USE OF NATURAL DAYLIGHTING IN ENERGY EFFICIENT BUILDINGS

By Dean Powell

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The illumination of interior spaces by natural lighting has been used throughout the centuries in as many ways as there are styles of architecture. When the only means of artificial lighting was through the use of crude torches or inefficient oil lamps, all lighting during the daylight hours was accomplished by natural lighting. Many of the techniques developed in historical times can be applied to present day usage through architectural adaptation of basic concepts.

The methods utilized for daylighting, fall into two broad areas. The first is the use of direct sunlight through windows or other openings located on the south, east, or west side of a building. This is a harsh, gross use of the maximum amount of light available from the sun and has been used, quite effectively, throughout history, for lighting large volumes of space, with openings that were quite often small in comparison to surrounding structural masses. Tall buildings made the best use of this type of lighting, since the height of the exposed walls allowed the use of openings so placed to illuminate opposite walls effectively. When used in Cathedrals, these openings were usually arranged to provide dramatic lighting of the altar area and oriented to, in general, direct this light from the side or rear of the building. Since reading or fine seeing tasks were not involved, the brightness contrasts were not important. The second general method used for daylighting, has been through the use of "north lighting" or redirected lighting. North lighting is, in itself, a description of the method. All areas of the sky are filled with air, water and dust molecules which produce a natural scattering of the sunlight throughout the air space resulting in a diffused lighting source which, when utilized through openings facing north, result in high levels of direct lighting without the glare which is present when direct sunlight is used.

Natural lighting fell into disuse with the advent of higher efficiency artificial lighting sources and the concept of a totally controlled environment (windowless spaces, all season air conditioning, etc.). When we became aware of the fact that our fuel/energy sources were not unlimited, immediate attention was directed to the use of solar energy for heating of buildings. "Active" solar collector systems were the first to gain prominence as being a "new and developing" art. Not far behind this search was the "passive" solar system. "Back to basics" became the watchword for a more economical method of using solar energy. In the rush to utilize the sun's rays directly, however, the effect of sunlight on seeing ability was largely ignored. The use of direct sunlight for passive heating of spaces is, in general, a reasonably economical method of solar heating. To combine this direct sunlight method for heating and for providing natural daylighting within a space becomes a much more difficult task. We can learn from our historic predecessors about the use of free lighting from the sun and the open sky. We can also learn to integrate this sun for both heating and lighting.

Control is the essence of all systems utilizing natural light. Control and the ability to calculate with some reasonable degree of accuracy, the end results. Ability to handle the variability of lighting conditions presented by natural light is also of primary importance. The extreme variability of natural daylighting sources in Albuquerque is indicated in Figure No. 1.

As can be seen in this graph, the use of daylighting in the high altitude areas of the southwest involves an extra burden of control due to the high intensity of available sunlight and the clarity of the air. Measurements of the unobstructed sun in the latter part of June on a clear day, reveals readings of 7500 footcandles. This same unobstructed sun in December measures 4000 foot-candles. Equivalent measurements, with light obscuring clouds, reveal an intensity of approximately 6000 footcandles of summertime light in all directions including horizontal, north, east, south and west. Measurements with heavy cloud cover (with light rain) drops this available light to approximately 1000 footcandles in all directions. In considering daylight designs in this area, the problem of control is one of major importance. In northern areas of the United States, buildings can be oriented toward the south to take maximum advantage of the

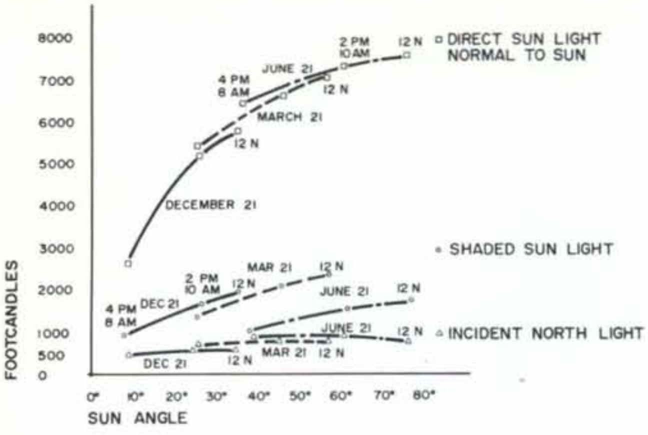

FIGURE 1 DAYLIGHTING ILLUMINANCE FROM IES LIGHTING HANDBOOK, 5TH EDITION FIGURES 7-7 AND 7-8 MODIFIED TO CORRELATE WITH CLEAR SKY READINGS IN ALBUQUERQUE

heat of the sun and the light of the sun. In this area, heat and lighting become two distinct design problems. With a two to one ratio of intensity between winter and summer and the very high candle power available, the use of direct sunlight for daylighting becomes one of reducing this direct sunlight to a usable level. Many different factors contribute to the amount of light received on a vertical or horizontal surface of a building. In this area, ground light itself (reflection of skylighting onto the ground) also becomes a problem of control. Many different architectural considerations should be made for the use of natural daylighting. One of the time honored methods for control of sunlight is the use of an overhang above windows. An overhang, however, is a detriment to the proper utilization of north lighting. Any openings facing the south should use an overhang and proper placement of windows to prevent the direct entry of sunlighting into the space.

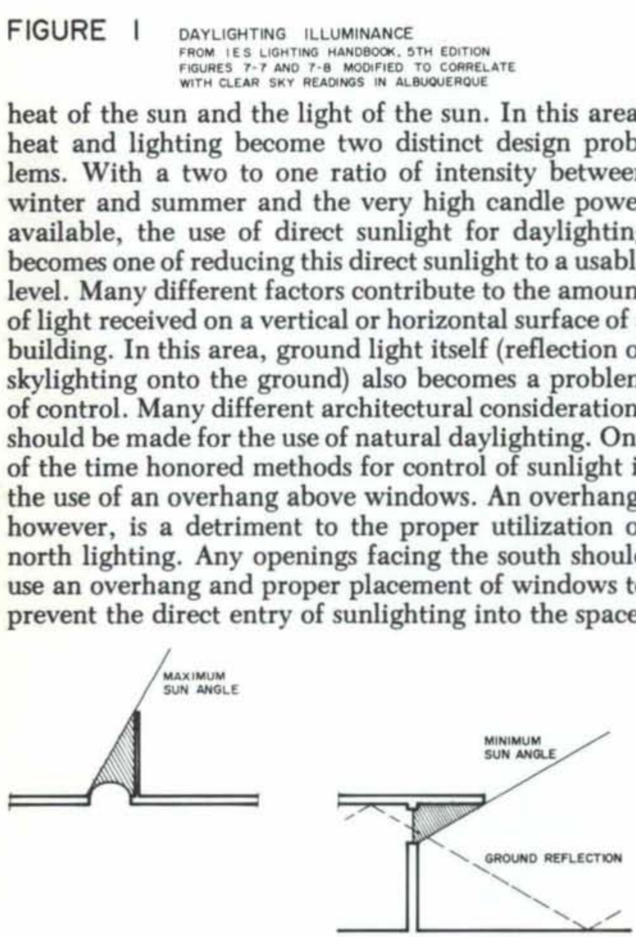

FIGURE 2 DIRECT SUN LIGHT CONTROL

In addition, direct visual contact to harsh ground lighting areas should be avoided. Propitiously placed screen walls along the south side of a building, which would prevent direct entry of sunlight and reduce the direct component of ground lighting, is an excellent way of controlling the entry of these harsh, high intensity rays of light.

Figure No. 2 illustrates several methods for control of direct sunlight and ground lighting. These methods of control include the redirecting of sunlight, through a series of baffles, to absorb and scatter direct rays onto a large enough surface to keep the contrast levels between a normal interior space and the lighted surface to a level which does not produce excessive eye fatigue. It is in this area of contrast, between lighting surfaces and working planes, that can produce high fatigue and increase chances for accident in an industrial environment. Vertical sunlight traps can also be used to redirect sunlight on to surfaces that could then be considered as the light source for lighting a space. Louvers and baffles can be used, as well as low transmission glass.

In utilizing "north lighting" or natural sky scattering of light particles to produce the necessary diffusing medium within a space, the control of the entry of the natural light is greatly simplified. In Albuquerque, the natural north light varies from slightly more than 900 footcandles per square foot in the summertime to slightly more than 600 footcandles per square foot in the wintertime, producing an overall uniformity of lighting levels that is not dependent upon the seasons or ordinary sun angles. This natural light scattering by air molecules results in a lighting source for which, when seen through unobstructed clear glazing, the brightness does not appear at the glazing point, but is distributed throughout the depth of field. With properly sized glazing, enough of this well diffused light source can be admitted to light most spaces without resorting to baffles, moveable louvers, or other devices.

Under high overcast conditions, where the sunlight is scattered through light colored clouds, the "high sky" effect results in as much as 6000 footcandles in all directions. This lighting is reduced to approximately 2000 footcandles under shaded conditions. This additional light would, under these conditions, produce a greater brightness from shaded north and south light glazed areas but should still be within acceptable limits of glare. The number of days that this condition exists in New Mexico does not exceed 5 or 6 during the year and, as such, can be considered to be of negligible importance. Even under heavy cloud conditions, with light rain falling, the north light still maintains a level of around 600 footcandles.

One major solution to the use of natural light scattering by air molecules is through the use of a vision strip at the top of a wall on the south side of a building, with overhang to shield it from the direct rays of sun at minimum winter conditions, and vertical baffle to shield this strip from a setting west sun. If a space, which is lighted by this means on the south side, also has available north light fenestrations, the overall illumination within the space can be

reasonably uniform. If the space is unusually large, the use of facing clerestories or baffled skylighting will average out the illumination in the space. Through judicious use of natural daylighting (both north and south light) different spaces can be lighted in a variety of ways to suit the use and to accommodate the exposure. For instance, in an area reserved for general storage which can use some heating through natural solar means, a combination of passive solar heating and direct sunlight would be tolerable. On the other hand, lighting in an office space must consider maintenance of lighting at contrast levels of less than 2 to 1, a maximum of 200 footcandles or less.

In considering daylighting design for any building, it should be kept in mind that relatively even illumination in the working space must be maintained during operational hours. This usually means that some artificial lighting must be installed to aid the natural daylighting available to provide lighting during non-daylight hours. The location of artificial lighting fixtures should be placed to boost only those areas where additional lighting is required. The use of the concept of task lighting both for natural daylighting and artificial lighting should be considered, in order that a minimum amount of energy be expended for general lighting. If the space is to be used during other than daylighting hours, the artificial lighting task should be considered with minimum acceptable lighting levels. This artificial lighting should also be arranged in such a manner as to allow a variation in the artificial levels to match variations which will occur in the daylighting levels. "Storage" of energy for solar heating can be accomplished but such storage of light cannot be accomplished. This supplementary artificial lighting then is most efficiently used when it is compatible with and complementary to the designed daylighting. Control of the artificial lighting to provide the complement and boost to daylighting can be accomplished in its simplest form through proper switching or through more sophisticated means of automatic control. Systems are presently available, on the market, that can either control the intensity of artificial lighting by automatic sensing of the daylighting available or can control certain areas of artificial lighting to serve a complementary light to natural daylighting at all times.

In summary, daylighting design can be most efficiently used when the conditions available for natural daylighting are considered initially in orientation of the building and when architectural features such as clerestories, north facing fenestration, screenwalls, properly located skylights, etc. Proper use of reflecting and diffusing surfaces, high transmission glass, special and orientation of openings and balance of natural and artificial lighting sources, can produce a building that can be energy efficient for heating and cooling while utilizing a minimum of energy expenditure for lighting *W.D.P.*

UNIVERSITY ENERGY INSTITUTES

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The New Mexico Energy Institutes at the University of New Mexico (Albuquerque), New Mexico State University (Las Cruces), and the New Mexico Institute of Mining and Technology (Socorro) officially inaugurated a formal New Mexico Energy Research and Development program in June 1976. The 1974 Legislature, spearheaded by Mr. Bob Grant, created the opportunity for this arrangement by allocating $2 million annually for an energy R & D program.

The proposed intent of this unique arrangement between state government and the universities through the Energy Institutes was to take advantage of and utilize the available expertise at the universities to address fuel and energy problems of New Mexico and seek solutions for the benefit of the citizens of New Mexico.

The first problem facing this program of the New Mexico Energy Resources Board (ERB) was, what university was going to do what energy research work? this was "solved" by dividing energy into convenient