TEST CERTIFICATE

Cost effectiveness of MaxCell multiple duct systems 4016-3

The certifying body hereby declares that after the testing process documented in Test Report No. 32/2012, combinations of the following components have qualified as cost-effective and efficient in fulfilling the demands made on cable ducts in the scope of FTTH network expansion:

- MaxCell multiple duct system 4016-3 with an integrated cable-pulling rope, Ø 3.5 mm
  Manufacturer: MaxCell Innerduct
- MaxCell aramide endless pulling grip, sizes M5/18 and L11/36
  Manufacturer: MaxCell Innerduct
- MaxCell cable seal MXCRTBVL
  Manufacturer: Wolf Kabeltechnik GmbH, 70437 Stuttgart, Germany

The qualification test verified that:

- frictional resistance is reduced by up to 75% compared with other combinations
- up to 55% of the cable duct space is utilizable, while allowing cables of varying types to be installed and removed in accordance with requirements
- no sheath abrasion or damage to the MaxCell multiple duct system 4016-3 is caused in the course of initial or subsequent cable installations
- it is possible to install the cables with a minimal use of machinery
- the cable duct and cables were sealed against gas and water entry by means of the reusable MaxCell cable seal, MXCRTBVL. This ensures the prevention of cable damage by water entry or damage caused during installation by silted-up ducts.

Applicable Test Report:	PB 32/2012
Date of certification:	24 April 2012
This certificate is valid until	23 April 2014

Stuttgart, 24.04.2012

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Gütesiegel GS
Prüfzertifikat
15-10-PB31/2012
Gültigkeit 23.04.2014

Summary of test results

MaxCell multiple duct system 4016-3	Cost effectiveness

The MaxCell multiple duct was tested in terms of cost-effectiveness and efficient utilization of cable duct space within the scope of FTTH network expansion. The requirement is that it must be possible to carry out retrofitting and dismantling several times on an occupied cable duct. According to an article published (in German)in the Dialog Consult Newsletter No. 1/2010 regarding fibre-optic connections in telecommunication networks (FTTx), underground engineering costs constitute 70-80% of the total investment for route construction. Therefore optimal utilization of cable ducts plays an extremely important role.

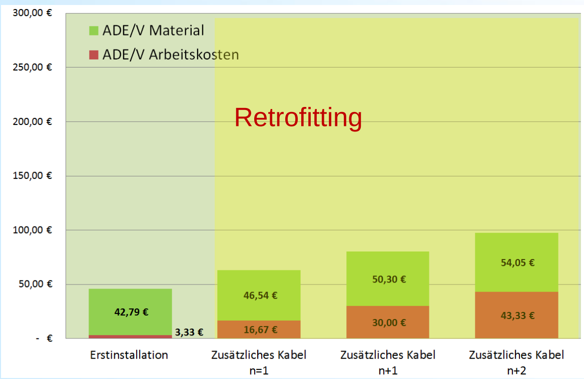
Test setup and results:

After the configuration of the first MaxCell multiple duct system in an s-shaped pipe bend, 50 x 1.8 mm, was completed, a second MaxCell multiple duct system 4016-3 was pulled in. It was possible to install another 3 cables (Ø ~13.5 mm each) in this second MaxCell duct system, using a 10 m/min winch, due to the pulling rope integrated in the system. Hence it was possible to utilize 55 % of the available duct space for 6 cables with the MaxCell multiple duct system.

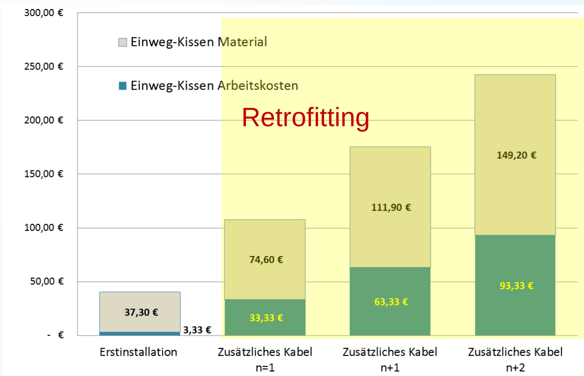
Increased cost-effectiveness due to the reusable cable sealing system, MXCRTBVL/ Wolf ADE/V

Example: Wolf Kabeltechnik GmbH cost model: "Total material and labour costs for reusable sealing elements compared with disposable sealing cushions"

Reusable cable sealing system MXCRTBVL/ Wolf ADE/V



Disposable sealing cushions



The reusable cable sealing system MXCRTBVL/ Wolf ADE/V has a higher initial cost than the disposable sealing cushion. But a comparison of costs for 3 applications shows that the accumulated material costs for the reusable sealing system are only ~ 1/3 of those for the disposable system. The labour costs for the reusable sealing system come to about half those of the disposable system. (Detailed information available on request from Wolf Kabeltechnik GmbH)

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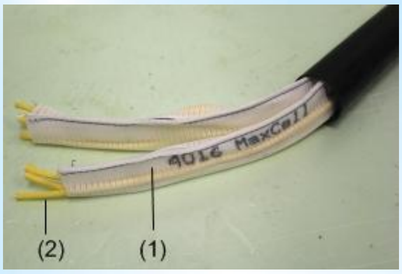
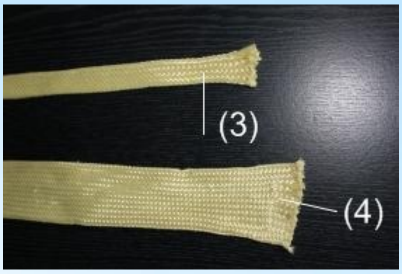
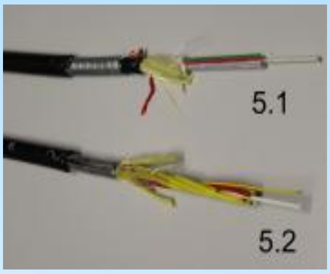
Components required for the laying process and test setup



MaxCell 4016-3
(1) extra-flexible multiple duct system with cable-pulling rope (2)

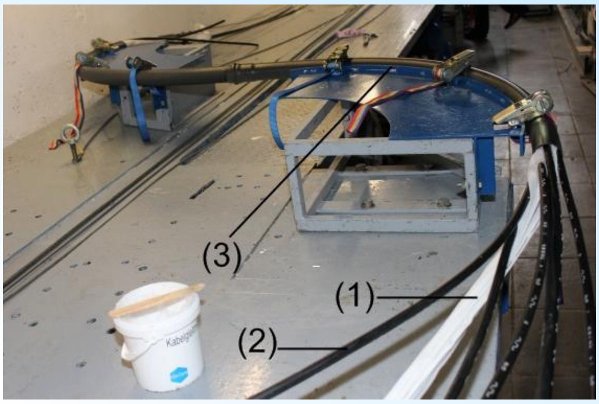


Aramide cable pulling grip
Endless pulling grip (without pulling loop)
(3) Size M 5/18 (4) Size L 11/36



(5.1) A-DQ2Y(SR)2Y Ø 13.0 mm
(5.2) A-DF(ZN)(L)2Y Ø 13.5 mm

Test setup based on DIN EN 60794-1-2 Method E18
"Cable bending under tension"
(1) MaxCell multiple duct system 4016-3
2 samples in a curved duct
(2) Optical cables 1-6 were pulled into the MaxCell duct system one by one
(3) Curved duct 50x1,8 mm



Test results

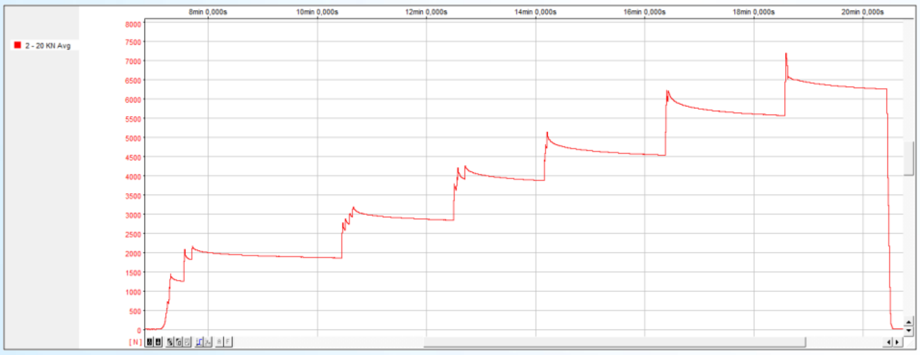
MaxCell pulling rope (integrated) [redacted]

The synthetic cable-pulling ropes integrated in the MaxCell multiple duct system 4016-3 have been developed for a pulling tension of max. 5500 N. The properties determined in the course of testing were all advantageous. The stage of "Pushing or blowing in wire cable ropes" is no longer necessary and there is no danger of cutting through the protective duct.

The cables can be pulled in at low cost, with minimal use of machinery, e.g. using a cable capstan winch, PSW 10-13.

Test diagram:
Breaking resistance of the pulling rope

Actual value determined for breaking resistance approx. 7300 N



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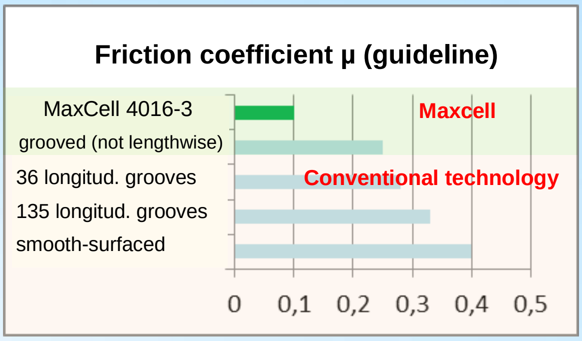
Test results

MaxCell multiple duct system 4016-3

Friction coefficient 0.1 µ reduced by 75%!

The coefficient of friction coefficient between the MaxCell multiple duct system 4016-3 and the LDPE cable sheaths was only 0.1 µ. This means a 75% reduction of the friction coefficient in direct comparison with unlubricated cable ducts, 50 x 4.6 mm (conventional technology).

Comparative tests with continuous lubrication did not produce any further reduction of the 0.1 µ friction coefficient in the MaxCell multiple duct system.



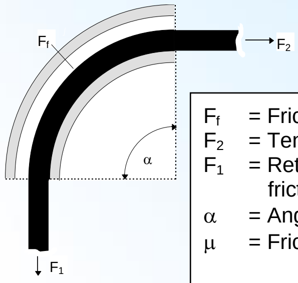
The low cable-pulling friction coefficient value of 0.1 µ for the MaxCell multiple duct system 4016-3 reduces tension forces, thus increasing the laying lengths that can be achieved.

Theoretical background:

Prediction for cable tensile strength

Fig. A.1 Calculation of cable tensile forces acc. to DIN EN 60794-1/ Appendix A Abs. 2.3

Example:	Conventional technology	MaxCell 4016-3
Friction coefficient µ	0.40	0.10
Cable mass at F1 [kg/m] at F2 [kg/m]	 15 28.05	 15 17.55



F_f = Friction force
F_2 = Tensile force at front end of cable [daN]
F_1 = Retention force after removal of friction force [daN]
α = Angle of curvature
µ = Friction coefficient

$$F_2 = F_1 \cdot e^{\mu\alpha}$$

Tensile force at the start of the cable

Any bends in the cable route will increase the pulling force required for installation. This increase must be added to the result of the above calculation and can be calculated according to the values given in the following table.

Tensile force correction factor f for angle of curvature Kurvenwinkel α

Sliding friction µ

µ	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°	
0,60	1,37	1,60	1,87	2,19	2,57	3,00	3,51	4,11	4,81	5,63	6,59	
0,55	1,33	1,54	1,78	2,05	2,37	2,74	3,16	3,65	4,22	4,87	5,63	
0,50	1,30	1,48	1,69	1,92	2,19	2,50	2,85	3,25	3,70	4,22	4,81	
0,45	1,27	1,42	1,60	1,80	2,03	2,28	2,57	2,89	3,25	3,65	4,11	
0,40	1,23	1,37	1,52	1,69	1,87	2,08	2,31	2,57	2,85	3,16	3,51	Conventional technology
0,35	1,20	1,32	1,44	1,58	1,73	1,90	2,08	2,28	2,50	2,74	3,00	
0,30	1,17	1,27	1,37	1,48	1,60	1,73	1,87	2,03	2,19	2,37	2,57	
0,25	1,14	1,22	1,30	1,39	1,48	1,58	1,69	1,80	1,92	2,05	2,19	
0,20	1,11	1,17	1,23	1,30	1,37	1,44	1,52	1,60	1,69	1,78	1,87	
0,15	1,08	1,13	1,17	1,22	1,27	1,32	1,37	1,42	1,48	1,54	1,60	
0,10	1,05	1,08	1,11	1,14	1,17	1,20	1,23	1,27	1,30	1,33	1,37	MaxCell
0,05	1,03	1,04	1,05	1,07	1,08	1,10	1,11	1,13	1,14	1,15	1,17	
0,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	

MaxCell aramide pulling grip	No damage to the duct system Tensile strength of the pulling grip

The MaxCell aramide pulling grip provided caused no damage whatsoever to the MaxCell multiple duct system 4016-3 or the optical cable. [Note: the tests were carried out without using any additional insulating tape]. In a comparison test with an undamaged metal pulling grip there was no damage of any sort to the MaxCell multiple duct system 4016-3 or the optical cable

The tensile force values specified by the manufacturer were complied with.

Type	Max. tensile force Nominal	Breaking force Actual
M5/18	5500 N	7300 N
L11/36	10000 N	12500 N

Photos: Test results

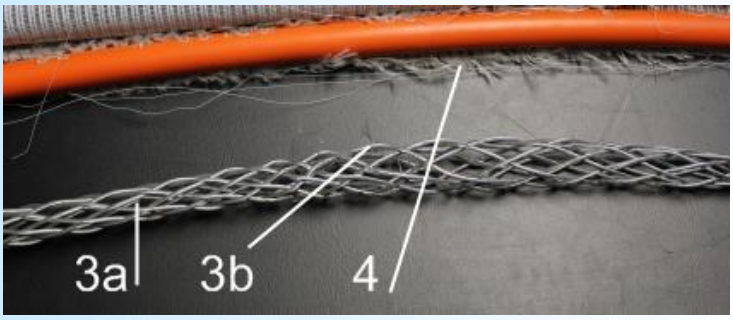
1. Utilization of MaxCell components

1 MaxCell aramide pulling grip

2 The MaxCell multiple duct 4016-3 is undamaged after cable installation with an aramide pulling grip

2. Comparison test

In a comparison test with a damaged metal pulling grip, the MaxCell multiple duct system was damaged. If a metal pulling grip is used, it must be inspected for damage beforehand.



3a Metal pulling grip

3b Broken steel wire

4 a MaxCell multiple duct 4016-3, damaged by a metal pulling grip in a 90° deflecting device

MaxCell multiple duct system 4016-3	No abrasion of the cable sheath

In contrast to currently used technology, after a simulation of cable retrofitting, in which the cable was removed under a tensile load of up to 1.6 x W (cable weight) and a friction value of ~ 0.10 µ, there was no evidence of abrasion of the LDPE cable sheath.

The consequences of water entry in cables and cable splice sleeves do not apply for the MaxCell multiple duct system 4016-3.

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Test Report No.: PB 32/2012

Pulling performance of cables in MaxCell multiple duct systems for local network cables and FTTH network expansion

Product: MaxCell highly flexible multiple duct systems, Type 4016-3, for cost-effective and efficient use of space in cable ducts

Scope of testing:

- Pulling performance of MaxCell multiple duct systems in plastic ducts and pulling performance of cables
- Pulling performance of pulling aids and cables in MaxCell multiple duct systems and determination of change of line pull
- Determination of the friction coefficients of the relevant installation components under tensile load
- Determination of mechanical property changes in the outer and inner cable construction elements and the MaxCell multiple duct systems

Client: MaxCell Innerduct, Wadsworth Ohio, USA

Testing specifications: Based on:

DIN EN 60794-1-2/ Method E18 (test using a dynamic s-shape)

Cable testing under tension

DIN EN 60794-1-1/ Appendix A "Guide for laying optical fibre cables"

- Fibre Optics CT Testing specification PG20-2 Test No. 1346

Stuttgart, 22.02.2012

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Project manager:
Managing director

Mechanical and dynamic
measuring technology:

Test certificate
15-01-PB226/2011
Valid until 30.11.2013

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