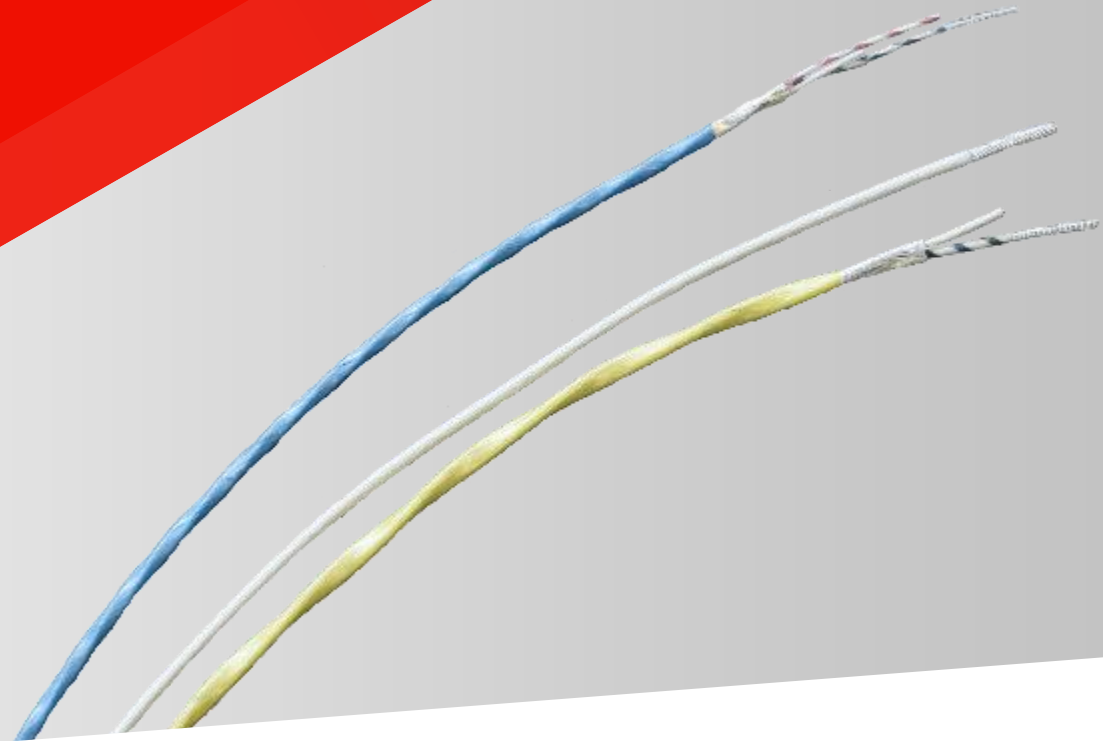


LIGHTEST AND SMALLEST LOW EARTH ORBIT WIRES AND CABLES TYPE LEW ACCORDING TO ESCC 3901/026

GORE® SPACE CABLES, TYPE LEW

Nicole Kaika
Application Engineer
W. L. Gore & Associates GmbH
Performance Solutions Division
Germany

Space Passive Component Days
14. October 2022



Together, improving life



ESCC 3901/026 – GORE® Space Cables Type LEW (Low Earth Orbit Wire)

Content

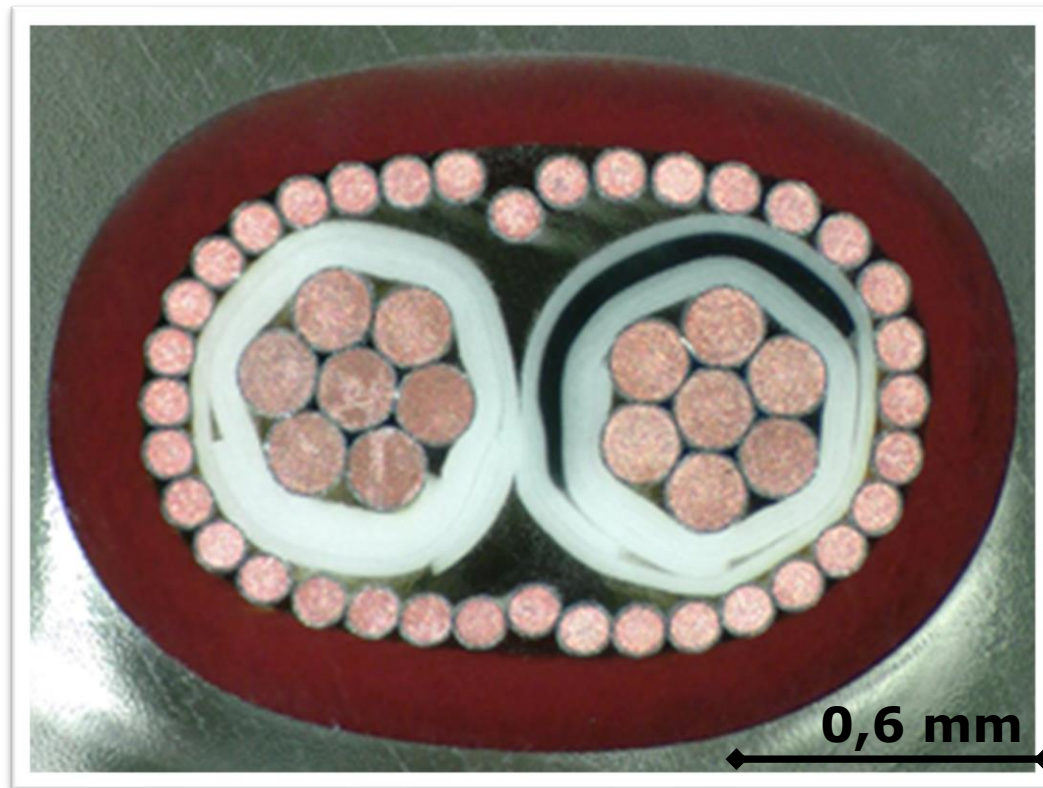
- ESCC 3901/026 – GORE® Space Cables Type LEW
- Evaluation & Qualification Tests
- ESCC 3901/026 Characteristics in ESCC 3901 Context
- Mechanical Wire Performance Test Examples

ESCC 3901/026 – GORE® Space Cables Type LEW

Characteristics & Variants



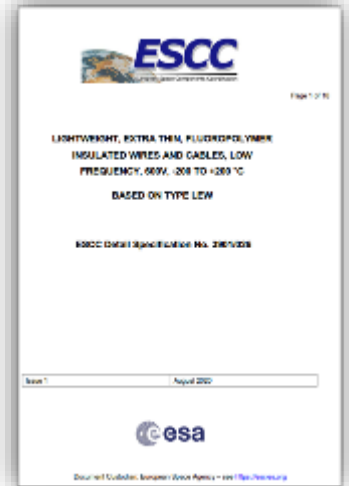
- **Lightest ESCC 3901 Variants in LEO**
- Utilize thin high strength PTFE Fluoropolymer tape Insulation
- Design Concept: 2 independent Insulation layers
- Operating **600 V_{rms}**
-200°C to +200°C
- Minimal diameters
- Flexible
- Small bend radius
- ATOX resistant
- Low outgassing, nontoxic



ESCC 3901/026
Variant No 11
LEW 21-28-C

ESCC 3901/026 – GORE® Space Cables Type LEW Characteristics & Variants

- **Lightest ESCC 3901 Variants in LEO**
- Utilize thin high strength PTFE Fluoropolymer tape Insulation
- Design Concept: 2 independent Insulation layers
- Minimal diameters
- Operating **600 V_{rms}**
-200°C to +200°C
- Flexible
- Small bend radius
- ATOX resistant
- Low outgassing, nontoxic





ESCC Detail Specification No. 3901/026

PAGE 7

ISSUE 1

TABLE 1(a) – TYPE VARIANTS

Variant No.	Shielded		No. of Cores	Wire Size ISO / (AWG)	Stranding No. of Strands = Diameter (mm)	Conductor Characteristics			Shield Strand Dia (mm)	Core Max Dia (mm)	Finished Wire or Cable Characteristics	
	Yes	No				Max Dia (mm)	Nom Sect. (mm ²)	Max Ohmic Resistance (Ω/km)			Max Dia (mm)	Max Weight (kg/km)
01		x	1	- / (28)	7×0.127	0.39	0.09	253	-	-	0.62	1.14
02		x	1	001/(26)	19×0.1 (1)	0.47	0.15	157	-	-	0.71	1.63
03		x	1	002/(24)	19×0.12 (1)	0.58	0.25	111	-	-	0.83	2.25
04		x	1	004/(22)	19×0.15 (1)	0.78	0.4	58	-	-	1.1	3.74
05		x	1	006/(20)	19×0.2 (1)	0.99	0.6	32	-	-	1.25	6.2
06		x	1	012/(16)	19×0.3 (1)	1.49	1.2	14	-	-	1.8	13.5
07		x	2	001/(26)	19×0.1 (1)	0.47	0.15	170	-	0.75	1.45	3.4
08		x	2	002/(24)	19×0.12 (1)	0.58	0.25	120	-	0.85	1.8	4.9
09		x	2	004/(22)	19×0.15 (1)	0.78	0.4	63	-	1.1	2.2	7.6
10		x	2	006/(20)	19×0.2 (1)	0.99	0.6	35	-	1.26	2.5	12.7
11	x		2	- / (28)	7×0.127	0.39	0.09	258	0.079	0.7	1.75	5.9
12	x		2	001/(26)	19×0.1 (1)	0.47	0.15	170	0.079	0.75	1.65	7.1
13	x		2	002/(24)	19×0.12 (1)	0.58	0.25	120	0.079	0.85	2.2	9
14	x		2	004/(22)	19×0.15 (1)	0.78	0.4	63	0.079	1.1	2.45	12.6
15	x		2	006/(20)	19×0.2 (1)	0.99	0.6	35	0.079	1.26	3	19
16	x		3	- / (28)	7×0.127	0.39	0.09	259	0.079	0.7	1.85	7.9
17	x		3	001/(26)	19×0.1 (1)	0.47	0.15	171	0.079	0.75	2.05	9
18	x		3	002/(24)	19×0.12 (1)	0.58	0.25	121	0.079	0.85	2.3	11.3
19	x		4	- / (28)	7×0.127	0.39	0.09	260	0.079	0.7	2	9.1
20	x		4	001/(26)	19×0.1 (1)	0.47	0.15	171	0.079	0.75	2.2	11
21	x		4	002/(24)	19×0.12 (1)	0.58	0.25	122	0.079	0.85	2.4	14.3

NOTES:

1. In accordance with ISO 2635, AWG sizes are given for reference.

21 Variants
AWG 28 bis 16

Single wires

Pairs

Shielded Pairs,
Tri's & Star
Quads

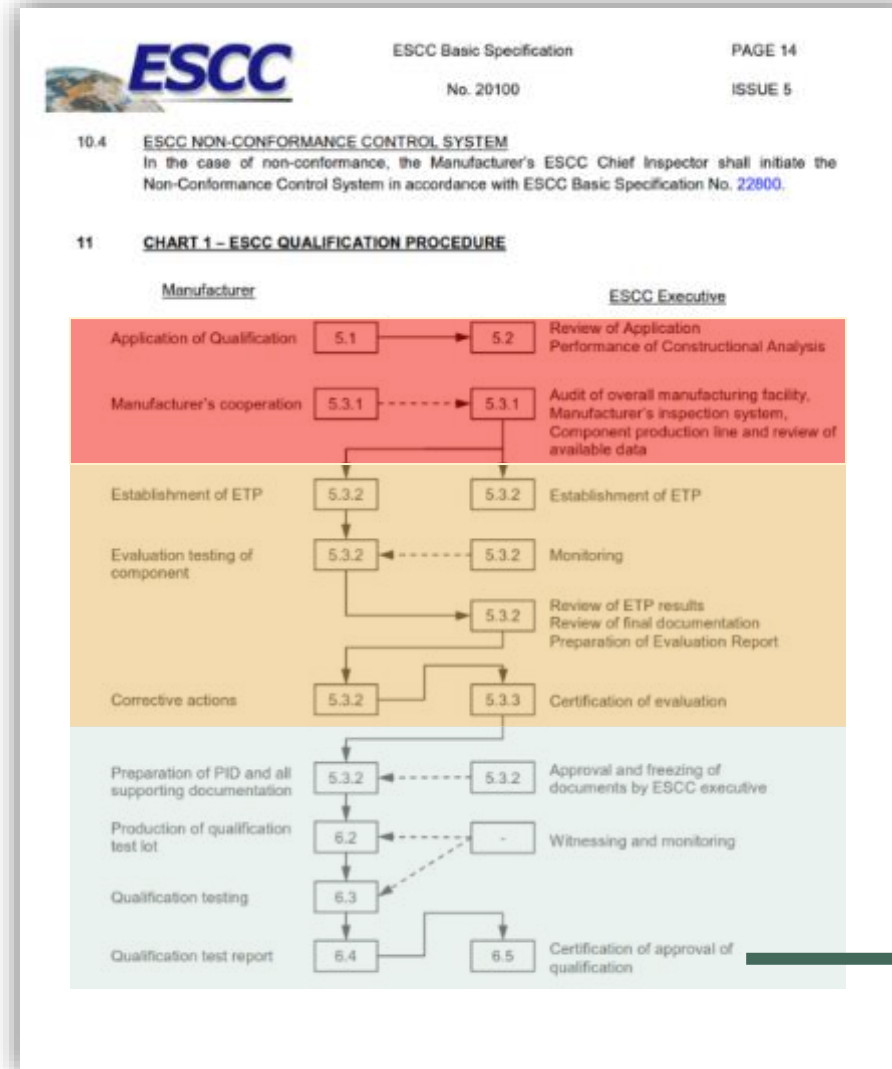
Process Flow for New Component Qualification acc. to ESCC 20100

New Component Qualification Procedure acc to ESCC 20100 Chart 1

Application

Evaluation

Qualification



ETP= Evaluation Test Plan

ESCC 3901/026 – GORE® Space Cables Type LEW

Evaluation: Final Production Tests for 3 selected Representatives



ESCC 3901 Para.	Test Description	Variant No 14 LEW 21-22-C		Variant No 11 LEW 21-28-C		Variant No 06 LEW 10-16-N	
		Measured	Specified	Measured	Specified	Measured	Specified
9.1	External Visual Inspection	Passed	see 9.1	Passed	see 9.1	Passed	see 9.1
9.2	Weight	11,7 g/m	max. 12,6 g/m	5,3 g/m	max. 5,9 g/m	12,9 g/m	max. 13,5 g/m
9.3	Dimensions cond. strands con. diam. out. Dia.	Passed max. 0,74 mm 19 av. 0,15 mm max 2,28 mm	Passed Max. 0,76 mm 19 nom 0,15 mm max 2,45 mm	Passed max. 0,38 mm 7 av. 0,124 mm max 1,60 mm	Passed Max. 0,39 mm 7 nom 0,127 mm max 1,75 mm	Passed max. 1,46 mm 19 av. 0,3 mm max 1,66 mm	Passed Max. 1,49 mm 19 nom 0,3 mm max 1,8 mm
9.4	Coating	Passed Passed	Passed Passed	Passed Passed	Passed Passed	Passed Passed	Passed Passed
9.5	Conductor Resistance	51,1 Ohm/km	Max. 63 Ohm/km	210,1 Ohm/km	Max. 258 Ohm/km	13,2 Ohm/km	Max. 14 Ohm/km
9.6	Spark	Passed	@ 1,0kV rms	Passed	@ 1,0kV rms	Passed	@ 2,5kV rms
9.7	Voltage	a. Passed b. Passed b. Passed	@ 1,0kV rms @ 3,5kV DC @ 3,5kV DC	a. Passed b. Passed b. Passed	@ 1,0kV rms @ 3,5kV DC @ 3,5kV DC	a. Passed	@ 2,5kV rms
9.8	Insulation Resistance	a. Passed b. Passed	>30MΩ km >750MΩ km	a. Passed b. Passed	>30MΩ km >750MΩ km	a. Passed	>750MΩ km
9.9	Stripping Capability	Passed	See 9.9	Passed	See 9.9	Passed	See 9.9
9.10	Anthony and Brown	0 0	cond. 0-3 Sh. 0-3	0 0	cond. 0-3 Sh. 0-3	1	cond. 0-3
4.4	Marking	Passed	See 4.4	Passed	See 4.4	Passed	See 4.4

ESCC Generic Specification
No. 3901
PAGE 19
ISSUE 3

CHART II - FINAL PRODUCTION TESTS

Production and Controls in accordance with Section 6 of this specification

Para. 9.1	External Visual Inspection
Para. 9.2	Weight
Para. 9.3	Dimensions
Para. 9.4	Coating Tests
Para. 9.5	Conductor Resistance
Para. 9.6	Spark Test
Para. 9.7	Voltage Test
Para. 9.8	Insulation Resistance
Para. 9.9	Stripping Capability
Para. 9.10	Solderability
Para. 4.4	Marking

TO CHART IV OR V

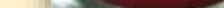
Destructive Analysis

Passed

ESCC 3901/026 – GORE® Space Cables Type LEW Evaluation

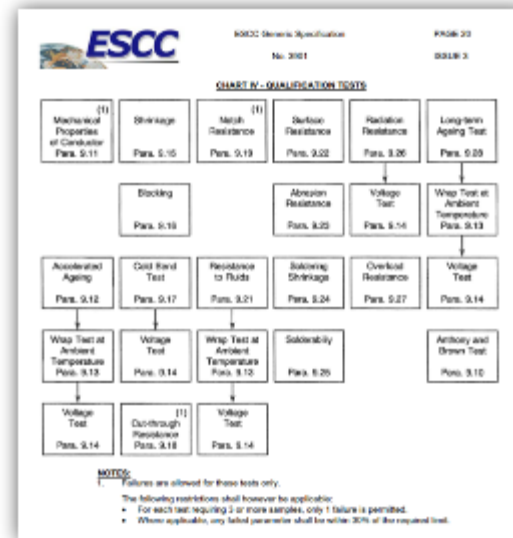
NEW additional Stress Tests to establish the margins between the specified conditions for use and real strength



ESCC 3901 Para.	Test Description	 Variant No 14 LEW 21-22-C	 Variant No 11 LEW 21-28-C	 Variant No 06 LEW 10-16-N
-----------------------	---------------------	---	--	---

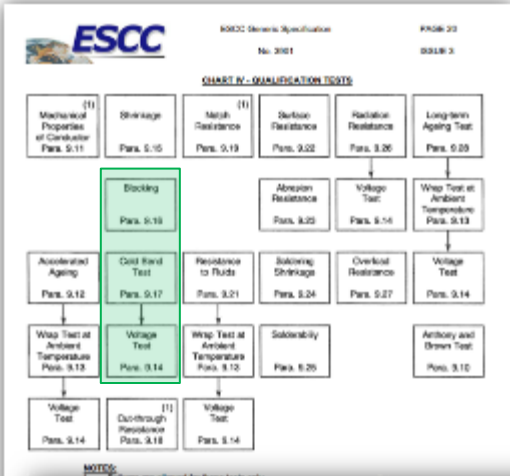
2 Levels of **Stress test runs** added
applying harsher test conditions
compared to standard qualification
acc. to ESCC 3901 chart IV

- increased temperatures
- increased mechanical loads
- increased Radiation Dose

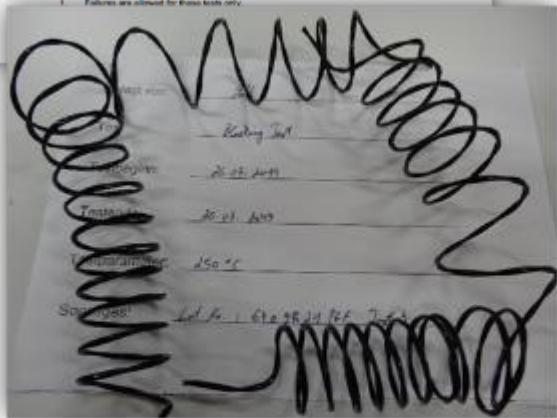


ESCC 3901/026 – GORE® Space Cables Type LEW Evaluation

Stress Tests Examples to establish the margins between the specified conditions for use and real strength



ESCC 3901 Para.	Test Description	Variant No 14 LEW 21-22-C		Variant No 11 LEW 21-28-C		Variant No 06 LEW 10-16-N	
		<i>Measured</i>	<i>Specified</i>	<i>Measured</i>	<i>Specified</i>	<i>Measured</i>	<i>Specified</i>
9.16	Blocking	OK OK OK	25mm 6h, 230°C 6h, 240°C 6h, 250°C	OK OK OK	10mm 6h, 230°C 6h, 240°C 6h, 250°C	OK OK OK	15mm 6h, 230°C 6h, 240°C 6h, 250°C
9.17	Cold Bend	OK OK	300g ,4h@ -80°C 2,5KV AC 8 mm 6 mm	OK OK	250g ,4h@ -80°C 2,5KV AC 6 mm 4 mm	OK OK	500g ,4h@ -80°C 2,5KV AC 10 mm 8 mm



9.16 Blocking Test after 250°C (specified 230°C)



9.17 Cold Bend Test at -80°C
6 mm Mandrel diameter (specified 8 mm)

ESCC 3901/026 – GORE® Space Cables Type LEW Evaluation

NEW additional Stress Tests to establish the margins between the specified conditions for use and real strength



ESCC 3901 Para.	Test Description	Variant No 14 LEW 21-22-C	Variant No 11 LEW 21-22-C	Variant No 15 LEW 21-22-C
				

2 Levels of Stre
applying t
compare
acc. to Es

- increased Radiation Dose
- increased Mechanical loads
- increased Temperature

Variant No 14
LEW 21-22-C

Variant No 11
LEW 21-22-C

Stress Evaluation incl. new Stress Test approach
ALL TESTS PASSED

Accelerated Aging
Para. 9.12

Gold Bond Test
Para. 9.17

Resistance to Fluids
Para. 9.21

Solowing Shrinkage
Para. 9.24

Overload Resistance
Para. 9.27

Wear Test at
Para. 9.18

Volume
Para. 9.22

Adhesion Resistance
Para. 9.23

Voltage Test
Para. 9.16

Wear Test at
Para. 9.19

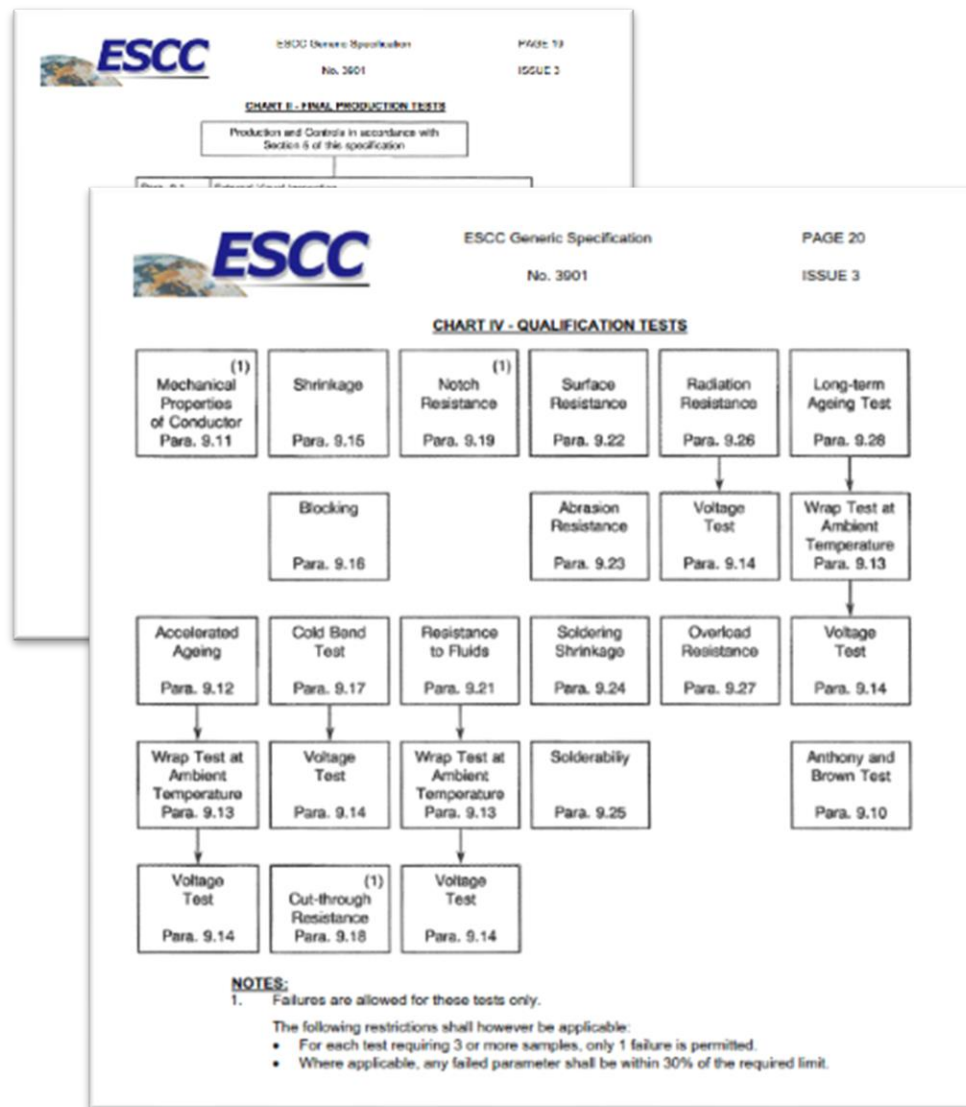
Solubility
Para. 9.25

ESCC 3901 Para.	Test Description	Variant No 14 LEW 21-22-C		Variant No 11 LEW 21-28-C		Variant No 06 LEW 10-18-N	
		Measured	Specified	Measured	Specified	Measured	Specified
9.11	Mechanical Properties of Conductor	min 19.5%	min. 10%	min 6.8% min 38.4 kg/mm ²	min. 6% 35 kg/mm ²	min 19.9%	min. 10%
9.12	Accelerated Ageing	OK OK OK	25 mm, 700g o-s 1.5kV AC/1 min o-s 1.5kV AC/1 min s-w 1.5kV AC/1 min 120h, 230°C 120h, 240°C 120h, 250°C	OK OK OK	10 mm, 500g; o-s 1.5kV AC/1 min o-s 1.5kV AC/1 min s-w 1.5kV AC/1 min 120h, 230°C 120h, 240°C 120h, 250°C	OK OK OK	15 mm, 500g; 10 mm, 500g; 2.5kV AC/1 min 120h, 230°C 120h, 240°C 120h, 250°C
9.15	Shrinkage Test	max. 0,1 mm max. 0,1 mm max. 0,1 mm	max 2,0 mm 6h @ 200°C 6h @ 210°C 6h @ 230°C	max. 0,0 mm max. 0,0 mm max. 0,0 mm	max 2,0 mm 6h @ 200°C 6h @ 210°C 6h @ 230°C	max. 0,2 mm max. 0,2 mm max. 0,3 mm	max 2,0 mm 6h @ 200°C 6h @ 210°C 6h @ 230°C
9.16	Blocking	OK OK OK	25mm 6h, 230°C 6h, 240°C 6h, 250°C	OK OK OK	10mm 6h, 230°C 6h, 240°C 6h, 250°C	OK OK OK	15mm 6h, 230°C 6h, 240°C 6h, 250°C
9.17	Cold Bend	OK OK	300g 4h @ -80°C 2.5kV AC 8 mm 8 mm	OK OK	250g 4h @ -80°C 2.5kV AC 6 mm 4 mm	OK OK	300g 4h @ -80°C 2.5kV AC 10 mm 8 mm
9.18	Cut-through Resistance	av. 61,66 N	av. min 45 N	av. 21,94 N	av. min 14 N	av. 47,99 N	av. min 46 N
9.19	Notch Resistance	OK	See 9.19 6 mm	OK	See 9.19 3,5 mm	OK	See 9.19 6 mm
9.21	Resistance to Fluids	OK OK 2,00% max (a)	10mm, 300g 2,5kV AC/1 min ≤5%	Not performed on this variants			
As shown there is a margin in all Specified tested originally							min 125 MOhm 90h @22°C 90h @25°C 90h @25°C
							min. 100 cycles @450g @450g @450g
							max. 1,5mm 5s @ 320°C 5s @ 330°C 5s @ 340°C
							See 9.25 5s @235°C
							variants
		OK	See 9.27				
9.28	Long-Term Ageing	OK OK OK	25 mm, 700g o-s 1,5kV AC/1 min o-s 1,5kV AC/1 min 2000h @ 200°C 2000h @ 210°C 2000h @ 230°C				

Stress Tests have shown there is a more robust margin in all Specified values than expected originally

ESCC 3901/026 – GORE® Space Cables Type LEW Qualification

Qualification Results for another 2 cable variants



ESCC 3901 Para.	Test Description	Variant No 10 LEW 21-20-C			Variant No 07 LEW 21-26-C			
		Measured	Specified	Measured	Specified			
9.1	External Visual Inspection	Passed	see 9.1	Passed	see 9.1			
9.2	D C R	9.11	Mechanical Properties of Conductor	min 19,9%	min. 10%	min 7,7% min 37,6 kg/mm²		
9.3							min. 6% 35 kg/mm²	
			25 mm, 800g		15 mm, 500g			
	9.	9.19	Notch Resistance	Passed	See 9.19 7 mm	Passed	See 9.19 4 mm	
9.4								
9.5	C R	9.22	Surface Resistance	min 30,1 10 ¹² Ω mm	min 125 MΩ mm 96h @22°C	min 8,7 10 ¹² Ω mm	min 125 MΩ mm 96h @22°C	
9.6		9.	9.23	Abrasion Resistance	min. 216 cycles	min. 100 cycles @440g	min. 665 cycles	min. 100 cycles @330g
9.7		9.	9.24	Soldering Shrinkage	max. 0,3 mm	max. 1,5mm 5s @ 320°C	max. 0,3 mm	max. 1,5mm 5s @ 320°C
9.8	I R							
9.9	S C	9.	9.25	Solderability	con. Passed sh. Passed	See 9.25 5s @235°C	con. Passed sh. Passed	See 9.25 5s @235°C
9.10			9.27	Overload Resistance	Passed	See 9.27	Passed	See 9.27
4.4	a	9.	9.28	Long-Term Ageing	Passed	25 mm, 800g c-s 1,5kV AC/1 min c-s 1,5kV AC/1 min 2000h @ 200°C	Passed	15 mm, 500g c-s 1,5kV AC/1 min c-s 1,5kV AC/1 min 2000h @ 200°C

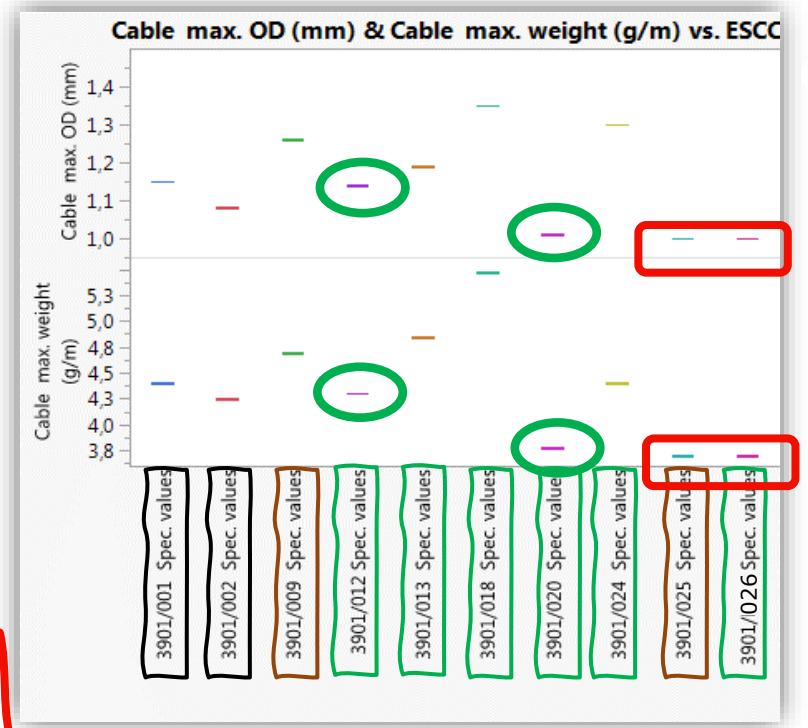
11

GORE® Space Cables Type LEW in ESCC 3901 Context

Active ESCC 3901 Detail Specifications and QPL manufacturers

Example: Weight and Dimension Spec Limits of AWG 22 Single Wire for active ESCC 3901 Options

ESCC 3901/													
001	002	009	012	013	017	018	019	020	021	022	024	025	026
FA 1871	FA 1872	SPC	55/995X	MTV/BTV	SPP	SPM	SPL	Crosslinked ETFE	SPLD	Crosslinked ETFE	CSWL	CSC	LEW
Nexans	Nexans	GORE	Tyco Electronics	Nexans	GORE	GORE	GORE	Tyco Electronics	GORE	Tyco Electronics	GORE	GORE	GORE
Draka Fileca	Draka Fileca		AXON Cable	AXON Cable		Bizlink Special Cables	Bizlink Special Cables		Bizlink Special Cables		AXON Cable		
AXON Cable	AXON Cable					AXON Cable	AXON Cable		AXON Cable				



xxx Materials for preferred use in LEO (ATOX)

xxx Materials for preferred use GEO (Radiation)

xxx Materials single wires GEO, multicore variants LEO

ESCC 3901/025 & 026 are lightest and thinnest qualified ESCC 3901 cable options

LEO Orbit

GEO Orbit

GORE® Space Cables Type LEW in ESCC 3901 Context

Example:
Weight and Diameter Comparison to **ESCC 3901/012**
(based on Spec 55 cross-linked ETFE)

ESCC 3901/026 (LEW)							Corresponding Var. of ESCC 3901/012		ESCC 3901/026 compared to ESCC 3901/012	
Variant	Shielded		No. of cores	Wire Size AWG	Max dia- meter [mm]	Max weight [g/m]	Max diameter [mm]	Max weight [g/m]	Max diameter [mm]	Max weight [g/m]
	Yes	No								
1		x	1	28	0,62	1,14	0,70	1,35	-11%	-16%
2		x	1	26	0,71	1,63	0,86	2,11	-17%	-23%
3		x	1	24	0,83	2,25	0,99	2,97	-16%	-24%
4		x	1	22	1,00	3,70	1,14	4,30	-12%	-14%
5		x	1	20	1,25	6,20	1,41	6,91	-9%	-10%
6		x	1	18	1,57	10,59	1,78	15,59	-5%	-7%
7			1	16	1,92	17,43	2,17	24,43	-19%	-23%
8			1	14	2,29	28,12	2,57	38,12	-9%	-20%
9			1	12	2,77	36,86	3,08	50,86	-4%	-14%
10			1	10	3,35	48,48	3,71	68,48	-9%	-12%
11			1	8	4,03	66,86	4,44	93,86	-25%	-40%
12			1	6	4,81	92,22	5,28	128,22	-25%	-45%
13			1	4	5,79	120,20	6,34	165,20	-23%	-41%
14			1	3	6,95	153,31	7,61	208,31	-23%	-35%
15			1	2	8,25	193,45	9,03	268,45	-23%	-35%
16	x		2	20	3,0	19,0	3,59	27,06	-16%	-30%
17	x		3	28	1,85	7,9	2,43	12,69	-24%	-38%
18	x		3	26	2,05	9,0	2,72	17,05	-25%	-47%
19	x		3	24	2,30	11,3	3,01	20,42	-24%	-45%
20	x		4	28	2,0	9,1	2,64	15,05	-24%	-40%
21	x		4	26	2,2	11,0	2,95	20,34	-25%	-46%
22	x		4	24	2,4	14,30	3,27	24,50	-27%	-42%

ESCC 3901/026 Variants up to 47%* lighter and 27% thinner

Example:
Weight and Diameter Comparison to **ESCC 3901/020**

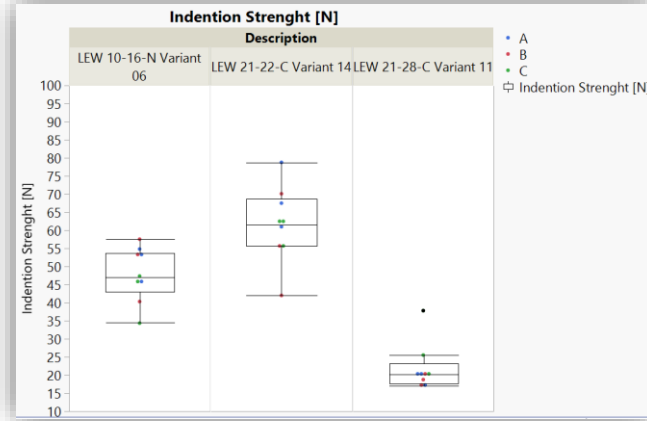
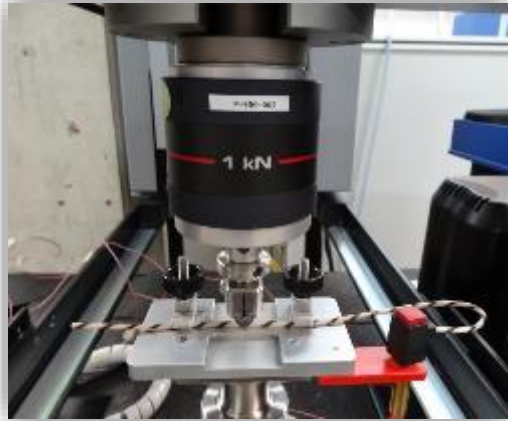
Corresponding Var. of ESCC 3901/020		ESCC 3901/026 compared to ESCC 3901/020	
Max diameter [mm]	Max weight [g/m]	Max diameter [mm]	Max weight [g/m]
0,63	1,15	-2%	-1%
0,75	1,81	-5%	-10%
0,87	2,50	-5%	-10%
1,01	3,78	-1%	-2%
1,26	6,31	-1%	-2%
1,90	14,05	-5%	-4%
1,50	3,73	-3%	-9%
1,74	5,15	3%	-5%
2,02	7,79	9%	-2%
2,52	13,00	-1%	-2%
2,06	7,71	-15%	-23%
2,31	9,86	-16%	-28%
2,55	11,97	-14%	-25%
2,85	15,64	-14%	-19%
3,35	22,39	-10%	-15%
2,16	10,10	-14%	-22%
2,43	13,15	-16%	-32%
2,69	16,25	-14%	-30%
2,32	12,26	-14%	-26%
2,61	16,15	-16%	-32%
2,91	20,13	-18%	-29%

Crosslinked ETFE Extrusion

*)Typical Variant Mix in a missions' application ends up with **35%** mass saving on average

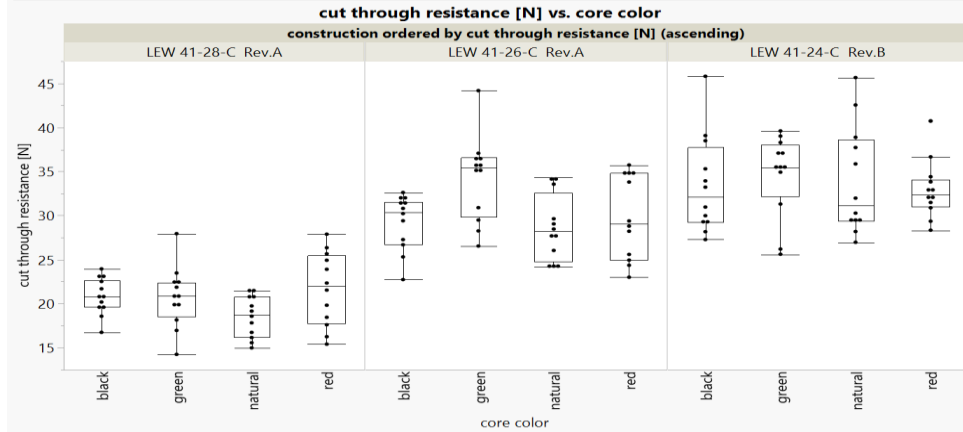
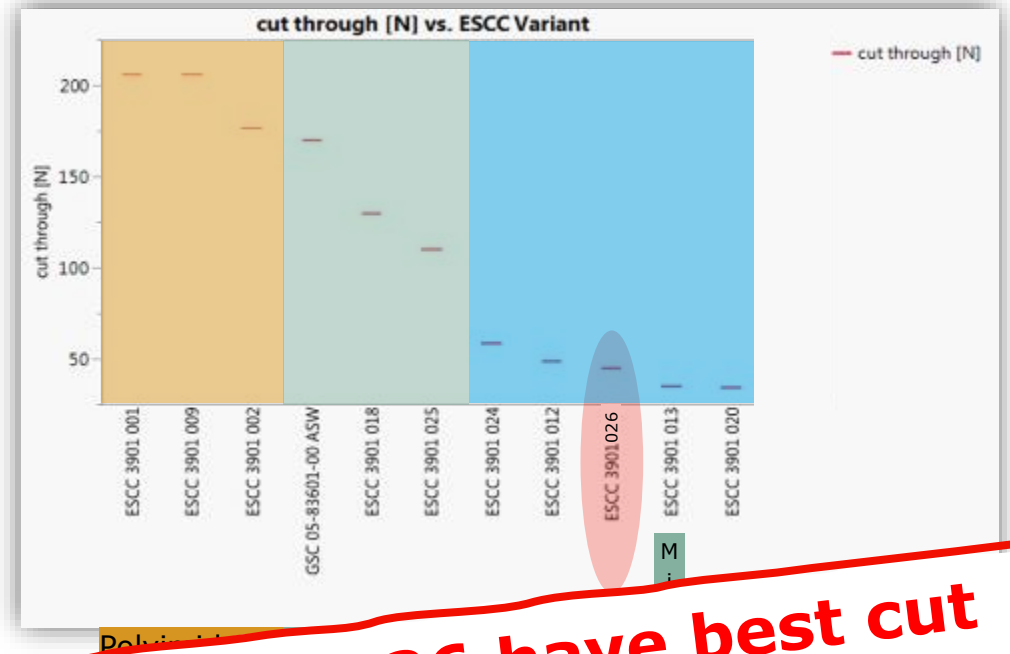
ESCC 3901/026 – GORE® Space Cables Type LEW

Mechanical Performance Test: Cut Through Indention Strength



ESCC 3901 Insulation Materials:

Example: Cut-Through Pass/Fail limits [N]
for AWG 22 single wire mean value



Test Conditions ESCC 3901 Para 9.18:

3 different samples, 3 Tests on each one, shifted 75 mm and to
Specified: Mean value of 9 results

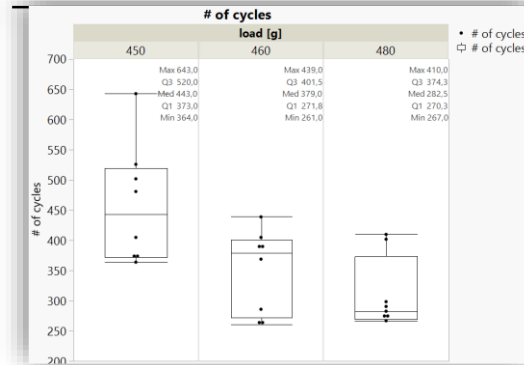
ESCC 3901/026 have best cut through to wall thickness performance ratio

ESCC 3901/026 – GORE® Space Cables Type LEW

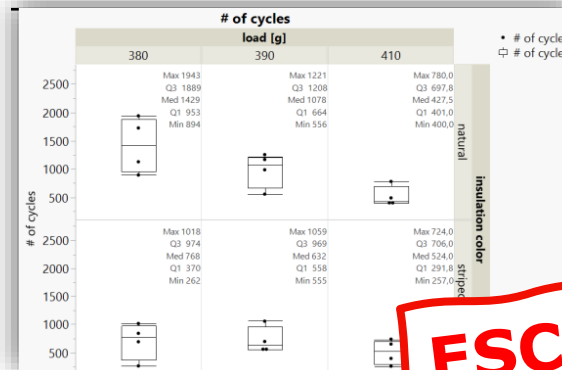
Mechanical Performance Test: Abrasion Resistance

ESCC 3901 Isolation Materials:

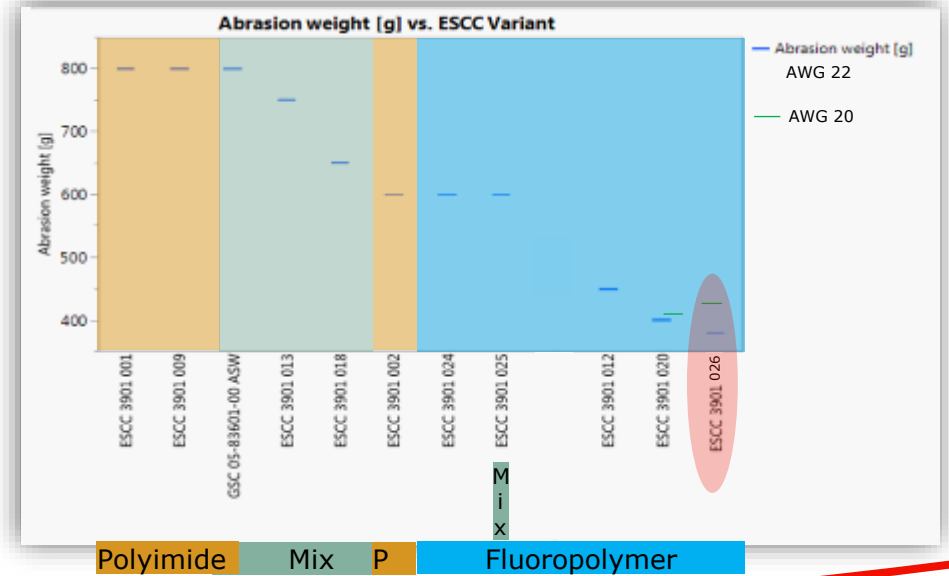
Example: Specified Weight Load [g] AWG 22/20



Variant No. 06 LEW1016N



Variant No. 14



ESCC 3901/026 offer lightest and thinnest cable solutions for LEO maintaining heritage ESCC 3901 performance characteristics

Test Conditions ESCC 3901 Para 9.23

1 sample, 4 Tests on each one, shifted 100 mm and turned 90°

Specified: minimum 100 cycles each

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GRACIAS	TAPADH LEAT
THANK YOU	DANKE
고맙습니다	謝謝
ありがとう	TACK
谢谢	

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Your contact:

Nicole Kaika

Application Engineering/Performance Solutions Division
nkaika@wlgore.com

T +49 9144 601 6219 M +49 173 2863349

W. L. Gore & Associates GmbH

Nordring 1
91785 Pleinfeld
Germany
gore.com

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W. L. Gore & Associates GmbH

Nordring 1, 91785 Pleinfeld, Germany
T +49 9144 601 0 F +49 8946124 0 gore.com

