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LIGHTNING PROTECTION "MESH METHOD": CAN IT BE ANALYSED WITH ELECTRO-GEOMETRICAL THEORY?

Second International Symposium
„Lightning Physics and Effects"
Vienna, 19-20 April 2007

Franklin rods or meshworks?
Which of the methods dominates in our towns?

10a.1

26th International Conference on Lightning Protection
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STANDARDISATION OF LIGHTNING PROTECTION BASED ON THE PHYSICS OR ON THE TRADITION?

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Abstract

Since the installation of the first „lightning protection system" by Franklin the main principles remained valid up to day, namely: to intercept, to conduct down and to ground. Then the first recommendations rarely gave general rules but

of the protective effect. In the case of other structures the new results have almost no effect on the standardization of lightning protection systems. Although the Hungarian Standard introduced the rolling sphere in 1962 [11] and after 1970 several countries dealt with its application, IEC TC81 accepted it only after hard discussion. Finally

3.5. Problems of the mesh wide method

This construction method has been verified by long experience without any theoretical or experimental research. Its protective effect probably origins from the good electric conductivity of the air termination system (a grounded metal structure) against the insulating or wrong conductive materials of the roof to be protected. This supposed effect shows the application limits of the mesh wide at metallic surfaces, where the different conductivity doesn’t exist.

Golde R. H.

(Golde R. H.: *Lightning*. London, Academic Press, 1977.)

" Apart from special cases a genuine Faraday cage hardly constitutes a practical solution to the lightning problem"

A CRITICAL REVIEW OF NONCONVENTIONAL APPROACHES TO LIGHTNING PROTECTION

BY M. A. UMAN AND V. A. RAKOV

Neither data nor theory supports claims that "lightning elimination" and "early streamer emission" techniques are superior to conventional lightning protection systems.

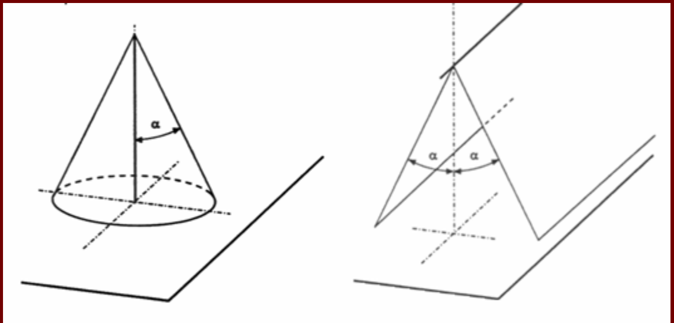
CONVENTIONAL SYSTEMS. Properly de- ... tems (e.g., NFPA 1997, her... and the efficacy of the conventi...

According to some standards, a wire mesh covering the top of the structure may play the role of the air terminals. (Note that the rolling sphere method would predict that lightning can attach to the structure between the metal mesh conductors unless the mesh is elevated above the top of the structure.) For example, IEC (1993) states that a mesh size of 15 m × 15 m is equivalent to protection with lightning rod air terminals designed for an assumed 45-m striking distance. Apparently, the specified relationship between mesh size and striking distance is a matter of experience rather than theory.

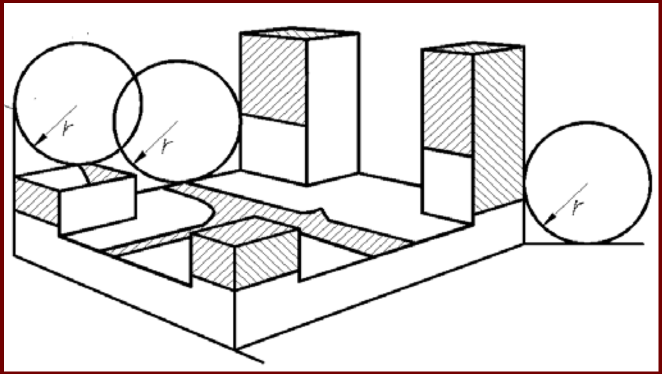
... is enhanced by ... surface such as trees and grounded air terminals on struc-

Air terminals design methods by IEC 61024-1

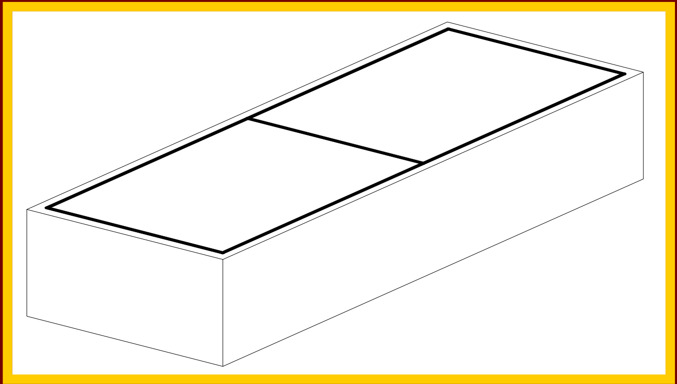
Protecton Angle method



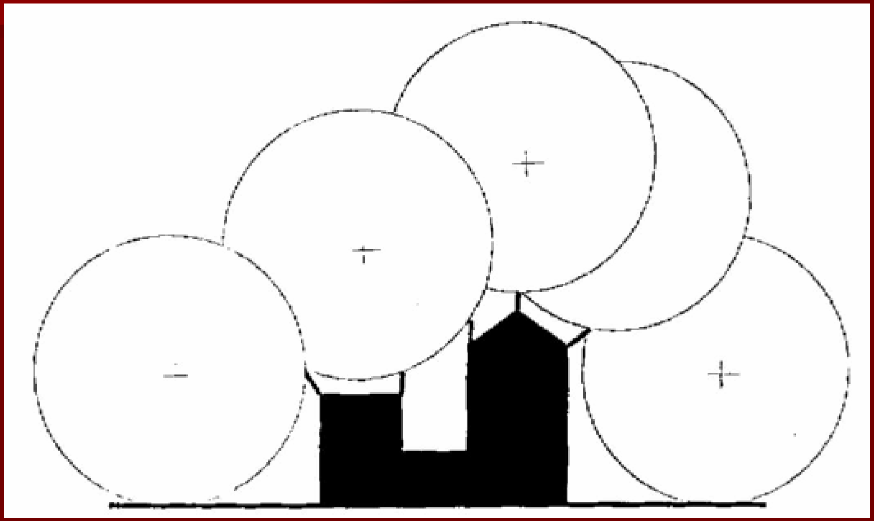
Rolling Sphere method



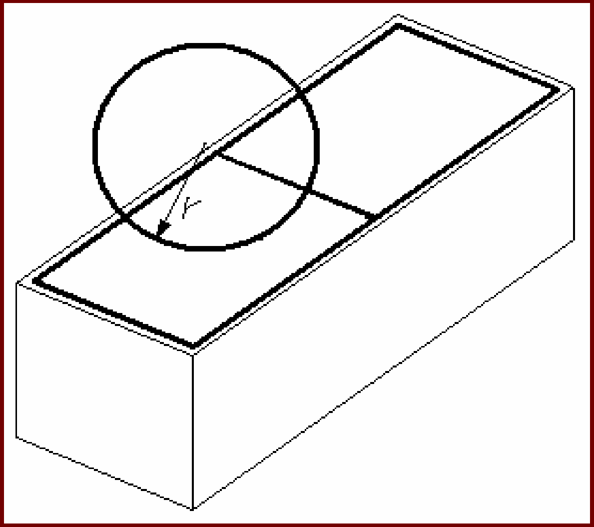
Meshwork method



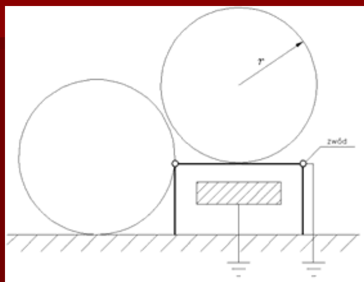
Reliable protection...



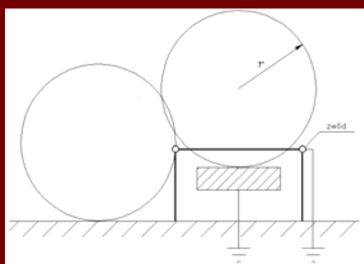
Protection... ???
RELIABLE
according IEC, if
the square side is
short enought
(e.g. M ≤ 20 m for
the IV protection
level)



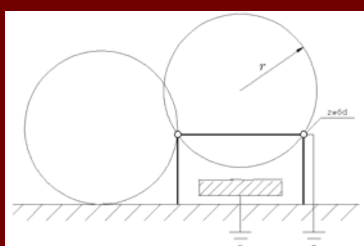
”Rolling Sphere” method: conventional (a), modified (b, c) ones



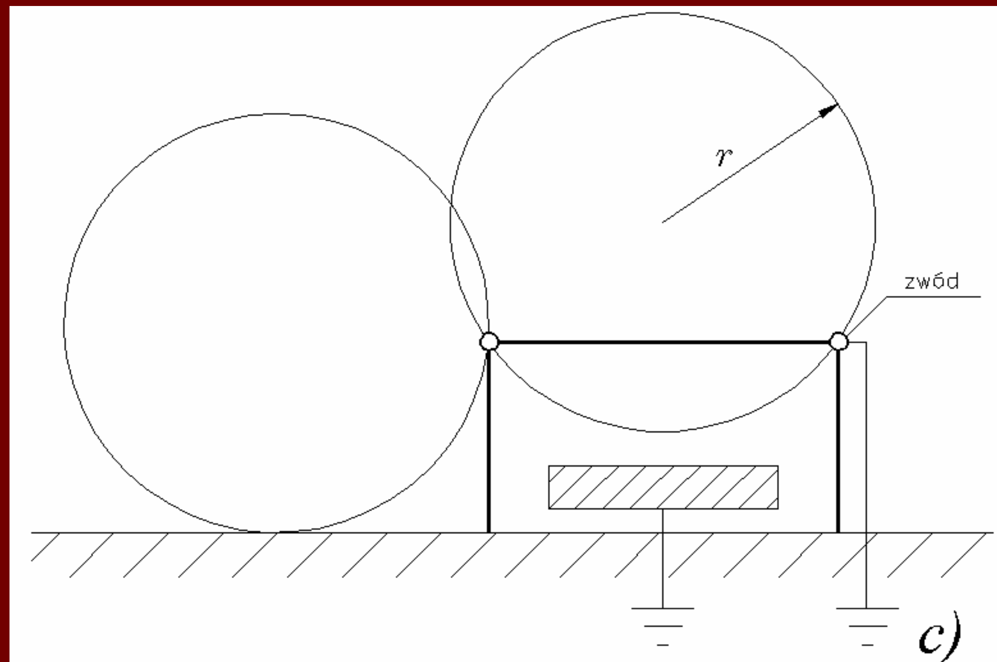
a)



b)



c)



LIGHTNING PENETRATION THROUGH THE MESH FOR *VERTICAL* LEADER DIRECTION

1. Orientation distance, D

$$f(D) = \frac{1}{D \cdot c \cdot s\sqrt{2\pi}} \exp[-\frac{1}{2}(\frac{1}{c \cdot s}\ln\frac{D}{D_{50\%}})^2] \quad (1)$$

$$D = k \cdot I^c \quad (2)$$

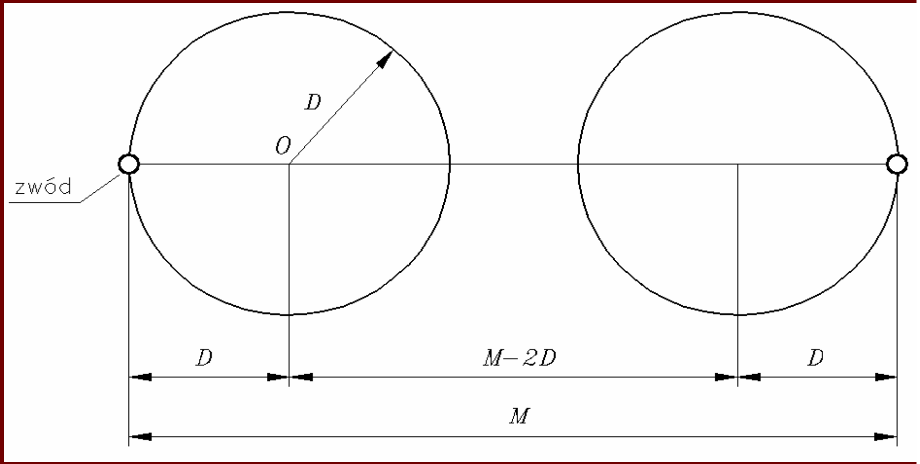
2. Leader slope, φ

$$\varphi = 0 \quad (3)$$

MODEL I

($\varphi = 0$)

Number of lightnings penetrating **totally** the mesh:



$$N_{Mv} = N_g \int_0^{\frac{M}{2}} (M-2D)^2 g(D)\,dD =$$

$$= N_g \int_0^{\frac{M}{2}} (M-2D)^2 \frac{1}{D \cdot p \cdot s\sqrt{2\pi}} \exp[-\frac{1}{2}(\frac{1}{p \cdot s} \ln \frac{D}{D_{50\%}})^2]dD$$

$$k_{fv} = \frac{N_{Mv}}{N_g \cdot M^2}$$

Protection failure coefficient k_{fv} for $M = 20$ m

	$D_{50\%} = 50\ m$	$D_{50\%} = 100\ m$	$D_{50\%} = 150\ m$
s=0,5 c=0,65 ($s\cdot c$= 0,325)	2,27E – 9	2,41E – 18	<1,0E–20
s=1,0 c=0,75 ($s\cdot c$= 0,75)	1,15E – 3	5,30E – 5	6,17E – 6
s=1,5 c=0,85 ($s\cdot c$= 1,275)	2,11E – 2	5,90E – 3	2,48E – 3

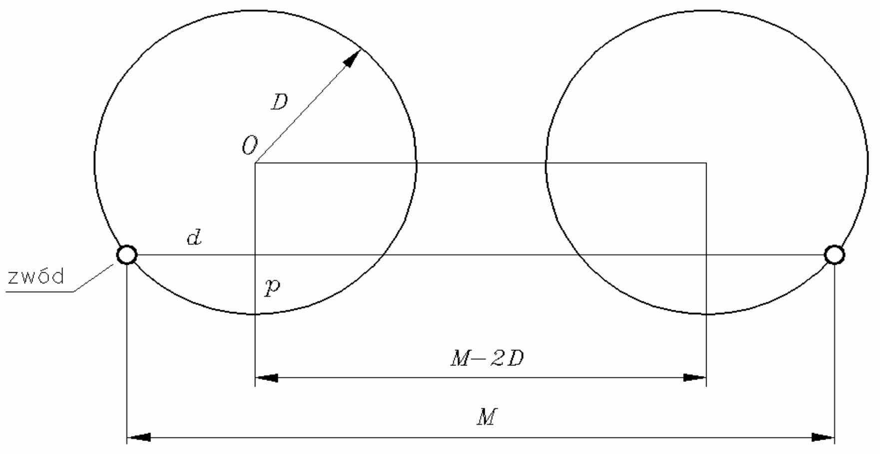
Protection failure coefficient k_{fv} for $M = 5$ m

	$D_{50\%} = 50\ m$	$D_{50\%} = 100\ m$	$D_{50\%} = 150\ m$
s=0,5 c=0,65 ($s\cdot c$=0,325	–	–	<1,0E–20
s=1,0 c=0,75 ($s\cdot c$= 0,75)	1,12E – 6	1,14E – 7	5,36E – 8
s=1,5 c=0,85 ($s\cdot c$= 1,275)	7,52E – 4	1,42E – 4	4,64E – 5

MODEL II

($\varphi = 0$)

Number of lightnings penetrating **partially** the mesh to contact the element in the distance *p* below the meshwork



$$N_{Mpv} = N_g \int_0^{\frac{\frac{M^2}{4}+p^2}{2p}} (M-2r)^2 g(D)dD =$$

$$= N_g \int_0^{\frac{\frac{M^2}{4}+p^2}{2p}} (M-2\sqrt{(2D-p)p})^2 \frac{1}{D\cdot p\cdot s\sqrt{2\pi}} \exp[-\frac{1}{2}(\frac{1}{p\cdot s}\ln\frac{D}{D_{50\%}})^2]dD$$

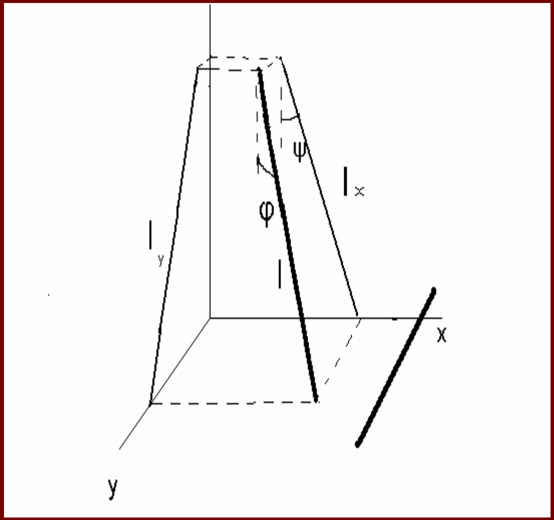
Protection failure coefficient k_{fv} $(p = 1\ m)$, for $M = 20$ m

	$D_{50\%} = 50\ m$	$D_{50\%} = 100\ m$	$D_{50\%} = 150\ m$
s=0,5 c=0,65 ($s \cdot c$=0,325	1,10E – 2	9,90E – 5	1,24E – 6
s=1,0 c=0,75 ($s \cdot c$= 0,75)	4,29E – 2	8,61E – 3	2,55E – 3
s=1,5 c=0,85 ($s \cdot c$= 1,275)	9,07E – 2	3,92E – 2	2,18E – 2

Protection failure coefficient k_{fv} $(p = 1\ m)$, for $M = 5$ m

	$D_{50\%} = 50\ m$	$D_{50\%} = 100\ m$	$D_{50\%} = 150\ m$
s=0,5 c=0,65 ($s \cdot c$= 0,325)	–	–	<1,0E–20
s=1,0 c=0,75 ($s \cdot c$= 0,75)	4,29E – 6	6,35E – 8	3,73E – 9
s=1,5 c=0,85 ($s \cdot c$= 1,275)	1,22E – 3	2,40E – 4	8,37E – 5

MODEL OF LIGHTNING PENETRATION THROUGH THE MESH FOR *REAL* LEADER DIRECTION



Interpretation of the angle *ψ*

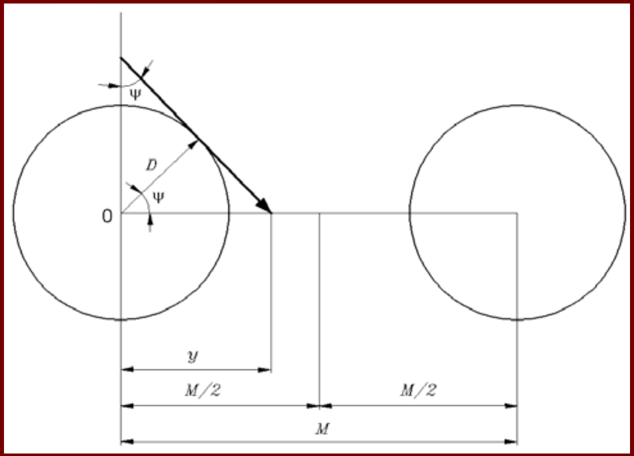
Leader slope *ψ:*

$$f(\psi) = \frac{2}{\pi}\cos^2\psi$$

Model III

$$f(\psi) = \frac{2}{\pi}\cos^2\psi$$

Number of lightnings penetrating **totally** the mesh



$$N_M = N_{Mz} = 2 \cdot N_g \int_{D_{\min}}^{\frac{M}{2}} dD \int_{D}^{M-D} dy \int_{\arccos\frac{D}{y}}^{\arccos\frac{D}{M-D}} g(D)(M-2D)g(\psi)\cos\psi d\psi =$$

$$= 2 \cdot N_g \int_{D_{\min}}^{\frac{M}{2}} dD \int_{D}^{M-D} dy \int_{\arccos\frac{D}{y}}^{\arccos\frac{D}{M-D}} \frac{1}{D \cdot c \cdot s\sqrt{2\pi}} \exp[-\frac{1}{2}(\frac{1}{c \cdot s}\ln\frac{D}{D_{50\%}})^2](M-2D)\frac{2}{\pi}\cos^2\psi\cos\psi d\psi$$

Protection unreliability coefficient k_f for $M = 20$ m

	$D_{50\%} = 50\ m$	$D_{50\%} = 100\ m$	$D_{50\%} = 150\ m$
s=0,5 c=0,65 ($s \cdot c$= 0,325)	3,62E – 10	3,88E – 16	<1,0E–20
s=1,0 c=0,75 ($s \cdot c$= 0,75)	1,08E – 4	5,69E – 6	7,08E – 7
s=1,5 c=0,85 ($s \cdot c$= 1,275)	1,09E – 3	3,50E – 4	1,59E – 4

Protection unreliability coefficient k_f for $M = 5$ m

	$D_{50\%} = 50\ m$	$D_{50\%} = 100\ m$	$D_{50\%} = 150\ m$
s=0,5 c=0,65 ($s \cdot c$= 0,325)	–	–	<1,0E–20
s=1,0 c=0,75 ($s \cdot c$= 0,75)	1,36E – 7	1,47E – 9	7,17E – 11
s=1,5 c=0,85 ($s \cdot c$= 1,275)	6,83E – 5	1,31E – 5	4,38E – 6

COMPARISON OF RESULTS FOR VERTICAL AND REAL LEADER DIRECTION

$$f_v = \frac{N_{Mv}}{N_M}$$

Coefficient of " overvaluation" f_v for $M = 20\ m$

	$D_{50\%} = 50\ m$	$D_{50\%} = 100\ m$	$D_{50\%} = 150\ m$
s=0,5 c=0,65 (s·c=0,325	6,27	6,21	–
s=1,0 c=0,75 (s·c= 0,75)	10,65	9,31	8,71
s=1,5 c=0,85 (s·c= 1,275)	19,36	16,86	15,60

Coefficient of " overvaluation" fv for $M = 5\ m$

	$D_{50\%}$= 50 m	$D_{50\%} = 100\ m$	$D_{50\%} = 150\ m$
s=0,5 c=0,65 (s·c= 0,325)	–	–	–
s=1,0 c=0,75 (s·c= 0,75)	8,26	7,76	7,48
s=1,5 c=0,85 (s·c= 1,275)	11,00	10,83	10,58

CONCLUSIONS (1)

The analysis corroborates high efficiency of the Meshwork Method. In particular, when any conducting elements in the object interior are not closer to the meshwork surface than half of the square side length, the mean value of the protection failure coefficient is in the range from about 5×10^{-5} to about 10^{-7}, depending on the M value according to protection level (M varies between 5 m and 20 m). When conducting elements of the interior are close to the roof surface, the protection effectiveness falls; for the distance between them and the roof surface $p = 1$ m and $M = 20$ m, the k_f becomes about 10^{-2}, but for $M = 5$ m the k_f value is low, about $5 \cdot 10^{-7}$.

CONCLUSIONS (2)

The calculated protection unreliability is strongly influenced by the lightning parameters values

Considerable discrepancy between the parameters *D50% , s, c* (found by many researchers over many years in various places) makes it impossible to obtain unambiguous quantitative evaluation of efficiency that is valid for all regions of the world.

Thank you for your attention!