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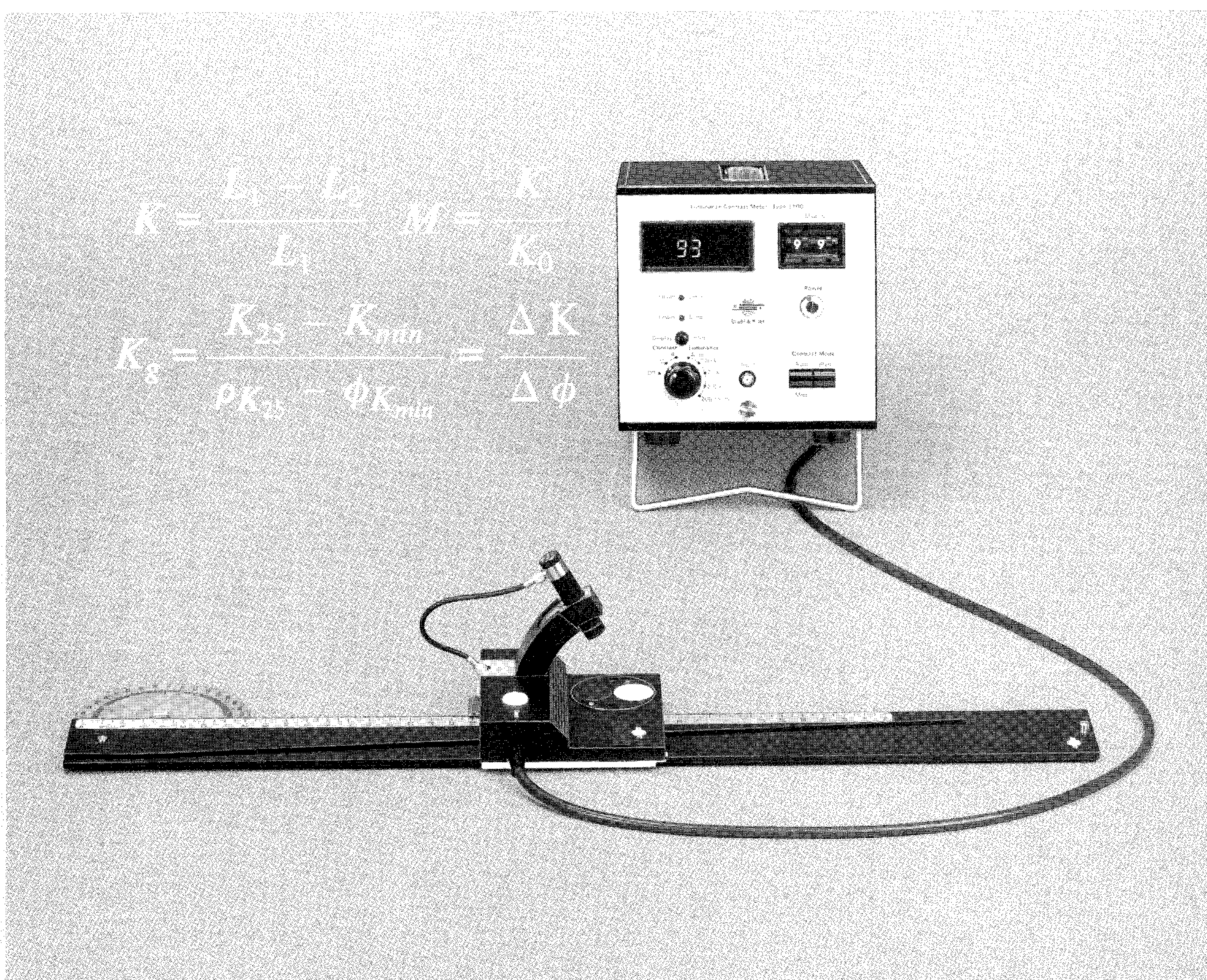

Practical Information about Contrast Rendering at the Office Worker's Desk

Reiner Pusch

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The Significance of Contrast for Vision

Contrast plays a crucial role in all visual perception by human beings. As everybody knows, vision can be divided into basic viewing activities, which in each case depend on the contrasts of the object viewed. Even with the basic viewing activity the sensitivity of discrimination is determined by the fact that a human being can only perceive objects if they present certain luminance differences against the background luminance; that is, if the object possesses enough contrast relative to its surroundings.

In contrast to illumination, it is the luminance of a visual object which produces the correlation with visual perception by human beings; the luminance L and the luminance contrast K are combined as measurement parameters for the perception of visual objects. It is consequently of great importance to use the luminance contrast K as the indicator of lighting quality for the office work place.

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Definitions of Contrast and Contrast Rendering

The term contrast is used according to the well known definition:

$$K = \frac{L_1 - L_2}{L_1}$$

where L_1 is the surrounding luminance and L_2 is the object luminance. The contrast K is a luminance difference relative to the surrounding luminance (1). Studies have determined the reduction in contrast resulting from light reflections or different systems of illumination (1, 2).

In particular we must refer to an evaluation technique for the characteristics of the contrast reduction, the ESI technique (3). In this technique the contrast reduction and its effect on visual performance is described quantitatively. In order to identify the contrast reduction in a lighting position, the contrast K is established relative to the contrast K_0 at fully diffuse light incidence, a ratio which is named the contrast rendering factor M:

$$M = \frac{K}{K_0}$$

The contrast rendering factor presupposes certain reflection properties of the background and the visual task, which must be kept constant during the investigation of K and K_0. During the investigations the dependence of the contrast rendering factor M on various paper and printing specimens was ascertained (4).

For the assessment of the contrasts K, K_0, the contrast rendering factors M, and the ESI values indoors, computers were used. The evaluation values for different lines of sight corresponding to the different arrangements of the writing desks were worked out in this way.

Measurement of Contrast

For advance planning with contrasts and contrast rendering factors, the practical information about these assessment values is necessary in the design of illumination installations. In principle the contrasts and the contrast rendering factors could be worked out from individual luminance measurements.

The Company of Brüel & Kjær has developed a luminance meter which can also determine luminance contrast and contrast reduction directly.

The design of the instrument is characterized by the luminance meter and two standard reflectance surfaces, which are measured one after the other. Contrast K is indicated straightaway from the luminances L_1 and L_2 of the two reflectance surfaces. The instrument aLso permits the dialling-in of a fixed contrast value, hence for instance the contrast for diffuse light-incidence K_0, through which the contrast reduction R is registered directly. The connection between the contrasts and the contrast rendering factor M exists as follows:

$$R = \frac{K_0 - K}{K_0} \; 100\% = (1 - M) \; 100\%$$

As can be seen from the measurement arrangement in Fig.1, the luminance meter has a measurement direction with the angle Θ, which persistently assumes the eye of the observer to be 40 cm above the table's edge. The measuring angle Θ is increased as the measuring point is moved from the table's edge towards the middle of the table.

The combined measurement system can also be directed sideways on a radius arm. In this way the evaluation values throughout the working areas on the writing desk can be measured at the correct angle.

Because the measurements of the luminance values, contrasts and the contrast rendering factors are dependant on the reflections of the reflectance surfaces, is it also necessary to specify the reflection characteristics of the reflectance surfaces in the interpretation of the measurement results. The reflectance surfaces used by B & K P1 and P2 show a clear reflection characteristic, which is illustrated in Fig.2, as a plot of the luminance factor β as the function of the angle of light incidence, γ_i. The luminance factor β is the quotient of the luminance of the reflectance surface and the luminance of a fully diffusely reflecting reflectance surface. The reflectance surfaces used by B & K P1 and P2 can be rated according to the Reitmaier rating scale (1) with a brightness perception G = 2 to 2,5, that is with a medium brightness.

For the discussion of the measurement results, the function $\beta = \int (\gamma_1)$ for the value of the "Pencil Task" has also been illustrated. These plots are almost independent of the angle of light incidence γ_i, PT1 and PT2 are almost diffuse with a brightness perception G = 1,1.

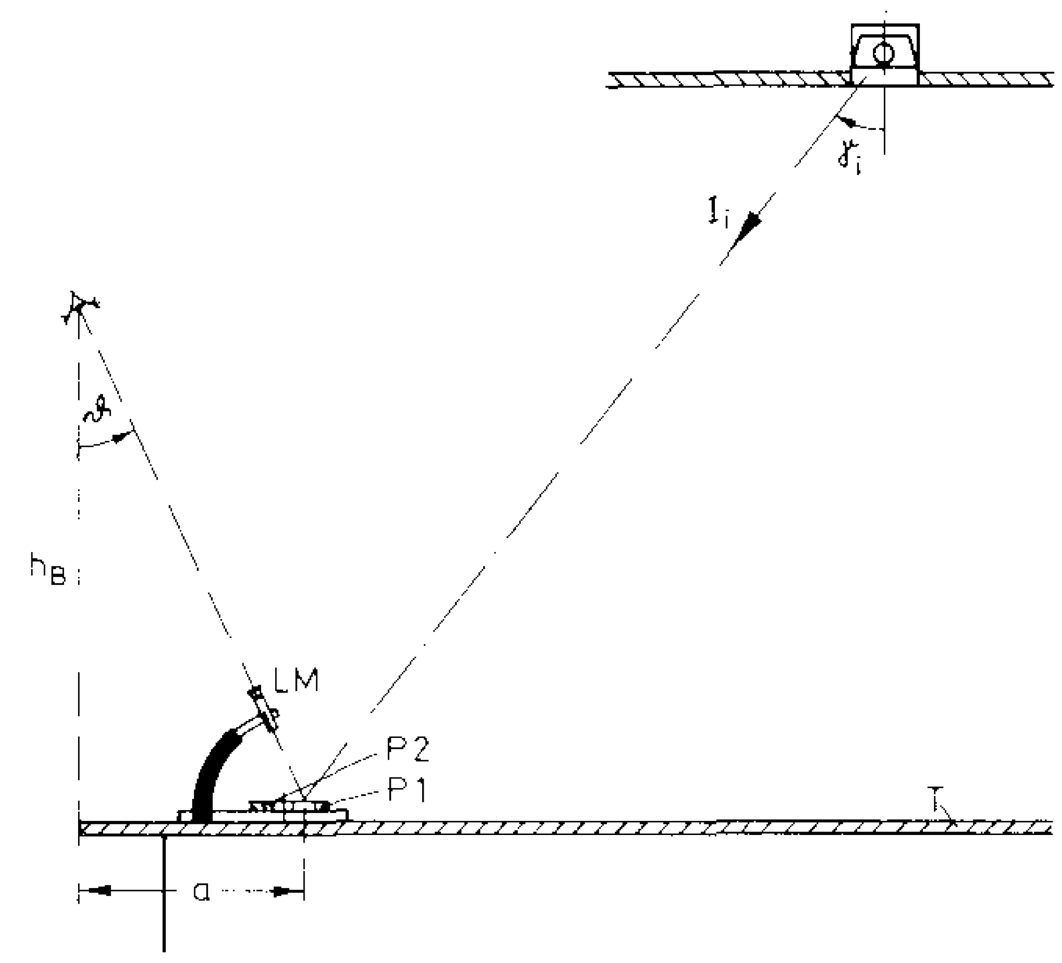

Fig.1.
Measuring arrangement
LMLuminance meter
P1 Test object for measuring the background luminance
P2 Test object for measuring the task luminance
ϑ Angle of measurement, corresponding to viewing direction
h_β Height of the observer's eye above the table surface
T Table surface
I_i luminous intensity of the *i*th light
γ_i Irradiation angle
α Distance of the measuring point from the edge of the table

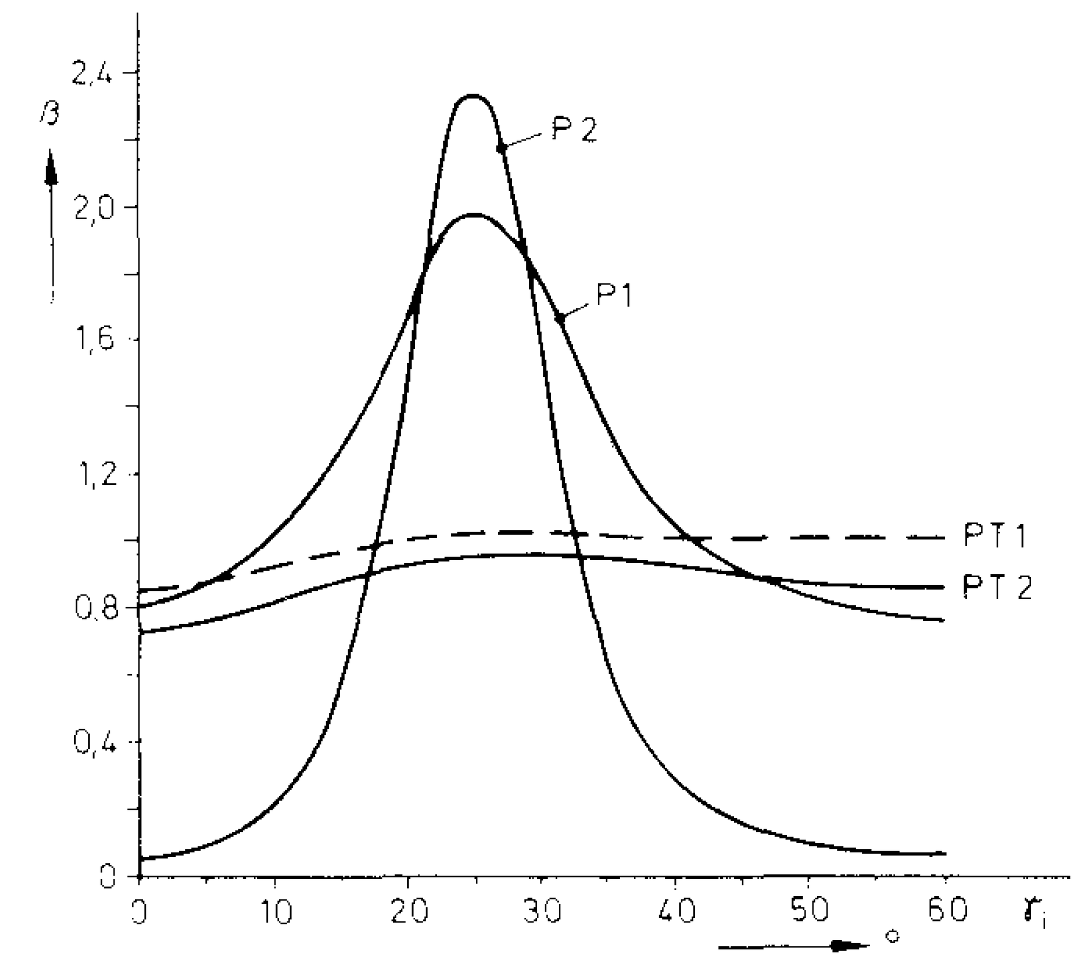

Fig.2.
Luminance factor β as a function of incident light angle γ_i
P1, P2 test objects for background and task luminance as supplied by Brüel & Kjær
PT1, PT2 values for background and task luminance of the "Pencil Task"

Table 1. Survey of the Lighting Installations Measured

Lighting Installation	Type of Room	Type of Luminaire	Installation of Luminaires	Number of Measured Places	Arrangement of Places
1	Office	Luminaire with louvres	Broken light-band	5	Diagonal
1a	Office	Luminaire with louvres + desk lamp	Broken light-band	4	Diagonal
2	Drawing office	Specular-reflector luminaires	Broken light-band	6	Along and crosswise
3	Work place with VDU terminal	Specular-reflector luminaires	Broken light-band	6	Crosswise between light-bands
4	Office	Luminaire with white plastics diffuser	Light-band	5	Diagonal between light-bands
5	Office	Luminaire with white louvres	Light-band	7	Crosswise between light-bands

Measurement results on Real Desk Work Places

Measurements were carried out with the luminance contrast meter in various offices and drawing offices (7). Table 1 gives a survey of the light installations measured. The rooms were all in use, they had not been selected from the point of view of contrast rendering, and the furnishing of the rooms was first and foremost based on requirements of work.

The results of the measurements of the luminance contrast K and the contrast rendering factors M for the lighting installations are included in Table 2. Only the values measured in this way at the work place at a measurement angle Θ = 25° were recorded, from which the minimum and the maximum value and a mean value of a lighting installation were taken.

The results of the contrast K and the contrast rendering factors M are altogether very alike. Through an adequate selection of lights and a relatively favourable arrangement of work places with regard to the lighting installation good contrast conditions have been achieved. The lower values in installation 1 were raised quite considerably through the practical management of the lighting installation as 2 K – lighting, installation 1 a (5, 6). In installation 4, an unfavourable site is diagnosed with k_{min} = 86%; in the middle, good contrast conditions are also given at the work places in this room.

Besides the measurements at the respective work places, a systematic section through a room can also be undertaken. This evaluation possibility will be shown by means of lighting installation 2. The arrangement of lights and the position of the measuring points at intervals of 40 cm in the room is shown in Fig.3. This representation of the contrast rendering factors M of the measuring points 1 to 6 is followed in the line of sight along and across the row of lights in Fig.4. Owing to the broad polar diagram of these lights a higher contrast rendering factor M is always shown longitudinally in the measurement direction; on the other hand the measurements across the light bands bring clear deviations from the contrast rendering factors M. The measurement results make it possible to establish good positions for the work places. With places arranged across the light bands the middle of the work place should be at points 1, 5 or 6, as the measuring points lying between them are lower, i.e. the contrast is more unfavourable.

Comparison of the Results of the Measurements

The absolute values K and M are dependant on the reflectance surfaces, which were used at the measurement. As the luminance factor β of the B & K reflectance surfaces are not identical with the values of the "Pencil Task" tests, a direct record of the contrast rendering factors M according to the ESI-procedure is not possible. For some of the work places measured a mathematical comparison between the contrast rendering factors M and the data of

Table 2
Measuring results of luminance contrasts K and contrast rendering factors M

Lighting installation	Measurement value at the work place					
	Luminance contrasts K %			Contrast rendering facter M		
	K_{min}	K_{max}	K_m	M_{min}	M_{max}	M_m
1	76	93	88	0,84	1,02	0,968
1a	90	95	92,7	0,97	1,03	1,01
2	87	96	92,7	0,96	1,05	1,02
3	89	95	93,8	0,96	1,04	1,02
4	86	95	92,2	0,95	1,04	1,01
5	89	95	92,2	0,97	1,04	1,01

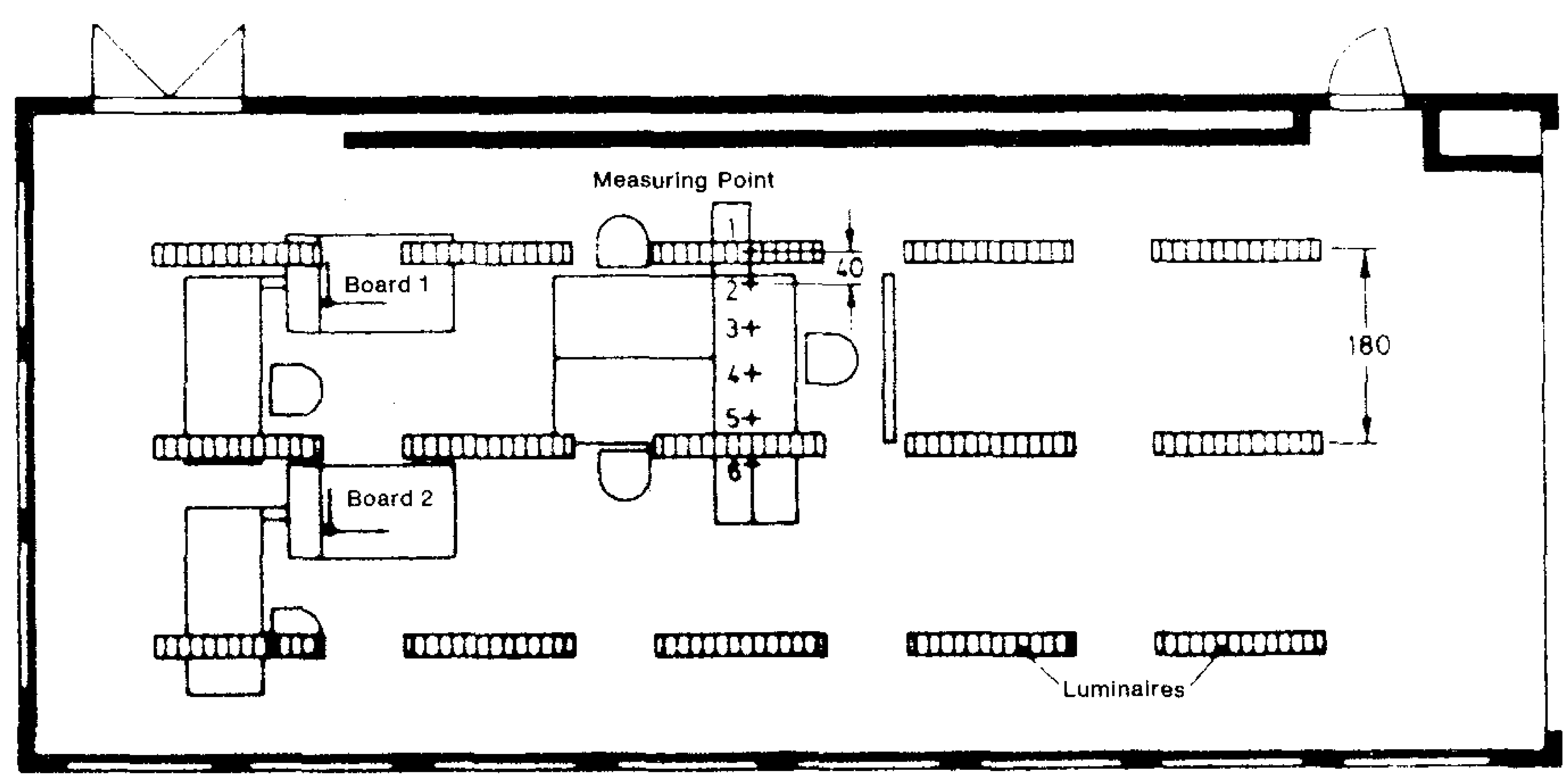

Fig.3
Lighting Installation 2
Arrangement of the reflector-screen lights and position of the measuring point

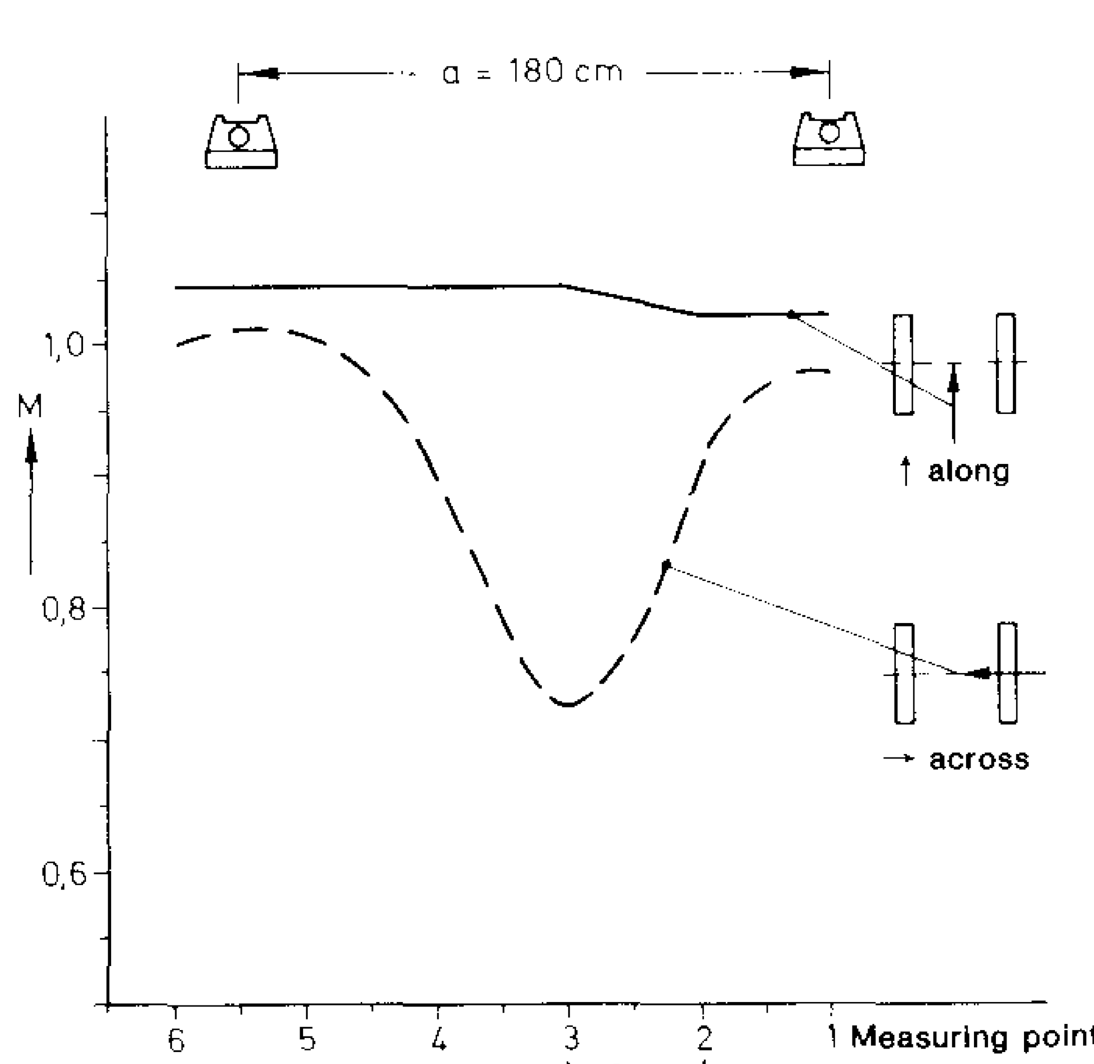

Fig.4
Local distribution of contrast rendering factors M for the lines of sight along and across the row of lights

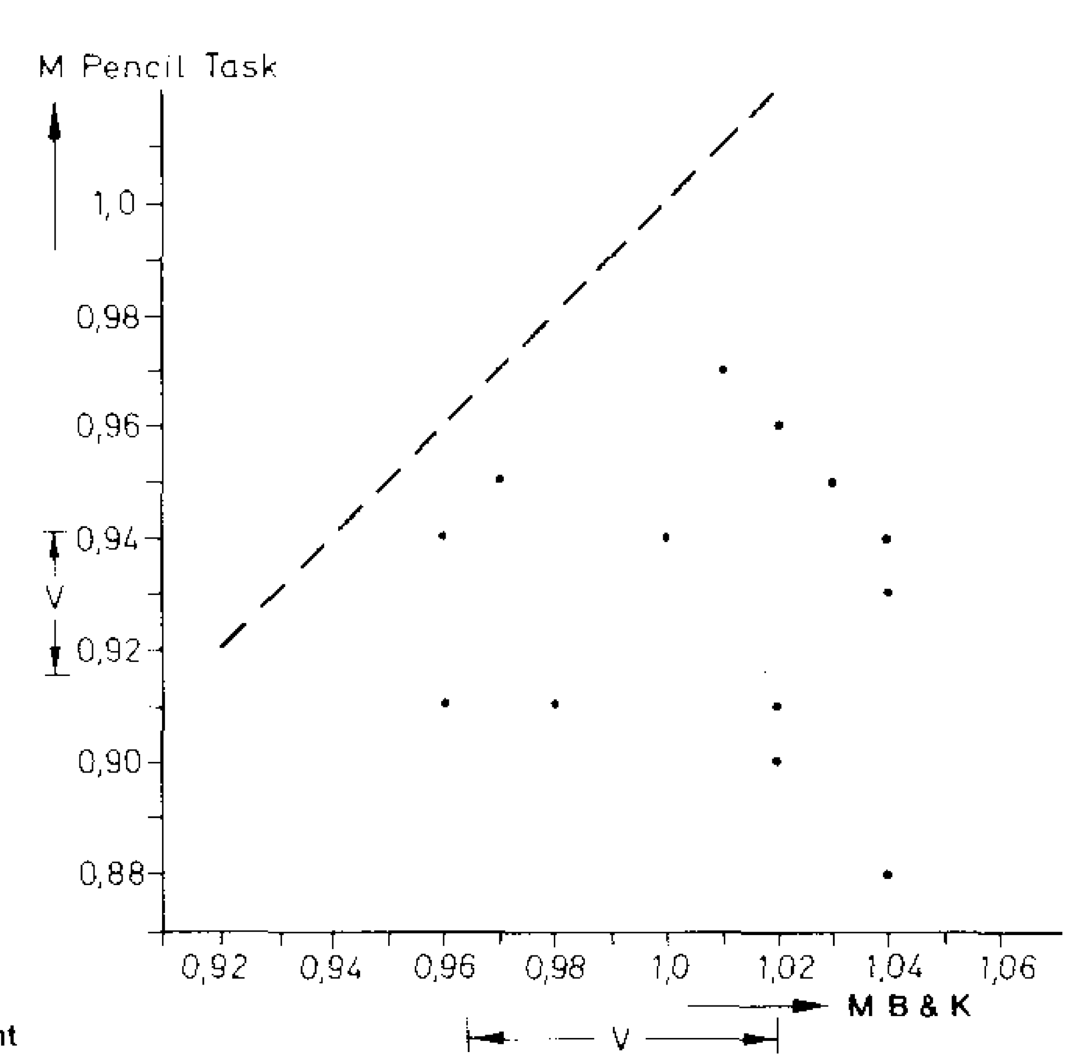

Fig.5
Comparison of contrast rendering factors M between measurements with B & K test objects and calculated values for the "Pencil Task"

the "Pencil Task" were carried out. The values that are put together in Table 3 illustrate that there were also found better and worse contrast rendering factors with the "Pencil Task", however, between them the values are less differentiated than with the B & K reflectance surfaces. These quantitative differences can be traced to the more highly reflecting parts in the reflection characteristics of the B & K reflectance surfaces.

A comparison between the two contrast rendering factors from the "Pencil Task" and the B & K standard shows even higher values with the B & K reflectance surfaces, with a standard deviation S = 0,1044. The description of this comparison follows in Fig.5. With due regard to the small number of spot checks with the contrast standard, confidence limits for the values which are here under consideration have been worked out. The contrast rendering factors M of the "Pencil Task" lie within confidence limits V = ± 0,0134 and for the B & K reflectance surfaces within the limits V = ± 0,0288. Thus a differentiated statement about the contrast rendering factors for the measurement values can be reached with the B & K reflectance surfaces.

Directional Measurement Values

The assessment of a work place with the quantities contrast K and contrast rendering factor M can also be made from different viewing angles ϑ and all directions φ. In this way the contrast and the contrast rendering factors of a site are obtained as functions of direction, i.e., the combined statement about the contrast viewing in the working area. For site 5 in the lighting installation 2 the directional recording (mapping) of the contrast is shown in Fig.6. The regional change of the contrast and consequently also of the contrast rendering factor is clear from the measurement. The contrasts are clearly reduced in the outer areas, where there are worse viewing conditions than in the central part of the working area.

Previous measurements gave only the results of the measurement angle ϑ = 25° in each case, which can be seen as the mean viewing angle of human beings at desk work places.

Table 3
Comparison of contrast rendering factors M

Lighting Installation	Work Place	Measurements with B & K test objects	Calculations with "Pencil Task" values
1	1	1,02	0,9
	2	0,96	0,91
	3	1,0	0,94
	4	0,84	0,92
	5	1,02	0,91
1a	1	1,03	0,95
	2	0,97	0,95
	5	1,04	0,96
2	4	1,04	0,94
	5	0,98	0,91
	6	0,96	0,94
3	2	0,96	0,91
	3	1,04	0,93
	4	1,04	0,88

Standard deviation: s = 0,1044

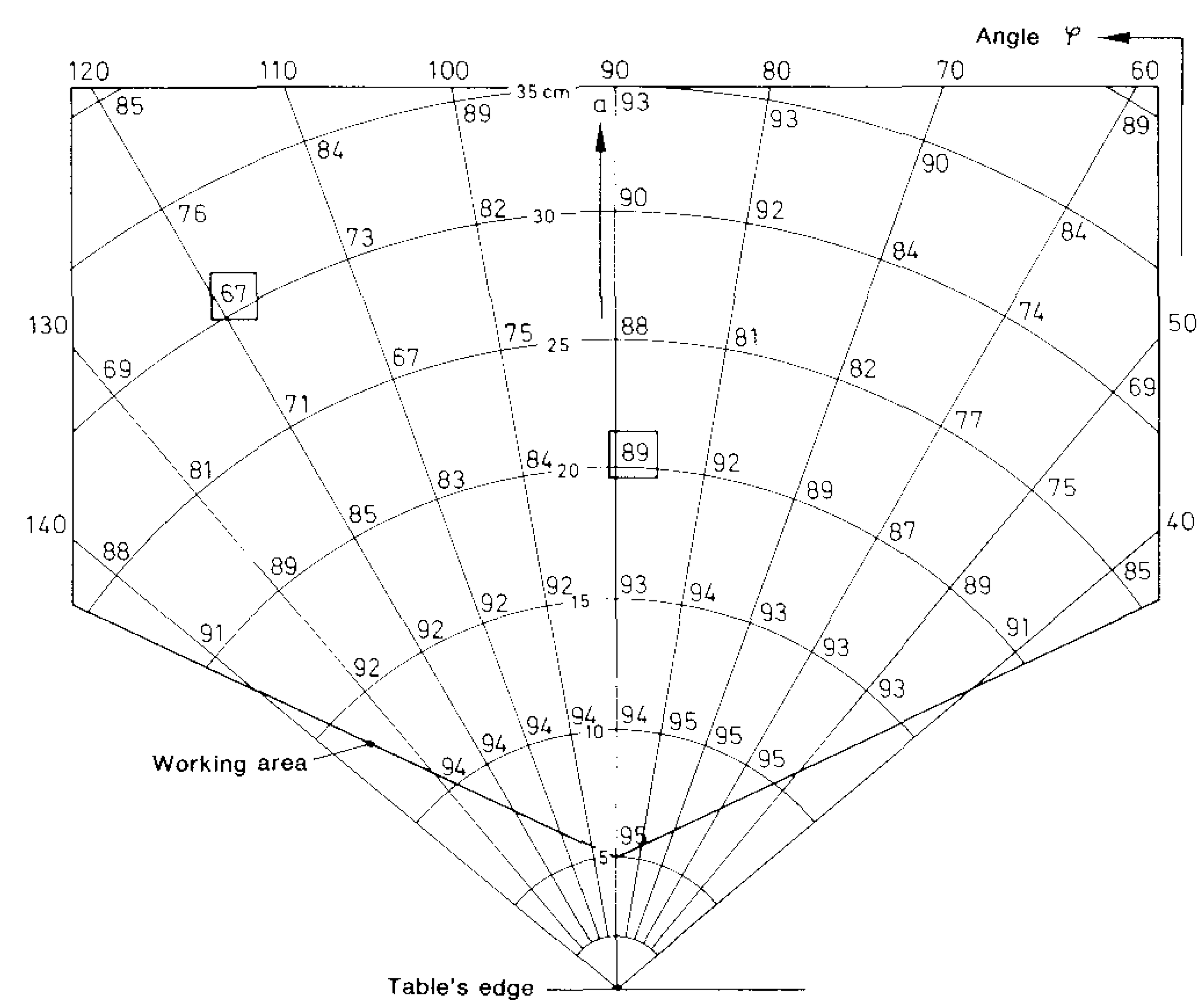

Fig.6
True-angle recordings of the contrasts K for work place 5, lighting installation 2, K_{25} = 89% with ϑ = 25°, K_{min} = 67%

This contrast value is marked as K_{25} in Fig.6. The minimum contrast has been marked with K_{min} in the figure. For most work places it appears to be sufficient to record the values K and M with the viewing angle ϑ = 25°. At places which must be described as critical the directional rating is certainly interesting and of strong value as evidence. Only through this recording of the full work field does a statement about the regularity of the contrast and the contrast rendering factors become meaningful.

In order to reach a simpler statement about the regular distribution of the contrasts on the work field, a contrast gradient K_g can be determined besides the value K_{25}. In this way the difference of the contrasts

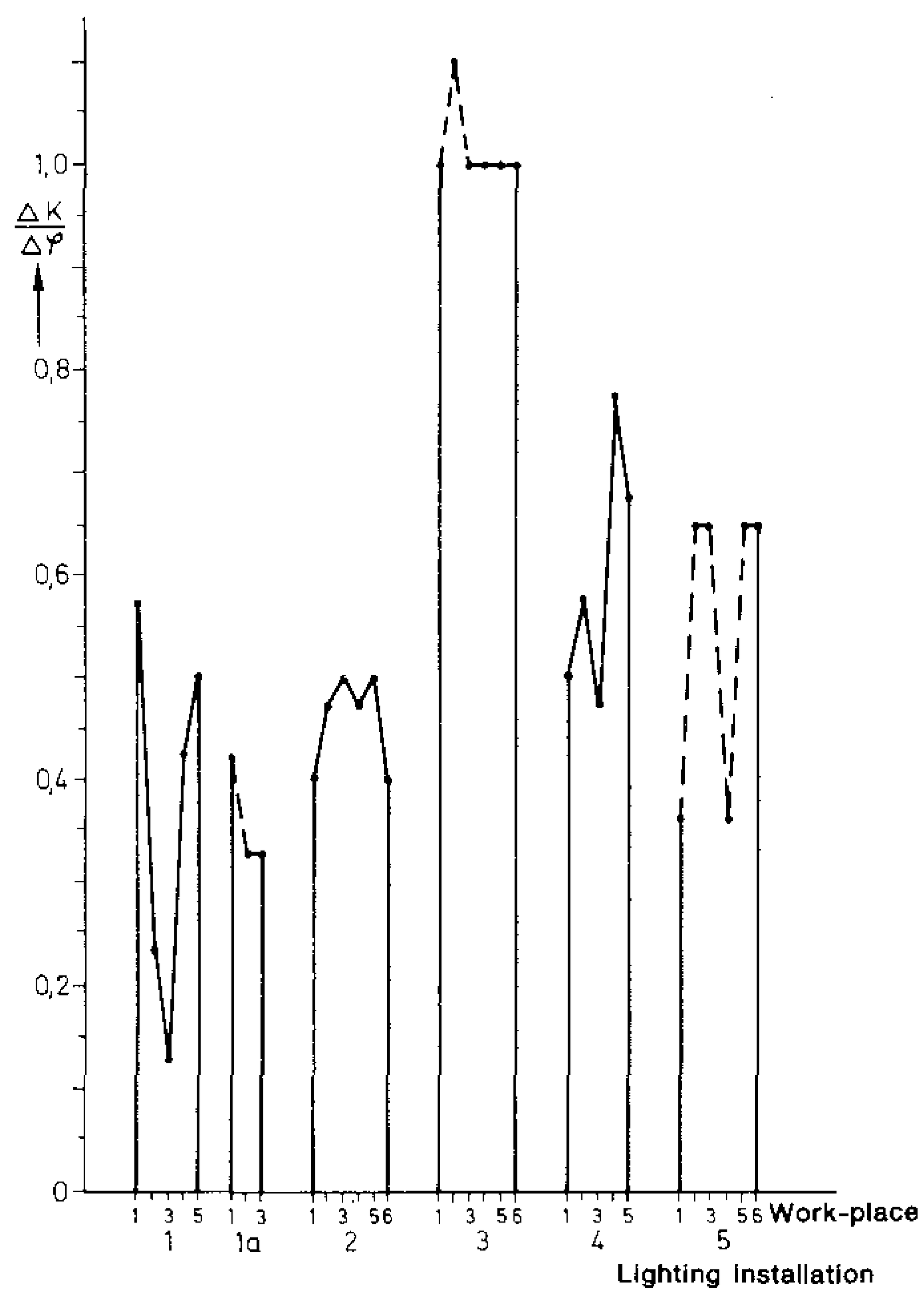

Fig.7
Contrast gradients Δ K/Δφ for the work places recorded

$K_{25} - K_{min}$ versus the difference in the angle φ for these two contrasts is obtained:

$$K_g = \frac{K_{25} - K_{min}}{\varphi K_{25} - \varphi K_{min}} = \frac{\Delta K}{\Delta \varphi}$$

For the work places assessed here the contrast gradient K_g was determined in each case. The K_g values of each place can be seen in Fig.7. In this connection it shows that differences exist in the contrast gradient from one installation to another. The regularities of the contrasts in the lighting installations are also different throughout. Low contrast gradients mean little deterioration of the contrasts within the work area respectively — the contrast decreases only at the edge of the work area.

From Fig.7 it is clear that the lighting installations 1, 1a and 2 obtain low contrast gradients on an average of all work places, that is show good regularities for the contrast viewing in the whole work field.

Further Usage

It can be shown with the measurements that we have carried out here, that contrasts K and contrast rendering factors at the office work place can be determined for installed lighting systems. With this technique it is possible to achieve an optimization of the work places whereby both the lighting system and the position of the work places can be altered according to the lighting system (5,6).

From the estimation values of the viewing angle $\vartheta = 25°$ a statement about the total work field can be reached by means of the contrast gradient. It can be necessary to gather experience of these values, in order to arrive at permissible limits.

The drawback of the different reflection characteristics between "Pencil Task" and B & K should be removed by the fact that an international convention is agreed about the usage of a reflectance surface.

The facility for measuring contrasts at the work place must be looked upon as something very positive. Hereby a step towards better judgement of the situation at the work place has also been taken, and consequently towards the improvement of viewing conditions.

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