Natural Lighting at the Kimbell Museum

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The inspiration for the Kimbell Museum design is found in the museum's architectural program written by the original Kimbell Museum director, Richard Brown. Brown devotes a section of the program to lighting and, in particular, to natural lighting. Were natural lighting excluded from the museum, writes Brown, visitors would seem "vacuum packed in a can." Moreover, "The visitor must be able to relate to nature momentarily from time to time—actually to see at least a small slice of foliage, sky, sun, water. And the effects of changes in weather, position of the sun, seasons, must penetrate the building and participate in illuminating both the art and the observer."'

Architect Louis Kahn held similar views about the importance of natural light to all buildings, not only museums. While designing the Kimbell, he asked, "How can one imagine a building of spaces not seen in natural light?" In contrast to the "static qualities" of artificial light, he preferred "...the endlessly changing qualities of natural light, in which a room is a different room every second of the day."?

Out of discussion between client and architect came a design whose natural light was admitted to galleries through skylights. Nature was not visible through the opaque perimeter walls of the museum, but people moving through the museum would see nature in glass walled courtyards cut into the museum's interior. In the galleries, the changing light of the sky is reflected by ceilings which act as natural lighting fixtures.

The chief source of natural light to the galleries are 2'-6" wide linear roof skylights. From the design's beginning, the roof was planned as a series of parallel channels or half cylinder shapes and these skylight slits were located at the top edges of the spanning shapes. Roof forms were aligned from north to south and the building entrance was located on the west at the edge of a park. This orientation is most efficient for gathering the sun's light though most of its arc and avoids angular differences sun angle differences between summer and winter. This orientation also prevents too much or too little light at the ends of the enclosure when the sun is at the horizon. In the completed design, the west porches shield a narrow strip of horizontal glass above gallery walls from the setting sun and the museum is not opened until the rising sun has climbed into the sky. (Fig.1)

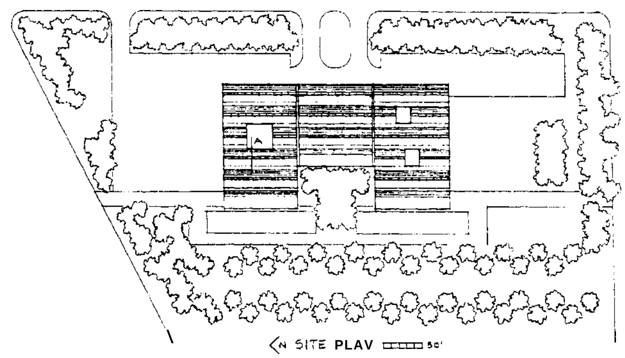

Fig. 1. Site plan.

Skylights admit natural light to a suspended reflector that, in turn, illuminates the cycloidal concrete gallery ceilings. A series of sketches found in Loud's The *Art Museums of Louis I. Kahn*[3] reveal that the cycloid and reflector were products of a long period of design work. Early sketches include angled configurations and some reflectors also housed heating and cooling ducts. Marshall Meyers illustrates the evolution of reflector and ceiling design in his "Masters of Light: Louis Kahn."[4] His own drawings,made in Kahn's office, first show a ceiling section formed by two quarter circles connected by a flat plane with the skylight at its center. A gently curved suspended panel both reflects light onto the ceiling and transmits light to the floor below. A later version includes the cycloid shape Meyers suggested to Kahn and another transparent reflector in a half circle shape. From the interior, it was hoped that the reflector would allow a narrow view of the sky.

Initial reflector designs considered bent glass sheets covered with a thin deposit of aluminum. These ideas were simulated in architectural models by lightly mirrored heat formed Plexiglass. Although modelling was promising, translating the ideal into reality presented formidable problems and no engineering or construction inventions appeared to resolve the difficulties. The expense of glass forming, the durability of the deposited surface, and code requirements for overhead glass all stood in the way of this proposal.

Some progress was made when Richard Kelly, a lighting consultant, joined the design team. After considering acrylic solutions, he proposed that the reflector be made of perforated aluminum sheet chemically polished on one surface. Kelly sketched the approximate curve required to bounce light onto the concrete ceiling. A computer calculated the curve precisely and light intensity levels were estimated. None of these calculations confirmed that the design would distribute natural light as intended. Meyers admits that "...we were really flying by the seat of our pants."' Only tests within the completed cycloid could demonstrate the success of the design.

When two reflector prototypes were finally lifted into place in June 1971, neither was satisfactory. One version containing large perforations in the aluminum sheet admitted too much light. The noon sun shined directly on south facing walls. Such light would injure art hung on these walls. A second reflector with smaller widely spaced holes was insufficiently transparent. It was a dark skylight shield whose perforations Meyers called "stars in a night sky."[6]

The failure of the test reflectors disappointed all and led to thoughts of abandoning transparency altogether. A suggestion from Frank Sherwood of the associated Fort Worth architectural office initiated new thinking about the perforated sheets. Sherwood proposed that the very top of the reflector be made of opaque aluminum while the remainder be perforated. This eliminated direct sunlight at noon, but also curtailed views of the sky. (After building occupancy, a 6" vertical fin was extended from the reflector top to shield galleries from direct natural light during all seasons.) In places where art is not displayed, such as the lobby, it was decided to perforate all the reflector despite sunlight entry. In these locations, it is possible to glimpse the sky. Reflector experiments went on for eight months before a final design was approved.

A visitor to the completed museum would hardly imagine the anguish that accompanied the perfection of its natural lighting. The Kimbell Museum fulfills Director Brown's vision. It lives up to Kahn's prediction made early in the design process. "... I felt that the rooms structured in concrete will have the luminosity of silver. ... This light will give a touch of silver to the room without touching the objects directly, yet give the comforting feeling of knowing the time of day."[7]

The illuminated cycloid ceilings give the museum a life that can't be captured in photographs. The experience of light in the museum derives from its subtle variations. As the positions of sun and clouds change, so changes interior lighting. As visitors move only a few steps, the character of the cycloid surface and the light it reflects also change. The ceilings amplify exterior light variations by concentrating them in the skylight aperture and projecting them onto a concrete surface of great depth and character.

Cycloid surfaces were left untouched after the removal of forms just as Kahn directed. It's possible to inspect the cycloid surfaces from the upper library level where the cycloids are within reach. There one sees the imprint of the butt jointed marine plywood form and its fastenings. The concrete surface retains the plywood's linear wood grain patterns and there are lines of finish nail head impressions along the faint plywood joints. It appears that the forms required patches between pours because smeared outlines can be found in the concrete. As the concrete set, puddles of water collected along the coated form surface and, from some points of view, the puddles appear as splotches of white haze. Form coating and oiling was not uniform andoverpaintings and drip lines add to the imperfections of the cycloid surface.

The details of these imperfections are not easily seen from the gallery floor when the cycloids are illuminated by a bright sky. Looking up, visitors see an obscure circumferential pattern that derives from rivulets of water and plywood sheet joints. More striking are larger but generally circumferential areas that appear lighter and darker or glossier or duller. These are the remains of puddling, patching, and coating. The surfaces offer a beneficial effect as a visitor proceeds along the gallery. With just one step a dark area turns light and what was glossy becomes dull. Illuminated by the reflectors, these imperfect cycloid surfaces no longer appear to be made of concrete. They are silver light sources of varying depth and changing pattern. One would never recognize that the illuminated ceiling and the support columns below the light are made of exactly the same material.

Natural light enters the museum from several other sources: two interior courtyards, curved lunette windows between cycloids and outside walls, vertical glazing at joints between the building's three sections, and aglass entrance wall leading to the lobby and bookshop. Two walls of the of the smaller south courtyard are glazed and it is covered by a white net. Light entering the larger north courtyard is tempered by flowering rose vines winding within steel cables stretched over the courtyard's top. There are vertical blinds on the inside of three courtyard walls and the fourth, nearest the lobby, is glazed from floor to the underside of the cycloid ceiling. A Maillol sculpture—a horizontal bronze figure whose hip perches on a pedestal—is an attractive court feature that serves as an orientation point for the lobby, restaurant, and an adjacent gallery.

The remaining light sources project stripes of sunlight onto interior surfaces. When the sun is low in the sky, lunette windows and apex skylights project diagonal stripes of light onto travertine faced gallery end walls and the ceiling ends. These thin bands add another changing light pattern to the interior. As the sun sets, sunlight crosses under the entrance porch to create a line of light that advances across the lobby floor and onto the oak doors at the rear of the bookshop. This light is abetted by reflections from pools that line most of the museum's west elevation.

For those who were present during construction, the evolution of the illuminated ceilings and the interiors they light must have taken place over a long period. Photographs showing the beginning and the end of site light design accompany Marshall Meyers's article "Masters of Light: Louis Kahn." In each photograph the camera is pointed at the end wall of a gallery and the small courtyard is visible to the right. When the first photograph was taken, only the museum's concrete shell was complete. Lunette window, skylight, and courtyard appear as glaring light sources. Dark walls and cycloids are not illuminated; parts of the gallery floor are lit by a stripe of light from the skylight and by reflected light form the court walls. The later photograph shows the luminous finished interior. Here the reflector has activated the cycloid skylight source and it illuminates all interior surfaces. An oak floor and creamy travertine walls are resplendent in the ceiling light. The reflector itself is a satin anodized aluminum frame supporting bright translucent curved surfaces. What first appeared static and dark has been transformed into a bright interior filled with natural light.

A museum guard explained that the cycloids are at their brightest during clear summer days. When a cumulus cloud obscures the sun, there is an abrupt change in gallery light intensity. The change is sufficiently sudden to unsettle visitors. At one time the museum turned off all incandescent lights during a summer period so that works would be lit by natural light only. Even on clear days, however, there was too much variation in the lighting of works to allow long term inspection.

The museum's artificial light comes from incandescent lamps in steel cylindrical fixtures. The cylinders are painted to match the anodized aluminum reflectors and mounted either on tracks mounted on flat ceilings or at the bottom edges of reflectors. Some of these lighting fixtures are low voltage units with adjustable transformers; others are 120 or 150 volt lamps. Bulbs and baffles located at the lower ends of the fixtures provide a range of light beams from a narrow spot to a general flood. A usual method of lighting paintings is to focus lights on the paintings and provide general, less intense lighting for the travertine or linen covered walls. Since the paint surface of some old paintings is not perfect, sometimes lights are adjusted to illuminate only the best portions of the painting. Experiments with haylide lamps prior to construction demonstrated that these bulbs provide too white a light. The paintings lost warmth under these bulbs and travertine's character was bleached away.

On March 22, 1996 the author measured light levels at the Kimbell Museum. Two methods were used: periodic measurements by automatic instruments set in fixed locations and readings from a hand held light meter in many locations. On this sunny day there were high thin clouds in the sky. (Fig.2)

Unfortunately, this data was collected by a beginner at light measurement. In retrospect, more useful results would have been obtained from a larger number of sampling devices positioned to record readings on both halves of the reflector surface, both sides of the cycloid ceilings, opposite walls, and the floor

With the help of Museum Superintendent Larry Eubank and the museum staff, automatic light measuring devices known as "hobos" were placed in the gallery adjacent to the

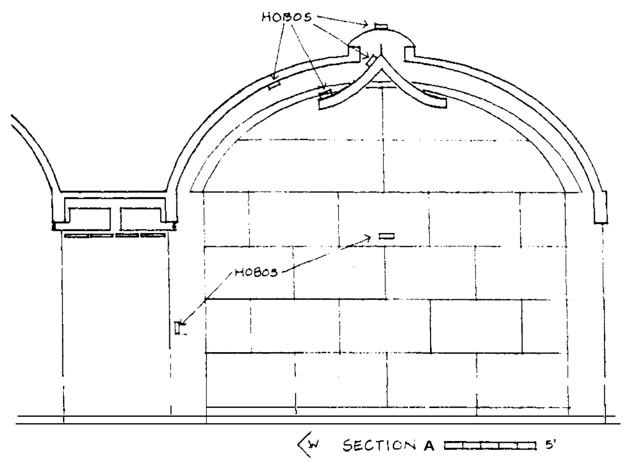

Fig. 2. Section **AA.**

north wing light court. They were placed atop the skylight aimed toward the sky, at the top and bottom edge of the reflector face aimed at the east facing cycloid ceiling, in the middle of the west half of the cycloid ceiling, on the west wall 4'-6" off the floor, and on the north end wall 10'-0" off the floor. All functioned through the day with the exception of the top reflector hobo. This hobo produced erratic results.

Although museum visitors may imagine that the museum interior is as bright as outside surroundings, there is a great reduction in light levels as it passes between skylights, reflectors, and cycloid ceilings. Generally there is only one 2'-6" skylight aperture for every 23' cycloid span plus 7' of flat ceiling. The intense lighting of the cycloid ceilings, the shining lengths of reflectors, lunette windows that 'lift' the cycloids above opaque walls, side lighting from courts and windows, and the light colors of the interior all encourage visitors to fancy that the building does not establish conventional spacial boundaries, but that its surfaces hover about a luminous atmosphere.

The hobo measuring sky brightness atop the skylight produced a reading of 899 foot candles at midday. Readings on the ceiling (21.5 fc) and the wall (5.34 fc) also reached their high points at midday, but their readings were a great deal lower than the sky, similar differences were discovered throughout the day although all other readings were less than those at midday. At 9:03 AM and 5:03 PM, sky readings were 145 fc and 133 fc. Simultaneous wall readings were the exactly the same at 3.17 fc. These times mark the outside limits of useful natural light on the museum interior. Earlier or later the cycloids cease to shine and the cycloid half toward the sun is a great deal brighter than the other.

The intensity of outside light must be tempered for two reasons. First, its ultraviolet component will injure paintings and must be removed by bouncing the light before it reaches the art. Second, it would be impossible to examine a painting in any detail under direct midday sun especially when it is surrounded by light surfaces that are lit with the same intensity. After all, the paintings were probably made in a studio where light levels were substantially less than those in the midday sky.

Viewers can also best study art when the light on the painting is constant or changes gradually over long periods. The Kimbell's cycloids moderate the shifts in sky intensity to produce tolerable levels and shifts on the museum walls. Measuring through the 9 AM - 5 PM day, the sky differential was 899 fc - 139 fc = 760 fc. During the same period the wall readings ranged from 5.34 fc to 3.17 fc for a differential of 2.17 fc.

The constant character of wall lighting was due to incandescent lighting which contributed to wall readings. In a two hour period after the sun had set, the wall readings measured 2.45 fc. This might be taken as the incandescent contribution to wall light intensity during all periods. When the incandescent figure is subtracted from the 3.17 fc readings at the beginning and the end of the measurement day, it is evident that the incandescent contribute most of the wall illumination when the sun is low. At midday, when wall readings reach 5.34 fc, 54% of wall illumination is supplied from the ceiling. As mentioned above, incandescent lighting also maintains constancy when clouds make abrupt changes to natural light levels.

Visitors are aware of light intensity differences within the skylight-reflector-cycloid-wall system as well as differences between midday and low sun periods. When the sun is high, the reflector offers a bright band of curved panels within a duller silver frame. At such times the cycloid ceilings are also silver, but their bright surfaces seem deep and varied. Both reflectors and ceilings have a great deal more illumination than walls. The reflector reached 31.7 fc between 10 AM and 11 AM. The ceiling's maximum was 21.5 fc at midday. Little data was gathered about light levels at the floor, but this relatively dark oak surface appears to be more brightly lit than the walls. Hand held readings at 3:30 PM yield wood floor readings of 8.5 - 9.5 fc and travertine floor (under flat ceilings) readings of 7.5 - 9.5 fc while wall readings were 5.96 fc. (Hand held readings were consistently higher than hobo readings. Hobo sky and ceiling readings were 256 fc and 5.58 fc at the same time.)

Variation in reflector and ceiling illumination in periods before and after midday adds to the lively character of museum lighting. It appears that the high reading from the hobo located on the reflector's lower edge occurred at 10 AM -11 AM when the rising sun shinned directly on the device. Presumably all the lower reflector edge also achieved its maximum illumination at the same time. As the sun's angle changed, the lineal area of maximum illuminations moved along both the aluminum fabric reflector surface and the cycloid ceiling. This phenomenon is most apparent when the sun is so low that only the half cycloid on the sun's side is illuminated. Another test that placed lines of hobos on both the reflector and ceiling surfaces would verify the movement of light intensity through the day.

It is the combination of skylight frame depth and the reflector's extended fin that exclude low sunlight from half the cycloid. When the sun's angle reaches about 36 degrees above the horizon, it no longer shines into the opposite half of the reflector, but only onto the reflector frame face. The lower the sun goes, the less of the face is illuminated and the smaller the amount of light that can bounce from face to reflector to ceiling. On the sun's side of the cycloid, low angle sunlight strikes the fin and reflector top directly offering more illumination to the sun half of the cycloid. Conversely, the high fin is necessary to keep the low angle sun from skipping past the opposite reflector's low edge and placing a horizontal band of direct sunlight on the ceiling's low edge.

Observations, but not measurements, were made on the following day, March 23. This was a cloudy day when clouds or groups of clouds ranged from white to middle grey. Without the sun's direct light, the cycloid ceilings lost their brilliance and depth. The patches that were placed upon the original coated form were apparent as dull grey areas. Occasionally the clouds brightened and so did the galleries, but they never brightened to the levels of a sunny day.

The absence of high intensity sky lighting changed some of the sunny day characteristics of the interior. Differences in half cycloid lighting occurred closer to midday. Shadows of the struts across the skylight frames appeared. Windows played a more visible role in lighting. Light admitted through a horizontal slit window was visible as an illuminated band on the opposite half cycloid. Lunettes offered triangular light patches to thecycloids. Probably this newly apparent lighting was overwhelmed by reflected sunlight on the previous day.

On cloudy days and after the sun sets, the museum looses the lively character that makes it so attractive in sunlight. Cloud reduced light levels turn the brilliant cycloids into concrete. In the evening, the cycloids disappear because artificial light is directed only to walls and floors. Paintings receive the greatest amount of this artificial light and they stand out as illuminated rectangles against a relatively murky background. Because the painting light comes from can fixtures directed at the paintings, there are points of glare or shadows cast by visitors. An evening in the galleries demonstrates how important the contribution of natural light is to both the paintings and the museum interior.

A second examination of Richard Brown's original program reveals that the museum's objectives did not focus primarily upon the natural lighting of art. Brown asks that "... as many people as possible ... experience those [art] objects as effectively and as pleasantly as possible ... " He elaborates by saying, "... a visitor to an art museum ought to be charmed; otherwise, why should we expect him to come? ... architectural conditions should be so disposed as to encourage the visitor's complete absorption in contemplation of that world [of art]." Recalling Kahn's statements it is evident that he also concentrates on the interior environment for art. His aim is rooms for art enlivened by the "endlessly changing qualities of natural light." When the program considers lighting paintings, it acknowledges that natural light cannot be the only source. "... artificial light must be sufficient to do the whole job of making complete visual appreciation of art objects a pleasure."[8]

Director Brown was experienced in museum work when he wrote the Kimbell program. No doubt he had hung works in the artificially lit white walled and ceilinged galleries in vogue at the time. Probably he knew first hand how artificial lights could be manipulated to make paintings appear their best. But he rebelled against the prevailing views of art presentation on behalf of viewers who felt "... vacuum packed in a can" under such conditions.

What Kahn achieved at the Kimbell Museum went beyond focussing natural light on paintings as if it were a natural spotlight. Borrowing terms usually associated with work place lighting, the Kimbell Museum successfully integrates ambient light and task lighting. Ambient light in museum galleries is the natural lighting that originates in the skylights. Incandescent fixtures direct task lighting to the works of art. These fixtures are close to illuminated objects and produce such a controlled intensity that viewers' attention is focus upon the works alone. Natural light participates in wall lighting, but, more important, it does not distract from a viewer's "complete absorption" by intensely illuminated art. The achievement of this design is reconstituting natural light in a controlled enclosure without either destroying its essence or overwhelming the art on display.

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