 243) and ISO/TC 209 in the DIN standards committee "Heating and ventilation technology and their safety", approved the adoption of the relevant sections 7 and 8 of the current IEST-RP-CC 004.4 recommendation is simply unacceptable and possibly also legally contestable because the error in the standard has been noted in the literature for 1 to 2 decades.

2- Implausible metrological approach

If a HiTech cleaning wiper is tested in terms of its cleaning effectiveness for thin and ultrathin particle and filmic contamination the premise is that the object surface contamination is absorbed/picked up and removed by it in the shortest possible time, and as completely as neccessary. The intention behind the procedure is therefore to achieve an optimally clean object surface. From a procedural point of view, the cleaning wiper used has after performing the cleaning operation fulfilled its function and would be normally disposed of.

The analytical aim is therefore to determine the filmic mass and for particle and fiber number concentration of the contamination on the object surface before vs. after the cleaning procedure has taken place. By comparing the two measured values, the cleaning effectiveness for both types of contamination (filmic, particulate, fibrous) can often be calculated unequivocally. In order to carry out relevant measurements, measuring devices, for determining the number and size of the particular and fibrous matter on surfaces as well as microgram balances for the determination of the mass of the filmic contamination are required.

In principle, the metrological procedure described above is in line with the aim of the goal orientated knowledge acquisition. This however, does not apply to the provisions specified in the practice recommendation IEST-RP-CC 004.4 (paragraph 7 and 8 which has been made part of ISO 14644-18). Knowing the number of particles, fibers and fiber fragments extracted from the wiper or even the extracted mass of chemical com-

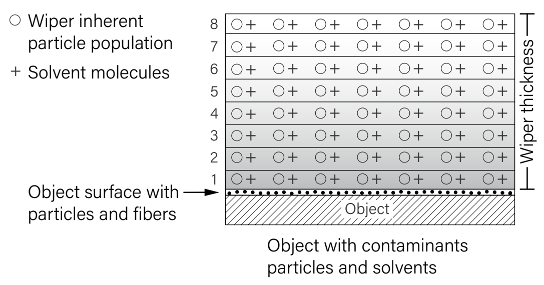

Fig. 2 Schematic, representation of a cleaning wiper in profile, here divided into 8 imaginary layers. During a wiping procedure, there is an interaction between the lower 1 - 3 layers of the wiper and the object surface. However, the test (according to IEST-RP-CC 004.4) is carried out as if all layers were in full-surface interaction with the object surface.

ponents is not meaningful in relation to the mass or number concentration of the particle and fibre contamination left on the *object surface* after a wiping procedure. This is especially attributable to the generated textile abrasion and the displacement forces of the wiping cleaning procedure.
For reasons of explicability, in figure 2, we have divided a cleaning wiper into eight imaginary lateral layers throughout the wiper structure. Assuming the wiper is in a solvent soaked state, there are abrasion-particles, oligomers, fibers and fiber-fragments attached to the yarn-surfaces.

When a solvent soaked wiper comes into contact with a dry object surface there is initially a change in the actual adhesive forces between the interfaces of the particular contamination and the object surface. As a result of this particles adhering to the object surface etc. could be freed from their resting places and become floating in their liquid environment. In fig. 2 the lower layers towards the bottom surface of the wiper will interact with the object surface and its particles, possibly also with the remainders of their original textile furnishing substances. Depending on the surfactant-containing fractions of these substances micelle-formation could occur, which then could result in an even more significant reduction in the adhesive forces between the particles etc. and the object surface.

However, these systems are subject to a certain imponderability because surfactant residues from the textile furnishing of the yarns would come into contact with both, the alcoholic solvent and the contamination of unknown chemical composition on the object surface. On top of all this the effects highlighted above also depend on the degree to which the pore volume of the textile wiper is filled with the impurity mass in the assumptions concerning matters of the degree “fine” or “precision” cleaning of HiTech-surfaces the average mass of impurity should not exceed a thickness of 25% of the wiper-thickness.The upper layers (in fig. 2 shown lighter) are less involved in the exchange of substances with the object surface or not at all depending on the filling degree of the textile pore volume. However, according the IEST test method all particles extracted clearly influence the measurement result because of the extraction procedure intended there. Due to the displacement forces of the wiping procedure, newly developed particles are “pushed away” from the object surfaces, so that at the end, of the cleaning procedure, there are greatly reduced particle quantities here – always provided the object surfaces are of low roughness. Also this effect is not simulated in the IEST-test method.

In this respect, the chosen metrological approach of the IEST test concept is not feasible and must be discarded for any ISO-Standard inclusion. Wiping cleaning should be viewed as a physical-chemical phenomenon because of the various surface interactions involved.

2.1 Surface oriented, particle measurement technology
The question arises as to why in the American test recommendation of the Institute of Environmental Sciences and Technology, Illinois - USA, IEST-RP-CC-004.4 (sections 7 and 8) there is no test method related to a *surface cleanliness parameter* for the post cleaning state of object surfaces, as well as for the particle configuration before and after the wiping cleaning procedure (cleaning effectiveness).

For example, the following recording, options are available:

Particle contact method

- **Particle stamp** (spring-loaded) - Clean Controlling GmbH - D-78576 Emmingen-Liptingen. Adhesive particle collector for microscopic viewing, counting and electronic processing of the data.

Surface particle visualization

- **CC-Microlite** - Clear & Clean GmbH - D-23568 Luebeck. Scattered light visualization device for microscopic viewing, counting and electronic processing for particles on black glass collector plates - Type CC900, CC901

Surface particle measurement

- **Part-Sens 4.0** - PMT GmbH - D-71296 Heimsheim. Surface particle scanner from particle diameter 5 µm on smooth surfaces. On surfaces with higher roughness using an adhesive intermediate substrate (contact method).

- **CIX 100** - Evident Europe GmbH (Olympus) D-20355 Hamburg. Scanning microscope for particle diameters from 2.5 µm to 42 mm.

- **Particle scanning systems** also from Keyence: (VHX6000), Leica (Emspira III) and Zeiss (Axio-Zoom V16).

- **Differential Interference Contrast Microscopy** (DIC) according to Nomarski or Jamin-Lebedeff is very well suited for the visual inspection of film-like and possibly particulate surface contamination up to a magnification of 1000x. This in combination with the linear wiping simulator according to Labuda/Schöttle Type MK1 constitutes a reliable hardware combination for visualizing the cleaning effectiveness of HiTech precision and fine cleaning wipers, also in combination with different solvents. The disadvantage of the method, however, is the non-existing suitability to digitally represent the results.

Use cycles of HiTech cleaning wipers **in the dry delivery state**	Use cycles of HiTech cleaning wipers **in the solvent-soaked delivery state**
1. Dry storage in purity-compliant packaging	1. Moist storage in cleanliness packaging
2. Manual packaging removal	2. Manual packaging removal
3. Solvent impregnation using a spray bottle	3. Folding the wiper twice (e.g., to 8 use surfaces)
4. Folding the wiper twice (e.g. to 8 usable surfaces)	4. Wiper transport to the application site
5. Wiper transport to the application site	5. wischende Reinigungsprozedur
6. Wiping cleaning procedure	6. Disposal of the HiTech cleaning wiper
7. Disposal of the HiTech cleaning wiper	
In this cleaning procedure, the cleaning wiper is only in the dry state during cycles 1 and 2 – i.e., for a period of approx. 4 s = 6.66% of a total of approx. 60 s of the average total period of use. A Gelboflex simulation of HiTech cleaning wipers is therefore not plausible	In this application, the cleaning wiper is in a solvent-soaked state from storage to the cleaning procedure and is never in a dry state. The simulation of a solvent-soaked wiper by a dry one according to the Gelboflex test therefore seems absurd and the method should be withdrawn.

Tab. 1 The individual usage cycles of HiTech cleaning wipers when delivered dry and when soaked in solvent.

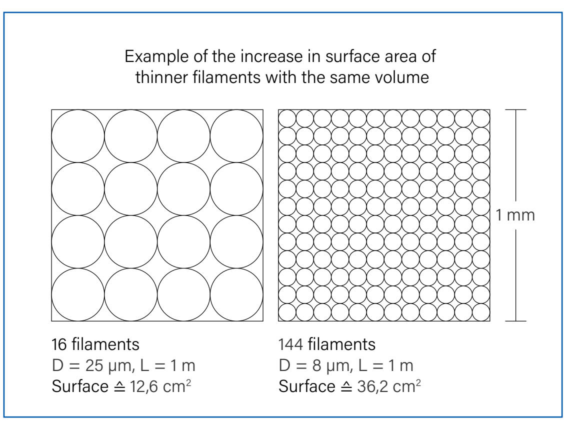

Fig. 3 Schematic, inner filament surface of HiTech cleaning wipers. The thinner the filaments in the yarn strand, the larger the intrinsic yarn surface area, the larger the number of extracted particles.

2.2 Implications of standardization errors

It cannot be denied that the essential specification error identified and documented above actually led to a mususe of the product. The American and consequently the international HiTech industry believed in the correctness of the IEST test method for decades and refrained from using wipers that are more suitable for cleaning. In one case, the author himself found out 20 years ago that the test laboratory of a US company based in the German state of Saxony rejected the technically more effective wiper "A" with micro-filaments because it had been tested according to the IEST method RP-CC 004.2 and naturally released more particles into the test liquid than in the case of the wiper "B" from a US manufacturer made from thicker filaments (although it was less effective in terms of cleaning). If the wiper had been tested using a realistic, i.e., surface-based test-method, wiper A would have been chosen by the user and he would have benefited from its higher cleaning effectiveness, i.e., shorter cleaning time [4].

The following is an explanation of the technical relationships: Knitted wipers made of thinner filaments in the yarn strand (smallest equivalent filament diameter = approx. 2 µm) generally allow a higher number of knit stitches per cm^2 of textile surface to be realized in terms of knitting technology.

Wipers with more knit stitches have (with non-proportional correlation) a higher cleaning effectiveness than those with fewer stitches/cm^2. This is especially true for the contaminant categories of thin and ultrathin organic contamination layers of low to medium viscosity and for submicron particles (microfiber wipers). At the same time, thinner filaments have a larger surface area per unit volume than thicker ones (Fig. 3). Therefore: Based on the assumption of a homogeneous particle distribution, wipers with thinner filaments have a higher particle load per unit volume than those with thicker filaments. An example: When using the Recommended Practice IEST-RP-CC-4.4 - Paragraph 7.1 Sample Preparation (volume extraction), significantly more particles get into the test liquid when testing wipers made of microfilament yarn than when testing wipers with larger filaments diameters.

We find that the number of particles extracted from a HiTech cleaning wiper is completely irrelevant to the assessment of the expected or actual surface cleanliness after a wiping cleaning procedure.

The basis for the dissent is the fact that the method does not integrate the wiping cleaning procedure itself and its effective physical forces, in particular the *particle-rebinding effect* for textile-particles generated by abrasion.

3- The Gelboflex problem (ISO 9073-10)

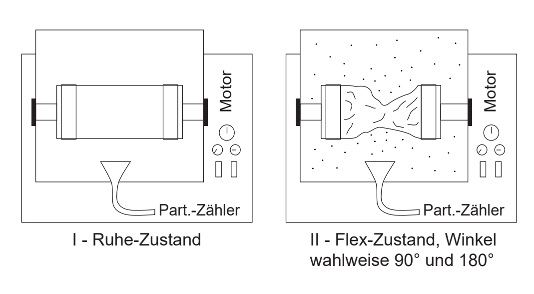

Fig. 4 Schematic of the Gelbo flex tester in two states

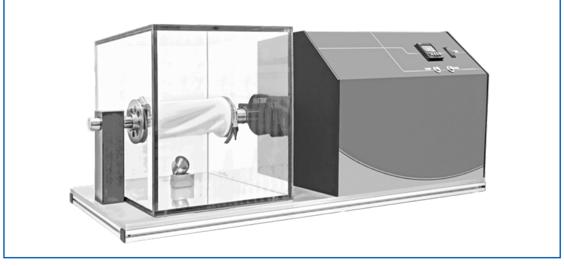

Fig. 5 Flextester according to Gelbo

Elsewhere in ISO 14644-18 (see Tab. D4, Appendix D, page 47) reference is made to the ISO 9073-10 standard - *Test methods for nonwovens in the dry state*, in which one of the so-called *modified Gelboflex methods* is recommended [5]. The device has, we now believe, unfairly gained a certain recognition among cleanroom consumables testers. In principle, it is a test system that is only suitable to a very limited extent even for testing cleaning wipers used in the dry state. In reality, however, HiTech cleaning wipers are *almost never* used in a dry state. If it does happen, then mainly to absorb *liquid spills and splashes* (spill control), with the liquid absorption of the wipers taking effect when the wiper is placed on the spilled liquid or splash, and therefore hardly any particle-generating surface friction occurs. Table 1 shows an overview of the soaking states of HiTech cleaning wipers in the sequence of their usage cycles.

As part of an assumed total usage time of 60 s for a single practical cleaning application of HiTech cleaning wipers, their *exposure time in the dry state* lasts only a few seconds. Experience shows that when carrying out the so-called *modified Gelboflex test* according to ISO 9073-10 [5] (particle release in the dry state), insufficient quantities of particles for statistical test purposes are produced. Therefore test-engineers prescribe excessively long test times, in order to generate unrealistically elevated quantities of particles. Conversely, if practice-orientated test times are adapted to the practice-

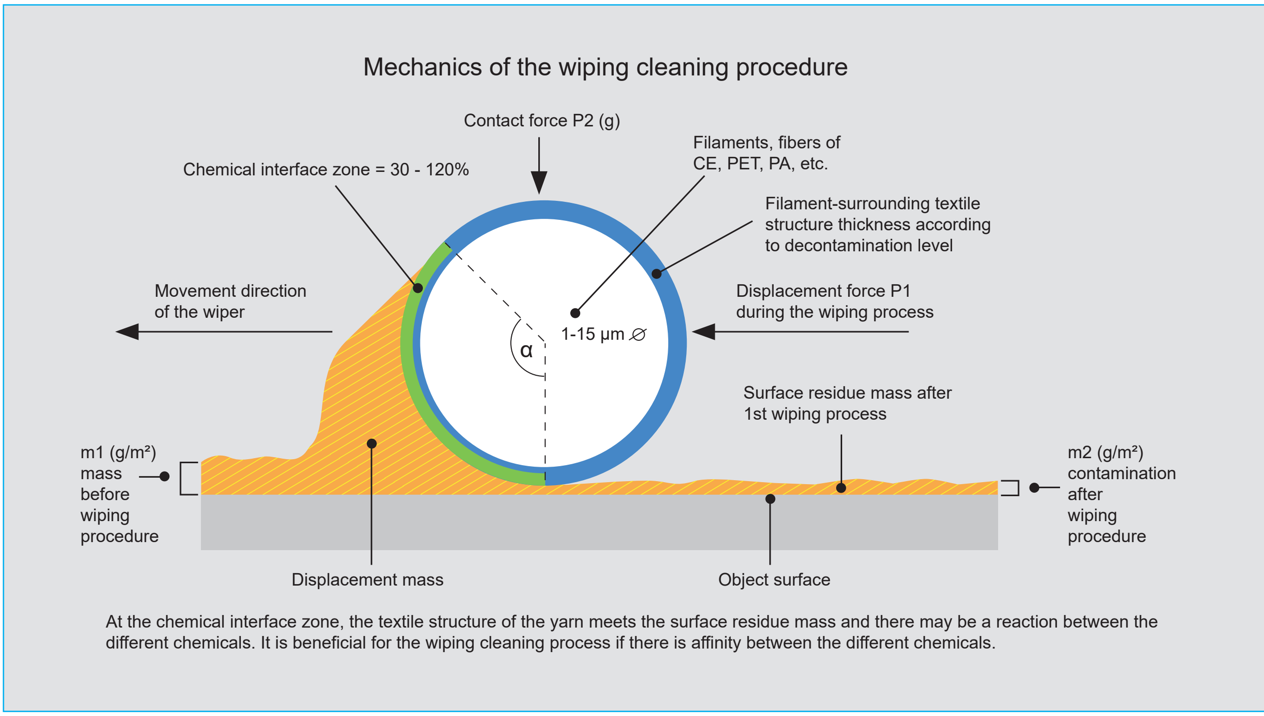

Fig. 6 Explanatory schematic: Mechanics of the wiping cleaning procedure

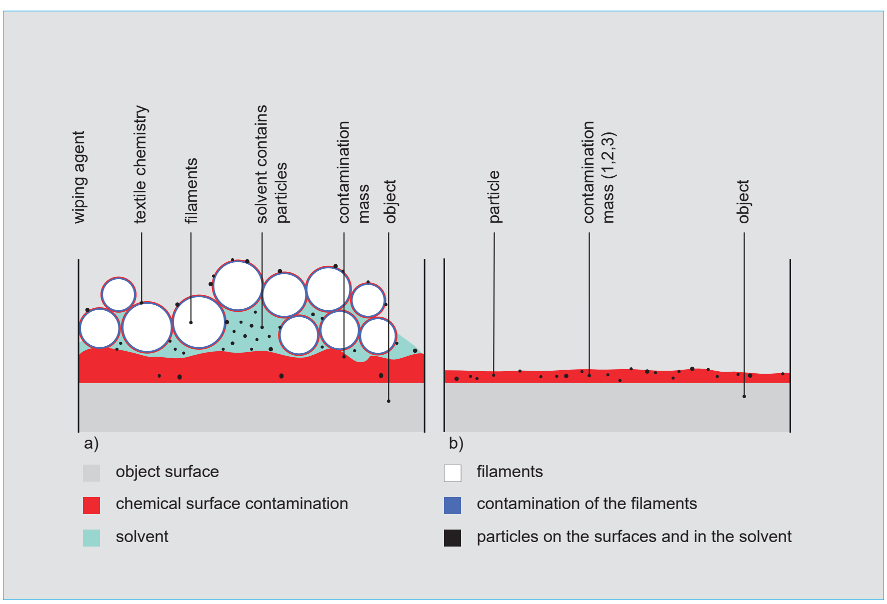

Fig. 7 Schematic, sectional images of a contaminated surface during and after a wiping cleaning procedure, a) solvent-soaked cleaning wiper interacting with the contaminated object surface, b) reduced contamination mass on the object surface after the wiping cleaning procedure

On Fig. 7:
After one or more cleaning procedures according to Fig. 7 a), the following residual substances and objects are on the object surface, see Fig. 7 b)

1 - contamination mass in state b)
2 - filmic and particulate contamination from the wiper filaments
3 - particulate contamination from solvent residues

There is a finite surface contamination state that cannot be reduced by continued wiping cleaning procedures.

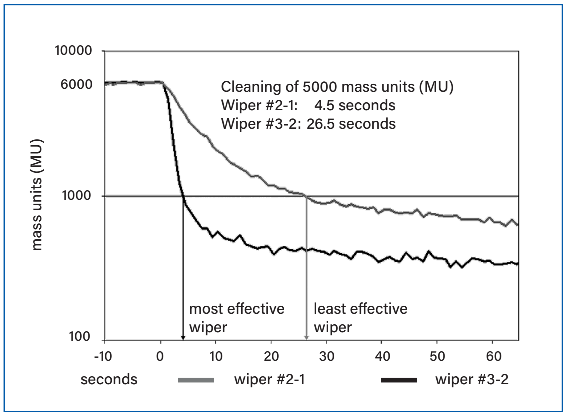

Fig. 8 Rotary wiping simulator Mk III (according to Labuda and Schöttle), range of cleaning effectiveness of commercially available HiTech cleaning wipers, comparison of the wiper with the highest (27 seconds) vs. the lowest (4 seconds) specific cleaning time.

induced particle release, two or three device torsions suffice for adequate simulation. However, the unwanted handling-related particle release during test preparation is often greater than the measurement (torsion)-related release, so that large standard deviations of the measured values arise and experience has shown that the results often prove to be unusable. An improvement in testing technique was achieved through the introduction of magnetic retaining rings for the test specimens. The erroneous scientific test approach, on the other hand, could not be revised. The determining parameter for simulating the wiping cleaning procedure is the friction force occurring with the physical stress applied to the test object. This parameter however, cannot be simulated by twisting the test specimen.

For the above reasons, the Gelboflex method does not rank among the test methods that can be recommended for suitability testing of cleaning wipers. If the author remembers correctly, the method was presented and described by Edward Paley (Texwipe) in May 1985 in the US journal MICRO.

Since then, like Paley, many of us have succumbed to the apparent simplicity of the method, including the author. A non-university automation institute has for a long time even been offering suitability certificates for HiTech cleaning wipers based on this method with a 5-year validity period (- once clean, always clean -) and a leading German cleanroom accessories tradehouse with a certain affinity for cleaning by wiping recently presented a fashionably attractive agitation frame for testing HiTech cleaning wipers in dry condition, even though these are scarcely used practice.

4- Microfilament yarn wipers

HiTech cleaning wipers with elevated precision cleaning effectiveness are usually made of knitted fabrics from synthetic multifilament yarn (PET, PA or PP) and then if necessary, laboriously decontaminated. Multifilament yarn is manufactured in different numbers of filaments and with average diameters from 0.4 to approx. 20 µm. The thinner the filaments of the yarns from which a HiTech cleaning wiper is knitted, the higher their cleaning effectiveness both for particles in the micron and submicron range as well as for thin, film-like contamination in the nanometric range.

The smaller the average filament diameter of a multifilament yarn, the larger the yarn surface area per volume unit (see Fig. 3). Under the assumption of a homogeneous particle distribution on the filament surfaces, the intrinsic particle load in the volume theoretically increases with increasing fineness of the filaments. This means: A polyester wiper with the dimensions 23 x 23 cm² and a mass of 10 g, which is knitted from yarns with a circle-equivalent filament diameter of 10 µm, has a significantly lower intrinsic total surface area than one made from yarns of only 5 µm diameter.

However, it should not go unmentioned that there are several modifying influences on the release of particles from textile structures such as HiTech cleaning wipers. These are:

1. surrounding medium (DIW or DIW+IPA)
2. material moisture
3. type and mass of surfactant furnishing
4. degree of twisting of the yarns
5. texturing of the yarns
6. electric field influences

For the above reasons alone, the type of particle collection specified in the American IEST-RP-CC 4.4 [6] (extracting and counting) cannot provide any insights, e.g., because, according to this method, the measured particle number concentration depends on the filament diameter of the specified yarn. The result determined in this way does not correlate with the most informative cleanliness parameter: *the object surface cleanliness* after a wiping cleaning procedure.

5- Test equipment for particle release from textile fabrics

After we realized that the then available range of testing devices for our special purposes - namely the practical simulation and measurement of the use-related particle release from textile fabrics, in particular HiTech cleaning wipers - was based on a series of incorrect assumptions by former IEST panel members, we decided to develop alternative test devices under the direction of the experienced mechanical engineer Klaus Schöttle. A whole series of simulators were then developed and evaluated by the university affiliated German Textile Research Center North-West (DTNW) in Krefeld. These are in use today and are indispensable for our wiper and cleanliness research [9,14] (see also Section 2, *Surface-oriented particle measurement technology*). Table Section 12 (Appendix A) is intended to briefly explain the methodology of various test methods applied and their simulation approach.

6- Editorial proposals

In the German original text of this article chapter 6 refers to the various technical terms used in here and their semantics in German. Therefore this portion of scripture is not translated into English.

7- Standardization ethics

Standardization of technical products and systems is intended to serve the common good. As a result, it also has an ethical component - we believe equally important as its technical one. Ever since the automotive industry‘s emissions scandal, we have known that we need to revive engineering ethics, especially when environmental issues are involved. This raises a bunch of legitimate questions such as: May standardization serve the purpose of keeping foreign companies out of the domestic market? Are employees of non-university institutes allowed to get involved in standardization work while their institute is active in the commercial test certificate business?

Are exclusion paragraphs such as § 10.2 of the *Guidelines for standards committees in DIN, September 2013 edition*, potentially discriminatory? Should they be abolished?
(Text: *Unless otherwise specified in the rules of procedure of the standards committee, the working committee decides on its composition itself*.)
This means that unwelcome, dissenting or competitors of committee members can be prevented from free access to the standards committees, even in a capacity as corresponding members (as actually happened during the elaboration of ISO standard 14644-18). This encourages clique formation and potentially fraud. But there is also food for thought when there are representatives of almost all nationally recognized manufacturers of a certain product group in a national standards committee, but not a single one from independent scientific institutes or authorities.

It is also problematic if, for example, standards or leading institutes are generously sponsored by manufacturers or associations, as is definitely the case in some countries. Does the committee chair or someone else in such case have to ensure that propriety is ensured in the committee? Do they have a right or even an obligation to enforce this? In the end, standardization can only be successful if it is based on unhindered engineering ethics [7].

And one more comment: With the extensive literature that our laboratory alone have written on the subject of test methods for HiTech cleaning wipers, there is a high probability that one or the other standard engineer knew about the incorrect approach contained in the IEST-RP-CC-4.4. Nevertheless, working group 4 of the IEST did not plan any changes, but carried the error from version 4.3 of the practical recommendation to version 4.4. In our opinion, this very fact also should give food for thought.

8- Summary

8.1 In the new ISO standard 14644-18 (draft), test methods from other specifications, e.g., IEST-RP-CC004.4 Para. 7 and 8, which, due to a test concept error in the wiping agent/cleaning wiper product, are misleading and impractical for determining a theoretical contamination risk (particle number concentration after liquid immersion).

8.2 The above IEST test methods needlessly included in this ISO standard-contain almost exclusively the determination of the product purity (intrinsic purity parameter), while the surface-based *cleaning performance* of the wiper actually required by the user (dynamic performance parameter) is not addressed there at all.

8.3 There is no currently known correlation between the volume purity of a HiTech cleaning wiper (as a spatial structure) and the use-related contamination of an object surface (as a surface entity). A test result based on the IEST method is therefore unacceptable to the user because it is misleading, can lead to incorrect product evaluations and costly false conclusions (see section *Effects of standardization errors*, p. 7).

8.4 The author has therefore made suggestions as to which test and simulation-methods or instruments could perhaps be used to determine the particles and chemicals release from HiTech cleaning wipers with a higher degree of probability. Also the risk of contamination for the clean environment should be assessed more realistically and practically. Therefore this paper should be seen as an invitation to other authors and inventors to come up with new and better ideas.

9- Closing recommendation of the author

The standard DIN ISO 14644-18 (draft), which was completed in 2022, should be finally referred to a competent group of specialists due to the serious conceptual and metrological errors it contains and, where necessary reworked - in the sense of corrected metrology. At the same time, the need to implement such a comprehensive standard for the product cleanroom consumables should be fundamentally rediscussed and reassessed. Perhaps the document can also be simplified in terms of its extended practicality. Exposed specialists from textile technology should be requested for participation in the standardization committee (e.g., in Germany: Professor Dr. Robert Groten, TH Niederrhein, Professor Dr. Jochen Gutmann, University of Duisburg-Essen, Professor Dr. Torsten Textor from the Textile Faculty, Reutlingen University, who has previously dealt with textile-technical tests for the techniques of cleanroom work [9]). In the USA, the internationally renowned technologist Dr. Kash Mittal, one of the most knowledgeable experts in the field of surface cleanliness and adhesion could be contacted. He is the editor or co-editor of over 200 specialist books. Winning him over to a cooperation could be a great achievement.

The problem of volume extraction to gain insight into surface cleanliness after wiping also affects the issues of NVR measurements and ionic contamination, which are affected by the same objectionable standardization errors.

Appendix B to ISO 14644-18 “Effects of consumables on cleanliness levels in cleanrooms” of the new standard should be deleted. The content is not suitable as part or appendix of an ISO standard due to its distance from working practice, although it could be of interest as a technical paper (see the author‘s paper no. 35 in the journal ReinRaumTechnik 2/2017 special supplement on the same topic, where the topic is already discussed we believe for the first time. A cardinal problem is the introduction of hazard classes relating to the different consumables in relation to the environmental cleanliness and the metrology required as a result).

This commentary primarily relates to the HiTech cleaning wipers product. However, the new ISO 14644-18 standard draft from 2022 refers to the entire spectrum of so-called *cleanroom consumables*, the specification of which would have to be re-evaluated separately.

10- References

[1] VDI 2083 sheet 9.2 *Reinraumtechnik - Verbrauchsmaterialien im Reinraum* [Cleanroom technology - consumables in the cleanroom]

[2] DIN EN ISO 14644-1 *Classification of air purity based on particle concentration*

[3] IES-RP-CC-004-87-T - *Testing Cleanrooms* (replaced by [6])

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11- Glossary

object surface	An object's outwardly delimiting surface. Example: window pane, table tennis ball, optical lens, also called extrinsic surface.
HiTech wiping agent	Cleaning agent for wiping up and retaining contaminants in cleanrooms and clean areas.
HiTech cleaning wiper	Textile fabric for absorbing and retaining contaminants in cleanrooms and clean areas.
intrinsic surface	Also called inner surface (in cm^2), volume-related surface of spatial structures whose "inner surface" exceeds the outer surface in terms of area (examples: air and liquid filters, foams, textile structures, soil).
Particle and fiber emission	Particles removed from their previous resting place by physical push or pull forces acting in addition to gravity.
Particle and fiber scattering	Particles, fibers and suspended particles mobilized solely by gravity (particle shedding).
Particle release	General term for the dissolution of particles from their current resting place, without reference to the dissolution forces causing it.
Techniques of clean working	All industrial and manual activities that must be carried out exclusively within the framework of increased environmental cleanliness.

12- Table of test methods and devices - Appendix A

Standards, methods, instruments	Test objective and test result	Explanation of the simulation and criticism
IEST-RP-CC004.4 (Test note in ISO 14644-18)	**searched characteristic** Particle concentration per unit area of a test surface **the wrong method** Particle number concentration in a test liquid	**particle extraction** by immersing and moving the specimen (wiper section) in the DI water bath. Particles in it are collected, counted and classified **criticism** Test result is here: Extracted particles per unit volume of wiper. The result is not related to the characteristic sought: particles per unit area after wiping cleaning procedure.
ISO 9073-10 (Test note in ISO 14644-18)	**searched characteristic** Particle concentration per unit area of a test surface **the wrong method** Particle concentration in the air particle cloud of an agitation environment	**torsional stress** When dry, HiTech cleaning wipers are mechanically loaded by oscillating torsional stress. The air particles released into a test chamber environment are sucked in by means of an air particle counter, electronically counted and classified. **criticism 1** HiTech cleaning wipers are used almost exclusively in a solvent-soaked state. The measured value according to the ISO 9073-10 standard is therefore unrelated to the characteristic sought (cleanliness of the test surface). **criticism 2** The test load of the HiTech cleaning wiper is often chosen too high for reasons of more impressive statistics compared to the load in use (simulation error).
C&C-Methode W-PF-LWS Linear wiping simulator type MK I or MK II - according to Labuda/Schöttle	**searched characteristic** cleaning performance of HiTech cleaning wipers **measured characteristic** cleaning performance of HiTech cleaning wipers	**particle release due to material abrasion** The specimen (cleaning wiper section) is moved linearly over a clean object surface, or alternatively a defined contaminated object surface, according to the reproducible parameters (speed, test weight, test area). The degree of contamination is determined analytically before and after the wiping procedure. **approach** Both the cleaning performance and the material abrasion of HiTech cleaning wipers for particulate and filmic dirt can be simulated under realistic conditions.
C&C-Methode W-PF-RWS Rotation wiping simulator according to Labuda/Schöttle	**searched characteristic** Number of particles released during a wiping procedure **measured characteristic** Number of particles released during a wiping procedure	**particle abrasion** With the Labuda dish method, the specimen (cleaning wiper section) is rotated in a V4A test dish under slight pressure over a defined rough or profiled dish base (roughness, kurtosis, cross profile). Particles released into the dish are then flushed out, counted and classified). **approach** This method simulates the number of released particles that are transferred from a damp cleaning wiper to a test surface during wiping cleaning.
C&C-Methode W-FA Rotation wiping simulator according to Labuda/Schöttle	**performance parameters** Max. cleaning performance per time unit of HiTech cleaning wipers **measured characteristic** mass of contamination removed by a wiping procedure in total and per unit time	**impurity removal** with a HiTech cleaning wiper from a rotating V4A roller that is coated with a thin layer of oil. This is cleaned when the specimen (cleaning wiper) is pressed against the rotating roller by gravity. The mass of the oil film, which decreases over the course of the test, is determined by laser fluorescence measurement. **approach** The removal of contamination by various wiping agents, e.g., thin oil films can be determined in units of mass per unit time.

W= wiping procedure PR= particle release LWS= linear wiping simulation RWS= rotary wiping simulation
RFR= rotary film removal