Report

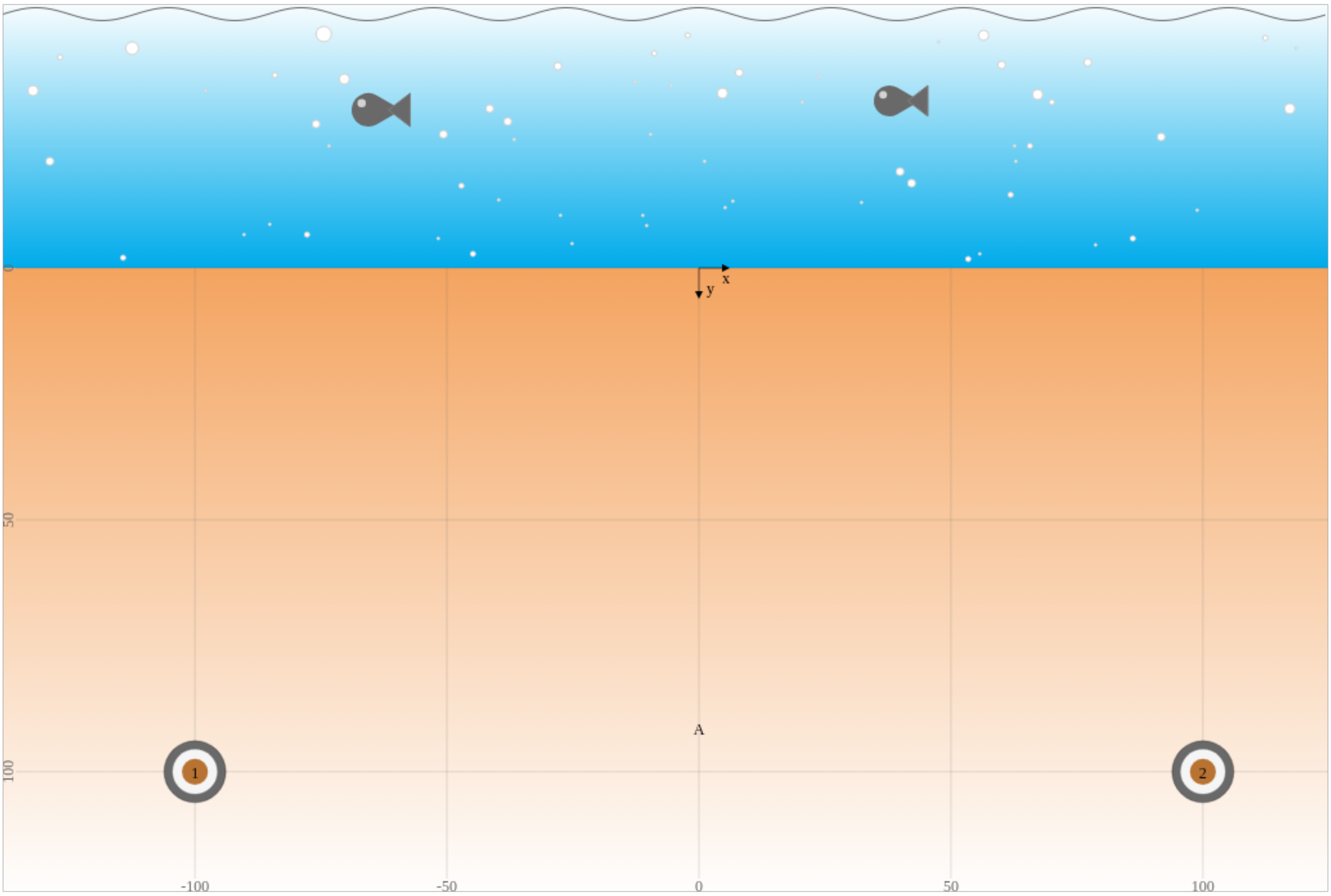
Title	Case study 7: A 320kV HVDC submarine bipole
Project	Verification CIGRE TB 880
Created	Date: 2025-05-26 Time: 13:18 Software version: f8c9 (2025-05-24)

Arrangement

Arrangement	**buried project** (#46707)
Options	None
CIGRE TB 880, guidance points	02, 06, 09, 26, 31
Systems	A

Statistics

Number of iterations of the solver	N_{calc}	10
Sum of currents from all systems	I_{sum}	2311.1 A
Sum of average conductor temperatures from all systems	θ_{sum}	70 °C
Number of overheated electrical systems		0
Sum of losses from all systems	W_{sum}	115.033 W/m



Systems

Following systems are active in the arrangement:

#	Object	Current [A]	Temp. [°C]	Losses [W/m]	Load
		I_c	θ_c | θ_e	W_{sys}	LF
A	16325 CIGRE TB 880 Case 7 320kV HVDC submar...	2311.1	70.0 | 43.0	115.0	1.00

Objects

Following objects are used:

16325 CIGRE TB 880 Case 7 320kV HVDC submarine bipole

Ambient

Calculation method		IEC Standard subsea (preview)
Ambient temperature	θ_a	15 °C
Thermal resistivity soil	ρ_4	0.8 K.m/W
Thermal conductivity soil	k_4	1.25 W/(m.K)
Volumetric heat capacity soil material $10^{-4} \frac{{k_4}^{0.2}}{4.68}$	$c_{p,soil}$	2234.3 J/(kg.K)
Thermal diffusivity soil	δ_{soil}	5.00e-7 m²/s
Ratio thermal resistivity dry/moist soil $\frac{\rho_{4d}}{\rho_4}$	v_4	1

Constants

Standard acceleration of gravity	g	9.80665 m/s^2
Archimedes' constant π	π	3.141592653589793
Absolute temperature	θ_{abs}	273.15 K
Stefan Boltzmann constant	σ	5.67036713e-8 W/m^2K^4
Vacuum permeability	μ_0	1.2566370614359173e-6 H/m
Vacuum permittivity	ϵ_0	8.854187817620389e-12 F/m

System A (High voltage cable)

Ampacity

Cable		CIGRE TB 880 Case 7 320kV HVDC submarine bipole
Rounded value, CIGRE TB 880	I_c	2310 A
Conductor current	I_c	2311.1 A

$$\sqrt{\frac{\theta_c - \theta_a + (v_4 - 1)\,\Delta\theta_x - v_4\Delta\theta_p - \Delta\theta_d}{R_c\left(T_1 + n_{ph}\left(1+\lambda_1\right)T_2 + \left(1+\lambda_1+\lambda_2+\lambda_3\right)\left(n_{ph}T_3 + n_{cc}\left(T_{4i} + T_{4ii} + T_{4\mu}v_4\right)\right) + n_{cc}\lambda_4\left(\frac{T_{4ii}}{2} + T_{4\mu}v_4\right)\right)}}$$

Operating voltage	U_o	320 kV
Number of sources in system	N_c	2
Number of conductors combined	n_{cc}	1

HVDC

Conductor current rating-field limited — $I_{c,ins}$ — 2046.43 A

$$\sqrt{\frac{\Delta\theta_{i,max}}{R_{c,ins}T_{ins}}}$$

Electrical resistance @ field limited conductor temperature — $R_{c,ins}$ — 1.0279e-5 Ω/m

$$R_{c20}\left(1 + \alpha_c\left(\theta_{c,ins} - 20\right)\right)$$

Field limited conductor temperature — $\theta_{c,ins}$ — 56.16 °C

$$\frac{\Delta\theta_{i,max}}{T_{ins}}\frac{T_{ins}}{\Delta\theta_i}\Delta\theta_c + \theta_a$$

Load

System frequency	f	0 Hz
Continuous load	LF	1 p.u.

Arrangement

Arrangement		flat
Position cable 1	$x_1\|y_1$	-1000.0 | 1000.0 mm
Position cable 2	$x_2\|y_2$	1000.0 | 1000.0 mm
Separation of conductors in a system	s_c	2000 mm
Mean distance between the phases	a_m	2000 mm
Geometric mean distance between phases of the same system	GMD	2 m

$$S_m$$

Depth of laying of sources	L_c	1000 mm
Depth of laying	L_{cm}	1 m
Outer diameter	D_o	0.1234 m
Substitution coefficient u	u	16.2075

$$\frac{2L_{cm}}{D_o}$$

Geometric constant of circle buried — g_u — 32.384

$$u + \sqrt{u^2 - 1}$$

Temperature

Temperature conductor — θ_c — 70 °C

$$\theta_a + \Delta\theta_c - (v_4 - 1)\,\Delta\theta_x + v_4\Delta\theta_p$$

Temperature conductor shield $\theta_c - (T_{ct} + T_{scb}) W_c$	θ_{cs}	65.37 °C
Temperature of insulation $\theta_c - (T_{ct} + T_{scb}) W_c - T_{ins} \left(W_c + \frac{W_d}{2}\right)$	θ_i	51.07 °C
Temperature screen/sheath	θ_s	48.65 °C
Temperature sheath $\theta_c - T_1 \left(W_c + \frac{W_d}{2}\right)$	θ_{sh}	48.65 °C
Temperature armour $\theta_c - T_1 \left(W_c + \frac{W_d}{2}\right) - n_{ph} T_2 \left(W_c (1 + \lambda_1) + W_d\right)$	θ_{ar}	46.69 °C
External temperature object $\theta_c - T_1 \left(W_c + \frac{W_d}{2}\right) - n_{ph} T_2 \left(W_c (1 + \lambda_1) + W_d\right) - n_{ph} T_3 (W_I + W_d)$	θ_e	43.01 °C

Temperature rise

Temperature rise conductor — $\Delta\theta_c$ — 55 K

$$n_{ph} (W_c T_{int} + W_d T_d) + n_{cc} \left(W_d (T_{4i} + T_{4ii} + v_4 T_{4ss}) + (W_c + W_s + W_{ar} + W_{sp}) (T_{4i} + T_{4ii} + v_4 T_{4\mu}) + W_{duct} \left(\frac{T_{4ii}}{2} + v_4 T_{4\mu}\right)\right)$$

Temperature rise dielectric losses $W_d \left(n_{ph} T_d + n_{cc} (T_{4i} + T_{4ii} + T_{4ss} v_4)\right)$	$\Delta\theta_d$	0 K
Temperature difference insulation $T_{ins} \left(W_c + \frac{W_d}{2}\right)$	$\Delta\theta_i$	14.2963 K
Temperature rise by other buried objects $\sum_{k=1}^{q} \Delta\theta_{kp}$	$\Delta\theta_p$	0 K
Critical soil temperature rise	$\Delta\theta_x$	0 K

Losses

Ohmic

Conductor losses (phase) $I_c^2 R_c$	W_c	57.516 W/m
Armour losses (phase) $\lambda_2 W_c$	W_{ar}	0 W/m
Duct losses	W_{duct}	0 W/m
Ohmic losses (phase) $W_c (1 + \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4)$	W_I	57.516 W/m

Dielectric

Dielectric losses (phase)	W_d	0 W/m

Total

Total losses (phase) $W_I + W_d$	W_t	57.516 W/m

Total losses (object) $n_{ph} W_t$	W_{tot}	57.516 W/m
Total losses (system)	W_{sys}	115.033 W/m

Thermal resistance

Thermal resistance ambient $= T_{4ss} = T_{4iii} = \frac{\rho_4}{2\pi}\left(\ln\left(g_u\right) + \ln\left(F_{mh}\right)\right)$	$T_{4\mu}$	0.4869 K.m/W
Mutual heating coefficient $\prod_{k=1}^{q} \frac{d_{pk1}}{d_{pk2}}$	F_{mh}	1.414

Cable

Internal thermal resistance for current losses $\frac{T_1}{n_{ph}} + T_2 + T_3$	T_{int}	0.4693 K.m/W
Internal thermal resistance for dielectric losses $\frac{T_1}{2n_c} + T_2 + T_3$	T_d	0.28371 K.m/W

Other characteristics

Earthing

earthing screen/sheath		both-side bonding
Variation of spacing		No variation

Loss factor

loss factor DC system	$\lambda_{\#}$	none

Drying-out of soil

Characteristic diameter drying zone	D_{dry}	0.123 m
Depth characteristic diameter drying zone	L_{dry}	1 m
Geometric constant of circle drying zone	g_{dry}	1 p.u.
Substitution coefficient g	g_a	1

Electrical parameters

System

System length	L_{sys}	1000 m
Power factor	$\cos\varphi$	1

Resistance

Electrical resistance conductor R_{cDC}	R_c	1.0768e-5 Ω/m → 0.0108 Ω
Electrical resistance DC conductor $R_{c20}\left(1 + \alpha_c\left(\theta_c - 20\right)\right)$	R_{cDC}	1.0768e-5 Ω/m → 0.0108 Ω
Electrical resistance sheath $R_{sh}\left(1 + \alpha_{sh}\left(\theta_{sh} - 20\right)\right)$	R_{sh}	3.4458e-4 Ω/m → 0.3446 Ω
Electrical resistance shield	R_s	3.4458e-4 Ω/m → 0.3446 Ω

Reduction factor $\frac{R_s}{\sqrt{{R_s}^2 + {X_s}^2}}$	RF	1
Electrical resistance armour $R_{ar}\left(1 + \alpha_{ar}\left(\theta_{ar} - 20\right)\right)$	R_{ar}	2.6904e-4 Ω/m → 0.269 Ω

Electrical field strength, capacitive load current

Electrical field strength insulation inner/outer $\frac{U_e}{1000} \frac{1}{r_x \ln\left(\frac{r_{osc}}{r_{isc}}\right)}$	E_i	25.207 | 16.134 kV/mm
Radius to point x in insulation	r_x	28.45 | 44.45 mm
Line-to-ground voltage $1000 U_o$	U_e	320000 V

Load, Voltage drop

Apparent power generator-side $U_o I_c$	S_G	739.551 MVA
Voltage drop $2 R_c \cos\varphi$	V_{drop}	0.022 V/(A.km) → 49.8 V = 0.02%
Inductance (mean) $\frac{\mu_0}{2\pi} \ln\left(\frac{GMD}{GMR_c}\right)$	L_m	9.221e-7+0.000e0j H/m → 0.9221 mH

Telegrapher equation

Surge impedance	Z_C	0.0000+0.0000j Ω
Propagation constant	γ_C	0.000e0+0.000e0j

Impedance valid up to 100 Hz without earth return

Positive sequence admittance	Y_1	0.000e0+0.000e0j S/m → 0 S
Positive sequence impedance $R_1 + jX_1$	Z_1	1.077e-5+5.794e-7j Ω/m → 0.0108+0.0006j Ω
Positive sequence reactance $\omega \frac{\mu_0}{2\pi} \ln\left(\frac{GMD}{GMR_c}\right)$	X_1	5.794e-7 Ω/m → 0.0006 Ω

Cable datasheet

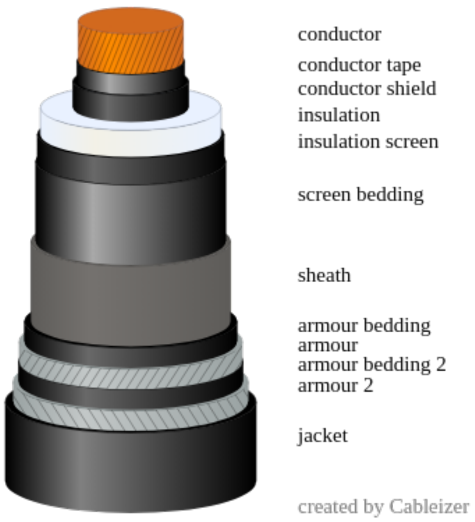
Title CIGRE TB 880 Case 7 320kV HVDC submarine bipole (#16325)

Warning! DC voltage in IEC 60287 is limited to 5 kV.
Info! Electric stress is higher than recommended in NF-C33-253 ($U_n \geq 230$ kV).
Info! Electric stress is higher than recommended in CIGRE ELT-151 ($U_n \geq 330$ kV).
Cable is used in following systems: A

CIGRE TB 880, guidance points 15, 20, 23, 25, 30, 32, 33, 34, 38, 39, 42, 44, 45

General Data

Rated line-to-line voltage	U_n	330 kV
Base voltage for tests	U_0	190 kV
Highest voltage for equipment	U_m	362 kV
Nominal system frequency	f	0 Hz
Number of conductors cable	n_c	1
Number of phases in a cable	n_{ph}	1



Cable elements

Conductor

Cross-sectional area conductor	A_c	1 x 2000 mm^2
Conductor material	M_c	Copper, round stranded
External diameter conductor	d_c	51.6 mm
Radius conductor	r_c	25.8 mm

$$\frac{d_c}{2}$$

Insulation

Insulation material	M_i	Crosslinked polyethylene (XLPE)
Thickness conductor tape	t_{ct}	0.65 mm
Thickness conductor shield	t_{cs}	2 mm
Thickness insulation	t_{ins}	16 mm
Thickness insulation screen	t_{is}	1.5 mm
Thickness insulation	t_i	20.15 mm

$$t_{ct} + t_{cs} + t_{ins} + t_{is}$$

Material of conductor tapes — Semiconducting tapes

Screen bedding

Screen bedding material		Water-blocking tapes, semi-conducting
Thickness screen bedding	t_{scb}	0.8 mm

Sheath

Sheath material	M_{sh}	Lead
Thickness sheath	t_{sh}	2.3 mm
corrugated		No

Armour bedding

Armour bedding material	M_{ab}	Polyethylene (LDPE)
Thickness armour bedding $t_{ab,1} + t_{ab,2}$	t_{ab}	3.65 mm
Thickness armour bedding 1	$t_{ab,1}$	3.25 mm
Thickness armour bedding 2	$t_{ab,2}$	0.4 mm

Armour

Construction of armour	a_{type}	Steel wires flat
Thickness armour	t_{ar}	2.5 mm
Factor between AC and DC resistance armour $\frac{1.4-1.2}{5-2}(t_{ar}-2)+1.2$	f_{ar}	1.2333e0 Ω/m
Number of wires armour	n_{ar}	40
Diameter armour wire $\sqrt{\frac{4t_{ar}w_{ar}}{\pi}}$	d_f	4.886 mm
Width armour	w_{ar}	7.5 mm
Width of flat wires armour 1	$w_{a,1}$	7.5 mm

Input data for double layered armour

Thickness armour 1	$t_{a,1}$	2.5 mm
Thickness armour 2	$t_{a,2}$	2.5 mm
Width of flat wires armour 1	$w_{a,1}$	7.5 mm
Width of flat wires armour 2	$w_{a,2}$	7.5 mm
Number of wires armour 1	$n_{a,1}$	40
Number of wires armour 2	$n_{a,2}$	40
Length of lay armour 1	$p_{a,1}$	1000 mm
Length of lay armour 2	$p_{a,2}$	1000 mm

Jacket

Jacket material	M_j	Polypropylene (PP)
Thickness jacket	t_j	4 mm

Overall

External diameter object	D_e	123.4 mm
Absorption coefficient solar radiation	σ_{sun}	0.4
Emissivity cable	ϵ_e	0.9
Reflectivity cable $1-\epsilon_e$	η_e	0.1

Mass cable $m_{hollow} + m_{metal}$	m_{tot}	37.879 kg/m

Electrical

Conductor

Electrical resistance DC conductor 20°C	R_{c20}	9.0000e-6 Ω/m
Standard DC resistance of conductor	R_{co}	0.009 Ω/km
Coating of wires		plain
Skin effect coefficient	k_s	1
Proximity effect coefficient	k_p	1
Geometric mean radius conductor $K_{GMR} r_{z1}$	GMR_c	0.01989 m
Factor geometric mean radius	K_{GMR}	0.771
Constant relating to conductor formation	K_{BICC}	0.0519
Number of wires conductor	n_{cw}	53
Diameter of wires conductor (average)	d_{cw}	4.478 mm

Insulation

Capacitance, with approximation (CIGRE TB 880) $\frac{1}{2\pi\epsilon_0}\frac{10^{-9}}{18}C_b$	C_b	3.113e-10 F/m
Capacitance (exact) $\frac{2\pi\epsilon_0\epsilon_i}{\ln\left(\frac{r_{osc}}{r_{isc}}\right)}$	C_b	3.117e-10 F/m
Capacitance to earth C_b	C_E	3.113e-10 F/m
Vacuum permittivity	ϵ_0	8.854187817620389e-12 F/m
Radius above the inner semi-conducting layer $\frac{d_c}{2} + t_{ct} + t_{cs}$	r_{isc}	28.45 mm
Radius over capacitive insulation layers $\frac{D_{ins}}{2}$	r_{osc}	44.45 mm
Velocity of propagation $\frac{1}{1000\sqrt{\mu_0\epsilon_0\epsilon_i}}$	v_{prop}	189605.4 km/s

Screen + Sheath

Electrical resistance sheath $10^6\frac{\rho_{sh}}{A_{sh}}$	R_{sh}	3.0915e-4 Ω/m
Electrical resistance screen/sheath 20°C	R_{so}	3.092e-1 Ω/km

Armour

Electrical resistance armour $10^6\frac{f_{ar}\rho_{ar}}{A_{ar}}$	R_{ar}	2.2693e-04 Ω/m
Electrical resistance armour, CIGRE TB 880 $F_{lay,ar} R_{ar}$	R_{ar}	2.4020e-04 Ω/m

Effective length per unit lay length armour $\sqrt{1+\left(\frac{\pi d_{ar}}{L_{lay,ar}}\right)^2}$	$F_{lay,ar}$	1.0584
Length of lay armour	$L_{lay,ar}$	1000 mm
Inductance H_1 armour $10^{-7}\pi\mu_e\frac{n_{ar}{d_f}^2}{L_{lay,ar}d_{ar}}sin\left(\phi_{ar}\right)cos\left(\gamma_{ar}\right)$	H_1	2.5185e-7 H/m
Inductance H_2 armour $10^{-7}\pi\mu_e\frac{n_{ar}{d_f}^2}{L_{lay,ar}d_{ar}}sin\left(\phi_{ar}\right)sin\left(\gamma_{ar}\right)$	H_2	2.5186e-7 H/m
Inductance H_3 armour	H_3	0.0000e0 H/m
Longitudinal relative permeability steel wires	μ_e	400
Transverse relative permeability steel wires	μ_t	1
Relative permeability steel wires	μ_s	300
Angle between armour and cable axis	ϕ_{ar}	0.334 rad
Angular time delay	γ_{ar}	0.785 rad

Radius

Radius conductor	r_{z1}	0.0258 m
Radius shield (inner)	r_{z2}	0.0456 m
Radius shield (outer)	r_{z3}	0.0456 m
Radius sheath (inner)	$r_{z2,sh}$	0.0456 m
Radius sheath (outer)	$r_{z3,sh}$	0.0502 m
Radius armour (inner)	r_{z4}	0.0527 m
Radius armour (outer)	r_{z5}	0.0577 m
Radius outersheath	r_{z6}	0.0617 m

Material parameters

Conductor

Electrical resistivity conductor material	ρ_c	1.724e-8 Ω.m
Temperature coefficient conductor material	α_c	3.93e-3 1/K
Reciprocal of temperature coefficient conductor material	β_c	2.345e2 K
Volumetric heat capacity conductor material	σ_c	3.45e6 J/(K.m^3)
Thermal conductivity conductor material	k_c	384.62 W/(m.K)
Density conductor material	ζ_c	8.94 g/cm^3

Insulation

Relative permittivity insulation material	ϵ_i	2.5
Loss factor insulation material	$\tan\delta_i$	0.001
Thermal resistivity insulation material	ρ_i	3.5 K.m/W
Volumetric heat capacity insulation material	σ_i	2.40e6 J/(K.m^3)
Density insulation material	ζ_i	0.923 g/cm^3
Limitation of temperature rise insulation material	$\Delta\theta_{i,max}$	10.7 K
Max. temperature conductor	θ_{cmax}	70 °C
Max. temperature conductor, emergency overload	θ_{cmaxeo}	105 °C
Max. temperature conductor, short-circuit	θ_{cmaxsc}	250 °C

Conductor tape

Thermal resistivity conductor tape	ρ_{ct}	12 K.m/W
Density tape material	ζ_{tape}	0.34 g/cm^3

Conductor shield

Thermal resistivity conductor shield	ρ_{cs}	2.5 K.m/W
Insulation screen		
Thermal resistivity insulation screen	ρ_{is}	2.5 K.m/W

Screen bedding

Thermal resistivity screen bedding	ρ_{scb}	12 K.m/W
Volumetric heat capacity screen bedding	σ_{scb}	2.00e6 J/(K.m^3)
Density tape material	ζ_{tape}	0.34 g/cm^3

Sheath

Specific electrical resistivity sheath material	ρ_{sh}	2.140e-7 Ω.m
Temperature coefficient sheath material	α_{sh}	4.00e-3 1/K
Reciprocal of temperature coefficient sheath material	β_{sh}	2.300e2 K
Volumetric heat capacity sheath material	σ_{sh}	1.45e6 J/(K.m^3)
Thermal conductivity sheath material	k_{sh}	33.4 W/(m.K)
Density sheath material	ζ_{sh}	11.34 g/cm^3

Armour bedding

Thermal resistivity armour bedding $\frac{\rho_{ab,1}t_{ab,1} + \rho_{ab,2}t_{ab,2}}{t_{ab}}$	ρ_{ab}	3.02 K.m/W
Volumetric heat capacity armour bedding $\frac{\sigma_{ab,1}t_{ab,1} + \sigma_{ab,2}t_{ab,2}}{t_{ab}}$	σ_{ab}	2.40e6 J/(K.m^3)
Density armour bedding material $\frac{\zeta_{ab,1}t_{ab,1} + \zeta_{ab,2}t_{ab,2}}{t_{ab}}$	ζ_{ab}	0.93 g/cm^3
Thermal resistivity armour bedding 1	$\rho_{ab,1}$	2.66 K.m/W
Thermal resistivity armour bedding 2	$\rho_{ab,2}$	6 K.m/W
Volumetric heat capacity armour bedding 1	$\sigma_{ab,1}$	2.40e6 J/(K.m^3)
Volumetric heat capacity armour bedding 2	$\sigma_{ab,2}$	2.40e6 J/(K.m^3)

Armour

Specific electrical resistivity armour material	ρ_{ar}	1.380e-7 Ω.m
Temperature coefficient armour material	α_{ar}	4.50e-3 1/K
Reciprocal of temperature coefficient armour material	β_{ar}	2.022e2 K
Volumetric heat capacity armour material	σ_{ar}	3.80e6 J/(K.m^3)
Thermal conductivity armour material	k_{ar}	36.1 W/(m.K)
Density armour material	ζ_{ar}	7.85 g/cm^3

Jacket

Thermal resistivity jacket material	ρ_j	6 K.m/W
Thermal resistivity additional layer	ρ_{jj}	2.5 K.m/W
Volumetric heat capacity jacket material	σ_j	1.80e6 J/(K.m^3)
Electrical conductivity jacket material	κ_j	1.00e-14 S/m
Density jacket material	ζ_j	0.91 g/cm^3

Thermal resistance

Internal thermal resistances for rating calculation

Thermal resistance conductor—sheath $T_{ct} + T_{cs} + T_{ins} + T_{is} + T_{scb} + T_{scs} + T_{dsh}$	T_1	0.3713 K.m/W
Thermal resistance armour bedding T_{ab}	T_2	0.0341 K.m/W
Thermal resistance jacket $T_j + T_{jj}$	T_3	0.064 K.m/W
Thickness conductor—sheath $t_i + t_{scb} + t_{scs} + \frac{H_{sh} + \Delta H}{2}$	t_1	20.95 mm
Thickness sheath—armour $\frac{H_{sh} + \Delta H}{2} + t_{ab}$	t_2	3.65 mm
Thickness armour—surface $t_j + t_{jj}$	t_3	4 mm

Cable elements

Thermal resistance, transient $T_1 + T_2 + T_3$	T_{tot}	0.4693 K.m/W
Thermal resistance insulation $T_{ct} + T_{cs} + T_{ins} + T_{is}$	T_i	0.33829 K.m/W
Thermal resistance conductor tape $\frac{\rho_{ct}}{2\pi} \ln\left(\frac{d_c + 2t_{ct}}{d_c}\right)$	T_{ct}	0.04752 K.m/W
Thermal resistance conductor shield $\frac{\rho_{cs}}{2\pi} \ln\left(\frac{D_{cs}}{D_{cs} - 2t_{cs}}\right)$	T_{cs}	0.029 K.m/W
Thermal resistance insulation $\frac{\rho_i}{2\pi} \ln\left(\frac{D_{ins}}{D_{ins} - 2t_{ins}}\right)$	T_{ins}	0.24856 K.m/W
Thermal resistance insulation screen $\frac{\rho_{is}}{2\pi} \ln\left(\frac{D_{ins} + 2t_{is}}{D_{ins}}\right)$	T_{is}	0.01321 K.m/W
Thermal resistance screen bedding $\frac{\rho_{scb}}{2\pi} \ln\left(\frac{D_{scb}}{D_i}\right)$	T_{scb}	0.03296 K.m/W
Thermal resistance armour bedding $T_{ab,1} + T_{ab,2}$	T_{ab}	0.03407 K.m/W
Thermal resistance armour bedding 1 $\frac{\rho_{ab,1}}{2\pi} \ln\left(\frac{D_{ab,1}}{D_{shj} - (H_{sh} + \Delta H)}\right)$	$T_{ab,1}$	0.02713 K.m/W
Thermal resistance armour bedding 2 $\frac{\rho_{ab,2}}{2\pi} \ln\left(\frac{D_{ab,2}}{D_{ab,2} - 2t_{ab,2}}\right)$	$T_{ab,2}$	0.00694 K.m/W
Thermal resistance jacket $\frac{\rho_j}{2\pi} \ln\left(\frac{D_j - 2t_{jj}}{D_j - 2\left(t_j + t_{jj}\right)}\right)$	T_j	0.06401 K.m/W

Dimensions

Diameter

External diameter conductor	d_c	51.6 mm
Diameter over conductor shield $d_c + 2(t_{ct} + t_{cs})$	D_{cs}	56.9 mm
Diameter over insulation $d_c + 2(t_{ct} + t_{cs} + t_{ins})$	D_{ins}	88.9 mm
Diameter over insulation incl. insulation screen $d_c + 2(t_{ct} + t_{cs} + t_{ins} + t_{is})$	D_i	91.9 mm
Diameter over insulation screen $d_c + 2t_i$	D_{is}	91.9 mm
Diameter over screen bedding $d_c + t_{i1} + 2t_{scb}$	D_{scb}	93.5 mm
Equivalent diameter of screen and sheath	d_s	95.8 mm
Mean diameter sheath $D_{shb} + t_{sh} + H_{sh} + \Delta H$	d_{sh}	95.8 mm
Diameter over sheath $D_{shb} + 2(t_{sh} + H_{sh} + \Delta H)$	D_{sh}	98.1 mm
Diameter over sheath jacket	D_{shj}	98.1 mm
Diameter over armour bedding 1 $D_{sh} + 2t_{ab,1}$	$D_{ab,1}$	104.6 mm
Diameter over armour bedding 2 $D_{ab,1} + 2(t_{a,1} + t_{ab,2})$	$D_{ab,2}$	110.4 mm
Equivalent diameter of screen/sheath and armour $\sqrt{\frac{{d_s}^2 + {d_{ar}}^2}{2}}$	d_e	103.358 mm
Mean diameter armour $D_{ab} + t_{a,1} + t_{a,2}$	d_{ar}	110.4 mm
Diameter over armour $D_{ab} + 2(t_{a,1} + t_{a,2})$	D_{ar}	115.4 mm
Diameter over jacket $D_{ar} + 2(t_j + t_{jj})$	D_j	123.4 mm

Area

Cross-sectional area conductor	A_c	2000 mm^2
Cross-sectional area insulation $\frac{\pi}{4}\left({D_{is}}^2 - {d_c}^2\right)$	A_i	4542 mm^2
Cross-sectional area screen bedding $\pi t_{scb}(D_{scb} - t_{scb})$	A_{scb}	233 mm^2
Cross-sectional area sheath $d_{sh} t_{sh} \pi$	A_{sh}	692.22 mm^2
Cross-sectional area armour bedding $\frac{\pi}{4}\left({D_{ab}}^2 - (D_{ab} - t_{ab})^2\right)$	A_{ab}	593.8 mm^2
Cross-sectional area armour $n_{ar} t_{ar} w_{ar}$	A_{ar}	750 mm^2

Cross-sectional area jacket $\frac{\pi}{4}\left({D_j}^2-\left(D_j-2\left(t_j+t_{jj}\right)\right)^2\right)$	A_j	1500.4 mm^2