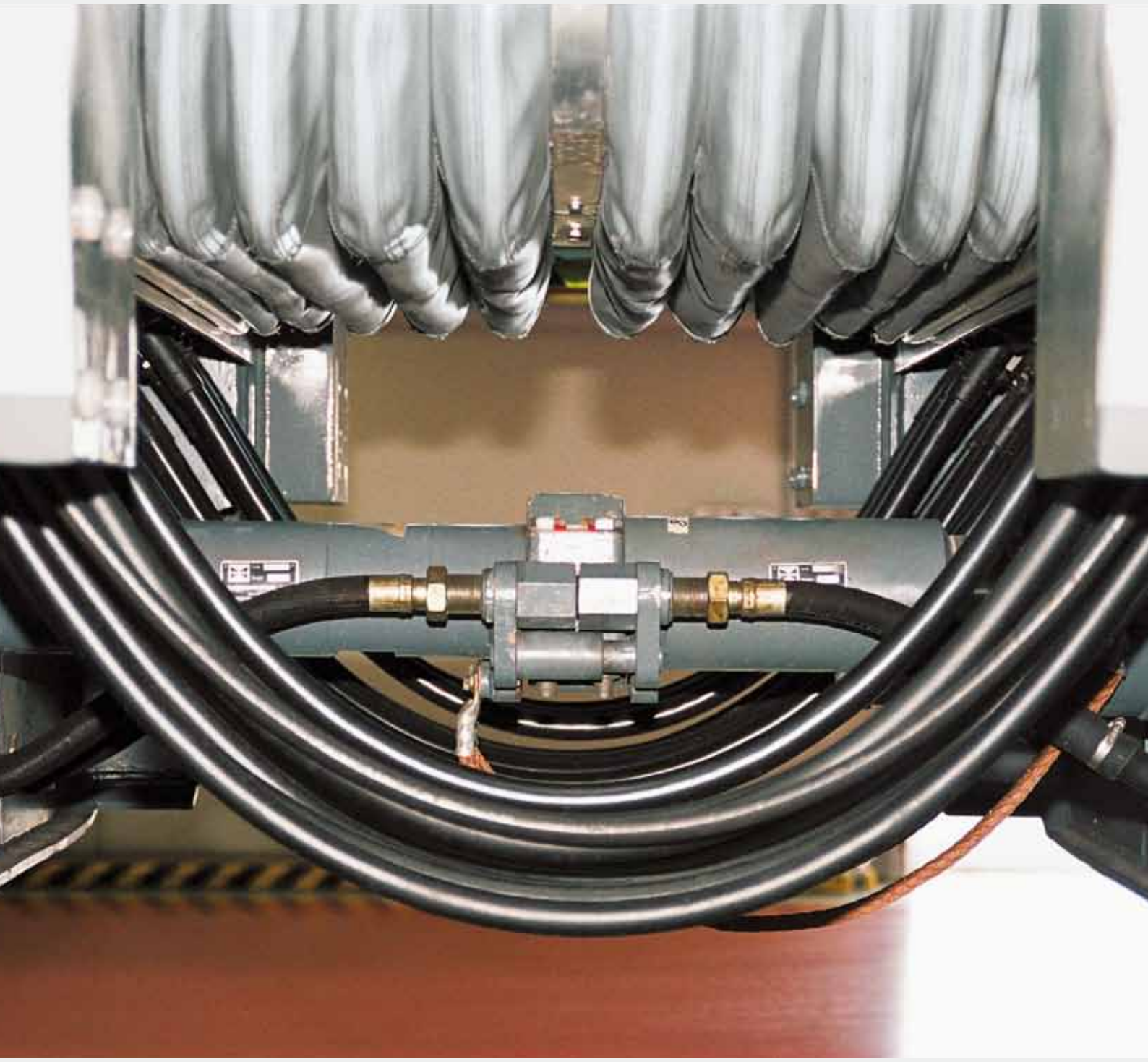
Inter-Vehicle Jumper Systems

White paper

Edition 2011



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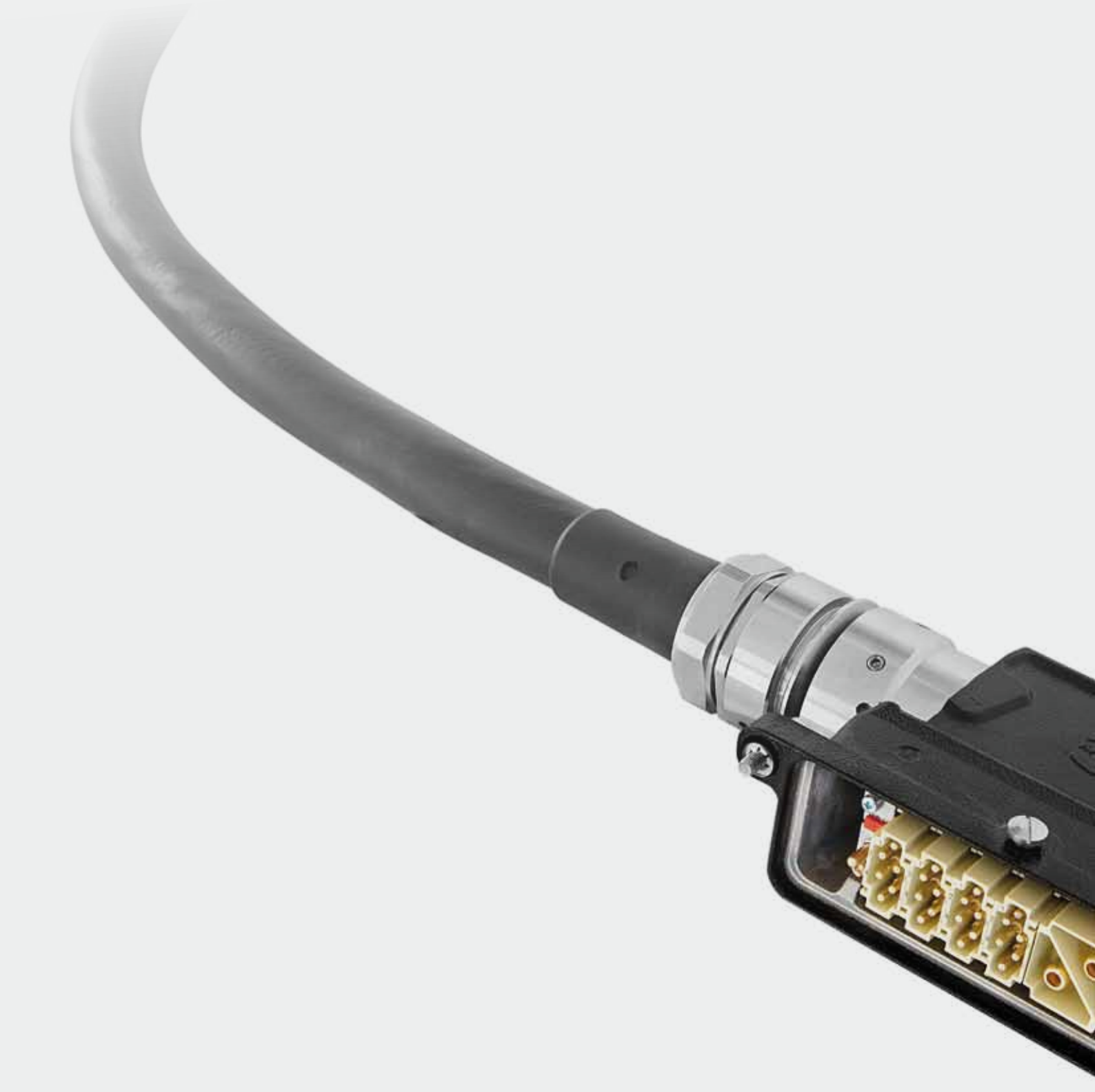
High-performance connections



Inter-vehicle jumper systems with HUBER+SUHNER railway cable systems

Expertise across the board

The HUBER+SUHNER Group is a leading international manufacturer of components and systems for electrical and optical connectivity. Our main markets are communications, transport and industry. Combined under one roof in-depth knowledge in the key technological areas of low frequency (cable), radio frequency and fiber optics .
With many years of experience in the railway sector, HUBER+SUHNER is able to manage the most complex projects. Sustained growth rates demonstrate that HUBER+SUHNER railway cable systems are more than capable of meeting the growing challenges of todays market. Many blue-chip companies all over the world opt for products and services of HUBER+SUHNER.

Partners and customers of HUBER+SUHNER benefit from:

- an unrivalled, global production, logistical and sales network
- in-depth product expertise in low frequency, radio frequency and fiber optics applications
- professional and reliable, global project management

About the author

Urs Meissner is Product Marketing Manager Railways for Cable Systems at HUBER+SUHNER in Pfäffikon, Switzerland.
Many thanks to Rudolf Benninger, Cable Design Engineer at HUBER+SUHNER, for his valuable technical input to this paper.

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Inter-vehicle jumper systems

Cost benefit

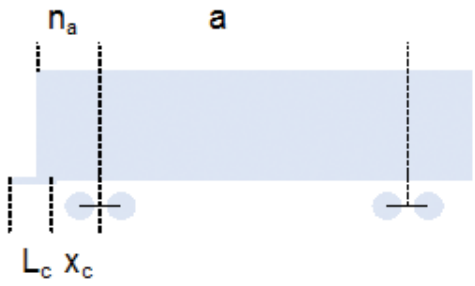
Today's inter-vehicle jumper systems must be capable of withstanding a diverse array of electrical, mechanical and climatic conditions Therfore , the design of the inter-vehicle jumper system must consider the influence from; flow of current and the resulting heating, vibration, bending and torsion, as well as ambient temperature, ballast strikes, weathering, oils + fluids and various types of cleaning agent, to ensure long term service life. The requirements of the Operator with regard to a reliable electrical connectivity from vehicle to vehicle, are subject to conflicting priorities with regard to cost and benefit (service life). The more energy that is required, the denser the signal transmission and data traffic. Each of these factors adds to the complexity of the cable construction, which influences costs.

Requirement: innovative and reliable solutions at an affordable costs

Inter-vehicle jumper systems must satisfy the technical requirements of customers as well as the demands of a market that must have a cost / benefit ratio. Therefore some points must be borne in mind when developing and designing electrical inter-vehicle jumper systems.

Basics: vehicle geometry

Designing a reliable system requires precise specifications. The vehicle geometry data is a particularly important factor.



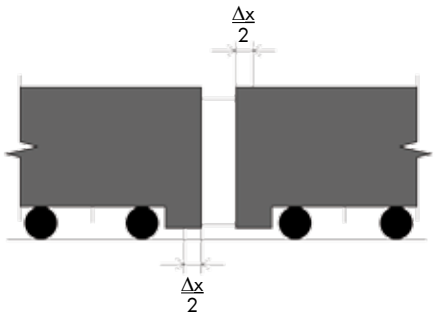
Vehicle geometry	Expression	Unit	Value
Vehicle geometry data Bogie centre-to-centre distance	a	[mm]	17375
Coupling length nominal/ transition	2*Lc	[mm]	2210
Distance from centre of bogie to coupling pivot point	Xc	[mm]	2595
Distance from centre of bogie to end of inter-vehicle	na	[mm]	3300

(Table: vehicle geometry)

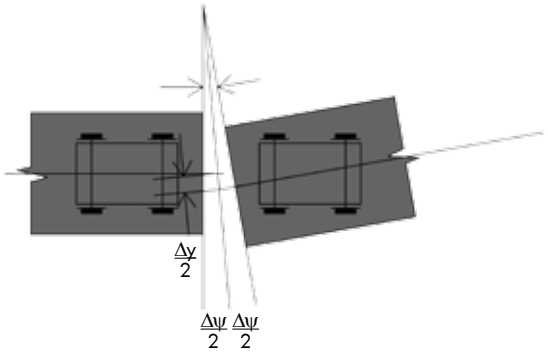
Load test: relative movement between the vehicles

Electrical inter-vehicle jumper systems are installed between two mechanically-coupled vehicles and may contain power, signal, communication and data cables. It is essential to know exactly how the two vehicles move so that the system can be designed in such a way that this movement does not exert too much strain on the transition. Kinematic aspects, together with the vehicle geometry, therefore forms the basis of the system design.

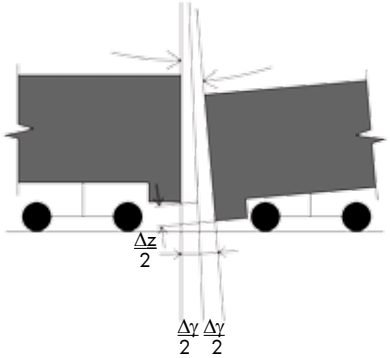
- Push and pull: longitudinal travel
  The extent to which the coupling compresses and decompresses in the coupling axis when accelerating and braking is referred to as longitudinal travel.



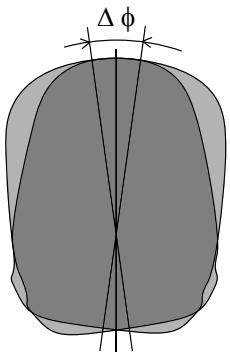
- Lateral deflection: axial offset
  When a train crosses a set of points, for example, two coupled wagons will experience an axial offset with respect to one and another. This relative deflection is known as the axial offset. Of significance in its calculation is the bisector of the articulation angle of the two vehicles, which is located exactly midway between the front walls of the two vehicles and relates to their longitudinal axis.



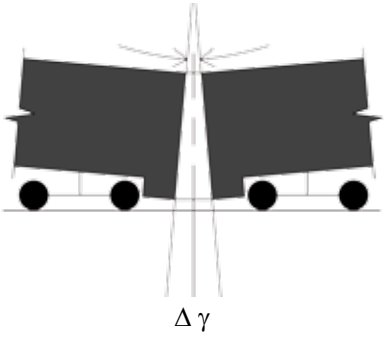
- Higher and lower: height offset
  If the vehicles move vertically in relation to each other, this is referred to as the height offset and takes the pitch angle into account. Of significance in its calculation is the bisector of the pitch angle of the two vehicles, which is located exactly midway between the front walls of the two vehicles.



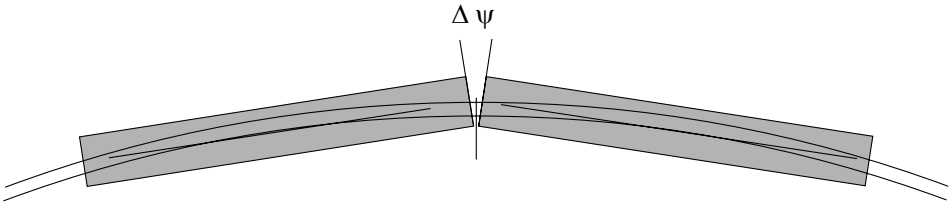
- Back and forth: roll angle
  If a vehicle starts to roll, the rotation around its own axis is referred to as the roll angle. This is expressed as a relative angle between two vehicles.



- Up and down: pitch angle
  "Pitch" is understood to be the vertical movement of a vehicle. It is caused by the influence of varying forces at a particular level that lies between the fronts of the vehicles. The pitch angle thus describes the relative vertical angle between two vehicles.



- Left and right: articulation angle
  When a train travels around a curve, the relative horizontal angle between two vehicles changes. This change is known as the articulation angle.



A decisive factor in the design of an inter-vehicle jumper systems system is the totality of all six relative movements and their maximum amplitudes, which are summarised in the table below.

Type of movement	Unit	Value
Longitudinal travel: push / pull	Δx [mm]	+ 60 /-70
Axial offset	Δy [mm]	± 610
Height offset	Δz [mm]	± 265
Roll angle	$[\Delta \phi]$ [°]	± 3.8
Pitch angle	$[\Delta \gamma]$ [°]	± 3.0
Articulation angle	$[\Delta \psi]$ [°]	± 9.6

(Table: relative movements)

The vehicle geometry data and the relative movements directly affect the cable bending radius and the torsion, which together define the limits of the system. The bending radius in turn depends on the cable construction and the choice of material used for the cable jacket. HUBER+SUHNER RADOX® materials and cables are designed specifically to meet these requirements.

Another important factor: the frequency distribution of the movements

Of course, not every movement in the day-to-day operation of a train results in a maximum deflection. Different curve radii also generate different degrees of cable bending. The greater understanding we have of the loads that occur, the more accurately can the service life of an inter-vehicle jumper systems cable be predicted.
If one knows the actual route profile of a train, then the frequency distribution of the movements can be calculated. This distribution then becomes another variable in the design of the cable. The movements listed below are half cycles: they start from their normal position and go to their respective maximums and back again.

Extent of deflection / movement	Vibrations / 1 Mio. km	Geometric deflections/ 1 Mio. km	Total movements / 1 Mio. km
10 %	6.30 E+07	2.00 E+05	6.32 E+07
20 %	1.83 E+07	2.00 E+05	1.85 E+07
30 %	2.57 E+06	2.00 E+05	2.77 E+06
40 %	6.43 E+05	2.00 E+05	8.43 E+05
50 %	6.43 E+05	2.00 E+05	8.43 E+05
60 %	0.00 E+00	7.87 E+05	7.87 E+05
70 %	0.00 E+00	4.86 E+05	4.86 E+05
80 %	0.00 E+00	1.37 E+05	1.37 E+05
90 %	0.00 E+00	1.37 E+04	1.37 E+04
100 % (maximum deflection)	0.00 E+00	2.00 E+03	2.00 E+03
Total movements	8.52 E+07	2.43 E+06	8.76 E+07

(Table: frequency distribution of movements)

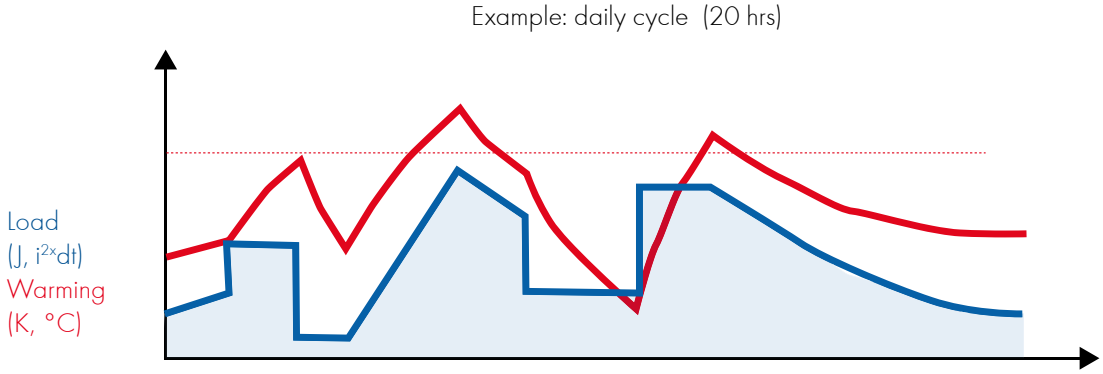
Things get hot at –50 °C: effect of ambient temperature

An ambient temperature in the range –25 °C to +90 °C poses no particular problems for HUBER+SUHNER inter-vehicle jumper systems during normal operations. At lower temperatures, down to –50 °C, additional attention must be paid to the design of the cable. The prescribed standard tests, such as the cold winding test and impact test, are no longer adequate in such cases, as they do not satisfactorily reflect true operating conditions. HUBER+SUHNER therefore carries out in-depth movement tests in climatic chambers down to –50 °C.

Photo: test configuration in climatic chamber

Realistic: determining the permitted operating temperature

In order to determine the permitted operating temperature of an inter-vehicle jumper systems cable, it is not sufficient to only consider the ambient temperature; the heat generated by the flowing currents must also be taken into account. This is done using current load profiles. Once the current load is known, an appropriate cable cross-section can be determined that will limit the maximum jacket operating temperature from being reached. Although the design of current load profiles is highly complex, it is the calculation that most closely approximates operational practice. [i = f(t); W = i2*dt]



(Diagram: current load profile)

The following table provides a good starting point for a current load profile. It shows the current flow as a function of time and the speed of the vehicle.

t [s]	Ieff [A]	V [km/h]
228.88	936.28	189.0
234.31	936.24	190.8
239.87	936.20	192.6
245.58	936.16	194.4
251.43	936.14	196.2
257.43	936.12	198.0
263.58	936.10	199.8
269.90	936.08	201.6
276.39	936.06	203.4
283.06	936.06	205.2
289.92	936.06	207.0
296.98	936.04	208.8
304.25	936.06	210.6
311.74	936.04	212.4
319.45	936.04	214.2
327.42	936.06	216.0
335.65	936.08	217.8
344.15	936.08	219.6
347.99	589.22	220.0
699.01	589.22	220.0
699.48	531.12	219.6
700.51	530.92	217.8

(Table: current load profile)

Varied and complex: fire safety requirements

Customer specifications frequently quote several fire protection standards, all of which need to be complied with. This requires a high degree of flexibility with regard to the material used in the cable jacket and a careful choice of material. The cross-linked RADOX® EM104-J jacket material from HUBER+SUHNER fulfils the majority of today's most commone used fire safety rquirements and and offers significant advantages compared with non-cross-linked TPU / polyurethane materials.

Standard DIN 5510-2 : 2007	Remarks AT, (BE), CH, DE, NL, NO, SE	Test procedures	TPU	EM104-J
Vertical flame spread		EN 60332-1-2		
Vertical flame spread	Bunched	EN 50266-2-5, EN 50266-2-4		
Smoke density	Not required for inter-vehicle jumper systems	EN 61034-2		
Corrosivity of gases evolved during combustion		EN 50267-2-2		
Amount of halogen acid gas		EN 50267-2-1		
Fluorine content		EN 60684-2, 45.2		
Toxicity		EN 50305, 9.2		
NF F16-101 : 1988	BE, CH, FR, NL, NO, SE			
Vertical flame spread		NF C32-070, 2.1		
Vertical flame spread	Bunched	NF C32-070, 2.2		
Smoke density		X10-702-2		
Toxicity		NF X70-100		
BS 6853 : 1999 + GM/RT 2130 : 2008	GB			
Vertical flame spread		EN 60332-1-2		
Vertical flame spread	Bunched	EN 50266-2-4, BS 6853 An. D.8.7		
Smoke density		BS 6853 An. D		
Toxicity		BS 6853 An. B		
UNI CEI 11170 : 2005	IT			
Vertical flame spread		EN 60332-1-2		
Vertical flame spread	Bunched	EN 50266-2-5 (EN 50305, 9.1.1)		
Smoke density		EN 61034-2		
Degree of corrosion of gases evolved during combustion		EN 50267-2-2		
Amount of halogen acid gas		EN 50267-2-1		
Fluorine content	Not required for inter-vehicle jumper systems	EN 60684-2, 45.2		
Toxicity		EN 50305, 9.2		
CEN/TS 45545-2 : 2009	Across EU in future			
Vertical flame spread		EN 60332-1-2		
Vertical flame spread	Bunched	EN 50266-2-5, EN 50266-2-4		
Smoke density		EN 61034-2		
Toxicity		CEN/TS 45545-2; C.16.4		

Green Satisfied
Red Not satisfied
Yellow Dimension-dependent

(Table: fire protection requirements)

A clean business: resistance to cleaning agents

Dust, ozone, sulphur dioxide, salt and salt spray, coolants, anti-freeze, hydraulic fluids, lubricants: numerous airborne agents occur on the railways. Inter-vehicle jumper systems must demonstrate a good resistant – to most common used railway cleaning agents. This list shows the most used cleaners and their pH-values.

Type of cleaner	ph-value
Neutral cleaner	6 - 7.5
Weak alkaline cleaner	9.5 - 12.5
Alkaline cleaner	9.5 - 11
Hydrochloric cleaner	0.5 - 2
Oxalic cleaner	1
Phosphoric cleaner	1 - 2
Phosphoric mixed cleaner	1 - 2
Acidic window cleaner	2 - 3
Alkaline window cleaner	9
Window rinsing liquid	2 - 2.5
Powdered pumice (window cleaner)	7 - 7.5
Graffiti remover	5 - 8.5

(Table: railway cleaning agents)

Powerful impact: ballast strike

Ballast strikes the underside of the vehicle at approximately the speed at which the train is travelling. This can result in serious impairment of the system, particularly in the case of low-hung inter-vehicle jumper systems. The risk is particularly pronounced in high-speed vehicle movements.

The ballast strike phenomenon can be caused by:
- aerodynamic loads, in particular the increased longitudinal flows underneath the train
- falling ice, in other words the working loose at high speeds of accumulated ice, which then falls onto the track bed
- high ballast levels
- monobloc concrete sleepers
- size of ballast

A distinction is made between the following degrees of damage:
- light, sporadic ballast strike by chips of ballast weighing up to 70 g
- sporadic strikes by chips weighing up to 150 g
- massive ballast strike, caused by falling ice, involving chips of ballast weighing up to 200 g

The cable insulation may be damaged depending on the weight and speed of the ballast. Attention must be paid to any nicks in the sleeve insulation. In any nicks or cuts are found in the cable it must be replaced as a matter of urgency in order to avoid the risk of further damage which will cause premature failure on the Inter vehicle jumper system and continued running service of the vehicle. Protection against the effects of ballast strike can only be achieved through design measures, or the addition of wind deflectors and protective plates.

Service life and costs: the RAMS and LCC analysis

Vehicle operators demand long- service life of products with the highest levels of safety, functionality and economy. This means:

- total reliability
- simple maintenance
- efficient fault detection

Movement clearance, cable design and environmental influences play an important role when considering the service life of inter-vehicle jumper systems (RAMS analysis). The keywords are reliability, availability, maintainability and safety, or RAMS. Below is an example.

			Cable		Assemblies	
		Reliability	**Failure rate**	**Service life**	**Failure rate**	**Service life**
Reliability	Product characteristics	Component reliability	λ = 0.125 / Jahr	8 years	λ = 0.125 / year	8 years
		FIT	2600 fit		2600 fit	
		- Chemical degradation (tinning of the wire) - Electrical degradation - Thermal degradation - Mechanical loads - Environmental influences				
		System architecture and redundancy	N/A		As shown in drawing:	
Availability	Operational influences	System availability	Cable availability A = 1 - H x MDT		Availability A = 1- H x MDT	
		Maintenance-friendly construction	A = 1 (cable) – no statements can be made regarding system availability, but cables may have an influence		A = 1 (cable) – no statements can be made regarding system availability, but cables may have an influence	
		Unscheduled interruptions	No assessment possible		No assessment possible	
		Scheduled interruptions	No maintenance interventions required for fixed cables → visual inspection		No maintenance interventions required for system cables → visual inspection	
Maintain-ability		**Maintainability**				
		- Maintenance / actions	None		None	
		- Installation / dismantling	Replacement of cable		Replacement of system cable	
Safety		**Safety**				
		- Safety risks for people and the environment	The "cable" product does not constitute any risk. A fire test and toxicity test, for example, are carried out according to the CEN/TS standard.		The "system cable" product does not constitute any risk. Continuity and insulation tests have been carried out.	
Spare parts		**Spare parts**				
		- Availability of spare parts	Replacement of cable		Replacement of system cable	
		- Configuration management				
		Obsolescence				
			Provided, i.e. customers are consulted in the event of changes and informed when withdrawn.		Provided, i.e. customers arecon-sulted in the event of changes and informed when withdrawn.	

(Table: RAMS/LCC analysis)

Low maintenance costs must be demonstrated as part of Life Cycle Costing (LCC). The formula used is as follows:

LCC = VP / n + u + ek
VP = selling price to customer
n = average useful life in years
u = recurring annual costs, e.g. for maintenance and repairs
ek = costs of disposal

Structured approach to solutions adopted by HUBER+SUHNER

The modular approach to solutions, with freely selectable services, enables HUBER+SUHNER expertise to be employed right from the outset of the "Electrical inter-vehicle jumper systems" subproject. The earlier HUBER+SUHNER obtains an insight into the project, the more flexibly we can employ on the design and functionality to the customer's requirements.

«Innovative inter-vehicle jumper systems solution: the benefit is co-design.»

Photo: Innovative underfloor inter-vehicle jumper systems

Co-design

As a system provider, HUBER+SUHNER can deliver professional advice from the development phase onwards.

1. On-site design support
   a. Optimised cable selection from the HUBER+SUHNER cable portfolio according to customer specification
   b. Assessment and optimisation of inter-vehicle jumper systems system limits
   c. Advice and recommendations concerning kinematic aspects
   d. Advice and recommendations concerning logistic aspects, such as transportation and packaging concepts
   e. Definition of service-life trials for establishing system service life

2. Virtual design support
   a. Computer-aided verification of kinematic system taking specific cable properties such as flexibility and temperature effects into account

3. Identifying inter-vehicle jumper systems
   a. Use of technology to make the life cycle management of the operator more efficient

Greater protection: the cable design

Suspension and guidance are the main factors determining the service life, and hence the cost efficiency, of inter-vehicle jumper systems cables. The stranding of the individual components is user-specific and has a positive effect on pliability, flexibility and stability. The torsional load on the cable elements is reduced; special design features guarantee excellent operational stability. The compact design offers the individual cable elements greater protection against vibration and acceleration than the looser design commonly found in corrugated tubes

Less load: the design of the connections

HUBER+SUHNER encases the cables in an anti-kink sleeve, which effectively joins them permanently to the cable jacket. This construction ensures that torsional forces are transferred to the cable penetration (plug and sleeve) and that the cable elements are not exposed to any clamping forces. It also prevents the cable from kinking when it is bent. The operational benefits of the anti-kink sleeve are obvious: as the cable elements are "supported" by the cable jacket, the sleeve and the screw fastening, they are not exposed to any load and there is none of the problematic trapping of cable elements at clamping points caused by screw fastenings.

Playing safe: the UNI-DICHT strain relief system

The deliberate clamping area gradation of the UNI-DICHT system provides an optimal transmission of clamping forces to the individual components involved. As the pressure is distributed over a wide area, there is to all intents and purposes no chance of any damage. Sealing to IP68 and cable relief is also guaranteed. The UNI-DICHT inserts are also fitted with a membrane that provides sealing to IP54, even if the fastening is not appropriately tightened.

Shorter service life: the standard commercial clamping system

Compared with the HUBER+SUHNER UNI-DICHT system, clamped joints and other systems with cable relief have obvious drawbacks. For example, these types of construction are not accompanied by a manufacturer's guarantee. As the cable elements are self-supporting due to the clamping effect of the screw fastening, their service life is reduced dramatically.

In addition, the torsion permanently damages the clamp between seal and jacket, which can, among other things, cause condensation to form. Condensation provides a breeding ground for bacteria, which may attack the cable's insulation material causing degradation. Furthermore, ice is likely to form when the temperature drops below zero. Moreover, the torsion in the seal will mean that the required protection class will only be provided for a short while. The cable may kink if it is bent in the vicinity of the clamp, and the length difference in the unstranded elements, which have simply been twisted, makes it significantly more sensitive. The fact that no account is taken of vibration in the case of clamped joints and other systems with cable relief can also has negative repercussions.

Comparatively better: cable relief using an anti-kink sleeve

Cable relief for the cable jacket on system cables made by HUBER+SUHNER is provided by the anti-kink sleeve on the screw fastening. This construction produces an even, parabolic transition from the moving cable to the rigid screw fastening and increases the service life markedly: this is ten to twenty times higher than for systems without the sleeve. The diameter and length of the sleeves are adapted to suit the installation requirements and the complete bushing - cable, sleeve and screw fastening – is torsion-proof, dustproof and waterproof.

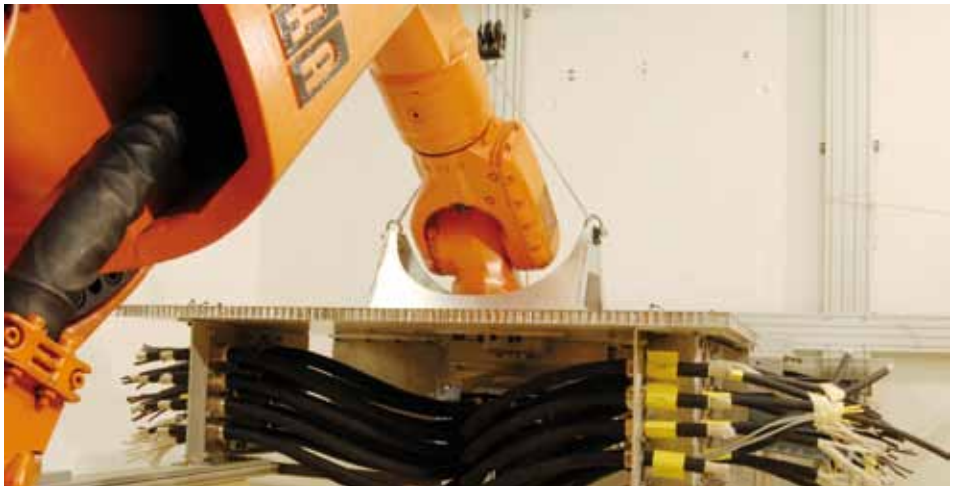
HUBER+SUHNER inter-vehicle jumper systems cables with anti-kink sleeves benefit from clear and reproducible installation conditions without imposing any radial constraints on the internal cable structure. Their small diameter also means they can be used in situations where space is at a premium. Another benefit of screw fastenings is that they enable the service life to be calculated in advance: approximations can be made by carrying out dynamic long-term tests.

Even though the corrugated tube solution and screw fastenings of various manufacturers have the advantage of easy-to-use assemblies, the undefined pressure of the screw fastenings on the cable dramatically reduces service life – partly as a result of the ensuing sealing problems. The fact that only part of the diameter of the corrugated tube is used makes its dimensions much larger, so it takes up more space with limited bending radii. Retrofitting of additional cores, however, is only possible by modifying the cable (assuming the layout inside the cable permits) whereas this can be done without any difficulty in the case of corrugated tube versions, although the capacity of the pipe will be a limiting factor.

Quality on the test rig: the HUBER+SUHNER test centre

HUBER+SUHNER inter-vehicle jumper systems solutions undergo systematic checks. Intensive movement testing can be carried out in our in-house test centre. The test program can be defined jointly with the customer so that it ends up as an endurance test. Various simulators are available for this purpose:

- 6-axis robot
- 2-axis motion tables
- eccentric machines for oscillation testing
- apparatus for carrying out bending and abrasion tests



Inter-vehicle jumper systems solution in test centre

«Genuine «swiss made»: HUBER+SUHNER patented solutions.»

HUBER+SUHNER patents

Cable anti-kink and strain relief and the procedure for installing an anti-kink sleeve.
This construction ensures that the forces exerted on the cable are always transferred to the cable penetration and that the cable elements are not exposed to any clamping forces. They also prevent the cable from kinking when it is bent.

Connecting cable for the electrical connection of two spatially separated pieces of equipment and the use of such a connecting cable.
This construction provides reliable bridging of even small spatial distances by making in a central section of the suspended connecting cable a preformed, arc-shaped and dimensionally stable loop, the radius of which is smaller than half the difference of the cable and suspended loop diameters typical of cables.

Feed-through EMC anti-kink sleeve.
This construction assumes a screw fastening for a cable with the following structure: the outer shielding is encased in a cable jacket over which an anti-kink sleeve has been applied. This has fixing points for the cable screw fastening.

Market leaders trust HUBER+SUHNER

DOSTO Electric double deck train with inter-vehicle systems from HUBER+SUHNER

Project share of HUBER+SUHNER

- Consulting
- Cable design and production
- Design and production of special strain relief grommets
- System Engineering
- Production
- Logistics
- Quality Assurance

Customer requirements

- Long project running time
- Cable fire performance requirements in accordance with European Standards
- Fixed price

Technical customer value

- Perfectly coordinated HUBER+SUHNER products
- Tested and optimised solutions

Commercial customer value

- Predictable costs thanks to fixed price
- Low project risks
- Just in time delivery

GTW with inter-vehicle systems in conduit solution

Project share of HUBER+SUHNER	• Development • Production • Logistics
Customer requirement	• Short project running time • Fixed price
Technical customer value	• Perfectly coordinated HUBER+SUHNER products • Tested and optimised cable solutions
Commercial customer value	• Predictable costs thanks to fixed price • Low project risks • Just in time delivery

FLIRT with inter-vehicle systems in conduit solution

Project share of HUBER+SUHNER	• Development evaluation
Customer requirement	• Short project running time • Processing of 3 supplier components (70 % of the products supplied)
Commercial customer value	• Reduction of the number of prototypes = reduction of costs • Professional change management

VELARO D inter-vehicle systems designed and developed by HUBER+SUHNER. Inter-vehicle systems suspended under carriage coupling

Project share of HUBER+SUHNER

- Development and design of networked RADOX system cables in accordance with fire protection requirements:
  - CEN/TS 45545
  - DIN 5510-2
  - NF F 16-101/-102/-103
  - UNI CEI 11170-1/-2/-3
- Development and design of cable conduits and their suspension for installation of RADOX system cable
- Production
- Logistics

Customer requirement

- Minimum bending radii
- Static and dynamic loading
- Aerodynamics and stone impact protection
- Weight management
- Service friendliness
- Increased performance requirements as a result of assemblies being used externally on very high speed trains
- Product validation by extensive testing

Technical customer value

- Perfectly coordinated HUBER+SUHNER products
- System solutions optimally developed to customer requirements
- Tested and optimised cable solutions

Commercial customer value

- Cost-efficient pre-fabricated solutions
- Low project risks
- Just in time delivery

DESIRO double deck EMU inter-vehicle systems from HUBER+SUHNER

Project share of HUBER+SUHNER	• Development • Production • Logistics
Customer requirement	• Short project running time • Fixed price
Technical customer value	• Solution optimally developed to meet customer requirements • Tested and optimised carriage transitions
Commercial customer value	• Predictable costs thanks to fixed price • Low project risks • Just in time delivery

ICE3 inter-vehicle systems from HUBER+SUHNER

Project share of HUBER+SUHNER	• Development • Production • Logistics
Customer requirement	• Static and dynamic stressing • Increased requirements owing to outdoor applications in very high speed trains • Proof of quality by testing
Technical customer value	• Perfectly coordinated HUBER+SUHNER products • Developed solution demonstrably tailored to customer needs • Tested and optimised carriage transitions as system cables
Commercial customer value	• Cost-effective pre-fabricated solution • Low project risks • Just in time delivery

Bridging our technologies. Wherever you are.

AUSTRALIA

HUBER+SUHNER (Australia) Pty Ltd
Unit 6, 4 Skyline Place Frenchs Forest
AU-Sydney NSW 2086
Tel. +61 (0)2 8977 1200
Fax +61 (0)2 9972 7549
info.au@hubersuhner.com

BRASIL

HUBER+SUHNER América Latina Ltda
Av. Rui Barbosa, 3613 Alto da Ponte
BR-12212-531 São José dos Campos-SP
Tel. +55 12 3946 9500
Fax +55 12 3946 9528
info.br@hubersuhner.com

CHINA

HUBER+SUHNER (Hong Kong) Ltd
Unit 1101 & 1121, Level 11, Tower 1
Grand Central Plaza
No. 138 Shatin Ruralo Committee Road
Shatin, N.T., HK-Hong Kong
Tel. +852 2866 6600
Fax +852 2866 6313
info.hk@hubersuhner.com

HUBER+SUHNER (Shanghai) Co., Ltd
Part B 2-3, 2/F
333 Fu Te Xi Yi Road Waigaoqiao
CN-Shanghai 200131, P.R. China
Tel. +86 (0) 21 5899 3808
Fax +86 (0) 21 5899 1860
infoshanghai@hubersuhner.com

HUBER+SUHNER (Shanghai)
Transmission & Communication
Manufacture Co., Ltd
1330, Jin Hu Road
Jin Qiao, Pu Dong New District
CN-Shanghai 201206, P.R. China
Tel. +86 (0) 21 5899 3808
Fax +86 (0) 21 5899 1860
infoshanghai@hubersuhner.com

DENMARK

HUBER+SUHNER A/S
Kirke Vaerløsevej 14
DK-3500 Vaerløse
Tel. +45 48 100 500
Fax +45 48 100 555
info@hubersuhner.dk

FRANCE

HUBER+SUHNER France
21 E, rue Jacques-Cartier
FR-78960 Voisins-le-Bretonneux
Tel. +33 (0)1 61 37 25 55
Fax +33 (0)1 30 64 73 68
info.fr@hubersuhner.com

GERMANY

HUBER+SUHNER GmbH
Mehlbeerenstr. 6
DE-82024 Taufkirchen
Tel. +49 (0)89 612 01 0
Fax +49 (0)89 612 01 162
info.de@hubersuhner.com

INDIA

HUBER+SUHNER Electronics Private Limited
682, Udyog Vihar, Phase V
IN-Gurgaon 122 016, Haryana
Tel. +91 (0)124 452 6100/200
Fax +91 (0)124 410 27 04
info.in@hubersuhner.com

MALAYSIA

HUBER+SUHNER (Malaysia) Sdn. Bhd.
Lot 24, Jln Pengacara U1/48
Temasya Industrial Park
40150 Shah Alam
MY-Selangor
Tel. +60 3 7628 0202
Fax +60 3 7628 0303
sales.my@hubersuhner.com

SINGAPORE

HUBER+SUHNER (Singapore) Pte Ltd
11 Chang Charn Road
#05-02 Shriro House
SG-Singapore 159640
Tel. +65 6573 5500
Fax +65 6473 5522
info.sg@hubersuhner.com

SWEDEN

HUBER+SUHNER AB
Knarrarnäsgatan 7
Box 1247
SE-164 28 Kista
Tel. +46 (0)8 447 5200
Fax +46 (0)8 447 5201
info.se@hubersuhner.com

SWITZERLAND

HUBER+SUHNER AG
CH-9100 Herisau
Tel. +41 (0)71 353 41 11
Fax +41 (0)71 353 44 44
info@hubersuhner.com

HUBER+SUHNER AG
CH-8330 Pfäffikon ZH
Tel. +41 (0)44 952 22 11
Fax +41 (0)44 952 24 24
info@hubersuhner.com

THAILAND

HUBER+SUHNER (Thailand) Co., Ltd.
896/3 SV City Office Tower 1,
4th Floor, Rama III Road,
Kwaeng Bangpongpang,
Khet Yannawa,
TH-Bangkok 10120
Tel. +66 (0)2 682 6868
Fax +66 (0)2 682 6669
info.th@hubersuhner.com

GREAT BRITAIN

HUBER+SUHNER (UK) Limited
Telford Road
GB-Bicester
Oxfordshire OX26 4LA
Tel. +44 (0)1 869 364 100
Fax +44 (0)1 869 249 046
info.uk@hubersuhner.com

USA

HUBER+SUHNER, Inc.
19 Thompson Drive
US-Essex Jct.
VT 05452
Tel. +1 800 493 9758
Fax +1 802 878 9880
info.na@hubersuhner.com

UAE

HUBER+SUHNER Middle East Trading LLC
Dubai Investments Park*
European Business Center, Office 156
N 25° 00' 13.83''/ E 55° 09' 19.06''
P.O.Box 75843
Dubai (United Arab Emirates)
Tel. +971 4 81 35 35 - 0
Fax +971 4 81 35 35 - 1
info.me@hubersuhner.com

HUBER+SUHNER is certified according to
ISO 9001, ISO 14001, ISO/TS 16949 and IRIS.

WAIVER

It is exclusively in written agreements that we provide our customers with warrants and representations as to the technical specifications and/or the fitness for any particular purpose. The facts and figures contained herein are carefully compiled to the best of our knowledge, but they are intended for general informational purposes only.

HUBER+SUHNER AG
Cable Systems
Tumbelenstrasse 20
8330 Pfäffikon
Switzerland
Tel. +41 44 952 2211
Fax +41 44 952 2670
info@hubersuhner.com

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hubersuhner.com