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Test report

Cleanroom suitability tests on materials

Customer:	Gerflor ZI du Bois des Lots 26130 Saint-Paul-Trois-Châteaux FRANCE
Project Manager:	Dr.-Ing. Udo Gommel
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2 Introduction and objectives

Gerflor is an established manufacturer of chemistry and industrial materials. The components are produced under high quality requirements and are successfully implemented in a wide range of industries.

To secure the market position of Gerflor in the sector of cleanroom technology, the aim is to identify optimization potentials for its products. The suitability of a product for use in clean areas is significantly influenced by the materials used in its manufacture.

The industrial alliance "Cleanroom Suitable Materials CSM" has developed procedures for determining the cleanroom suitability of materials. Depending on the area of implementation concerned, the behavior of materials with regard to particle emission is taken into consideration. The tests are carried out in a standardized way in compliance with relevant national and international norms.

The results obtained provide an objective and substantiated basis for comparison and can be referred to when selecting suitable materials for specific manufacturing environments and areas of implementation. In consequence, this improves the cleanroom suitability of the respective products.

3 Materials tested

TP01	
Description of test piece	Decoclean
Company name	Gerflor
Color	White
Manufacturing date	4/2/2019
Batch number	0902157
Surface	Smooth

Figure 1 Overview of materials tested

	Particle emission	Outgassing	Riboflavin	Chemical resistance	Biological resistance	Antibacterial activity	H_2O_2 absorption/desorption
TP01	X						

Figure 2 Overview of tests performed

4 Overview of results

Particle emission (CSM classification/VDI 2083 Part 17 according to ISO 14644-1)			
Material pairing			ISO Class
Specimen	Counter specimen	Lubricant	
Decoclean	stainless steel 1.3541/1.4034	(none)	**5**

Figure 3 Overview of results obtained

5 Airborne particle emission tests on application with tribological stress according to CSM classification and VDI 2083 Part 17

5.1 Procedure for particle emission tests

5.1.1 Cleanroom-suitable material test bench

A special, cleanroom-suitable material test bench developed by Fraunhofer IPA and called "Material Inspec" is used for the tests. The test bench enables material pairings to be subjected to controlled tribological stress and permits the resulting particulate emissions to be measured without the influence of any cross-contamination.

Figure 4 Cleanroom-suitable material test bench "Material Inspec" developed by Fraunhofer IPA with module for ball on disk test. The module can be replaced if necessary with the module for reel on disc test.

Tribological stress

The cleanroom-suitable material test bench "Material Inspec" enables tests to be carried out using the tribological methods known as **reel-on-disk** and **ball-on-disk** tests.

With the ball-on-disk test, a ball with a **radius r** is pressed onto the face of a disk with a **normal force F**. In the process, the disk rotates with a **frequency f** so that a **relative velocity v** results at the point of contact. The **single measurement track s** is calculated from the circumference of the circle with the radius r. The **number of revolutions N** is the number of rotations completed by the disk beneath the ball during the test.

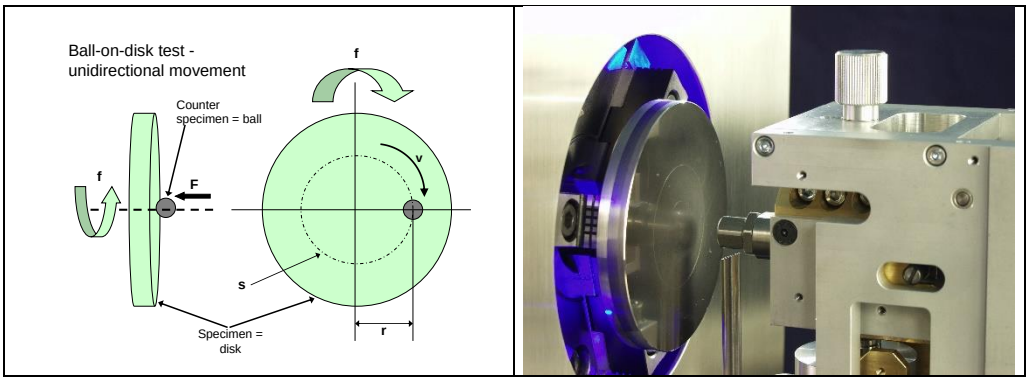

Figure 5 Tribological stress on material pairing – principle of ball-on-disk test

The ball-on-disk test simulates pure dynamic friction between two materials. The point of contact is punctiform; this fact needs to be taken into consideration when assessing the resulting local force applied.

All of the tests which are carried out are model tests. This means that the forces mentioned or applied are similar to but may not be exactly the same as those encountered in reality. This fact requires special consideration when interpreting the results and transferring them to real components.

5.1.1.1 Force transmission and measurement recordings

The normal force is applied using a force transmission unit. The **normal force** applied is recorded continuously during the test using a load cell based on the principle of the strain gauge.

Particle measurement

Particulate emissions are measured directly beneath the point of contact of the material test specimen.
The area of contact has been specially designed from an airflow point of view to ensure that the majority of particles emitted are detected.

Particle emissions are measured continuously during the tests with a measuring interval of 6 seconds (determined by the device used).

5.1.1.2 Test parameters

For the ball-on-disk test the essential test parameters affecting particulate emission include the **single measuring track s,** the **relative velocity v**, the **normal force F** and the **number of revolutions N**. Standardized sets of stress parameters is formed using these values to facilitate the comparison of results obtained from the various tests.

Ball-on-disk test

Set of parameters	s [mm]	v [mm/s]	F [N]	N
ball-on-disk-test				
A13	250	150	3	1500

Figure 6 Defined set of stress parameters; ball-on-disk-test

The amount of stress to be applied to each material pairing is decided upon individually by Fraunhofer IPA on taking into account the quantity of particles generated and the measuring range of the device used in the test.

The following table shows the degree of accuracy achieved when setting the test parameters as well as fluctuations in these parameters which are experienced during the tests.

	Accuracy; maximum variation during test
	ball-on-disc-test
Normal force F	0.01 N; +/- 3 %
Single measuring track s	0.1 mm; n.a.
Relative velocity v	0.5 mm/s; +/- 3 %
Number of revolutions N	+/- 1 %

Figure 7 Degree of accuracy achieved when setting the test parameters and fluctuations thereof during the test

5.1.1.3 Cleanroom environment

All tests are carried out at the Fraunhofer IPA Competence Center for Ultraclean Technology and Micromanufacturing. Measurements are taken in a cleanroom fulfilling Class 1 specifications (in accordance with ISO 14644-1). A vertical, unidirectional airflow prevails in the cleanroom with a first air flow velocity of 0.45 m/s. Environmental conditions are kept constant with a room temperature of 22 °C ± 0.5 °C and a relative humidity of 45 % ± 5 %.

In compliance with ISO 14644-1, Cleanroom "Class 1" means that only two particles the size of 0.2 µm may be found in a reference volume of one cubic meter in the first air (filtered air introduced into the cleanroom). In practical operation, even fewer particles are found in this class.

5.1.2 Particle measuring technique

Optical particle counters are utilized to determine particle emission during the tests.

Optical particle counters function according to the theory of scattered light. Using a sampling probe, a defined volume of air of 1 cubic foot (1 cft = 28.3 liters) is sucked in per minute and guided into a measuring chamber via a tube connected to it. The air sucked in is illuminated by a laser beam. As soon as a particle carried by the airflow is hit by a light ray, the light is scattered and recorded by photo-detectors.

The amount of impulses registered equates to the number of particles found in the volume of air; the height of the impulse gives an indication of particle size.

Depending upon the size and amount of particles generated, the following measuring device is used.

Model	Company	Particle sizes detected
LasAir II 110	PMT AG, Heimsheim	0.1 / 0.2 / 0.3 / 0.5 / 1.0 / 5.0 µm

Figure 8 Optical particle counters used to record particle emissions

The volume of air sucked in by the device is 1 cft/min = 28.3 l/min.
In order to obtain a chronological progression of the particles emitted, particle measurements are recorded every 6 seconds.

5.1.3 Test procedure

The test specimens are **introduced** into the cleanroom before the tests are commenced. In the process, the surfaces of the test pieces and a new ball (for each test series) are cleaned to remove any sedimented particles or filmy contamination which may be present.

Where possible, the **tribological test** is carried out using **one set of stress parameter**, taking into account the quantity of particles generated. To ensure reliability of the results, **10 repeated tests** are carried out for each set of stress parameter.

5.2 Material samples for particle emission tests

Tested materials					
ID[1]	Specimen	Typ of load	Counter specimen	Lubricant	Load
IP Gerflor 10	Decoclean	Ball-on-disk-test	stainless steel 1.3541/1.4034	(none)	A13

Figure 9 Materials for the particle emission tests

For the material pairing IP Gerflor 10, a floor covering founded on a 15 mm thick disk with and a diameter of 140 mm is used as a specimen.
A ball with a diameter of 5 mm and a roughness of max. 0.020 µm, made of stainless steel 1.3541/1.4034, is used as counter specimen.

Photographs of the materials tested:

Figure 10 Materials tested – left: Decoclean; – right: stainless steel 1.3541/1.4034

[1] Material identifier used within this report.

5.3 Particle emission results

5.3.1 Differential progression of particle emission

5.3.1.1 Method

Particle emission is measured every 6 seconds during the application of tribological stress. Depending upon the particle counter used, particle emission is classified into various **particle size channels**. The values measured are expressed **cumulatively**, i.e. the result for one size always includes all particles equal to or larger than the reference size for that channel. For example, the information obtained for the particle size 0.1 µm includes all particles with a diameter of 0.1 µm or larger.

Each diagram shows the progression of particle emission measured in the smallest particle size channel for the ten repeated tests on application of one set of stress parameters. Where appropriate, the **scale of the y-axis** is adjusted, please note that the scale may vary from one graph to another!

5.3.1.2 IP Gerflor 10: Decoclean versus stainless steel 1.3541/1.4034

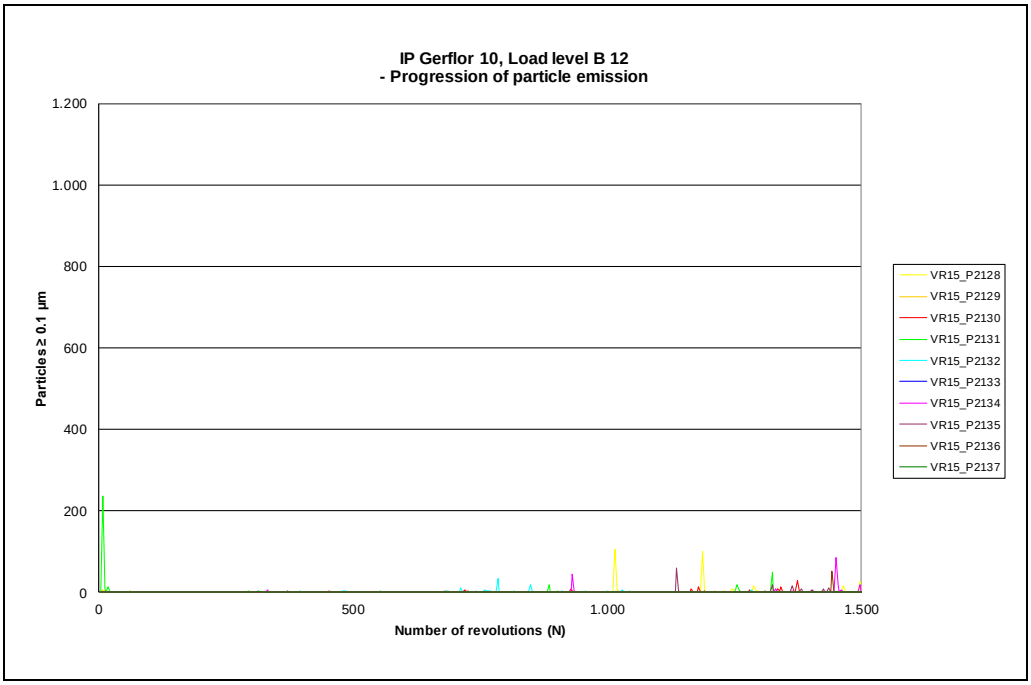

Figure 11 IP Gerflor 10 – progression of particle emission, particle size 0.1 µm, set of stress parameters A13

5.3.2 Size distribution of the emitted particles

5.3.2.1 Measurement Method

From the particle emission progression data, the percentage of each particle size in relation to the total count of emitted particles is calculated. If, for example, the particle sizes 0.1 µm, 0.2 µm, 0.3 µm, 0.5 µm, 1.0 µm and 5.0 µm are recorded by the optical particle counter, the percentage of the

- Particles in the size channel 0.1 µm relates to particles with a diameter of 0.1 µm to 0.2 µm,
- Particles in the size channel 0.2 µm relates to particles with a diameter of 0.2 µm to 0.3 µm,
- Particles in the size channel 0.3 µm relates to particles with a diameter of 0.3 µm to 0.5 µm,
- Particles in the size channel 0.5 µm relates to particles with a diameter of 0.5 µm to 1.0 µm,
- Particles in the size channel 1.0 µm relates to particles with a diameter of 1.0 µm to 5.0 µm,
- Particles in the size channel 5.0 µm relates to particles with a diameter equal to or greater than 5.0 µm.

Values are obtained from all ten repeated tests. The size channel stated is dependent upon the optical particle counter used in the tests.

In order to ensure reliability of the data, only those percentages of particles are calculated where a minimum of 100 particles was observed in the smallest size channel in the course of the entire test.

The following diagrams show the particle size distribution for the material pairings and the corresponding sets of stress parameters. If data is absent in the diagram, this means that the required minimum count of 100 particles was not recorded in the smallest size channel.

5.3.2.2 IP Gerflor 10: Decolclean versus stainless steel 1.3541/1.4034

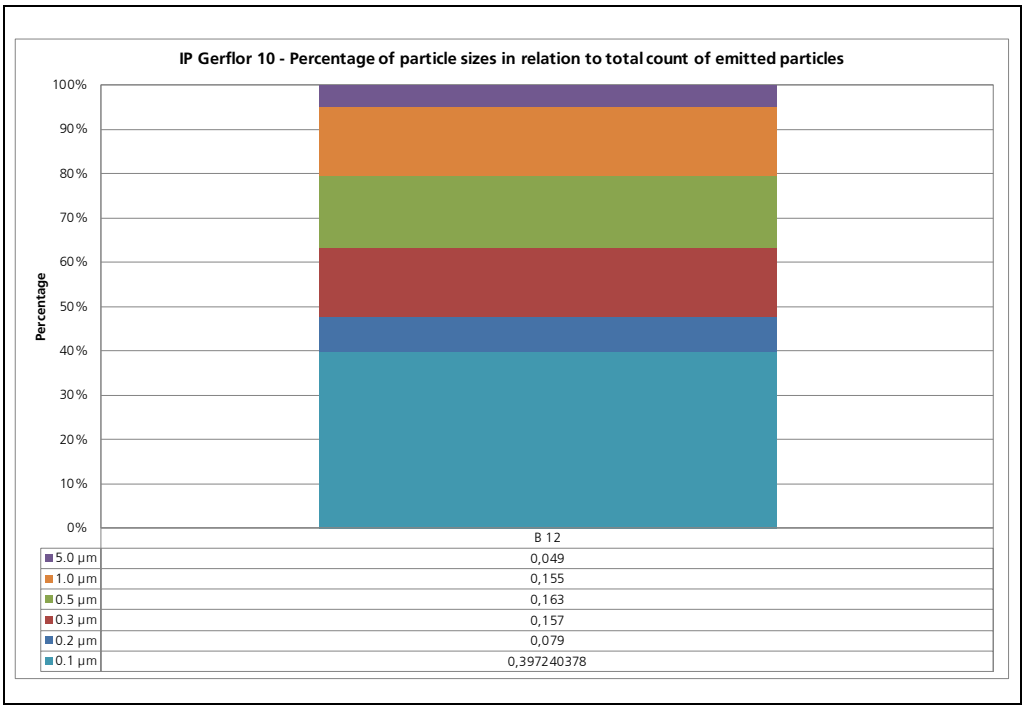

Figure 12 IP Gerflor 10 – required minimum count of 100 particles was not recorded

5.3.3 Classification according to CSM classification and VDI 2083 Part 17

5.3.3.1 Method

In general, airborne particulate contamination is the main issue considered when assessing cleanroom suitability. The most important aspects of this are the size and concentration of airborne particles. Relevant standards state limiting values for the concentration of airborne particles in dependence upon particle size, as found in ISO 14644-1. This norm describes the quality of cleanrooms using Air Cleanliness Classes ranging from 1 to 9. The lowest class, Class 1, fulfills the highest requirements with regard to air cleanliness; the limiting value of particles permitted increases with each successive cleanroom class. Calculations can be made for limiting values of any particle size between 0.1 µm and 5.0 µm for all classes using the method for calculating permitted limiting values as described in ISO 14644-1. The norm states the maximum permitted number of particles of each size for the reference volume (in this case: 1 m^3).

The tests performed record particle emissions generated when tribological stress is applied to material pairings. The amounts of particles measured are dependent upon the material pairing concerned and the set of stress parameters applied. In order to better appreciate the differences, Fraunhofer IPA has developed a method which enables classifications to be made based on the measurement results obtained using the procedure stated in ISO 14644-1.

In accordance with the procedure laid down in ISO 14644-1 for determining the permitted particle concentration of different Air Cleanliness Classes, limiting values are ascertained for the given particle size classes taking the test conditions into consideration. The limiting value is obtained from the test volume of air (sampling time multiplied by the particle counter's constant volume flow of 28.3 l/min) and the permitted particle concentrations (particles/m^3) for the corresponding Air Cleanliness Class and particle size. A comparison of these limiting values with the total counts of emitted particles gives the classification figure for the test. The calculation method has been extended to include particles sized between 0.1 µm and 25.0 µm.
Care is to be taken when comparing the classification figures; consideration of the particle size in relation to the values and also of the set of parameters applied in the respective test.

Then repeat measurements are carried out on each material pairing. This figure is used in the corresponding tables and diagrams.
The following tables show the classification figures obtained for the material pairing. The availability of classification figures for the various particle sizes depends upon the resolution of the optical particle counter used.

5.3.3.2 Overview of classification results

Decoclean							
Load level	Normal force	Detected particle size					
		0.1 µm	0.2 µm	0.3 µm	0.5 µm	1.0 µm	5.0 µm
A13	3 N	2.3	2.8	3.1	3.4	3.7	4.6
						Classification relevant to documents:	5

Figure 13 IP Gerflor 10: Decoclean versus stainless steel 1.3541/1.4034
Overview of classification value attained in accordance with ISO 14644-1

The level of particulate contamination emitted during application of tribological stress on the material pairing **Decoclean versus stainless steel 1.3541/1.4034** lies within the permissible values of the corresponding Air Cleanliness Class **ISO Class 5** in accordance with ISO 14644-1.

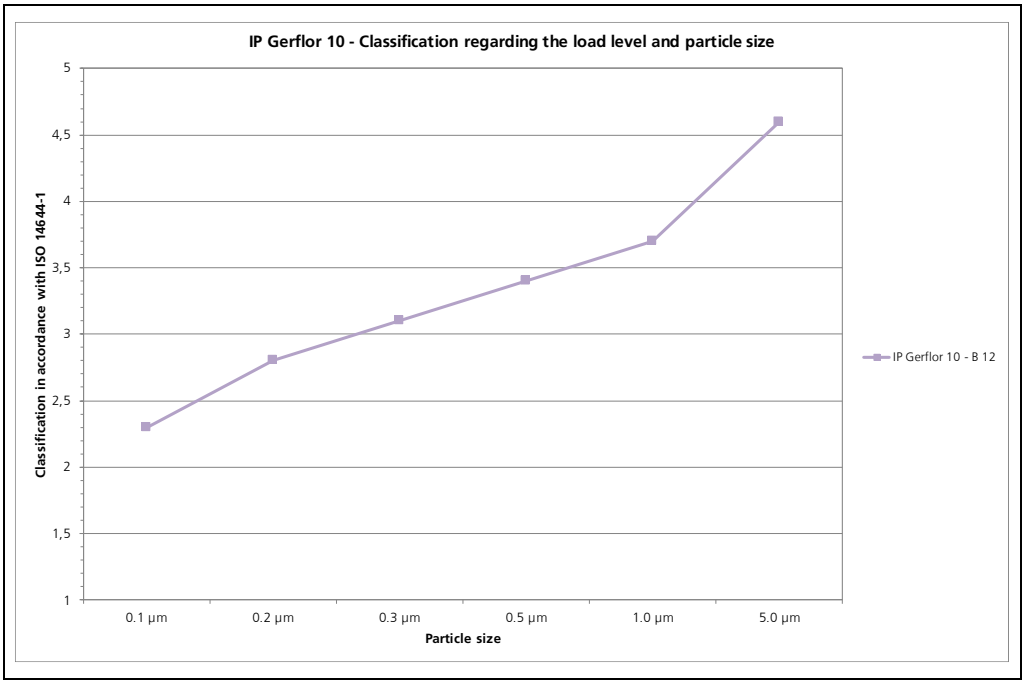

Figure 14 IP Gerflor 10: Decoclean versus stainless steel 1.3541/1.4034
Classification in accordance with ISO 14644-1 in dependence upon the particle size.