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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

International Conference on Lightning Protection

Cracow, Poland • September 2-6, 2002

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 the IEC 10241 standard introduced it but the ENX

It is supposed that protected space exists outside the sphere. Because the radius of the sphere is related to an assumed lightning current it can be stated: "Inside the protected space no lightning stroke needs to be expected if its current exceeds the assumed value". But it doesn't mean that all lightning penetrate into the protected space in the case of lower current. To the assumed lightning current below a probability of occurrence $P(t)$ what can be connected also to the radius of the sphere. This relation leads often to a confuse interpretation as it will be shown by an example. If $P(t) = 80\%$, then from lightning which strike the structure, 80% is expected to penetrate into the protected space. But it is a mistake that the efficiency of air termination is 80% and therefore 20% steady states shielding failure. According to a correct interpretation: The efficiency is higher the 80 (may be even 99% or higher).

Based on the rolling sphere method many studies try to find a relation between the radius and the efficiency risk but it is a hopeless deadlock [11]. Standardized values of the radius are the output compromises in construction, which cannot be calculated on physical processes. Application of rolling sphere method has been verified with long experience first of all in Hungary (since 1962) but in some other countries about 20 years. The most important advantage of the rolling sphere method is that only one parameter (radius) is necessary and in spite of this it can be generally used without any contradiction.

Recently some ideas were presented to use different radii either on different parts of the structure depending from the shape of the air termination and the structure to be protected. In some cases such a view could be used correctly, but it must be used at different surfaces too, which are often applied on buildings [10].

3.5. Problems of the mesh wide method

This construction method has been verified with long experience without any theoretical or experimental research. Its protective effect probably originates 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.

According to this method the air termination grid forms a network whose meshes are smaller than $a \times a$ (e.g. $5 \text{ m} \times 5 \text{ m}$, $10 \text{ m} \times 10 \text{ m}$, $20 \text{ m} \times 20 \text{ m}$). According to this definition the mesh is always quadratic. Because it is not so, the value a can be taken as the greater side of a rectangular mesh [1, 2, 4]. Although other mesh forms must be also used in many cases as illustrated by some examples in Figure 5. The previous definition occasionally proves a failure at the triangular, trapezoid or polygonal meshes. Taking as the largest side of the mesh would be a solution at rectangular mesh but it can lead to very large mesh in the case of a hexagon. It could be said that the

mesh must be fit into the given quadratic contour, but this is an administrative solution without any reason.

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 originates 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.

According to this method the air termination system



Figure 6. Several arrangements of the down conductors.

Figure 6 demonstrates the reason of this requirement. According to the old rule all four arrangements are

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

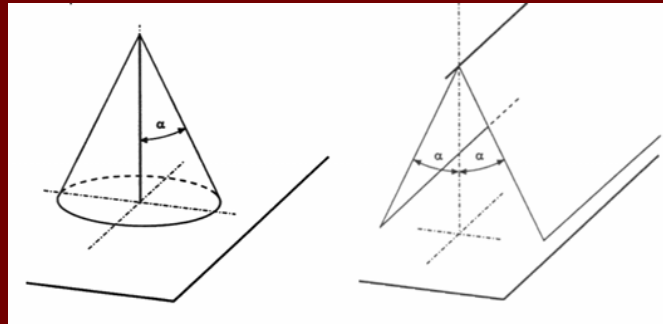
CONVENTIONAL SYSTEMS. Properly designed systems (e.g., NFPA 1997, IEEE 1998) and the efficacy of the conventional systems in practice. According to some standards, a wire mesh covering the top of the structure may play the role of the air terminals. (Note that the rolling sphere method would predict 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 objects such as trees and grounded air terminals on struc-

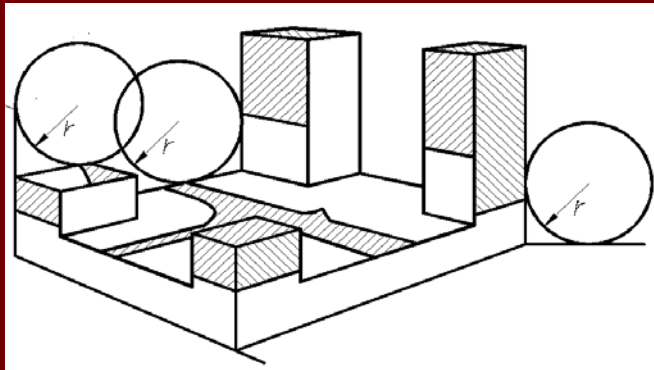
©2002 American Meteorological Society

Air terminals design methods by IEC 61024-1

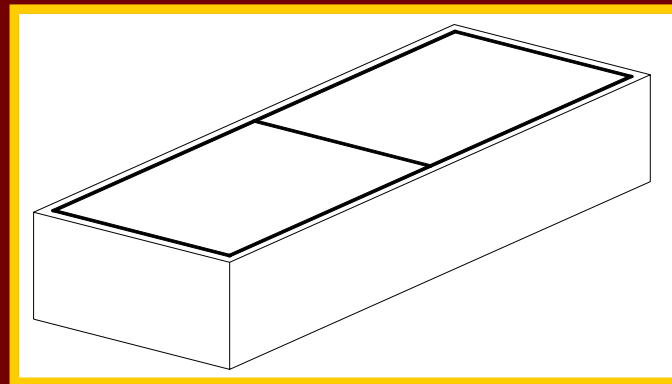
Protecton Angle
method



Rolling Sphere
method



Meshwork
method

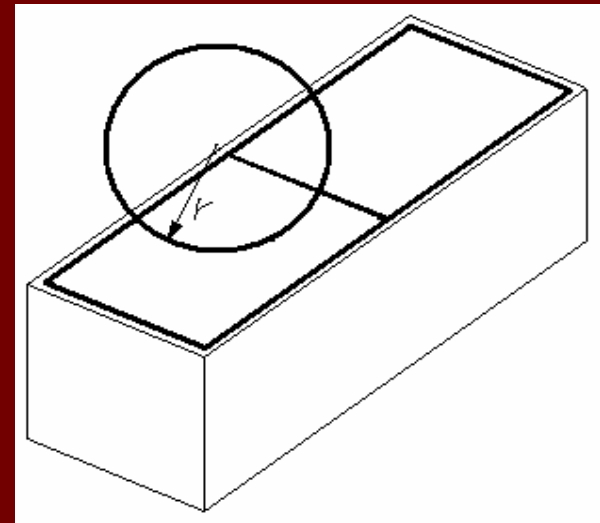
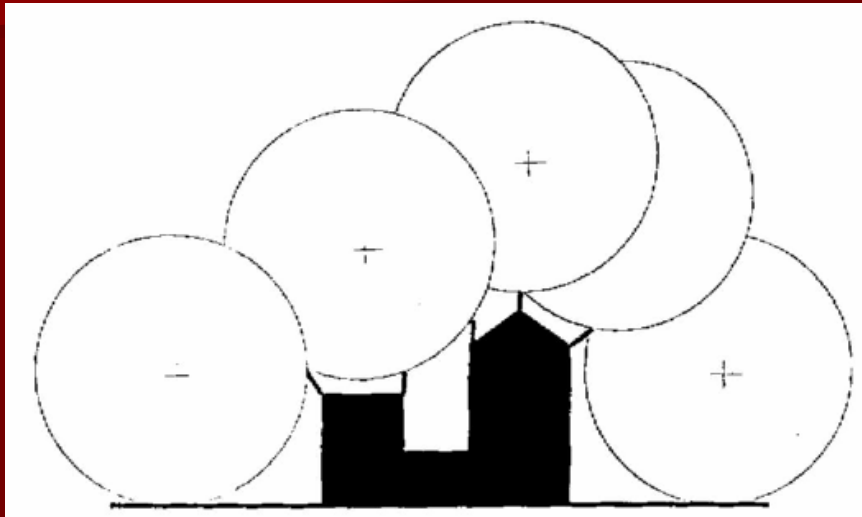


Reliable protection...

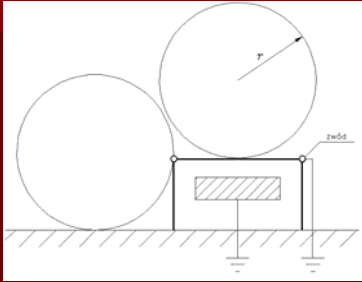
Protection... ???

RELIABLE

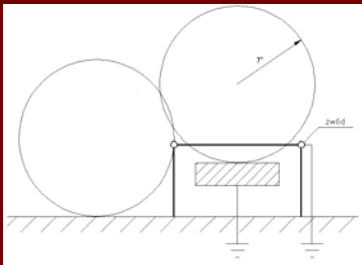
according IEC, if
the square side is
short enough
(e.g. $M \leq 20$ m for
the IV protection level)



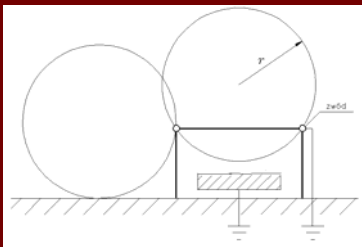
"Rolling Sphere" method: conventional (a), modified (b, c) ones



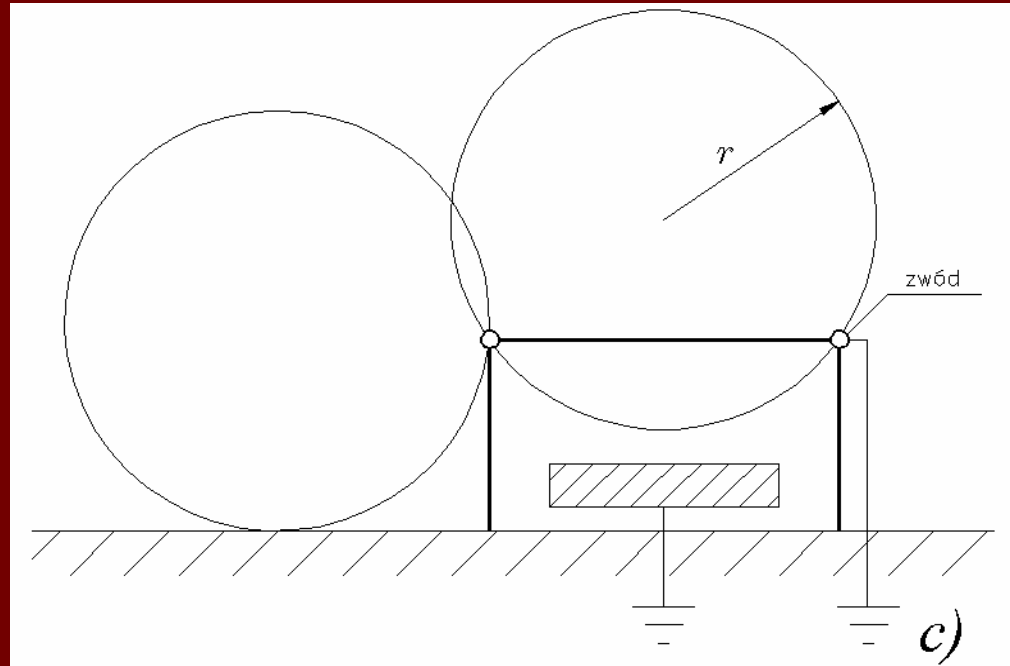
a)



b)



c)



c)

LIGHTNING PENETRATION THROUGH THE MESH FOR VERTICAL LEADER DIRECTION

1. Orientation distance, D

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

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

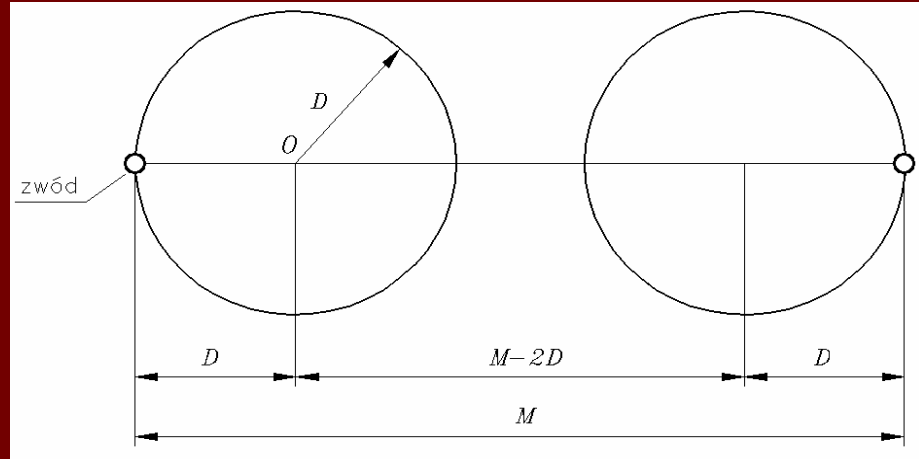
2. Leader slope, φ

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

MODEL I

$$(\varphi = 0)$$

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



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

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

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

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

	$D_{50\%} = 50$ 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

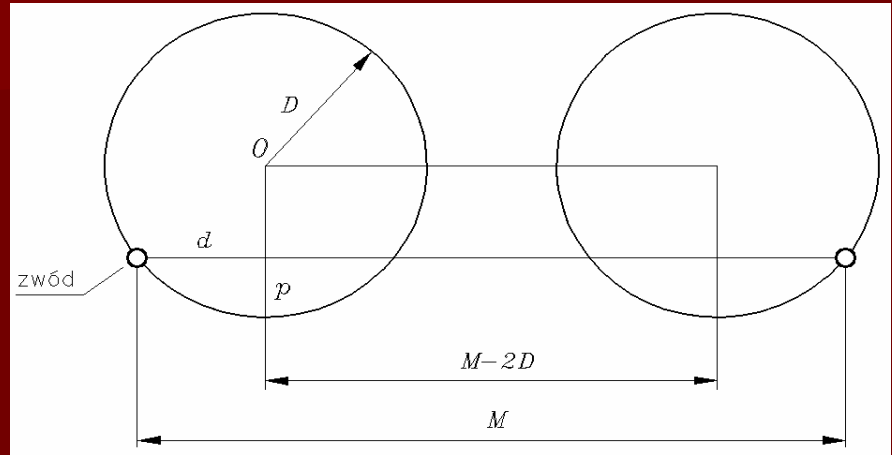
Protection failure coefficient k_{fv} for $M = 5$ m

	$D_{50\%} = 50$ 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



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

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

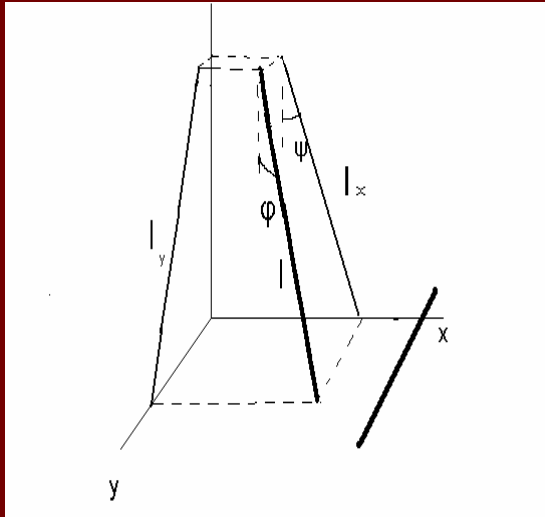
Protection failure coefficient k_{fv} ($p = 1 m$), for $M = 20 m$

	$D_{50\%} = 50 m$	$D_{50\%} = 100 m$	$D_{50\%} = 150 m$
$s=0,5$ $c=0,65$ ($s \cdot c=0,325$)	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

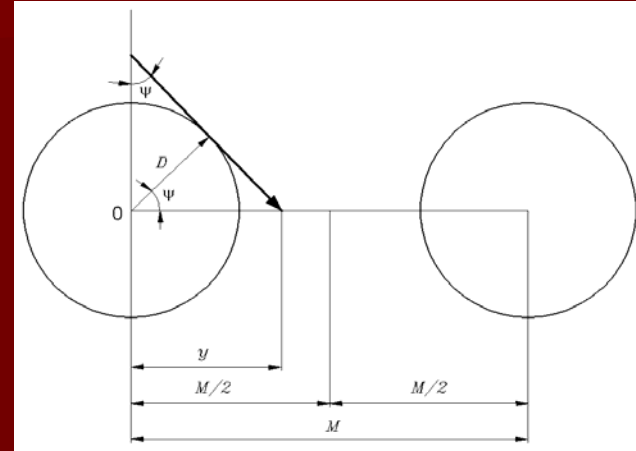
Leader slope ψ :

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

Model III

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

Number of lightnings penetrating **totally** the mesh



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

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

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

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

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

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

Coefficient of " overvaluation" f_v for $M = 5 m$

	$D_{50\%} = 50 m$	$D_{50\%} = 100 m$	$D_{50\%} = 150 m$
$s=0,5$ $c=0,65$ ($s \cdot c=0,325$)	–	–	–
$s=1,0$ $c=0,75$ ($s \cdot c=0,75$)	8,26	7,76	7,48
$s=1,5$ $c=0,85$ ($s \cdot c=1,275$)	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!