CABLE PARTICULATION STUDY FOR CLEANROOM ENVIRONMENTS

White Paper

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Introduction

Particle generation from cables in cable chains is a complex problem for cleanroom environments. To minimize particulation means eliminating as much friction among cables and tubes as possible. Although particulation can be reduced by minimizing moving components, it is impossible to eliminate cable movement in automated manufacturing lines. In addition, the dividers and shelves used to separate round cables and tubes are another source of particulation. If dividers are not used or installed improperly, friction among cables and tubes results in creeping, walking, or twisting of these components, which in turn increases particulation.

As much as possible, system design engineers should reduce the number of moving components and the friction among these components to achieve a low-particulation cable system that will last for tens of millions of cycles.

Cable chain manufacturers provide detailed guidelines for proper cable management to determine the cleanliness of your system. However, cables and cable chains used in cleanroom environments should be tested to identify the particulation characteristics of the cable materials and the interactions of these cables within the overall system.

W. L. Gore & Associates contracted with the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart, Germany, to measure the particulation of two Gore cables for ISO cleanroom certification. While the Fraunhofer certification should only be used to compare cables and cable chains evaluated under the same testing conditions, Fraunhofer's tests show that Gore's cables maintain the lowest particulation levels for repeated flexing.

Test Design

To determine whether particulation was due to the cable or cable chain, Gore tested identical flat cables run through two different cable chains made by the same manufacturer. They selected two non-metal cable chains for the test — a low-vibration, quiet, and clean cable chain (Chain A) and a conventional chain design with links and pins (Chain B). In addition to testing GORE® Trackless High Flex Cables (TK 31540-01), they evaluated three cable chain combinations:

- **Cable Chain A** contained two GORE® High Flex Flat Cables positioned one on top of the other
- **Cable Chain B** contained two GORE® High Flex Flat Cables positioned one on top of the other
- **Cable Chain A** contained two round cables with low particulation jackets positioned beside one another without dividers. To achieve the lowest possible abrasion on these cables, Gore sized the chain with sufficient space so that the cables would not touch.

Figure 1: Optical Particle Counters in Critical Cable Chain Areas

Each cable chain was set up vertically to correspond with the direction of the cleanroom's airflow to ensure that all emitted particles were recorded. Critical areas of the cable chains that would most likely generate particles were identified, and optical particle counters were placed at three positions in these areas on each cable (Figure 1). Each counter would record particles ranging in size from 0.1 to 5.0 micrometers.

The airborne particle emission measurements were recorded for 100 minutes at each point, and each cable was tested at velocities of 0.5, 1.0, and 2.0 meters per second.

Fraunhofer then calculated the maximum number and arithmetic mean of particles by size (0.1, 0.2, 0.3, 0.5, 1.0, and 5.0 micrometers) at each measurement location to determine the amount of particulation following the criteria set forth in Guideline VDI 2083 Part 9.1. To determine the operating utility of each cable chain system, Fraunhofer used these results to identify the measuring point that recorded the highest amount of particulates. The operating utility was then used to classify the ISO cleanliness classification.

Test Results

The optical particle counters registered that GORE® Trackless High Flex Cables and Cable Chain A containing GORE® High Flex Flat Cables emitted zero particulates at each measurement point (Tables 1 and 2). Using the probability calculations set forth in VDI Guideline 2083 and ISO 14644-1, Fraunhofer determined that these cables had less than 0.1% probability of emitting particulates at each of the tested velocities.

Table 1: Results of GORE® Trackless High Flex Cables

Particles per Cubic ft. µm	Velocity			Probability of Exceeding Limits %
	0.5 m/s	1.0 m/s	2.0 m/s	
0.1	0.0	0.0	0.0	< 0.1
0.2	0.0	0.0	0.0	< 0.1
0.3	0.0	0.0	0.0	< 0.1
0.5	0.0	0.0	0.0	< 0.1
1.0	0.0	0.0	0.0	< 0.1
5.0	0.0	0.0	0.0	< 0.1

Table 2: Results of GORE® High Flex Flat Cables in Cable Chain A

Particles per Cubic ft. µm	Velocity			Probability of Exceeding Limits %
	0.5 m/s	1.0 m/s	2.0 m/s	
0.1	0.0	0.0	0.0	< 0.1
0.2	0.0	0.0	0.0	< 0.1
0.3	0.0	0.0	0.0	< 0.1
0.5	0.0	0.0	0.0	< 0.1
1.0	0.0	0.0	0.0	< 0.1
5.0	0.0	0.0	0.0	< 0.1

Cable Chain A containing round cables with low-particulation jackets emitted particles at varying rates, depending on the velocity (Table 3). Using the calculations set forth in VDI Guideline 2083 and ISO 14644-1, Fraunhofer determined that this cable chain/cable system has a 3% probability of emitting particulates.

Table 3: Results of Round Cables in Cable Chain A

Particles per Cubic ft. µm	Velocity 0.5 m/s	Probability of Exceeding Limits %	Velocity 1.0 m/s	Probability of Exceeding Limits %	Velocity 2.0 m/s	Probability of Exceeding Limits %
0.1	0.3	< 0.1	2.5	< 0.1	0.0	< 0.1
0.2	0.1	< 0.1	1.3	< 0.1	0.0	< 0.1
0.3	0.1	< 0.1	1.0	< 0.1	0.0	< 0.1
0.5	0.1	0.2	0.7	< 0.1	0.0	< 0.1
1.0	0.0	3.0	0.4	0.8	0.0	< 0.1
5.0	0.0	< 0.1	0.0	3.0	0.0	< 0.1

Cable Chain B with GORE® High Flex Flat Cables also emitted particles at varying rates, depending on the velocity

(Table 4). Using the calculations set forth in VDI Guideline 2083 and ISO 14644-1, Fraunhofer determined that this cable chain system has as much as 3% probability of emitting particulates.

Table 4: Results of GORE® High Flex Flat Cables in Cable Chain B

Particles per Cubic ft. µm	Velocity 0.5 m/s	Probability of Exceeding Limits %	Velocity 1.0 m/s	Probability of Exceeding Limits %	Velocity 2.0 m/s	Probability of Exceeding Limits %
0.1	1.3	< 0.1	0.6	< 0.1	1.7	< 0.1
0.2	0.5	< 0.1	0.3	< 0.1	0.9	< 0.1
0.3	0.4	< 0.1	0.3	< 0.1	0.7	3.0
0.5	0.4	< 0.1	0.3	< 0.1	0.6	3.0
1.0	0.3	< 0.1	0.2	< 0.1	0.5	3.0
5.0	0.2	1.6	0.1	0.6	0.1	2.0

The test results indicate that velocity played a factor in the amount of particulation for some of the cable chain systems but not all. Based on ISO guidelines, Fraunhofer determined the ISO 14644-1 cleanroom certifications based on the velocity that generated the most particulation (Table 5).

Table 5: ISO Cleanroom Certifications

Cable Type	Cable Chain	Velocity			ISO Class Certification
		0.5 m/s	1.0 m/s	2.0 m/s	
GORE® Trackless High Flex Cables	None	Class 1	Class 1	Class 1	Class 1
GORE® High Flex Flat Cables	A	Class 1	Class 1	Class 1	Class 1
GORE® High Flex Flat Cables	B	Class 5	Class 5	Class 5	Class 5
Round Cables	A	Class 3	Class 4	Class 1	Class 4

Conclusion

GORE® Trackless High Flex Cables are the cleanest, high-flex option for consistently low particulation. Engineered for applications with stroke lengths up to 1.5 meters, these cables eliminate the need for cable chains, dividers, and shelves, so they can reliably be used in Class 1 cleanrooms.

Testing identical GORE® High Flex Flat Cables with two different cable chains indicates that the particulation was caused by the cable chain, not the cable. They maintained the lowest particulation levels for repeated flexing in cable chains. These cables have a unique, low friction, extremely low particulation jacket, which qualifies for ISO 14644-1 Class 1 cleanroom applications. In addition to eliminating the need for dividers and shelves in cable chains, the flat construction distributes the force placed on the cable jacketing, which translates to less wear on the cable jacket and less friction caused by movement. By placing all electrical cables, hoses, and fiber optic constructions inside Gore's cables, smaller and lighter cable chains can be used.

With the round cable chain system, Gore wanted to achieve the lowest amount of particulation and, therefore, used only two cables with low particulation jackets in a low-vibration, clean cable chain without dividers or shelves. Because the particulate results varied depending on the velocity, this cable system can be used in ISO 14644-1 Class 4 cleanrooms. This design, however, does not accurately reflect cable chain systems used in the real world because most of them are filled with as many cables, tubes, dividers, and shelves as possible, which increases the amount of friction and particulation that can occur.

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