Luminance distribution of Intermediate Sky

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A new advanced system of daylight prediction has been developed and presented by the authors for the highest utilization of natural daylight and appropriate saving of the electrical power consumed by the artificial lighting in daytime. Though the research works for this system and for the Mean Sky upon which it is based have already been published[4)~11)], one of the most essential parts of the research work, that is, the framing of the Intermediate Sky and its detailed contents have been only presented in a brief paper in Japanese[8)].

The Intermediate Sky was framed mainly from the current materials which had already been gathered by the authors before starting of the research work, as the measurement to be required for the establishment of the Intermediate Sky should be carried out for a very long time.

The procedure of framing the Intermediate Sky and its results are stated in this paper.

1. Introduction

After the CIE Standard Overcast Sky[1)] was recommended in 1955 as the standard of the luminance distribution of the sky for daylighting calculations, most of the daylight prediction methods proposed by many research workers in the world have been developed based upon the CIE Standard Overcast Sky or the Uniform Sky[2)] which was generally used as the luminance distribution of the sky for daylighting calculations before the CIE Standard Overcast Sky was recommended.

The Uniform Sky is less reasonable for daylighting prediction than the CIE Standard Overcast Sky, because the luminance distribution of the actual sky is never uniform. However, in many countries, especially in Japan, which are located mainly in low latitude or middle latitude, the luminance distributions expressed by the CIE Standard Sky, *i.e.* the CIE Standard Overcast Sky above mentioned or the CIE Standard Clear Sky[3)] recommended in 1973 by CIE seem to be not so frequently observed in the actual sky conditions as those of the other skies, *e.g.* thinly cloudy sky, partially cloudy sky, misty sky, blue sky with clusters of white clouds, thickly cloudy sky with big blue patches, etc. are.

The daylight prediction really useful for the energy saving should be based upon the real luminance distribution of the sky. For this reason, the Mean Sky[4)~11)] and the Average Sky[12)~14)] have been proposed which show the average luminance distribution of the sky during the total working hours of a defined period (when the working duration of a day is set 8 hours, for example, the total working hours amount to 8 times the working days during that period).

The daylight prediction based upon the Mean Sky may be more precise and more statistical than those based upon the other skies. Its practical method of daylight prediction has already been developed and proposed by the authors.

2. Mean Sky and intermediate Sky

A method of composing a Mean Sky has been developed by the authors, as a large scale measurement of very long years should be required to establish statistically a standard of the Mean Sky which shows the average luminance value of each sky element of the whole sky. Thus, it has been considered that a Mean Sky can be estimated with a few typical types of the luminance distribution of the sky which are prepared to represent all sky conditions and with their frequencies of occurrences related to the fixed term throughout a year and the fixed working duration of a day. For a new method of daylight prediction, a Mean Sky has been prepared relying on the materials currently applicable by conveniently dividing the actual sky conditions into three types, *i.e.* the Clear Sky, the Overcast Sky and the Intermediate Sky.

The Clear Sky has been defined to include both the sky condition of the CIE Standard Clear Sky and those actual sky conditions close to it under which the luminance distribution of the CIE Standard Clear Sky can be applicable to the daylighting calculations.

The Overcast Sky has been defined to include both the sky condition of the CIE Standard Overcast Sky and those actual sky condition close to it under which the luminance distribution of the CIE Standard Overcast Sky can be applicable to the daylighting calculations.

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The Intermediate Sky has been defined as the luminance distribution which represents all the sky conditions except the Clear Sky and the Overcast Sky defined above.

3. Measurement of luminance distribution of actual skies

Since 1969, measurements of the luminance distributions of the whole sky under various conditions was carried out by the authors, though intermittently, for over 10 years.

At the beginning of the measurements, the point by point measurement method was applied with a highly accurate luminance meter held on a manually turning table which enabled the measurement instrument to scan the whole sky both vertically and horizontally.

However, a practical system of photographic photometry using a camera with 180° fish-eye lens of orthographic projection developed by one of the authors[15)~17)] superseded the point by point method, for its fatal disadvantage that the sky condition sometimes changed before the measurement was made of all measurement points scattered over the whole sky.

By this photographic photometry, about 1,000 iso-luminance distribution diagram of the whole sky luminance distribution were made in orthographic projection. Though the photographic photometry could measure the whole sky at once when the lens was pointed to the zenith, due to the original characteristics of the orthographic projection, the image of the low altitude parts of the sky became smaller as it got apart from the optical axis, and the analysis of it were very difficult. So, to examine the luminance of the low altitude parts of the sky, about 100 measurements were added with the optical axis of the orthographic projection lens being pointed horizontally to the four cardinal direactions, *i. e.* the north, the east, the south and the west.

4. Framing of the luminance distribution of the Intermediate Sky

For convenience of the inspection and the mutual comparison of about 1,000 samples, the luminance distribution curves of each sample along the directional circle including the solar position on the celestial sphere and along that perpendicular to it at the zenith, and also many iso-luminance distribution diagrams of the whole sky were drawn and examined.

The examination of the luminance distribution of the sky were carried out mainly depending on the relative luminance value to the zenith luminance, as the general tendency had been inferred from the results of measurements that the differences among the relative luminance distributions of the sky at the same solar altitude and under the same sky condition were comparatively small even if the absolute values of luminance were discrepant.

All the 192 samples gathered during 1973 were mainly investigated as they were regarded to be relatively well-assorted throughout a year by the results of above examination and the fields notes on the sky conditions, etc. written down at the measurements. After general consideration on the sky condition, the zenith luminance, the iso-luminance distribution diagram, the luminance distributions along the two directional circles and so on, the 192 samples were classified as follows:

(1) 5 samples which were very close to the CIE Standard Overcast Sky;
(2) 21 samples which were fairly close to the CIE Standard Overcast Sky;
(3) 2 samples which were very close to the CIE Standard Clear Sky;
(4) 9 samples which were fairly close to the CIE Standard Clear Sky;
(5) 109 samples which could be regarded as neither the CIE Standard Overcast Sky nor the CIE Standard Clear Sky, and the sky conditions of the day were rather stable;
(6) 46 samples which could be regarded as neither the CIE Standard Overcast Sky nor the CIE Standard Clear Sky, and the sky conditions of the day were not stable.

For the rough framing of the luminance distribution of the Intermediate Sky, the 155 samples of (5) and (6) were divided into groups of every 10°, from 10° to 70° of the solar altitude. After the inspection of all luminance distributions along the two directional circles of each group, a typical luminance distribution of each group was temporarily assumed, and according to the similarity to the typical luminance distribution along the two directional circles and etc., 6 samples were drawn from each group.

As the first step of this stage, a luminance distribution of the Intermediate Sky along the two directional circles corresponding to a solar altitude was determined, after careful consideration on the general characteristics of the luminance distribution of the sky, *e.g.* continuity, etc., and on mean luminance values of the sky elements of 12 samples of two adjacent groups (for example, for the luminance distribution of the solar altitude of 30° the 6 samples of the group of solar altitude from 20° to 30°, and those from 30° to 40°). As the second step, the luminance distributions along several other directional circles were additionally determined in the same way. As the final step, the luminance distributions of the Intermediate Sky of the whole sky corresponding to the solar altitudes of every 10°, from 10° to 70° were estimated.

Furthermore, about 100 measurements carried out by four times photographic photometry with the orthographic projection lens being pointed to four cardinal directions were processed into iso-luminance distribution diagrams of the low parts

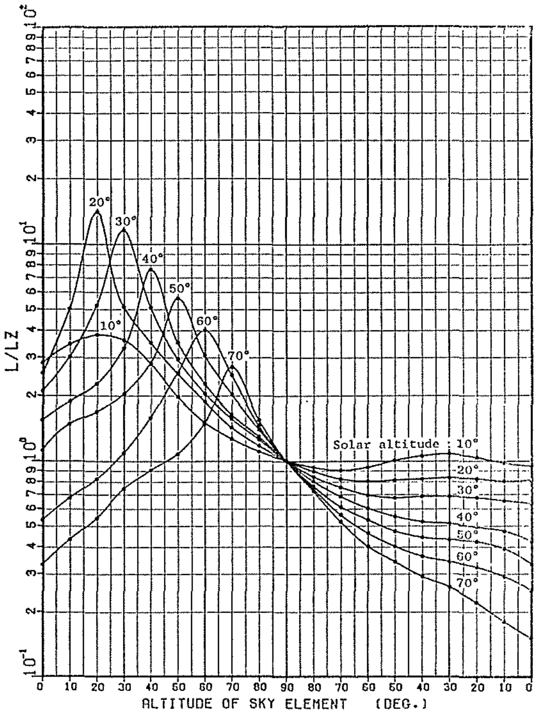

Fig. 1–(1) *Relative luminance of sky elements to the zenith luminance along the directional circle including the solar position.*

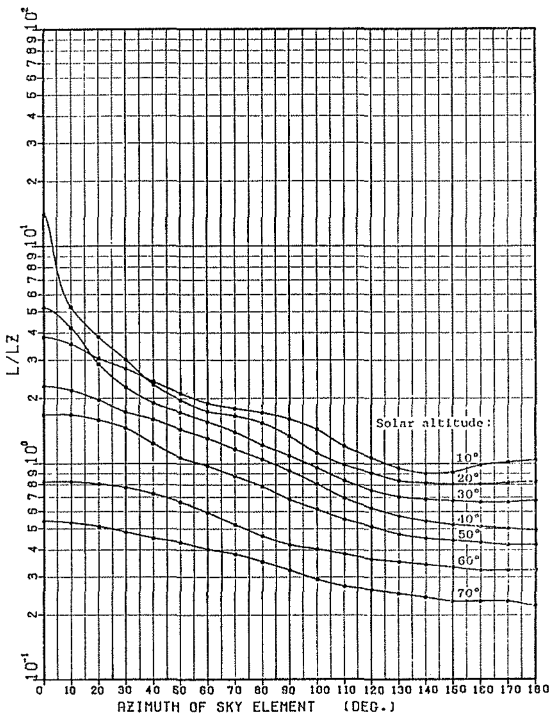

Fig. 1–(3) *Relative luminance of sky elements to the zenith luminance along the iso-altitude circle (altitude of the sky element = 20°).*

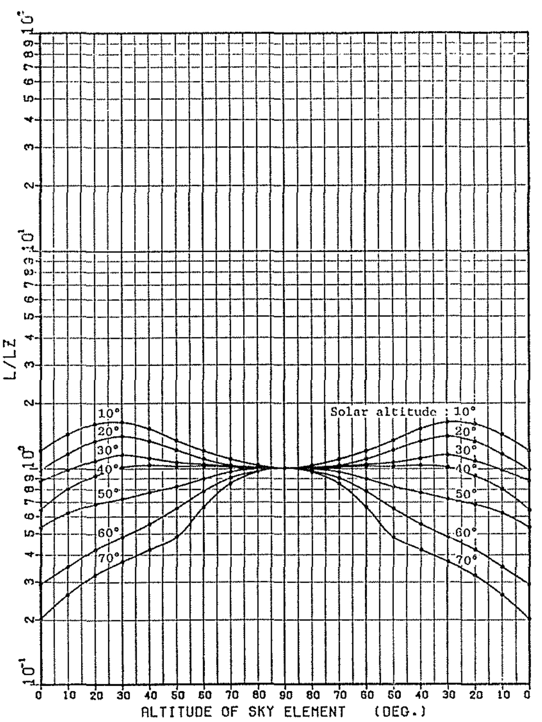

Fig. 1–(2) *Relative luminance of sky elements to the zenith luminance along the directional circle perpendicular to that of including the solar position.*

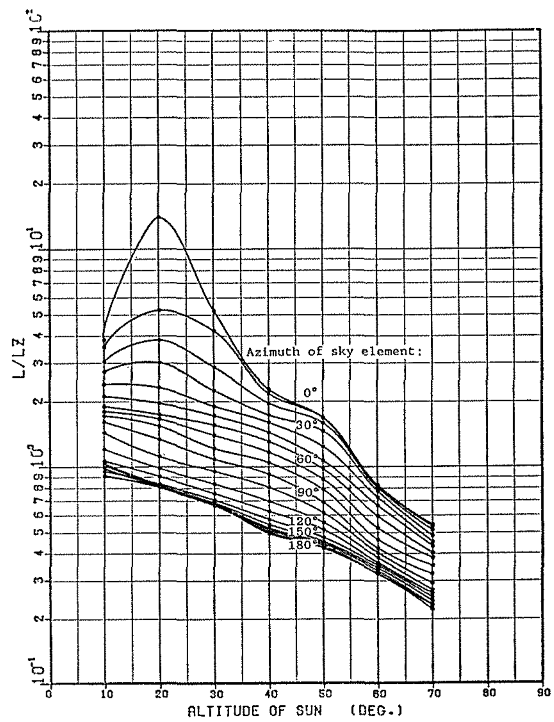

Fig. 1–(4) *Variation according to the solar altitude (altitude of the sky element = 20°).*

of the sky whose altitudes of sky elements were not higher than 60°. And then they were dealt with in the almost same way as the whole sky samples.

Before the finally settling the luminance distribution of the Intermediate Sky, the revisions of it were repeated many times by means of following procedures:

(1) verifying of the luminance distributions of the whole sky by comparing them with those of the low parts of the sky;

(2) a little correction to keep the luminance value fluctuating smoothly both with time and in space at all the ordinary sky elements except the special ones whose positions on the celestial sphere were same as that of the sun.

For the item (2) above, many figures were drawn and inspected which showed the variation of the luminance value along a directional circle on the celestial sphere or along an iso-altitude circle, the variation according to the solar altitude and so on. The examples of them are shown in **Fig. 1–(1)** to **Fig. 1–(4)**.

The data corresponding to the solar altitude of below 0° were too few to determine the luminance distribution of the sky when the solar altitude was 0°. However, the ratio of the duration when the solar altitude is below 5° to the total working duration is small in Japan, for instance, when the 8 hours working duration from 9 a.m. to 17 p.m. is set, the maximum value of the ratio shown at the point of high latitude in Japan is only 3.2%. So the lack of the standard of the luminance distribution of the solar altitude of 0° seems to have little effects upon daylight prediction based upon the Mean Sky.

The data corresponding to the solar altitude of over 75° were also not enough.

The luminance values of the solar position on the celestial sphere were approximately estimated from the values of the positions near the sun, as the measurement values of the solar position had not been gained because the light form there was interrupted by a little circular shading plate held aloft over the orthographic projection lens in order to avoid the effects of the direct sun beam.

The definitive results of this research work were shown in terms of the ratio of the luminance value of each sky element to that of the zenith. **Table 1–(1)** to **Table 1–(7)** show the luminance ratio of all sky elements of every 10° in the altitude and every 10° in the azimuth from the sun. **Fig. 2–(1)** to **Fig. 2–(7)** are respectively the whole sky diagrams of iso-luminance ratio distribution of the solar altitude of every 10°, from 10° to 70°, in the stereographic projection.

5. Conclusion

The luminance distribution of the Intermediate Sky proposed in this paper have been considered to be reasonable and to be applicable to the daylighting prediction or the daylighting calculation by the authors, after many inspections.

A Mean Sky has been composed with the Intermediate Sky by the authors and a practical method has also been developed by the authors to estimate both the direct daylight factor and the indirect daylight factor, and consequently the daylight factor as the mean value in the total working duration throughout a year. Papers concerned with them have already been published.

Table 1–(1) *Relative luminance of sky elements to the zenith luminance (solar altitude 10°).*

A \ h	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
0°	2.82	3.44	3.81	3.60	2.80	1.97	1.50	1.26	1.10	1.00
10°	2.68	3.20	3.54	3.33	2.62	1.95	1.50	1.25	1.09	1.00
20°	2.42	2.80	3.04	2.93	2.43	1.91	1.50	1.25	1.08	1.00
30°	2.13	2.46	2.73	2.60	2.20	1.81	1.47	1.24	1.08	1.00
40°	1.91	2.19	2.38	2.30	2.03	1.75	1.45	1.22	1.08	1.00
50°	1.79	1.98	2.10	2.06	1.90	1.68	1.42	1.21	1.07	1.00
60°	1.70	1.80	1.89	1.90	1.80	1.59	1.39	1.19	1.07	1.00
70°	1.60	1.71	1.79	1.80	1.70	1.52	1.34	1.16	1.06	1.00
80°	1.40	1.60	1.71	1.72	1.62	1.44	1.27	1.13	1.05	1.00
90°	1.20	1.43	1.60	1.63	1.52	1.34	1.20	1.10	1.03	1.00
100°	1.06	1.25	1.43	1.46	1.38	1.23	1.11	1.04	1.01	1.00
110°	0.97	1.09	1.20	1.24	1.22	1.10	1.01	0.98	0.98	1.00
120°	0.95	1.00	1.06	1.06	1.01	0.96	0.94	0.94	0.96	1.00
130°	0.94	0.94	0.95	0.94	0.91	0.92	0.91	0.92	0.95	1.00
140°	0.93	0.92	0.90	0.90	0.91	0.91	0.90	0.91	0.95	1.00
150°	0.92	0.90	0.91	0.94	0.94	0.92	0.90	0.91	0.94	1.00
160°	0.90	0.92	0.98	1.01	0.99	0.94	0.91	0.90	0.94	1.00
170°	0.93	0.96	1.01	1.05	1.04	0.98	0.92	0.90	0.94	1.00
180°	0.94	0.97	1.03	1.07	1.05	1.00	0.93	0.90	0.93	1.00

Table 1–(2) *Relative luminance of sky elements to the zenith luminance (solar altitude = 20°).*

A \ h	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
0°	2.53	5.00	14.00	5.10	3.49	2.51	1.87	1.42	1.17	1.00
10°	2.37	4.26	5.23	4.50	3.41	2.46	1.83	1.40	1.16	1.00
20°	2.08	3.28	3.81	3.72	3.10	2.37	1.75	1.38	1.15	1.00
30°	1.83	2.53	3.00	3.00	2.70	2.15	1.67	1.35	1.14	1.00
40°	1.65	1.92	2.30	2.49	2.34	1.95	1.60	1.33	1.13	1.00
50°	1.53	1.73	1.95	2,03	2.02	1.80	1.54	1.31	1.11	1.00
60°	1.42	1.61	1.73	1.83	1.80	1.68	1.46	1.25	1.10	1.00
70°	1.29	1.52	1.65	1.70	1.64	1.52	1.34	1.18	1.08	1.00
80°	1.08	1.35	1.53	1.58	1.52	1.37	1.21	1.10	1.03	1.00
90°	0.98	1.16	1.33	1.40	1.33	1.21	1.10	1.03	1.01	1.00
100°	0.94	1.00	1.11	1.20	1.16	1.07	1.00	0.98	0.99	1.00
110°	0.90	0.92	0.98	1.02	1.00	0.95	0.93	0.94	0.96	1.00
120°	0.86	0.88	0.90	0.89	0.88	0.88	0.88	0.90	0.94	1.00
130°	0.84	0.84	0.83	0,81	0.81	0.82	0.83	0.86	0.92	1.00
149°	0.83	0.83	0.81	0.80	0.80	0.80	0.81	0.84	0.90	1.00
150°	0.83	0.82	0.80	0.81	0.81	0.81	0.81	0.83	0.90	1.00
160°	0.82	0.81	0.80	0.81	0.81	0.81	0.80	0.82	0.89	1.00
170°	0.82	0.81	0.81	0.82	0.82	0.81	0.80	0.82	0.89	1.00
180°	0.81	0.80	0.82	0.83	0.82	0.81	0.80	0.82	0.89	1.00

Table 1–(3) *Relative luminance of sky elements to the zenith luminance (solar altitude = 30°).*

A \ h	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
0°	2.09	3.00	5.20	11.50	5.08	2.93	2.04	1.56	1.25	1.00
10°	2.00	2.72	4.20	5.20	4.12	2.86	2.03	1.55	1.24	1.00
20°	1.70	2.24	2.86	3.25	2.95	2.48	1.96	1.53	1.23	1.00
30°	1.52	1.86	2.23	2.56	2.46	2.17	1.86	1.49	1.21	1.00
40°	1.40	1.66	1.89	2.15	2.19	2.02	1.73	1.41	1.18	1.00
50°	1.30	1.53	1.71	1.89	1.94	1.78	1.53	1.29	1.22	1.00
60°	1.19	1.38	1.55	1.66	1.68	1.56	1.34	1.19	1.08	1.00
70°	1.03	1.23	1.39	1.46	1.47	1.38	1.21	1.11	1.05	1.00
80°	0.94	1.09	1.21	1.30	1.28	1.20	1.13	1.07	1.03	1.00
90°	0.87	0.98	1.08	1.15	1.11	1.06	1.04	1.02	1.00	1.00
100°	0.82	0.90	0.95	0.97	0.96	0.95	0.94	0.95	0.97	1.00
110°	0.78	0.82	0.83	0.83	0.84	0.85	0.86	0.90	0.95	1.00
120°	0.75	0.75	0.75	0.74	0.75	0.77	0.80	0.85	0.92	1.00
130°	0.73	0.71	0.70	0.69	0.70	0.72	0.75	0.81	0.89	1.00
140°	0.70	0.69	0.68	0.68	0.68	0.69	0.72	0.79	0.87	1.00
150°	0.68	0.67	0.67	0.67	0.68	0.68	0.71	0.77	0.86	1.00
160°	0.66	0.66	0.66	0.67	0.68	0.67	0.70	0.76	0.85	1.00
170°	0.64	0.65	0.66	0.68	0.68	0.67	0.69	0.76	0.85	1.00
180°	0.63	0.65	0.67	0.68	0.68	0.67	0.69	0.75	0.84	1.00

Table 1–(4) *Relative luminance of sky elements to the zenith luminance (solar altitude = 40°).*

A \ h	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
0°	1.53	1.87	2.26	3.30	7.60	3.50	2.26	1.63	1.29	1.00
10°	1.50	1.82	2.16	2.94	3.95	3.08	2.19	1.62	1.27	1.00
20°	1.40	1.72	1.95	2.40	2.65	2.45	2.04	1.57	1.24	1.00
30°	1.30	1.57	1.72	1.93	2.60	2.03	1.80	1.48	1.21	1.00
40°	1.19	1.42	1.59	1.74	1.79	1.75	1.59	1.38	1.18	1.00
50°	1.08	1.28	1.43	1.54	1.60	1.53	1.42	1.28	1.13	1.00
60°	0.96	1.16	1.30	1.37	1.42	1.36	1.27	1.18	1.08	1.00
70°	0.85	1.03	1.16	1.26	1.27	1.22	1.16	1.10	1.05	1.00
80°	0.75	0.91	1.04	1.13	1.14	1.12	1.09	1.06	1.03	1.00
90°	0.64	0.80	0.92	1.01	1.03	1.02	1.02	1.01	1.00	1.00
100°	0.57	0.71	0.80	0.86	0.89	0.90	0.91	0.94	0.97	1.00
110°	0.53	0.62	0.69	0.74	0.77	0.79	0.83	0.88	0.94	1.00
120°	0.50	0.57	0.62	0.65	0.68	0.71	0.76	0.82	0.91	1.00
130°	0.48	0.53	0.57	0.60	0.63	0.66	0.70	0.77	0.87	1.00
140°	0.46	0.51	0.54	0.56	0.59	0.62	0.67	0.74	0.85	1.00
150°	0.44	0.49	0.52	0.54	0.56	0.59	0.64	0.72	0.83	1.00
160°	0.43	0.48	0.51	0.52	0.54	0.57	0.62	0.70	0.82	1.00
170°	0.42	0.47	0.50	0.51	0.53	0.56	0.61	0.69	0.81	1.00
180°	0.42	0.47	0.49	0.51	0.52	0.55	0.60	0.68	0.80	1.00

Table 1-(5) *Relative luminance of sky elements to the zenith luminance (solar altitude = 50°).*

A \ h	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
0°	1.11	1.47	1.67	2.03	2.82	5.60	3.05	2.02	1.39	1.00
10°	1.10	1.44	1.67	2.00	2.60	3.45	2.80	1.95	1.35	1.00
20°	1.05	1.36	1.58	1.87	2.25	2.59	2.35	1.85	1.34	1.00
30°	1.00	1.22	1.45	1.67	1.93	2.06	1.99	1.67	1.31	1.00
40°	0.95	1.07	1.23	1.43	1.62	1.72	1.66	1.50	1.25	1.00
50°	0.90	0.98	1.06	1.21	1.34	1.43	1.42	1.32	1.18	1.00
60°	0.84	0.92	0.97	1.06	1.15	1.22	1.23	1.18	1.08	1.00
70°	0.75	0.84	0.87	0.92	1.00	1.07	1.10	1.08	1.04	1.00
80°	0.65	0.73	0.78	0.81	0.86	0.92	0.99	1.02	1.03	1.00
90°	0.53	0.62	0.68	0.72	0.77	0.82	0.89	0.96	0.99	1.00
100°	0.47	0.55	0.61	0.64	0.68	0.72	0.80	0.90	0.96	1.00
110°	0.42	0.50	0.55	0.58	0.61	0.65	0.72	0.82	0.92	1.00
120°	0.38	0.46	0.51	0.53	0.56	0.60	0.67	0.75	0.88	1.00
130°	0.36	0.43	0.47	0.49	0.52	0.56	0.62	0.70	0.84	1.00
140°	0.35	0.41	0.45	0.47	0.49	0.52	0.58	0.66	0.81	1.00
150°	0.34	0.40	0.44	0.45	0.47	0.50	0.55	0.64	0.78	1.00
160°	0.34	0.39	0.43	0.44	0.46	0.49	0.54	0.62	0.77	1.00
170°	0.33	0.39	0.42	0.43	0.45	0.48	0.53	0.62	0.76	1.00
180°	0.33	0.39	0.42	0.43	0.44	0.47	0.53	0.61	0.76	1.00

Table 1-(6) *Relative luminance of sky elements to the zenith luminance (solar altitude = 60°).*

A \ h	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
0°	0.53	0.67	0.82	1.08	1.57	2.55	4.00	2.48	1.45	1.00
10°	0.52	0.67	0.82	1.06	1.50	2.29	3.16	2.27	1.42	1.00
20°	0.50	0.66	0.80	1.00	1.35	1.92	2.32	1.97	1.38	1.00
30°	0.48	0.63	0.77	0.94	1.15	1.48	1.76	1.70	1.32	1.00
40°	0.45	0.59	0.72	0.86	1.00	1.21	1.40	1.42	1.22	1.00
50°	0.40	0.53	0.66	0.78	0.88	1.05	1.18	1.22	1.15	1.00
60°	0.36	0.47	0.59	0.69	0.80	0.92	1.04	1.11	1.09	1.00
70°	0.32	0.42	0.52	0.60	0.72	0.84	0.94	1.02	1.05	1.00
80°	0.30	0.38	0.46	0.53	0.63	0.75	0.88	0.97	1.00	1.00
90°	0.29	0.35	0.42	0.48	0.55	0.65	0.78	0.90	0.97	1.00
100°	0.28	0.34	0.40	0.45	0.51	0.58	0.70	0.82	0.94	1.00
110°	0.27	0.33	0.38	0.42	0.47	0.52	0.62	0.76	0.90	1.00
120°	0.27	0.32	0.36	0.40	0.44	0.49	0.57	0.69	0.85	1.00
130°	0.26	0.31	0.35	0.38	0.42	0.46	0.53	0.64	0.82	1.00
140°	0.26	0.30	0.34	0.37	0.40	0.44	0.50	0.61	0.79	1.00
150°	0.25	0.29	0.33	0.36	0.38	0.42	0.48	0.59	0.76	1.00
160°	0.25	0.29	0.32	0.35	0.38	0.41	0.47	0.57	0.75	1.00
170°	0.25	0.29	0.32	0.34	0.37	0.41	0.46	0.56	0.74	1.00
180°	0.25	0.29	0.32	0.34	0.36	0.40	0.46	0.56	0.74	1.00

Table 1-(7) *Relative luminance of sky elements to the zenith luminance (solar altitude = 70°).*

A \ h	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
0°	0.33	0.43	0.54	0.74	0.90	1.07	1.48	2.70	1.54	1.00
10°	0.33	0.42	0.53	0.73	0.89	1.05	1.43	1.90	1.48	1.00
20°	0.33	0.41	0.51	0.69	0.87	1.02	1.30	1.55	1.35	1.00
30°	0.32	0.39	0.48	0.63	0.82	0.97	1.17	1.34	1.26	1.00
40°	0.31	0.38	0.45	0.58	0.76	0.93	1.05	1.18	1.19	1.00
50°	0.30	0.37	0.43	0.52	0.69	0.86	0.97	1.08	1.10	1.00
60°	0.29	0.35	0.40	0.47	0.61	0.79	0.92	1.00	1.05	1.00
70°	0.27	0.32	0.38	0.43	0.52	0.70	0.86	0.96	1.00	1.00
80°	0.23	0.29	0.35	0.40	0.46	0.57	0.78	0.93	0.99	1.00
90°	0.20	0.26	0.32	0.37	0.42	0.48	0.66	0.85	0.96	1.00
100°	0.18	0.24	0.29	0.34	0.38	0.44	0.54	0.74	0.91	1.00
110°	0.17	0.22	0.27	0.32	0.36	0.41	0.49	0.65	0.87	1.00
120°	0.16	0.21	0.26	0.30	0.34	0.39	0.47	0.60	0.82	1.00
130°	0.15	0.20	0.25	0.29	0.33	0.37	0.45	0.57	0.78	1.00
140°	0.15	0.19	0.24	0.28	0.32	0.36	0.43	0.55	0.75	1.00
150°	0.15	0.19	0.23	0.27	0.31	0.35	0.42	0.54	0.73	1.00
160°	0.15	0.19	0.23	0.27	0.30	0.34	0.41	0.53	0.72	1.00
170°	0.15	0.18	0.23	0.27	0.29	0.34	0.41	0.52	0.72	1.00
180°	0.15	0.18	0.22	0.26	0.29	0.34	0.40	0.52	0.72	1.00

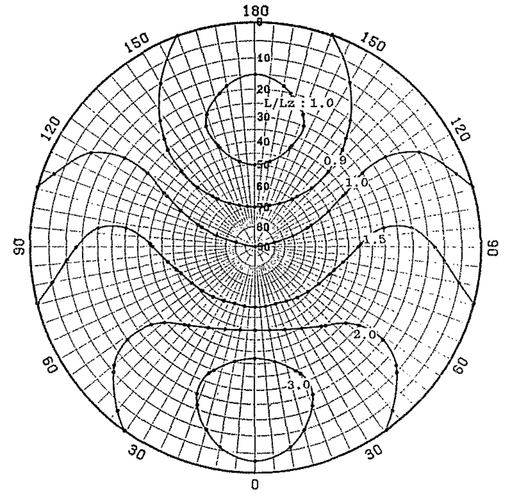

Fig. 2–(1) *Whole sky diagram of iso-luminance ratio distribution (solar altitude = 10°).*

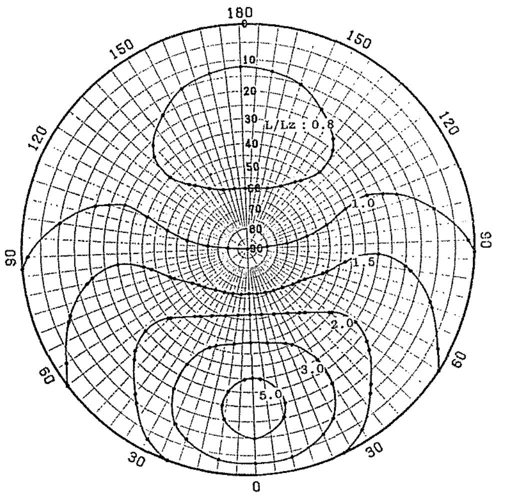

Fig. 2–(2) *Whole sky diagram of iso-luminance ratio distribution (solar altitude = 20°).*

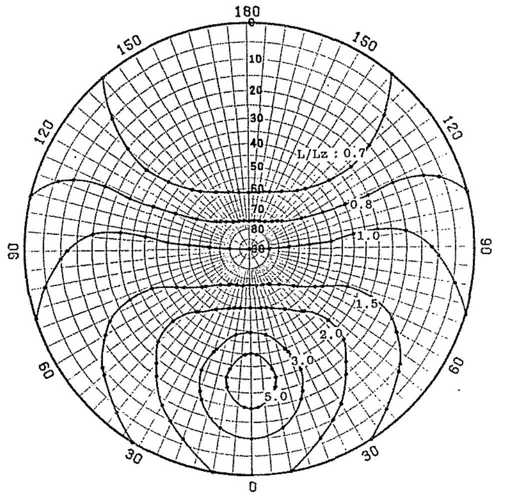

Fig. 2–(3) *Whole sky diagram of iso-luminance ratio distribution (solar altitude = 30°).*

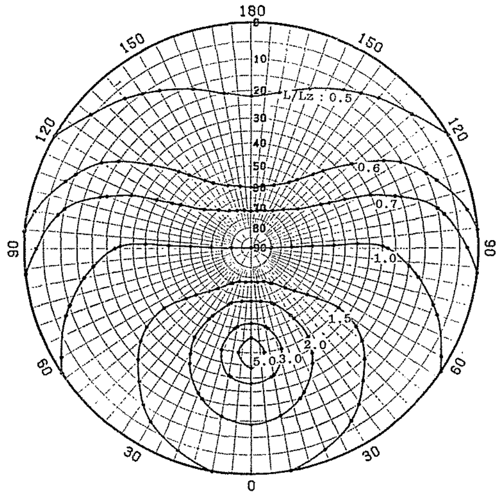

Fig. 2–(4) *Whole sky diagram of iso-luminance ratio distribution (solar altitude = 40°).*

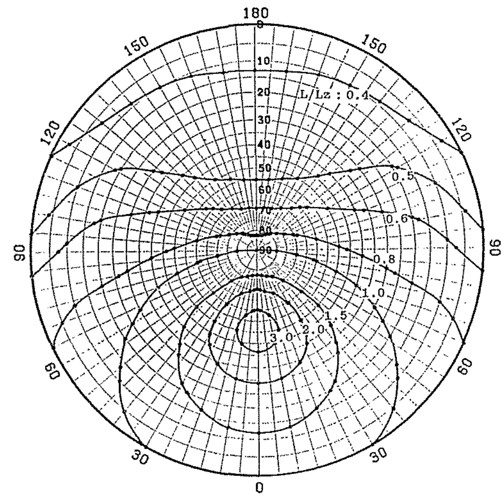

Fig. 2–(5) *Whole sky diagram of iso-luminance ratio distribution (solar altitude = 50°).*

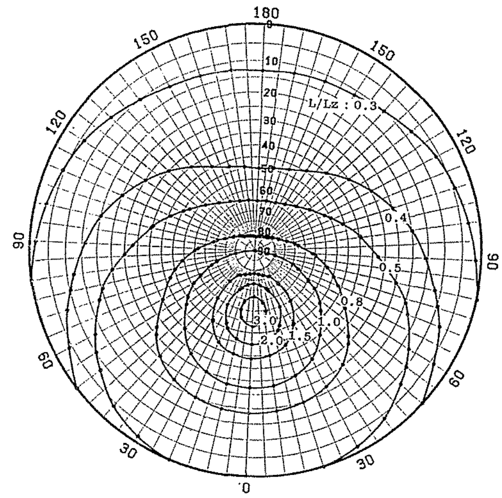

Fig. 2–(6) *Whole sky diagram of iso-luminance ratio distribution (solar altitude = 60°).*

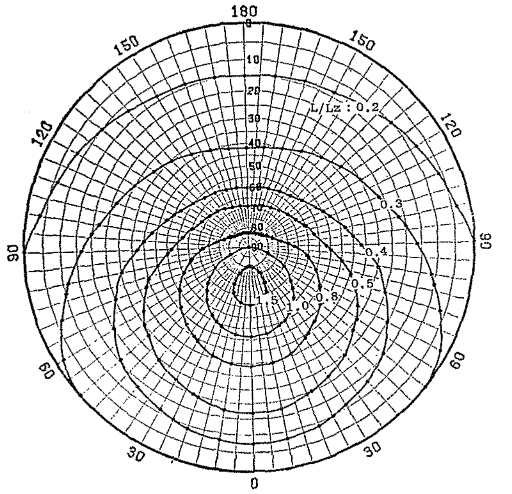

Fig. 2-(7) *Whole sky diagram of iso-luminance ratio distribution (solar altitude = 70°).*

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