SEREC
LIGHTNING: DETECTION and PROTECTION

ETZ Zurich,
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LIGHTNING PROTECTION

IEC EN 62305 Standard

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Chairman of CENELEC TC 81X (Lightning Protection)

IEC TC 81 : LIGHTNING PROTECTION

IEC 62305-1 **Part 1 : General Principles**

- 1-1 Protection against lightning
- 1-2 Test parameters simulating the effects of lightning on LPS components

IEC 62305-2 **Part 2 : Risk management**

- 2-1 Risk assessment method
- 2-2 Risk components for structures
- 2-3 Risk components for services

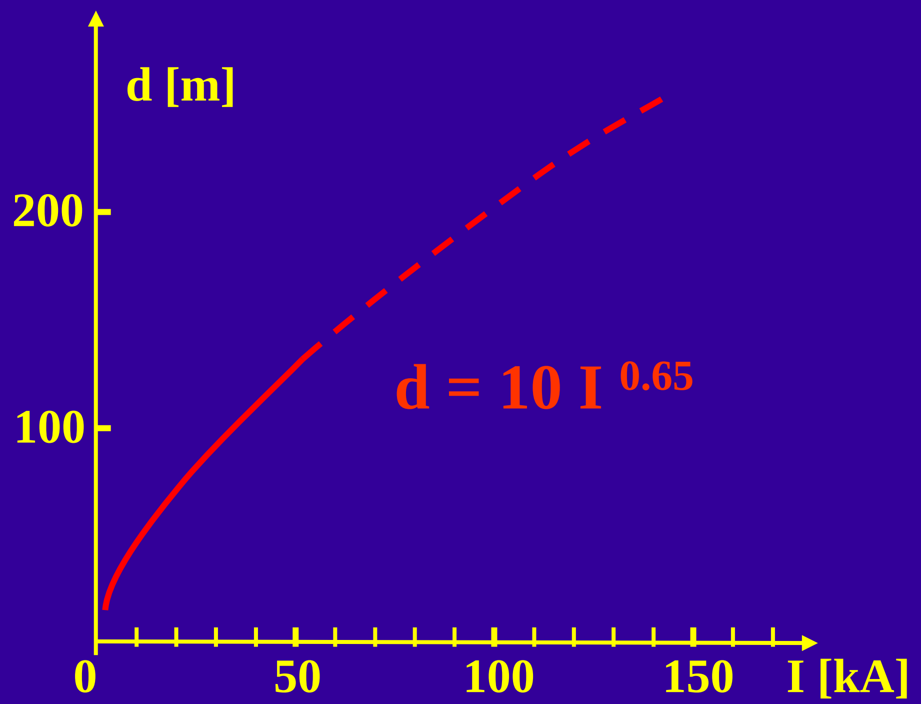
IEC 62305-3 **Part 3 : Physical damage and life hazard**

- 3-1 Lightning protection system (LPS) = external + internal
- 3-2 Protection measures against injuries of living beings due to touch and step voltages
- 3-3 Design, installation, maintenance and inspection of LPS

IEC 62305-4 **Part 4 : Electrical and electronic systems within structures**

- 4-1 Protection against LEMP : general principles
- 4-2 Earthing and bonding; magnetic shielding and line routing
- 4-3 SPD system
- 4-4 Management of an LPM system

Striking distance

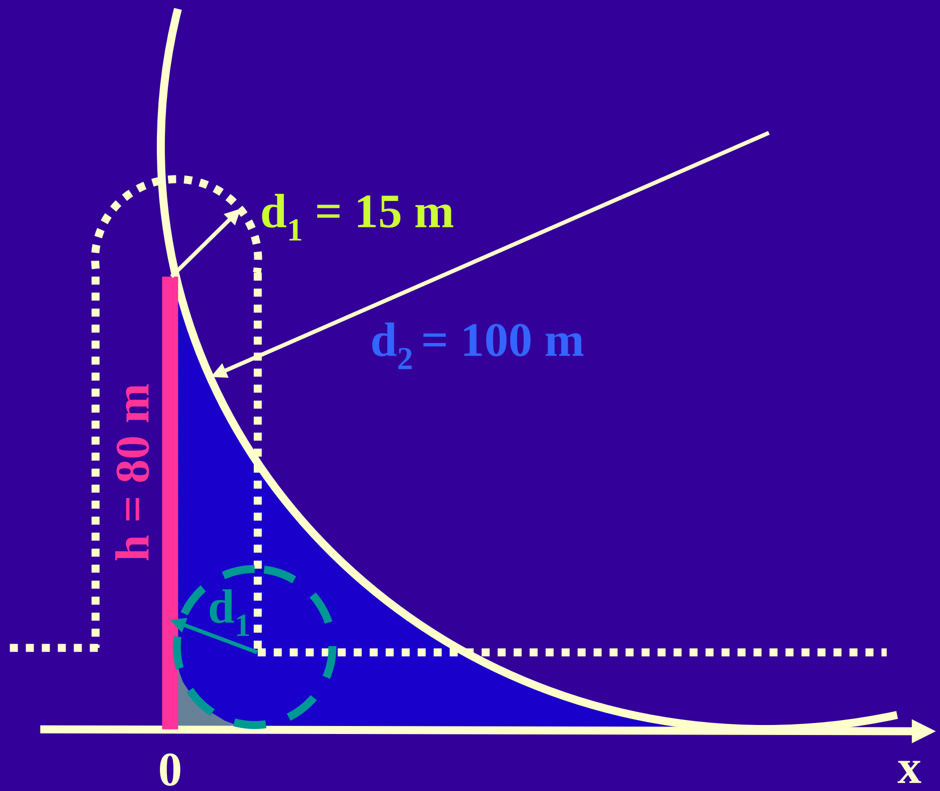


$$d = 10\ I^{0.65}$$

I [kA]	d [m]
2	15
5	27
10	45
30	91
50	127
100	(200)
150	(260)
200	(313)

$$I = 10.6\ Q^{0.7}$$

Electrogeometric model applied to a vertical rod



$$d = 10\,I^{0.65}$$

kA	m
2	15
10	45
35	100
100	200

ICLP:

www.iclp-centre.org

1) **Cautionary message**

2) **ESE and other non-conventional Lightning Protection Systems,**
by Prof. Aage E. Pedersen

*

CEB-BEC (January 2007)

Aware of the use of non-conventional LP systems (ESE, PDA…) on the Belgian market, CEB-BEC is following the advice of the international scientific community, insisting on the non-efficiency of such devices and strongly warns the users against the installation of these devices.

Part 1

General principles

SCOPE

Protection against lightning

of

- structures including their installations and contents as well as persons;
- services connected to a structure

Outside:

- railway systems;
- vehicles, ships, aircraft, offshore installations;
- underground high pressure pipelines;
- pipe, power and telecommunication lines not connected to a structure.

Sources of damages (S)

S1: strike to a structure

S2: ground close to a structure

S3: service entering a structure

S4: close to service entering a structure

Types or causes of damages (D or C)

C1: injury of living beings

C2: physical damages (fire, explosion…)

C3: failure of internal systems

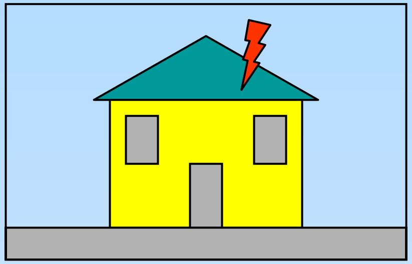
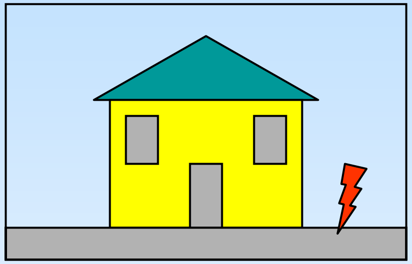
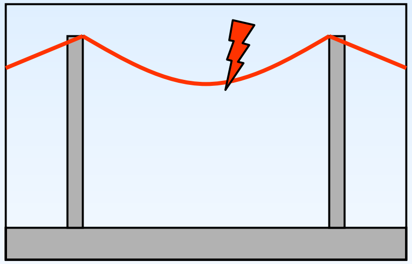
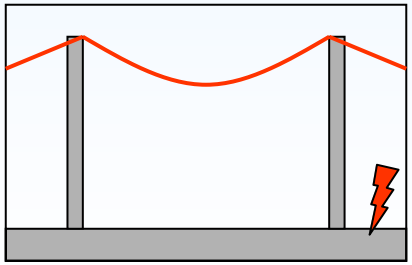
Types of losses (L) and risks associated (R)

L1: loss of living beings

L2: loss of public service

L3: loss of cultural heritage

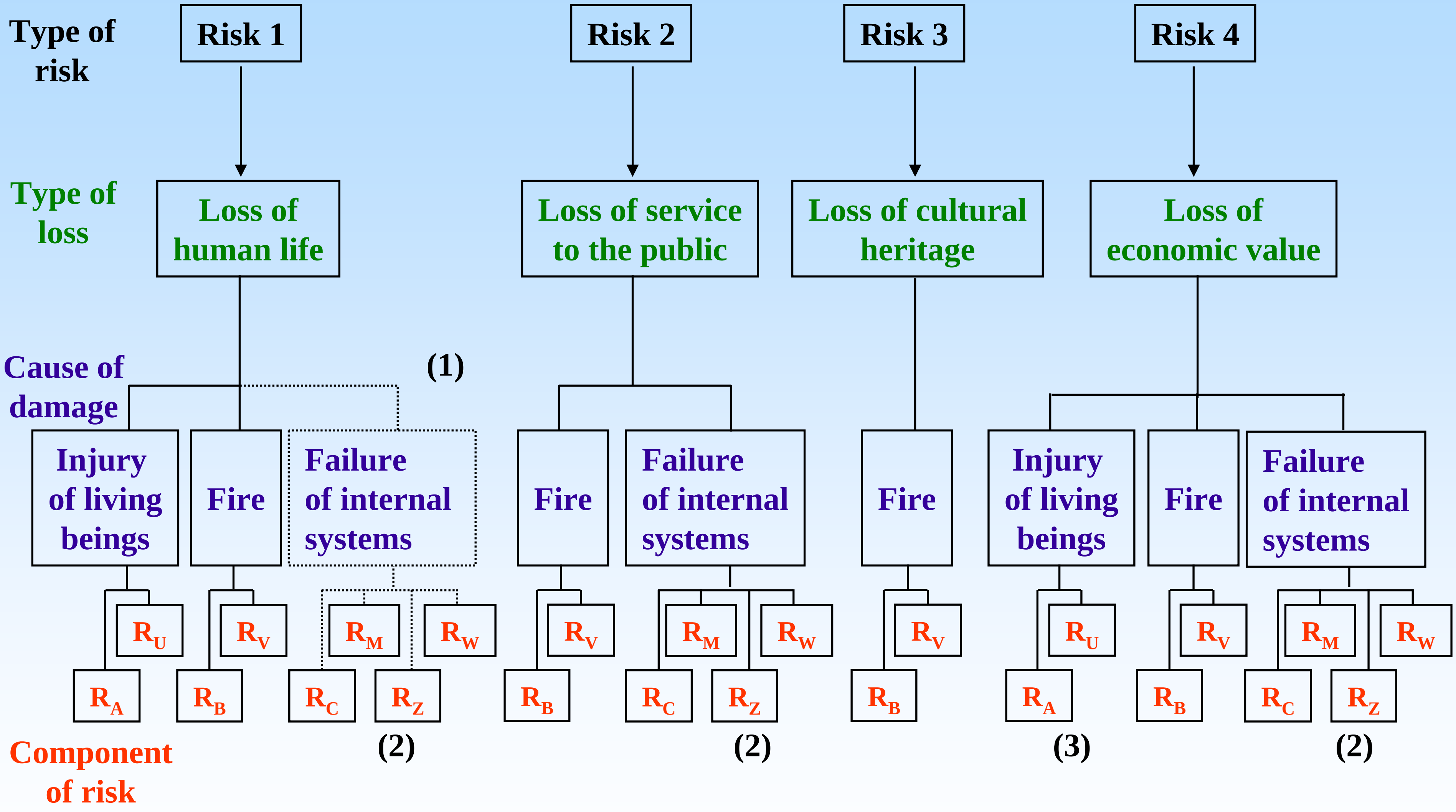
L4: loss of economic values

Point of strike	Example	Source of damage	Cause of damage	Type of damage
Structure		S1	C1 C2 C3	L1,L4[b] L1,L2,L3,L4 L1[a],L2,L4
Earth next to the structure		S2	C3	L1[a],L2,L4
Entering supply line		S3	C1 C2 C3	L1, L1,L2,L3,L4 L1[a],L2,L4
Earth next to entering supply line		S4	C3	L1[a],L2,L4

[a] For hospitals and explosive structures

[b] For agricultural properties (loss of animals).

Figure 1 **Types of loss resulting from different types of damage**



(1) Only for hospitals and structures with risk of explosion

(2) Only for structures with electronic systems

(3) Only for properties of agricultural value (loss of animals)

Typical values of tolerable risk R_T

Type of damage	R_T
Loss of human life	10^{-5}
Loss of service to the public	10^{-3}
Loss of cultural heritage	10^{-4}

R_4 (economic value)

measures convenient if $C_{RL} + C_{PM} < C_L$

with C_{RL} = residual loss when protection measures

C_{PM} = cost of protection measures

Lightning Protection Zones (LPZ)

Determined by protection measures such as LPS, shielding wires, magnetic shields and SPDs

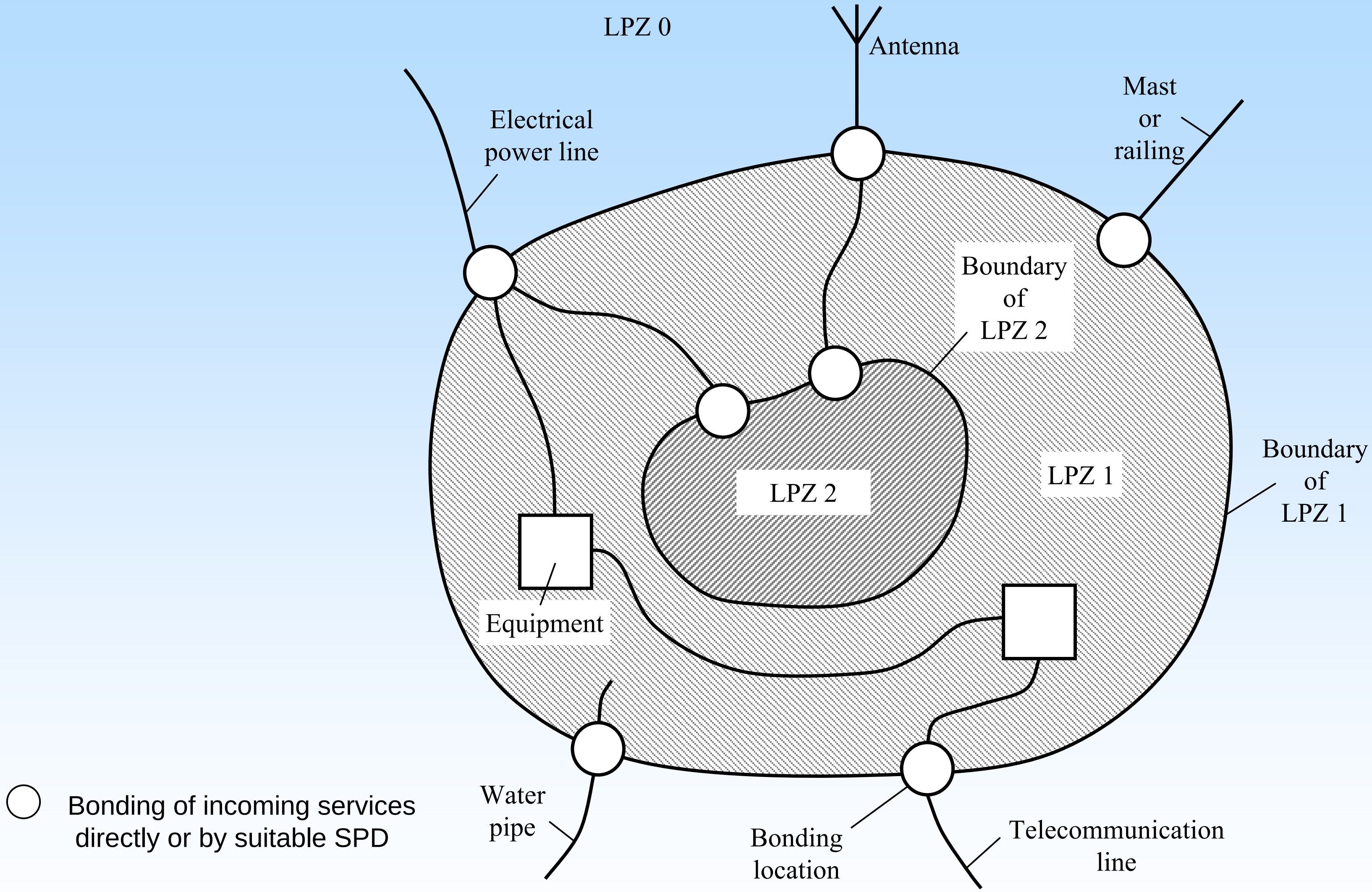
– LPZ 0_A : **Exposed** to direct lightning strikes.
Full lightning current and full lightning electromagnetic field.
Internal systems may be subjected to full or partial lightning surge current.

– LPZ 0_B : **Protected** against direct lightning strikes.
Partial lightning or induced current and **exposed** to full lightning electromagnetic field.

– LPZ 1 : Protected against direct lightning strikes.
Surge current is limited by current sharing and by SPDs at the boundary.
Spatial shielding may attenuate the lightning electromagnetic field (**damped lightning electromagnetic field**).

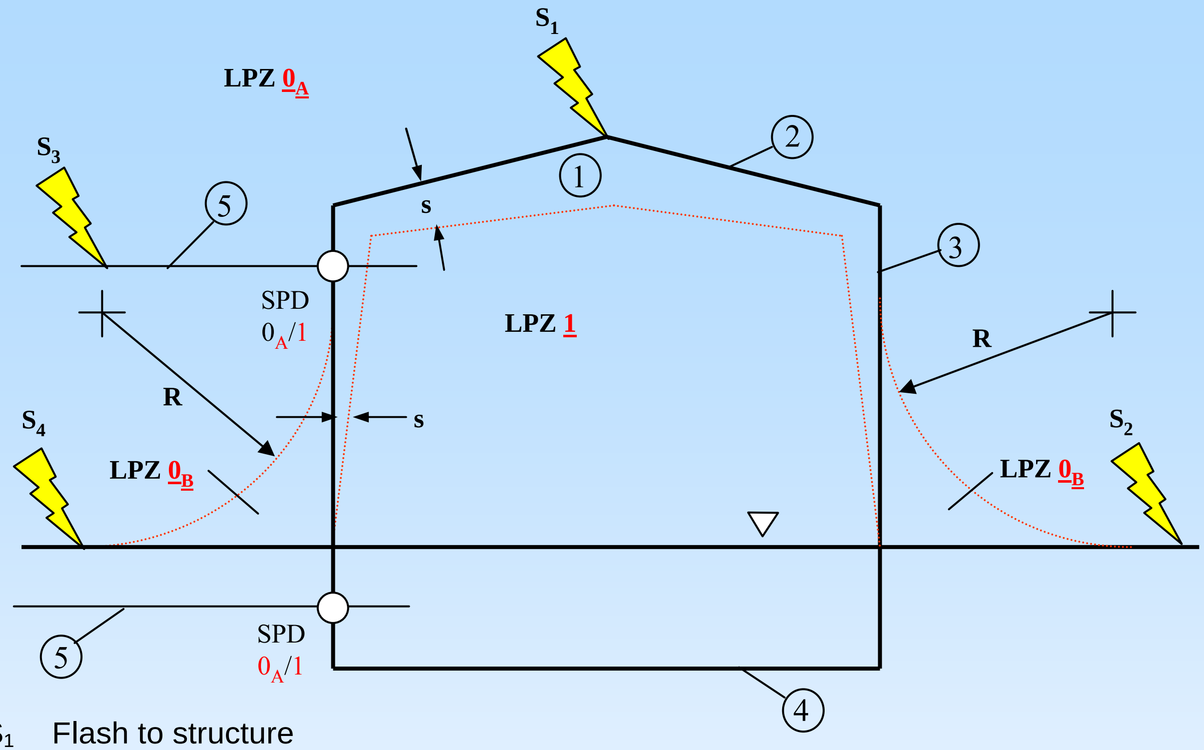
- LPZ 2, ..., n : as LPZ1, surge current is further limited by current sharing and by additional SPDs at the boundary.
Additional spatial shielding may be used to **further attenuate the lightning electromagnetic field**.

General principle for the division into different LPZ



This Figure shows an example for dividing a structure into inner LPZs.
All metal services entering the structure are bonded via bonding bars at the boundary of LPZ 1.
In addition, the metal services entering LPZ 2 (e.g. computer room) are bonded via bonding bars at the boundary of LPZ 2.

Figure 2 LPZ defined by an LPS (IEC 62305-3)

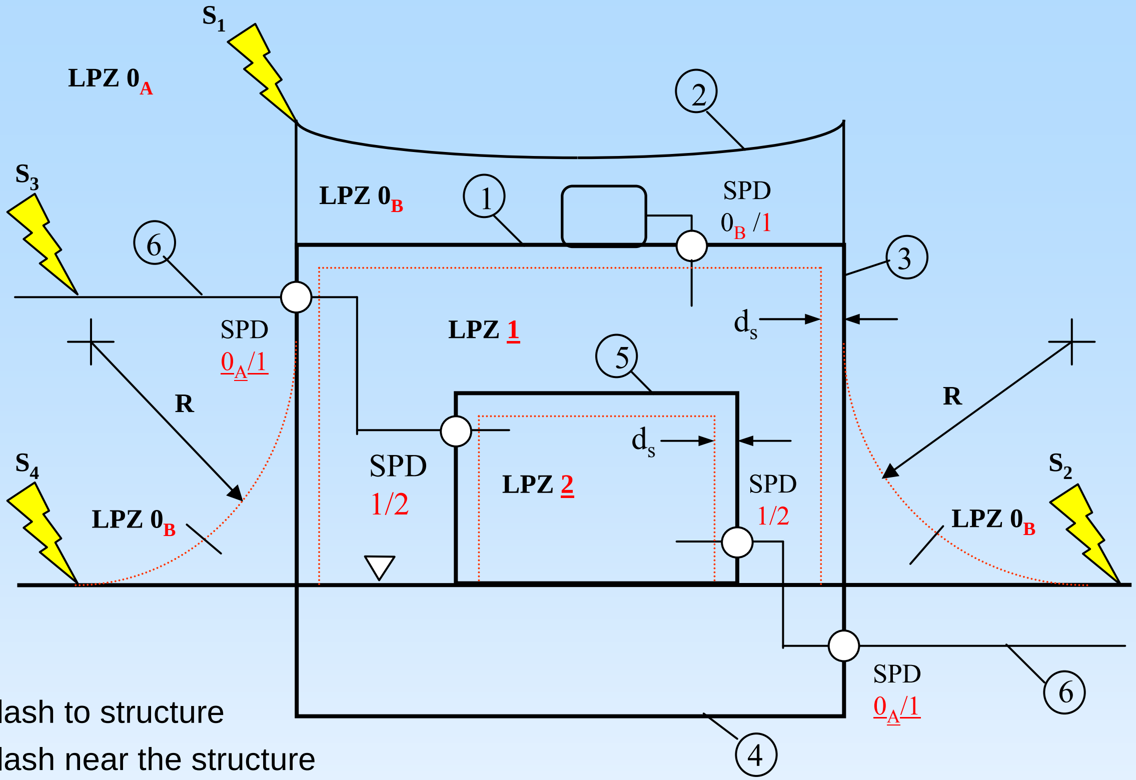


1	Structure	S_1	Flash to structure
2	Air-termination system	S_2	Flash near to the structure
3	Down-conductor system	S_3	Flash to service entering the structure
4	Earth-termination system	S_4	Flash near a service connected to the structure
5	Incoming services	R	Rolling sphere radius
		s	Separation distance against dangerous sparking

○ Lightning equipotential bonding (SPD)

LPZ 0_A	Direct flash, full lightning current
LPZ 0_B	No direct flash, partial lightning or induced current
LPZ 1	No direct flash, partial lightning or induced current Protected volume inside LPZ 1 must respect separation distance s

Figure 3
LPZ defined by protection measures against LEMP (IEC 62305-4)



1	Structure (Shield of LPZ 1)	S_1	Flash to structure
2	Air-termination system	S_2	Flash near the structure
3	Down-conductor system	S_3	Flash to a service connected to the structure
4	Earth-termination system	S_4	Flash near a service connected to the structure
5	Room (Shield of LPZ 2)	R	Rolling sphere radius
6	Services connected to the structure	d_s	Safety distance against too high magnetic field

○ Lightning equipotential bonding by means of SPDs

LPZ 0_A	Direct flash, full lightning current, full magnetic field
LPZ 0_B	No direct flash, partial lightning or induced current, full magnetic field
LPZ 1	No direct flash, limited lightning or induced current, damped magnetic field
LPZ 2	No direct flash, induced currents, further damped magnetic field

Protected volumes inside LPZ 1 and LPZ 2 must respect safety distances d_s

Parameters	Unit	Values (%) exceeding the indicated ones		
		95%	50%	5%
Peak currents				
first negative strokes and negative flashes	kA	14	30	80
subsequent negative strokes	kA	4.6	12	30
positive flashes	kA	4.6	35	250
Charge				
first negative strokes and	C	1.1	5,2	24
subsequent negative strokes	C	0.2	1.4	11
negative flashes	C	1.3	7.5	40
positive flashes	C	20	80	350
Front duration				
first negative strokes	µs	1.8	5,5	18
subsequent negative strokes	µs	0.22	1.1	4.5
positive flashes	µs	3.5	22	200
Maximum rate of rise (di/dt)				
first negative strokes	kA/µs	5.5	12	32
subsequent negative strokes	kA/µs	12	40	120
positive flashes	kA/µs	0.2	2.4	32
Pulse duration				
first negative strokes	µs	30	75	200
subsequent negative strokes	µs	6.5	32	140
positive flashes	µs	25	230	2000
Time intervals between				
negative strokes	ms	7	33	150
Flash duration				
negative (simple or multiple)	ms	0.15	13	1100
negative (multiple only)	ms	31	180	900
positive	ms	14	85	500
i^2dt integral				
first negative strokes and negative flashes	$A^2.s$	$6.0\ 10^3$	$5.5\ 10^4$	$5.5\ 10^5$
subsequent negative strokes	$A^2.s$	$5.5\ 10^2$	$6.0\ 10^3$	$5.2\ 10^4$
positive flashes	$A^2.s$	$2.5\ 10^5$	$6.5\ 10^5$	$1.5\ 10^7$

Table 5 –

Maximum values of lightning parameters according to LPL

First short stroke			LPL			
Current parameters	Symbol	Unit	I	II	III	IV
Peak current	I	kA	200	150	100	
Short stroke charge	Q_{short}	C	100	75	50	
Specific energy	W/R	kJ/Ω	10.000	5.625	2.500	
Time parameters	T_1 / T_2	µs / µs	10 / 350			
Subsequent short stroke			**LPL**			
Current parameters	Symbol	Unit	I	II	III	IV
Peak current	I	kA	50	37,5	25	
Average steepness	di/dt	kA/µs	200	150	100	
Time parameters	T_1 / T_2	µs / µs	0,25 / 100			
Long stroke			**LPL**			
Current parameters	Symbol	Unit	I	II	III	IV
Long stroke charge	Q_{long}	C	200	150	100	
Time parameter	T_{long}	s	0,5			
Flash			**LPL**			
Current parameters	Symbol	Unit	I	II	III	IV
Flash charge	Q_{flash}	C	300	225	150	

Table 6

Minimum values of lightning parameters and related rolling sphere radius corresponding to LPL

Interception criteria			LPL			
	Symbol	Unit	I	II	III	IV
Minimum peak current	I	kA	3	5	10	16
Rolling sphere radius	R	m	20	30	45	60

Table 7

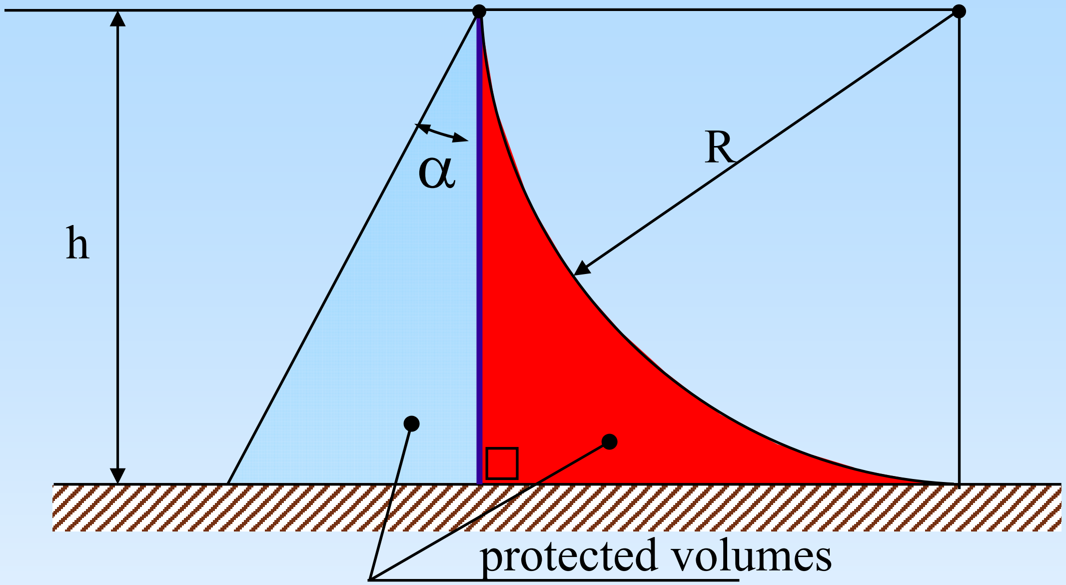
Probabilities for the limits of the lightning current parameters

Probability that lightning current parameters are	LPL			
	I	II	III	IV
smaller than the maxima defined in table 5	0.99	0.98	0.97	0.97
greater than the minima defined in table 6	0.99	0.97	0.91	0.84

Lightning protection level	Maximum values (Dimensioning criteria)		Minimum values (Interception criteria)		
	Max. lightning current peak value	Probability of the actually upcoming lightning current to be less than the max. lightning current peak value	Min. lightning current peak value	Probability of the actually upcoming lightning current to be higher than the min. lightning current peak value	Radius of the rolling sphere
I	200 kA	99 %	2.9 kA	99 %	20 m
II	150 kA	98 %	5.4 kA	97 %	30 m
III	100 kA	97 %	10.1 kA	91 %	45 m
IV	100 kA	97 %	15.7 kA	84 %	60 m

Lightning protection level	Interception criterion E_i	Radius of the rolling sphere (final striking distance) R (m)	Min. peak value of current I (kA)
IV	0.84	60	15.7
III	0.91	45	10.1
II	0.97	30	5.4
I	0.99	20	2.9

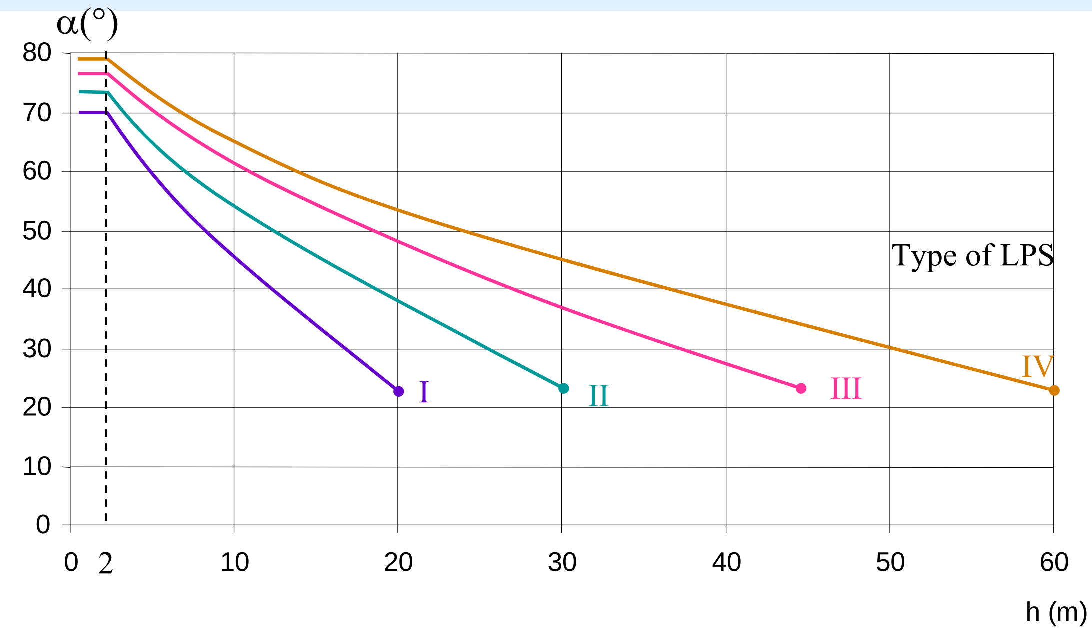
4 Lightning Protection Levels LPL (I,II,III,IV) with 4 types of relevant protection measures for the design of LPS are introduced



Level	R(m)	α(h = 20)	α(h = 30)	α(h = 45)	α(h = 60)	d(m)
I	20	25	*	*	*	5
II	30	35	25	*	*	10
III	45	45	35	25	*	15
IV	60	55	45	35	25	20

Rolling sphere radius, mesh size and protection angle corresponding to the type of LPS

	Protection method		
Type of LPS	**Rolling sphere radius *R* m**	**Mesh size *M* m**	**Protection angle $\alpha°$**
I	20	5 x 5	See figure below
II	30	10 x 10	
III	45	15 x 15	
IV	60	20 x 20	



NOTE 1 - Not applicable beyond the values marked with •. Only rolling sphere and mesh methods apply in these cases

NOTE 2 - *h* is the height of air–termination above the area to be protected.

NOTE 3 - The angle will not change for values of h below 2 m

Part 2

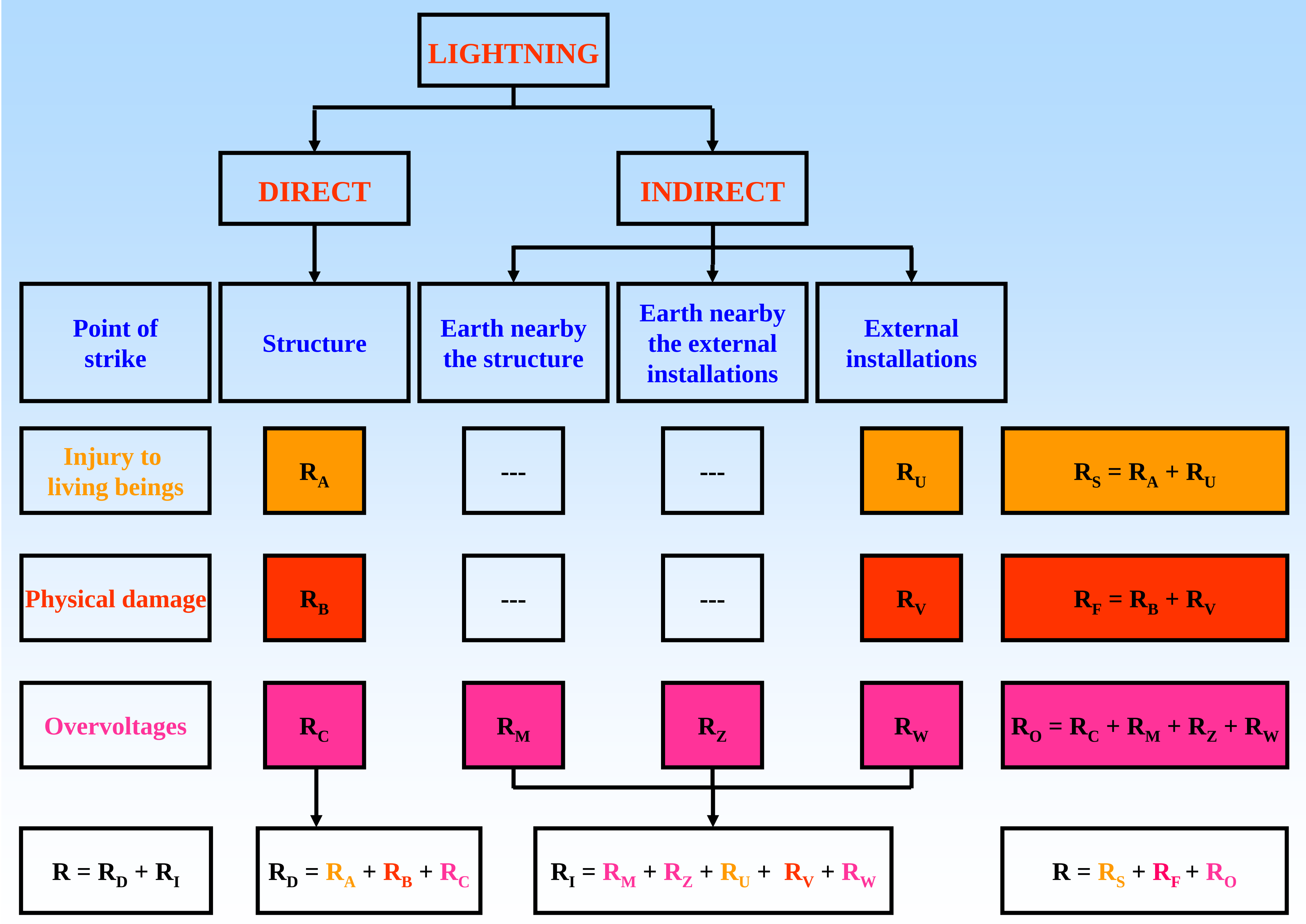
Risk management

SCOPE

Risk assessment for a structure or for a service due to lightning flashes to earth

To provide a procedure to **evaluate this risk**.

Once an **upper tolerable limit** for the risk has been selected, this procedure allows the selection of appropriate **protection measures** to be adopted to reduce the risk to or below the tolerable limit.


LIGHTNING
DIRECT
INDIRECT
Point of strike
Structure
Earth nearby the structure
Earth nearby the external installations
External installations
Injury to living beings
R_A

R_U
$R_S = R_A + R_U$
Physical damage
R_B

R_V
$R_F = R_B + R_V$
Overvoltages
R_C
R_M
R_Z
R_W
$R_O = R_C + R_M + R_Z + R_W$
$R = R_D + R_I$
$R_D = R_A + R_B + R_C$
$R_I = R_M + R_Z + R_U + R_V + R_W$
$R = R_S + R_F + R_O$

$$R_X = N \; P_X \; L_X \qquad X = A, B, \ldots$$

number of dangerous events (N)

probability of damage (P_X)

consequent loss (L_X)

for each type of loss L_1 to L_4
corresponding to a relevant risk (R_1 to R_4)
which is the sum of different risk components R_X

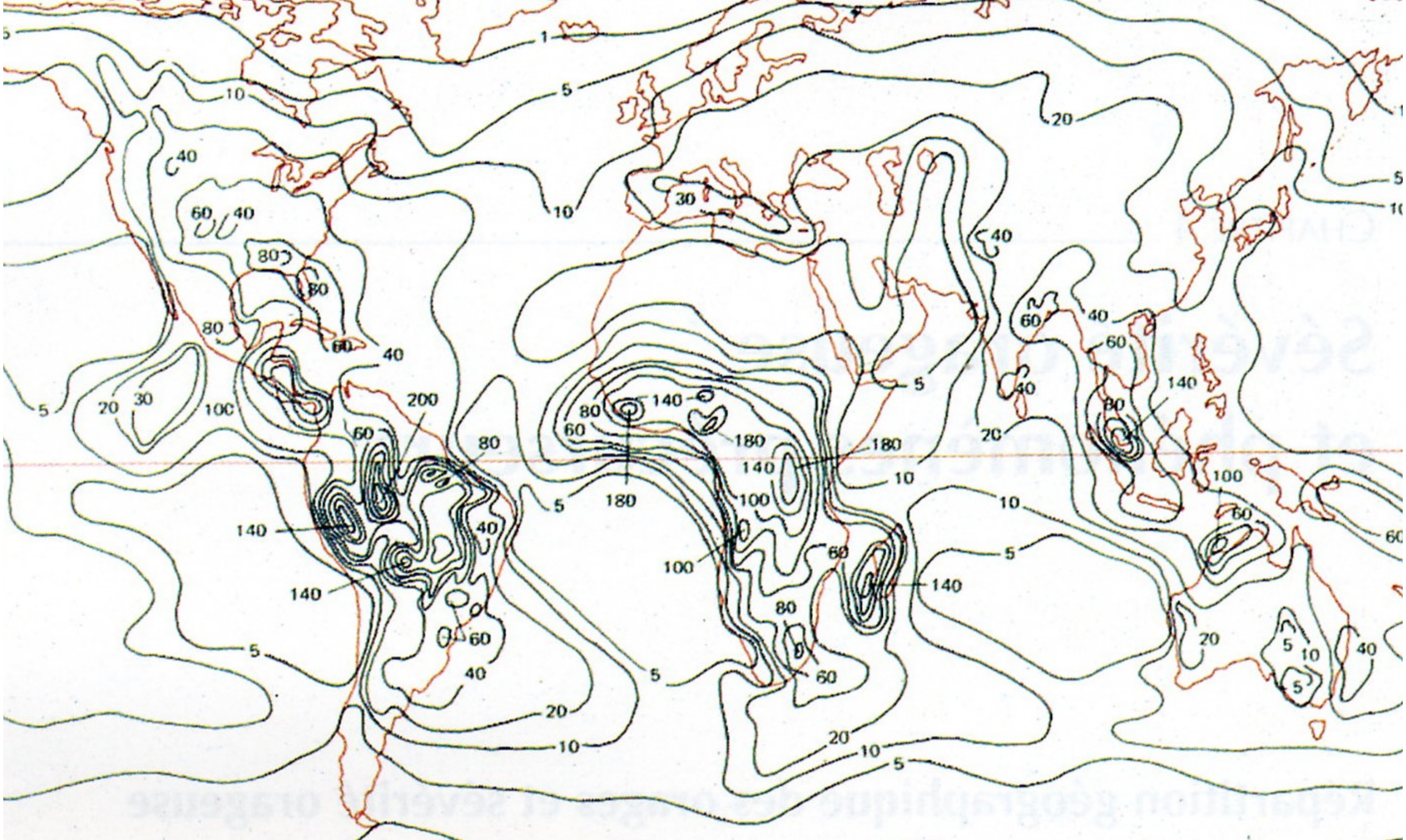
Assessment of the average number of flashes to a structure

$$N_D = Ng\, A_d\, C_d\, 10^{-6}$$

- Ng: lightning ground flash density
- A_d: collection area (m^2)
- C_d: relative location

Table A.2 - **Location factor C_d**

Relative location	C_d
Object surrounded by higher objects or trees	0.25
Object surrounded by other objects or trees	0.5
Isolated object: no other objects in the vicinity	1
Isolated object on a hilltop or a knoll	2

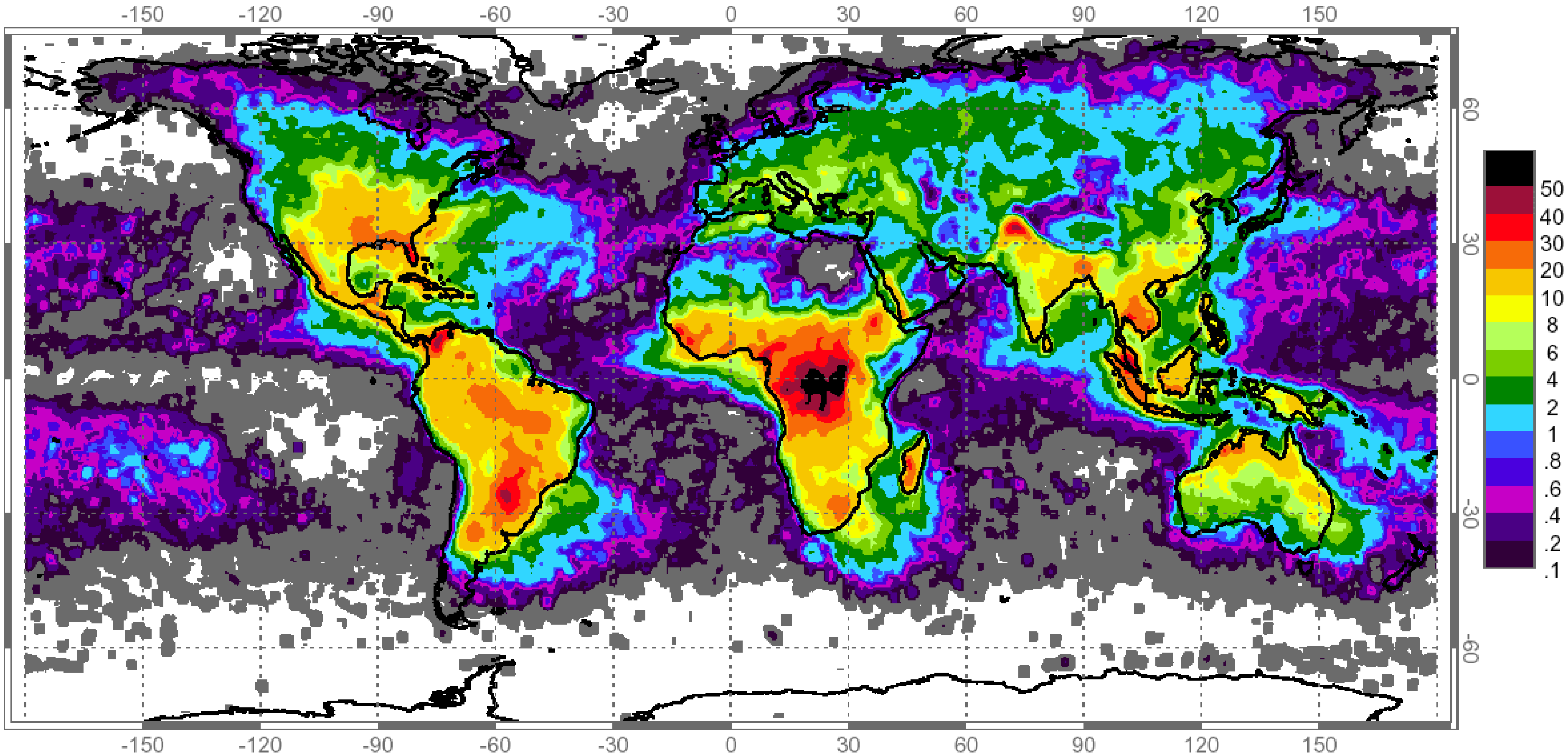


1
5
10
20
30
40
60
80
100
140
180
200

$$N_g = 0.04\ T_d^{1.25} \quad km^{-2}\ year^{-1}$$

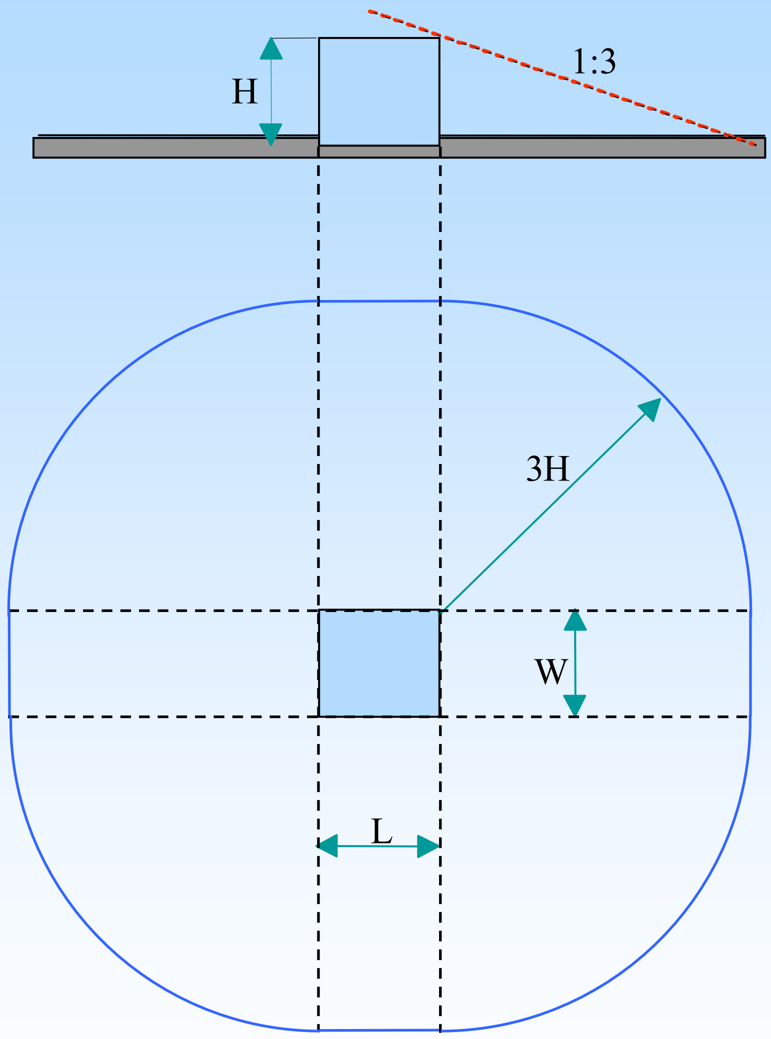
$N_g = 0.1\ km^{-2}\ year^{-1}$ on the oceans

$N_g = 8$ to $15\ km^{-2}\ year^{-1}$ in Brazil, **Colombia**…
Indonesia + Northern Australia,
Central- and South-Africa.



-150
-120
-90
-60
-30
0
30
60
90
120
150
60
30
0
-30
-60
50
40
30
20
10
8
6
4
2
1
.8
.6
.4
.2
.1

Figure A.1 – Collection area of an isolated structure



$$A_d = L\ W + 6\ H\ (L + W) + 9\ \pi\ H^2$$

Assessment of probability P of damage for a structure

Table B.1

Values of probability P_A that a lightning will cause a shock to living beings due to dangerous touch and step voltages

Protection measure	P_A
No protection measures	1
Electrical insulation of exposed conductor (e.g. at least 3 mm cross-linked polyethylene)	10^{-2}
Effective soil equipotentialization	10^{-2}
Warning notices	10^{-1}

Table B.2

Values of P_B depending on the protection measures to reduce physical damages

Characteristics of structure	Type of LPS	P_B
Structure not protected by an LPS	-	1
Structure protected by an LPS or structure with continuous metal or reinforced concrete framework acting as natural LPS, bonding and earthing included	IV	0.2
	III	0.1
	II	0.05
	I	0.02

Table B.3

Value of the probability P_{SPD} depending on LPL for which SPD are designed

LPL	P_{SPD}
No SPD system	1
III-IV	0.03
II	0.02
I	0.01

Losses L

For each type of loss L (L_1 to L_4) :

L_t , L_f , L_o

- L_t: touch and step voltages
- L_f: physical damages
- L_o: failure of internal structures

Ex : Loss of human life L_1

$$L_{1t} = \frac{n}{n_t} \frac{t}{8760}$$

(relative number of victims)

n = number of possible victims from a lightning strike

n_t = expected total number of persons in the structure

t = number of hours per year for which the persons are present in a dangerous place outside of the structure (L_t) or inside the structure (L_t, L_f, L_o)

Table C.1

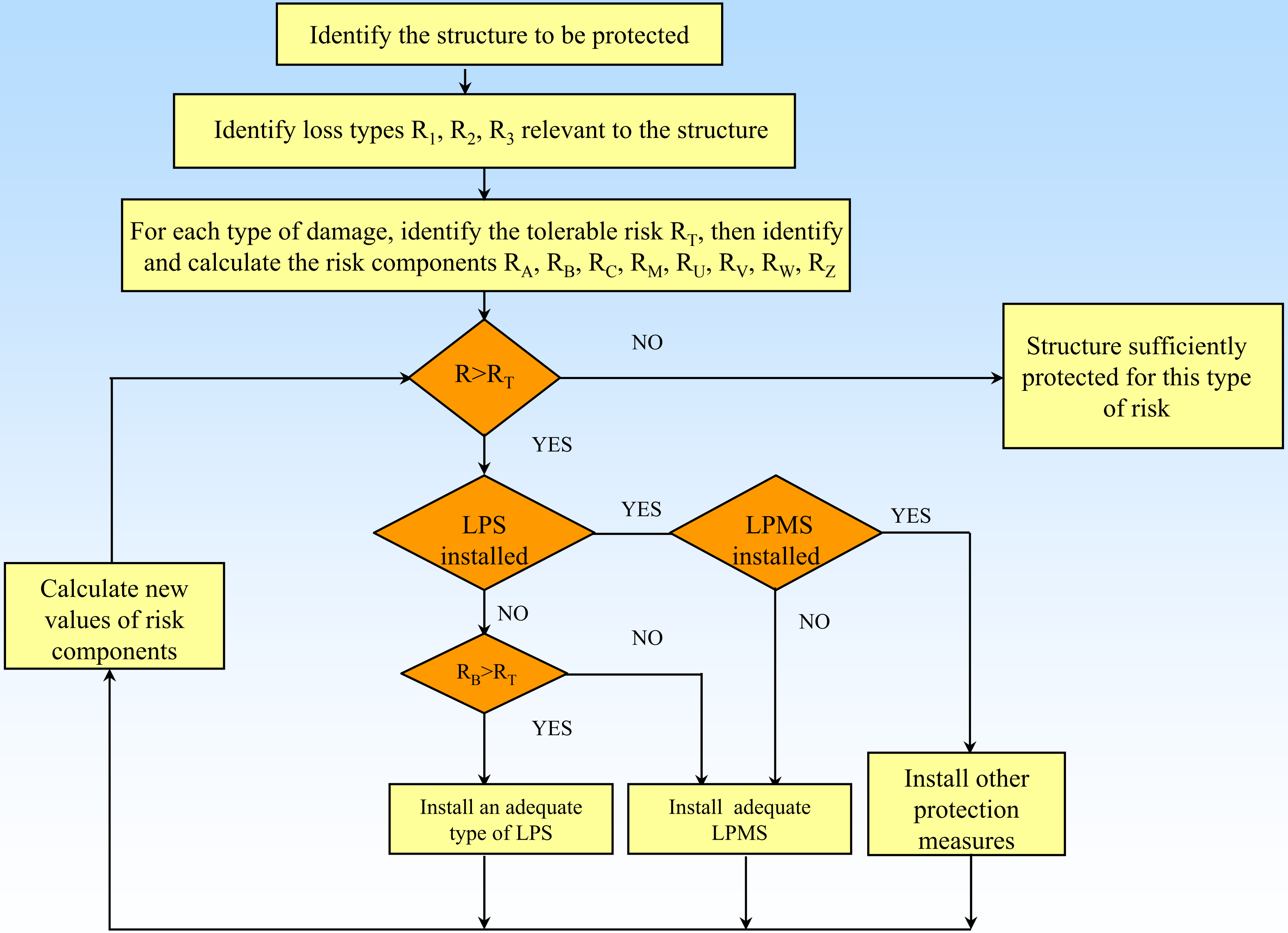
Typical mean values of L_t , L_f and L_o

Type of structure	L_t
All – Inside buildings	10^{-4}
All – Outside buildings	10^{-2}

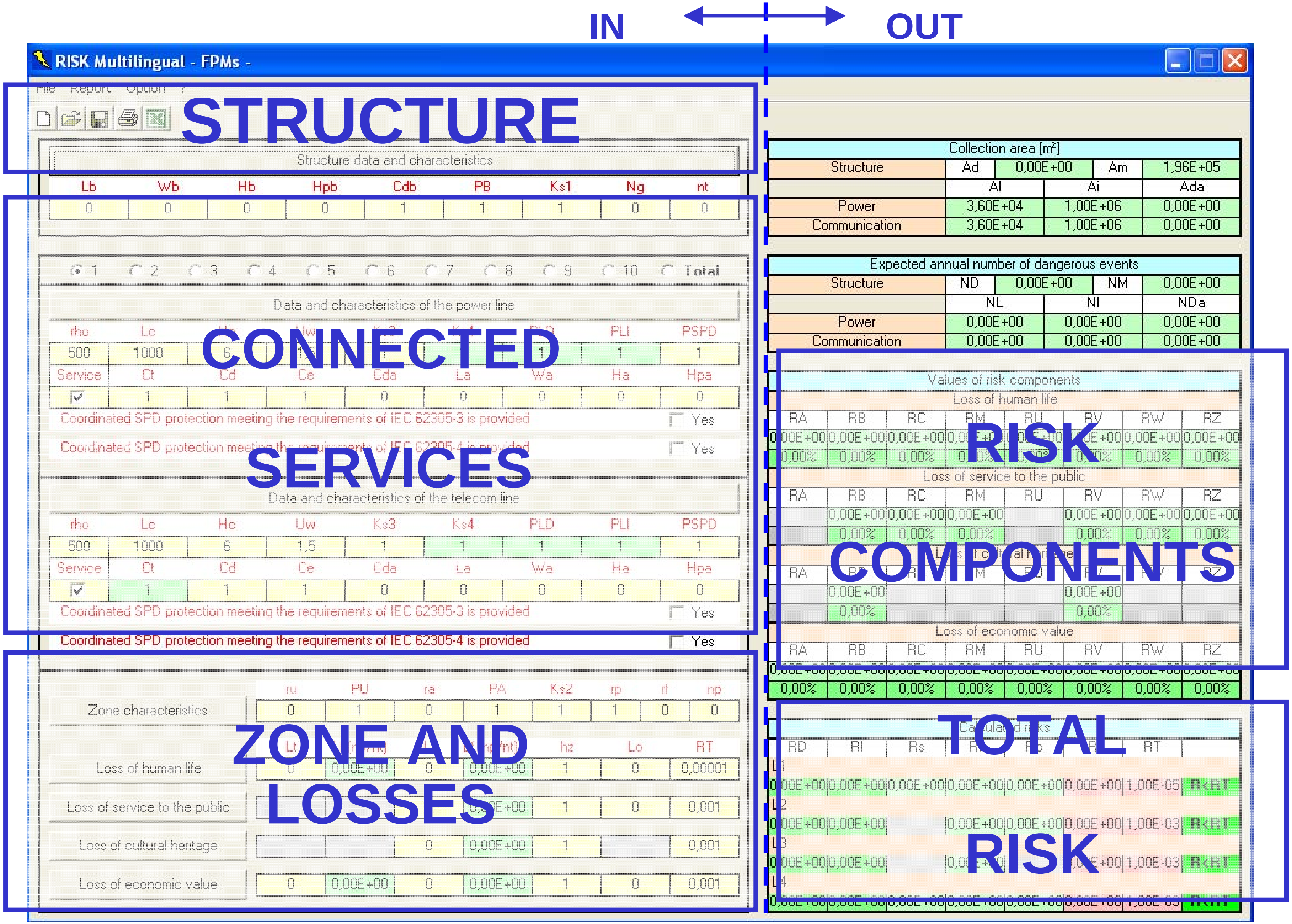
Type of structure	L_f
Hospitals, Hotels, Civil buildings	10^{-1}
Industrial, Commercial, School	$5\ 10^{-2}$
Public entertainment, Churches, Museum	$2\ 10^{-2}$

Type of structure	L_o
Risk of explosion	10^{-1}
Hospitals	10^{-3}

Figure 3 - **Procedure for selection of protection measures in a structure**



LPMS = LEMP protection measures system



IN
OUT
RISK Multilingual - FPMs -
STRUCTURE
Structure data and characteristics
CONNECTED SERVICES
Data and characteristics of the power line
Coordinated SPD protection meeting the requirements of IEC 62305-3 is provided
Coordinated SPD protection meeting the requirements of IEC 62305-4 is provided
Data and characteristics of the telecom line
ZONE AND LOSSES
Zone characteristics
Loss of human life
Loss of service to the public
Loss of cultural heritage
Loss of economic value
Collection area [m²]
Expected annual number of dangerous events
Structure
Power
Communication
Values of risk components
RISK COMPONENTS
TOTAL RISK

Part 3

Physical Damages and Life Hazards

SCOPE

Requirements for protection of a structure against physical damage by means of an LPS and for protection against injury to living beings due to touch and step voltages in the vicinity of a lightning protection system

1) Design, installation, inspection and maintenance of an LPS for structures of any height;

2) Establishment of measures for protection against injury to living beings due to touch and step voltages.

Physical damage to structures and life hazard

Against physical damage :

- external + internal LPS

Against injuries of living beings due to touch and step voltages :

- physical restrictions + warning notices ;
- insulation of exposed conductive parts ;
- increase of the surface soil resistivity

External LPS

1) Interception of direct strikes :

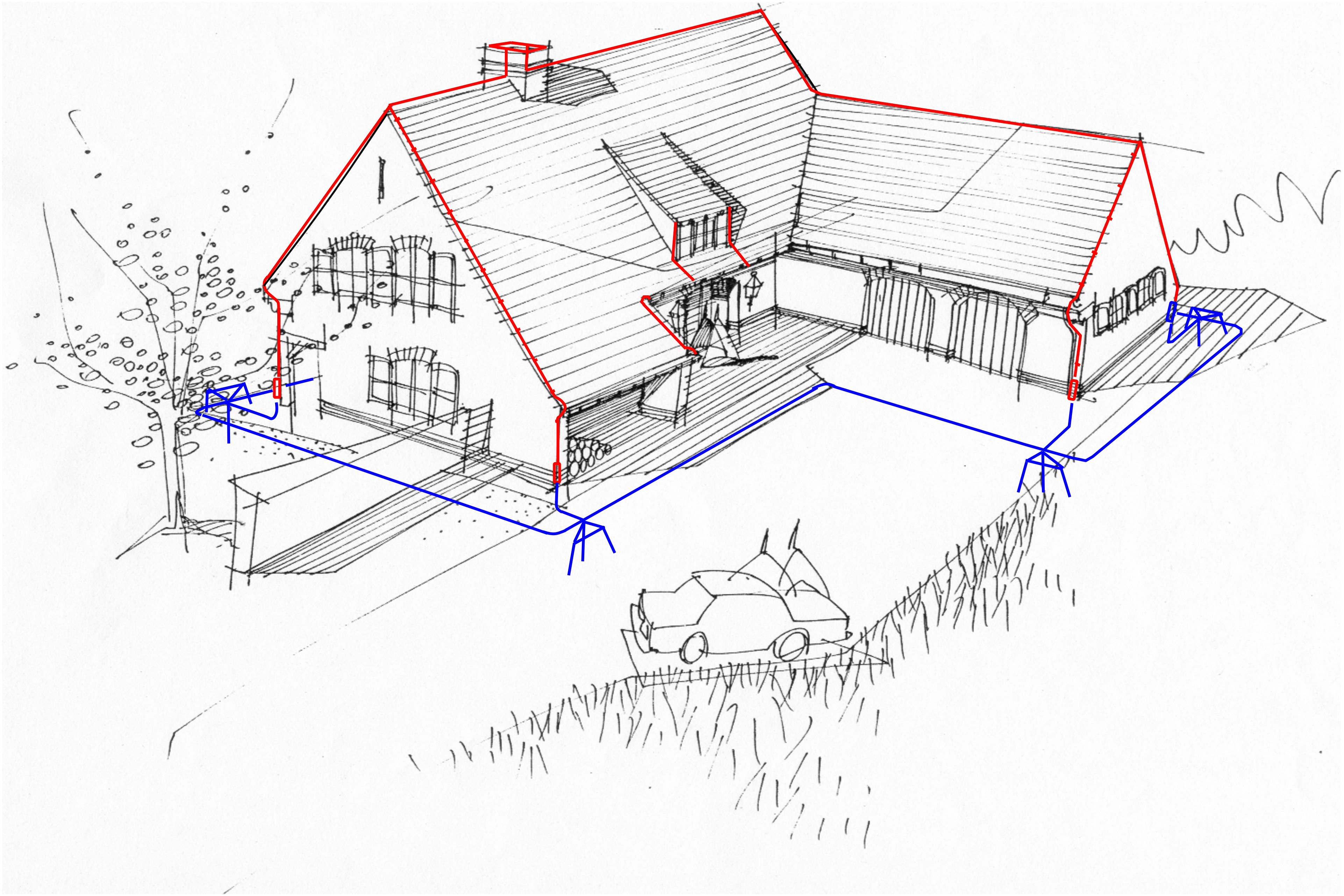
- air-termination system

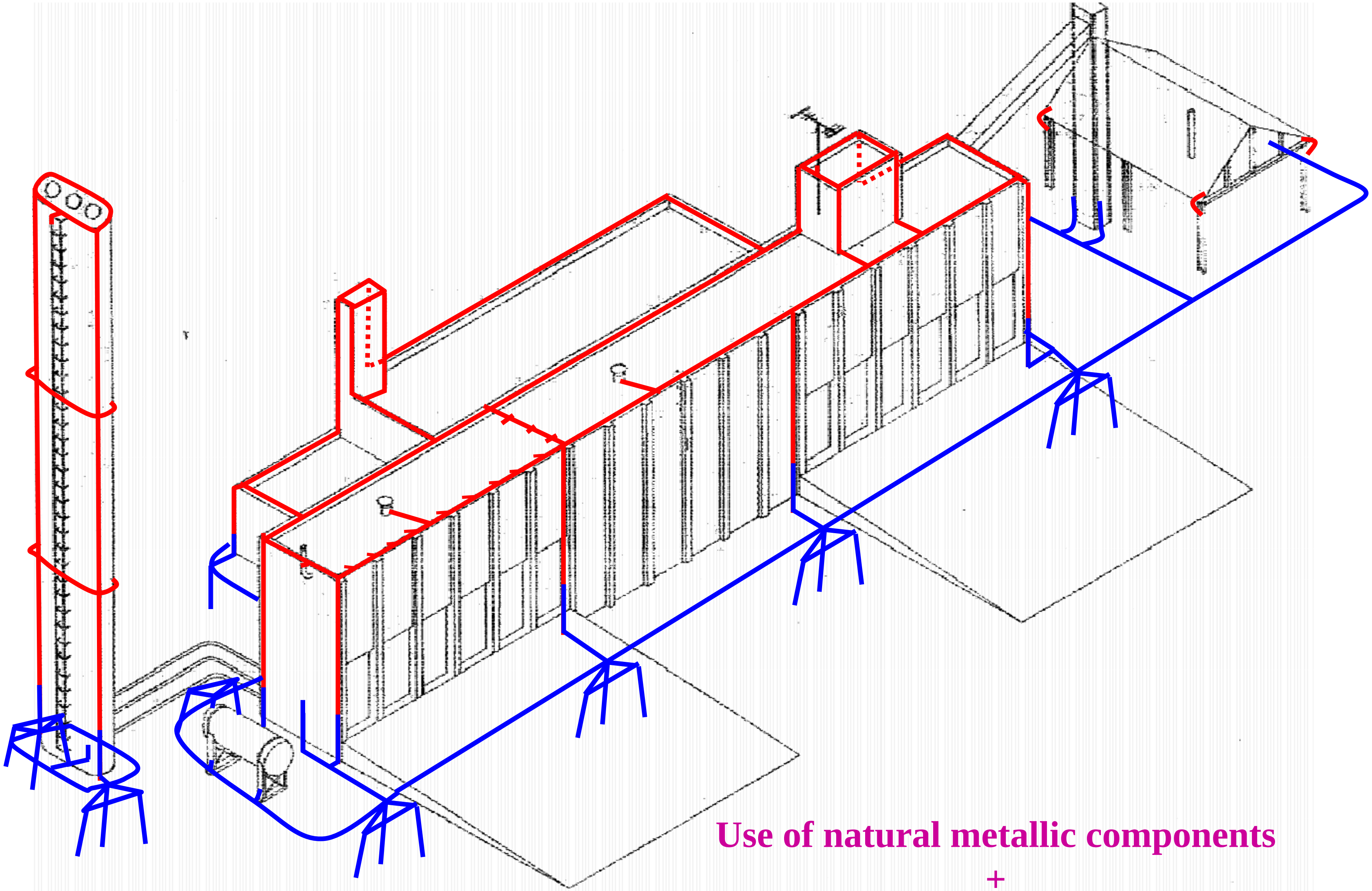
2) Conduction of the lightning current safely towards earth :

- down-conductor system

3) Dispersion of the current into the earth :

- effective earth-termination system





Use of natural metallic components

+

Be careful with the electrical continuity !

Properly designed air termination system :
any combination of rods, catenary wires
and meshed conductors.

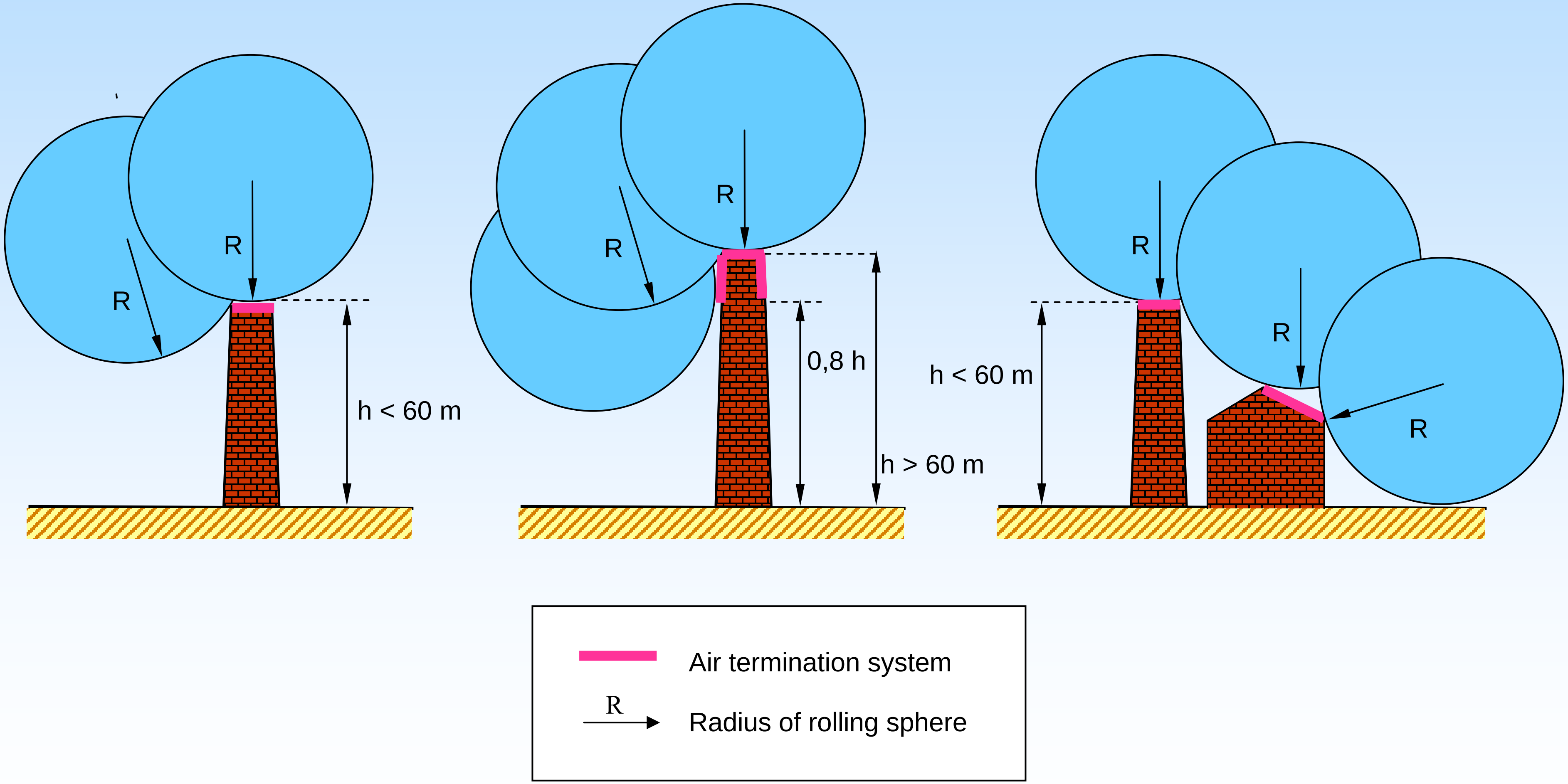
Great care to exposed points, corners and edges (upper parts!)

3 methods used :

- **RSM (EG model ; always !)**
- **Protection angle method (limited : height !)**
- **Mesh method (plane surfaces)**

Figure A.6

Design of an LPS air termination according to the “rolling sphere” method



NOTE The “rolling sphere” radius shall comply with the selected type of LPS (see table 2)

If there are external areas of the structure situated in heights which are higher than the radius of the corresponding rolling sphere (Tab. 5.1.1.3), an air-termination system has to be installed applying e.g. the mesh method.

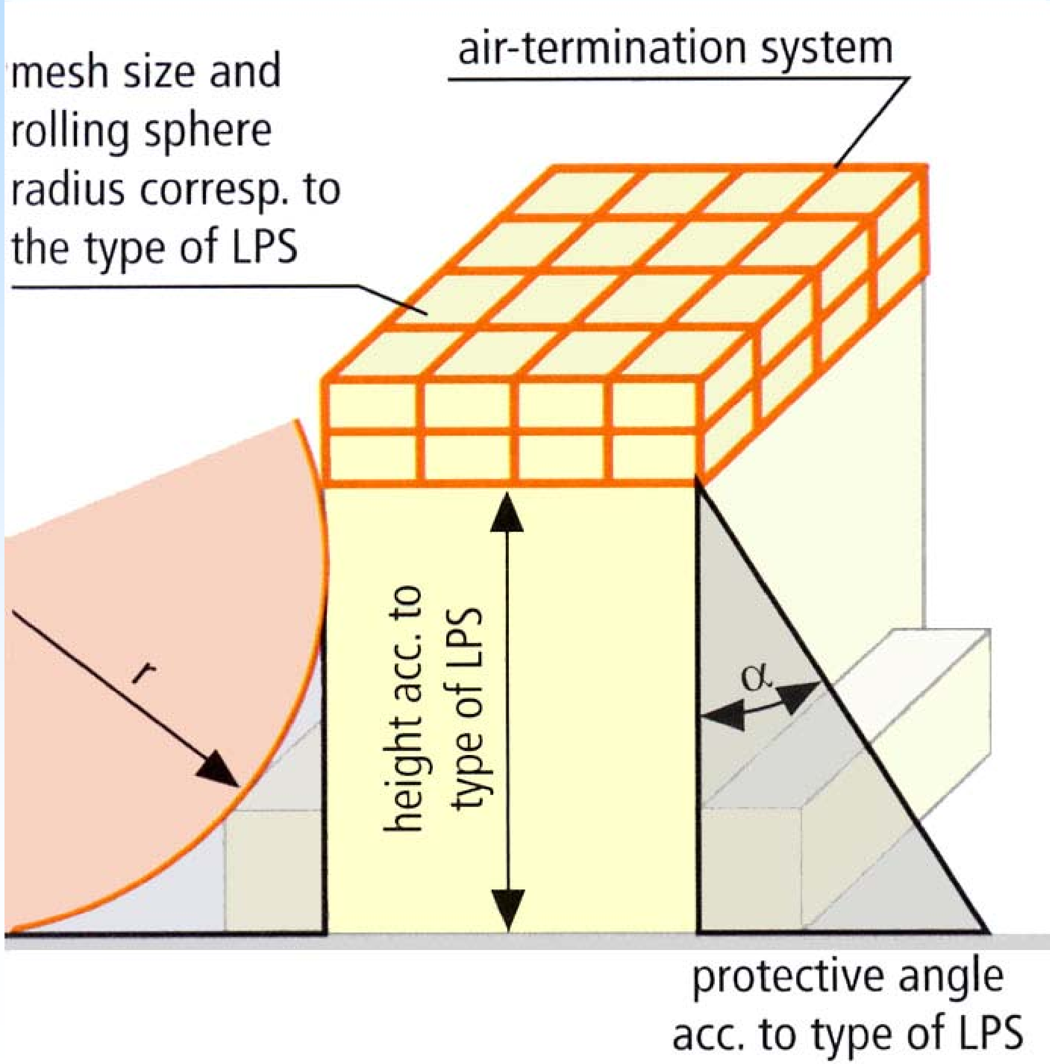


Table of minimum thicknesses of metal sheets for air-termination systems (see IEC 62305-3)

Class of LPS	Material	Thickness t (mm)	Thickness t’ (mm)
I to IV	Lead	-	2.0
	Stainless steel or galvanized steel	4	0.5
	Titanium	4	0.5
	Copper	5	0.5
	Aluminium	7	0.65
	Zinc	-	0.7

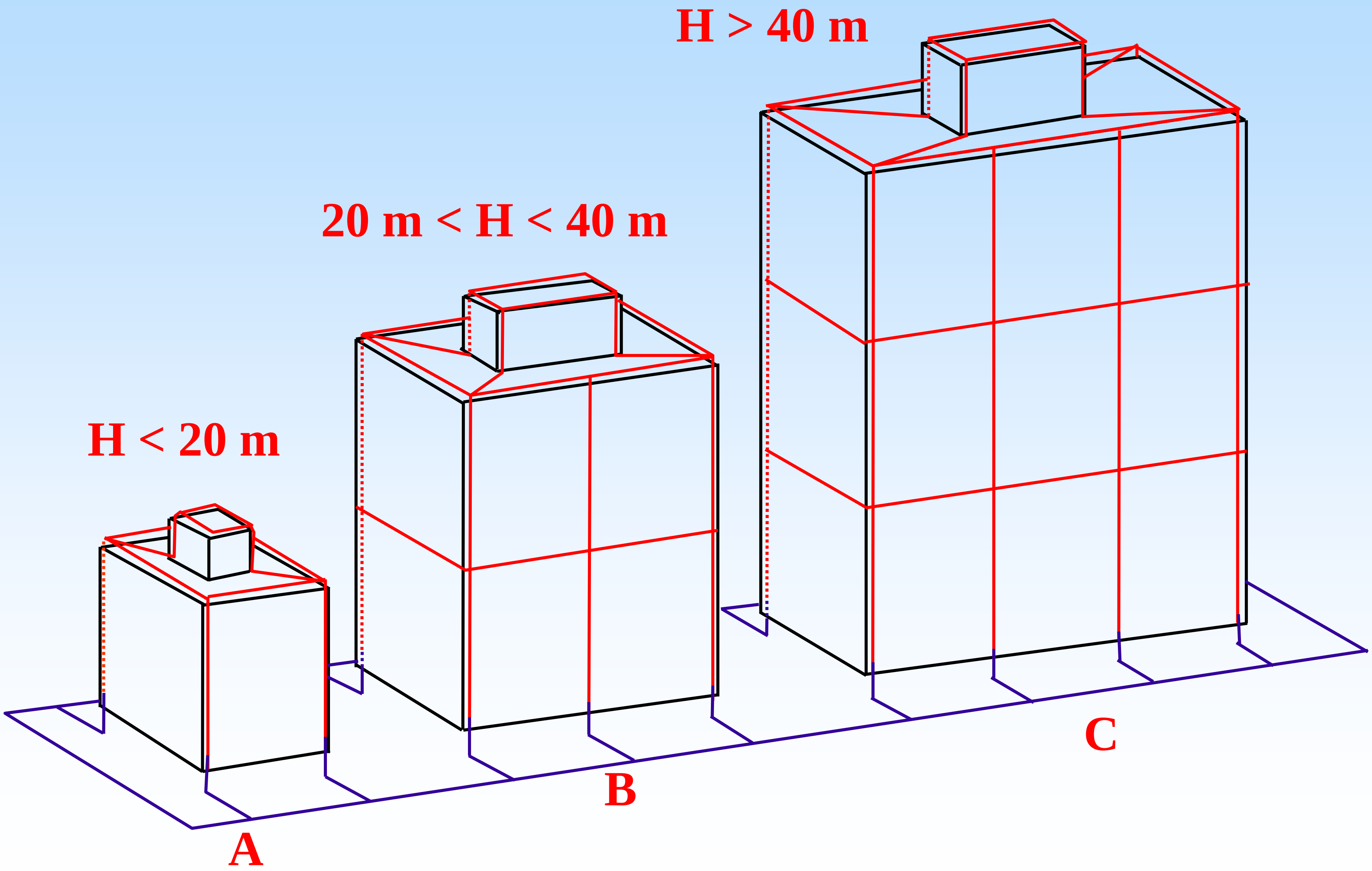
Down-conductor system

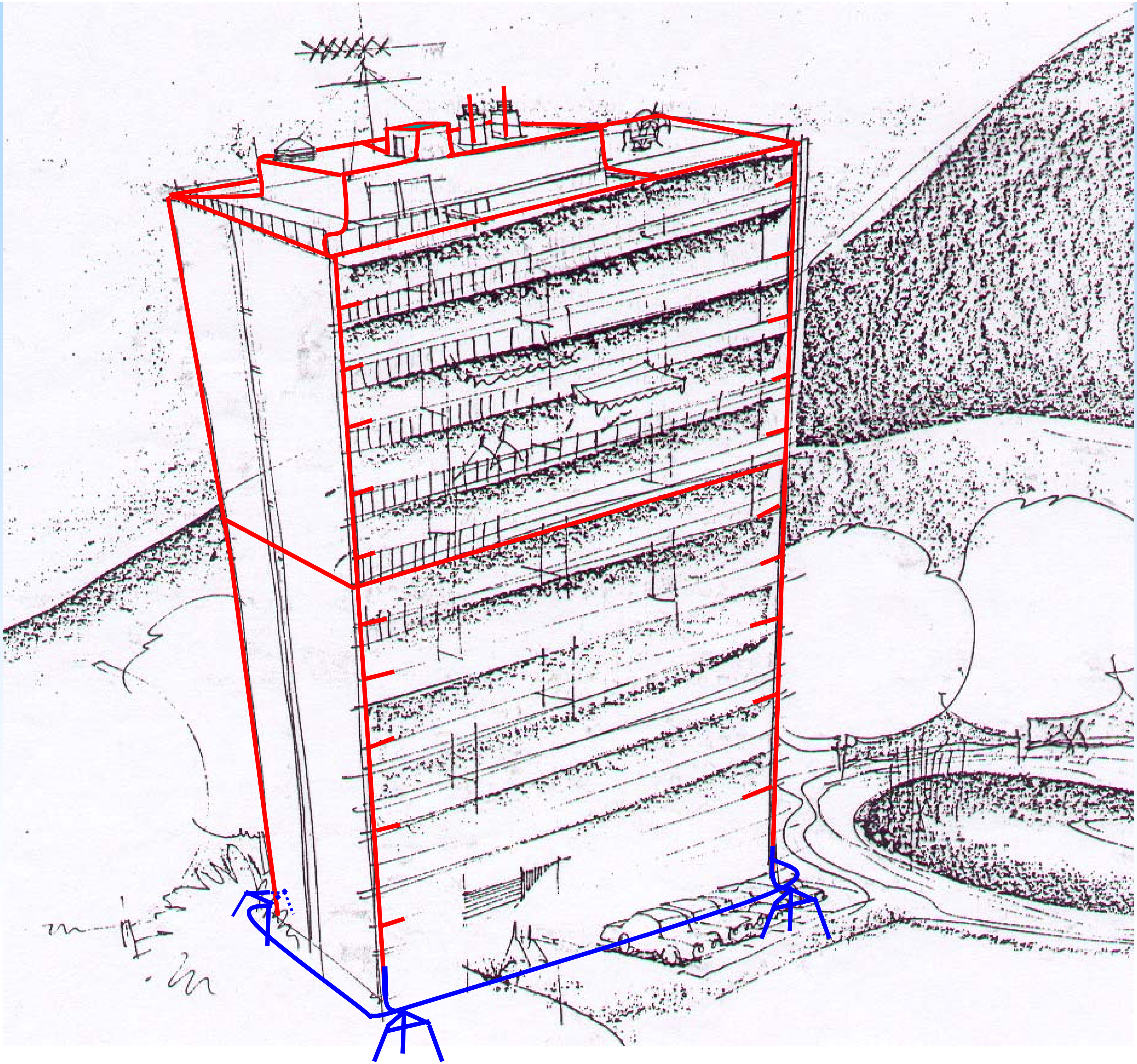
Class of LPS	Typical distances m
I	10
II	10
III	15
IV	20

Table 4

Typical values of the distance between down-conductors and between ring conductors according to the type of LPS

Down-conductor system



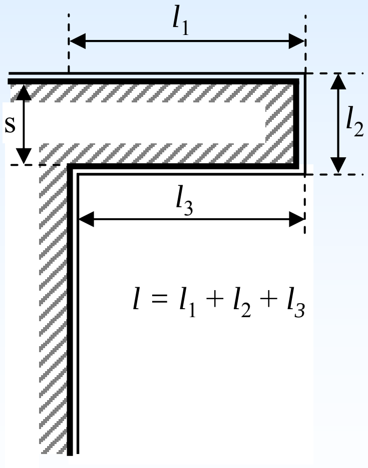


External and internal LPS
Dangerous sparking !

Equipotential bonding + separation distance

↓ bonding conductors or SPD between internal system and LPS

↓ $$s > k_i \frac{k_c}{k_m} l$$



k_i ← table 10

k_c ← table 11

k_m ← table 12

s depends on the LPL !

l(m) = distance to the nearest equipotential bonding point

Table 10 – Isolation of external LPS – Values of coefficient k_i

Class of LPS	k_i
I	0.08
II	0.06
III, IV	0.04

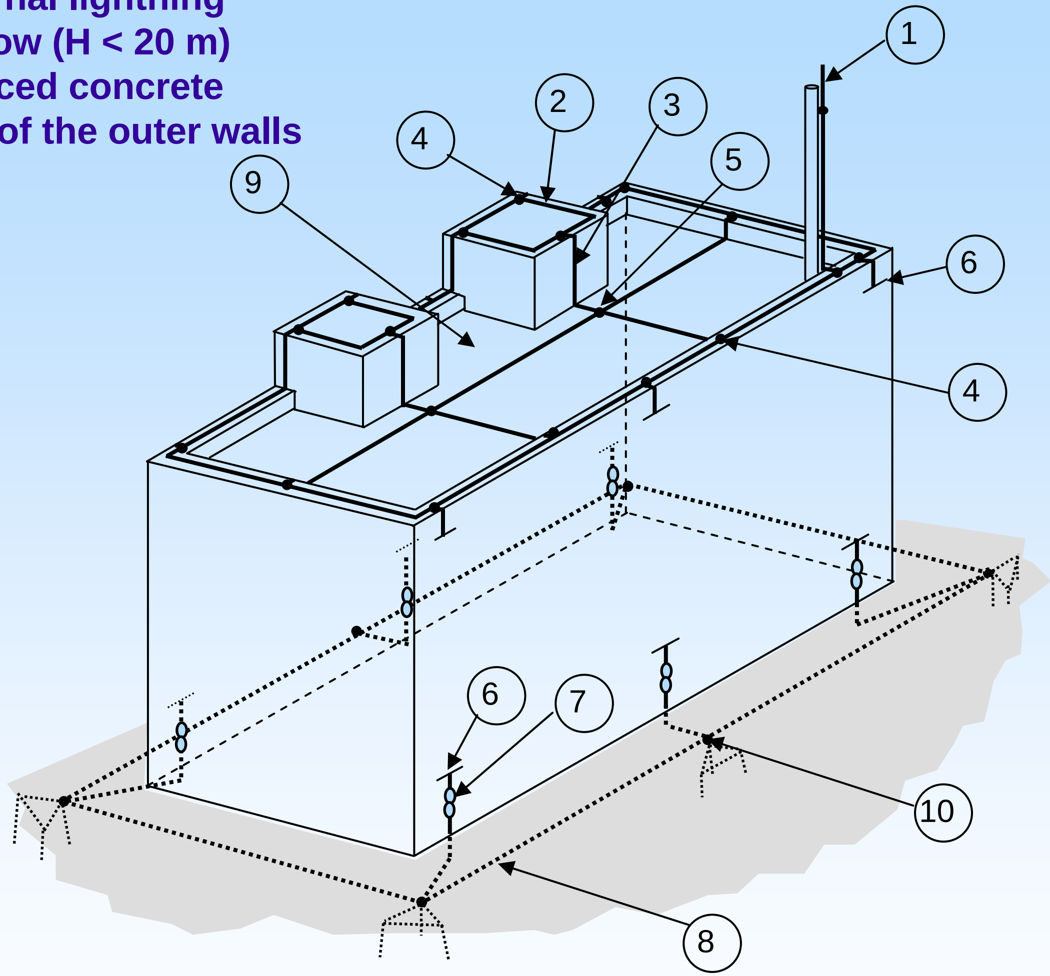
Table 11 – Isolation of external LPS – Values of coefficient k_c

Number n of down-conductors	k_c
1	1
2	1 ... 0.5
4, >4	1 ... 1/n

Table 12 – Isolation of External LPS – Values of coefficient k_m

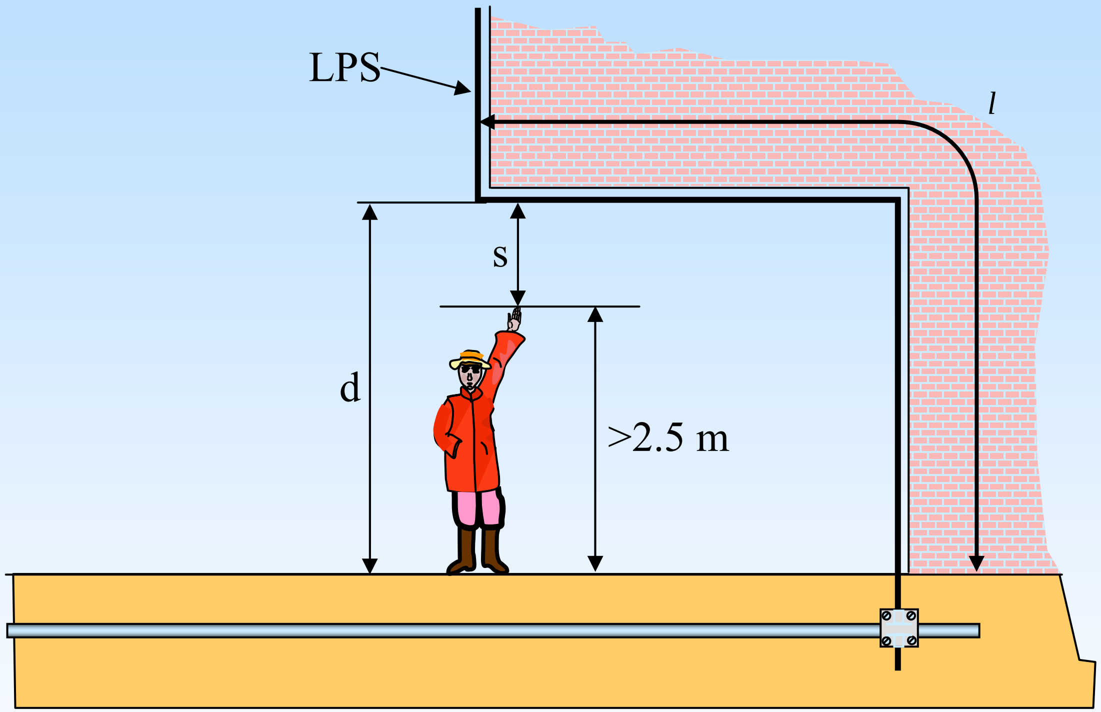
Material	k_m
Air	1
Concrete, bricks	0.5

Construction of the external lightning protection system on a low (H < 20 m) structure of steel-reinforced concrete using the reinforcement of the outer walls as natural components



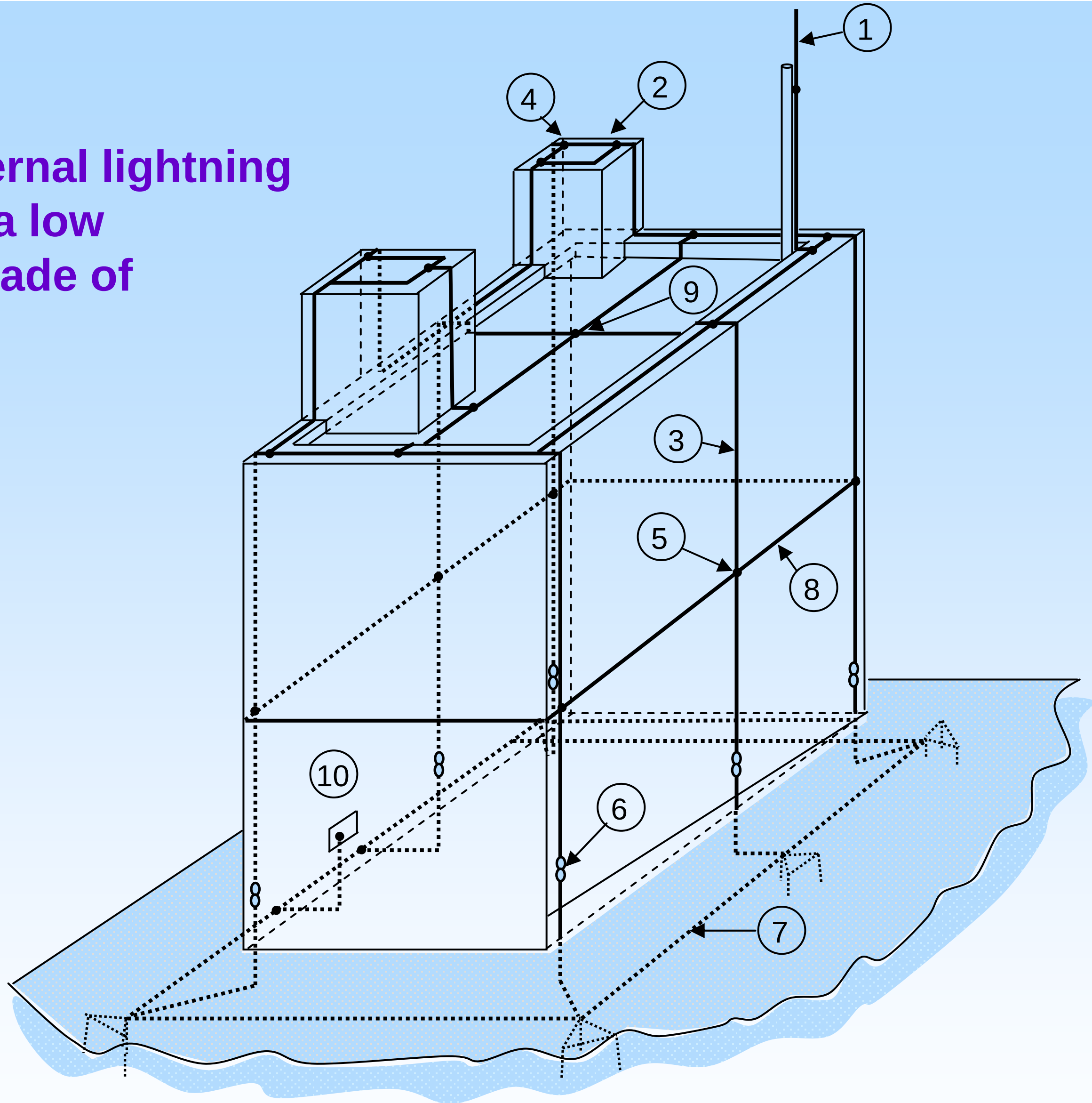
1: air-termination rod ; 2: horizontal air-termination conductor ; 3: down-conductor ; 4: T-type joint ; 5: cross-type joint ; 6: connection to steel reinforcing rods ; 7: test joint ; 8: ring earth electrode (type B earthing arrangement) ; 9: flat roof with roof fixtures ; 10: T-type joint, corrosion resistant.

Lightning protection system design for a cantilevered part of a structure



d > 2.5 + s

Positioning of the external lightning protection system on a low (H < 60 m) structure made of insulating material (wood, bricks, etc.)



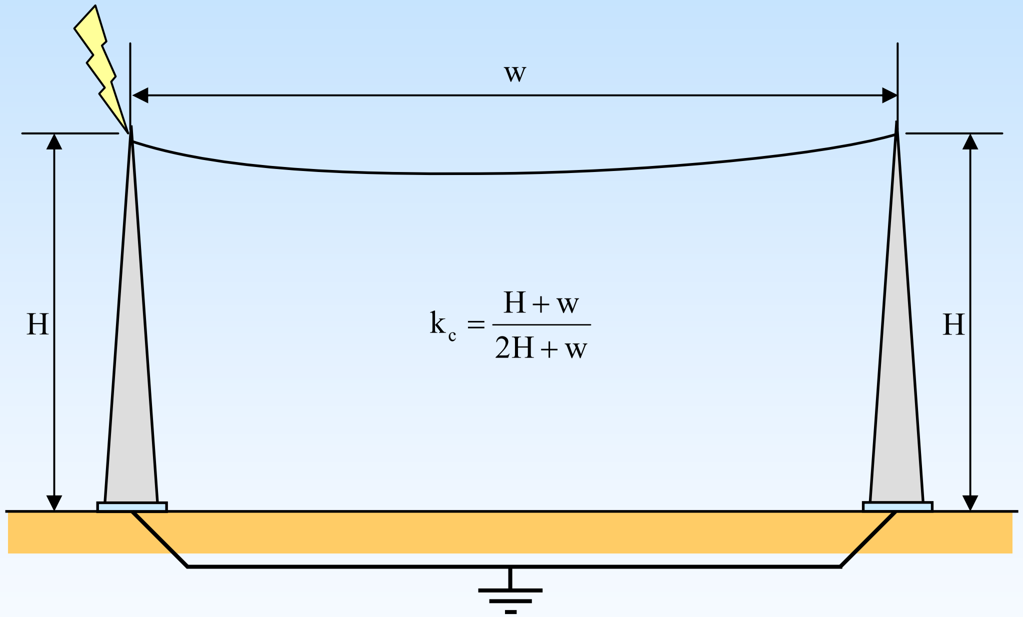
1:air-termination rod ; 2: horizontal air-termination conductor ; 3:down-conductor ; 4: T-type joint ; 5: cross type joint ; 6: test joint ;7: ring earth electrode (type B earthing arrangement) ; 8: equipotentialization ring conductor ; 9: flat roof with roof fixtures ; 10: terminal for connecting the equipotentialization bar to the internal LPS.

Values of the partitioning coefficient k_c

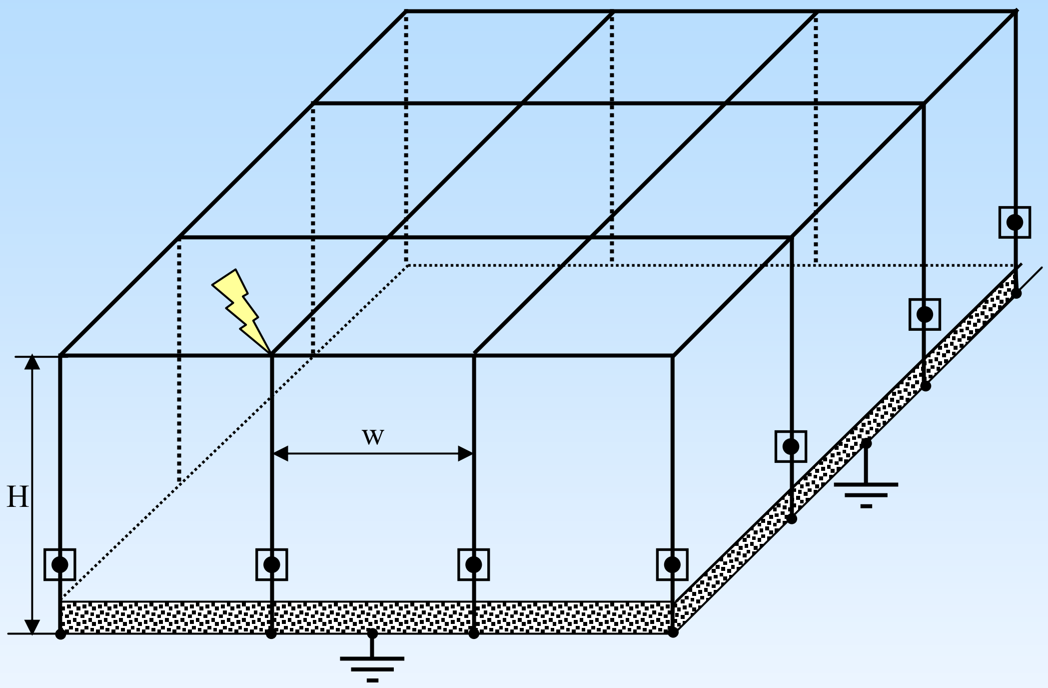
Type of air-termination system	Number n of down-conductors	k_c for type A earthing arrangement	k_c for type B earthing arrangement
Single rod	1	1	1
Wire	2	0.66 *	0.5 ... 1 **
Mesh	≥ 4	0.44 *	0.25 ... 0.5 ***
Mesh	≥ 4, connected by horizontal ring conductors	0.44 *	1/n ... 0.5 ****

•Valid for single earthing electrodes with comparable earthing resistances ; if earthing resistances of single earthing electrodes are clearly different $k_c = 1$ has to be assumed
** Values range from $k_c = 0.5$ where $w << H$ to $k_c = 1$ with $H << w$ (see figure 6.22)
*** The relation to calculate k_c in figure 6.24 is an approximation for cubic structures and for n 4 ; the values of H are assumed to be in the range of 5 to 20 m
**** If the down-conductors are connected horizontally by ring conductors, the current distribution is more homogeneous in the lower parts of the down-conductor system and kc is further reduced (especially valid for tall structures, see figure 6.24 where H, c_s and c_d are assumed to be in the range of 5 m to 20 m).

Partitioning coefficient k_c for a wire air-termination system and a type B earth-termination system



$$k_c = \frac{H + w}{2H + w}$$



$$k_c = \frac{1}{2n} + 0.1 + 0.2 \times \sqrt[3]{\frac{w}{H}}$$

where

n = total number of down-conductors (add internal down-conductors if they exist)

w = spacing between down-conductors

H = height (spacing) between horizontal ring conductors

Earth termination system (R<< !)

R < 10 Ω (low frequency)

Type A arrangement :

horizontal or vertical earth electrodes connected to each down conductor

length > l_1 (horizontal)

0.5 l_1 (vertical or inclined)

Type B arrangement :

ring conductor external to the structure in contact with the soil (or foundation earth electrode)

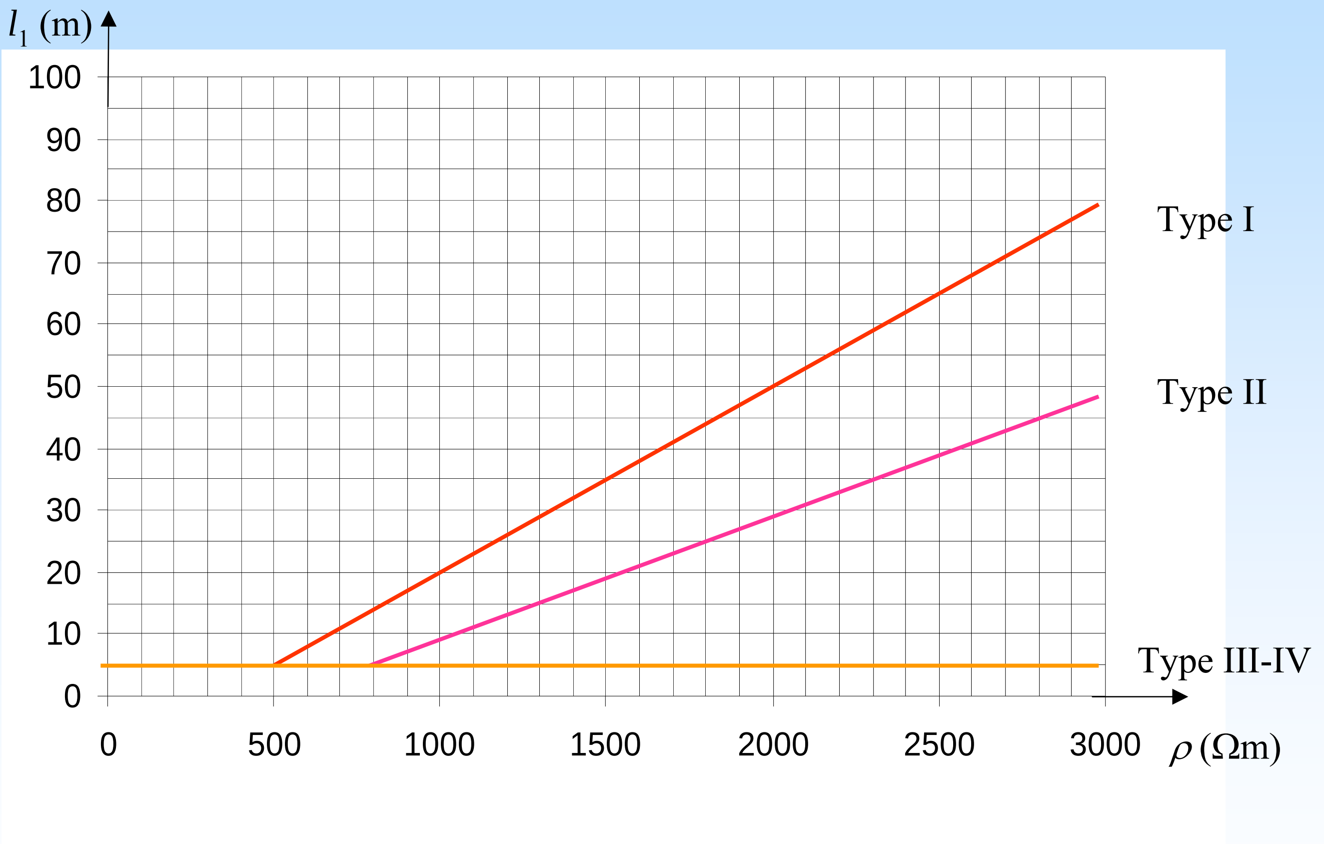
mean radius of the area r $\geq$ l_1

If r < l_1 , add horizontal or vertical (or inclined) electrodes of length l_r (horizontal) and l_v (vertical) connected to the ring earth electrode such as

$l_r = l_1 - r$ and $l_v = 0.5\,(l_1 - r)$

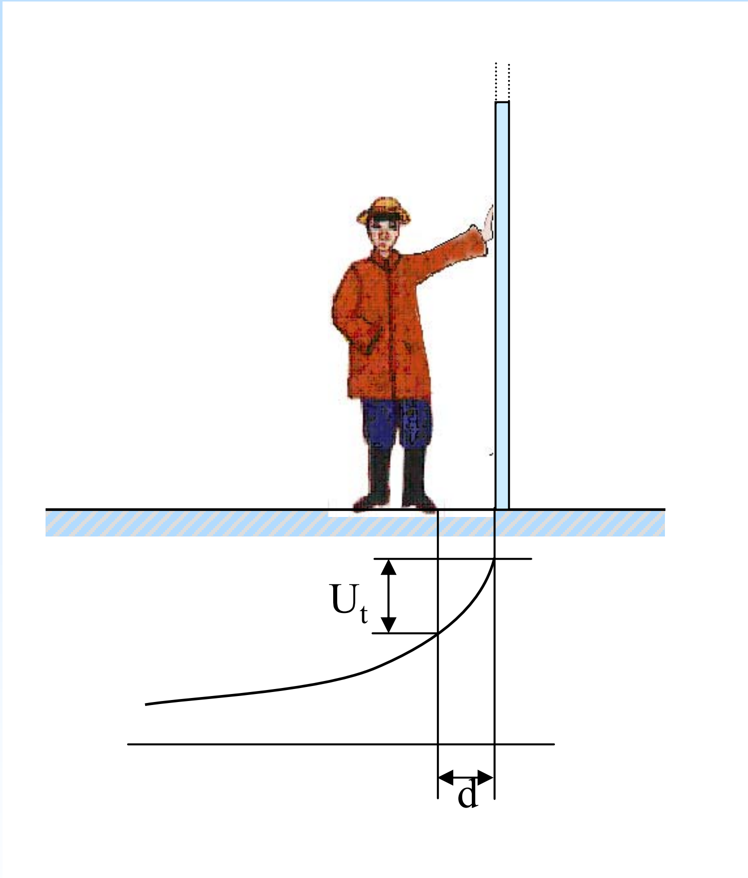
Figure 2

Minimum length l_1 of each earth electrode according to the type of LPS

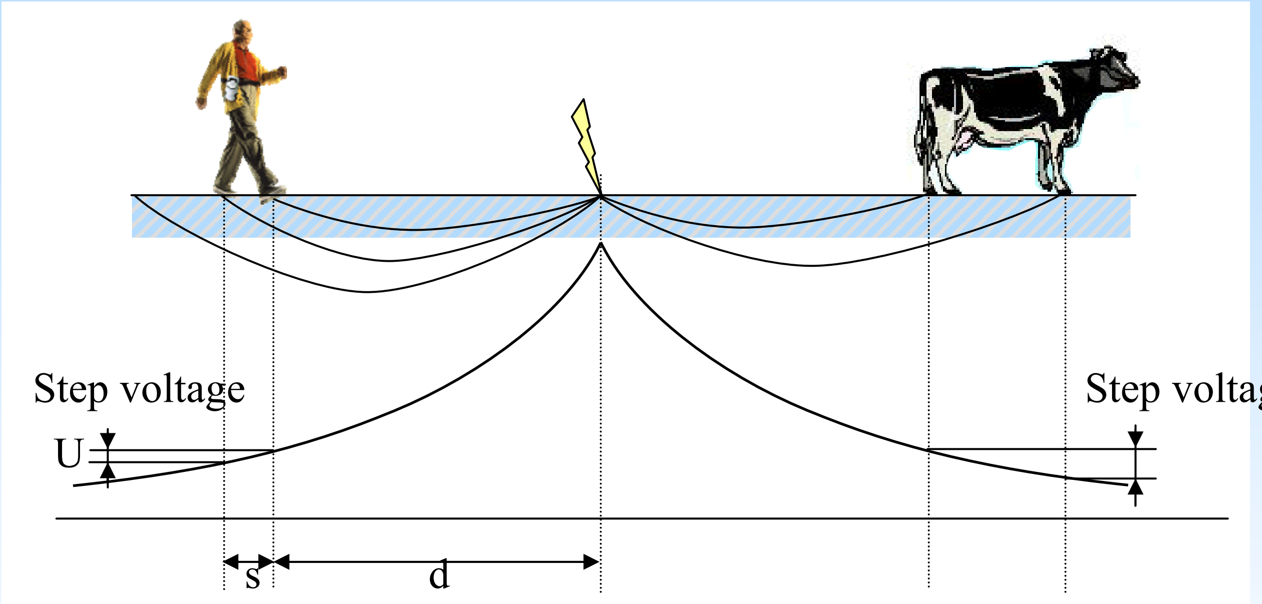


NOTE Types III and IV are independent of soil resistivity.

TOUCH VOLTAGE



STEP VOLTAGE



$$U = I \frac{\rho}{2\pi} \frac{s}{d(d+s)}$$

Protection measures against injuries of living beings

Vicinity of the down conductors of the LPS !

protection measures due to **touch voltages**
either by insulating the exposed down conductors
(e.g. 3 mm cross-linked polyethylene)
or by imposing physical restrictions and warning notices
to minimize the probability of down-conductors being touched

protection measures due to **step voltages**
by equipotentialising with a meshed earth-termination system
and by using the same other protection measures imposed for the touch voltages :
physical restrictions and warning notices to minimize the probability of access
to the dangerous area within 3 m of the down-conductor

Part 4

Electrical and electronic systems

within structures

IEC TC 81 : LIGHTNING PROTECTION

Electrical and electronic systems within structures

IEC 62305-4 **Part 4 : Electrical and electronic systems within structures**

- **4-1 Protection against LEMP : general principles**
- **4-2 Earthing and bonding; magnetic shielding and line routing**
- **4-3 SPD system**
- **4-4 Management of an LPMS**

SCOPE

Design, installation, inspection, maintenance and testing of a LEMP protection measures system (LPMS) for electrical and electronic systems within a structure, able to reduce the risk of permanent failures due to lightning electromagnetic impulse.

Outside:

- protection against electromagnetic interference due to lightning ;
- detailed design of the electrical and electronic systems themselves

Protection measures
to reduce failure of electrical and electronic systems

For structures :

LEMP protection measures system (LPMS) consisting of the following measures to be used alone or in combination :

- earthing and bonding measures
- magnetic shielding
- line routing
- coordinated SPD protection

For services :

- SPDs at different locations along the length of the line and at the line termination
- magnetic shields of cables

Introduction

- Permanent failure of electrical and electronical systems can be caused by the lightning electromagnetic impulse (LEMP) via:
  - conducted and induced surges transmitted to apparatus via connecting wiring;
  - the effects of radiated electromagnetic fields directly into apparatus itself.*

  *neglible for equipment that complies with relevant EMC standards

- Surges to the structure can be generated :
  - Surges external to the structure are created by lightning flashes striking incoming lines or the nearby ground, and are transmitted to electrical and electronic systems via these lines;
  - Surges internal to the structure are created by lightning flashes striking the structure or the nearby ground.

Design of an LPMS

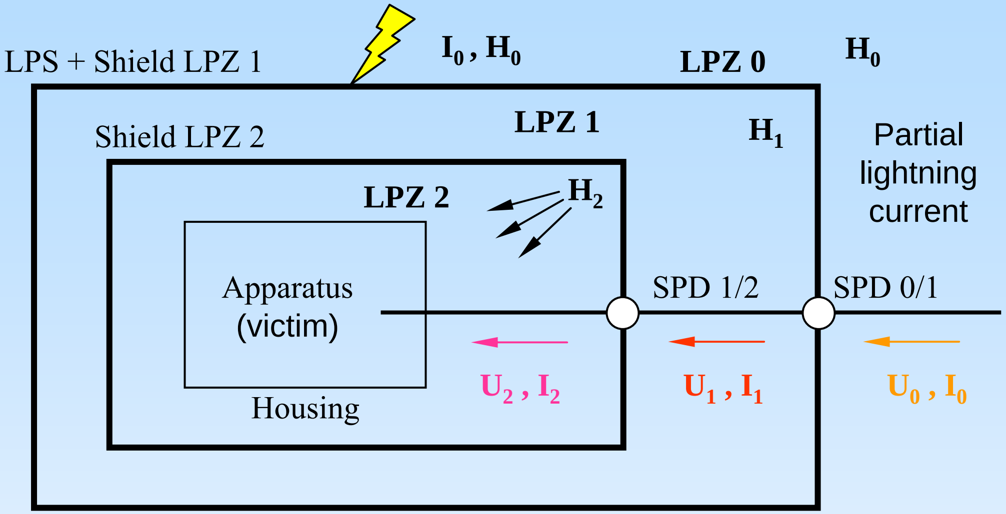
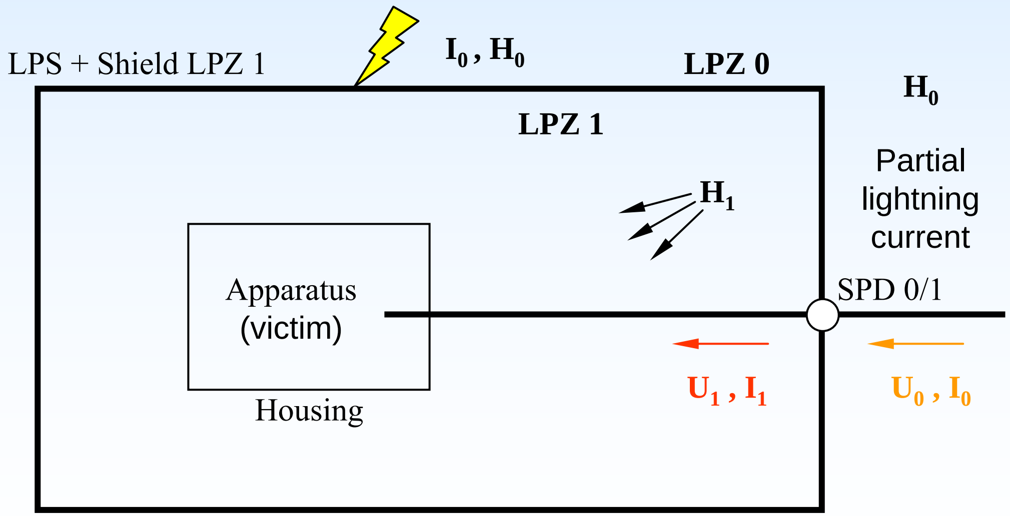


Figure 2a

LPMS using spatial shields and coordinated SPD protection. Apparatus well protected against conducted surges ($U_2 << U_0$ $I_2 << I_0$) as well as against radiated magnetic fields ($H_2 << H_0$)

Figure 2b

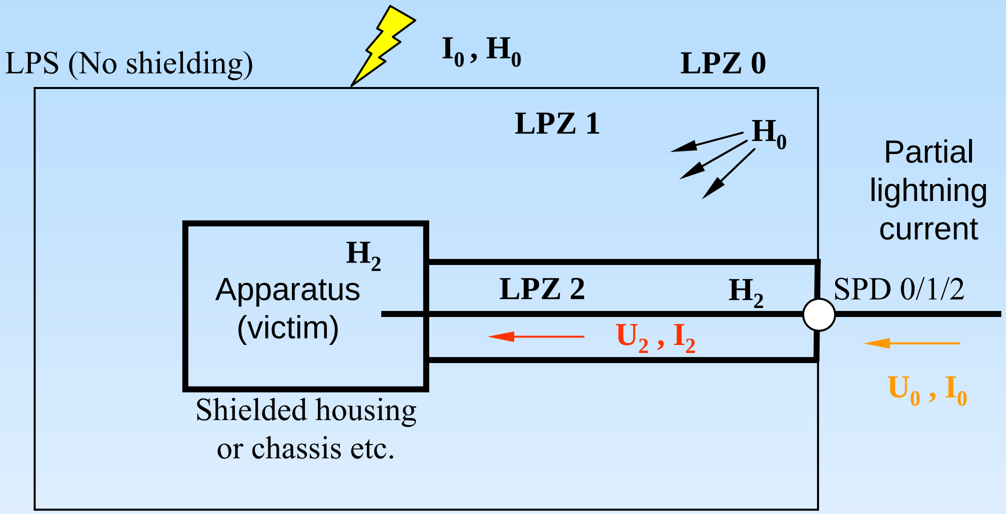
LPMS using spatial shield of LPZ 1 and SPD protection at entry of LPZ 1. Apparatus protected against conducted surges ($U_1 < U_0$ $I_1 < I_0$) as well as against radiated magnetic fields ($H_1 < H_0$)



Design of an LPMS

Figure 2c

LPMS using internal line shielding and SPD protection at entry of LPZ 1. Apparatus protected against conducted surges ($U_2 < U_0$ $I_2 < I_0$) as well as against radiated magnetic fields ($H_2 < H_0$)



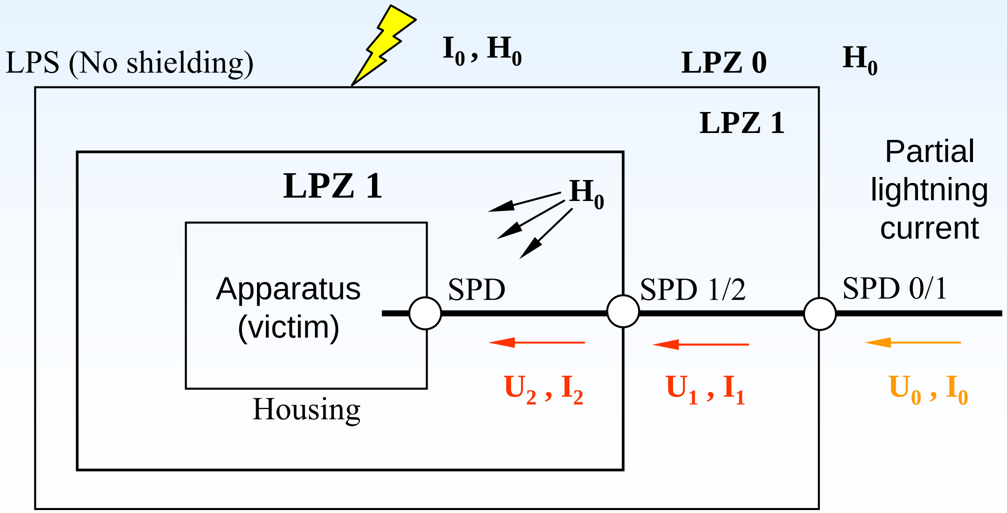


Figure 2d

LPMS using coordinated SPD protection. Apparatus protected against conducted surges ($U_2 << U_0$ $I_2 << I_0$) but not against radiated magnetic fields (H_0)

Type of LPS	Lightning impulse current capability		
	In TN systems	In TN systems (L-N)	In TN systems (N-PE)
I	≥ 100 kA / m	≥ 100 kA / m	≥ 100 kA
II	≥ 75 kA / m	≥ 75 kA / m	≥ 75 kA
III/IV	≥ 50 kA / m	≥ 50 kA / m	≥ 50 kA
m : Quantity of conductors, e.g. for L1, L2, L3, N and PE; m = 5			

Protection
to reduce the failure of internal systems (1)

Protection against LEMP to reduce the risk of failure of internal systems shall limit :

- overvoltages due to lightning flashes **to the structure** resulting from resistive and inductive coupling ;
- overvoltages due to lightning flashes **near the structure** resulting from inductive coupling ;
- overvoltages transmitted by **lines connected to the structure** due to flashes to or near the lines ;
- magnetic field **directly coupling** with internal systems.

Protection
to reduce the failure of internal systems (2)

System to be protected inside a LPZ 1 or higher

- magnetic shields to attenuate the inducing magnetic field
- suitable routing of wiring to reduce the induction loop

Bonding at the boundaries of LPZ for metal parts and systems crossing the boundaries (bonding conductors + SPDs)

Coordinated SPD protection

(overvoltages < rated impulse withstand voltage)

Basic protection measures in an LPMS

1) earthing and bonding :

earth-termination system + bonding network

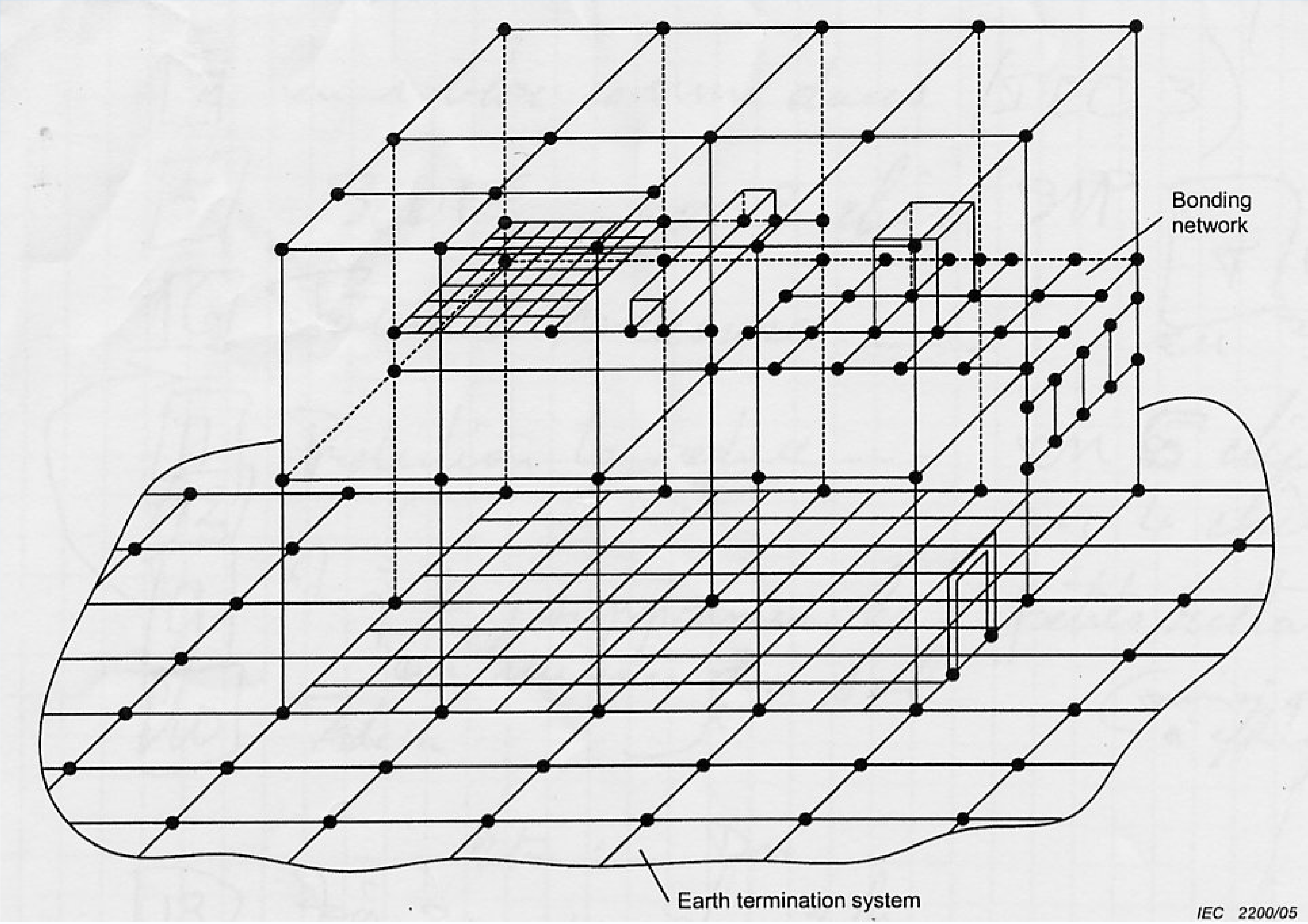
ex : each conductive service incoming to the structure shall be bonded directly or via suitable SPD at the entrance point.

2) magnetic shielding and line routing :

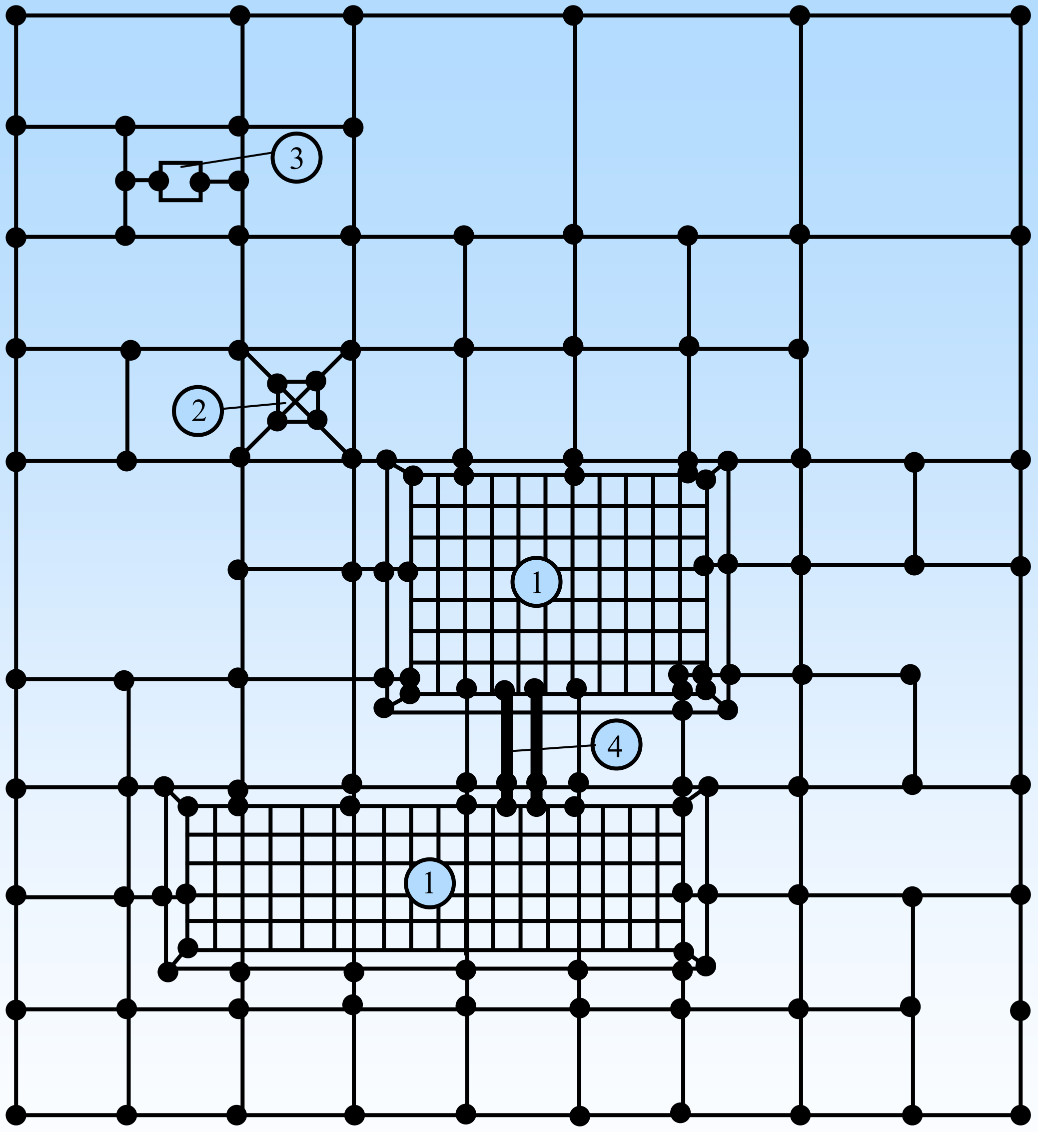
- **grid-like spatial shielding**
- **shielding of internal lines (shielded cables, cable ducts,...)**
- **shielding of external lines entering the structure**
- **line routing of internal lines (avoiding induction loops and reducing internal surges)**

3) surge protective device system (SPD system) :

limiting both external and internal surges (coordinated set of SPDs)



Example of a 3D earthing system consisting of the bonding network interconnected with the earth-termination system



Meshed earth-termination system of an industrial plant

1: buildings with meshed network of the reinforcement
2: tower inside the plant
3: stand-alone equipment
4: cable tray

CONCLUSION

IEC TC81 (+ CLC TC81X)

STANDARD TO BE IMPROVED
during the maintenance period

NATIONAL COMMITTEES
should avoid to promote fancy devices
which do not comply with it.