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Centralized Lighting Systems for Office Interiors

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Abstract

This paper describes a novel light distribution concept that uses a centralized distribution system, which is optically connected (with light guides) to a series of integrated work stations. The system uses a single HID source with a series of light guides over each task plane. This centralized lighting/work station maintains illuminance and contrast independent of occlusion effects from furniture and body shadow, while increasing the efficiency of light delivery to the task plane. Using a single HID to illuminate multiple task planes can reduce the number of lamps required leading to reduced mercury recovery costs associated with fluorescent lighting systems as well as reduced energy consumption. This concept also has the potential to reduce the costs of both materials and maintenance.

Back ground

Existing lighting design techniques generally do not explicitly define the spatial relationship between a visual task and a lighting source. Visibility, which is highly dependent on the spatial relationship between task and source, will thus vary as a function of interior design and occupancy characteristics. Lighting design techniques are also typically limited to an unobstructed room cavity; an environment that is rare in modern office applications. Room cavity obstructions—such as task stations and furniture—have been shown to have a substantial effect on task illuminance under real conditions. Furniture, partitions, and body shadow can reduce illuminance by 30 to 40 percent as a result of occlusion. These potential variations in contrast and illuminance suggest the need for alternative lighting systems and approaches that maintain lighting quality and illuminance. The development of furniture-integrated lighting approaches that maximize contrast and minimize obstruction losses would be of significant conservation benefit in the lighting design and specification process.

Description of Centralized Concept

The centralized lighting system uses a single high-lumen-output source and a centralized light distribution network to illuminate a group of task planes. The initial concept includes a single 200- to 250-watt HID (metal halide) lamp with a distribution box that is optically connected to four light guides that channel the light to four individual task stations. One light guide is positioned over each task plane, providing an even distribution of flux with minimal obstruction from body shadow and partition systems (Figs. 1 & 2). Positioning the fixture system in alignment with the coronal plane of the occupant provides a high level of contrast, as the veiling contribution is reflected away from the line of primary viewing. This placement also mitigates the obstruction of luminous flux from the fixture, resulting in minimal body shadow effects. The proposed candlepower distribution (see Fig. 2) would concentrate the flux within the immediate task plane area, further enhancing efficiency and reducing the potential for VDT imaging problems in adjacent work areas.

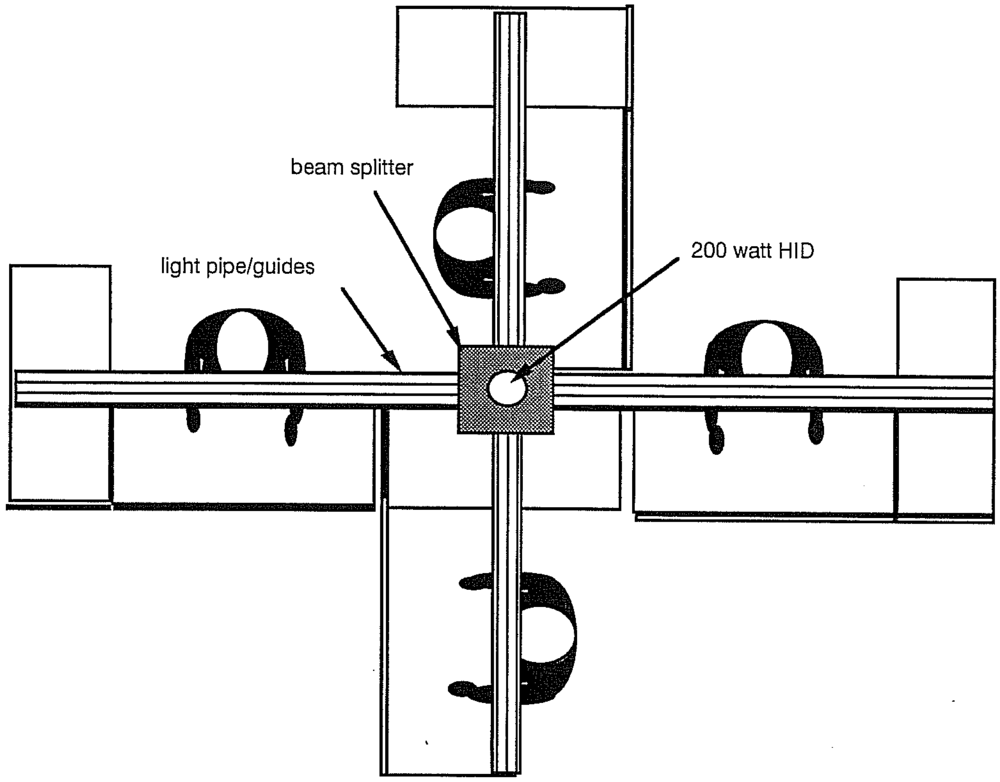

Figure 1 Plan View of Centralized System

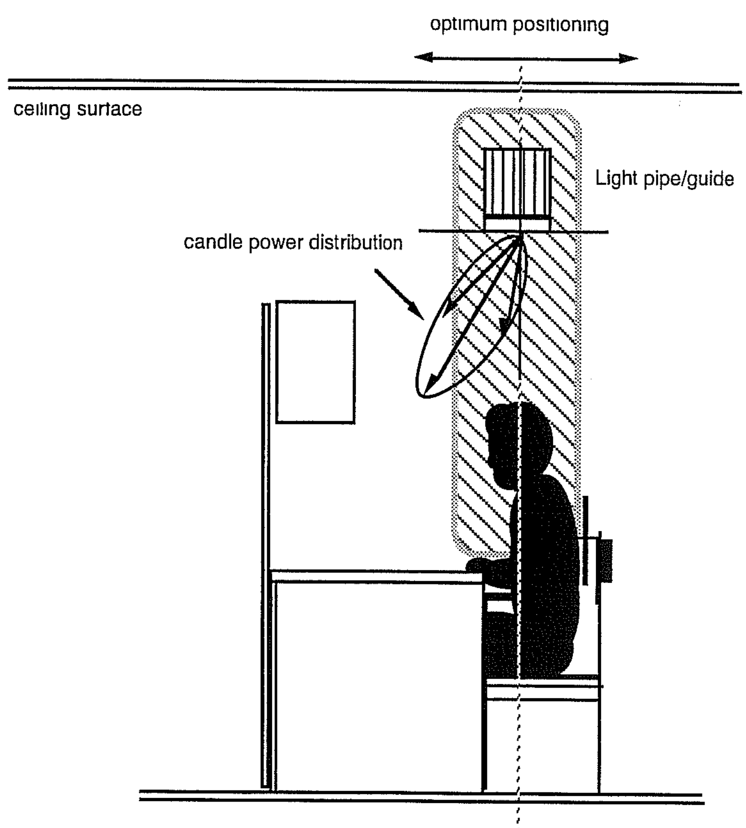

Figure 2 Cross Section of Light Pipe System

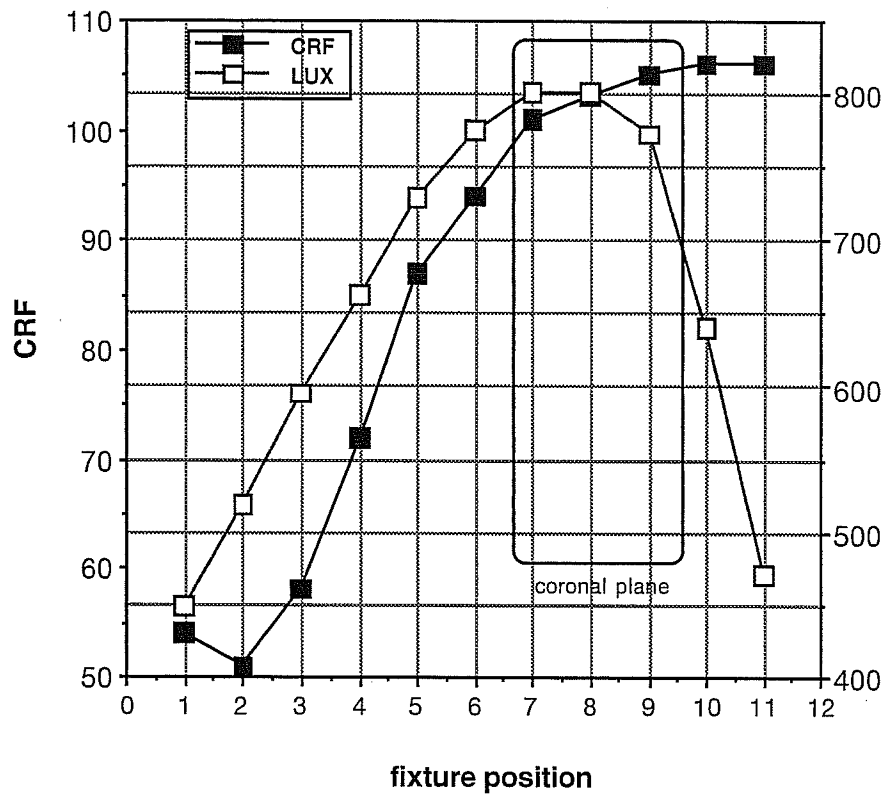

Figure 3. Illuminance and contrast as a function of fixture position

Figure 3 shows the variations in both illuminance and contrast as a function of fixture position indicating the relative effectiveness of the overhead coronal position of the fixture with respect to the task. Placement of the fixture system between position 7 and 9, corresponding to the coronal plane, provides an effective location in terms of both maintained contrast and illuminance across the task plane. Positioning of the fixture in front of the coronal plane of the body results in the potential for reduced contrast as a function of veiling reflections (positions 1 through 7). Positioning the fixture behind the coronal plane results in losses in illuminance due to occlusion from body shadow (positions 9 through 11).

The light guide is an optical channeling system similar in concept to fiber optics. Each guide includes a plastic channel with a rectangular section. This channel has a special internal optical surface produced by 3M Corporation. The surface material utilizes the concept of total internal reflection, allowing the guide to reflect light down the length of the section. The bottom surface of the channel is treated with a transmitting material that allows incident light to pass out of the channel and down to the task plane below. In this design, the guides are arranged in groups, coupled optically with a series of four reflectors to a single centralized source. This optical connection involves the use of a distribution system, or beam splitter, that distributes the luminous output of the single source to the multiple light guides. Figure 4 shows the schematic of a section of the beam splitter and the single HID source.

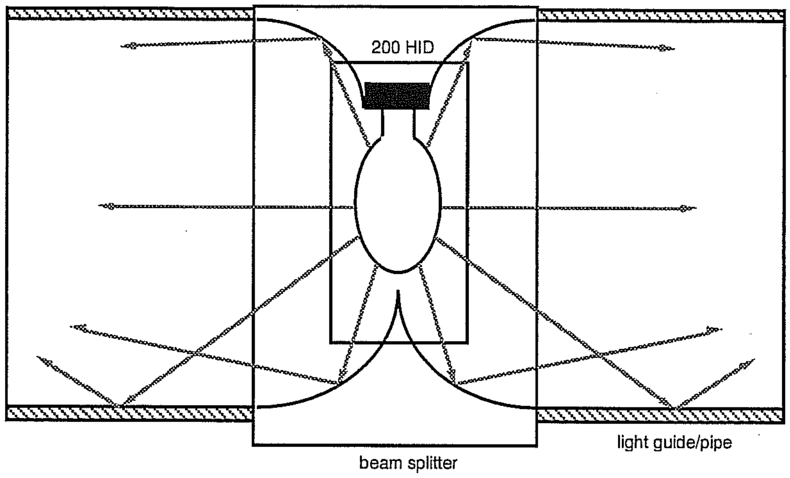

Figure 4 Section of Beam Splitter

The described centralized lighting system can significantly reduce the power requirements for lighting, offering potential efficiency enhancements over conventional lighting layouts. The overall power assignment per station with the single 250 watt HID is approximately 60 watts per station or per person. Initial laboratory measurements using a full scale prototype indicate that task plane illuminance with this system is approximately 90 foot-candles. These measurements indicate that the source wattage could be reduced to 200 watts and still maintain 60-70 foot-candles of task plane illuminance. Further efficiency enhancements can be achieved with enhanced optics for the distribution box and the light guide/channeling system. Power assignments per person are being projected at 30 to 50 watts.

This power assignment per person compares favorably with conventional systems that typically range in power per person for medium density office occupancies of 100 to 200 watts per person. This is based on an assumption of 1 to 2 fixtures per person using a regular grid of 2x4 troffers with 3 T8 lamps per fixture on a standard 8x8 grid.

Secondary benefits associated with the application of the centralized system include significant reductions in the amount of hardware and electrical components needed. The centralized lighting system uses only one lamp and one ballast for the lighting of four task stations. With conventional lighting system using recessed troffers many more lamps and ballasts would be required. The number of electrical hook-ups, junction boxes, and related wiring would also be greatly reduced, offering a savings in the design and construction of the layout. The centralized lighting system offers the potential of providing and maintaining the quality of light across the task plane at a significantly lower cost in comparison to standard uniform layouts.

Lamp disposal and mercury recovery are an increasing problem and represent added cost to the operation of commercial interiors. The centralized lighting system has the potential to reduce recovery costs and maintenance by reducing the number of lamps required to illuminate the space and by concentrating the mercury and hazardous material into a single lamp.

Layouts and Applications

In larger layouts, the centralized plan can be reproduced for large area applications. Figure 5 shows a plan layout of multiple stations, illustrating the use of the concept in a high-density application. The distribution system can also be applied in the lighting of applications involving long linear tasks. Figure 6 shows a plan view of the stations organized in a row. In this type of system, the wattage could be reduced in proportion to the number of task stations integrated with each distribution box.

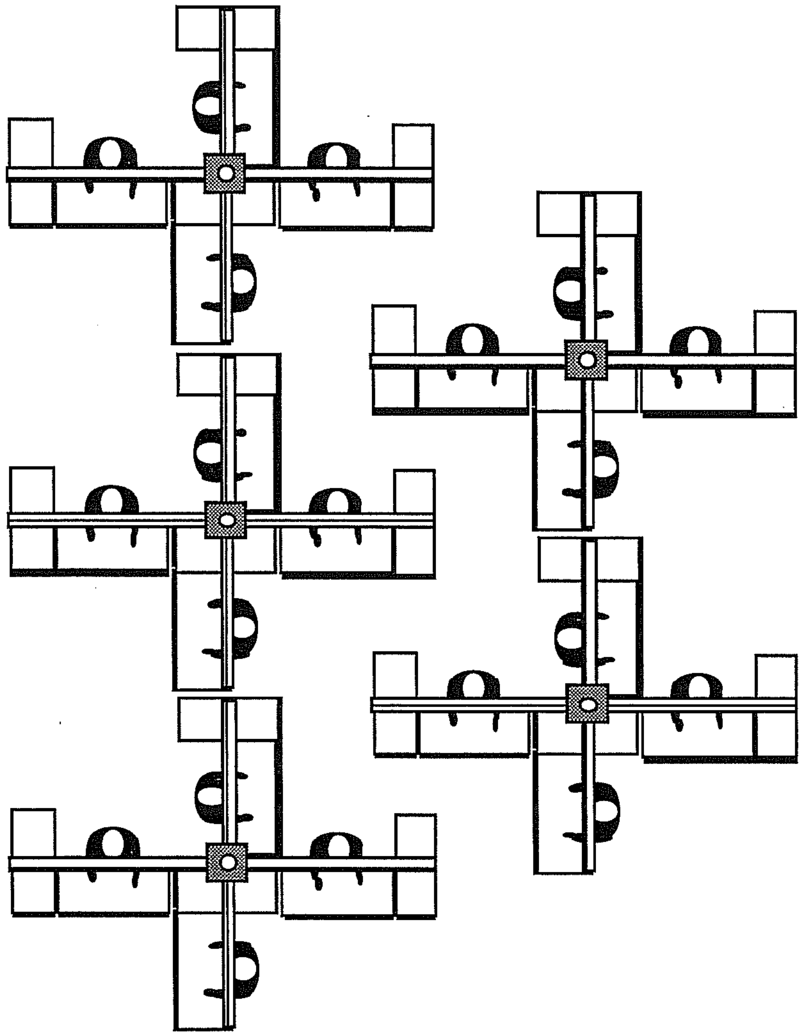

Figure 5 Centralized Lighting Layouts High-Density

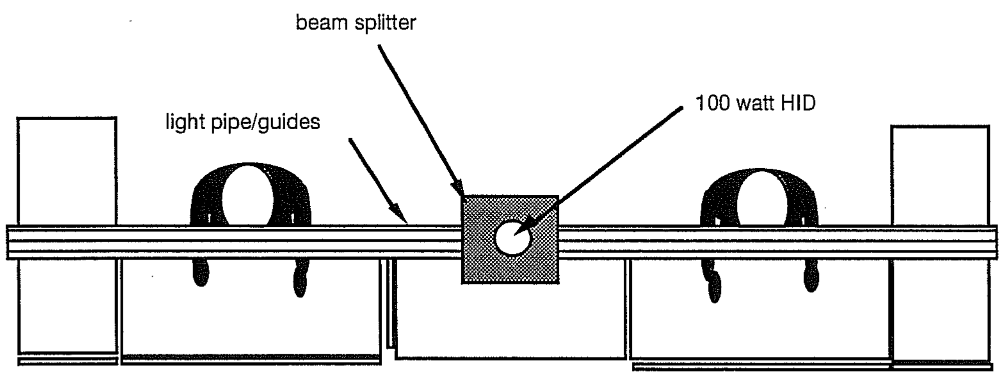

Figure 6. Row Applications of Linear Light Pipe

In addition the centralized lighting systems allows the opportunity to integrate the supply and return system of the HVAC for individual comfort control systems. The light pipe system can be easily configured as a distribution system providing individual control to each work station. The return system could be integrated within the beam splitter and light distribution system, providing a centralized pick-up point for return to the main air handler.

The centralized system can be developed as a modular system, incorporating the work station furniture, lighting, computer, HVAC and electrical components. As a complete system, the modular package could be integrated within the layout of the space as a function of the occupancy. This concept could simplify and accelerate both the architectural and interior design process.

Summary

The high-lumen source and unobstructed distribution system make this centralized lighting system unique in assuring lighting quality, while providing an efficient lighting supply. In addition to increased efficiency, this system may lower building costs, as it would require less hardware and labor. One of the most important potential advantages of the centralized lighting system is the maintenance of the effective task/source geometry, which promotes visual quality. The effectiveness of the fixture positioning will be maintained independent of changes in interior layout and occupancy.

The centralized lighting concept offers the potential to utilize some of the newer, high-efficiency HID sources. Existing and developing technologies can provide high-lumen-output systems with a small source. This presents advantages in terms of efficiency and the ability to design effective optical distribution systems.

Specific research issues that must be addressed include the design of the optics of the distribution box or beam splitter, the transmission surface of the guide, and the overall integration process in designing the work stations. Ongoing research is focusing on the development of full-scale prototypes that can be studied photometrically, and on the integration of furniture systems and integrated HVAC and controls.

ACKNOWLEDGMENT

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