PASSIVE LIGHT PIPES

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Summary

Passive hollow tubes consist of a light pipe transport section with, at the upper end, some device for capturing natural light and, at the lower end, a means of distribution of light within the interior. The wider use of the systems is currently limited by the lack of quantitative design methods other than those based on empirical data. This paper presents preliminary results of flux output and luminous intensity distribution for various configurations of passive solar light pipes, based on laboratory and field measurement. As well as indicating quantitative performance of passive light pipes, analysis of the results points the way toward prediction of performance of a wide range of system configurations.

1 Introduction

Over the past few years considerable research has been undertaken on the use of light pipes as transport devices or light emitters in buildings. The majority of systems in use employ electric lamps or sun tracking devices as light sources and thus rely on expensive equipment to capture, transport and distribute light. Recent interest has focused on passive light pipes as a means of lighting interiors. These devices operate according to the same physical principles as electric or solar systems to transport and distribute light but, due to their simplicity, are cheaper to construct and maintain.

Passive hollow pipes consist essentially of a vertical light pipe transport section with, at the upper end, some device for capturing natural light whilst preventing ingress of wind and rain and, at the lower end, a means of distribution of light within the interior. The upper end of the tube may be horizontal or inclined at some angle to the tube axis. The tube may be lined with highly reflective silvered material but contains no lenses or other devices to redirect the light. The hollow tube wall uses multiple specular reflection at the inner wall to transmit light. In general overall light transmission is a function of surface reflectance, input angles of the incident light, and the proportions of the tube in terms of the ratio of length to cross section area. If the light paths are long compared with the axial length the number of reflections are necessarily large, and thus light loss depends to a great extent on reflectance of the wall material. To minimise the number of reflections light should enter the tube as a near collimated axial beam.

A number of passive pipe systems are commercially available. They consist of a clear polycarbonate dome, rigid or flexible tubes coated with a reflective material, and a light diffuser made of opal or prismatic material. Rigid tubes may include bends or elbows. A modification to the basic systems cuts the upper end of the tube at an oblique angle and inclines the cut toward the equator. This 'light scoop' has the effect of increasing the flux output of the tube by a factor to up to two under clear sky plus sun but has a negative effect on output under overcast conditions.

A number of studies of passive pipe systems have produced empirical performance data for particular cases of system configuration and local daylight conditions, and this data may be applied to design of similar systems. All of the studies indicate that passive pipe systems have considerable potential as a primary light source for some types of building interior.

This paper presents preliminary results of flux output and luminous intensity distribution for various configurations of passive solar light pipes, based on laboratory and field measurements. As well as indicating quantitative performance of passive light pipes, analysis of the results point the way toward prediction of performance of a wide range of system configurations

2 Passive light tubes as a lighting solution

A number of investigations into performance of passive light pipes have been made. Love et al (1) compared the transport sections of a number of commercially available mirror light pipes. The work involved mounting pipes above a integrating chamber and measuring the illuminance within the integrator and the simultaneous external illuminance thus enabling the transmittance of various combinations of bends and straight pipe to be determined. Harrison et al (2) measured nadir illuminance and simultaneous external illuminance from a single pipe under laboratory conditions. The results indicated that nadir daylight factor (inside/outside illuminance ratio) ranges from 0.5% for overcast skies to 0.2% for clear skies. Data for working plane and/or nadir illuminance and simultaneous external illuminance for actual installations has been measured (3). A further study suggested that daylight factors of up to 1.0% could be obtained for pipes not exceeding aspect ratios of six (4).

It is clear from the literature that basic information on light transmission properties of some configurations of pipe and on quantities of planar illuminance delivered under certain circumstances has been established. Pipe transmission information makes possible estimation of flux output for given sky conditions and this may, together with the various measured nadir and working plane illuminance values, serve as 'rule of thumb' design guidance. This does not however address the problem of prediction of performance of installations which do not resemble those measured.

3 Experimental investigation

The work investigated flux output, luminous intensity distribution and illuminance distributions from a number of configurations of passive solar light pipes by a combination of laboratory and field measurement.

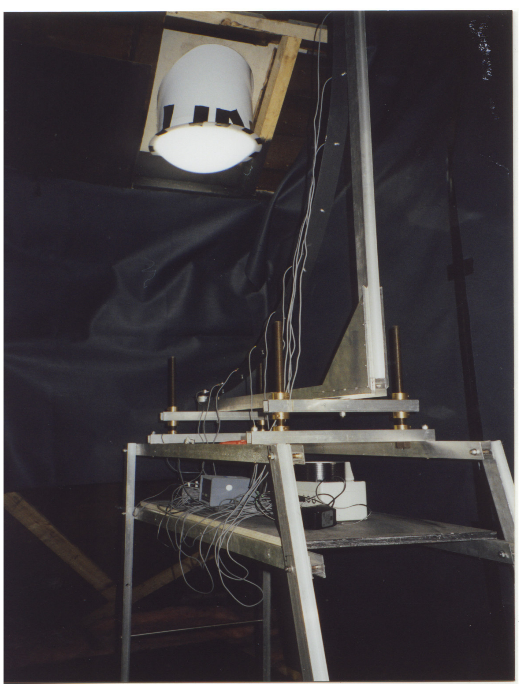

Figure 1 Apparatus to measure luminous intensity distribution from pipe emitter