International Standard 6504/1

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Paints and varnishes — Determination of hiding power — Part 1 : Kubelka-Munk method for white and light-coloured paints

Peintures et vernis — Détermination du pouvoir masquant — Partie 1 : Méthode de Kubelka-Munk pour les peintures blanches et les peintures claires

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been authorized has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 6504/1 was developed by Technical Committee ISO/TC 35, *Paints and varnishes*, and was circulated to the member bodies in April 1981.

It has been approved by the member bodies of the following countries :

Australia	Germany, F. R.	Poland
Austria	Hungary	Portugal
Belgium	India	Romania
Brazil	Ireland	Sri Lanka
China	Italy	Sweden
Czechoslovakia	Kenya	Switzerland
Dominican Republic	Netherlands	United Kingdom
Egypt, Arab Rep. of	Norway	USSR

The member bodies of the following countries expressed disapproval of the document on technical grounds :

Canada
France

Paints and varnishes — Determination of hiding power — Part 1 : Kubelka-Munk method for white and light-coloured paints

0 Introduction

This International Standard is one of a series of standards dealing with the testing and sampling of paints, varnishes and related products.

ISO 3905 and ISO 3906 specify methods for determining the contrast ratio of paints at a fixed spreading rate, by applying paint films to black and white charts and to polyester film respectively. They depend on the observation that there is a linear relationship between contrast ratio and reciprocal film thickness, at least over a limited range of film thickness.

Hiding power of paints is generally defined as the spreading rate required to give a contrast ratio of 98 %. To determine this by the methods specified in ISO 3905 and ISO 3906 would be time-consuming and require considerable extrapolation which often exceeds the limit of linearity of the relationship between contrast ratio and spreading rate. Therefore, this method for the determination of hiding power, involving the Kubelka-Munk (K-M) equations which relate scattering and absorption coefficients to optical properties, has also been standardized.

1 Scope and field of application

This International Standard specifies a method to be used for determining the hiding power (spreading rate necessary to give a contrast ratio of 98 %) of white or light-coloured paints. It is restricted to paint films having the tri-stimulus value of $Y > 70$. It is not applicable to fluorescent or metallic paints.

2 References

ISO 1512, *Paints and varnishes — Sampling.*

ISO 1513, *Paints and varnishes — Examination and preparation of samples for testing.*

ISO 1515, *Paints and varnishes — Determination of volatile and non-volatile matter.*

ISO 2808, *Paints and varnishes — Determination of film thickness.*[1]

ISO 2811, *Paints and varnishes — Determination of density.*

ISO 3905, *Paints and varnishes — Determination of contrast ratio (opacity) of light-coloured paints at a fixed spreading rate (using black and white charts).*

ISO 3906, *Paints and varnishes — Determination of contrast ratio (opacity) of light-coloured paints at a fixed spreading rate (using polyester film).*

3 Principle

The method is based on the Kubelka and Munk equations relating the scattering and absorption coefficients of pigmented films to their colour and opacity.

For the determination of hiding power, both the reflectance (R_B) of a paint film of thickness t on a black background and the reflectivity (R_∞) are required for introduction into the Kubelka-Munk equations (clause 4).

4 Kubelka-Munk equations

The Kubelka-Munk (K-M) equations required are

$$a = \frac{1}{2}\left(R_\infty + \frac{1}{R_\infty}\right) \qquad \dots (1)$$

$$b = a - R_\infty \qquad \dots (2)$$

$$R_B = \frac{1}{a + b \coth bSt} \qquad \dots (3)$$

$$R = \frac{1 - R_g (a - b \coth bSt)}{a + b \coth bSt - R_g} \qquad \dots (4)$$

where

R_∞ is the reflectivity, i.e. the reflectance of a paint film of such thickness that further increase in thickness gives no further change in reflectance;

R_B is the reflectance of a paint film of thickness t applied over a black background;

R is the reflectance of a paint film of thickness t applied over a white background of defined reflectance R_g (for this method, $R_g = 0{,}80$);

S is the scattering coefficient per micrometre (μm^{-1});

t is the thickness, in micrometres, of the paint film.

When using equations (1) to (4) with this method, the measured CIE tristimulus values Y divided by 100 are inserted for R, R_B and R_∞, respectively.

1) At present at the stage of draft. (Revision of ISO 2808-1974.)

The hiding power $V_{0,98}$ is the spreading rate necessary to give a contrast ratio (R_B/R) of 0,98, and is determined via the equivalent film thickness $t_{0,98}$ according to the equation

$$V = \frac{1\,000}{t}$$

where

V is the hiding power, in square metres per litre;

t is the thickness, in micrometres, of the wet paint film.

From equations (3) and (4), when the contrast ratio (R_B/R) is equal to 0,98

$$\frac{a - 0{,}8 + b \coth bSt_{0,98}}{[a + b \coth bSt_{0,98}] \{ 1 - 0{,}8 [a - b \coth bSt_{0,98}]\}} = 0{,}98$$

or, after rearrangement

$$t_{0,98} = \frac{1}{bS} \operatorname{arcoth} \left(\frac{0{,}02 + \sqrt{D}}{1{,}568\ b} \right) \qquad \dots (5)$$

where

$D = 3{,}136\ a\ [1 - 0{,}98\ (1 - 0{,}8\ a)] - 2{,}508\ 4$

and

$$V = \frac{1\,000}{t} = \frac{1\,000\ bS}{\operatorname{arcoth} \left(\frac{0{,}02 + \sqrt{D}}{1{,}568\ b} \right)} = \alpha S \qquad \dots (6)$$

NOTE — If $y = \coth x$, $x = \operatorname{arcoth} y$.

It can be seen that for constant values of R_g (0,80) and contrast ratio (0,98), factor α is a function of R_∞.

The scattering coefficient S is determined from a rearrangement of equation (3), the values of a and b being known by calculation from equations (1) and (2) respectively, as follows :

$$St = \frac{1}{b} \operatorname{arcoth} \left(\frac{1 - aR_B}{bR_B} \right) \qquad \dots (7)$$

To simplify the calculations, graphs are available for the determination of the product St from measured values of R_B and R_∞.

The scattering coefficient S is calculated by dividing St by the film thickness t, and $V_{0,98}$ is obtained from equations (5) and (6). A table of values of α for various values of R_∞ simplifies the calculation.

NOTE — Suitable tables and graphs are referred to in DIN 53 162 and in ASTM D 2805. The table in annex B is taken, with modifications, from ASTM D 2805 and the graphs are from *Official Digest* **35**, 464, p.1871 (1963).

5 Apparatus and materials

5.1 Substrates

5.1.1 Determination of R_B

5.1.1.1 Glass plates, black, plane, polished, not less than 6 mm thick and of dimensions at least 200 mm × 200 mm,

or

5.1.1.2 Polyester film, clear, untreated, transparent, of uniform thickness between 30 and 100 µm, and of dimensions at least 100 mm × 150 mm, together with a glass plate as specified in 5.1.1.1.

NOTE — Commercially available polyester sheet has been found to be satisfactory.

5.1.2 Determination of R_∞

5.1.2.1 Smooth surfaced paper charts, readily wetted by, but impervious to, solvent and water-thinned paints, and similar in reflectance to the paint to be tested.

Suitable chart colours are grey for paints of low reflectivity and white for paints of high reflectivity. Alternatively, ceramic tiles or glass may be used.

5.2 Film applicators

A series of film applicators giving films of uniform thickness within the range 40 to 150 µm is required. For application to glass, bar applicators are suitable. For application to polyester film or paper charts, wirewound applicators are more suitable.

The film laid down shall be at least 150 mm wide (using glass) or 70 mm wide (using polyester film) to cover areas, at a uniform thickness, of at least 100 mm × 125 mm or 60 mm × 60 mm respectively. The application of uniform films is facilitated by the use of automatic applicators, which are recommended.

5.3 Reflectometer

A photoelectric instrument is required, giving an indicated reading proportional to the intensity of light reflected from the surface under test to an accuracy of 0,1 % of full scale deflection, and having a spectral response approximating to the product of the relative spectral energy distribution of CIE illuminant D 65 and the colour matching function $\bar{y}(\lambda)$ of the CIE standard observer.

NOTES

1 It is recognized that the relative geometrical arrangement of the illuminating beam and the light detector can affect the measurement of reflectance, but it is considered that variations arising from this factor in commercial reflectometers should be considerably less than the figures for reproducibility stated in clause 9. In the event of dispute, 8°/diffuse geometry, without gloss trap, should be used.

2 For other than reference purposes, illuminant C may be used.

5.4 Template

A rectangular metal template with minimum dimensions of 100 mm × 125 mm is required for films applied to black glass. For films on polyester film, a metal template or die stamp with minimum dimensions of 60 mm × 60 mm is required.

6 Sampling

Take a representative sample of the product to be tested as described in ISO 1512.

Examine and prepare the sample for testing as described in ISO 1513.

7 Procedure

7.1 Determination of R_∞

Apply a few millilitres of the paint sample in a line across one end of a paper substrate and spread it immediately by drawing down a suitable applicator at a steady rate so as to give a uniform film thickness. Repeat the operation so as to provide uniform films having dry film thicknesses of about 75, 100, 125 and 150 µm. Dry the coatings as described in 7.2.1.3. Measure the reflectance of each coating at four positions on each coated paper. Record the value of reflectance which is independent of the film thickness as the reflectivity R_∞.

NOTE — If the reflectance is still increasing when the film thickness reaches 150 µm, further coats should be applied until a constant reflectance is obtained.

7.2 Determination of R_B

7.2.1 Preparation of test films

Apply a film thickness that will give a dry film having a reflectance at least 0,02 lower than the reflectivity R_∞ of the paint sample.

7.2.1.1 Method using polyester film

Prepare the polyester film (5.1.1.2) for coating by either

a) spreading it on a black glass plate (5.1.1.1) which has first been moistened with just sufficient white spirit (a few drops), to hold the film in position by surface tension. Ensure that none of the liquid wets the upper surface of the film and that no air bubbles are trapped under it;

or, if wirewound applicators are to be used

b) by fixing the polyester film at one end and laying it over a flat rubber block.

Apply a few millilitres of the paint sample, according to the film thickness required, in a line across one end of the polyester film and spread it immediately by drawing down a suitable applicator at a steady rate to give a uniform film thickness. Prepare a total of four films in this way.

7.2.1.2 Method using black glass plates

Apply a few millilitres of the paint sample in a line across one end of a black glass plate (5.1.1.1) and spread it immediately by drawing down a suitable applicator at a steady rate to give a uniform film thickness. Repeat the application with different black glass plates (5.1.1.1) until four uniform films of approximately the same thickness have been prepared.

7.2.1.3 Drying and conditioning

With the coated substrates in a horizontal position, dry the paint by the appropriate procedure for the type of paint or as agreed between the parties. Maintain the dried test films at a temperature of 23 ± 2 °C in a dust-free atmosphere having a relative humidity of 50 ± 5 % for at least 24 h, but not more than 168 h, before carrying out the reflectance measurements.

7.2.2 Measurement of reflectance R_B

NOTE — Variation in readings is likely to be the result of non-uniform application of the paint film and is dependent on the techniques used. If the precision (clause 9) is not obtained, the technique should be re-examined.

7.2.2.1 Method using polyester film

Fix the coated polyester films over a black glass plate, introducing a few drops of white spirit between the underside of the film and the glass to ensure optical contact. Measure the reflectance of the test films at a minimum of four positions and calculate the mean reflectance R_B of each coated plate.

7.2.2.2 Method using black glass plates

Measure the reflectance R_B directly by means of the reflectometer (5.3), taking readings at a minimum of four positions on each coated plate, avoiding its edges, and calculate the mean reflectance R_B of each coated plate.

7.3 Determination of film thickness

NOTE — The method using polyester film (7.3.1) is preferred. Other methods for measuring wet film thickness, based on those given in ISO 2808, may also be found to be suitable.

7.3.1 Method using polyester film

By means of the metal template and a sharp knife or precision die stamp, cut equal areas of dimensions at least 60 mm × 60 mm from the centres of the coated polyester films.

Weigh the detached pieces to the nearest 0,1 mg. Remove the paint film by the use of a solvent which has been found to have no effect on the dry mass of the polyester film, and, after thorough drying, reweigh the film. Record the mass m of the paint film, i.e. the difference in mass between the coated and uncoated polyester film, and repeat the procedure with the other three films tested.

NOTE — If difficulty is experienced in removing the paint film with solvent, an approximation to the dry film mass may be obtained from the difference in mass between coated and uncoated polyester films of the same area.

7.3.2 Method using black glass plates

Cover the area of the film previously used for the measurement of reflectance R_B with the metal template (5.4), ensuring that the template is not within 20 mm of any edge of the film. Scrape away and discard the excess film around the template using a fresh razor blade in a holder. Remove the template and scrape the remaining film from the substrate on to a tared weighing dish. Manipulate the razor blade at all times so that the blade is almost flat on the glass and cannot nick or scratch the glass substrate. Record the mass m, to the nearest 0,1 mg, and repeat the procedure with the other three films tested.

8 Expression of results

8.1 Calculation of wet film thickness

Calculate the wet film thickness of each of the four films, from the equation

$$t = \frac{m}{A \times \varrho \times \mathrm{NV}} \times 10^8$$

where

m is the mass, in grams, of the paint film;

A is the area, in square millimetres, of the template;

ϱ is the density, in grams per millilitre, of the paint, determined by the method specified in ISO 2811;

NV is the non-volatile matter content, expressed as a percentage by mass, of the paint, determined by the method specified in ISO 1515;

t is the wet film thickness, in micrometres.

8.2 Calculation of hiding power

Calculate the hiding power, $V_{0,98}$, using the equations given in clause 4, from the measured values of R_B and t for each film, and from the mean value of R_∞.

Examples of the calculations, using both the table and graphs and directly from the equations, are given in annex C.

9 Precision

The precision of the method, as obtained by statistical examination of interlaboratory test results, is as follows.

9.1 Repeatability (r)

The value below which the absolute difference between two single test results on identical material, obtained by one operator in one laboratory using the same equipment within a short interval of time using the standardized test method, may be expected to lie with a 95 % probability, is 2 %.

9.2 Reproducibility (R)

The value below which the absolute difference between two single test results on identical material, obtained by operators in different laboratories, using the standardized test method, may be expected to lie with a 95 % probability, is 6 %.

10 Test report

The test report shall contain at least the following information :

a) the type and identification of the paint under test;

b) a reference to this International Standard (ISO 6504/1);

c) the result of the test;

d) the paint density and the non-volatile matter content, expressed as a percentage by mass, used in the calculation of the test result;

e) the drying time (and/or stoving conditions);

f) whether black glass plates or polyester film were used as the substrate;

g) any deviation, by agreement or otherwise, from the procedure specified;

h) the date of the test.

Annex A

Graphs for determination of St from R_B and R_∞

After determination of the values of R_B for each film and the mean value of R_∞, refer to the graph in figure 1 to ascertain which of the larger scale graphs is appropriate. (This is indicated by the encircled number.)

In each of the graphs, St is plotted against R_B for a range of values of R_∞, which are recorded on each curve. An example of the use of these graphs is given in annex C.

Annex B

Table of values of reflectivity R_∞ and factor α

R_∞	Factor α	R_∞	Factor α	R_∞	Factor α	R_∞	Factor α
0,125	1 352,1	0,455	391,3	0,630	249,4	0,805	151,4
0,150	1 153,1	0,460	386,3	0,635	246,2	0,810	149,0
0,175	1 006,5	0,465	381,2	0,640	243,0	0,815	146,6
0,200	893,1	0,470	376,3	0,645	239,8	0,820	144,1
0,225	802,3	0,475	371,4	0,650	236,6	0,825	141,9
0,250	727,6	0,480	366,7	0,655	233,5	0,830	139,5
0,275	664,8	0,485	361,9	0,660	230,5	0,835	137,2
0,300	611,0	0,490	357,3	0,665	227,4	0,840	135,0
0,310	591,6	0,495	352,7	0,670	224,3	0,845	132,7
0,320	573,2	0,500	348,3	0,675	221,3	0,850	130,4
0,330	555,2	0,505	343,8	0,680	218,4	0,855	128,2
0,335	546,8	0,510	339,4	0,685	215,4	0,860	126,0
0,340	538,8	0,515	335,1	0,690	212,5	0,865	123,8
0,345	530,9	0,520	330,8	0,695	209,6	0,870	121,7
0,350	523,2	0,525	326,7	0,700	206,7	0,875	119,6
0,355	515,5	0,530	322,5	0,705	203,8	0,880	117,4
0,360	508,0	0,535	318,4	0,710	201,0	0,885	115,4
0,365	500,7	0,540	314,4	0,715	198,2	0,890	113,3
0,370	493,5	0,545	310,5	0,720	195,3	0,895	111,3
0,375	486,6	0,550	306,5	0,725	192,6	0,900	109,4
0,380	479,7	0,555	302,6	0,730	189,9	0,905	107,5
0,385	473,0	0,560	298,9	0,735	187,2	0,910	105,5
0,390	466,4	0,565	295,0	0,740	184,6	0,915	103,7
0,395	459,9	0,570	291,2	0,745	181,8	0,920	101,9
0,400	453,6	0,575	287,5	0,750	179,2	0,925	100,2
0,405	447,4	0,580	283,8	0,755	176,6	0,930	98,5
0,410	441,4	0,585	280,3	0,760	174,0	0,935	96,9
0,415	435,4	0,590	276,7	0,765	171,4	0,940	95,4
0,420	429,5	0,595	273,2	0,770	168,8	0,945	93,9
0,425	423,4	0,600	269,6	0,775	166,3	0,950	92,5
0,430	418,0	0,605	266,2	0,780	163,8	0,955	91,3
0,435	412,6	0,610	262,8	0,785	161,2	0,960	90,0
0,440	407,1	0,615	259,4	0,790	158,7	0,965	88,9
0,445	401,8	0,620	256,0	0,795	156,3	0,970	88,0
0,450	396,5	0,625	252,7	0,800	153,9	0,975	87,2

Annex C

Examples of the calculation of hiding power from measurements of R_B and R_∞

C.1 Determination of the scattering coefficient, S

C.1.1 Determine St from the appropriate graph relating R_B, R_∞ and St. For example, for a white paint with $R_B = 0{,}78$ and $R_\infty = 0{,}92$, reference to the graph in figure 1 indicates that the large scale graph required is that in figure 12. The intersection of the relevant lines gives $St = 3{,}70$.

C.1.2 Divide St by t (for example 18,7 µm; the scattering coefficient, S, is thus 0,198 μm^{-1}).

C.2 Determination of hiding power, V

C.2.1 Refer to the table in annex B to obtain the value of α for the determined value of R_∞. For $R_\infty = 0{,}92$, $\alpha = 101{,}9$. Therefore,

$$V = \alpha S = 20{,}2 \text{ m}^2/\text{l}$$

C.2.2 If tables and graphs are not available, the calculations may be carried out as follows.

C.2.2.1 Determine a and b from R_∞, using equations (1) and (2), as follows :

$$a = \frac{1}{2}\left(R_\infty + \frac{1}{R_\infty}\right) = \frac{1}{2}(0{,}92 + 1{,}086\ 96) = 1{,}003\ 48$$

$$b = a - R_\infty = 1{,}003\ 48 - 0{,}92 = 0{,}083\ 48$$

C.2.2.2 Determine S from R_B and R_∞, using equation (7), as follows

$$St = \frac{1}{b}\operatorname{arcoth}\left(\frac{1 - aR_B}{bR_B}\right)$$

$$= \frac{1}{0{,}083\ 48}\operatorname{arcoth}\left[\frac{1 - (1{,}003\ 48 \times 0{,}78)}{0{,}083\ 48 \times 0{,}78}\right]$$

$$= \frac{1}{0{,}083\ 48}\operatorname{arcoth}\left(\frac{0{,}217\ 29}{0{,}065\ 11}\right)$$

$$= \frac{1}{0{,}083\ 48}\operatorname{arcoth} 3{,}337\ 2$$

$$= \frac{0{,}309\ 1}{0{,}083\ 48} = 3{,}703$$

Using the value of t taken for the example in C.1.2, i.e. 18,7 µm,

$$S = \frac{3{,}703}{18{,}7} = 0{,}198\ \mu\text{m}^{-1}$$

as in C.1.2.

C.2.2.3 Determine $t_{0,98}$ using equation (5), as follows

$$t_{0,98} = \frac{1}{0{,}083\,48 \times 0{,}198} \operatorname{arcoth} \left(\frac{0{,}02 + \sqrt{D}}{1{,}568 \times 0{,}083\,48} \right)$$

Calculate D as follows

$$D = 3{,}136 \times 1{,}003\,48 \times \{ 1 - 0{,}98\,[1 - (0{,}8 \times 1{,}003\,48)] \} - 2{,}508\,4$$

$$= 0{,}030\,3$$

Therefore

$$\sqrt{D} = 0{,}174\,1$$

and

$$t_{0,98} = \frac{1}{0{,}016\,53} \operatorname{arcoth} \left(\frac{0{,}02 + 0{,}174\,1}{1{,}568 \times 0{,}083\,48} \right) = \frac{\operatorname{arcoth} 1{,}483}{0{,}016\,53}$$

$$= \frac{0{,}818}{0{,}016\,53} = 49{,}48\ \mu\text{m}$$

C.2.2.4 Determine V using equation (6), as follows

$$V = \frac{1\,000}{49{,}48} = 20{,}2\ \text{m}^2/\text{l}$$

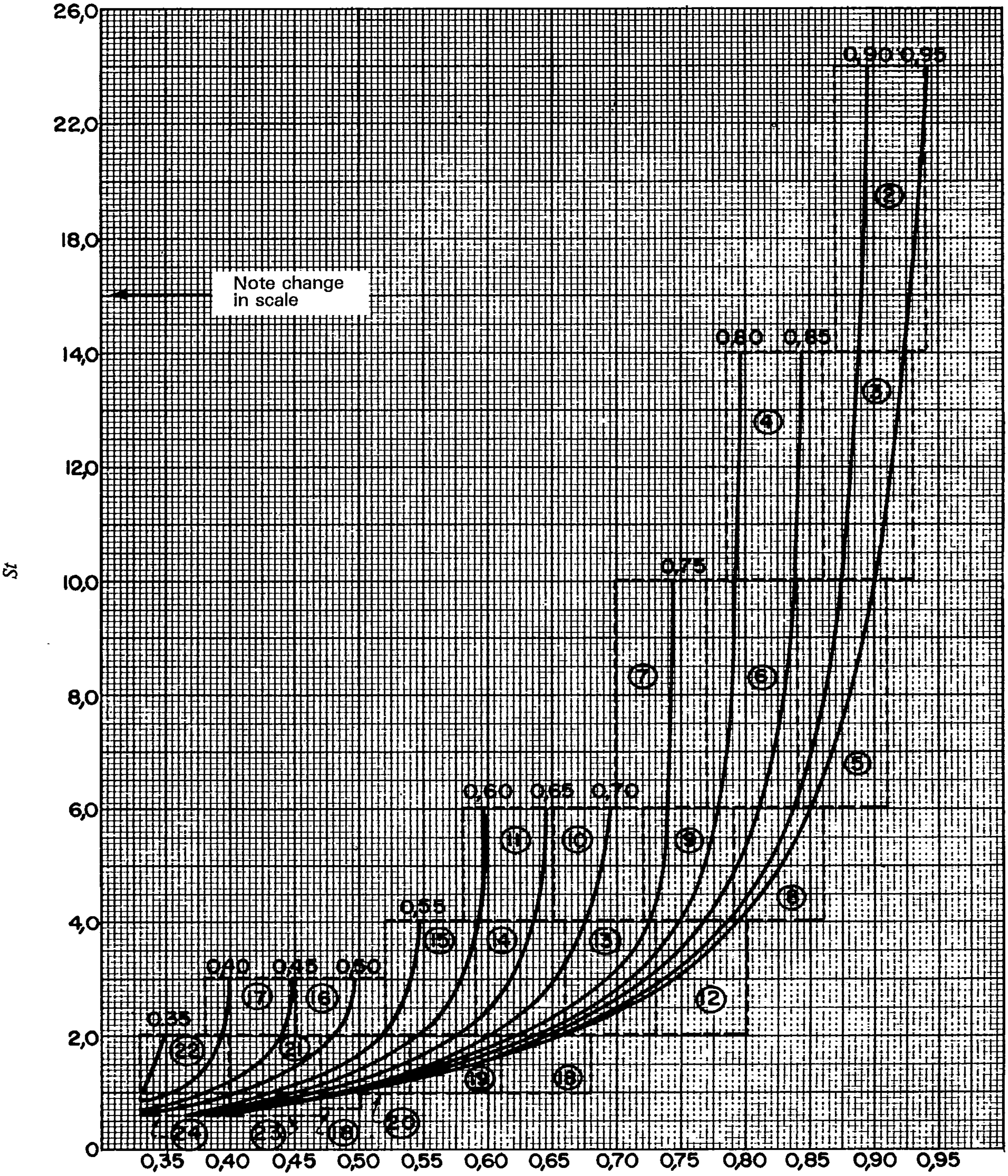
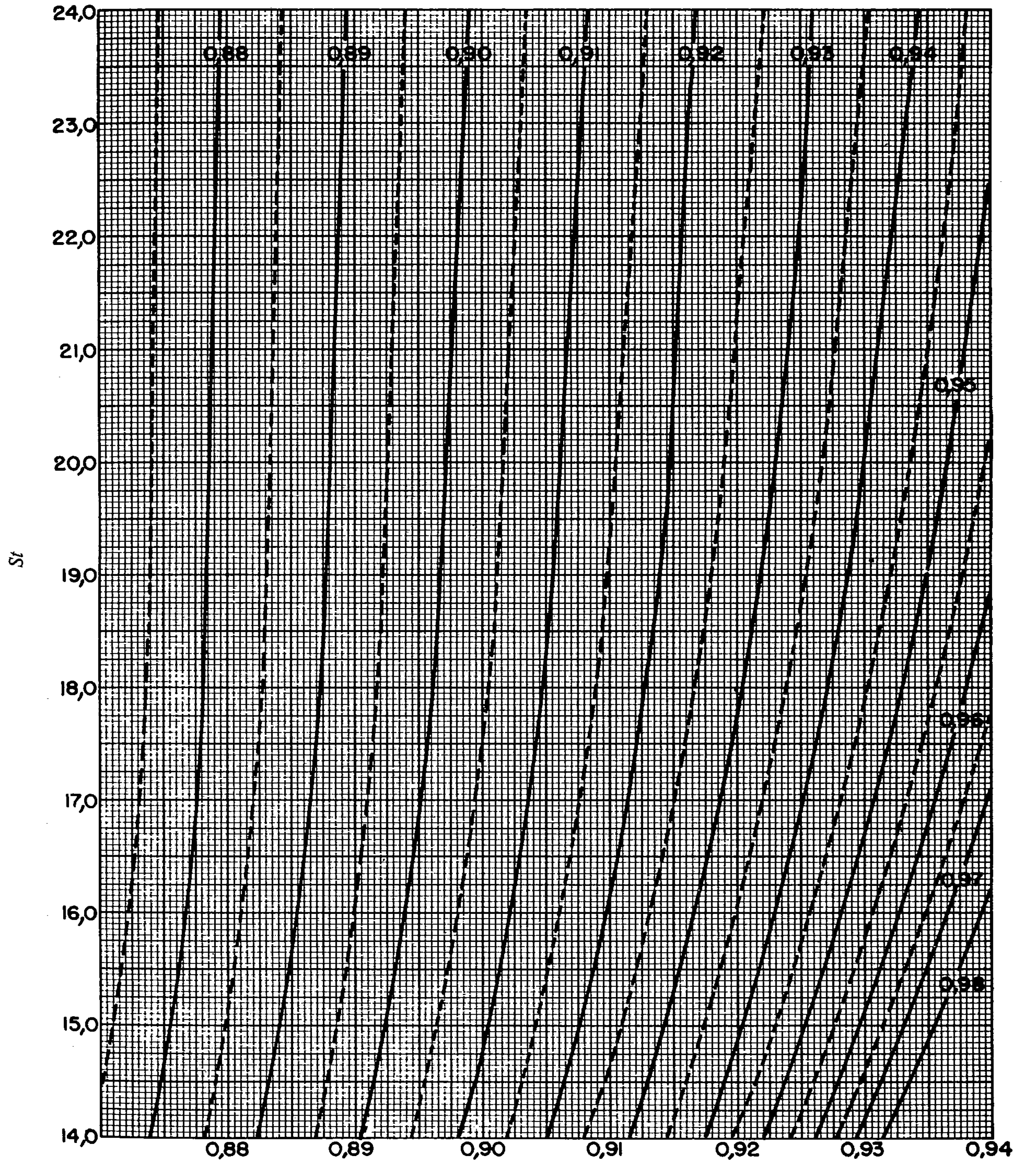


Figure 1 — Index graph for determination of St from values of R_B and R_∞



Reflectance R_B over black substrate

Figure 2 — Values of St for the ranges
$0,87 \leqslant R_B \leqslant 0,94$
$0,88 \leqslant R_\infty \leqslant 0,98$

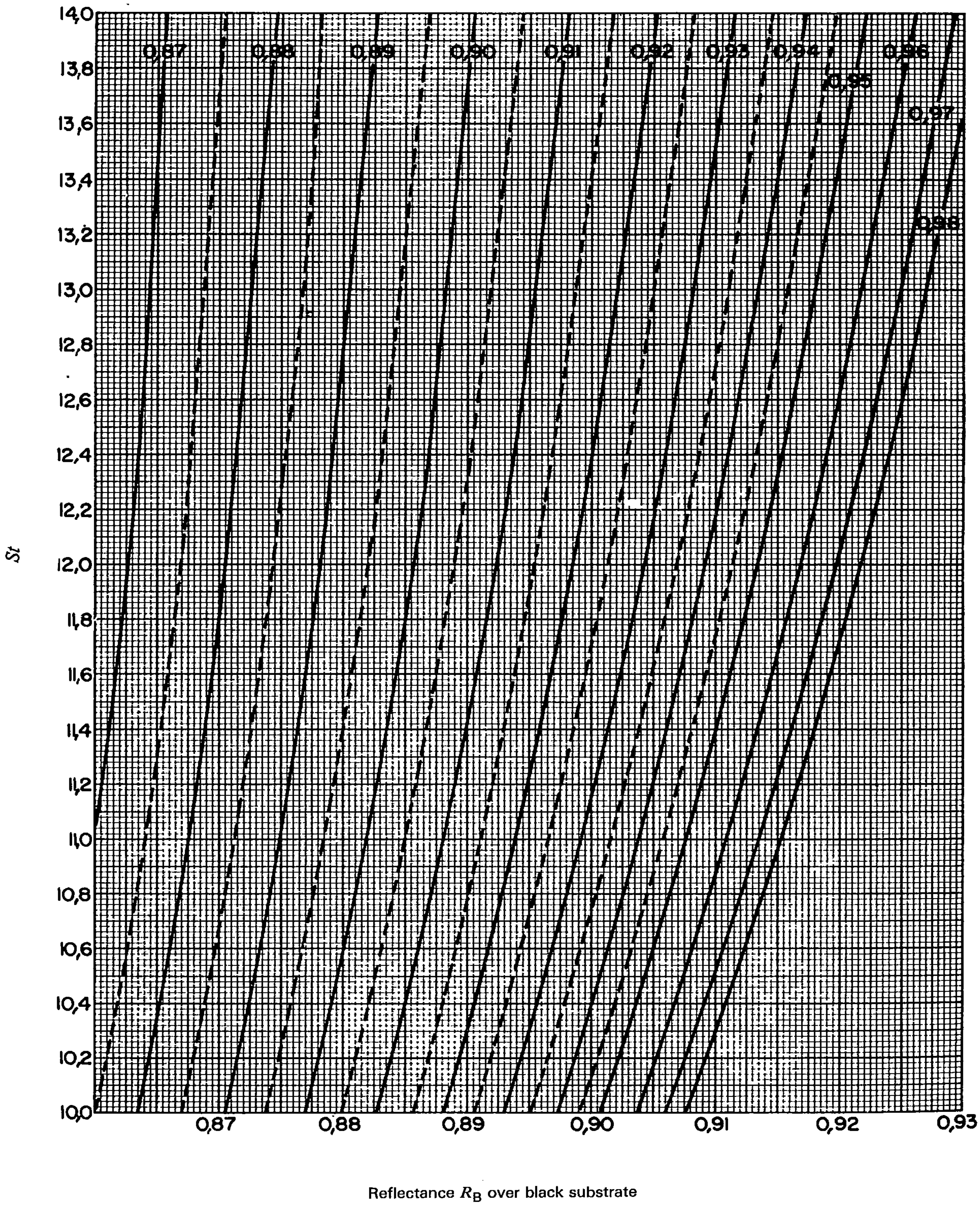


Figure 3 — Values of St for the ranges
$0{,}86 \leqslant R_B \leqslant 0{,}93$
$0{,}87 \leqslant R_\infty \leqslant 0{,}98$

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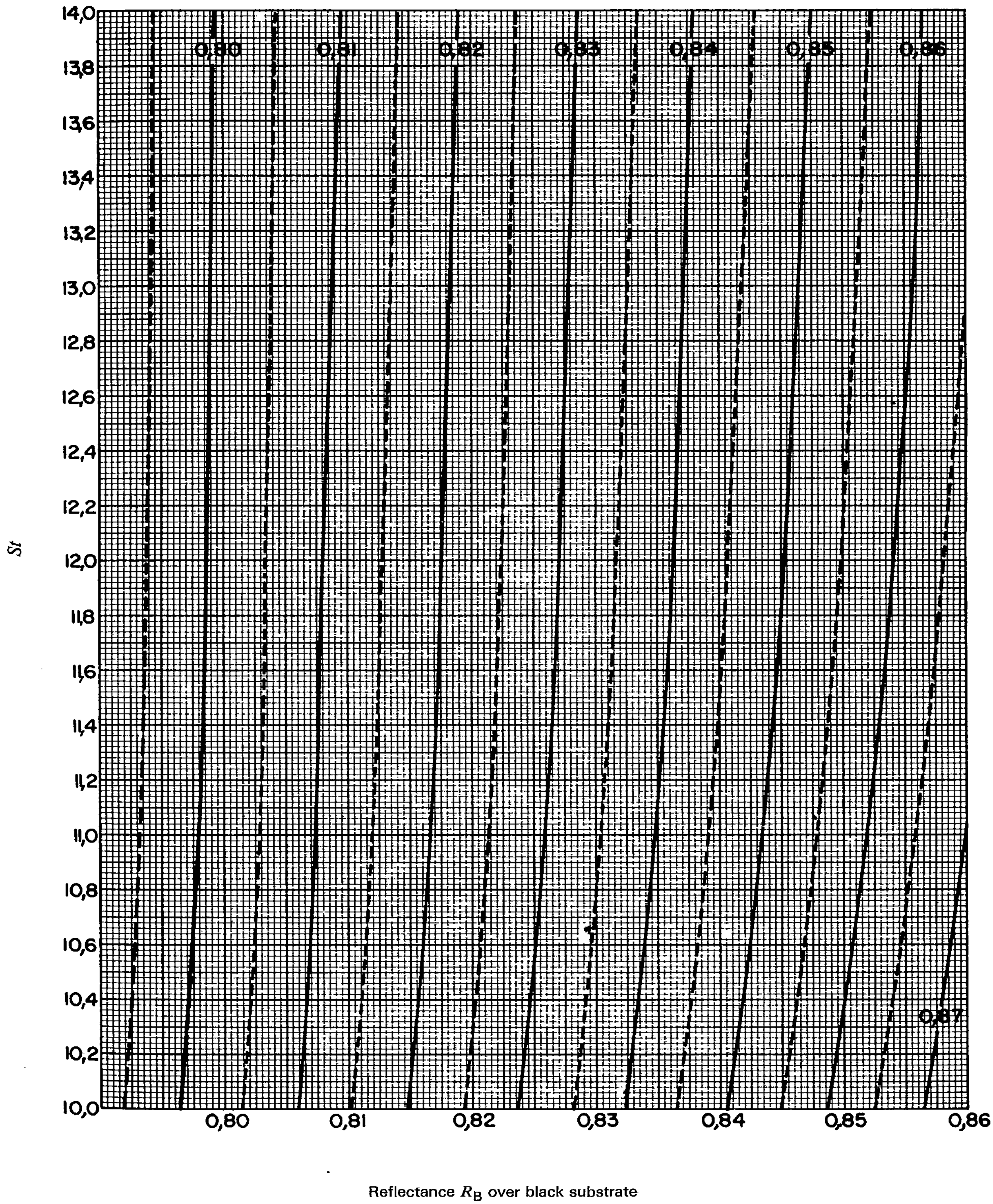

Figure 4 — Values of *St* for the ranges
$0,79 \leqslant R_B \leqslant 0,86$
$0,80 \leqslant R_\infty \leqslant 0,86$

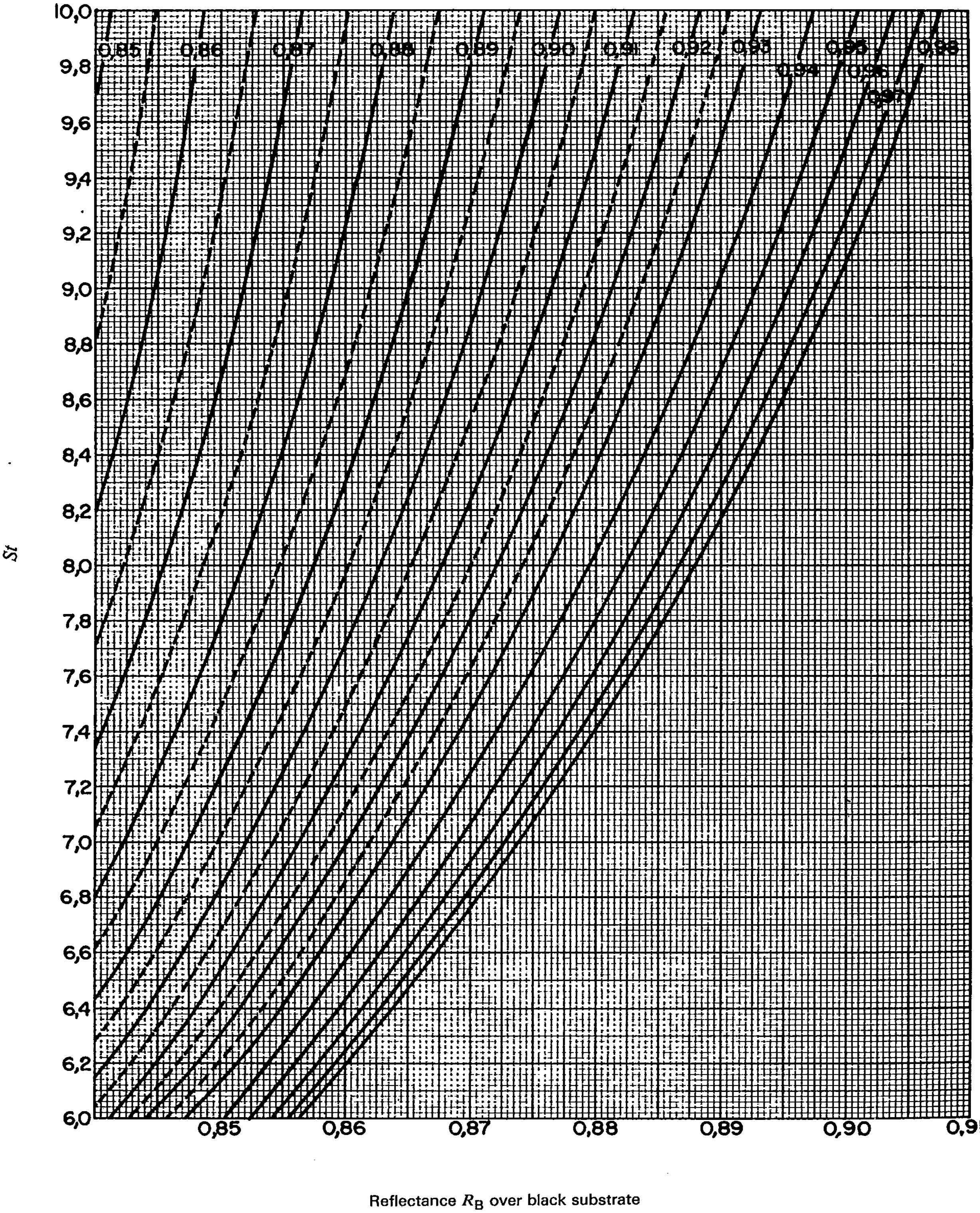

Figure 5 — Values of *St* for the ranges
$0{,}84 \leqslant R_B \leqslant 0{,}91$
$0{,}85 \leqslant R_\infty \leqslant 0{,}98$

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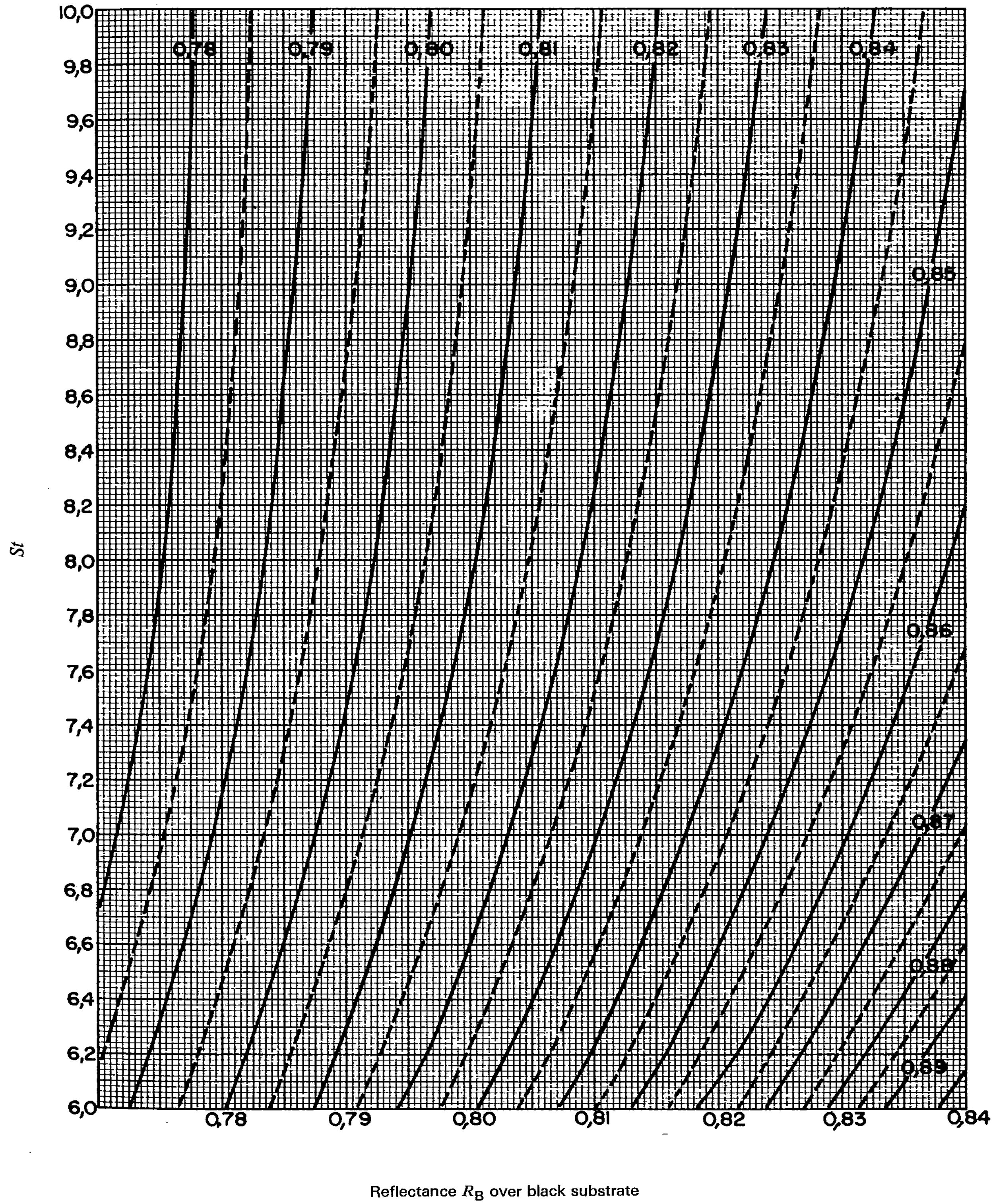

Figure 6 — Values of St for the ranges
$0,77 \leqslant R_B \leqslant 0,84$
$0,78 \leqslant R_\infty \leqslant 0,89$

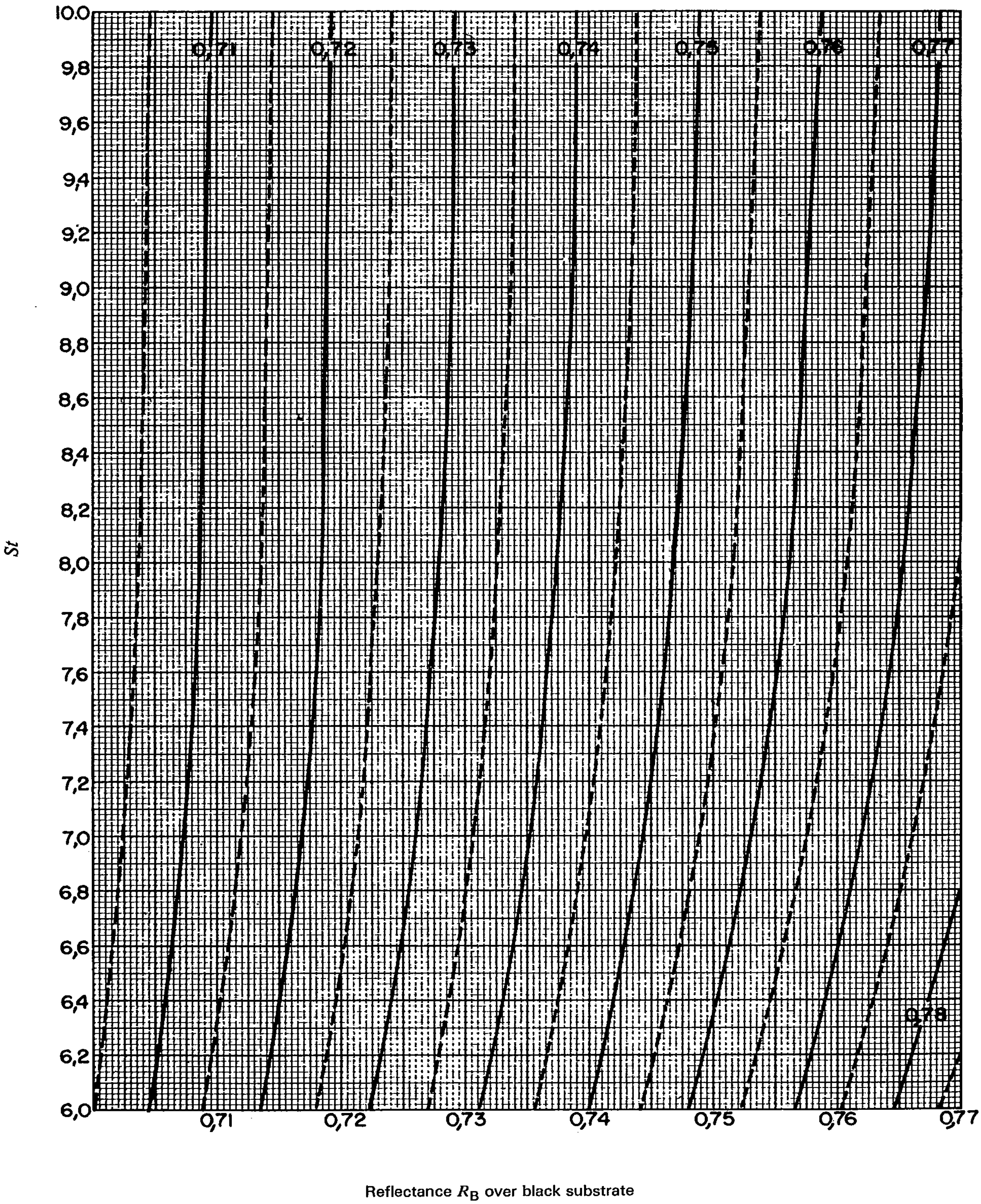

Figure 7 — Values of *St* for the ranges
$0,70 \leqslant R_B \leqslant 0,77$
$0,71 \leqslant R_\infty \leqslant 0,77$

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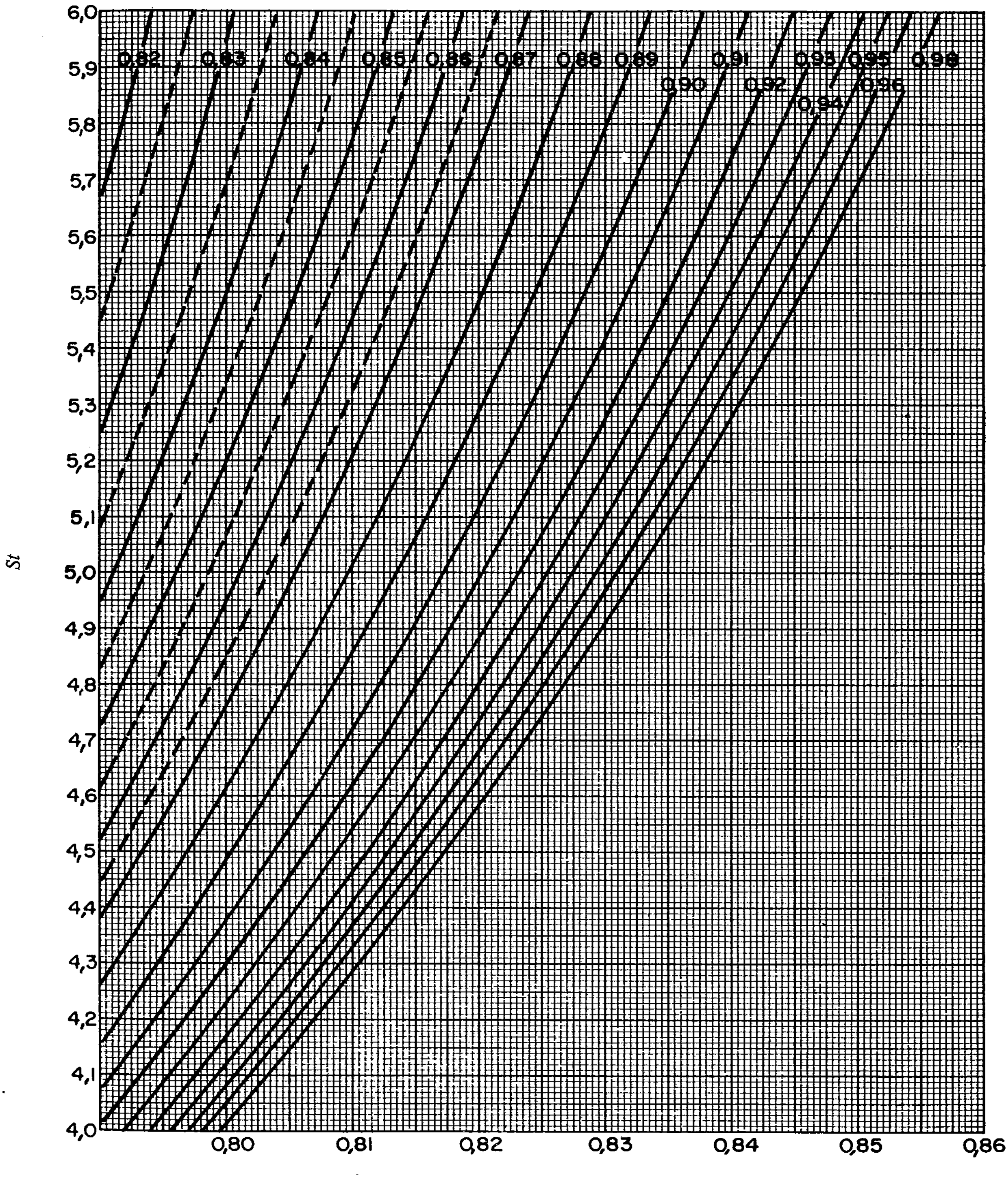

Figure 8 — Values of St for the ranges
$0{,}79 \leqslant R_B \leqslant 0{,}86$
$0{,}82 \leqslant R_\infty \leqslant 0{,}98$

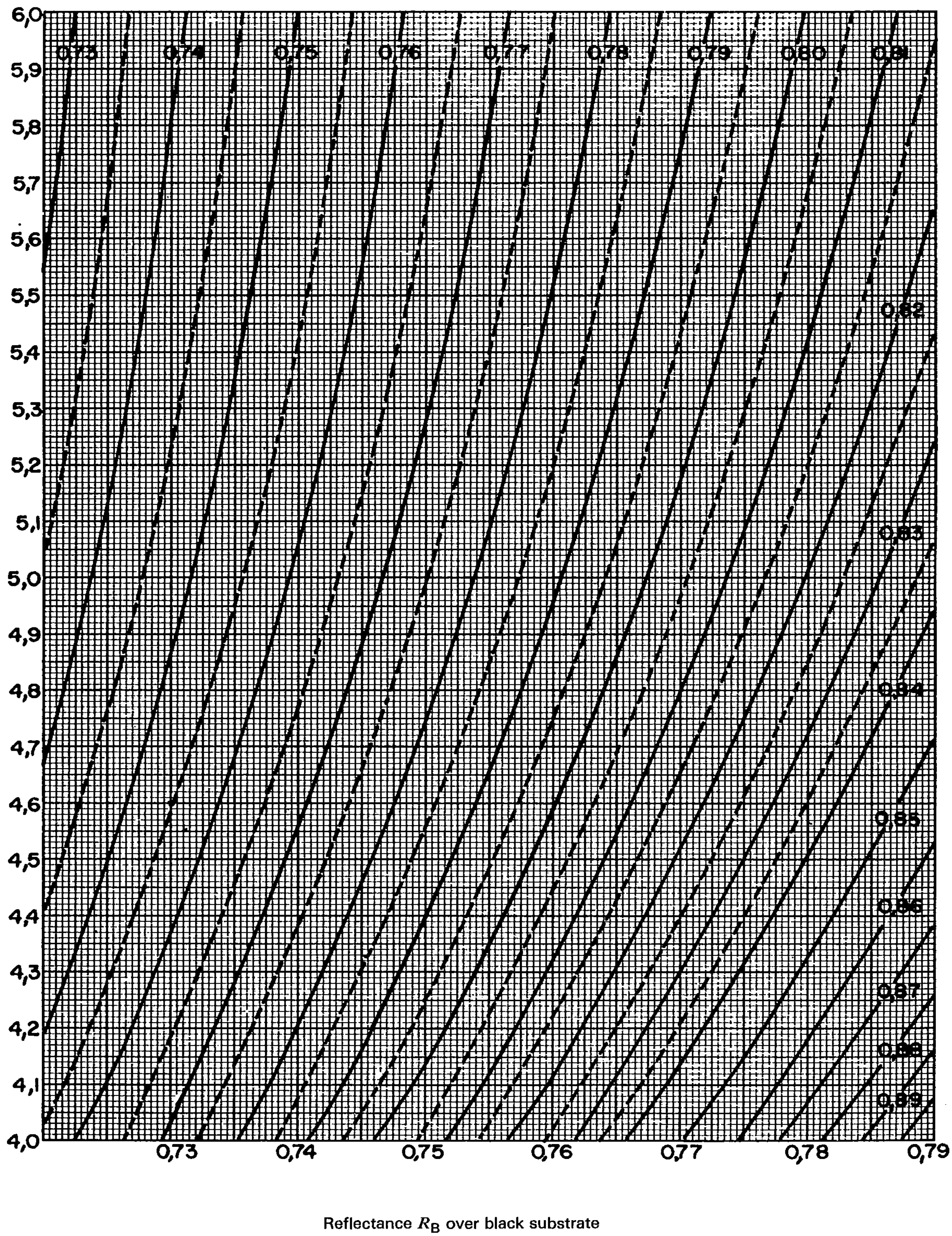

Figure 9 — Values of St for the ranges
$0,72 \leqslant R_B \leqslant 0,79$
$0,73 \leqslant R_\infty \leqslant 0,89$

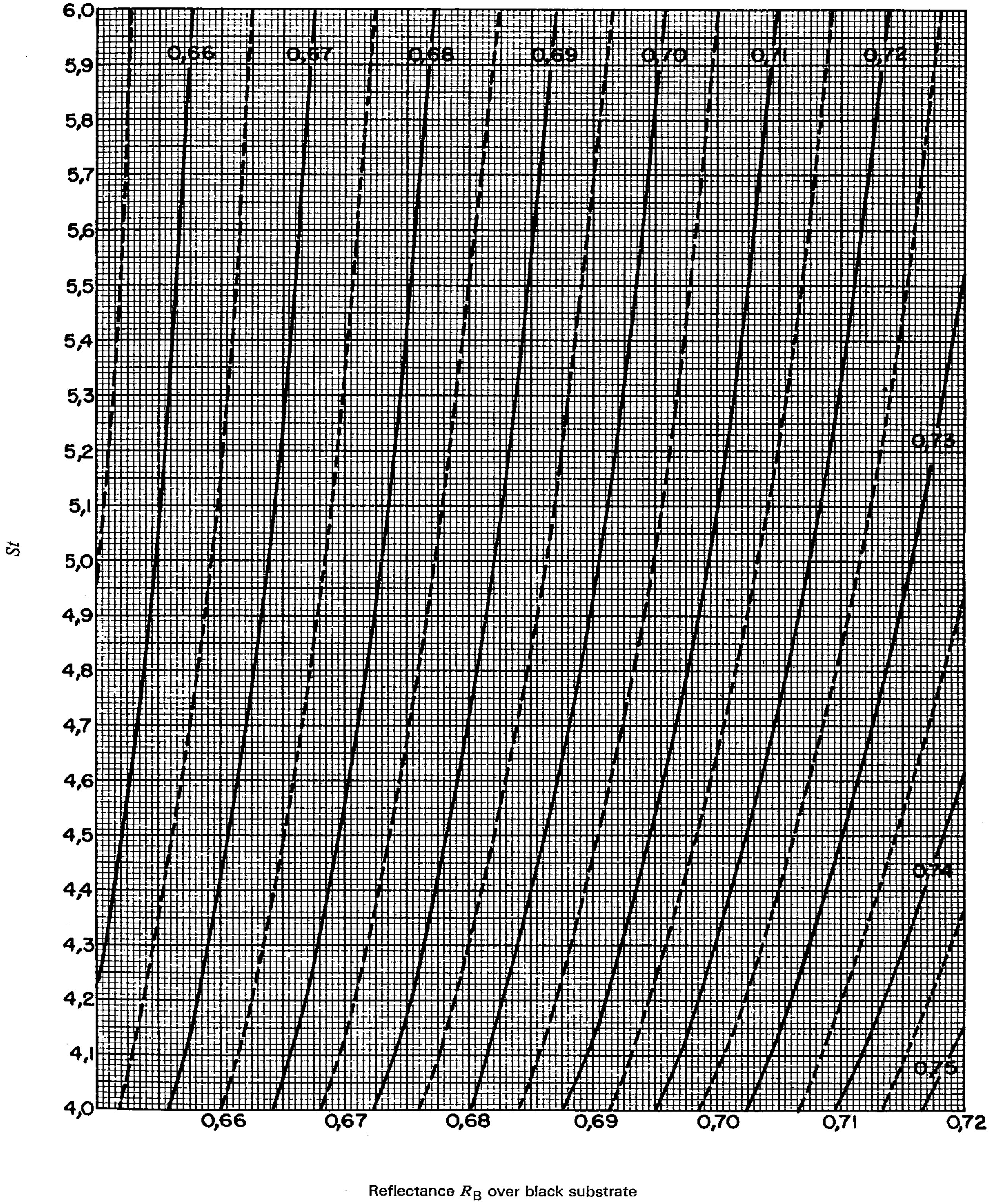

Figure 10 — Values of St for the ranges
$0,65 \leqslant R_B \leqslant 0,72$
$0,66 \leqslant R_\infty \leqslant 0,75$

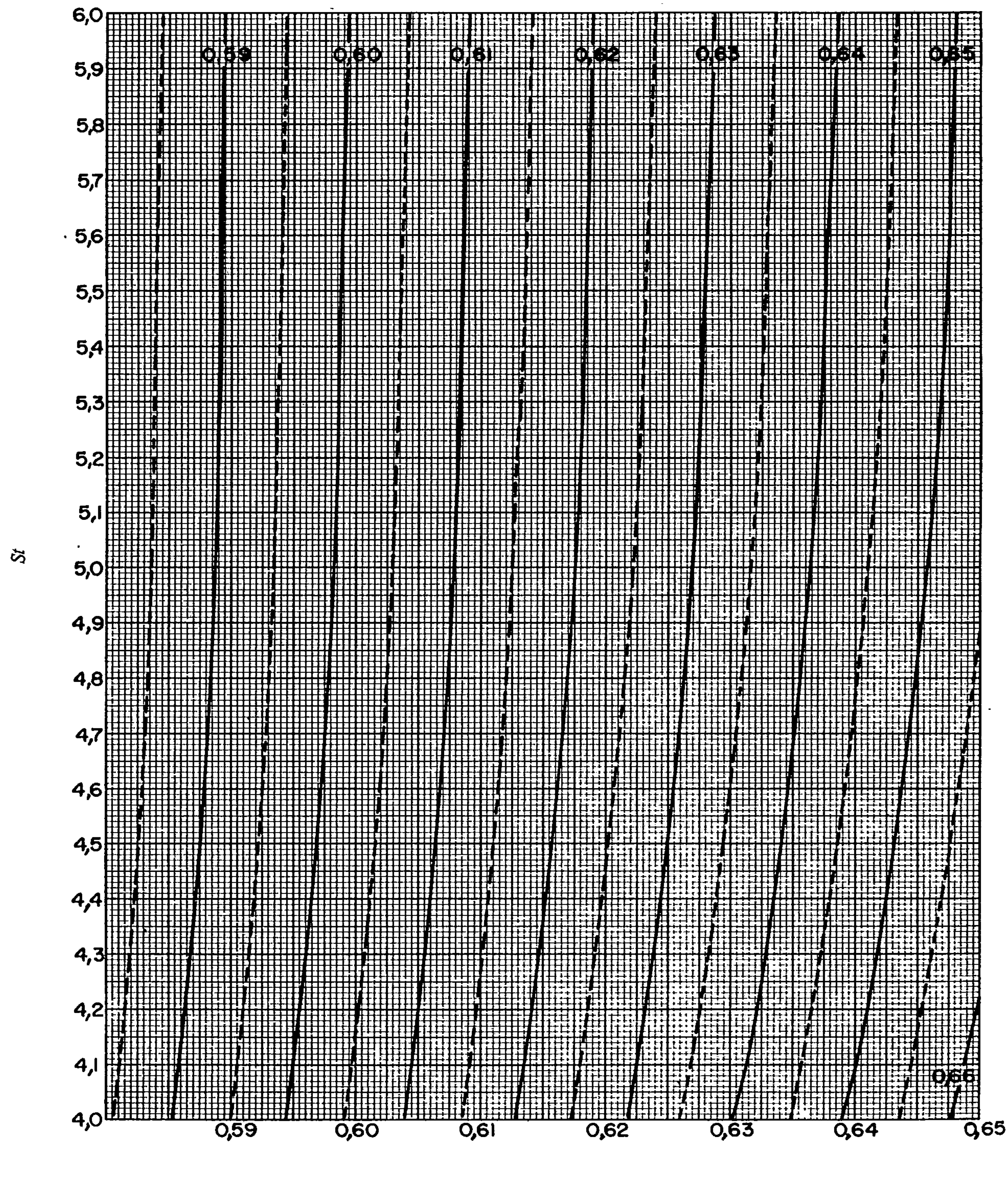

Figure 11 — Values of St for the ranges
$0,58 \leqslant R_B < 0,65$
$0,59 < R_\infty < 0,66$

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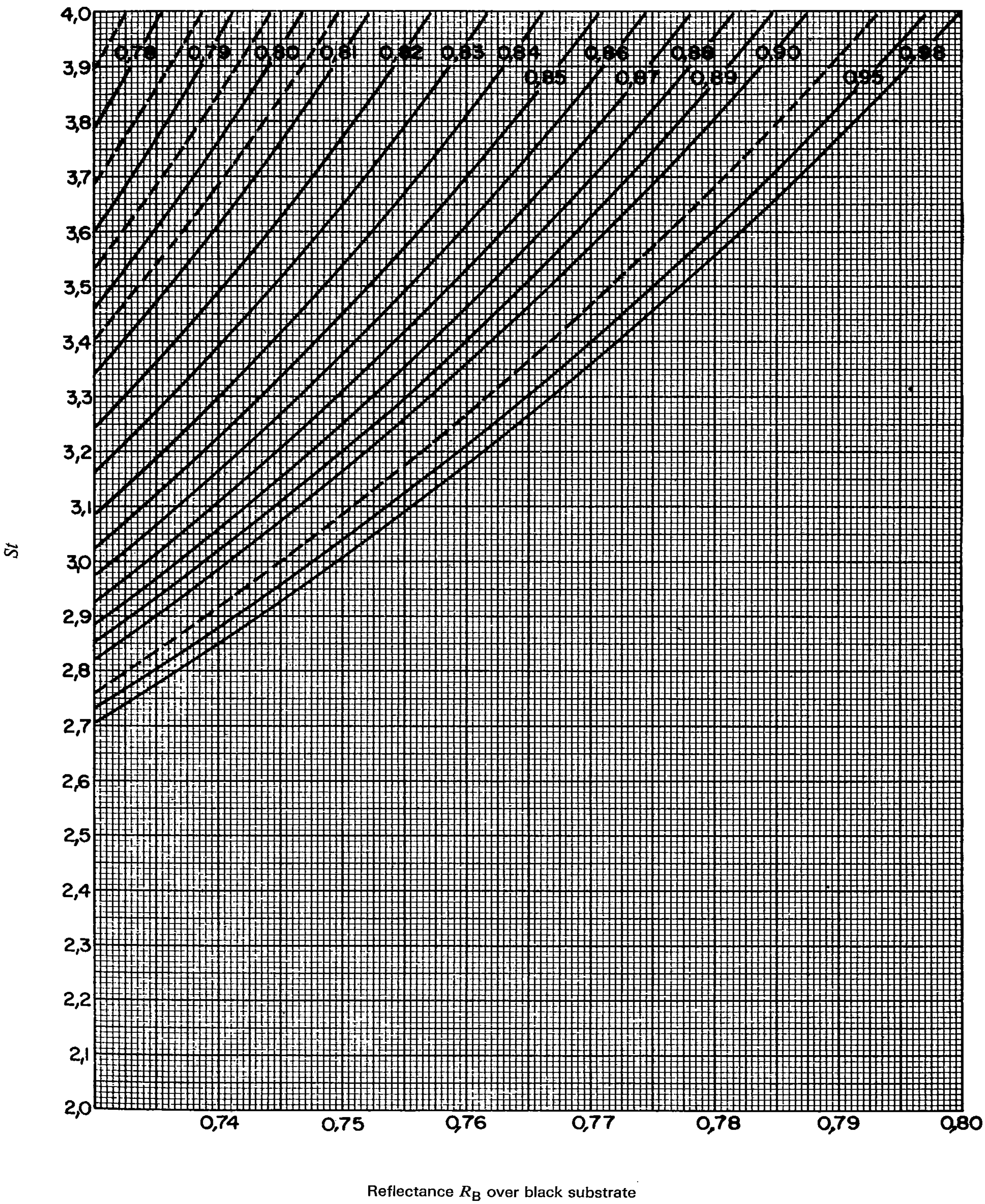


Figure 12 — Values of St for the ranges
$0,73 \leqslant R_B \leqslant 0,80$
$0,78 \leqslant R_\infty \leqslant 0,98$

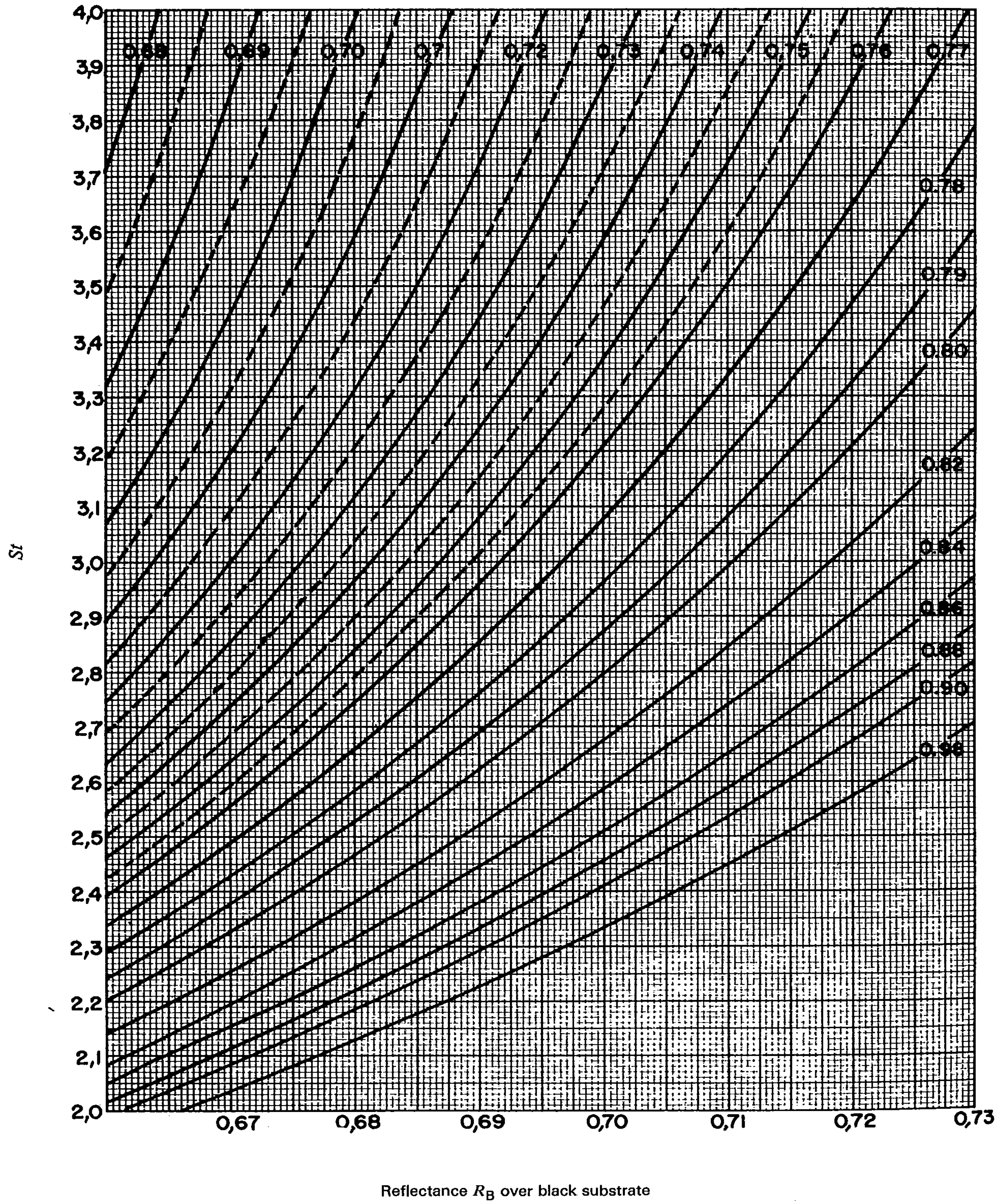


Figure 13 — Values of *St* for the ranges
$0,66 \leqslant R_B \leqslant 0,73$
$0,68 \leqslant R_\infty \leqslant 0,98$

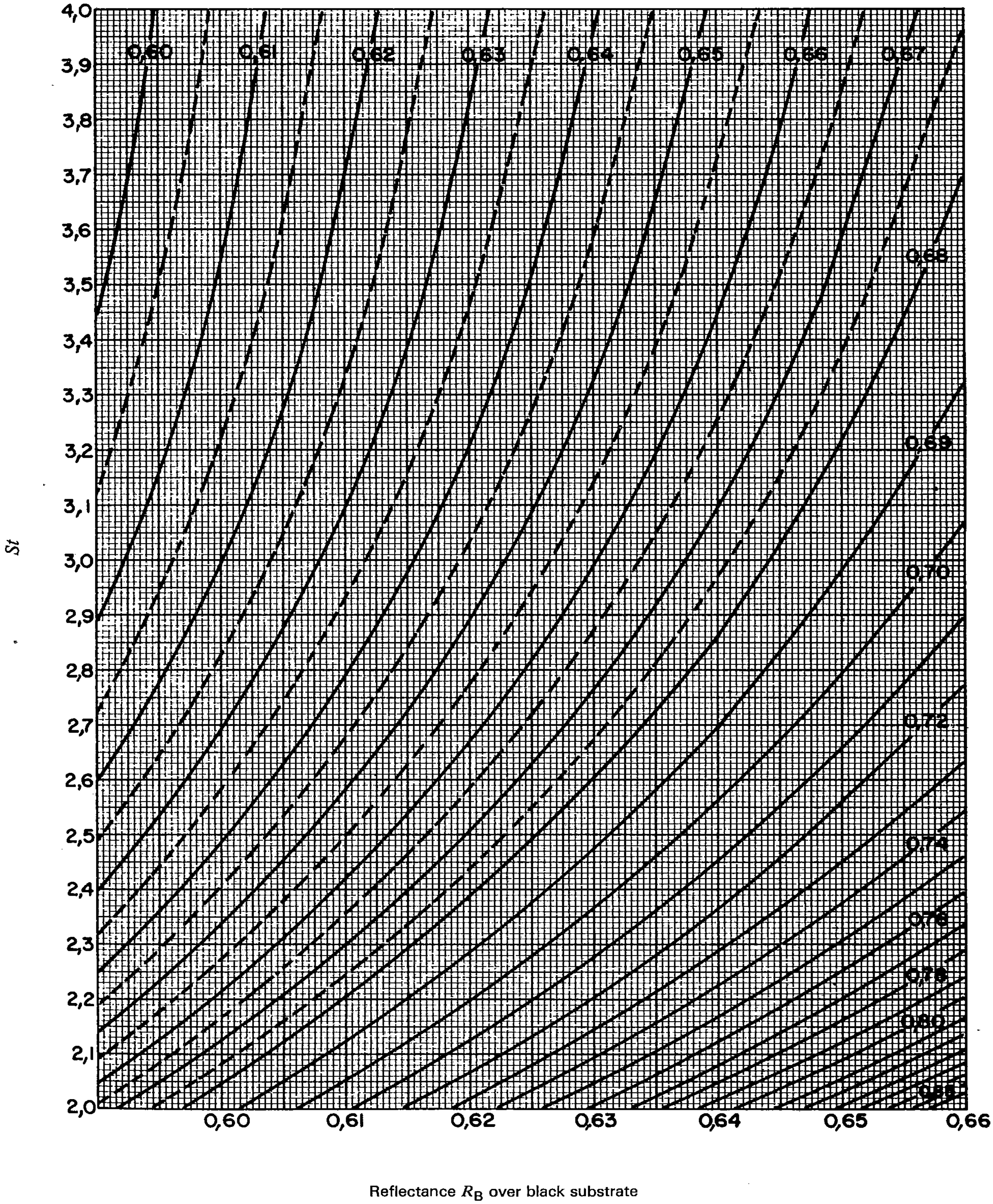
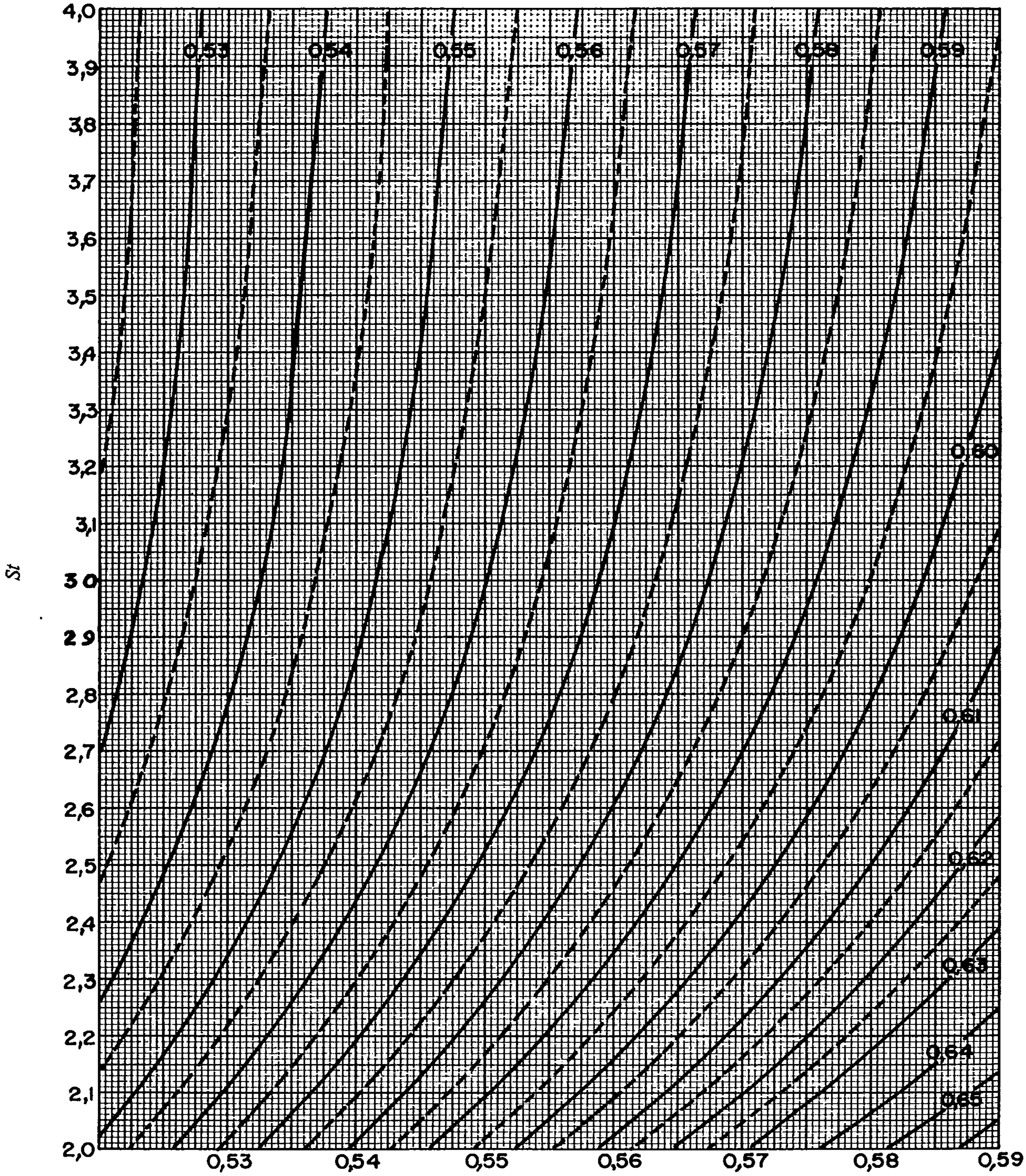


Figure 14 — Values of St for the ranges
$0,59 \leqslant R_B \leqslant 0,66$
$0,60 \leqslant R_\infty \leqslant 0,85$



Reflectance R_B over black substrate

Figure 15 — Values of St for the ranges
$0{,}52 \leqslant R_B \leqslant 0{,}59$
$0{,}53 \leqslant R_\infty \leqslant 0{,}65$

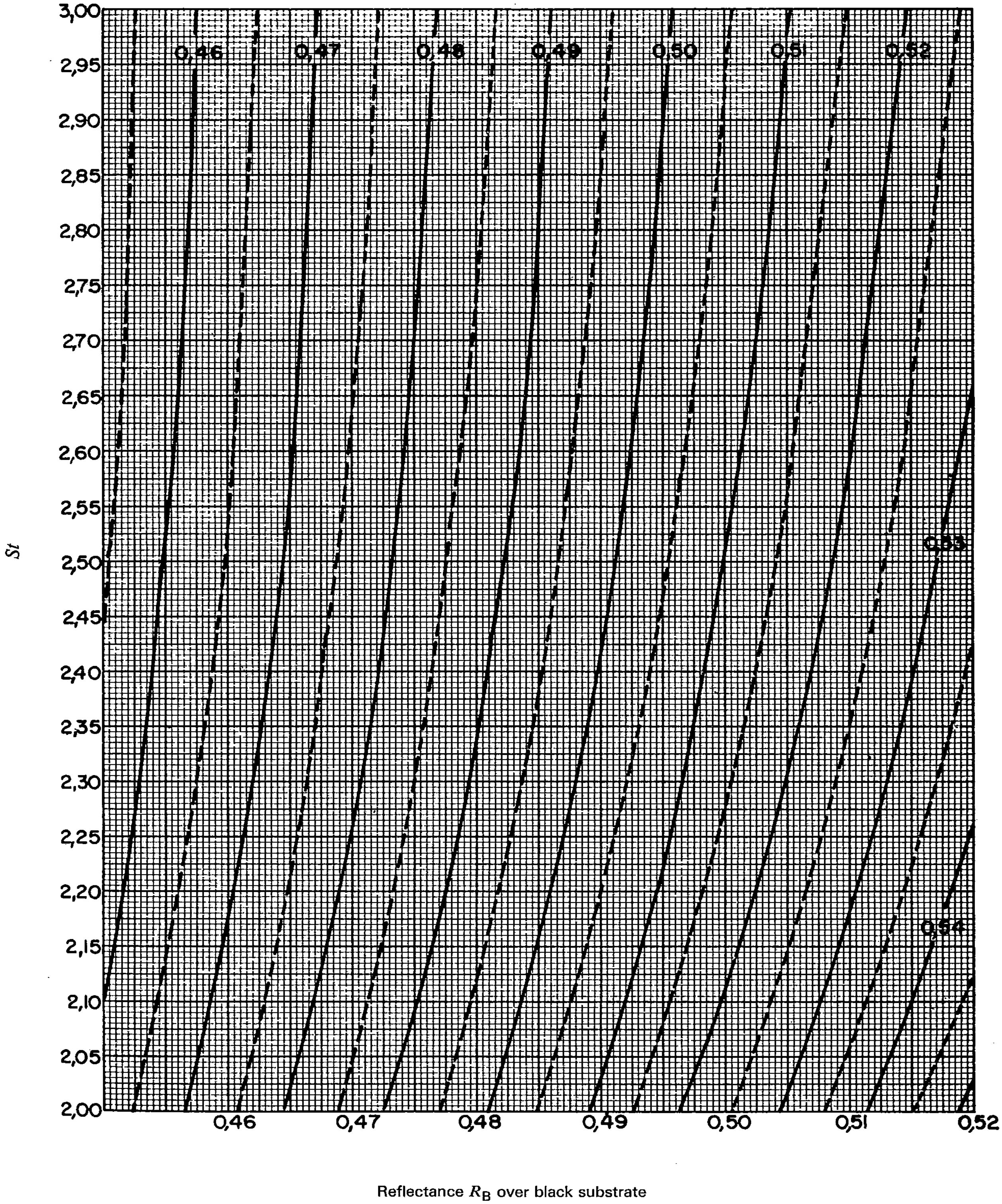


Figure 16 — Values of *St* for the ranges
$0,45 \leqslant R_B \leqslant 0,52$
$0,46 \leqslant R_\infty \leqslant 0,54$

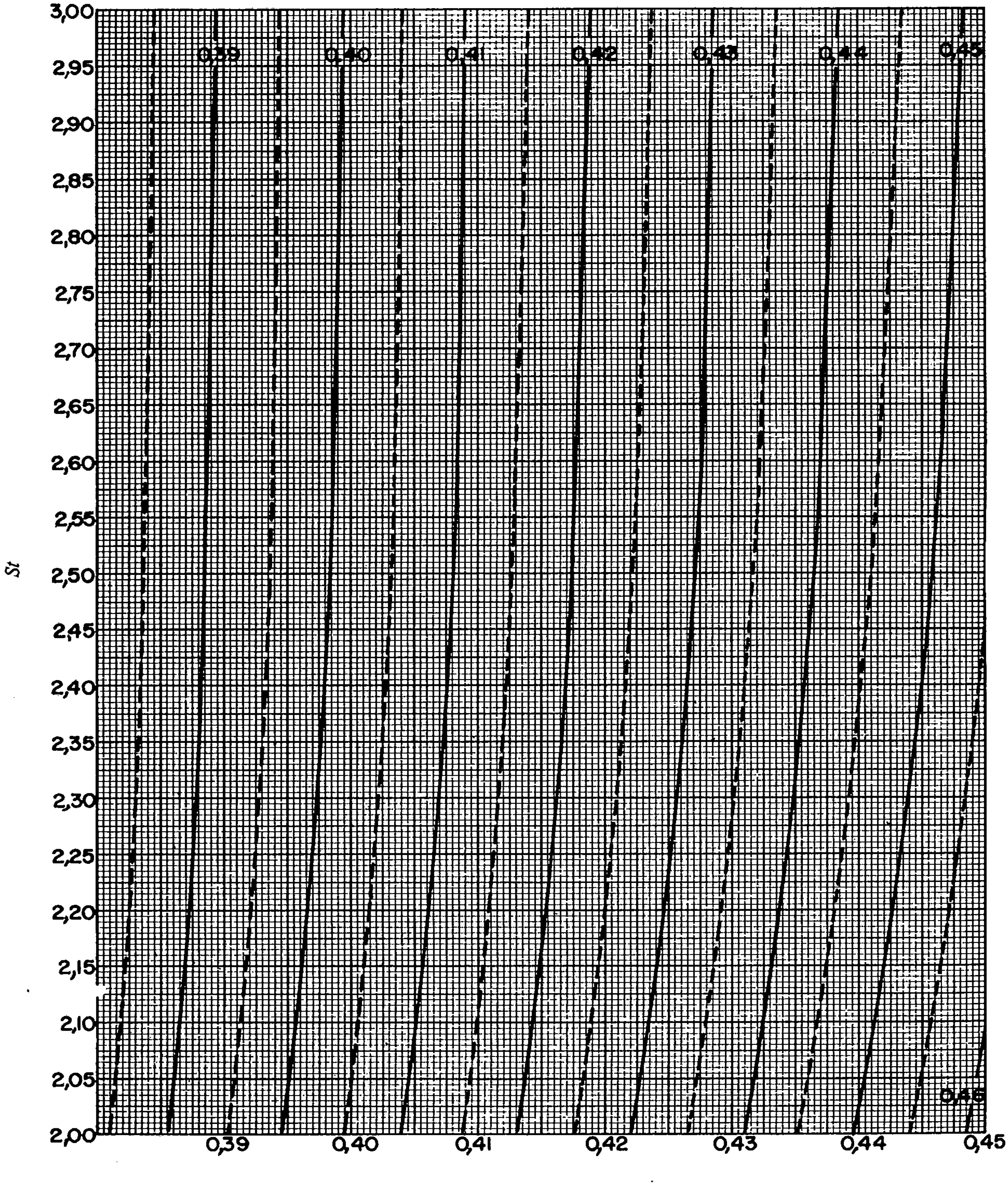
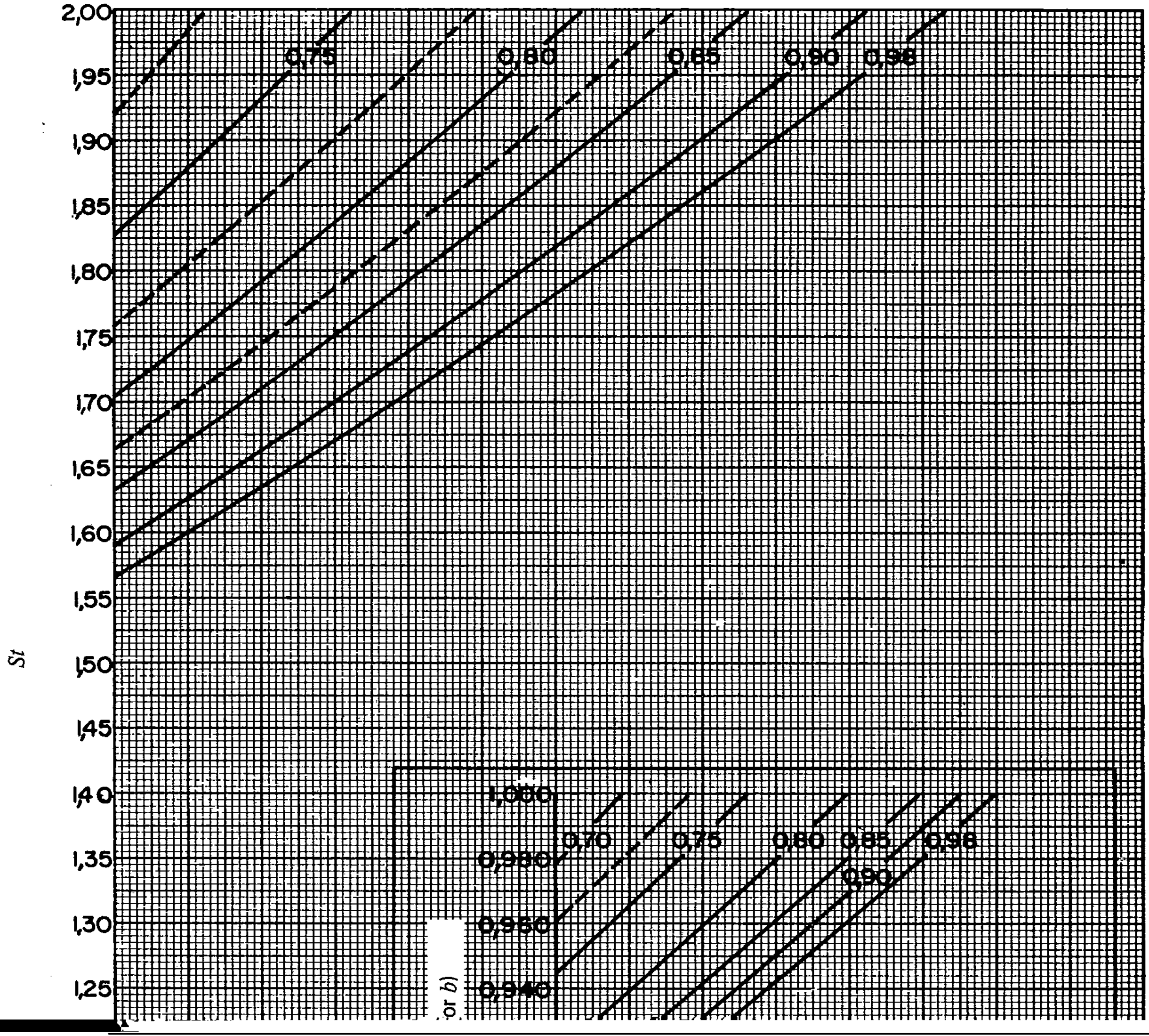


Figure 17 — Values of St for the ranges
$0,38 \leqslant R_B \leqslant 0,45$
$0,39 \leqslant R_\infty \leqslant 0,46$


2,00
1,95
1,90
1,85
1,80
1,75
1,70
1,65
1,60
1,55
1,50
1,45
1,40
1,35
1,30
1,25
St
0,75
0,80
0,85
0,90
0,98
1,000
0,980
0,960
0,940
0,70
0,75
0,80
0,85
0,90
0,98

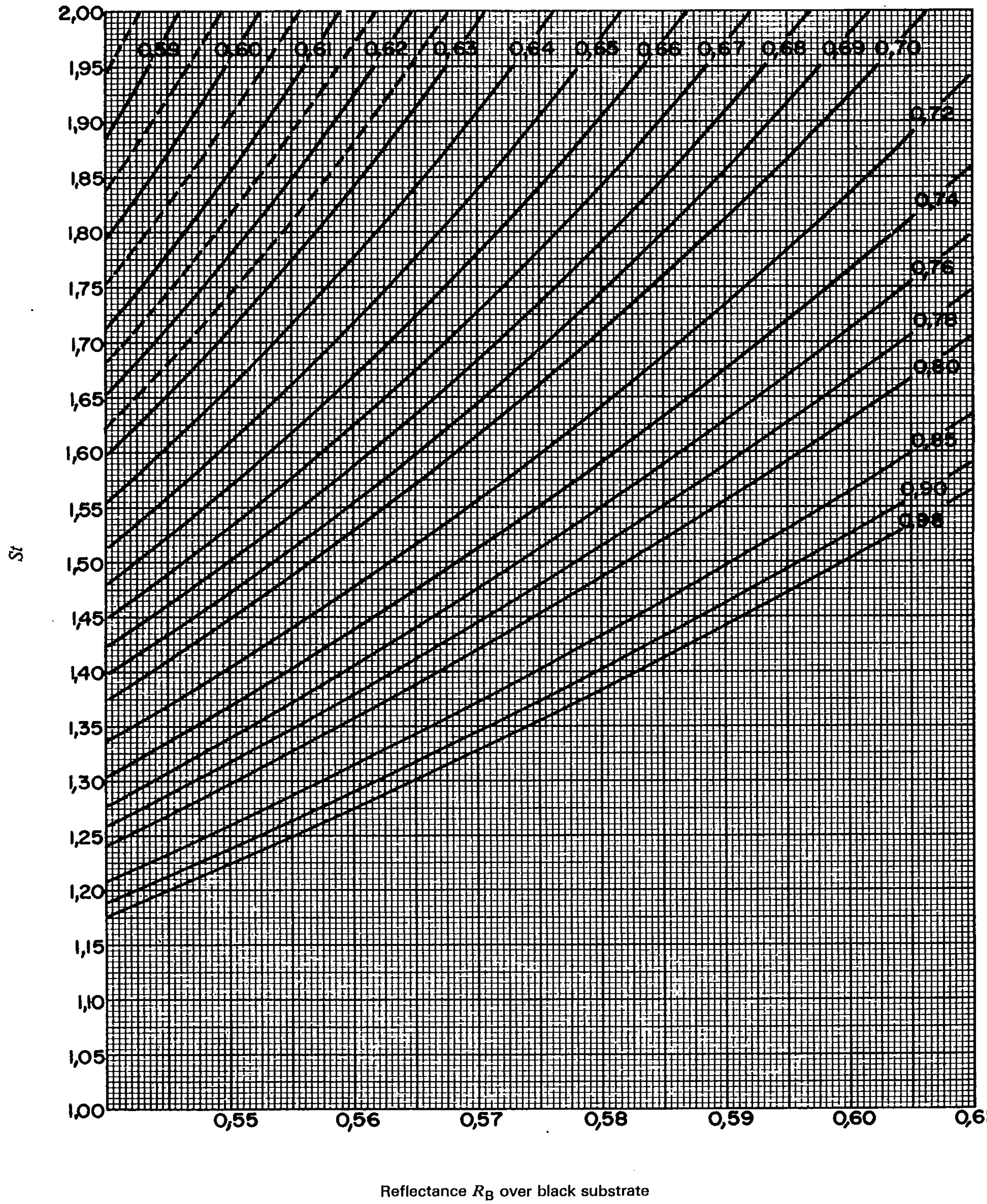


Figure 19 — Values of St for the ranges
$0,54 < R_B < 0,61$
$0,59 < R_\infty < 0,98$

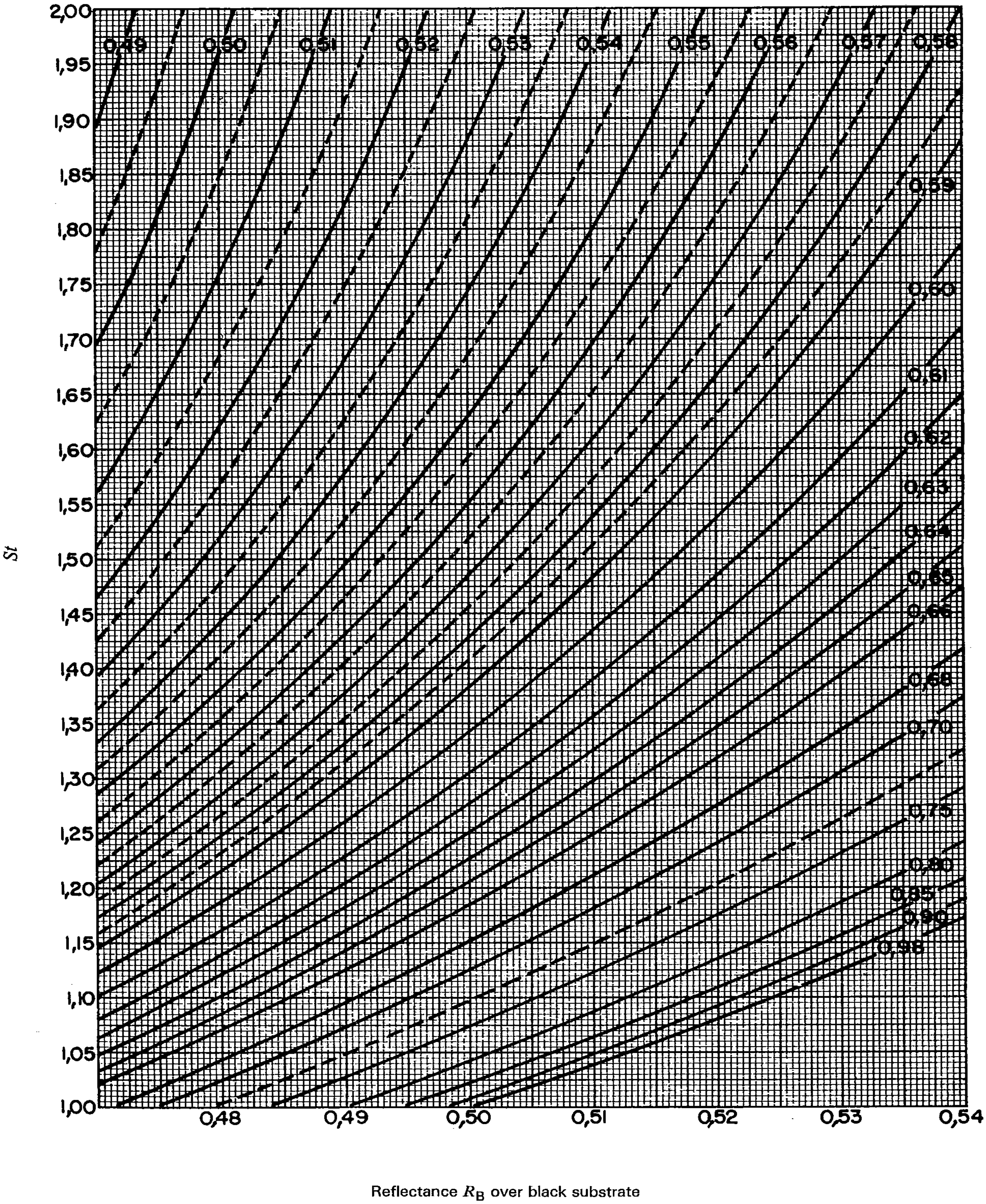


Figure 20 — Values of St for the ranges
$0,47 \leqslant R_B \leqslant 0,54$
$0,49 \leqslant R_\infty \leqslant 0,98$

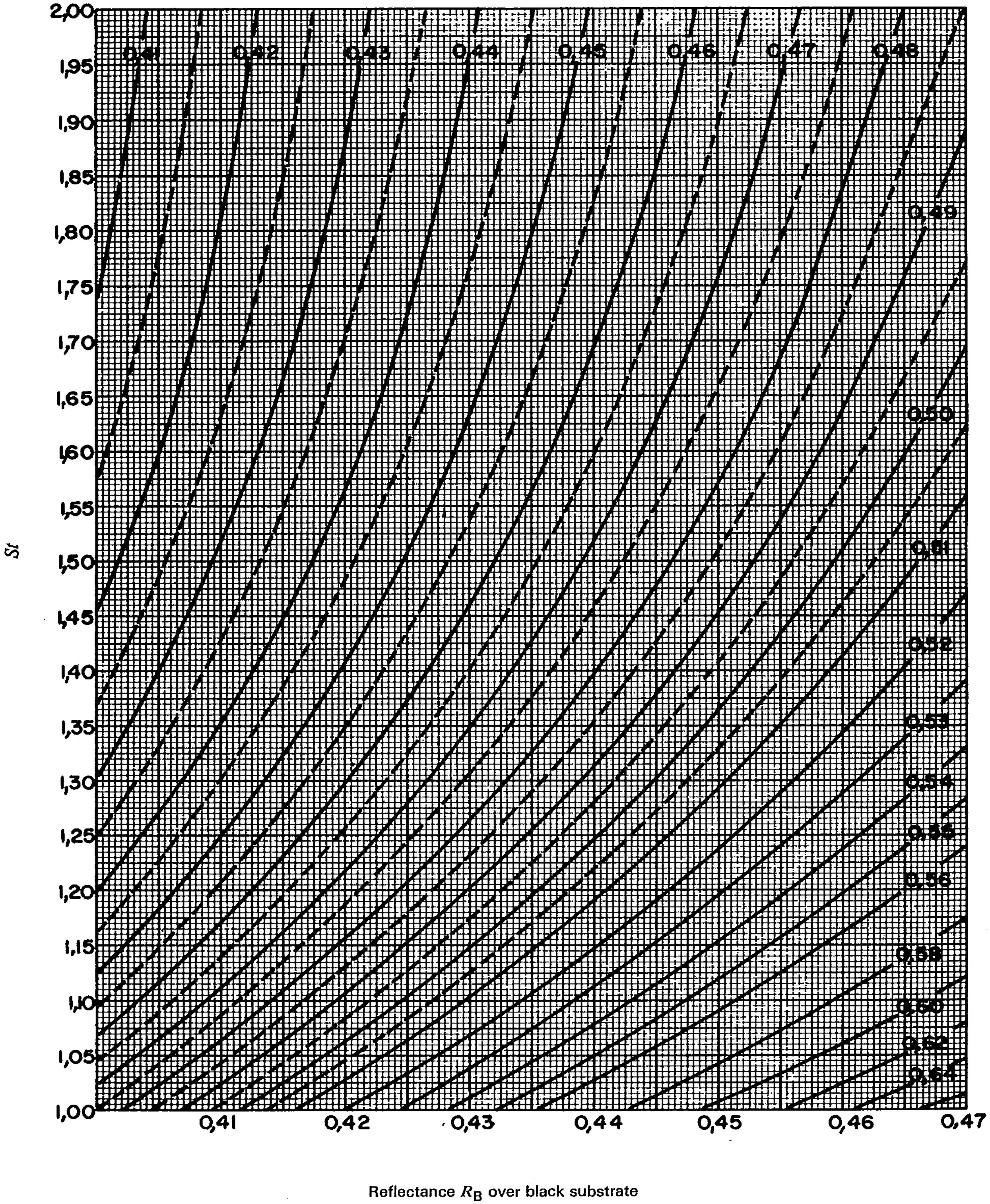


Figure 21 — Values of *St* for the ranges
$0,40 \leqslant R_B \leqslant 0,47$
$0,41 \leqslant R_\infty \leqslant 0,64$

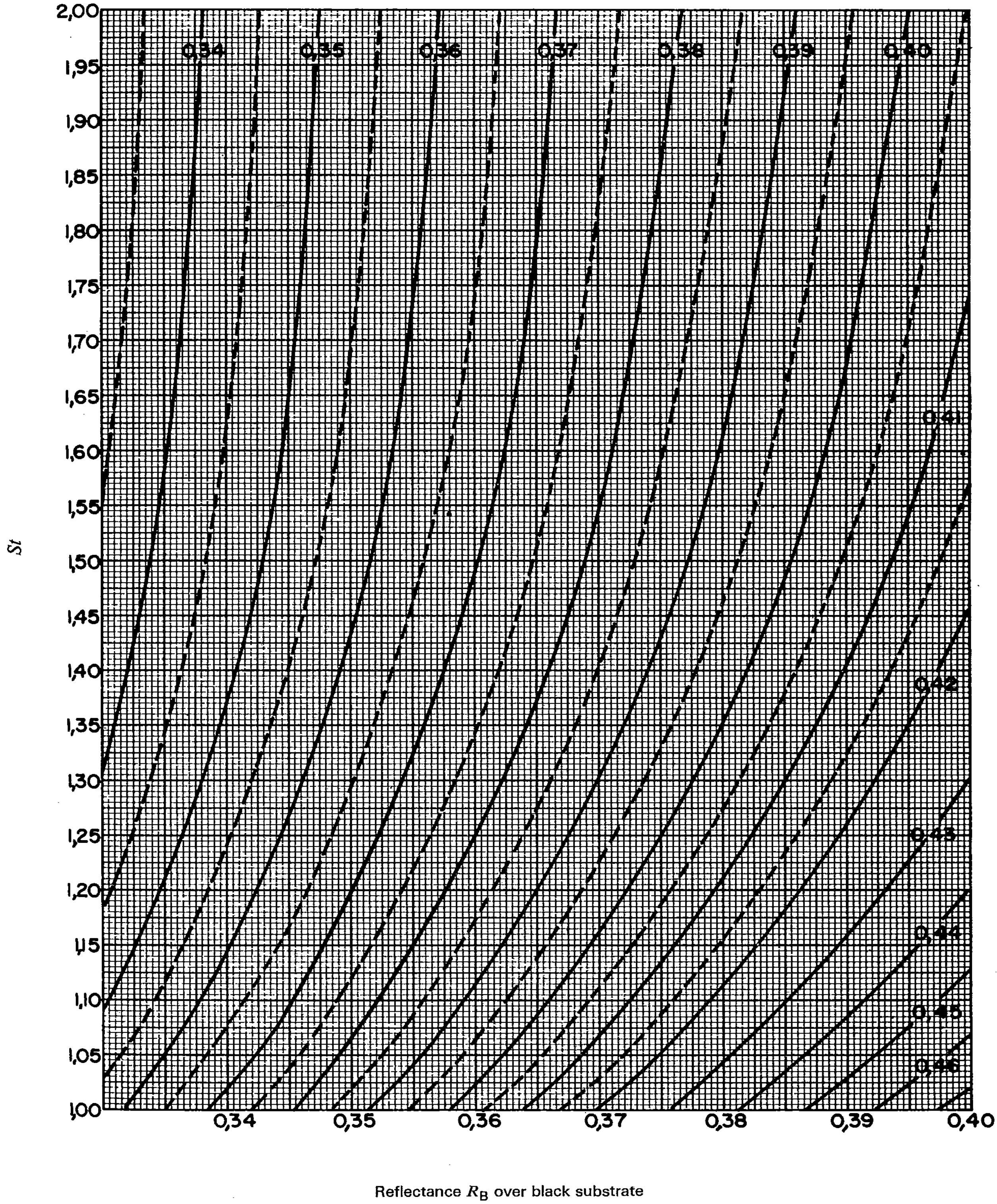
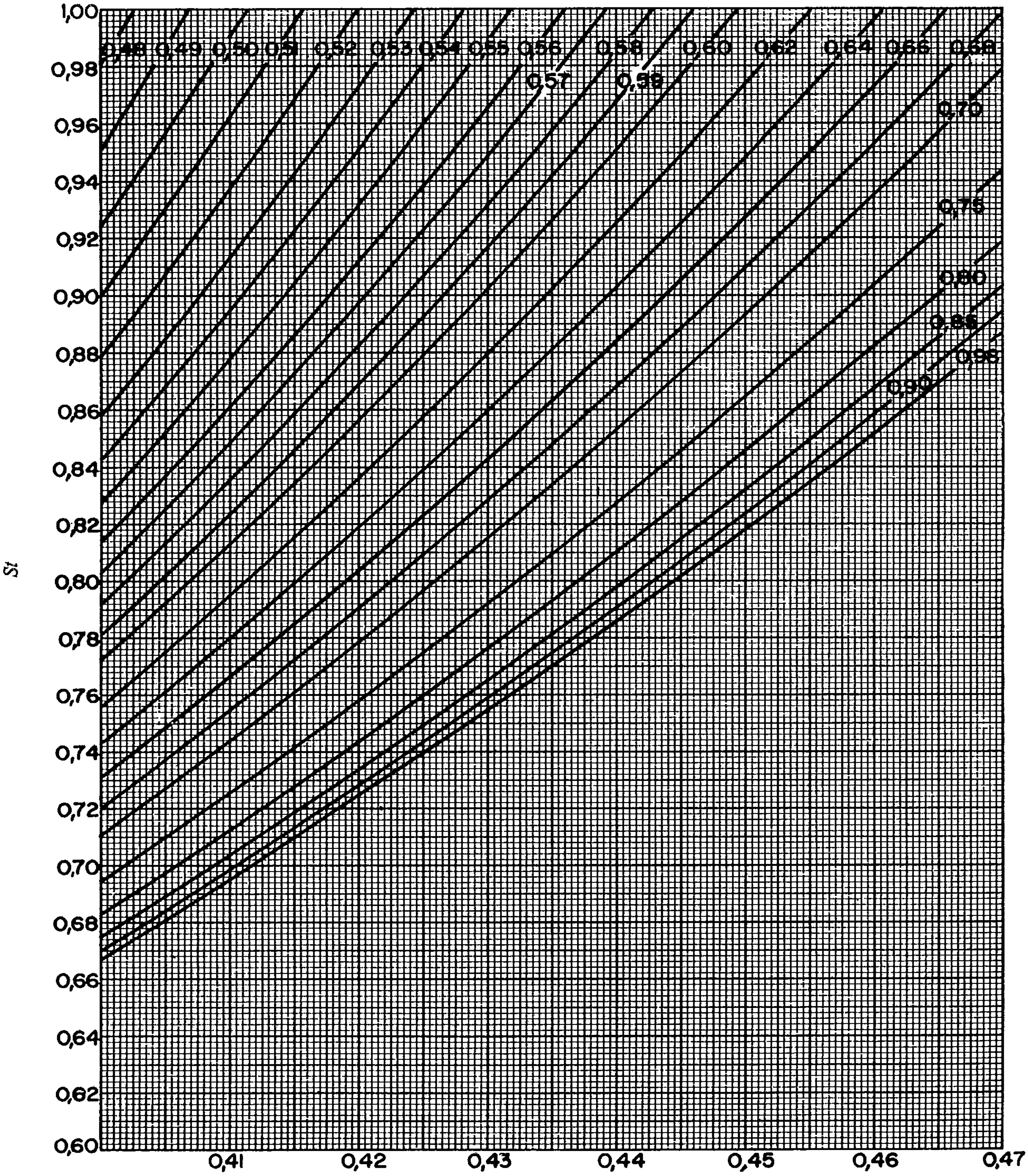


Figure 22 — Values of *St* for the ranges
$0,33 \leqslant R_B \leqslant 0,40$
$0,34 \leqslant R_\infty \leqslant 0,46$



Reflectance R_B over black substrate

Figure 23 — Values of *St* for the ranges
$0,40 \leqslant R_B \leqslant 0,47$
$0,48 \leqslant R_\infty \leqslant 0,98$

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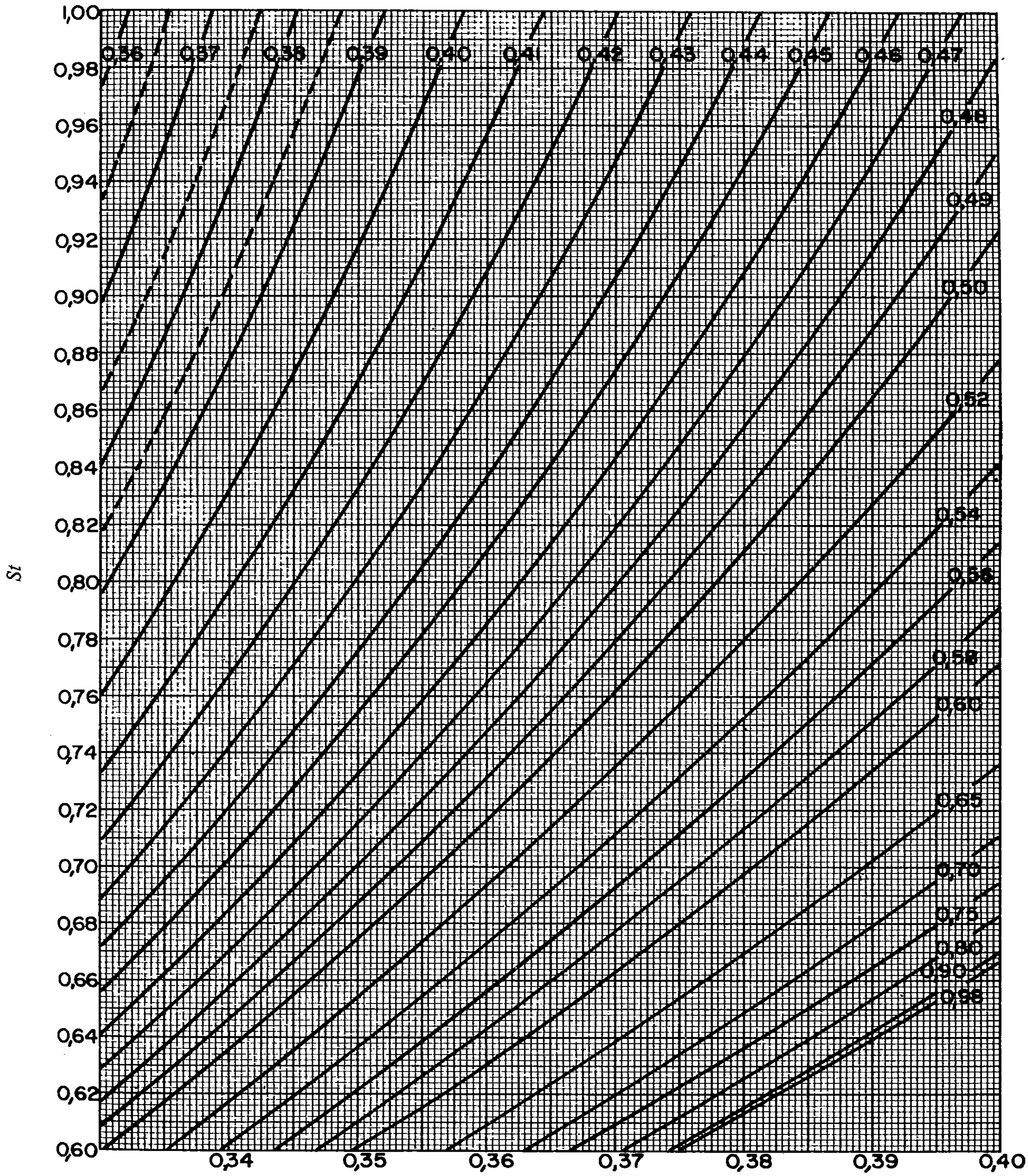

Reflectance R_B over black substrate

Figure 24 — Values of St for the ranges
$0,33 \leqslant R_B \leqslant 0,40$
$0,36 \leqslant R_\infty \leqslant 0,98$