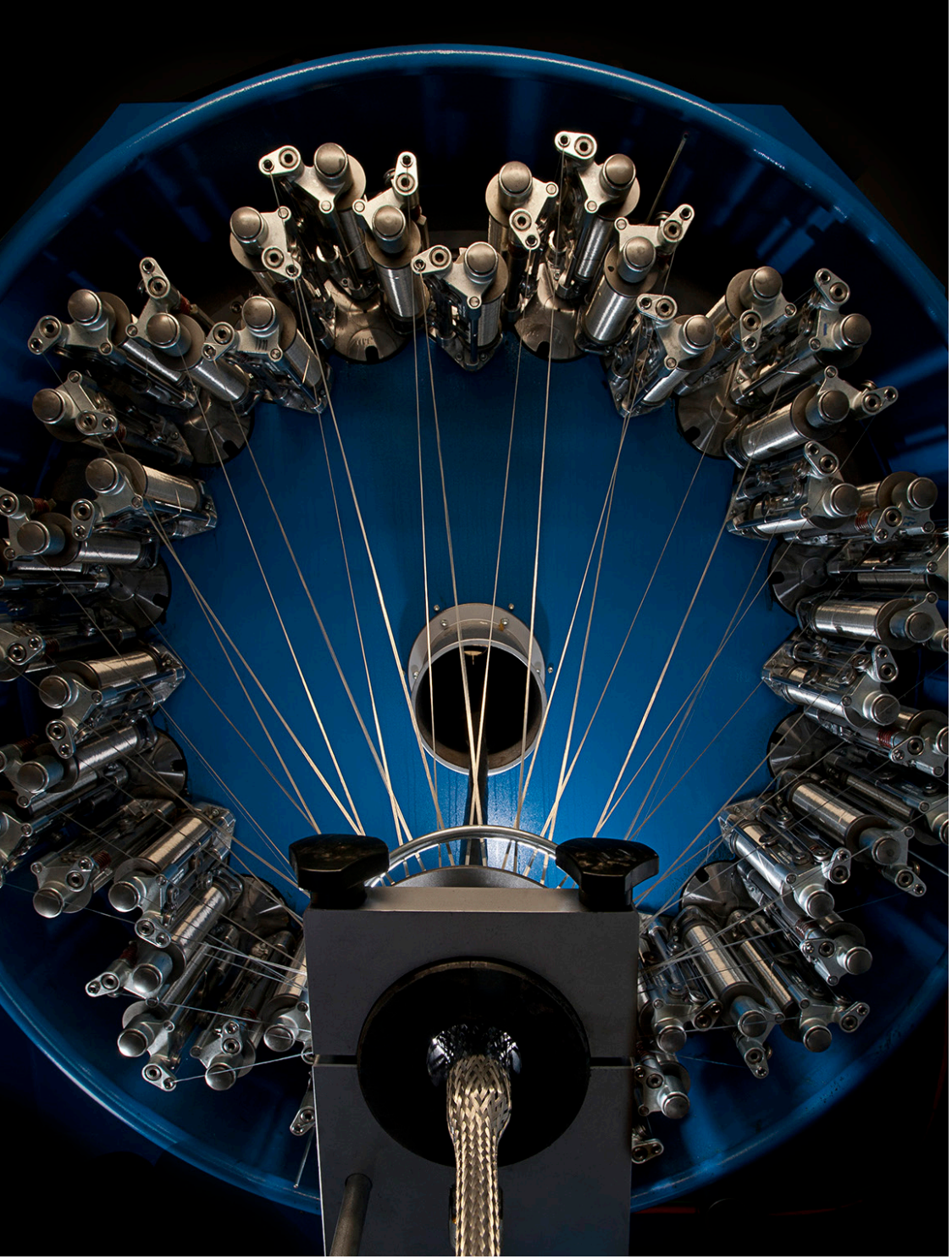


Custom design

Cables for demanding applications

> We are a high specification, custom-design wire and cable manufacturer specialising in niche products for demanding applications.

As a custom design cable manufacturer, we have expertise in taking multiple elements (cores, screens, coaxes, data pairs, strain relief, vent tubes and many more) and combining them into cables. Habia Cable's aim is to supply the right cable for any given application, avoiding the need to compromise with an off-the-shelf product that doesn't quite fulfil all your requirements.

High specification products

The design and manufacture of custom design cables is Habia Cable's core business, from simple wires in non-standard sizes, coaxial cables with odd impedance requirements or complex multi-core hybrid cables, we have attempted to explain many of the considerations that go into custom designed cables (see Checklist opposite).

Standard items

Format for cable descriptions is explained in the tables on these pages. It is a detailed system that enables us to accurately identify your cable just from the desciption. Howevever to use this system for the complexity of a composite cable would result in very long description strings.

Conductors

With many different sizes, types and standards available, this section includes a explanation of the various types and their key properties, along with a cross-reference table detailing the most common sizes, their strandings, weights, CSA and resistance.

Insulation

This section gives an overview of the many different criteria for selecting the most appropriate insulation, along with a comparison table of Habia Cable's available materials. Also included are the de-rating factors for:

- Temperature
- Multiple cores
- Installation
- Safe handling

Cabling

An explanation of the pros and cons associated with different cabling methods and lay-lengths.

Tapes, binders and fillers

The performance of a cable can often be significantly improved with the choice of binder and/or filler used within it. A brief over-view of the available types is offered here.

Shielding

This section covers both the different options available for electrical, mechanical and magnetic shielding, along with details of our Harnbraid range of over-braiding.

Sheathing

As with the insulation, there are a number of important criteria for selecting the sheath. Along with an over-view of these properties this section includes a comparison table of the the materials suitable for use as a cable sheath.

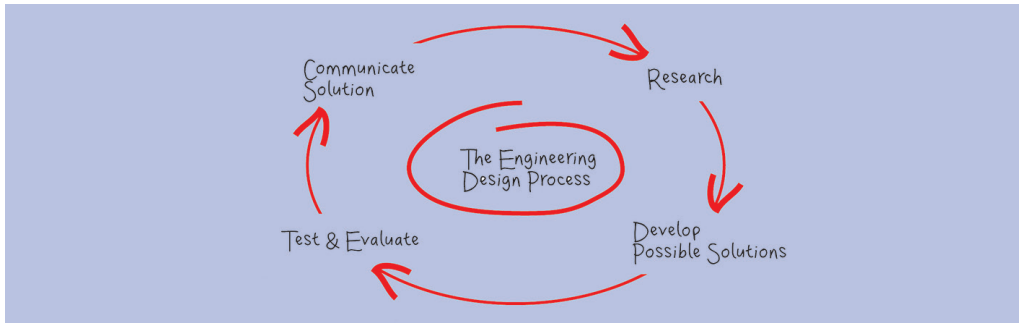
Finished Cables

Along with the options available for inclusion in hybrid cables, the options for delivery (lengths and reel options) can be found in this section. Also included are notes on the flexibility and/or flex-life of different cables and the recommended minimum bend radius.

Checklist

Helpful information to process your enquiry

Enquiry Checklist		
Things to consider to help us design your cable as efficiently as possible		
Delivery	Expected delivery	How much cable do you require for this order?
	Expected per year	Will you require the cable again? Reduced prices for volumes are available.
	Lengths per spool	Many customers prefer to have only one length per spool but there is a cost for this.
	Multiples	Do you require several pieces of a certain length?
	Unbroken lengths	Cable will be supplied in "unspecified random lengths" unless otherwise requested.
Construction	Colour, marking & identification	We offer full colour coded cores or white and numbered in most instances.Sheaths are black as standard, printed with Habia's name, number and traceable details.
	Conductor size	Specified by the pins in the connector or the current rating required for the cable.
	Insulation & sheath materials	Is there a particular material that has been specified for your application?
	Number of cores	How many cores do you require to transmit your signal / power?
	Outer diameter	Are there size constraints on the cable, e.g. the diameter imposed by the connector?
	Sheath / Jacket	Are inner screens sheathed from one another and should there be an overall sheath?
	Shield / Screen	Is electrical interference an issue, either within the cable or from an external source?
	Smooth & round design	This is particularly necessary for mating moulded connectors to a sheath.
	Special requirements	Do you require any other elements in the cable: tubes? strain relief?
Physical properties	Chemical resistance	Some plastics are easily degraded in oils, fuels and other agressive chemicals.
	Fixed, flexing or dynamic use?	Will the cable be installed and left alone, moved occasionally or be in constant motion?
	Flame retardancy	Important if your cable is likely to be exposed to fire and flame spread is an issue.
	Halogen content	Important if the cable is installed in enclosed areas near people / sensitive equipment.
	Minimum Bending Radius (MBR)	Most of our cables achieve 5x OD for fixed use, 10x OD flexing and 20x OD dynamic.
	Radiation resistance	Stated in 'Total Integrated Dose (TID)' or 'per hour' values in Gray (Gy).
	Smoke generation	If the cable burns and releases smoke, will loss of visibility cause a problem?
	Temperature	What is the temperature range over which the cable must operate and/or be stored?
	Water resistance	If immersed in water, can the cable be flooded, or is water-blocking required?
Electrical properties	Attenuation (dB/100m)	The loss of power over the length of a coaxial or data cable at a specified frequency.
	Capacitance (nF/km or pF/m)	This is the amount of electrostatic energy stored in a coaxial or data cable
	Current rating (Amps)	This is determined by the conductor size, insulation thickness and temperature rating.
	DC resistance (Ω/km)	This is a function of conductor size, a larger conductor offers less resistance.
	Frequency range (MHz or GHz)	This is the frequency range over which the signal or power is transmitted.
	Impedance (Ω)	An Ohm (Ω) is the ratio of voltage to current (can be calculated from the capacitance)
	Voltage rating (Volts)	This is a function on the insulation material and thickness.



Descriptions & marking

How we identify our cables

With many combinations of components, materials and sizes, Habia Cable has a quick and simple identification system of code letters and numbers to quickly and easily identify your cable.

Standard items
The format for cable descriptions is explained in the tables on these pages. It is a detailed system that enables us to accurately identify your cable just from the description.

Composite cables
A simplified format is used for complex cables, naming the insulation and sheath material and the number of overall cores / components (e.g. ETFE / HFS 100 - 2x2 + Fibre).

Flexibility
A third option for descriptions / marking is also available where we can keep the customer's description as our own if requested.

Jacket marking
Habia Cable inkjet mark our cables as standard. Printing can be done in White, Yellow or Black (depending on background jacket colour) and will typically have intervals of either 250mm for normal text or 1000mm if a running meter mark is required (0001, 0002, 0003 etc...).

Some special characters can be adopted (e.g. the UL mark).

Habia Cable prefers to print a minimum of the following information on every cable for the purposes of traceablilty:

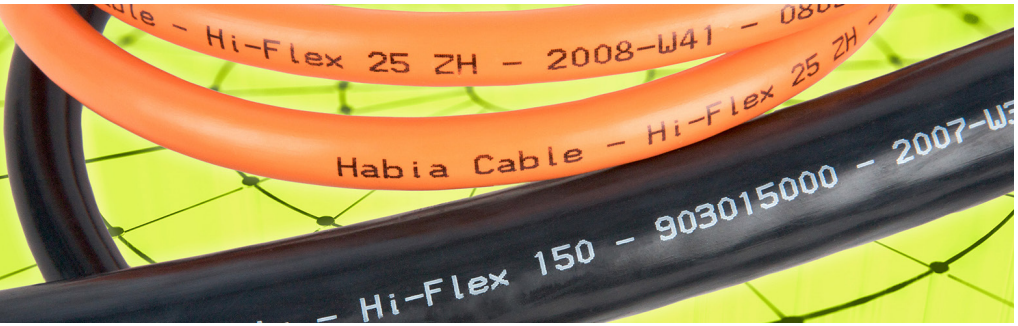
Habia Cable - Article Number - Year and Week of manufacture - Unique Batch Code

Example:
- **Habia Cable - 700012345 - 2014-W01 - 140101001**

Description format

1-2 3333 - 456-7 (8) Example: H-RN 2419 STI 2 (Al/Pr)

Other common notes	/8
Number of cores	/7
Sheath family / material code	/6
Twisted or flat	/5
Screened or unscreened	/4
Size and stranding	/3
Insulation family / material code	/2
Specification	/1



Descriptions & marking

How we identify our cables

Meaning					
Option / Example		Definition		Notes	
Pos. 1 Specification	(no letter)	NEMA	French norm.	-	
	B	British Standard		-	
	D	Defence Standard		-	
	H	Habia Internal Spec.	VG spec.	-	
	M	Mil / SAE spec.		In general accordance (not QPL listed)	
Pos. 2 Insulation (Pos. 6 Sheaths)	A	PFA		Insulation & Sheath	
	B	HFI 150		Insulation & Sheath	
	D	HFI 140		Insulation	
	E	PTFE		Insulation & Sheath (smaller sizes)	
	F	LSI 155		Insulation & Sheath	
	G	MPR 100	MPR 105	Insulation	Insulation & Sheath
	H	TWI 205		Insulation & Sheath (smaller sizes)	
	I	HFS 100	TPU 90 TPU 90 M	Sheath	
	K	FEP		Insulation & Sheath	
	M	HFI 260		Insulation & Sheath (smaller sizes)	
	P	HFI 90 H	HFI 90 L	Insulation	Insulation & Sheath
	Q	HFS 105 XL B		Sheath	
	R	TPS 130	TPS 100 TPS 120	Insulation	Sheath
	RN	HFI 147		Insulation	
	Si	HFR 150		Insulation & Sheath	
	V	PVC		Sheath	
	W	HFS 80 variants		Sheath	
	X	HFS 107 XL HFS 107 XL B	HFS 125 XL	Sheath	
	XC	HFI 121 XL		Insulation & Sheath	
	Y	TPS 125 XL		Insulation & Sheath	
	Z	ETFE		Insulation & Sheath	
Pos. 3 Conductor size / stranding	3001	Size / Stranding	1 strand	AWG conductor (example is 30 AWG)	
	2807	Size / Stranding	7 strands	AWG conductor (example is 28 AWG)	
	8133	Size / Stranding	133 strands	AWG conductor (example is 6 AWG)	
	0,5	Size	Metric: Class 5	Standard conductor (example is 0.5mm²)	
Pos. 4 Shield type		Unscreened		-	
	S	Screened		Braid as standard - see section 8	
	SS	Double screened		Braid as standard - see section 8	
Pos. 5 Cabling	(no letter) or F	Flat cable		'F' is rarely used, field is usually left blank	
	T	Twisted cable		Screened single cores also use 'T' on	
Pos. 6	Refer to Pos. 2				
Other common notations	(Al/Pr)	Aluminium / Polyester		At least one screen is a foil, usually with a drain wire	
	`	Armour		Usually refers to a Stainless Steel (St St) braid, can also sometimes refer to aramid	
	(Aramid)	Aramid strain relief		Usually refers to a braid, can also be a central core	
	Superscreened	Braid / foil / braid combination		Screened to protect from both electrical and magnetic interference	

Conductors

Available options

The central component of any cable, the conductor is the term used for the metallic wire or wires that carry the signal and/or power through the cable.

Metals

A wide range of metals can be used as a conductor. Copper (Cu) is by far the most common due to its relative low cost and availability.
Other options include aluminium, steel or tinsel wire (mixed strands of copper and cotton). While these may offer advantages in weight, strength or flex-life, they almost always come at the cost of reduced conductivity.

Plated copper such as Tin Plated Copper (TPC), Silver Plated Copper (SPC) and Nickel Plated Copper (NPC) offer additional benefits like improved temperature resistance, conductivity or solderability.

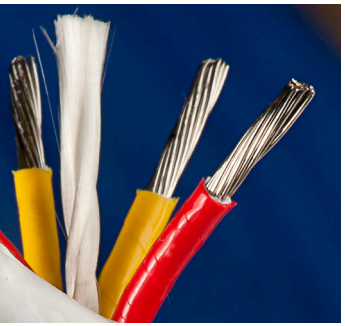
Purer conductors such as Oxygen Free High Conductivity (OFHC) copper can improve the signal performance and are often used for audio frequencies, whilst High Strength Copper Alloy (HSA) can improve flex-life compared to standard copper conductors.

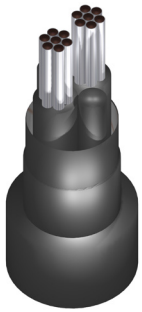
A variety of other alloys are often used for their unique conducting properties when exposed to heat. Known as resistance wires, they are used in thermocouple cables where they can detect variations in temperature.

The most commonly used are Nickel-Chromium (NiCr), Copper-Nickel (CuNi) and Iron (Fe).

Strandings

The simplest conductor is a single, solid strand. Although this offers the smallest diameter, the purest signal and the largest Cross-Sectional Area (CSA), this is also mechanically weak, solid conductors are prone to breaking after just a few cycles of bending.





Classes

Conductors are categorised into classes based on the number of wires. HIgher classes have more conductor strands:

- **Class 1**
  Solid, round
- **Class 2**
  Stranded conductor, (typically 7 or 19 strands)
- **Class 5**
  Multi-stranded for general, flexible use
- **Class 6**
  Extra-multi-stranded for dynamic use

To improve durability and flexibility it is common to strand multiple wires together, the more wires that are stranded together, the more flexible the conductor will be.

Sizes

There are many different national and international standards for identifying the size of a conductor and terminology such as BWG, SWG and Cmils; however American Wire Gauge (AWG) and Metric (mm^2) conductors are pretty much standard today. It is quite common to use both of these methods as they indicate subtly different sizes - see Habia Cable's AWG vs. Metric conversion table for details.
One note regarding AWG sizes is that the higher the number, the smaller the wire. For example: AWG 2 (8.64mm) is bigger than AWG 20 at just 0,96mm.

Other factors

Some other issues that influence the choice of conductor include, but are not limited to:

- **Crimp terminations**
  Use as few strands as possible and avoid rope-lay or bunched conductors.
- **Soldered terminations**
  Use TPC or SPC for best results and avoid NPC
- **Data / signal cable**
  For the best results, a solid or relatvely smooth-surfaced conductors and SPC
- **Dynamic / flexible use**
  Use as many strands as possible and high strength copper alloy for best results
- **High temperature use**
  For the best results, choose SPC (+200°C) or NPC (+260°C)

Weight and conductor resistance

Some values such as weight, resistance and CSA may vary slightly between different platings and wire specifications.

Some small sizes (normally AWG 32 to AWG 36) are recommended with High Strength Copper Alloy (HSA) conductors only as their size is too small to process safely with weaker materials.

Conductors

AWG vs. Metric conversion

Size		Stranding	Diameter			Resistance	Weight
AWG	CSA mm^2		Min	Nom	Max	Ω/km at 20°C TPC	Nom g/m
-	400	2,013 x 0.50	28.00	30.00	31.00	0.0495	3,588
-	300	1,525 x 0.50	24.00	26.00	27.00	0.0654	2,718
-	240	1,221 x 0.50	22.00	23.00	24.00	0.0817	2,176
-	185	925 x 0.50	19.00	20.00	21.00	0.108	1,649
-	150	777 x 0.50	17.00	18.00	19.00	0.132	1,385
-	120	629 x 0.50	15.00	16.00	17.00	0.164	1,121
0000	107	2,109 x 0.254	-	15.20	-	0.189	1,018
-	95.0	475 x 0.50	13.50	14.30	15.10	0.210	847
000	-	646 x 0.410	-	13.70	-	0.250	760
-	70.0	361 x 0.50	11.70	12.40	13.10	0.277	643
00	68.0	1,330 x 0.260	11.18	11.80	12.07	0.290	654
0	53.0	1,045 x 0.260	10.03	10.50	10.80	0.370	504
-	50.0	399 x 0.404	9.600	10.30	11.00	0.393	455
-	35.0	278 x 0.404	7.800	8.400	9.200	0.565	319
2	34.0	665 x 0.260	8.130	8.400	8.640	0.580	318
-	25.0	196 x 0.404	6.600	7.200	7.800	0.795	224
4	21.6	133 x 0.455	-	6.600	-	0.920	192
-	16.0	126 x 0.404	5.300	5.700	6.100	1.24	144
6	13.6	133 x 0.361	-	5.200	-	1.37	128
-	10.0	80 x 0.404	3.850	3.930	4.070	1.85	91.0
8	8.60	133 x 0.287	-	4.100	-	2.29	77.7
-	6.00	84 x 0.300	2.840	2.920	3.040	3.20	53.0
10	4.74	37 x 0.404	-	2.850	-	4.13	43.5
-	4.00	56 x 0.300	2.390	2.480	2.530	4.80	36.0
12	3.09	19 x 0.455	2.083	2.150	2.184	6.29	27.67
	3.00	37 x 0.320	2.020	2.100	2.180	7.60	23.30
-	2.50	50 x 0.254	1.870	1.950	2.010	7.80	21.90
14	2.00	37 x 0.250	1.680	1.750	1.820	10.90	16.69
	1.94	19 x 0.361	1.651	1.706	1.753	10.00	17.41
-	1.50	30 x 0.254	1.430	1.500	1.570	13.00	13.60
		19 x 0.320	1.470	1.520	1.570	13.00	13.60
16	1.23	19 x 0.287	1.321	1.358	1.397	15.81	11.00
	1.30	1 x 1.290	1.278	1.290	1.328	13.99	11.63
-	1.00	32 x 0.203	1.150	1.200	1.290	19.00	9.000
18	0.963	19 x 0.254	1.169	1.201	1.245	20.40	8.634
	0.897	7 x 0.404	1.194	1.212	1.270	21.45	8.049
	0.823	1 x 1.024	1.013	1.024	1.054	22.23	7.330
-	0.75	24 x 0.203	1.030	1.050	1.080	25.00	6.800
		19 x 0.226	1.030	1.080	1.150	25.00	6.800
19	0.650	1 x 0.900	0.855	0.900	0.909	28.50	5.662
20	0.615	19 x 0.203	0.940	0.961	0.991	32.02	5.512
	0.563	7 x 0.320	0.915	0.960	0.991	34.12	5.046
	0.519	1 x 0.813	0.805	0.813	0.838	35.21	4.620
-	0.500	19 x 0.180	0.860	0.880	0.900	38.00	4.300
	0.500	16 x 0.203	0.820	0.880	0.920	38.00	4.500

Continued on next page

Conductors

AWG vs. Metric conversion

Size		Stranding	Diameter			Resistance	Weight
AWG	CSA mm²		Min Ø	Nom Ø	Max Ø	Ω/km at 20°C TPC	Nom g/m
22	0.382	19 x 0.160	0.737	0.757	0.787	52.16	3.433
	0.354	7 x 0.254	0.712	0.762	0.788	54.79	3.188
	0.324	1 x 0.643	0.635	0.643	0.663	56.62	2.890
23	0.283	1 x 0.600	0.570	0.600	0.606	64.00	2.516
24	0.241	19 x 0.127	0.584	0.600	0.610	83.33	2.159
	0.220	7 x 0.203	0.585	0.609	0.635	85.95	2.033
	0.205	1 x 0.511	0.515	0.511	0.526	89.35	1.825
26	0.155	19 x 0.102	0.457	0.480	0.508	131.5	1.392
	0.140	7 x 0.160	0.458	0.480	0.508	139.7	1.263
	0.128	1 x 0.404	0.399	0.404	0.417	146.6	1.141
28	0.095	19 x 0.079	0.355	0.372	0.394	222.1	0.835
	0.089	7 x 0.127	0.356	0.381	0.406	223.7	0.793
	0.080	1 x 0.320	0.318	0.320	0.330	231.3	0.716
30	0.061	19 x 0.060	-	0.284	-	320.9	0.481
	0.057	7 x 0.102	0.280	0.306	0.330	354.3	0.511
	0.050	1 x 0.254	0.251	0.254	0.262	372.7	0.451
32	0.037	19 x 0.052		0.246		427.3	0.362
	0.035	7 x 0.079	0.224	0.237	0.279	597.1	0.307
	0.032	1 x 0.203	0.201	0.203	0.211	585.3	0.288
34	0.023	7 x 0.060	-	0.180	-	871.1	0.177
	0.020	1 x 0.160	0.157	0.160	0.168	950.2	0.179
36	0.014	7 x 0.050	-	0.150	-	1,160	0.123
	0.013	1 x 0.127	0.124	0.127	0.135	1,521	0.113

Variations

Weight and conductor resistance values may vary slightly for the different platings that can be offered (e.g. AWG 3007):

- **TPC** 355 Ω/km
- **SPC** 328 Ω/km
- **NPC** 348 Ω/km
- **HSA** 373 Ω/km

Sizes smaller than 36 AWG use High Strength Copper Alloy (HSA) as they are too small to process with weaker materials.

Effects of twisting and cabling

The resistance of a stranded conductor is around 3% higher than their equivalent solid conductor size.

Twisting the cores increases the conductor resistance with values around 5% higher than a straight, insulated conductor.

Insulation

Electrical protection

Insulation is necessary for the electrical isolation

between the conductor/s and the earth. The choice of insulation also has a significant impact on the overall performance of the cable since - regardless of flame barriers or screens - a cable should always be rated to its lowest performing part.

Many materials can be used for insulation, some of which can also be used for sheathing. All have their own advantages and limitations. For more information see 'Habia Cable's overview of insulation materials'.

Not all insulations and sheaths can be used together. High extrusion temperatures can damage low temperature insulations and the irradiation process is not suitable for all materials (e.g. PTFE cores and cross-linked sheaths should be avoided). Habia Cable takes these risks into account to avoid compromising the finished cable design.

Abrasion

Measures the rugged properties of a material. High abrasion resistance is ideal in dynamic cables where cores are required to move in relation to one other, or in relation to any shield as the cable is flexed.

Corrosivity

Many materials that are excellent in resisting fire, will release toxic and corrosive gases once they eventually ignite. These corrosive gases can damage sensitive equipment such as circuit boards and consideration to this should be given when installing cable in potentially sensitive areas.

Flammability

The degree to which a cable will burn and/or spread a fire. Most materials used by Habia Cable will self-extinguish once the flame source has been removed.

With many different fire standards in use, Habia Cable recommends IEC 60331 (fire resistance) and IEC 60332 (flame retardancy) as these apply to the completed cables and so are more truly representative tests.

Also often requested is flammability to UL 94 which uses a small sample of the sheath rather than the overall cable.

Flexibility

There are two key aspects to this. Flexibility is how far a cable can bend or drape, whilst flex-life is how often a cable can be flexed without breaking. Some materials may have poor flexibility, but are actually so strong that they offer a very good flex-life.

Fluid resistance

Many fluids actively break-down the chemical bonds of the insulation. An effect that is often magnified at elevated temperatures such as in an engine-bay. Where the insulation is concerned, this is the degree to which the fluid can permeate into and through it causing swelling and/or creating an electrical path from conductor to earth (known as arc tracking).

Radiation

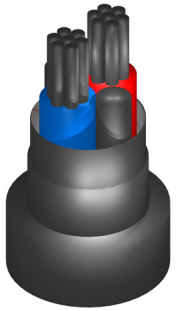
Continued exposure to radiation will break down plastic. Many different measurement scales exist, however the most common are Rads and Grays. Habia Cable will quote the Total Integrated Dose (TID) in Grays (Gy) unless otherwise specified.

Smoke & Fume

This refers to the level of smoke that is generated by a material under fire conditions. This is of key importance where visibility must not be impeded, such as a route to an exit.

As with flexibility and flex-life there is no link between smoke corrosivity and smoke generation (e.g. FEP is corrosive once burning, but is also one of the best examples of a low smoke material).

The other side of smoke corrosivity, halogen content refers to the toxic gases that can be emitted under fire conditions. Halogens can affect health and therefore halogen free cables should be installed in areas of high foot-traffic and/or enclosed spaces.



Insulation

De-rating factors

Temperature de-rating factors								
Ambient air temperature	Insulation temperature rating							
	80°C	100°C	125°C	135°C	150°C	180°C	200°C	260°C
0°C	1.52	1.37	1.28	1.24	1.21	1.18	1.15	1.10
10°C	1.40	1.28	1.21	1.19	1.16	1.14	1.11	1.08
20°C	1.28	1.19	1.15	1.13	1.10	1.08	1.07	1.05
30°C	1.14	1.09	1.07	1.06	1.05	1.04	1.03	1.02
40°C nominal ambient air temperature	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
50°C	0.82	0.89	0.92	0.93	0.94	0.95	0.96	0.97
60°C	0.65	0.78	0.83	0.86	0.88	0.90	0.92	0.94
70°C	0.42	0.65	0.74	0.79	0.82	0.85	0.88	0.91
80°C	-	0.50	0.65	0.71	0.76	0.81	0.84	0.88
90°C	-	0.40	0.54	0.63	0.69	0.76	0.79	0.85
100°C	-	-	0.42	0.54	0.61	0.71	0.75	0.82
110°C	-	-	0.27	0.44	0.53	0.65	0.70	0.79
120°C	-	-	0.17	0.32	0.45	0.59	0.65	0.75
130°C	-	-	-	0.16	0.35	0.53	0.60	0.72
140°C	-	-	-	-	0.23	0.46	0.54	0.69
150°C	-	-	-	-	-	0.38	0.49	0.65
160°C	-	-	-	-	-	0.30	0.42	0.61
170°C	-	-	-	-	-	0.19	0.36	0.57
180°C	-	-	-	-	-	-	0.28	0.53
190°C	-	-	-	-	-	-	0.18	0.49
200°C	-	-	-	-	-	-	-	0.45
210°C	-	-	-	-	-	-	-	0.40
220°C	-	-	-	-	-	-	-	0.35
230°C	-	-	-	-	-	-	-	0.29
240°C	-	-	-	-	-	-	-	0.23

Multicore de-rating factors													
	Number of cores												
	2	3	4	6	8	10	12	16	20	24	28	36	40
Factor	1.00	0.88	0.80	0.69	0.62	0.59	0.55	0.51	0.48	0.43	0.41	0.38	0.36

Installation method de-rating factors												
	Clipped to a vertical structure			Clipped to a horizontal structure			On solid metal trays			On aerated metal trays		
Number of cores	1	2	3	1	2	3	1	2	3	1	2	3
Without spacing	0.94	0.80	0.76	0.89	0.76	0.57	0.97	0.85	0.74	1.00	0.87	0.74
With spacing	0.94	0.90	0.87	0.89	0.81	0.77	0.97	0.96	0.93	1.00	1.00	1.00

Notes for using these tables

De-rating factors assume the insulation to be operating at its maximum temperature (e.g. in 40°C ambient air, the heat generated by the current passing through the conductor will generate an additional 40°C, raising an 80°C rated material to its maximum temperature).

Calculations should be made on the lowest rated material in the cable.

High conductor temperatures also create a high voltage drop.

Safe handling temperatures

High conductor temperatures can cause damage to their surroundings and temperature can increase more than is calculated if the cable is in a confined space.

Habia Cable recommend the following safe handling temperatures (referenced from MIL-STD-1472):

- **+85°C**
  Momentary contact
- **+69°C**
  Prolonged contact or handling

Cabling

Twisting methods

Cabling (also known as twisting) is the process

where cores are wrapped around one another, enabling the cable to be flexed more easily without failure. Without this rotation the core(s) on the inside of the bend would be placed under compression and the core(s) on the outside of the bend would be placed under tension, causing deformation of the cable, damage to the other cores in the centre of the cable and also breakages within the connectors.

Many different types of components can be cabled together, however unlike hand-built constructions it is essential that the diameter of the central layer is large enough to support further layers. For example: An 8 core cable with cores of equal size can be made as a single core in the centre with 7 cores around it if hand-built. Mathematically however it is only possible to place up to 6 cores around the centre if all cores are of equal size and machined cables must follow this mathematical model.

Other than a single core in the centre, the length of the cores can be up to 10% longer than the cable they are make up since they rotate around one another. The maximum conductor resistance Habia Cable specifies for cores within a multi-core cable will nominally be 5% higher than that specified in the single core datasheets to account for this extra length.

Flat cables

Up to 8 components (depending on size) can be laid side by side for inclusion in a flat cable design. Flat cables provide a significant benefit with regard to bend radius if the cable is being flexed in a single direction, as the cable can be made with a noticeably smaller overall dimension and yet still contain several elements. Flat cables are not appropriate for applications which require movement in multiple directions.

Direction

Most cables will be manufactured with alternating left-hand (S) and right-hand (Z) layers. This is done to make the cable evenly balanced which prevents it from twisting up into a coil under dynamic use. Each core will also often have back-twist applied to further prevent this twisting process and to ensure that the cable is as 'dead' as possible.
It is most common to have the final layer as a left-hand layer, an example of which is a typical 19 core cable that would have:

- **Centre**
  1x core laid straight.
- **1st layer**
  6x cores around centre with a right-hand lay
- **2nd layer**
  12x cores around 1st layer with left-hand lay

Torsion

The exception to the rule of alternating layers is where the application will require torsion to be applied to the cable (such as coiled/spiral cables). In this instance it is advantageous to have all the elements cabled in a single direction as this will help the cable to return to its original form each time, even when extended and retracted frequently.

Lay-lengths

Expressed in mm or inches, The lay-length is the distance a core rotates around the cable from it's starting position in a layer, around the cable and back to its original position. A short lay length will have a more springy and flexible feel to it while a long lay-length results in a stiffer cable.

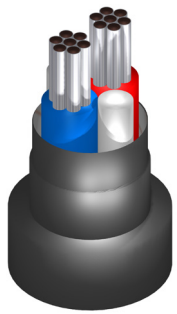
Longer lay-lengths can be produced significantly quicker and use less material which provides benefits in both manufacturing time and cost, so there are good reasons for using a long lay-length if flexibility is not critical to the cable design.

Habia Cable nominally use between 8x and 16x the cabled diameter, so for flexible cables a lay-length close to 8x the cabled diameter will be used, whilst normal use cables will be closer to 16x the cabled diameter.

Twists per inch

Lay length is often specified as a given number of twists per inch. This relates to the number of times a core should travel from its starting position at 12 o'clock, around the cable and back again over a given distance.

A cable requirement of 3 twists per inch would therefore require the same core to rotate around the cable and return to the 12 o'clock position 3 times over the distance of 1 inch (25.4mm) giving a lay length of approximately 8mm.



Tapes, binders & fillers

Additional elements

Often considered incidental in the design of a cable there are many reasons, both production and performance based for applying fillers, foils and tape binders. A binder is not a suitable insulating layer as binders can move when the cable is flexed. This means that screens may come into contact with one another. If isolation of the screen is required, an inner sheath or a sintered tape must be used.

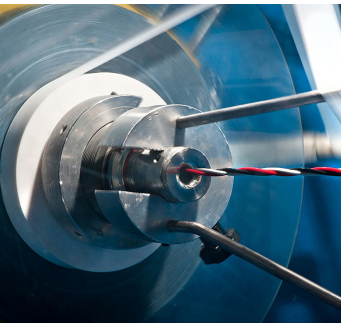
Many binders can be applied during the cabling and braiding, meaning little added cost for the inclusion of a binder.

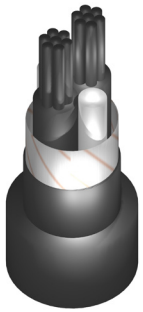
Available tapes

The two primary tapes and foils used by Habia Cable are polyester (Mylar) and PTFE. Each is available in a hard 'foil' and soft 'tape' version.

Polyester is used for general purpose and halogen free constructions whilst PTFE provides a high temperature option. Other tapes and foils include:

- **Al/Polyimide**
  A polyester-backed, polyimide foil used for electrical screening at high temperatures
- **Al/Pr foil**
  Polyester-backed, aluminium foil for electrical screening
- **Cu/Pr foil**
  Polyester-backed copper foil for electrical screening. Also offers improved fire performance over Al/Pr
- **Polyimide**
  Foil used for high temperatures and high radiation. Can be FEP coated for sintering
- **Low noise**
  A Carbon-loaded tape to reduce noise and interference
- **Mica**
  A flame barrier used in Habiaflame^2 constructions
- **µ-metal**
  A metallic foil providing magnetic shielding
- **SW tape**
  A water-swelling tape used to absorb water and prevent it from tracking through the interstices and into the connector





Production

It is often necessary to add a foil or tape to physically hold a cable together as it moves between different stages in production. As a general rule any cable with 8 or more cores in the final layer of cabling or a cable with a filling compound to remove all air-spaces in the cable will require a foil or tape to be applied for this purpose. A typical overlap is from 25% to 50%.

Protection

Braided electrical screens and armours can be abrasive to the cores over which they are placed. The application of a foil or tape can often prevent wear and tear to the cores within the cable as it is flexed.

Flexibility

Some tapes such as PTFE are very soft and low friction. This can enable the elements within a cable to move past one another, improving both the overall flexibility and flex-life of the cable.

Roundness

A pressure-extruded outer sheath allows the cable to be made perfectly smooth and round, however this pressure also forces the sheath material into the interstices of the braid and/or cores which makes it difficult to remove the sheath by hand and virtually impossible to remove with automated cut-and-strip equipment. The addition of a binder gives a smooth surface over which to extrude, enabling the sheath to be removed with relative ease.

Available fillers

The two primary types of filler used by Habia Cable are HT and LT. As with tapes, there are a number of other variants that can offer specific performance advantages:

- **HT**
  Fibrous, glass yarn, HT (High Temperature) fillers can meet the full temperature range of all Habia's materials; they are also soft, allowing for deformation within the cable that is necessary for dynamic use
- **LT**
  Low temperature fillers are normally solid plastic, used in the majority of cables with a moderate temperature range
- **Polyester**
  More expensive than LT, polyester fillers have a soft, rope construction that improves flexibility and offers a better temperature range
- **PTFE**
  Some data cables require PTFE fillers in order to provide better electrical stability
- **SW**
  Water-swelling fillers absorb and swell to prevent water from tracking through the interstices of the cable

Shielding

Comparison of shielding methods

Electrical shielding (or screening as it is also known) can be applied for mechanical, electrical and magnetic protection. Electrical screens come in the form of foiled tapes, spiral-wound (lapped) plated copper wires or braided screens of plated copper wire. Each of these provide protection from electrical interference from other elements within the cable (such as power and data cores in the same cable) or from external sources.

Foils

Foil screens are most effective at higher frequencies as they provide 100% coverage. However as they are quite thin and brittle they are not good for low frequency and/or dynamic use.

Foil screens require a drain wire (normally the same size as the cores) for termination into the connector. This is best placed in the interstices to help keep the surface smooth and round. If placed elsewhere a drain wire will often create a lump in the layer requiring a pressure-extruded sheath to keep the cable round.

A drain wire is not always necessary if the foil is combined with a braided screen.

Lapped screens

As a single layer of wire wound around the cable, a lapped screen doesn't quite have the robustness of a braid and must usually be held in place with tapes. It is perhaps the weakest of the screening options from an electrical stand-point, having neither the coverage of the foil for high frequencies, nor the thickness of copper for low frequencies.

Where lapped wire screens do excel is in their flexibility and flex-life.

Braided screens

Braided screens offer better long-term flexibility and a large amount of copper which is beneficial at lower frequencies.

Where many manufacturers offer just 70% optical coverage on a braid, Habia Cable standardises on a minimum coverage of 85%. As EMC shielding becomes more important, it is increasingly common to specify 'optimised' braided screens which have an optical coverage of >90% and/or multiple screens.

A combination of foil and braid will often provide the best screening over a wide range of frequencies.

Perfomance

There are two common methods of measuring the performance of an electrical screen. Shielding effectiveness is measured in dB, where the higher the value, the better the screen.

The second method (used by Habia) is surface transfer impedance which is measured in mΩ/m. In this instance, the lower the value, the better the screen.

Super-screened

This is the process whereby multiple braided screens and a µ-metal foil screen are used to provide complete electrical and magnetic protection. This combination of screen does significantly limit cable flexibility.

Mechanical

There are three common methods of mechanical protection, two of which are offered by Habia Cable:

- **Galvanised steel**
  This armour offers considerable protection to a cable but are big and bulky. They tend to be used on large power cables and as such are not offered by Habia Cable at this time
- **Stainless steel**
  Wire braids offered by Habia Cable in preference to galvanised steel as these offer significant crush and cut-through resistance without the bulk
- **Aramid**
  These braids can also be used where the cable must remain flexible. Aramid offers significant cut-through resistance, along with excellent tensile strength

Harnbraid

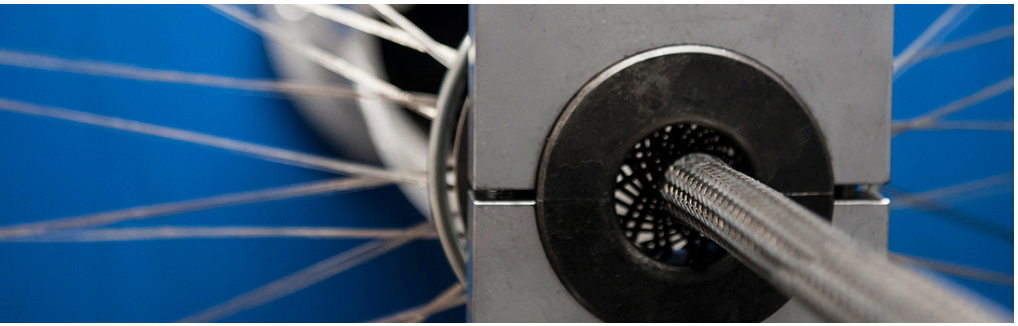
Over-shielding solutions

Description	Former	Construction				Cable bundle		Article No.
	Diameter	Number of carriers	Number of ends	Individual strand size	Min cov.	Min tolerance	Max tolerance	
	mm				%	mm	mm	
Harnbraid 90 -3.0	3.0 ± 0.13	16	5	36 / 0.13	90	2.0	3.5	9003
Harnbraid 90 -4.0	4.0 ± 0.25	16	7	36 / 0.13	90	3.0	5.0	9004
Harnbraid 90 -5.0	5.0 ± 0.25	24	6	36 / 0.13	90	4.0	6.0	9005
Harnbraid 90 -6.0	6.0 ± 0.25	24	7	36 / 0.13	90	5.0	8.0	9006
Harnbraid 90 -10.0	10.0 ± 0.25	24	9	34 / 0.16	90	7.0	12.0	9010
Harnbraid 90 -12.5	12.5 ± 0.25	24	10	34 / 0.16	90	11.0	14.0	9012
Harnbraid 90 -15.0	15.0 ± 0.38	24	11	32 / 0.20	90	13.0	18.0	9015
Harnbraid 90 -20.0	20.0 ± 0.38	36	7	30 / 0.25	90	17.0	23.0	9020
Harnbraid 90 -25.0	25.0 ± 0.38	36	9	30 / 0.25	90	22.0	28.0	9025
Harnbraid 90 -30.0	30.0 ± 0.38	36	9	28 / 0.32	90	27.0	40.0	9030
Harnbraid 101 -3.0	3.0 ± 0.13	16	10	38 / 0.10	93	2.5	5.0	10103
Harnbraid 101 -4.0	4.0 ± 0.25	24	7	36 / 0.13	93	3.5	9.0	10104
Harnbraid 101 -6.0	6.0 ± 0.25	24	9	36 / 0.13	93	4.5	11.0	10106
Harnbraid 101 -7.5	7.5 ± 0.25	24	14	36 / 0.13	93	7.0	16.0	10107
Harnbraid 101 -10.0	10.0 ± 0.25	36	12	36 / 0.13	93	8.0	22.0	10110
Harnbraid 101 -12.5	12.5 ± 0.25	36	15	36 / 0.13	93	11.0	24.0	10112
Harnbraid 101 -15.0	15.0 ± 0.38	36	16	36 / 0.13	93	13.0	28.0	10115
Harnbraid 101 -20.0	20.0 ± 0.38	48	16	36 / 0.13	93	16.0	38.0	10120
Harnbraid 103 -3.0	3.0 ± 0.13	16	10	38 / 0.10	93	2.5	5.0	10303
Harnbraid 103 -4.0	4.0 ± 0.25	24	7	36 / 0.13	93	3.5	9.0	10304
Harnbraid 103 -6.0	6.0 ± 0.25	24	9	36 / 0.13	93	4.5	11.0	10306
Harnbraid 103 -7.5	7.5 ± 0.25	24	14	36 / 0.13	93	7.0	16.0	10307
Harnbraid 103 -10.0	10.0 ± 0.25	36	12	36 / 0.13	93	8.0	22.0	10310
Harnbraid 103 -12.5	12.5 ± 0.25	36	15	36 / 0.13	93	11.0	24.0	10312
Harnbraid 103 -15.0	15.0 ± 0.38	36	16	36 / 0.13	93	13.0	28.0	10315
Harnbraid 103 -20.0	20.0 ± 0.38	48	16	36 / 0.13	93	16.0	38.0	10320

Available in sizes from 2.5mm to 50mm, Harnbraid is available in 90, 101 and 103 styles:

- **Harnbraid 90** and **Harnbraid 101**
  Tin Plated Copper (TPC)
- **Harnbraid 103**
  Nickel Plated Copper (NPC)

With a high usable expansion ratio (minimum of 2:1), optical coverage is a minimum of 90% (93% on the 101 and 103 sizes) and a maximum of >99%.
Harnbraid is supplied over an LDPE tube which can be easily removed, aiding the application of the braid over bundled wires.



Sheathing

Mechanical protection

The sheath (or jacket) offers isolation from the earth plane for any shielding of the cable. It is primarily used to provide mechanical protection from a wide variety of hazards. There is a wide range of materials that can be used for sheathing cables, all with their own advantages and limitations.

Habia Cable recycles waste material for re-use. For this reason Habia Cable will offer black sheaths wherever possible. Some materials have a lot of carbon black in them meaning that these materials cannot be coloured, they are only black. Other flame retardant materials use an additive that is naturally white in colour.

Abrasion

Measures the rugged properties of a material. Typically softer, more flexible sheaths will exhibit a high degree of abrasion loss. HFI 260 when used as a sheath exhibits possibly the best abrasion resistance.

Corrosivity

Although highly fire resistant, many materials will release toxic and corrosive gases once they eventually ignite. Corrosive gases can damage sensitive equipment such as circuit boards and consideration to this should be given when installing cable in potentially sensitive areas.

Flammability

The degree to which the sheath will burn and/or spread a fire once ignited. Most materials used by Habia Cable will self-extinguish once the flame source has been removed.

With many different national and international fire standards in use, Habia Cable recommends IEC 60331 and IEC 60332 (in applicable parts) as these test the completed cables and are therefore more truely representative of the application. Some materials can be improved by flame retardant (FR) additives.

Another commonly requested test is flammability to UL 94. This method tests a small sample of the sheath material and does not assess the overall cable construction.

Flexibility

There are two aspects to this:

- **Flexibility**
  The degree to which a cable can bend
- **Flex-life**
  The frequency over which a cable can be flexed without breaking

Materials may have poor flexibility, but are actually so strong that they can exhibit a very good flex-life.

Fluid resistance

Many fluids will actively break-down the chemical bonds of the sheath. An effect magnified when the fluids are at temperature (such as an engine-bay).

Cross-linked materials are particularly good at resisting damage from chemicals. Where the sheath is concerned, this is the degree to which water can either be absorbed by the sheath (swelling its size) or permeate through it, flooding the cable interstices and allowing water to track back up to the connector.

Radiation

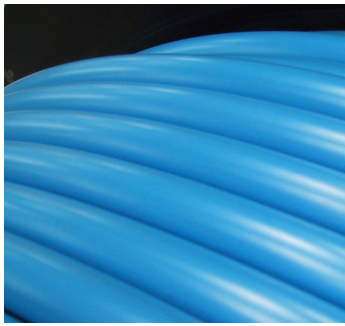
As with fuels and oils, continued exposure to radiation will break-down plastic. Many different measurement scales exist, however the most common are Rads and Grays. Habia Cable will quote the Total Integrated Dose (TID) in Gray (Gy) unless otherwise specified (e.g. 2x 10^5 Gy).

Smoke & Fume

This refers to the level of smoke that is generated by a material under fire conditions. This is of key importance where visibility must not be impeded (for example: the route to an exit).

As with flexibility and flex-life there is no link between smoke corrosivity and smoke generation, so whilst materials such as fluoropolymers might be very corrosive, they actually generate very little smoke.

The other side of smoke corrosivity, halogen content refers to the toxic gases that can be emitted by the sheath under fire conditions. Halogens can affect health and therefore halogen free cables should be installed in areas of high foot-traffic and/or enclosed spaces.



Finished cables

Hybrid cable designs

The core of Habia Cable's business model is design and manufacture of high specification, custom designed cables for demanding applications.

Habia Cable's ability to take many and varied components and combine them into a working, composite cable that is fit for function both electrically and mechanically is one of the best in the industry.

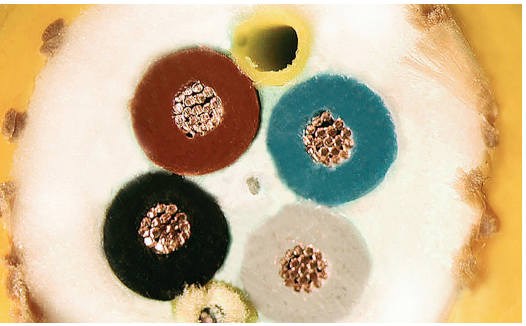
Composite cables offer a key benefit in umbilical and reeling cables as a single composite cable can do the work of a strain cable, electrical cable, power cable and even a number of hydraulic hoses. Components can include (but are by no means limited to):

Coaxials
With a wide variety of sizes and impedances available, Habia Cable are able to combine any of the RG Style, Multibend, Speedflex or Speedfoam coaxes within the design (Flexiform is not recommended for inclusion within composite cables due to its limited flex-life).

Habia Cable is also frequently called upon to design customised coaxials for use within composite cables and these can be modified to feature varied impedances, additional screening or alternative sheaths and colours (including unsheathed coaxial cables).

Data pairs
As with the coaxial cables, data and ethernet pairs are available in a range of sizes and impedances. Perhaps the most common are 90Ω (USB) and 100Ω (Cat 5) however 77Ω, 120Ω and 125Ω are also often requested.

Depending on the performance requirements of the cable, Habia Cable can make these components using either PE, PTFE or FEP dielectrics.



Power cores
Power cores can be varied in size and colour coding. They can also be electrically isolated from the rest of the cable if required.

Signal cores
Probably the main component of any composite cable, signal wires can also be electrically isolated from the rest of the cable and are often specified as screened twisted pairs, triples and quads. Either colour coded or numbered (depending on size and cost) for ease of termination.

Habia Cable can manufacture cables with hundreds of signal cores if required.

Strain wires
Can be applied as either a single, central strain cores and/or overall braid. Multiple strain wires throughout the cable are occasionally requested, but these are inadvisable as they often move within the cable when placed under strain, damaging the other components of cable as they do so.

The level of load that can be supported varies from cable to cable, but Habia Cable have had experience with cables that can take loads of several tonnes.

Tubes
Vent tubes are incorporated within cables for a variety of purposes as they are able to provide air in the cable for cooling, they can aid the buoyancy of a cable and they can carry high pressure air or oil for pneumatic and hydraulic use.

Once arranged in a suitable lay-up that can be produced by machine, the cable will be cabled together with back-twist and alternating layer directions to ensure the best possible construction.

Braids of plated copper, stainless steel wire or aramid strands can be added.

Depending on the performance of the materials within the cable a wide variety of inner and outer sheaths can be applied over the whole construction. These sheaths can be marked with either Habia Cable's standard printing, designed to simply identify the cable for future reference, or with the customer's requested printing.

Finished cables

Available options for custom-design cables

Singles and multi-cores
Core sizes from 36 AWG up to 95mm² (cabled). Single cores up to 400mm². Mark and trace or standard colour separation available for most materials, with bi-colour and tri-colour options available on request.

Data cables
77Ω, 90Ω, 100Ω and 120Ω shielded and un-shielded pairs and multi-pairs.

Vent tubes and hoses
PE, PTFE, ETFE and PA tubes in sizes from 1mm up to 18mm. Incorporated for buoyancy, pneumatics and cooling.

Signal cables
Shielded and un-shielded options in a range of materials.

Shielding (screening)
Braided and lapped (served) copper wire screens and foil and drain-wire shields.

Thermocouple pairs
Most common extension and compensation cables (e.g. EX, JX, KX, NX, TX, KCB and RCA/SCA types).

Coaxial cables
50Ω, 75Ω and 95Ω options in standard sizes from 1mm up to approx. 10mm. Standard and high-temperature (+200°C) options available.

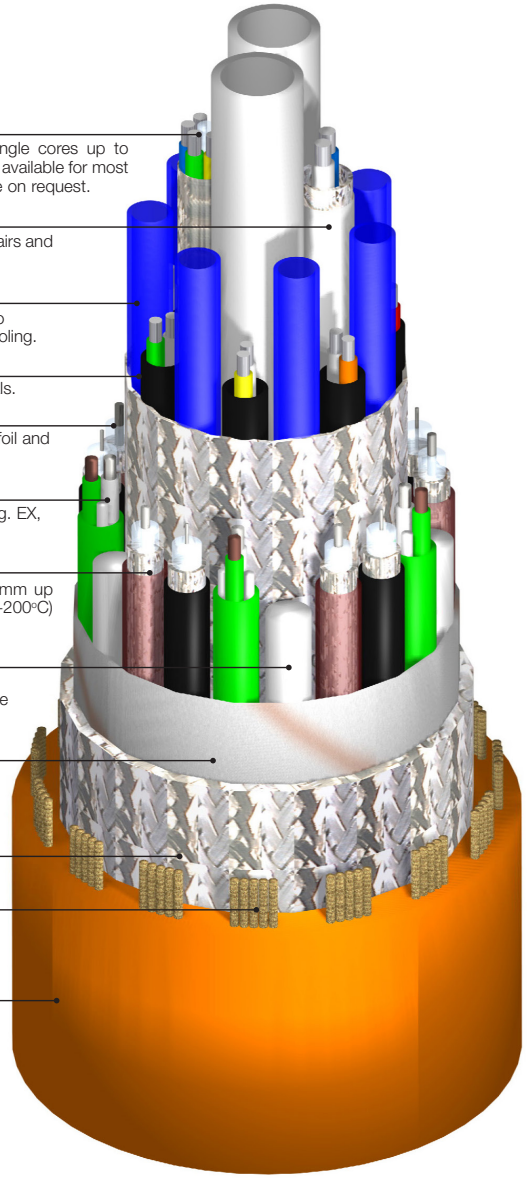
Fillers
Low, medium and high temperature fillers in solid and fibrous types for improved cable lay-up. Water-swellable options for fluid resistance.

Tapes and binders
Medium and high-temperature binders for improved dynamics and layer separation. Water-swellable option for fluid resistance.

Armouring
Stainless steel braids for cut-through resistance.

Aramid strain relief
Encapsulated or stand-alone braids and central strength members with breaking strains up to approx. 60 kN.

Sheathing (jacketing)
Diameters up to 70mm and temperatures ranging from -75°C up to +260°C.



Finished cables

Delivery, lengths and reels

Plastic delivery spools								
Type	Dimension							weight
	A	B	C	D	E	F	G	
	mm	mm	mm	mm	mm	mm	mm	kg
SD100/60K	16.5	60.0	100.0	38.0	45.0	25.0	3.5	0.06
E 100	16.0	80.0	100.0	80.0	100.0	20.0	7.0	0.09
E 125	16.0	80.0	125.0	100.0	125.0	20.0	7.0	0.15
E 160	22.0	100.0	160.0	128.0	160.0	32.0	13.0	0.25
SH370K	305.0	311.0	370.0	70.0	80.0	-	-	0.41
E 200	22.0	125.0	200.0	160.0	200.0	32.0	13.0	0.45
SD300K	51.5	212.0	300.0	91.0	103.0	44.5	11.0	0.65
K250	33.0	155.0	250.0	160.0	200.0	30.0	13.0	1.05
K355	33.0	220.0	355.0	160.0	200.0	80.0	25.0	1.85
B60	33.0	110.0	255.0	148.0	165.0	43.5	11.5	0.60
P3	75.0	110.0	280.0	265.0	285.0	43.5	9.5	0.73
P4	75.0	175.0	400.0	300.0	340.0	62.0	20.0	2.0
P5	75.0	202.0	480.0	340.0	380.0	65.0	20.0	2.0

Wooden delivery spools								
Type	Dimension							weight
	A	B	C	D	E	F	G	
	mm	mm	mm	mm	mm	mm	mm	kg
H400	35.0	200.0	400.0	200.0	230.0	85.0	22.0	3.0
H470	35.0	200.0	470.0	230.0	250.0	85.0	22.0	3.5
K6	75.0	250.0	600.0	400.0	464.0	100.0	40.0	12
K7	75.0	325.0	700.0	500.0	576.0	100.0	40.0	20
K8	75.0	375.0	800.0	500.0	576.0	100.0	40.0	25
K9	75.0	425.0	900.0	550.0	627.0	100.0	10.0	34
K10	107.0	500.0	1,000.0	600.0	715.0	150.0	50.0	46
K11	107.0	575.0	1,100.0	650.0	765.0	150.0	50.0	55
K12	107.0	675.0	1,200.0	850.0	980.0	300.0	50.0	90
K14	107.0	800.0	1,400.0	850.0	980.0	300.0	50.0	115
K16	107.0	950.0	1,600.0	850.0	1,012.0	300.0	50.0	195
K18	132.0	1,100.0	1,800.0	850.0	1,012.0	500.0	65.0	230

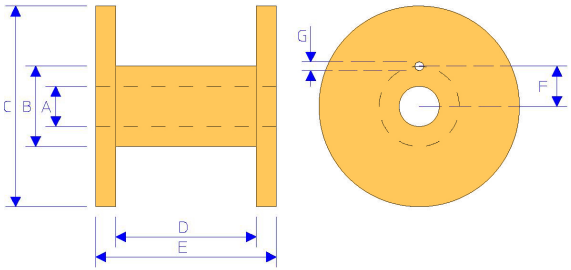
Delivery spool options

A number of standard spool sizes are available to choose from, provided that the inner diameter of the spool remains consistent with the MBR (Minimum Bend Radius) of the cable.

Habia Cable will supply the cable with all ends out and capped unless otherwise specified.

A number of different types are available: Plastic spools in PP or PS and Wooden spools.

Additionally, Habia Cable can supply in crates and barrels depending on the product. Please ask for details.



Finished cables

Recommended bend radius

Recommended MBR			
Type of usage	Definition	MBR for 'Standard cable'	MBR for Habiatron Q
Static (installation)	Flexed into position with no further movement	5 x overall cable diameter	7.5 x overall cable diameter
Flexing	General motion (e.g. unsupported cable movement)	10 x overall cable diameter	10 x overall cable diameter
Dynamic use	High frequency use (e.g. drag-chain)	20 x overall cable diameter	Not suitable for dynamic use

Flexibility and flexlife are two very differenty aspects

of bending a cable, however each has an impact on the recommended bend radius of the cable.

Flexibility

Flexibility indicates the unsupported 'drape' of a cable. Cables with highly stranded conductors, more elastic insulations and sheaths (such as rubber) and loosely braided screens will give a much better level of flexibility than harder materials such as fluoropolymers.

Flexlife

Flexlife gives an indication of how many times a cable can be repeatedly flexed without failure. Some aspects in the cable make-up are similar to flexibility when it comes to a good lay-up, such as highly stranded conductors and loose braids, however others can differ as friction plays a more significant part and as such strong, low-friction materials such as fluoropolymers can work much better than soft, weak materials such as rubber.

Recommended MBR

Recommendations are based on Habia Cable's understanding of our materials and experience gained on similar product types.

Given that the lay-up and bending properties of every cable are different, and that even minor changes in cable materials and lay-up can have significant effects on the flexibility and particularly the flex-life, then it is strongly recommended that the specific cable should be tested.

Habia Cable is unable to accept any liability and the use of this data is at the customer's discretion and risk.

It should be noted that figures stated here are guideline values only. Some cables like Hi-Flex may well be able to exceed these figures whilst other products with heavily filled, screened and armoured constructions may struggle to achieve the values quoted here.