GORE® Automation Cables

White Paper

WIRING THE FUTURE: CABLES IN LIGHTWEIGHTED AND COGNITIVE ROBOTS

Abstract

In lightweight and cognitive robots, achieving peak performance depends on the seamless integration of advanced components. Among these, flexible cables stand out for their pivotal role in enhancing operational adaptability, resilience, and efficiency. This white paper explores the critical importance of flexible cables in optimizing signal integrity, electrical performance, and environmental resilience within robotic systems. Just as the human body cannot survive without a functioning nervous and vascular system, robots cannot function without cables. They transport the required energy and information from A to B and ensure smooth interaction between all components. For over 60 years, Gore connects with our customers and partners across industries to understand, anticipate and find solutions to real-world problems. We test all our products extensively in laboratories under real-life conditions to ensure they last a long time — even in the most challenging environments where the cost of failure is high. Using our materials expertise and market insight, we partner to create meaningful, fit-for-use solutions that perform as promised and deliver shared value.

Connections that Count: Exploring the Vitality of Cables in Robotics

Flexible cables serve as the backbone of robotic systems, enabling the fluid movement of essential moving parts and joints. Beyond mere conduits, these cables are lifelines, tasked with enduring torsional stress while maintaining signal integrity and electrical performance. Their role in ensuring seamless operation cannot be overstated.

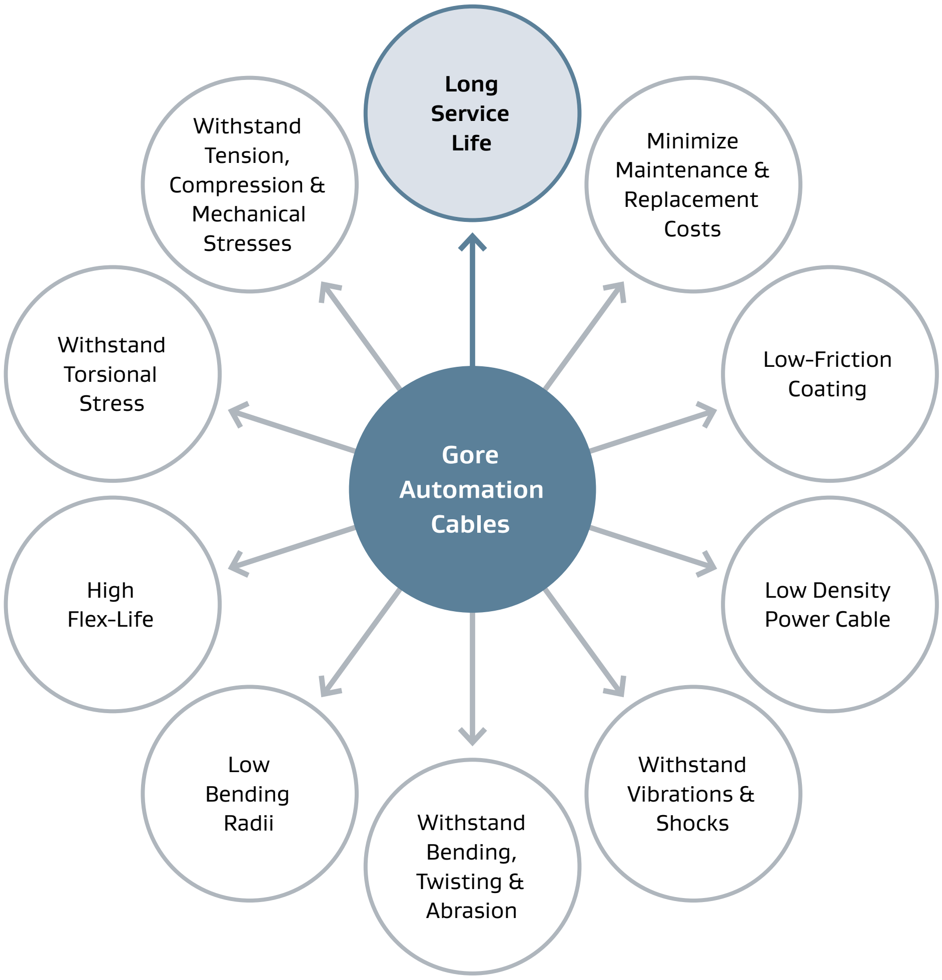
In addition to withstanding torsional stress, flexible cables must endure frequent bending cycles without succumbing to failure or performance degradation. High flex life is crucial for their longevity and reliability, especially in demanding operational environments. Their ability to rebound to their original shape after being stretched or compressed is paramount, ensuring consistent performance over time.

Durability and longevity are equally critical for flexible cables, which must withstand bending, twisting, and abrasion without compromising functionality. By displaying resilience in harsh conditions, flexible cables minimize the risk of damage, offering significant long-term benefits for robotic applications.

To further enhance performance, flexible cables often feature a low-friction coating. This specialized coating reduces wear and friction, particularly in cable carriers or conduits, thereby prolonging the lifespan of the cables. Whether facing rubbing or contact with other components, the low-friction coating mitigates potential issues, thereby enhancing overall efficiency and reliability in robotic systems.

Together, improving life

Connections that Count:
Exploring the Vitality of Cables in Robotics



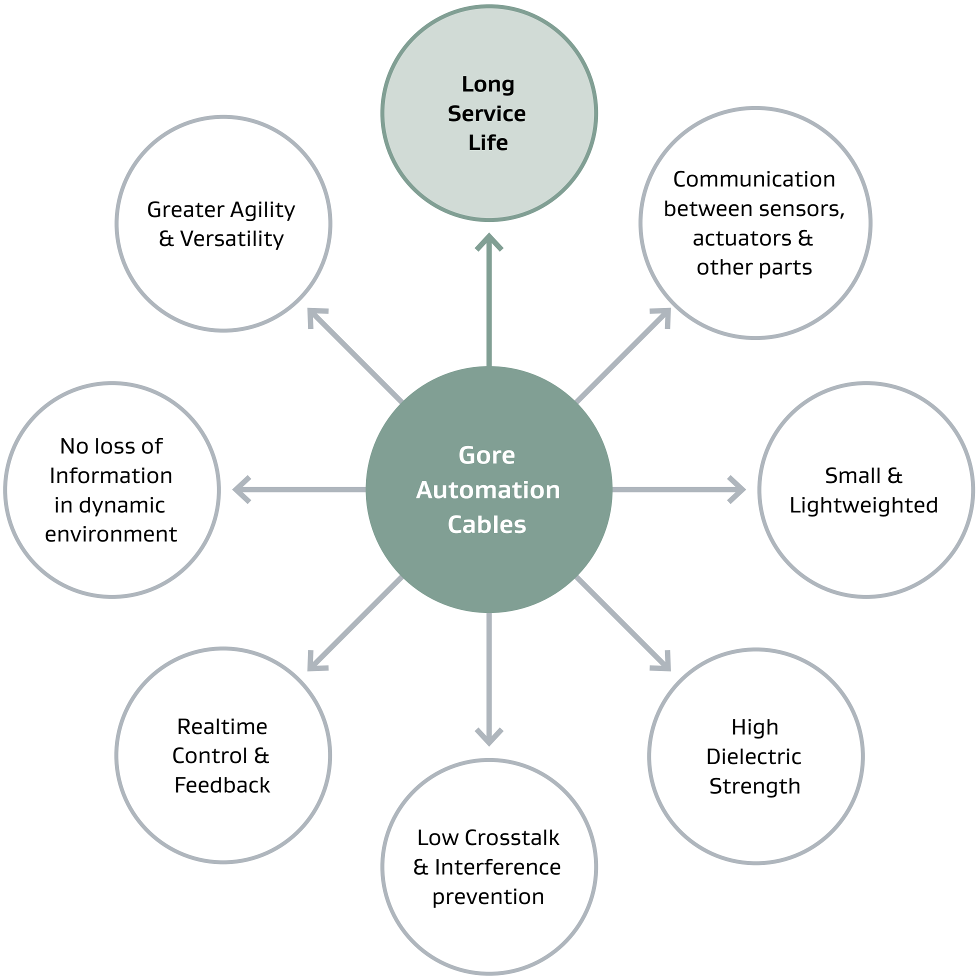
Size Optimized Data & Power Highways: The Backbone of Robotics through Cables

Maintaining reliable communication is key to seamless operation, especially when signals need to travel long distances. A cornerstone of this reliability is signal integrity, which hinges on minimizing crosstalk between signals to prevent interference and ensure precise data transmission. Moreover, supporting high-speed data transmission rates is vital for enabling real-time control and feedback, thereby boosting the responsiveness of robotic operations.

Efficient transmission of electrical signals and power lies at the heart of seamless robotic functionality. Additionally, high dielectric strength is essential for withstanding high voltages, thereby averting breakdown or insulation failure, and guaranteeing electrical safety and reliability across diverse operational environments. To uphold the uniform size of the robots while accommodating the heightened electronics and power requirements, minimizing the packing density of supply cables is essential.

As everywhere in technology, the size and weight of components are critical factors that significantly impact overall performance. This is especially true in applications where space and weight constraints are paramount. Embracing a lightweight and compact design not only shrinks the overall footprint of the robot but also enhances its maneuverability and efficiency, particularly in constrained environments. This not only contributes to weight reduction but also optimizes performance. By prioritizing size and weight optimization, robotic systems can attain greater agility and versatility across various applications, translating into improved performance and functionality.

Size Optimized Data & Power Highways:
The Backbone of Robotics through Cables



Environmental Resilience: How Cables Strengthen Robotic Solutions

Performance is not just about what a system can do — it is also about how well it can withstand the elements it encounters. From outdoor environments to industrial settings, robotic systems face a myriad of challenges, ranging from moisture and dust to UV radiation. That is why ensuring resistance to water, dust, and UV radiation is essential. These properties not only enable robots to maintain functionality in harsh conditions but also ensure longevity by preventing degradation over time.

Chemical resistance is another critical factor in the robustness of robotic components. Exposure to oils, solvents, and corrosive chemicals is commonplace in industrial environments. In marine applications, resistance to saltwater is crucial, while in clean areas like medical or chemical facilities, minimizing contamination risk is paramount. Low outgassing properties further bolster reliability, particularly in space robotics or cleanroom environments where even the slightest contamination can be detrimental.

Fire hazards are a constant concern in robotics, necessitating flame retardant properties to mitigate potential dangers from sparks or elevated temperatures. By incorporating flame retardant materials, robotic systems can operate safely across various environments without compromising performance or safety.

Temperature extremes are yet another challenge that robotic systems must confront. From freezing cold to scorching heat, maintaining functionality across diverse temperature ranges is essential for reliability and operational efficiency.

Electromagnetic interference (EMI) and radio frequency interference (RFI) present significant threats to signal integrity and overall performance in robotic systems. Incorporating measures to resist electromagnetic interference ensures that robots can prevent signal degradation and interference with other electronic devices, thereby ensuring consistent and reliable operation even in challenging electromagnetic environments.

Environmental Resilience:
How Cables Strengthen Robotic Solutions

Conclusion

In conclusion, flexible cables play a pivotal role in ensuring the efficiency, reliability, and longevity of robotic systems. Their flexibility and high mechanical strength, combined with durability, longevity, and low-friction coatings, render them indispensable components in the realm of robotics. Each aspect, from signal integrity optimization to environmental resilience, contributes to maximizing the performance and reliability of robotic systems.

From the selection of high-quality flexible cables to maintaining accurate communication, ensuring efficient electrical transmission, and addressing environmental challenges, every detail plays a crucial role in enhancing functionality and efficiency. By integrating these elements into robotic designs, engineers can minimize downtime, achieve greater efficiency, and ensure sustained operation across diverse applications.

As technology progresses, the importance of flexible cables in driving innovation and performance will only continue to grow. Through continuous innovation and attention to critical factors, robotic systems can advance automation and technology integration, driving progress in various industries. Flexibility, reliability, and resilience are the cornerstones upon which the future of robotics will be built, ushering in a new era of automation and efficiency.

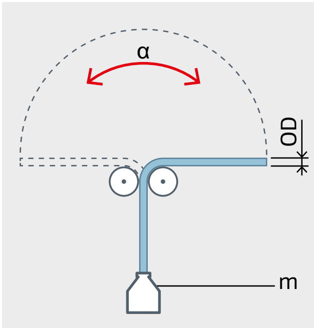
Unrivaled Performance: A Comprehensive Study of Cable Excellence

In our comprehensive study, we conducted tough testing using state-of-the-art TicToc-Tester to compare the performance of cables sourced from various vendors, including W. L. Gore & Associates (Gore). This test setup is shown in Figure 1 and is located in Gore's own facilities.

Our focus was on evaluating both electrical and mechanical specifications to provide a holistic assessment of the cables' capabilities. Figure 2 and Figure 3 provide a comparison of the most important key data.

TicToc Test (IEC 60227)

Bend radius ..... 32 mm
Bend angle α .... ±90° (180°)
Weight .... 500 g
Velocity .... 20 cycles/min



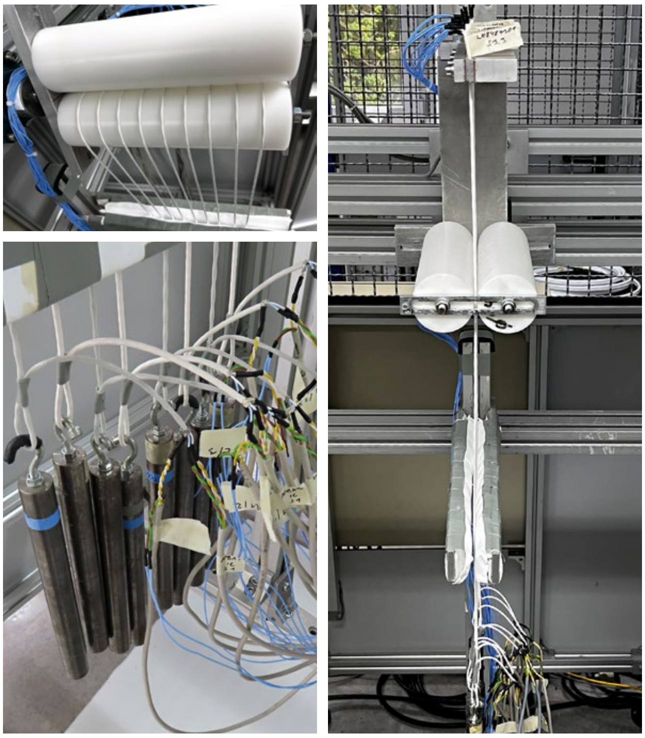


Figure 1: TicToc Tester — Test Environment

Shielded Twisted Pair (Gore)

Sample	BS (2.78 mm)	SWS (2.8 mm)
Conductor	AWG 26	AWG 26
Lay Length	30 mm	30 mm
Shield	Braided Shield	Braided Shield
Picks/Inch	12	12

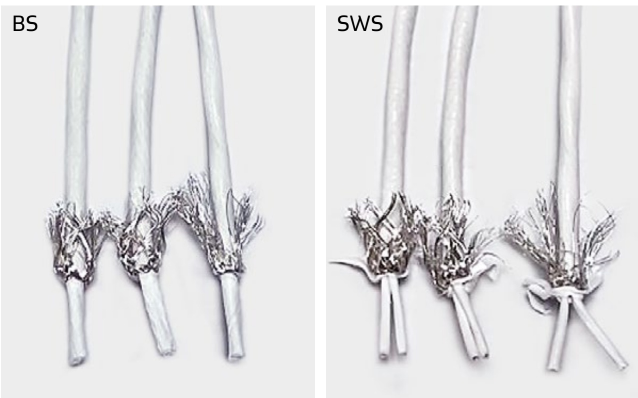


Figure 2: Test specimens from W. L. Gore & Associates

Shielded Twisted Pair (Other vendors)

Sample	VEN1 (4.63 mm)	VEN2 (3.43 mm)
Conductor	AWG 26	AWG 26
Lay Length	19.2 mm	32 mm
Shield	Foiled Shield & Braided Shield	Braided Shield
Picks/Inch	10	11

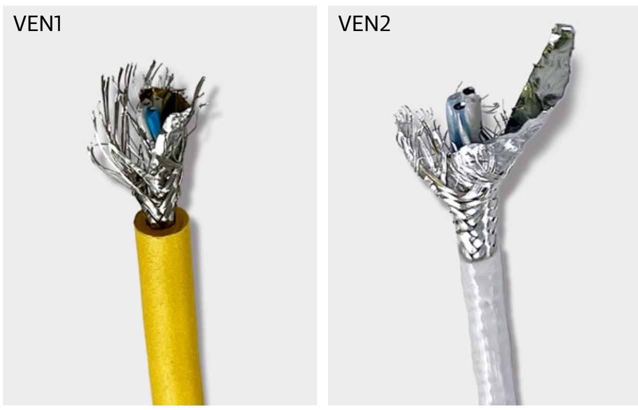


Figure 3: Test specimens from other vendors

It is worth noting that the cables selected for testing had similar electrical specifications, allowing for a direct comparison in this aspect. **Thanks to the use of unique materials and innovative manufacturing techniques, Gore's cables had a smaller diameter than their counterparts.**

Figure 4 shows the comparison before and after of all specimens. Some samples from one of the vendors (VEN2) have broken through completely (Jacket, Shielding and Conductor). These did not even last the one million cycles. In contrast, sample VEN1 from another vendor and samples BS and SWS from Gore are externally undamaged.

No Jacket Breakage (VEN1)
during TicToc-Test > 1 MM Cycles

Jacket Breakage Breakage (VEN2)
during TicToc-Test < 1 MM Cycles

No Jacket Breakage (BS/SWS)
during TicToc-Test > 1 MM Cycles

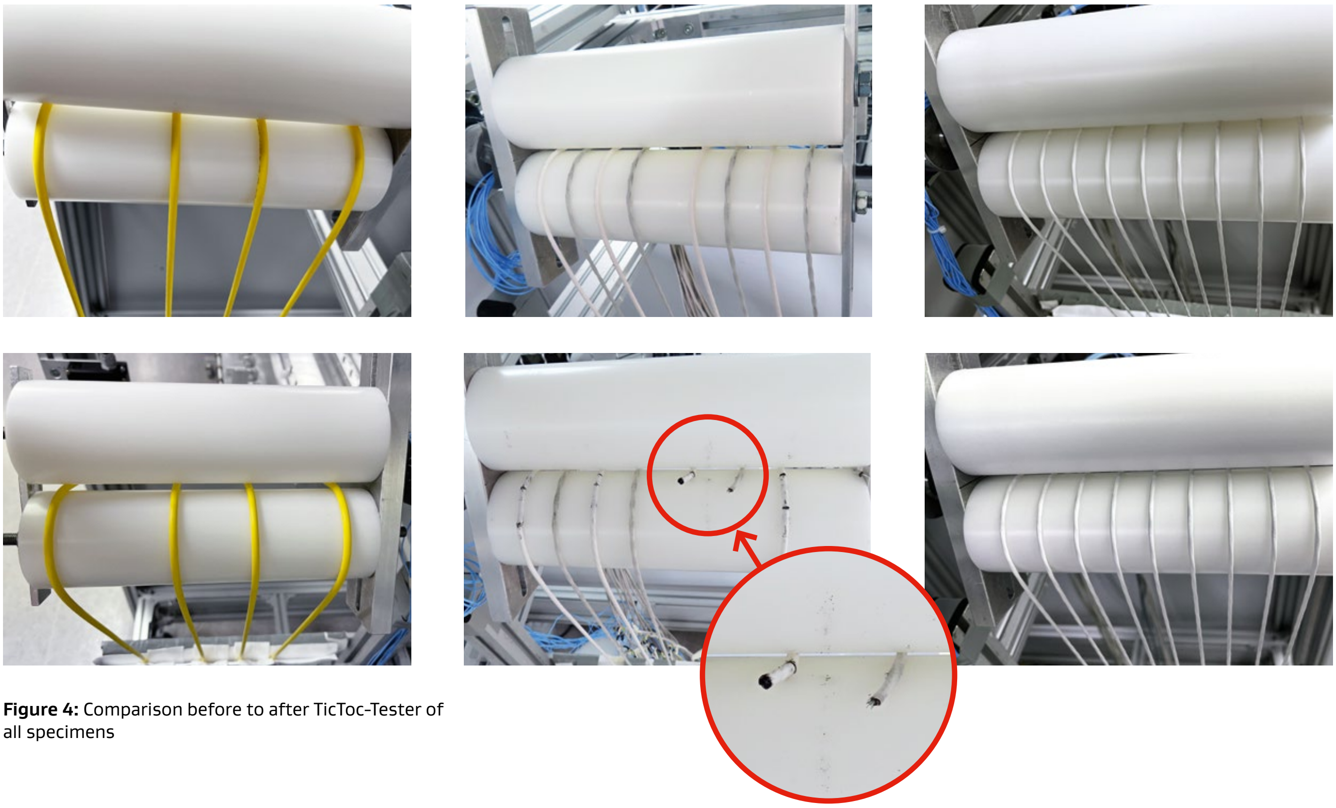


Figure 4: Comparison before to after TicToc-Tester of all specimens

Although the jacket of the VEN1 sample was completely intact, the inner components of the cable showed fatal weaknesses. The shield and conductor have broken through, and although not even reaching 200,000 cycles. As shown in Figure 5 the inner conductor survived approx. 120,000 cycles, whereas the shield withstood 185,000 cycles until it also broke through.

Despite the total failures in some samples of sample VEN2 where the jacket, shielding and conductor broke through, the surviving specimens achieved a considerable number of cycles before the conductor or shield broke through. As shown in Figure 5 the inner conductor survived approx. 789,000 cycles, whereas the shield withstood 731,000 cycles until it also broke through.

Sample	Component	Sample #	Initial Resistance [Ω]	Resistance [Ω] < 185 k Cycles	Relative Resistance Change [%]
VEN1	Conductor	1	0.258	∞	/
VEN1	Shield	1	0.023	∞	/
VEN1	Conductor	2	0.258	∞	/
VEN1	Shield	2	0.023	∞	/
VEN1	Conductor	3	0.258	∞	/
VEN1	Shield	3	0.023	∞	/

Conductor and shield resistance is measured every 20 minutes (about every 500 cycles) during the movement, measurement position is therefore random.

Reviewing the resistance measurement data there were no failures of the inner conductors or shieldings.

Maximum cycles without conductor breakage .... 125.000 Cycles
Maximum cycles without shield breakage .... 185.000 Cycles

Sample	Component	Sample #	Initial Resistance [Ω]	Resistance [Ω] < 789 k Cycles	Relative Resistance Change [%]
VEN2	Conductor	1	0.227	∞	/
VEN2	Shield	1	0.025	∞	/
VEN2	Conductor	2	0.227	∞	/
VEN2	Shield	2	0.025	∞	/
VEN2	Conductor	3	0.228	∞	/
VEN2	Shield	3	0.025	∞	/

Conductor and shield resistance is measured every 20 minutes (about every 500 cycles) during the movement, measurement position is therefore random.

Reviewing the resistance measurement data there were no failures of the inner conductors or shieldings.

Maximum cycles without conductor breakage .... 789.000 Cycles
Maximum cycles without shield breakage .... 731.000 Cycles

Figure 5: Electrical Resistance of Inner Conductor and Shielding before and after TicToc Tester — Other Vendors

Figure 6 shows the performance of all Gore specimens. They suffered neither external nor internal damage during the entire test. No defects were detected.

Among the tested cables, Gore's samples (BS & SWS) exhibited unparalleled mechanical (VEN2) and electrical performance (VEN1 & VEN2). This superiority can be attributed to the meticulous diligence to detail and advanced engineering processes employed in Gore's cable production. The reduction in diameter not only enhances the cables' aesthetics but also offers practical advantages in installations where space is limited.

Moreover, the insulation and dielectric materials utilized in Gore's cables are specifically engineered to excel in harsh environments. This strategic design consideration ensures that Gore's cables maintain optimal performance and reliability even in the most demanding conditions, making them ideal choices for a wide range of applications across industries.

In summary, our comprehensive testing revealed that **Gore's cables outperformed their counterparts in terms of mechanical- & electrical robustness, diameter reduction, and suitability for challenging environments.** These findings underscore the undeniable quality and innovation embedded within Gore's cable offerings, affirming their position as a leading choice for discerning customers seeking reliability and performance excellence.

Sample	Component	Sample #	Initial Resistance [Ω]	Resistance [Ω] > 1 MM Cycles	Relative Resistance Change [%]
BS	Conductor	1	0.260	0.261	0.38
BS	Shield	1	0.031	0.032	3.23
BS	Conductor	2	0.261	0.261	0
BS	Shield	2	0.031	0.032	3.23
BS	Conductor	3	0.261	0.26	-0.38
BS	Shield	3	0.031	0.031	0
SWS	Conductor	1	0.260	0.260	0
SWS	Shield	1	0.037	0.039	5.41
SWS	Conductor	2	0.263	0.262	-0.38
SWS	Shield	2	0.038	0.039	2.63
SWS	Conductor	3	0.263	0.263	0
SWS	Shield	3	0.04	0.04	5.26

Conductor and shield resistance is measured every 10 minutes (about every 250 cycles) during the movement, measurement position is therefore random.

Reviewing the resistance measurement data there were no failures of the samples' inner conductors or shieldings during Testing > 1 MM Cycles.

Figure 6: Electrical Resistance of Inner Conductor and Shielding before and after TicToc Tester — Gore

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