5.1 - TABLES OFCONSTRUCTIONAL DATA, ELECTRICAL CHARACTERISTICS AND CURRENT RATINGS

General presentation

The following tables are given as a guide to engineers involved in the study of network links, admissible current ratings as well as defining and selection of cable types.
The tables are not the definitive list of Liban Cables range but a simple solution guide to the most common cables used. Should a problem be unresolved by the tables then a case study could be carried out by Liban Cables, on base of specific request to reach the most appropriate tailored conception. In this event, please contact: **Liban Cables**

Two screen options for cables in the High Voltage 66 KV to 225 KV range are given, for copper or aluminium conductors:

1 - Lead sheath screen
2 - Copper or aluminium wire screen

Laying and Earthing conditions

We have retained only these most common configurations (see chapter 5.2 for other laying conditions):

• **Laying**	**Trefoil formation**		**Flat formation**	
	Buried cables	Cables in air	Buried cables	Cables in air
• Laying depth	d = 1.3 m		d = 1.3 m	
• Thermal conditions				
- Case N°1*	ρ_T = 1.0°C.m/W T = 20°C	T = 30°C	ρ_T = 1.0°C.m/W T = 20°C	T = 30°C
- Case N°2*	ρ_T = 1.2°C.m/W T = 30°C	T = 50°C	ρ_T = 1.2°C.m/W T = 30°C	T = 50°C
• Axial distance	Close formation		2 x outer diameter	
• Earthing method				
- S < 630 mm2	continuous earthing (with circulating currents in the metallic screen)		at one point only or perfect cross-bonding (without circulating current in the metallic screen)	
- S ≥ 630 mm2	at one point only or perfect cross-bonding (without circulating current in the metallic screen)		at one point only or perfect cross-bonding (without circulating current in the metallic screen)	

*ρ_T: Soil thermal resistivity - T: Soil or air temperature.

Admissible current ratings

Admissible current ratings given in the following pages are against the conditions given in the above table, for one circuit in operation with a load factor of 100%, in accordance with IEC Publication 60287.

5.2 - CORRECTING FACTORS FOR OTHER LAYING CONDITIONS

In the tables of the hereafter chapters 6.1 and 6.2, we have considered a single circuit composed of 3 cables under continuous operation and with the following laying conditions:

	Buried cables Depth of burial: d = 1.3 m		**Cables in air**	
	Trefoil formation	Flat formation	Trefoil formation	Flat formation
- Case N°1*	ρ_T = 1.0 and T = 20°C*		Air temperature = 30°C	
- Case N°2*	ρ_T = 1.2 and T = 30°C*		Air temperature = 50°C	

*ρ_T: Soil thermal resistivity, in °C.m/W - T: Soil temperature, in °C.

When for a particular project, one or more parameters of laying are different from those in the above mentioned table, the correcting factors given hereafter permit estimation of the current rating under the laying conditions of the project.

1. CASE OFBURIED CABLES

The corrected current rating Ic is imperatively the one given in the tables for the case N°1 multiplied by the correcting factors of:

- Depth of burial (Kd), if — d ≠ 1.3 meter
- Soil thermal resistivity (Kr), if — $\rho_T \neq$ 1.0°C.m/W
- Soil temperature (Kt), if — T ≠ 20°C
- Proximity effect (Kn), if — the number of circuits: n > 1

Example: Calculation of the corrected current rating for a 1 x 630 mm^2 copper 76/132 (145) KVcable, lead sheathed, laid in trefoil formation, with:

- d = 1.50 m
- ρ_T= 1.2°C.m/W
- T = 30°C
- n = 2 with axial spacing between circuits: s = 400 mm

The table of continuous current ratings gives for ρ_T= 1.0 and T = 20°C: I = 865 A and the tables of correcting factors give:

- For d = 1.50 m : Kd = 0.98
- For ρ_T= 1.2°C.m/W : Kr = 0.93
- For T = 30°C : Kt = 0.92
- For n = 2 and s = 400 mm : Kn = 0.79

The corrected current rating is: Ic = 865 x 0.98 x 0.93 x 0.92 x 0.79 = **573 A approx.**

2. CASE OF CABLES IN AIR

The corrected current rating Ic is **imperatively the one given in the tables for the case N°1** (Air temperature = 30°C) multiplied by the correcting factor of the air temperature (Ka) if $T \neq 30$°C.
There is no proximity effect in this method of laying when the axial distance between adjacent cables of 2 circuits side by side is superior to twice the external diameter of the cable.

Example: Calculation of the corrected current rating for a 1 x 630 mm^2 copper 76/132 (145) KVcable, lead sheathed, laid in flat formation, with:

- Air temperature T = 40°C

The table of continuous current ratings gives for T = 30°C : I = 1225 A and the tables of correcting factors give:

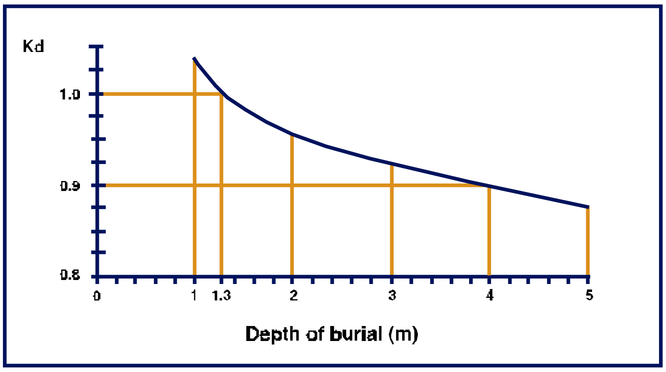
- For T = 40°C : Ka = 0.90

The corrected current rating is: Ic = 1225 x 0.90 = **1103 A approx.**

5.2 - CORRECTING FACTORS FOR OTHER LAYING CONDITIONS (cont.)

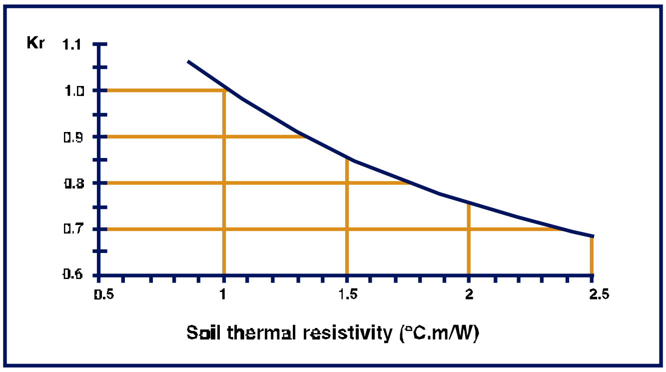
Depth of burial (Kd)

Edpth of burial (m)	Rating Factor
1.0	1.03
1.3	1.00
1.5	0.98
2.0	0.95
2.5	0.93
3.0	0.91
3.5	0.90
4.0	0.89
4.5	0.88
5.0	0.87



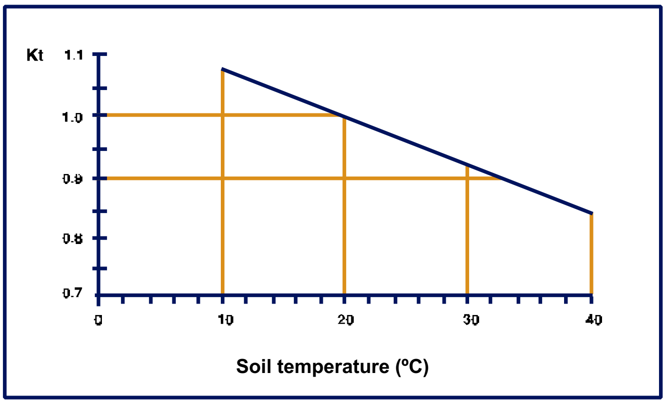
Soil thermal resistivity (Kr)

Soil thermal resistivity (˚C.m/W)	Rating Factor
0.85	1.06
1.0	1.00
1.2	0.93
1.5	0.86
2.0	0.76
2.5	0.69



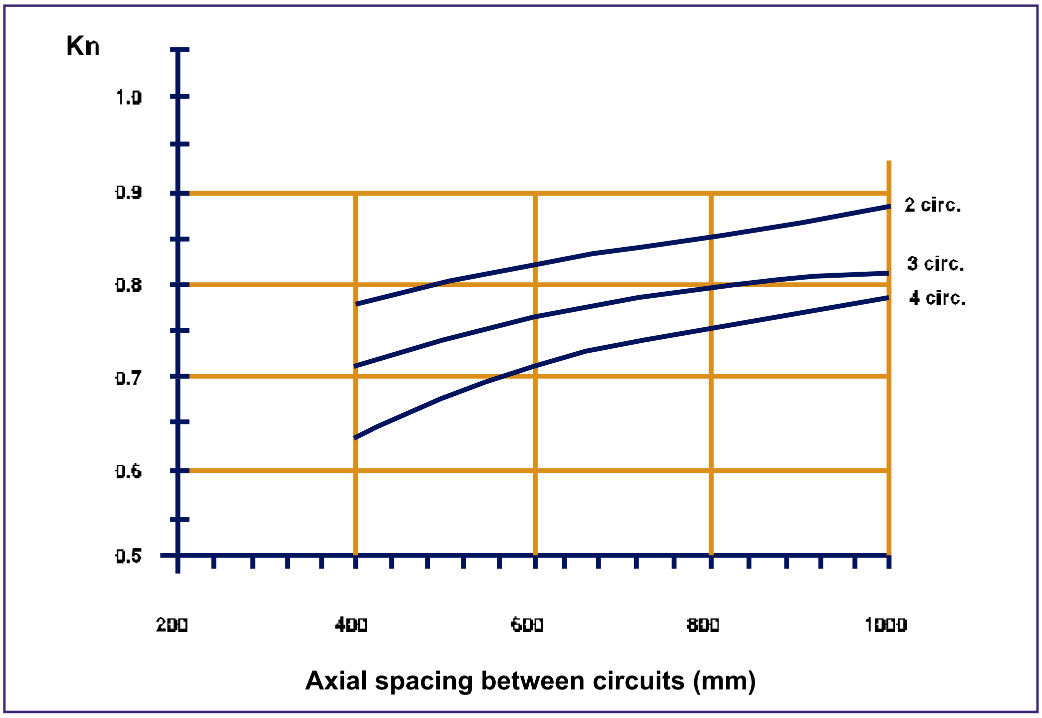
Soil temperature (Kt)

Soil temperature (˚C)	Rating factor
10	1.07
20	1.00
30	0.92
40	0.84



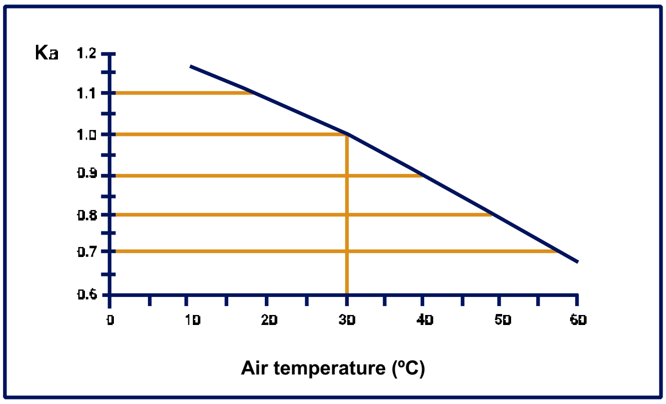
Proximity effect (Kn)

Axial spacing between circuits (mm)	Numberof circuits			
	1	2	3	4
400	1.00	0.79	0.71	0.65
600	1.00	0.85	0.76	0.72
800	1.00	0.88	0.79	0.75
1000	1.00	0.89	0.81	0.79



Airtemperature (Ka)

Soil temperature (˚C)	Rating factor
10	1.17
20	1.09
30	1.00
40	0.90
50	0.80
60	0.68



5.3 - SHORT-CIRCUIT CURRENT RATINGS

The following pages show the method for the calculation of short-circuit current ratings in the conductor and in the metallic screen, in accordance with IEC 949.

The short-circuit current ratings are given for:

1. Conductor	copper or aluminium
2. Metallic screen	in lead alloy
	in copper wires or flat wires
	in aluminium wires

Each case is accompanied by an example of calculation with a cable presented in the preceding pages.

Method of calculation

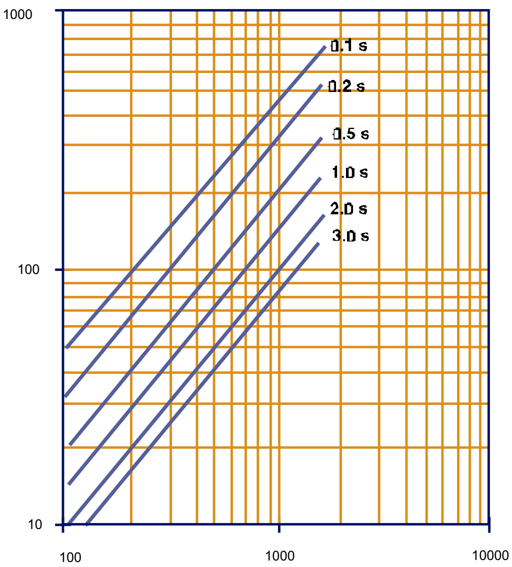
The calculation method takes into account an adiabatic heating.

- For the conductor	The obtained values are near the reality because the loss of heat in the insulation is insignifiant.
- For the metallic screen	The simplified method given in the following pages does not take into account the loss of heat in the external environment. Thereby the obtained values are on the low side but give an approximative value between 5% and 10% under the value of the admissible short-circuit current.

5.3 - SHORT-CIRCUIT CURRENT RATINGS (cont.)
COPPER CONDUCTOR

GENERAL

Short-circuit current (KA)



Cross-sectional area of copper conductor (mm²)

The following formula in accordance with IEC 949 takes into account an adiabatic heating, i.e. without loss of heat in the insulation.

$$I = 226 \frac{S}{\sqrt{t}} \sqrt{Ln \frac{234 + \theta_f}{234 + \theta_i}}$$

or

$$J = \frac{I}{S} = \frac{1}{\sqrt{t}} \left[226 \sqrt{Ln \frac{234 + \theta}{234 + \theta}} \right. \text{[redacted]} = \frac{1}{\sqrt{t}} \text{ x } 143.2$$

I : permissible short circuit current (A).
S : cross-sectional area of the conductor (mm^2).
t : short circuit duration time (s).
θ_f: final temperature (250˚C)
θ_i: initial temperature (90˚C)
J : permissible current density (A/mm^2)

Fort = 1s: J = Jo = 143.2 A/mm^2

$$\text{For } t \neq 1s: \; J = \frac{j_0}{\sqrt{t}}$$

Practical application

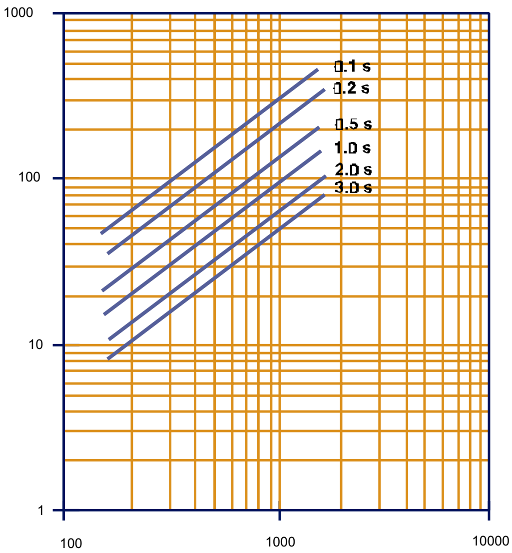
Example: a 630 mm^2 copper conductor will carry:

a) For 1 second:	Io = Jo x S = 143.2 x 630	= 90216 Amperes, i.e.	90.2 KA
b) For 0.5 second:	$I = \frac{j_0}{\sqrt{t}} \text{ X } S = \frac{I_0}{\sqrt{t}} = \frac{90216}{\sqrt{0.5}}$	= 127585 Amperes, i.e.	127.6 KA
C) For 2 seconds:	$I = \frac{j_0}{\sqrt{t}} \text{ X } S = \frac{I_0}{\sqrt{t}} = \frac{90216}{\sqrt{2}}$	= 63792 Amperes, i.e.	63.8 KA

5.3 - SHORT-CIRCUIT CURRENT RATINGS (cont.) ALUMINIUM CONDUCTOR

GENERAL

Short-circuit current (KA)



Cross-sectional area of aluminium conductor (mm²)

The following formula in accordance with IEC 949 takes into account an adiabatic heating, i.e. without loss of heat in the insulation.

$$I = 148 \frac{S}{\sqrt{t}} \sqrt{Ln \frac{228 + \theta_f}{228 + \theta_i}}$$

or

$$J = \frac{I}{S} = \frac{1}{\sqrt{t}} \left[148 \sqrt{Ln \frac{228 + \theta}{228 + \theta}} \text{[redacted]} = \frac{1}{\sqrt{t}} \times 94.5$$

I : permissible short circuit current (A).
S : cross-sectional area of the conductor (mm^2).
t : short circuit duration time (s).
θ_f: final temperature (250˚C)
θ_i: initial temperature (90˚C)
J : permissible current density (A/mm^2)

For t = 1s: J = Jo = 94.5 A/mm²

$$\text{For } t \neq 1s: \; J = \frac{j_0}{\sqrt{t}}$$

Practical application

Example: a 630 mm^2 aluminium conductor will carry:

a) For 1 second: Io = Jo x S = 94.5 x 630 = 59535 Amperes, i.e. 59.5 KA

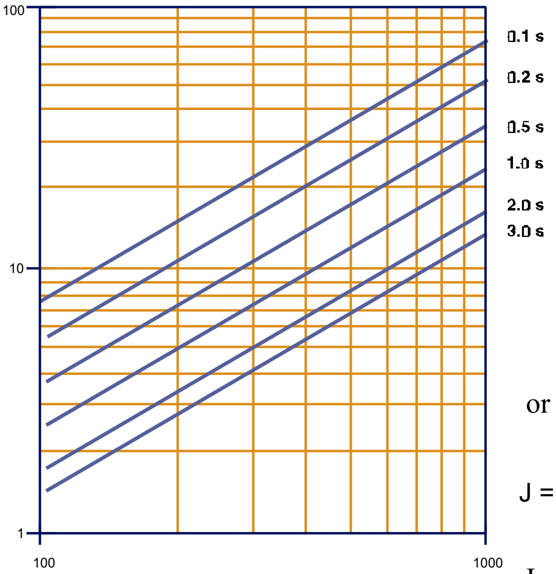
b) For 0.5 second: $I = \frac{j_0}{\sqrt{t}} \times S = \frac{I_0}{\sqrt{t}} = \frac{59535}{\sqrt{0.5}}$ = 84195 Amperes, i.e. 84.2 KA

C) For 2 seconds: $I = \frac{j_0}{\sqrt{t}} \times S = \frac{I_0}{\sqrt{t}} = \frac{59535}{\sqrt{2}}$ = 42097 Amperes, i.e. 42.1 KA

5.3 - SHORT-CIRCUITCURRENTRATING S (cont.)
LEAD METALLIC SCREEN

GENERAL

Short-circuit current (KA)



Cross-sectional area of lead screen (mm²)

The following formula in accordance with IEC 949 takes into account an adiabatic heating i.e. without loss of heat in the insulation but equally in the external environment. Thereby the more important the short-circuit duration is, the more pessimistic the calculated values.

$$I = 41 \frac{S}{\sqrt{t}} \sqrt{1\,n \frac{230 + \theta_f}{230 + \theta_i}}$$

or

$$J = \frac{I}{S} = \frac{1}{\sqrt{t}} \left[41 \sqrt{L\,n \frac{230 + \theta_f}{230 + \theta_i}} \right] = \frac{1}{\sqrt{t}} \times 24.3$$

I : permissible short circuit current (A).
S : cross-sectional area of the conductor (mm²).
t : short circuit duration time (s).
θ_f: final temperature (210°C)
θ_i: initial temperature (80°C)
J : permissible current density (A/mm²)

For t = 1s: J = Jo = 24,3 A/mm²

$$\text{For } t \neq 1s: \; J = \frac{j_0}{\sqrt{t}}$$

Practical application

Example: a 300 mm² aluminium conductor 64/110 (123) KV cable has, according to the dimensional table a lead screen of 400 mm2. This screen will carry:

a) For 1 second: Io = Jo x S = 24.3 x 400 = 9720 Amperes, i.e. 9.7 KA

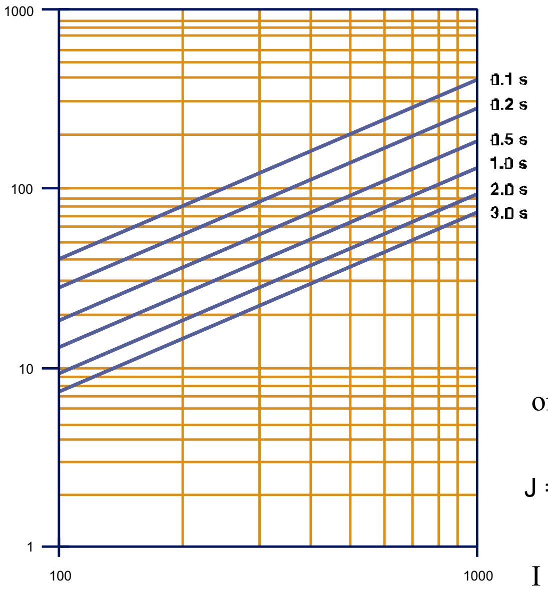
b) For 0.5 second: $I = \frac{j_0}{\sqrt{t}} \times S = \frac{I_0}{\sqrt{t}} = \frac{9720}{\sqrt{0.5}}$ = 13746 Amperes, i.e. 13.7 KA

C) For 2 seconds: $I = \frac{j_0}{\sqrt{t}} \times S = \frac{I_0}{\sqrt{t}} = \frac{9720}{\sqrt{2}}$ = 6873 Amperes, i.e. 6.9 KA

5.3 - SHORT-CIRCUIT CURRENT RATINGS (cont.) COPPER METALLIC SCREEN

GENERAL

Short-circuit current (KA)



Cross-sectional area of copper screen (mm²)

The following formula in accordance with IEC 949 takes into account an adiabatic heating, i.e. without loss of heat in the insulation but equally in the external environment. Thereby the more important the short-circuit duration is, the more pessimistic the calculated values.

$$I = 226 \frac{S}{\sqrt{t}} \sqrt{Ln \frac{234 + \theta_f}{234 + \theta_i}}$$

or

$$J = \frac{I}{S} = \frac{1}{\sqrt{t}} \left[226 \sqrt{Ln \frac{234 + \theta_f}{234 + \theta_i}} \right.$$ [redacted] $$= \frac{1}{\sqrt{t}} \text{ x } 133.0$$

I : permissible short circuit current (A).
S : cross-sectional area of the conductor (mm²).
t : short circuit duration time (s).
θ_f: final temperature (210°C)
θ_i: initial temperature (80°C)
J : permissible current density (A/mm²)

For t = 1s: J = Jo = 133.0 A/mm²

$$\text{For } t \neq 1s: \; J = \frac{j_0}{\sqrt{t}}$$

Practical application

Example: a 300 mm² Copper conductor 64/110 (123) KV cable has, according to the dimensional table a copper screen of 140 mm². This screen will carry:

a) For 1 second: Io = Jo x S = 133.0 x 140 = 18620 Amperes, i.e. 18.6 KA

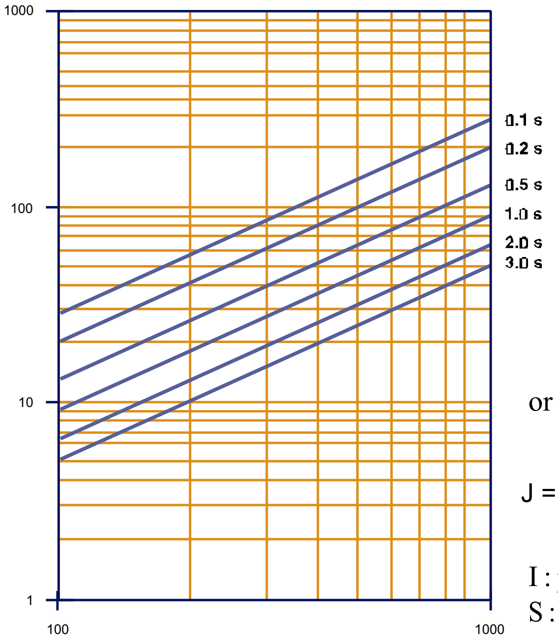
b) For 0.5 second: $I = \frac{j_0}{\sqrt{t}} \text{ X } S = \frac{I_0}{\sqrt{t}} = \frac{18620}{\sqrt{0.5}}$ = 26332 Amperes, i.e. 26.3 KA

C) For 2 seconds: $I = \frac{j_0}{\sqrt{t}} \text{ X } S = \frac{I_0}{\sqrt{t}} = \frac{18620}{\sqrt{2}}$ = 13166 Amperes, i.e. 13.2 KA

5.3 - SHORT-CIRCUIT CURRENT RATINGS (cont.) ALUMINIUM METALLIC SCREEN

GENERAL

Short-circuit current (KA)



Cross-sectional area of aluminium screen (mm²)

The following formula in accordance with IEC 949 takes into account an adiabatic heating, i.e. without loss of heat in the insulation but equally in the external environment. Thereby the more important the short-circuit duration is, the more pessimistic the calculated values.

$$I = 148 \frac{S}{\sqrt{t}} \sqrt{L\,n \frac{228 + \theta_f}{228 + \theta_i}}$$

or

$$J = \frac{I}{S} = \frac{1}{\sqrt{t}} \left[148 \sqrt{L\,n \frac{228 + \theta_f}{228 + \theta_i}} \; \text{[redacted]} = \frac{1}{\sqrt{t}} \times 87.8$$

I : permissible short circuit current (A).
S : cross-sectional area of the conductor (mm²).
t : short circuit duration time (s).
θ_f: final temperature (210°C)
θ_i: initial temperature (80°C)
J : permissible current density (A/mm²)

For t = 1s: J = Jo = 87.8 A/mm²

$$\text{For } t \neq 1s : J = \frac{j_0}{\sqrt{t}}$$

Practical application

Example: a 300 mm² aluminium conductor 64/110 (123) KV cable has, according to the dimensional table an aluminium screen of 140 mm². This screen will carry:

a) For 1 second: Io = Jo x S = 87.8 x 140 = 12292 Amperes, i.e. 12.3 KA

b) For 0.5 second: $I = \frac{j_0}{\sqrt{t}} \times S = \frac{I_0}{\sqrt{t}} = \frac{12292}{\sqrt{0.5}}$ = 17383 Amperes, i.e. 17.4 KA

C) For 2 seconds: $I = \frac{j_0}{\sqrt{t}} \times S = \frac{I_0}{\sqrt{t}} = \frac{12292}{\sqrt{2}}$ = 8692 Amperes, i.e. 8.7 KA

5.4 - DELIVERY AND LAYING

Delivery

All versions of cables given in this catalogue have standard delivery lengths of about 500 meters.
However, it is possible to increase the delivery lengths as long as the unloading equipment (hoists, etc...) at the arrival are competent, and if the forwarding conditions allow it.

Laying

Bending radius

The following table gives the minium bending radius for the cables given in this catalogue, in three situations. The bending radius are calculated according to the English ESI Standard 09-02.

On drum	During pulling	Afterlaying
R = 12.5 x D	Direct or in air: R = 30 x D In ducts: R = 35 x D	With former: R = 15 x D Without former: R = 20 x D

with D: External diameter of the cable.

Permissible mechanical force on the conductor

The maximum pulling force on the conductor is given by the following formula:

Max. pulling force = K x S **in daN**

Where S: Cross-sectional area of the conductor (mm^2)
K: Maximum stress (daN / mm^2)

with K: 6 daN/mm2 for copper conductor
K: 5 daN / mm2 for aluminium conductor

Maximum sidewall pressure

The maximum sidewall pressure is given by the following formula:

$$\textbf{Max. sidewall pressure} = \frac{\textbf{max. pulling force}}{\textbf{bending radius (direct orin air)}} \quad \textbf{in daN/m}$$

5.5 - DESIGN, MANUFACTURING AND TESTING OF XLPE INSULATED CABLES

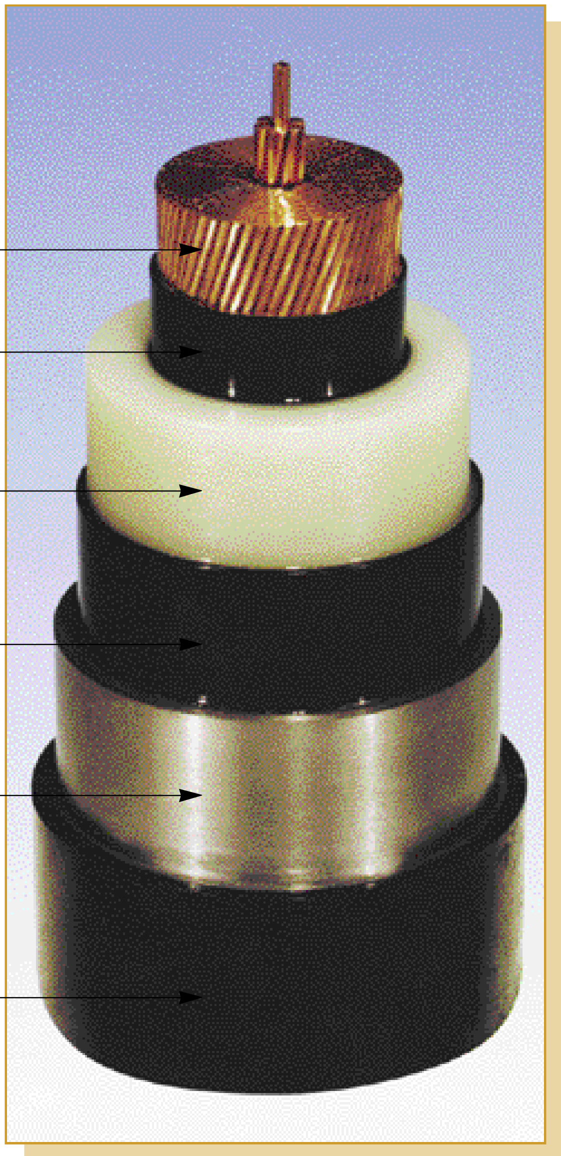
5.5.1 - DESIGN AND MANUFACTURING

Stranding

Insulation
Dry curing process,
Triple head extrusion

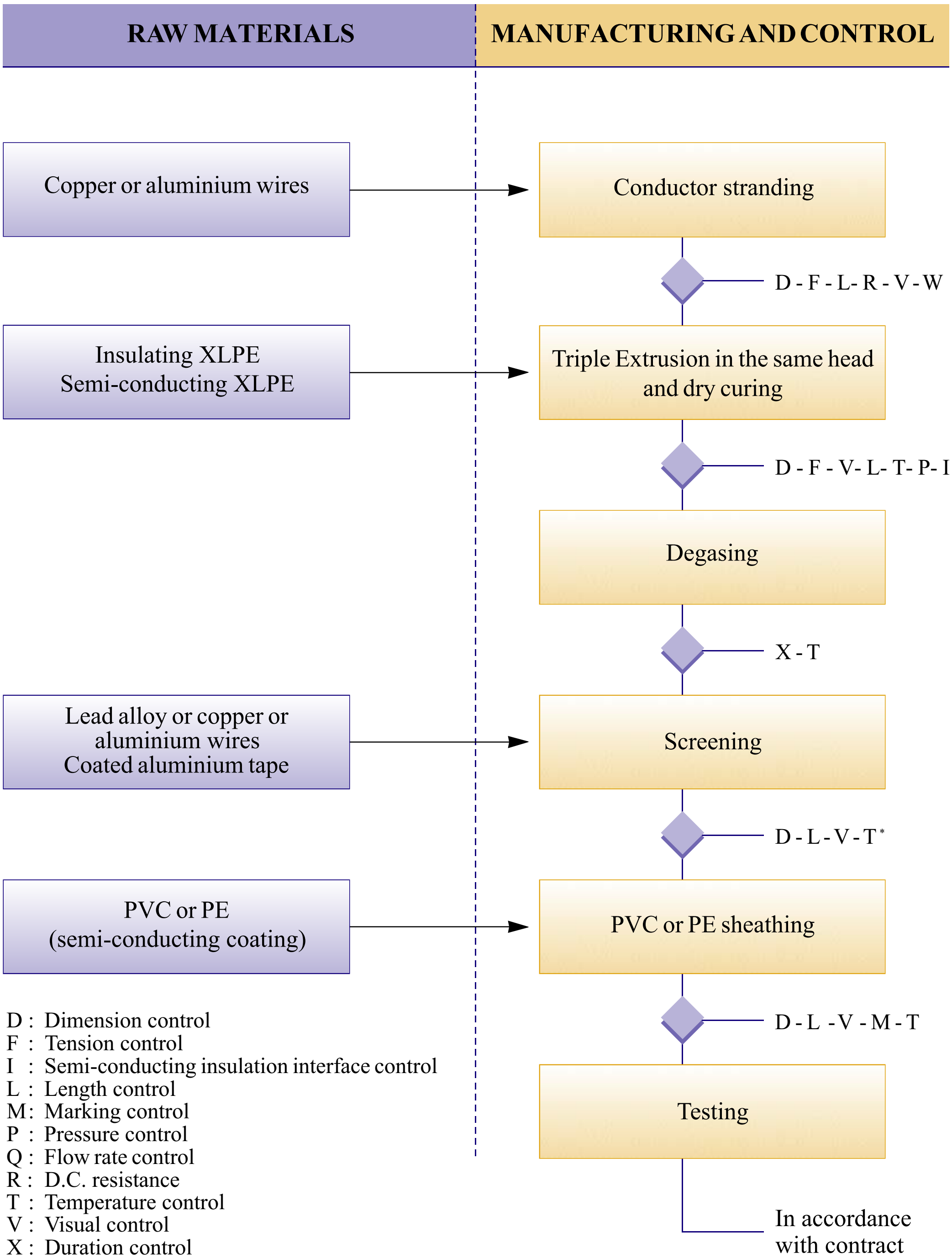
Screening
Lead sheath or metallic wires

Sheathing



	ROLE	COMPOSITION
CONDUCTOR (Cross-section: S)	• To carry current: - in normal operation. - in emergency operation. - in short-circuit operation. • To withstand pulling stresses during cable laying.	**Stranded Copperoraluminium wires.**
CONDUCTOR SCREEN	• To prevent concentration of electric field at particular points on the conductor. • To ensure close contact with the insulation.	**Extruded semi-conducting XLPE.**
INSULATION	To withstand during the designed cable service life different stresses and the following voltages: - rated voltage in normal operation. - lightning overvoltage. - switching overvoltage.	**Extruded insulating XLPE** The internal and external semi-conducting layers and the insulation are extruded in the same head at the same time, followed by a **dry curing** process.
INSULATION SCREEN	• To ensure close contact with the insulation. • To prevent concentrations of electric field at particular points.	**Extruded semi-conducting XLPE.**
METALLIC SHIELD	To provide: - an electrical screening (no electric field outside). - radial waterproofing. - an active conductor for the capacitive and homopolar short-circuit current. - a contribution for mechanical protection.	**Extruded lead alloy** or **Copperoraluminium wires** With outside a coated aluminium tape laid lengthwise and overlapped.
OUTER PROTECTIVE SHEATH	To insulate the metallic screen from the surrounding medium in order to protect it against corrosion	**Extruded insulating PVC orPE** With possibly a semi-conducting coating sheet to allow dielectric tests on sheath in plant and on site.

5.5.3 - MANUFACTURING AND CONTROLFLOWCHART



D : Dimension control
F : Tension control
I : Semi-conducting insulation interface control
L : Length control
M : Marking control
P : Pressure control
Q : Flow rate control
R : D.C. resistance
T : Temperature control
V : Visual control
X : Duration control
W : Welding control

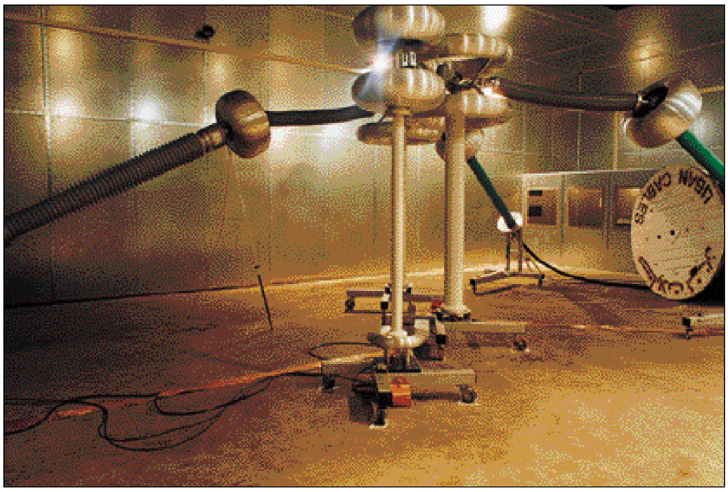
* for lead alloy sheathing only

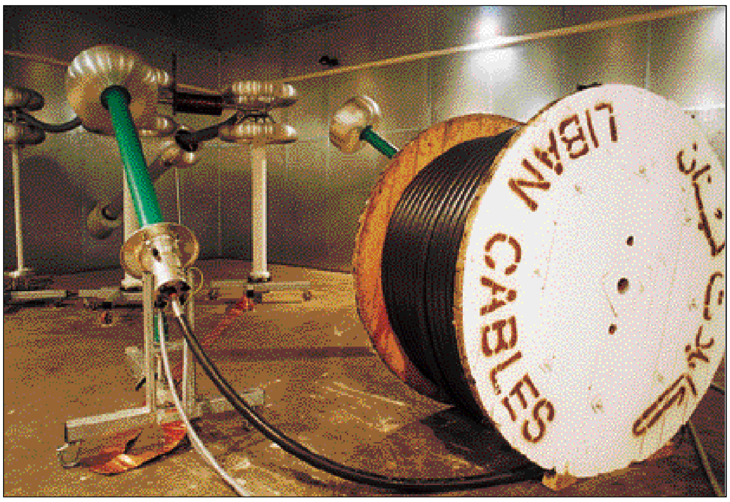
5.6 - HVROUTINE TEST LABORATORY

All the power cables manufactured in the power Department of LIBAN CABLES are systematically tested in this laboratory.

Test equipement:

- AC resonant system 350,5000 KUA, 50 Hz
- Partial discharge measurement equipment





Routine tests and some other tests are carried out in this laboratory.
The Faraday cage and its High Voltage transformer provide clearance sufficient for testing reels of cable up to 350 KV.