New artificial 'overcast and clear' sky with an artificial sun for daylight research

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The feasibility of model studies in daylight research of architectural spaces by means of artificial skies has been demonstrated several times already.[1-3] Almost all the artificial skies used until now simulated the luminance pattern of a densely overcast sky of either uniform or standard CIE luminance distribution. Although some artificial skies[4,5] have also been equipped with an artificial sun their luminance distributions followed neither any real, mean or ideal luminance patterns of the absolutely clear or partly cloudy skies in spite of the fact that during recent years several sky luminance measurements have been made and reported in different countries.[6-8]

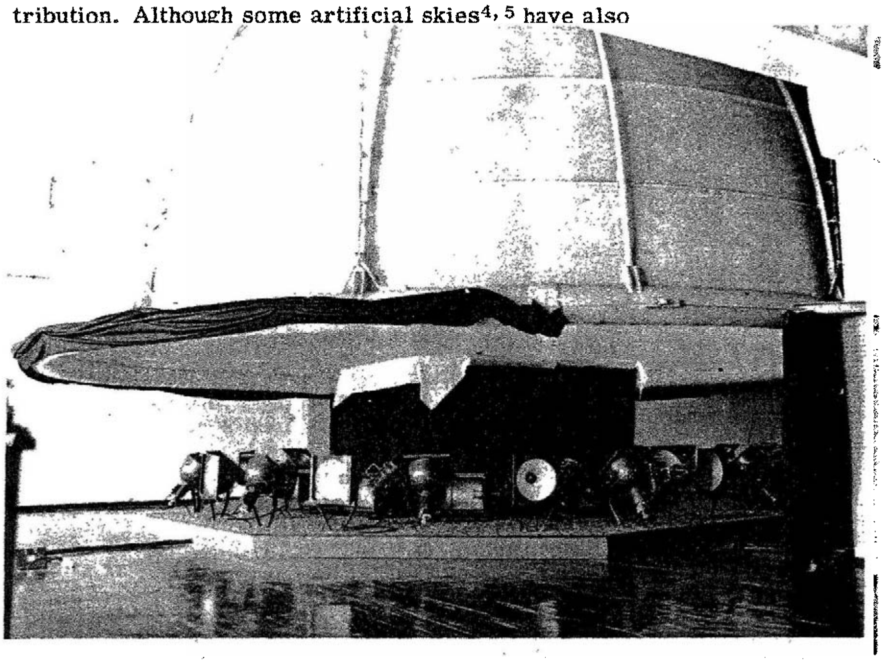

Fig. 1. New artificial sky at the Institute of Construction and Architecture, Bratislava.

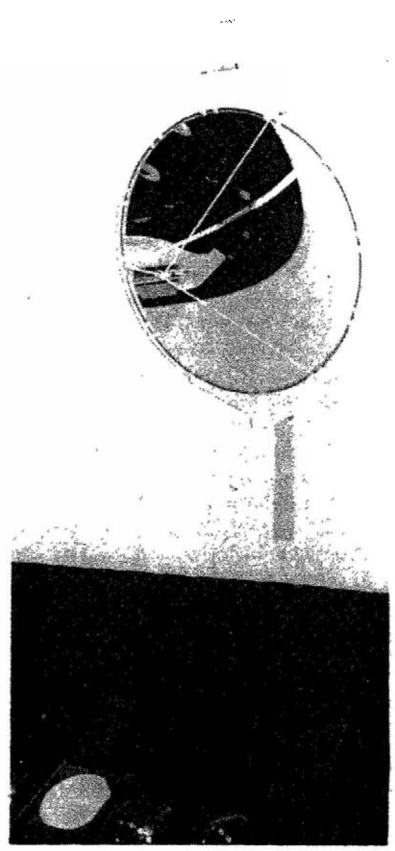

Fig. 2. Parabolic mirror used to simulate the Sun.

The present author proposed to CIE committee 3.2, now TC 4.2 (Daylight), in 1965 the standardization of the clear sky luminance pattern by means of the atmospheric diffusion indicatrix[9] and suggested a practical method for its measurement and evaluation.[10] After thorough consideration the original formula was recommended and internationally standardized by the CIE thus defining the conditions under the absolutely clear sky for theoretical (calculation) and experimental (model) daylight studies and predetermination.[11]

At the same time the author's research team at the Institute of Construction and Architecture, Slovak Academy of Sciences, Czechoslovakia, was responsible for the design, equipment and calibration of a hemispherical artificial sky (8 m in diameter) with an artificial sun (parabolic mirror with a diameter of 1.2 m). This work was successfully completed at the end of 1973.[12]

The multipurpose concept of this laboratory equipment was based on the simulation of the following daylight conditions:

(a) those occurring under the densely overcast sky, namely:

(i) the CIE sky with dark ground characterized by a horizon/zenith luminance distribution of 1 : 3;

(ii) the overcast sky with snow covered ground characterized by a ratio of 1 : 2;

(iii) the sky with uniform luminance;

(b) those occurring under the absolutely clear sky within solar altitudes from 15° to 65° (the latter being the maximum summer Sun position in Czechoslovakia).

This Research Note describes the artificial sky and the lighting system used to achieve this range of simulations.

The hemispherical dome of the artificial sky shown in Fig. 1 is of a tubular construction built on a circular 'horizon' tube suspended from the laboratory roof like a huge white chandelier.

The inner reflective surface is formed from gypsum plaster on mesh covered with three thin layers of a specially prepared mixture of barium sulphate with carboxymethyl cellulose. This matt white paint is successfully fulfilling the requirements for ideal reflectance and diffusion properties of the sky surface and has shown negligibly slight deterioration during four years of use. The hemispherical surface is interrupted only along the Sun meridian by a 10 cm wide slot which enables the height of the artificial sun to be adjusted (see Fig. 2). The sun is placed inside the sky hemisphere, unlike the previously usual attachment of the 'sun' parabolic mirror on the outer side of the artificial sky. Its rear side is thus conveniently used for the 'trough' lighting which enhances the high sun-corona luminances, only partly simulated by the focal sun source—an 800 W tungsten-halogen lamp. The light output from this lamp is directed mainly towards the parabolic mirror to form the parallel 'sun' beams.

The sun meridian slot is also used for ventilating the heat generated by the incandescent lamps of the floor mounted luminaires used to illuminate the sky surface. The 'podium' lighting system consists of two separate circuits simulating:

(a) the overcast skies using 12 wide angle 500 W fittings and four 2000 W narrow angle spotlights all

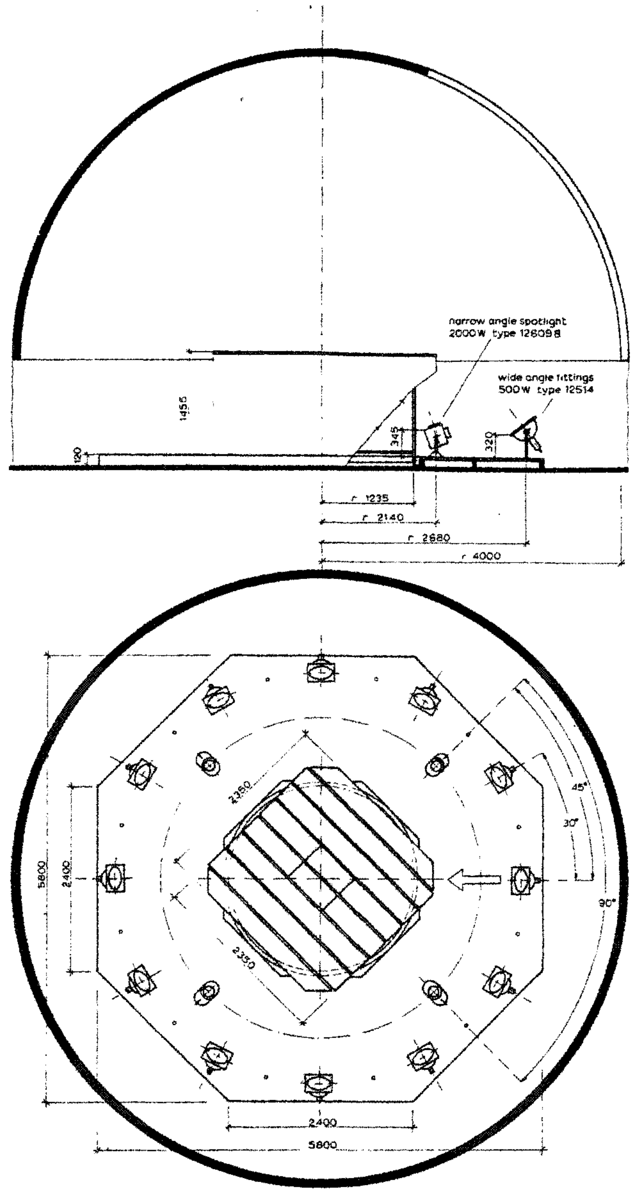

Fig. 3. Lighting arrangement for the overcast sky luminance distribution.

directed upwards towards the sky zenith, as shown in Fig. 3;

(b) clear sky conditions using 14 wide angle 500 W fittings and 12 rectangular 1000 W studio floodlights directed outwards towards the horizon of the artificial sky, as shown in Fig. 4. Behind the parabolic mirror of the artificial sun are located 64 40 W candle lamps.

The luminance effectiveness of these lighting systems is adjusted and controlled partly by the placing and directional characteristics of the fittings and partly by means of the 11 transductor dimmer circuits available for various interconnections with certain sources in the floor plug boxes. A specially designed calibration system enabled the distribution of the sources on the dimmer circuits and the adjustment of the luminous intensity of the used fittings and their proportionality (i.e. sun/sky ratio) to be fixed in order to achieve the luminance pattern as well as the correct illuminance distribution on the measurement table. (The calibration system and a description of the calibration results will be published later.)

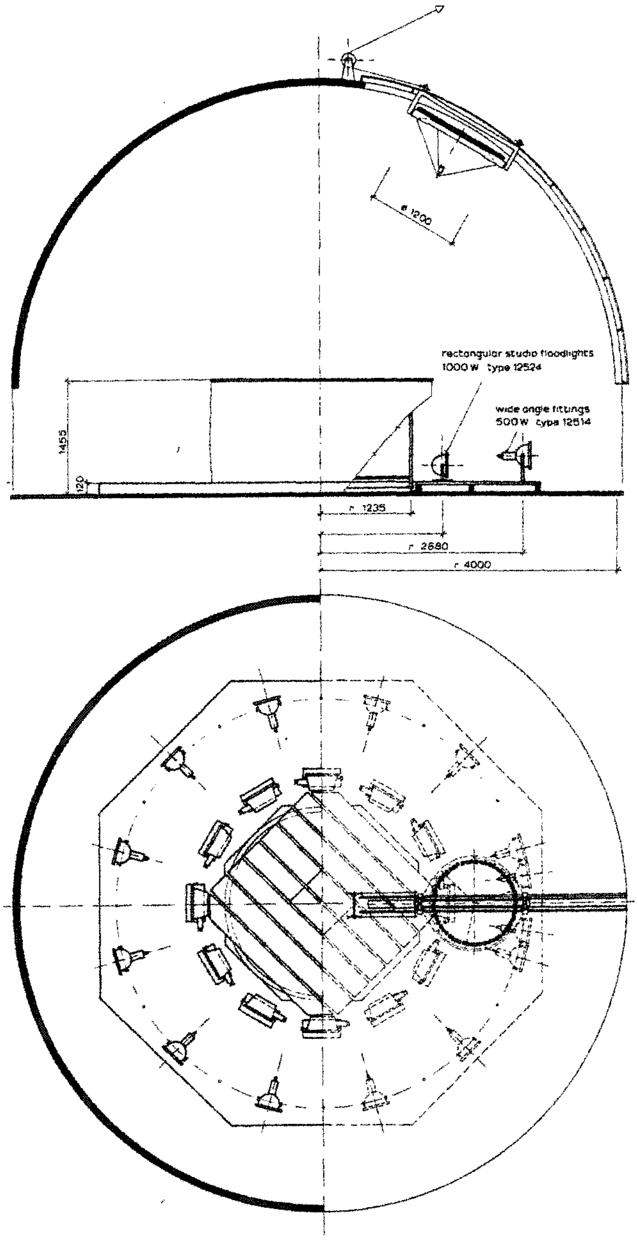

Fig. 4. Lighting arrangement for the clear sky luminance distribution.

The scale model is placed on the rotating table at a height of about 1450 mm above the floor. The azimuth of the sun and the orientation of the model house-fronts to the sun meridian or to the cardinal points are set by rotating the table. The exterior model space (models of exterior obstructions, e.g. house fronts simulating a street, a court-yard etc, or terrain of different reflection properties) is placed on the table and is easily adjusted during the measuring procedure as it is within arm's reach of a standing person.

During the measurements the experimenter sits underneath the table operating a measuring stand with two coupled EEL rectifier photocells. The models are without a floor and the stand is moved in slots in the table and placed at the desired measurement positions marked on a scale attached to the underside of the table top. Other instruments, such as the EEL-BRS daylight photometer, its luminance head, a small luminance meter and various photocells for measuring planar, scalar and vector illuminances are used in the same way. It is also possible to remove the middle section of the table top or the table itself and use the artificial sky for various subjective assessments or modelling effects, for measuring the transmission or reflection properties of building materials under typical overcast or clear sky conditions in the laboratory. The general advantages of such experiments are that the state of the light field is exactly defined and is stable, controlled and calibrated. The three year calibration process has been quite successful and the calibration results have demonstrated very good agreement between typical natural daylight conditions and their simulated states obtained under the new artificial sky.

Acknowledgement

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