

# Development of a new artificial sky

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## INTRODUCTION

The artificial skies are the most useful and effective for the prediction of daylit environment in buildings. During the last half-century many artificial skies have been constructed in various research organizations and universities in the world. The artificial skies can reproduce the sky luminance distribution.

A new artificial sky was intended to be developed and constructed by the authors, as there was only one old artificial sky in Japan.

## SURVEY OF ARTIFICIAL SKIES

The artificial skies already constructed all over the world were surveyed and inspected to establish the design concept of the new artificial sky. The artificial skies were roughly classified into following four types.

Mirror type artificial sky is a room of rectangular parallelepiped with a luminous ceiling and four mirror walls. It is to be attached at the outside of a daylighting opening of a model examined when it is small. Models are to be put on its inside centre when it is large enough. The artificial skies of this type seem to imitate roughly the CIE standard overcast sky only. (Fig. 1)

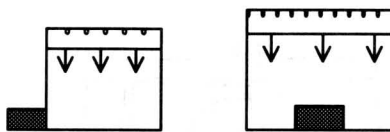


Fig. 1 Mirror type

Reflection type artificial sky is mainly composed of a dome and luminaires. The surface of the dome inside is finished with white diffuse opaque material. The luminaires are to be arranged at the dome centre or the dome skirt. They illuminate the dome inside surface and reproduce various kinds of the sky. The regulation of this type for a specific sky is

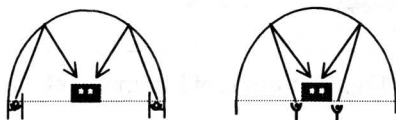


Fig. 2 Reflection type

supposed to be not easy. (Fig. 2)

Translucent type artificial sky consists of a luminous dome of permeable diffuse material. The luminaires are arranged just above the dome or the ceiling of the laboratory. It seems very difficult to estimate luminance of the dome surface because of interreflectin of inside of dome material. This type seems to compose approximately the CIE standard overcast sky only. (Fig. 3)

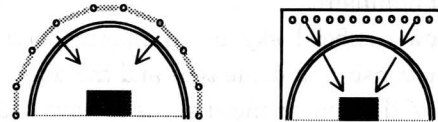


Fig. 3 Translucent type

Direct type artificial sky has a large number of luminaires arranged in hemisphere. All the luminaires point at the inside centre. Each luminaire is controlled separately according to the specific sky. This type is regarded to reproduce the accurate sky luminance distribution very easily. The illuminance on the model seems to be high. This artificial sky looks like a night sky with full of stars. (Fig. 4)

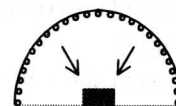


Fig. 4 Direct type

Some of artificial skies provide a movable artificial sun. Some have fixed ones. Most of the artificial suns consist of parabolic reflectors and halogen lamps.

An artificial ground is installed in the artificial sky. It can rotate corresponding to the azimuth of the sun.

## CONCEPTS OF THE NEW ARTIFICIAL SKY

The concepts of the newly developed artificial sky are decided as follows: The shape of the sky should be hemisphere, the direct type should be adopted, the luminaires are distributed all over the sky, all

over the sky should be luminous (not like a night sky with stars), a movable artificial sun and a rotatory artificial ground are necessary, all the system should be controlled by a microcomputer, monitoring equipment should be installed, blue and crimson skies should be imitated for demonstration, a powerful air condition system should be prepared.

### THE ARTIFICIAL SKY DEVELOPED AND CONSTRUCTED

853 luminaires are attached closely to the pipe frames that are set up for the luminaires in hemisphere and point at its centre. They form an artificial sky. All the luminaires are shaped not to make room between a luminaire and the other adjacent luminaires.

The new artificial sky is an intermediate type between translucent dome type and the direct type. A merit of the new artificial sky is to have both the features of the two types that light is diffused and that the sky luminance is controlled easily and accurately.

The diameter of the artificial sky is 5 m. The horizon of the artificial sky is 1.3 m high from the floor, so the inner height to the zenith is 3.8 m. (Fig. 5) The artificial sky is covered with 19 kinds of different shaped luminaires, as the sky vault is split horizontally into 19 by its height. The luminaire of the zenith is shaped round and the others are shaped similar trapezoid. (Fig. 6) The surface of every luminaire is covered with permeable opal acrylic resin diffuser. The light source in it is a 85W mini tungsten halogen lamp coated with a infrared reflective layer. (Fig. 7)

Two luminaires, except the zenith, symmetric with respect to the vertical orbit of the artificial sun from the horizon to the zenith, are coupled in order that their lighting levels can be controlled by one control circuit. The total number of the control circuits is 427. The maximum luminance value in common with all luminaires is set at the maximum luminance value of the luminaires which have the largest luminous area. The lighting level of each couple of luminaires can be varied in 100 steps. The maximum illuminance at the centre is 7,300lx.

The artificial sky can simulate many sky luminance distributions as follows: CIE standard clear sky ( the solar attitude from 0° to 90° by 5° intervals), CIE standard overcast sky (sky luminance level- high, medium and low ),

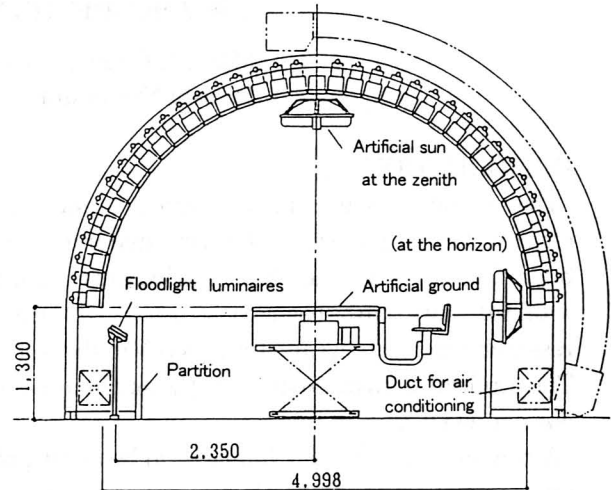


Fig. 5 Artificial sky system

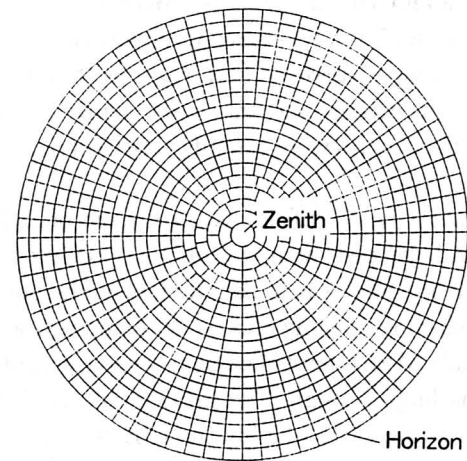


Fig. 6 Arrangement of 853 luminaires

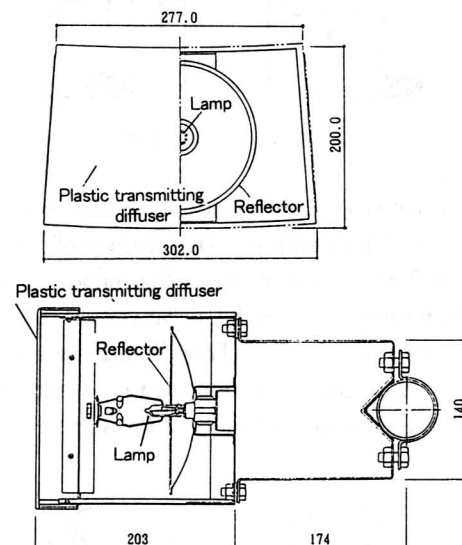


Fig. 7 Details of luminaire at 45° height

Intermediate sky ( the sun attitude from  $0^\circ$  to  $90^\circ$  by  $10^\circ$  intervals), Average sky ( main 34 cities in Japan and the average of them ), Uniform sky (sky luminance level- high and low ) and other reference skies, if necessary.

The artificial sun is a simulating apparatus of direct sunlight with an artificial light source. The artificial sun consists of a parabolic concave mirror of which diameter is 80 cm, a socket for a 500W or 85W mini tungsten halogen lamp, and a mini tungsten halogen lamp. (Fig.8)

The illuminance at the centre of illuminated ground is about 13,000 lx and uniformity ratio to the minimum illuminance in the main part of the lit-up area is about 1:6. The concave mirror with the light source can move from the horizon ( $0^\circ$  in height) to the zenith ( $90^\circ$  in height) in 6 minutes. (Fig. 9) Its height can be set by  $1^\circ$  steps. The artificial sky and the artificial sun can be lit at the same time.

In the artificial sky, a part corresponding to the artificial ground is a platform on which the scale models of buildings are put. The diameter of the round artificial ground is 1.5 m. The artificial ground can be rotated together with the movement of the artificial sun in order to reproduce the correct solar altitude and azimuth at the date and time at the geographical point to be referred. It takes 12 minutes for  $360^\circ$  rotation in azimuth of the artificial ground.

The artificial sky has supplementary floodlight luminaires, which simulate blue and crimson skies. The floodlight luminaires are arranged beneath the horizon at the skirt of the dome, and light up the inner surface of it like a reflection type artificial sky. 40 floodlight luminaires covered with blue transparencies are installed in order to illuminate the artificial sky vault with blue light like the blue sky. (500W mini tungsten halogen lamp is applied to the light source.) A movable stand with 5 floodlight luminaires covered with orange transparencies is also prepared to show the crimson sky in the twilight. (300W double-ended tungsten halogen lamps is applied to the light source.) A control device with 15 circuits is provided in order to vary their lighting level in 100 steps.

The solar position, i.e. solar altitude and azimuth, at any specified point in the world at any indicated time throughout a year can be instantly estimated by a microcomputer. The luminance distribution of any indicated reference sky is calculated by the

microcomputer and simulated on the artificial sky. The artificial ground rotates to show the correct sun position. All the characteristic data concerned above, i.e. light sources, lighting control equipment and circuits, are stored in the memory of the computer.

## DISCUSSION

The new artificial sky system introduced in this paper has been developed after inspections of various artificial skies in the world. It can be regarded as a variation of direct type, but every part of the artificial sky is luminous. It can imitate instantly any kind of sky luminance distribution. The artificial sky is unique and excellent, and has almost completely satisfied the authors. The experiments with the system have been attracting not only daylighting research workers but also amateur visitors to the institute as the experiments are easily understood.

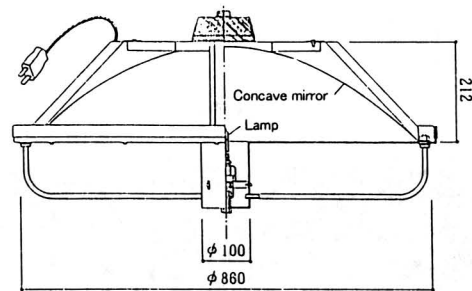


Fig. 8 Artificial sun

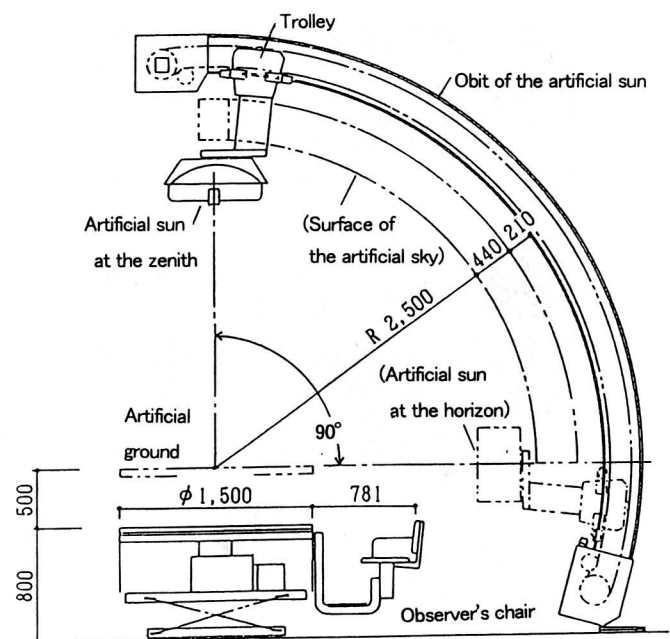


Fig. 9 Driving mechanics of the artificial sun

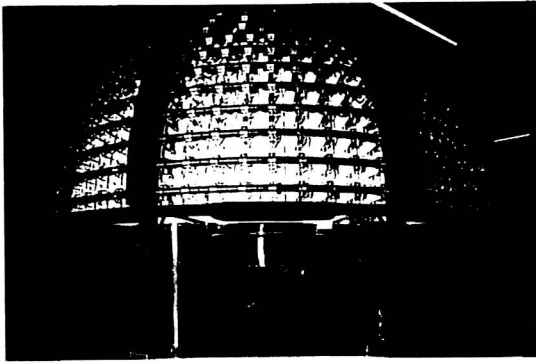
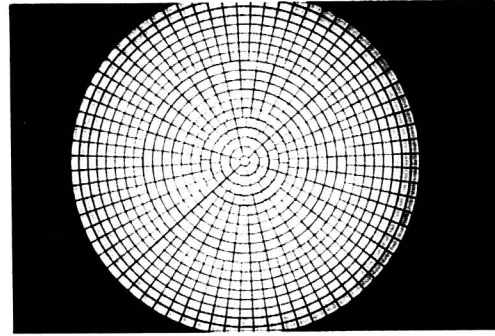


Photo. 1 External appearance



(a) Uniform sky

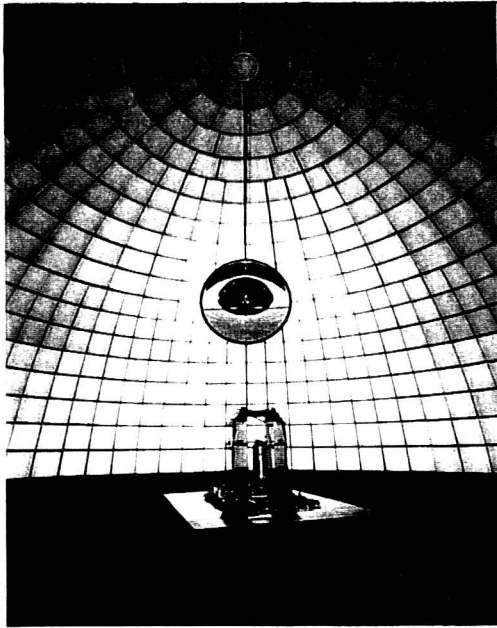
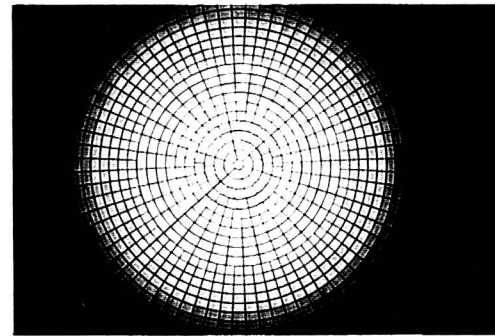
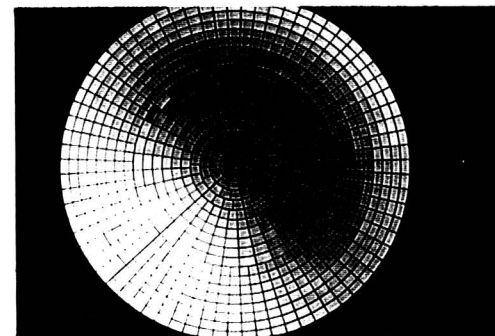


Photo. 2 Internal appearance



(b) CIE standard overcast sky



(c) CIE standard clear sky (30° height)

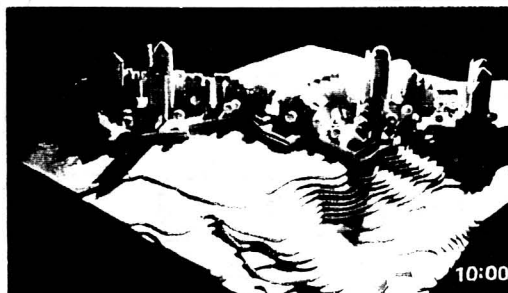
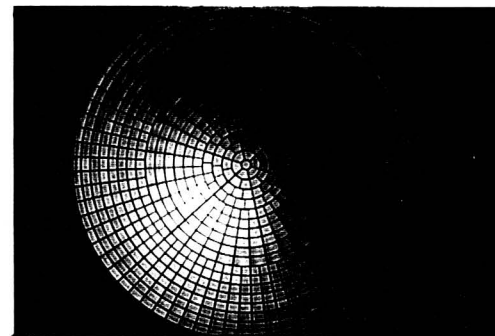


Photo. 3 Model study



(d) CIE standard clear sky (60° height)

Photo. 4 Sky luminance distribution of the artificial sky

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