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Cables for CLEAN rooms

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Key points:

- Cables that bump up against each other in cable carriers can be a source of contamination.
- Cable materials have a large impact on the amount of particulation a given cable will generate.

Resources:
W.L. Gore & Associates, *www.gore.com*

Gore particulation whitepaper, *www.gore.com/particulation*

Background on clean-room classifications, *http://en.wikipedia.org/wiki/Clean_rooms*

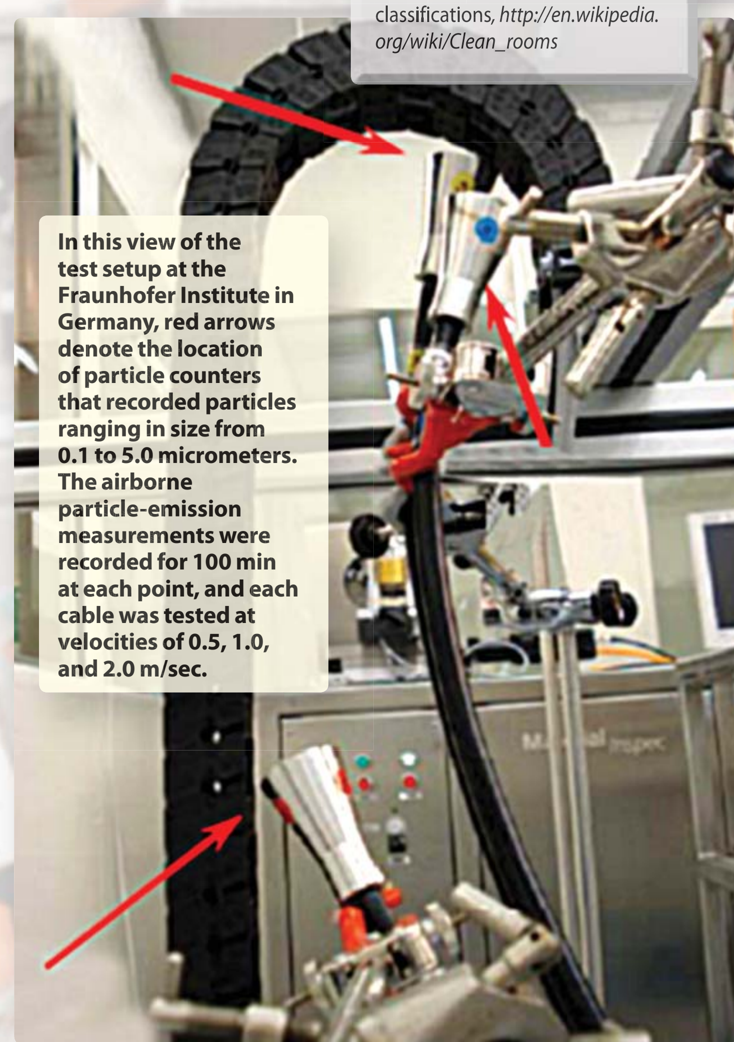
Moving cables generate particles, but only recently has this phenomenon been quantified.

In clean rooms, it is imperative that dust and particulates be eliminated to a high degree. But particulates are problematic for clean-room cable systems that flex or rub up against other items.

In that regard, cables for motion-control equipment sitting in clean rooms are especially prone to throw off particulates. For one thing, cable movement within the cable chain contributes to particulation. Second, the amount of force placed on cable surfaces can cause particulation at those critical points — whether the force is caused by continuous flexing or arises from the weight of the cables themselves.

For these reasons, cable systems for clean rooms must be designed to reduce friction to keep particulation down. And reducing friction improves cable performance and life. Remarkably, there has not been a lot of third-party testing to verify particulation behavior in cables.

Recently we contracted with the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Germany to measure the particulation of cables and cable chains for ISO clean-room certification. Fraunhofer tested GORE™ Flat Cables inserted in two different cable chains and a set of two round cables in a low-vibration cable chain. The round



In this view of the test setup at the Fraunhofer Institute in Germany, red arrows denote the location of particle counters that recorded particles ranging in size from 0.1 to 5.0 micrometers. The airborne particle-emission measurements were recorded for 100 min at each point, and each cable was tested at velocities of 0.5, 1.0, and 2.0 m/sec.

cables were constructed with a low-particulation jacket material. In addition, tests covered GORE's self-supported flat cable, which does not need a cable chain. Several interesting facts emerged that have a direct impact on cable management, particularly with respect to cable movement and velocity.

Round-cable movement

Round cables must be prevented from generating particles, they can't move within the chain. Otherwise, they tend to rub together and shed particles. Any movement results from both the acceleration of the cable chain and friction between the cables and the cable-chain components.

The conductors within the cable also move from the flexing motion energy which results in twisting, kinking, and walking. If the friction between conductor insulation, cable shielding, or jacketing is sufficiently high, the conductors creep within the cable. This action can result in kinks and a ruptured cable jacket. Such movement of the conductors causes round cables to corkscrew, which, in turn creates particles and causes conductors to fail.

Probability for particulation emission

CABLE/CABLE CHAIN	PROBABILITY
GORE™ Trackless Cable	Less than 0.1 %
Chain A with GORE™ High Flex Flat Cables	Less than 0.1 %
Chain B with GORE™ High Flex Flat Cables	3 %
Chain A with round cables	3 %

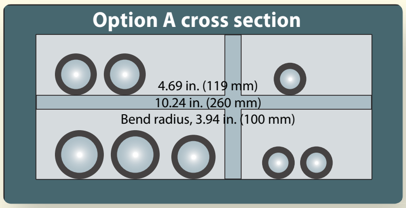
ISO Certification Class

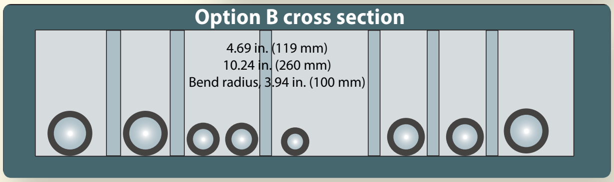
CABLE	ISO CERTIFICATION CLASS
GORE™ Trackless Cable	Class 1
Chain A with GORE™ High Flex Flat Cables	Class 1
Chain B with GORE™ High Flex Flat Cables	Class 5
Chain A with round cables	Class 4

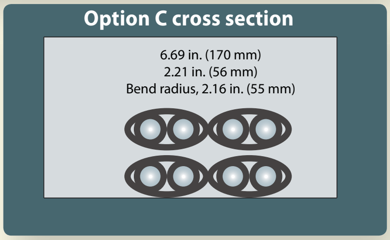
Particulation study details

The Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Germany measured the particulation of flat, round, and self-support cables for ISO clean-room certification. The setup for the rolling-flex-particulation test used two cable chains. Chain A was a low-vibration, quiet, clean-cable chain designed for use in ISO Class 1 Clean rooms. Chain B was a conventional chain designed with links and pins.

There were four cable-system configurations. One was a GORE™ Trackless Cable, a self-supported cable system that does not require a cable chain. Chain A was then configured to contain two GORE™ High Flex Flat Cables, positioned one on top of the other. Chain B was also configured to contain two GORE™ High Flex Flat Cables, positioned one on top of the other. Finally, Chain A was configured with two round cables having low-particulation jackets, positioned beside one another without dividers.







Particulation tests used a narrow chain with dividers and shelves separating round cables (option A), a wide chain with round cables side-by-side separated by dividers (option B), and a cable chain containing two flat cables (option C).

Technicians positioned three optical particle counters in critical areas on each cable and cable-chain combination that were most likely to generate particles. Each counter recorded particles ranging in size from 0.1 to 5.0 mm. Each cable was tested for 100 min at velocities of 1.64 (0.5 m), 3.28 (1.0 m), and 6.56 fps (2.0 m). Counters recorded airborne particles for 100 min. Using criteria set forth in Guideline VDI 2083 Part 9.1, Fraunhofer calculated the amount of particles at each measuring point and then determined the operating utility of each cable chain system. The operating utility was then used to classify the ISO cleanliness classification.

Test results indicated that the optical particle counters registered zero particulates at each measurement point for the self-supporting cable and for cable chain A with the flat cables. Cable chain B with the flat cables emitted particles at varying rates depending on the velocity — rates ranging from 0.1 to 1.7 particles/ft^3. Cable chain A containing round cables was also affected by velocity, emitting a range of 0.0 to 2.5 particles/ft^3.

Using calculations set forth in VDI Guideline 2083 and ISO 14644-1, Fraunhofer determined the probability that each cable and cable-chain system will emit particulates, as described in the accompanying table. Based on ISO guidelines, Fraunhofer also determined the ISO 14644-1 clean-room certifications based on the velocity that generated the most particulation, again depicted in the table.

Finally, it should be noted that the chain in these tests was sized to give the lowest possible abrasion on cables. So there was enough space to ensure cables would not touch. The results of testing done in a controlled environment such as at the Fraunhofer Institute should only be used to compare cables and cable chains used in similar environments.

The general rule of thumb for cable-chain designers is to allow space around each cable equaling 10% of the cable diameter. Shelves and dividers are added to the cable chain to separate and manage the movement of cables, so cables won't rub against one another.

While dividers and shelves are necessary when working with round cables, they significantly boost the overall height and width of the cable chains. If any cables are less than half the height of the chain, then a shelf should be added to prevent movement and buckling of these smaller cables.

The particulation study used only two cables with low-particulation jackets in a low-vibration, clean cable chain without dividers or shelves. The round cable system shed enough particles to qualify only for ISO Class 4 (Fed. Std. 209 Class 10) applications. The study's design, however, does not accurately reflect cable-chain systems used in the real world. Most such systems have cable chains filled as much as possible. So cable chains filled with round cables, tubes, dividers, and shelves will most likely emit even more particles.

The test results also indicated that velocity is a factor in how much particulation some types of cables and cable chains generate. But not all such gear behaves this way. Velocity and high acceleration cause particulation by generating high stress during flexing and friction as cables and chain components move against each other.

Flat cables

A flat cable can be an alternative to using round cables that require dividers and shelves. The study at Fraunhofer demonstrated that GORE™ High-Flex Flat Cables have a consistently low particulation that makes them candidates for Class 1 clean rooms. GORE™ Trackless Cables, appropriate for applications with stroke lengths up to 1.5 m, reduced the weight and stress of cable systems by eliminating the need for cable chains, dividers, and shelves.

For applications with longer stroke lengths, flat cables maintained the lowest particulation levels for repeated flexing in cable chains. Tests of the same flat cable in two different cable chains indicated that the particulation came from the cable chain, not the cable. A flat cable distributes weight across the width of the cable jacket, whereas the weight of a round cable concentrates on a small section of the jacket. The distribution of weight inherent with flat cables reduces force-concentration points among the cables stacked in the cable chain. This distribution of weight causes less friction during movement and less wear on the cable jacket. The flat construction also eliminates the need for cable-chain dividers and shelves, reducing the total weight of the cable system. Consequently, many systems can use a smaller cable chain than would otherwise be necessary.

The construction of flat-cable jackets is noteworthy. Providing a protective space for the individual conductors to move and relax as the cable flexes keeps the conductors from kinking and twisting. Therefore, velocity and acceleration of a flat cable does not harm conductors because the jacket absorbs the stress that is normally translated to the conductors.

In addition, the jacketing materials have an impact on cable management. For example, Gore uses a lightweight expanded polytetrafluoroethylene (ePTFE) in its jacket construction. This is half to a third the thickness of most round cable jackets and lets the cable meet UL requirements for safety and flame resistance.

In most of today's cable applications, the space available for cable-chain systems is extremely tight. Use of flat cables substantially reduces the total size and weight of the cable chain — often by as much as 50% of the chain width — because flat cables need no additional space for shelves and dividers.

For example, consider an application that needs a cable chain with a stroke length 3.3-ft long (1.01 m), a velocity of 2 fps (0.6 m/sec), an acceleration of 32.1 fps^2 (9.8 m/sec^2), and which executes 5 million strokes annually. Suppose the instrumentation needs eight round cables ranging from 0.23 to 0.35 in. (5.84 to 8.89 mm) in diameter. These cables can be arranged in the cable chain in three different ways.

First, individual round cables could sit in a narrow chain stacked and separated by dividers and shelves. Alternatively, individual round cables could go into a wide chain placed side by side with multiple dividers. Or, conductors could be arranged in two flat cables, each containing four round cables, stacked one on top of the other in a chain with no dividers.

Option A requires one divider, two side plates, and one shelf, installed in a cable chain 4.69-in. (119-mm) wide. Option B requires six dividers installed in a cable chain 3.9-in. (99-mm) high. Both cable chains are 10.24-in. (260-mm) wide, with a bend radius of 3.94 in. (100 mm). On the other hand, Option C with two flat cables needs a cable chain that is only 2.21-in. (56-mm) high and 6.69-in. (167.9-mm) wide, with a significantly lower bend radius of 2.16 in. (55 mm). Incorporating the eight cables into two flat cables significantly reduces the size of the cable chain and eliminates the need for dividers and shelves. **MD**