Jumper Solutions

White paper

Edition 2019

HUBER+SUHNER

Excellence in Connectivity Solutions

High-performance connections

Inter-vehicle jumper systems from HUBER+SUHNER

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. The company combines under one roof in-depth knowledge in the key technological areas of low frequency, 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 today's market. Many blue-chip companies all over the world opt for the products and services of HUBER+SUHNER.

Partners and customers of HUBER+SUHNER benefit from:

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

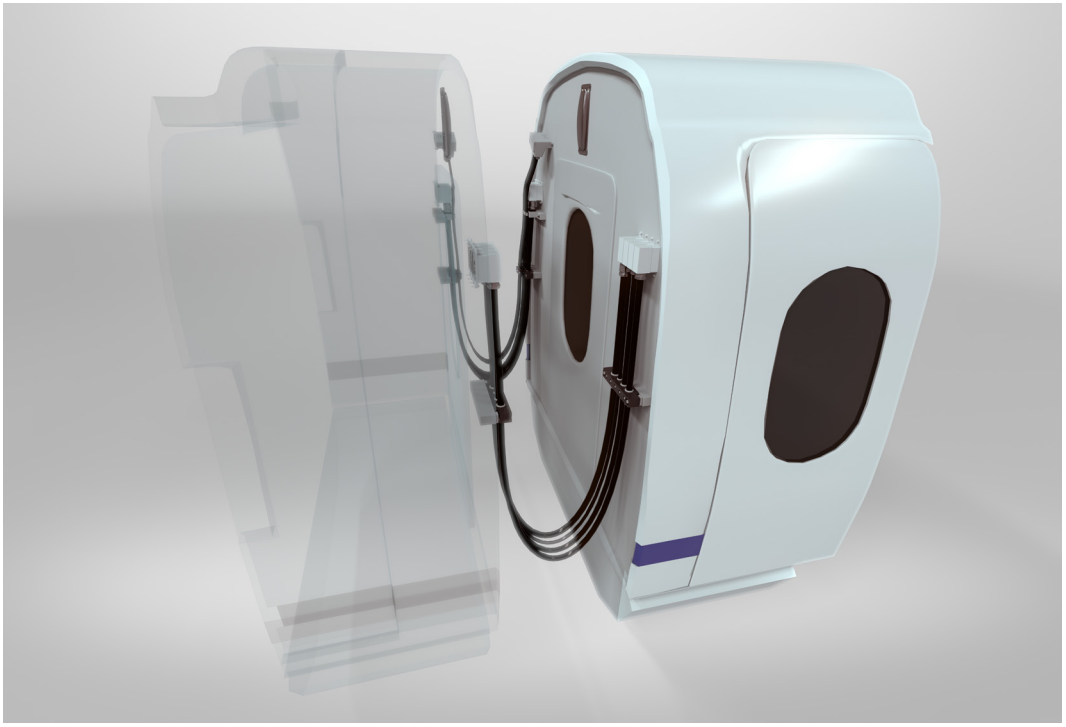
HUBER+SUHNER
Excellence in Connectivity Solutions

Jumper solutions

Today's rail jumper solutions must be capable of withstanding a diverse array of electrical, mechanical and climatic conditions. Therefore, the design of jumper solutions must consider the influences from the 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.

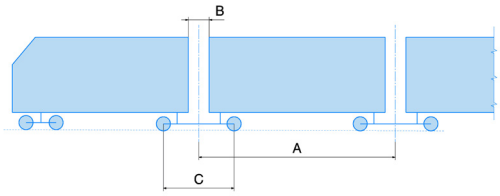
Innovative and reliable solutions at affordable costs

Jumper solutions must satisfy the technical requirements of customers as well as the demands of a market that needs to see an effective cost / benefit ratio. Therefore some points must be borne in mind when developing and designing jumper solutions. Jumper systems are installed between two mechanically coupled vehicles and may contain power, signal, communication and data cables. The cables can contain a combination of our in-house technologies, that is: low frequency (LF), radio frequency (RF) and fiber optics (FO), in a solution developed to meet specific customer requirements.

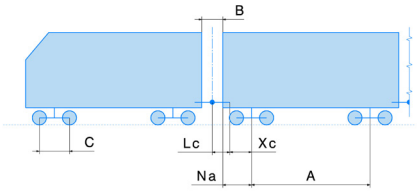


Designing an inter-vehicle jumper system
Vehicle and track geometry

Designing a reliable inter-vehicle jumper system requires precise specifications. The vehicle and track geometry data is a particularly important factor. The geometry differs depending on the bogie type.



Jacobs bogie

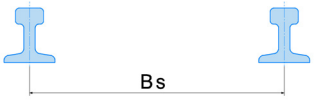
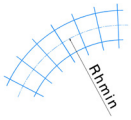
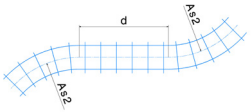
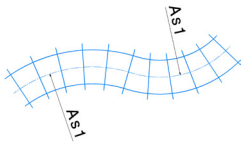
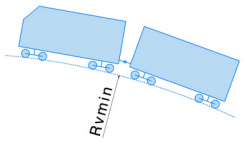


Classic bogie

Vehicle geometry data	Expression
Bogie centre-to-centre distance	A
Nominal coupling length	Lc
Distance from centre of bogie to coupling pivot point	Xc
Distance from centre of bogie to end of inter-vehicle	Na
Nominal vehicle transition	B
Spindle to spindle	C

(Table: vehicle geometry)

The track geometry is as important as the vehicle geometry and provides necessary input data for designing the right system.

Track width	Minimum horizontal radius in a curve	Radius of an S-curve with straight track section
		
Radius of an S-curve without straight track section	Super-elevation cant which can be found in curves and allows a faster curve handling	Minimum vertical radius on a hill (or in a valley)
		

Track geometry	Expression
Track width	Bs
Min. horizontal radius	Rhmin
Radius of an S-curve with straight track section	As2
Radius of an S-curve without straight track section	As1
Straight track section	d
Super-elevation cant	Vr
Min. vertical radius	Rvmin

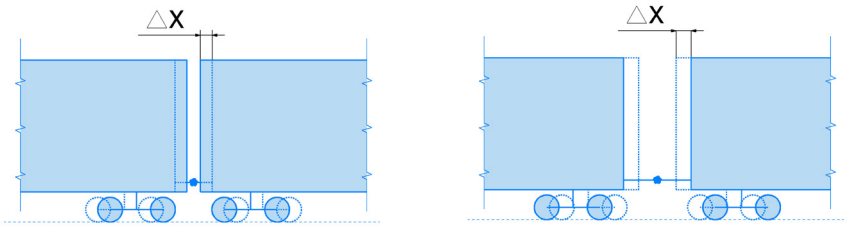
(Table: track geometry)

Relative movement between the vehicles

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 and track geometry, therefore forms the basis of the system design.

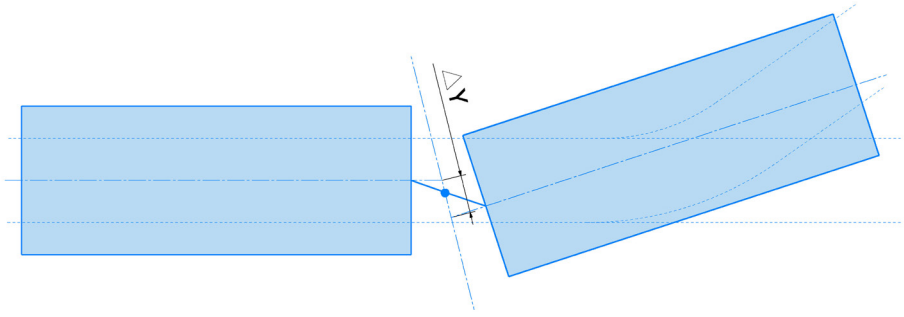
A decisive factor in the design of an inter-vehicle jumper system is the totality of all six relative movements and their maximum amplitudes.

- Longitudinal offset
  The extent to which the coupling compresses and decompresses in the coupling axis when braking and accelerating is referred to as longitudinal push and pull.

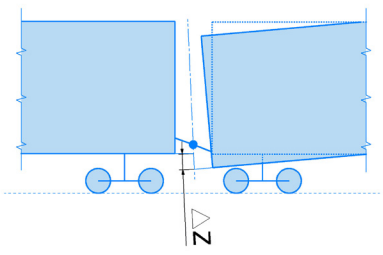


Push Pull

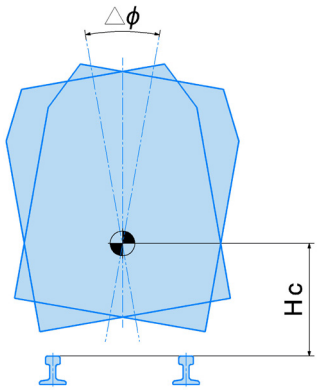
- Horizontal offset
  When a train crosses a set of points, for example, two coupled wagons will experience an axial offset with respect to one and another. This relative deflection is known as the horizontal offset.



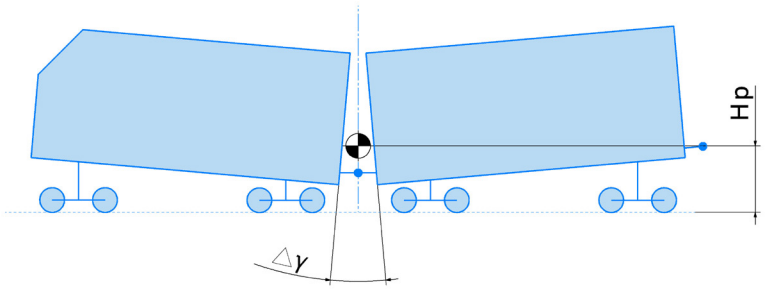
- Height offset
  If the vehicles move vertically in relation to each other, this is referred to as the height offset and takes the pitch angle into account.



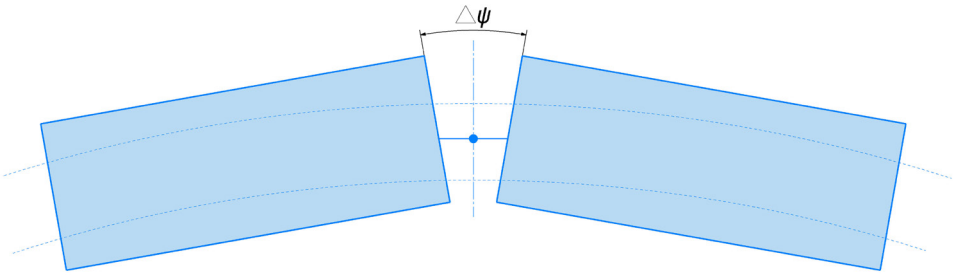
- Roll angle
  If a vehicle starts to roll, the rotation around its own axis is referred to as the roll angle. This is expressed as a relative angle between two vehicles.



- 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.



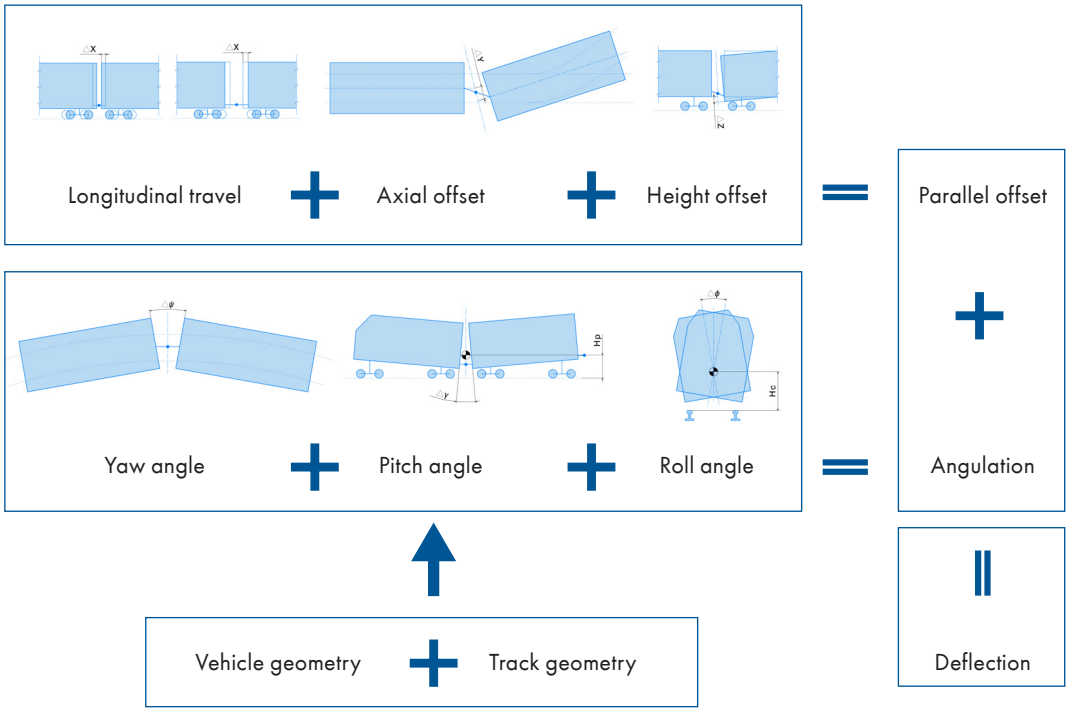
- Yaw angle
  When a train travels around a curve, the relative horizontal angle between two vehicles changes. This change is known as the yaw angle.



Type of movement	Expression
Longitudinal push and pull	Δx
Horizontal offset	Δy
Height offset	Δz
Roll angle	$[\Delta\phi]$
Roll pole	Hc
Pitch angle	$[\Delta\gamma]$
Pitch pole	Hp
Yaw angle	$[\Delta\Psi]$

(Table: Relative movements)

The deflection can either be calculated based on the relative movements of the vehicles or on the vehicle and track geometry. It is also used as a verification of the received data to guarantee a suitable design.



The deflection directly affects 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.

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 the understanding we have of the loads that occur, the more accurately the service life of an inter-vehicle jumper systems cable can be predicted.

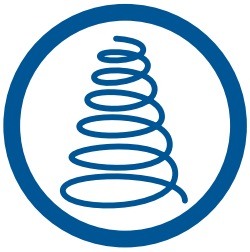
If one knows the actual route profile of a train, then the frequency distribution of the movements can be calculated. This distribution then becomes another variable in the design of the cable. The movements listed below are half cycles: they start from their normal position and go to their respective 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)

RADOX® cable technology

For our jumper solutions HUBER+SUHNER uses its broad RADOX® cable portfolio. The company has developed a range of insulation and sheath materials based on its wide experience in the industry. RADOX® is cross-linked and has enhanced material characteristics. It is easy to process, has world-wide industry approvals and low lifecycle costs, as well as the following benefits.



Increased Flexibilty

Low Corrosive Fume Emission

Flame-Retardant

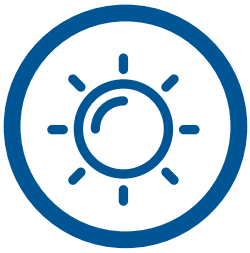
Low Toxicity

Mechanical-Resistant

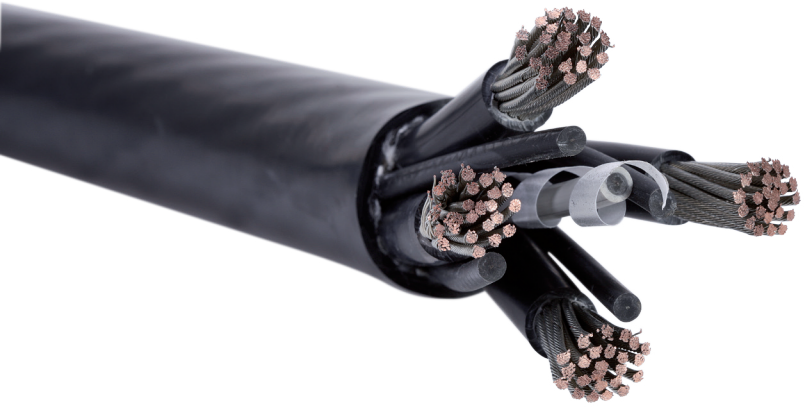
Weathering-Resistant

Low Smoke Emission

Oil-Resistant



Sunlight-Resistant



Fire safety requirements

Customer specifications quote fire protection standards which must 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 commonly used fire safety requirements and offers significant advantages compared with non-cross-linked TPU / polyurethane materials.

Standard EN 455545-2: 2013+A1:2015 HL1-HL3	Remarks Europe	Test procedures	TPU	EM104-J
Vertical flame spread		EN 60332-1-2		
Vertical flame spread	Bunched	EN 60332-3-24 EN 60332-3-25		
Smoke density		EN 61034-2		
Toxicity		EN 50305, 9.2		
Standard NFPA 130:2017	Remarks US	Test procedures	TPU	EM104-J
Vertical flame spread	Bunched	UL 1685, FT4		

Green Satisfied
Red Not satisfied

(Table: Fire protection requirements)

Resistance to cleaning agents

Numerous airborne agents occur on railways, including dust, ozone, sulphur dioxide, salt and salt spray, coolants, anti-freeze, hydraulic fluids, and lubricants. Jumper solutions must demonstrate good resistance to most commonly used railway cleaning agents. The list below shows the most common of these 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)

Resistance to 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 affected 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

Our cable insulation is capable of withstanding such ballast strikes as our cables are electron-beam cross-linked with RADOX® technology.

Reliability, Availability, Maintainability, Safety (RAMS) and Life Cycle Cost (LCC) analysis for service life and costs

Vehicle operators demand a long service life of products combined 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 jumper solutions (RAMS analysis). The keywords are reliability, availability, maintainability and safety, or RAMS.

			Cable		Assemblies	
Reliability	Product characteristics	**Reliability**	**Failure rate**	**Service life**	**Failure rate**	**Service life**
		Component reliability	λ = 0.125 / year	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	
Maintainability		**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 areconsulted in the event of changes and informed when withdrawn.	

(Table: RAMS/LCC analysis)

Example:
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 sooner HUBER+SUHNER obtains an insight into the project, the more flexibility we can employ in the design and functionality to meet the customer's requirements.

Photo: Innovative underfloor inter-vehicle jumper systems

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

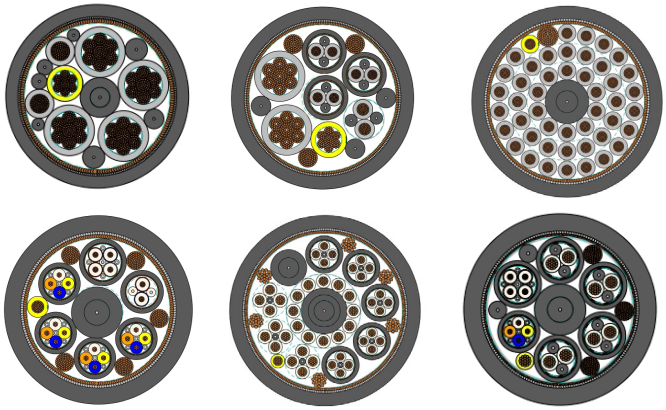
1. On-site design support
   a. Optimised cable selection from the HUBER+SUHNER cable portfolio according to customer specification
   b. Assessment and optimisation of inter-vehicle jumper systems system limits
   c. Advice and recommendations concerning kinematic aspects
   d. Advice and recommendations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

2. Solution design
    a. Computer-aided verification of the kinematic system, taking into account specific cable properties such as flexibility and temperature effects
    b. Customised cable design
    c. Computer-aided design of the solution
    d. Documentation, such as drawings, installation guide and maintenance instructions

3. Complementary services
    a. Project management
    b. Global supply chain
    c. Global production network
    d. Testing laboratory for basic and life-cycle testing
    e. First article inspection
    f. First installation on train

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 gives the individual cable elements greater protection against vibration and acceleration as compared to the looser design commonly found in corrugated tubes.



Design of the connections with our patented grommet solution

HUBER+SUHNER encases the cables in its patented grommet (cable gland or double bead grommet), which effectively joins them permanently to the cable jacket. The cable gland grommet is directly used on the connector, the double bead grommet is used in combination with a relief. This construction ensures that torsional forces are transferred to the cable 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 grommets are obvious: as the cable elements are "supported" by the cable jacket, the grommet and the cable gland or relief, they are not exposed to any load and there is none of the problematic trapping of cable elements at clamping points caused by cable glands. As the pressure is distributed over a wide area, there is little or no chance of any damage. Sealing to IP66 and cable relief is also guaranteed.

Shorter service life with standard commercial clamping system

Compared with the HUBER+SUHNER grommet solution, 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. 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 have negative repercussions.

Comparatively better solution with cable relief using a double bead grommet

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

HUBER+SUHNER inter-vehicle jumper systems cables with grommets 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.

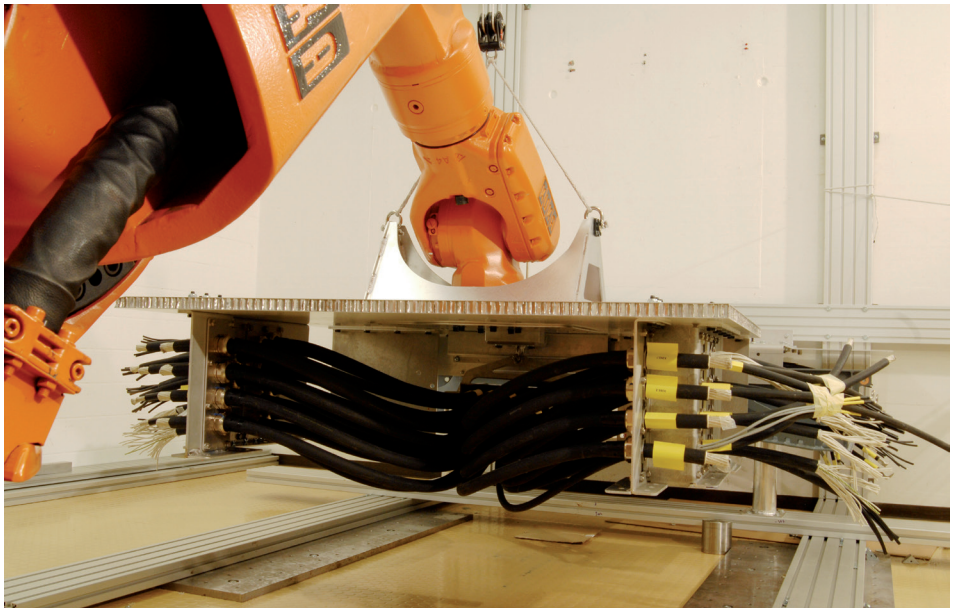
Even though the corrugated tube solution and screw fastenings of various manufacturers have the advantage of easy-to-use assemblies, the undefined pressure of the screw fastenings on the cable dramatically reduces service life – partly as a result of the ensuing sealing problems. The fact that only part 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.

The HUBER+SUHNER test centre

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

- 6-axis robots
- 2-axis motion tables
- Eccentric machines for oscillation testing
- Apparatus for carrying out bending and abrasion tests

"Genuine Swiss-made: HUBER+SUHNER patented solutions."



Inter-vehicle jumper system in test centre

Bridging our technologies. Wherever you are.

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HUBER+SUHNER is certified according to EN(AS) 9100, ISO 9001, ISO 14001, ISO/TS 16949 and ISO/TS. 22163.

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