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ABSTRACT

Photographs and descriptions of four projects using fabric to enclose large spaces are published so that administrators and designers looking for ways to build recreational facilities can consider these innovative shelters. Three of the four examples in this publication are air-supported structures: University of Santa Clara, Charles Wright Academy, and Milligan College. The other type of fabric roof, at La Verne College, is held up from a mast in a similar fashion to a circus tent. Four more large structures under construction or on the drawing boards are briefly described. Technological information and costs are provided. (Author/MLF)

A Report from Educational Facilities Laboratories

Four Fabric Structures

EA 007 562

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EFL

Educational Facilities Laboratories is a nonprofit corporation established in 1958 by The Ford Foundation to encourage and guide constructive changes in education and related facilities.

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Foreword

Two years ago in an EFL publication, **Physical Recreation Facilities**, we introduced three projects that held promise for using fabric to enclose large spaces. All three projects have now been constructed and we are publishing them here so that administrators and designers looking for ways to build recreational facilities can consider the possibility of these types of shelters. There is also another fabric structure included that wasn't in the previous publication, and a glimpse of four more large structures under construction or on the drawing boards.

EFL's interest in fabric structures goes back to 1959 when we supported the development of an airstructure enclosing a swimming pool at the Forman School in Connecticut. Since then, EFL has consistently advocated fabric structures for large enclosures of recreational activities (but not for classrooms until the interior climate can be more closely regulated).

Technological advances have produced fabrics that will last as long as regular roof coverings and that are strong enough to enclose professional football stadiums. However, it is still a new art form with no long history of performance, and each step forward is to be carefully considered. Schools and colleges that want to build fabric structures should realize that they will be exploring beyond the tried and true formulas of construction, and may encounter contingencies that could shake their confidence in the venture. But when the building is completed they will have the satisfaction of being on the leading edge of architecture and at an economical price.

Educational Facilities Laboratories

Introduction

Interest in physical recreation is changing, more people are doing something themselves rather than watching teams of athletes demonstrating their prowess. People are jogging, weightlifting, swimming, playing tennis or skating because it is fun, improves their health, and can be continued througho heir life. These lifetime sports are gradually displacing spectator sports, and schools and colleges acknowledging the change have to revamp their facilities to provide the necessary spaces for the activities.

Institutions that have to build new facilities are looking for ways to overcome the exorbitant cost of enclosing a large area that is uninterrupted by supporting columns or walls. For buildings the size of fieldhouses or larger, fabric roofs may be the solution to breaking the cost barrier. Initial costs of fabric structures in the United States have been significantly less than concrete, steel or timber structures. Weight has a lot to do with the cost savings since a fabric roof can be about one-tenth the weight of a conventional roof of similar span. Thus the walls and foundations can be proportionately smaller.

There are two basic types of fabric structures. Most of the fabric roofs built to date are held aloft by air pressure. Three of the four examples in this publication are airsupported structures. University of Santa Clara, Charles Wright Academy, and Milligan College. The other type of fabric roof, at La Verne College, is held up from a mast in a similar fashion to a circus tent.

Airstructures: From Bubbles to Arenas

Airstructures are a recent addition to the building vocabulary. The first to be built, though not the first to be designed, were developed for the U.S. government to enclose radar installations in the Arctic. From these spherical airstructures manufacturers developed fabric enclosures on a rectangular plan for warehouses, swimming pools, tennis courts, and other uses. Later, designers explored new forms of airstructures to make eye-catching pavilions at world fairs.

A major change in form occurred when fabric roofs were placed atop walls (usually earth berms) instead of rising from the ground to enclose the whole structure with fabric as in the bubbles used currently for tennis courts. With solid walls, the roof curvature can be flattened and thus reduce the interior volume (which saves on heating, cooling, and inflating costs) and produce an exterior that looks more permanent.

The advances in form were made possible by the improvements in fabrics. Early fabrics were not strong enough and did not have the necessary lifespan for the large permanent structures now being built. Seven years was once considered to be the maximum life of a fabric roof, now, fiberglass fabric coated with chemicals can be guaranteed against sun and pollution for the same 20 years that tar and felt roofing is guaranteed Also contributing to the long life of fabric roofs is a technique to reduce the stresses in the fabric on a large-span roof by extending steel cables across the roof to break it up into a series of small roofs with the fabric stretched much shorter distances between the cables

The landmark airstructure was the U.S. Pavilion at the 1970 World's Fair in Osaka, Japan. It was designed to withstand typhoons, and gave credibility to a construction technique that many people in the industry had considered to be impracticable. Sponsors of comparable airstructures invariably turned to the Osaka Pavilion for moral strength and technological proof before committing themselves to building their own.

The same type of fabric used for airsupported structures is also used for tent-like structures, such as the one at La Verne College where the roof is hung from masts instead of being pushed up by air. Like airstructures, the landmark tent structure was built at a world's fair, the West German Pavilion at Expo '67 in Montreal. Later, the same type of structure was built on a much larger scale for the Munich Olympic Games in 1972.

Swaying in the Wind

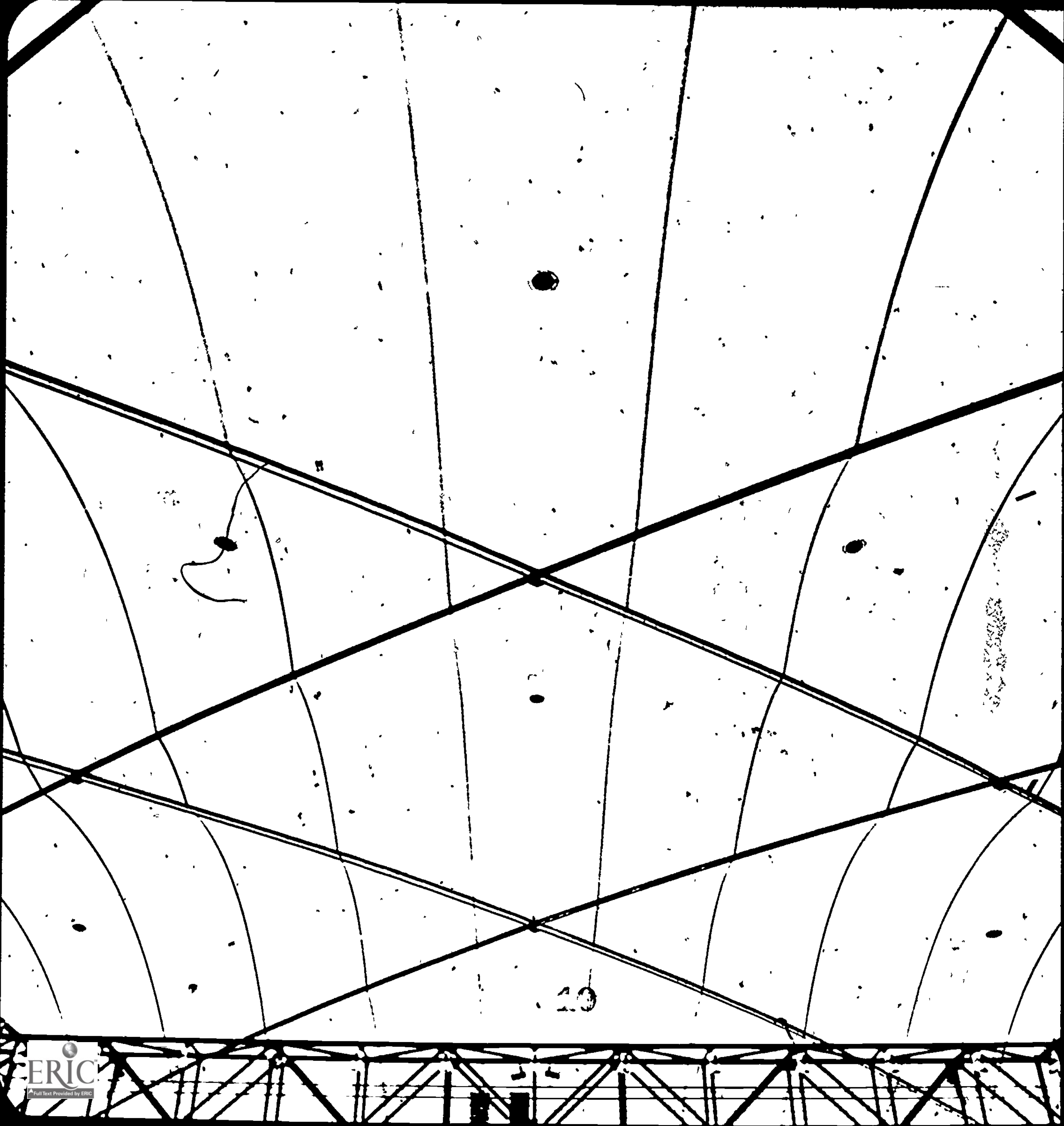
Airstructures are held up with low air pressure during normal wind conditions. When winds increase appreciably, the interior pressure is increased to counteract the movement of the roof and thus hold the structure rigid. The fluctuations in interior pressure are governed by automatic controls triggered by the outside wind speed. They can also be adjusted manually so that if high winds are predicted the airstructure can be inflated harder ahead of time.

Owners have to accustom themselves to a building that undulates under pressure It's a completely foreign experience since until now buildings have only moved perceptibly *in extremis*. An instruction manual should be written by the architect or engineer and given to the operating staff of any fabric structure. In addition to the daily operating instructions, it should tell what steps to take when certain wind speeds are predicted and encountered, and what action to take when snow falls.'

No matter how low the pressure is, the interior air always seeks to escape to the outside where the air pressure is normal. This presents a design problem with exits that is unique to airstructures. The structure must be sealed to prevent air leaking, and the simplest way to prevent air passing through an entrance is to install revolving doors with firm weather stripping to seal the edges. Emergency doors are "balanced" by placing the pivots closer to the center than the edge so that they don't fly open when the panic bar is touched. In addition to pedestrian entrances, an arena needs an airtight truck entrance. This can be provided through an air lock—a chamber in which a truck waits while doors at one end are closed before opening the doors at the other end.

Since the air pressure literally floats the roof over the structure, the fabric must be securely anchored to prevent it floating completely away. When a large roof is inflated the fabric exerts a considerable horizontal pull on the structure to which it is attached. This pull is counteracted with a perimeter beam atop the exterior wall that will not compress or buckle under the load, hence it is called a compression ring.

The three airstructures and the tent structure in this publication are considered by their owners to be inexpensive compared with rigid structures enclosing the same floor areas. The economy is effected by the small tonnage of materials to be bought, handled and erected, the shorter construction time to put the roof on, and the smaller foundations required for a lightweight structure There are some offsetting costs of heating and cooling a building with next to no insulating value over most of its surface (two of the four buildings are uninsulated), but at this writing none of the schools has operated its structure more than a few months, so costs are not yet recorded.

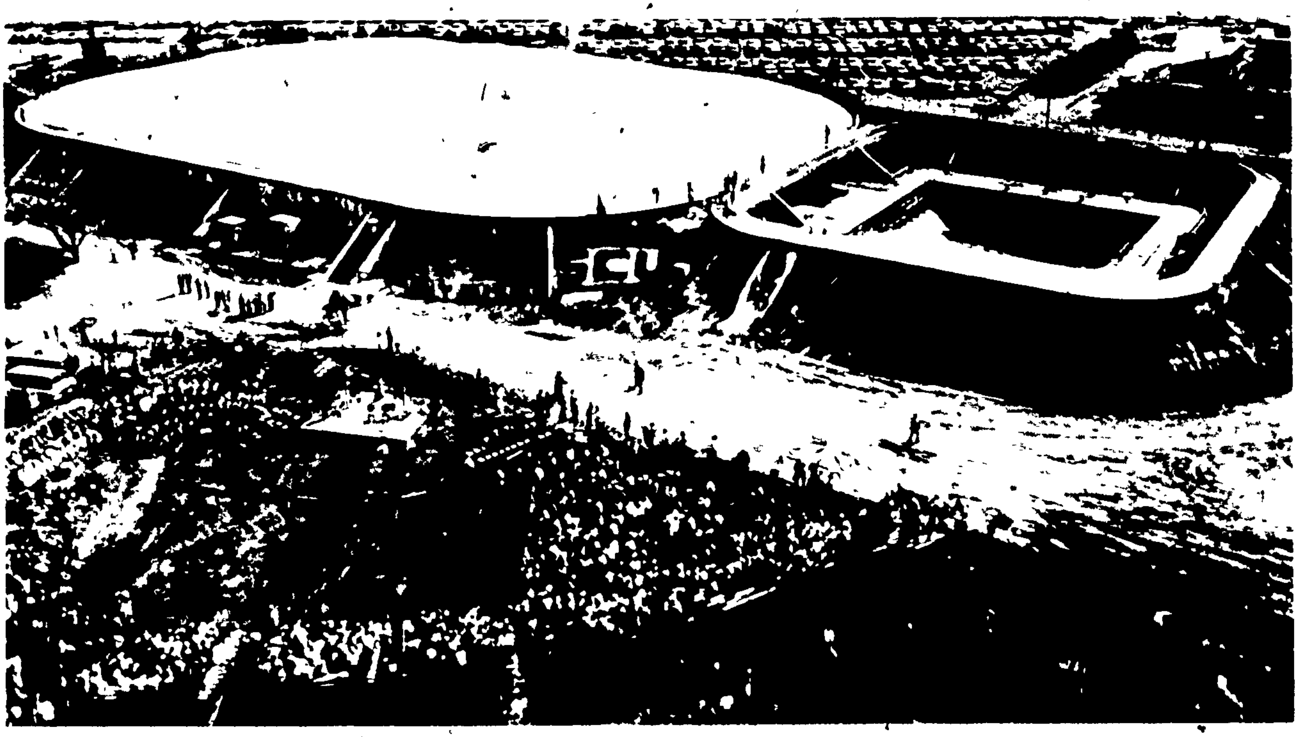


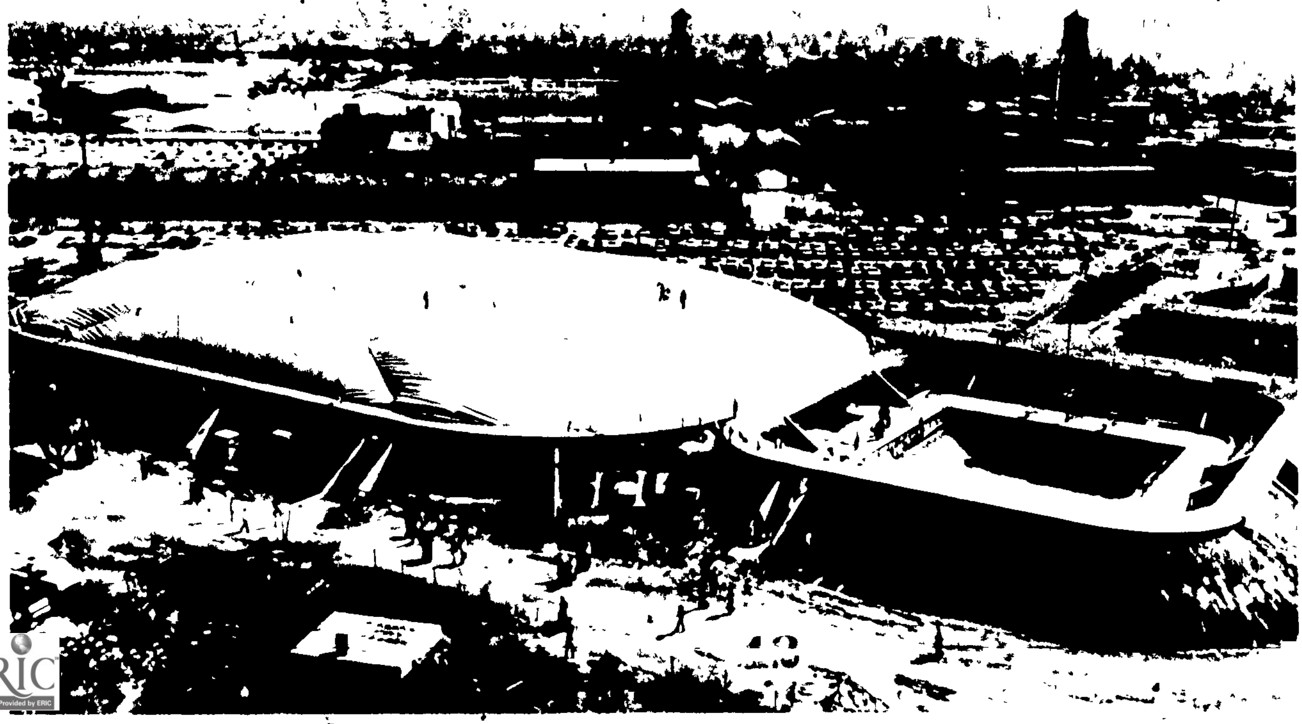
University of Santa Clara

When the time came for the **University of Santa Clara** to consider building a new student activities center, one of the criteria dealt with making the university visible to potential students, and another criterion required the building to not dominate the campus This paradox was solved with an airstructure that rises 35 feet at its highest point and slopes all around back to the ground The low profile of the structure doesn't intrude on the other architectural styles—basically Spanish Mission buildings set in well-cared-for grounds—and its originality and function are expected to make the university remembered by high school students evaluating colleges in northern California In addition to wanting a structure that makes the university a center of attention, the administrators faced the mundane reality of poor soil conditions that, in an area prone to earthquakes, would require extensive foundations for a long-span steel or concrete roof. Over all, the airstructure is about $250,000 cheaper than a rigid building enclosing the same volume, says the owner, or, to put it another way, if the university had insisted on a rigid structure it would have had to make do with a considerably smaller arena.

Eventually, the student activities center will be financed with pledges, but to tide over the four or five years in which the pledges will be honored, the university raised $4 million in tax-exempt revenue bonds. California enacted legislation in 1974 that permits educational institutions to sell tax-exempt bonds, and under this plan Santa Clara sold its bonds at 6.6%, saving an estimated $1.5 million in interest costs.

When the center was being planned, a survey of staff and students showed that swimming was a high priority in a list of activities that should be included. Because the climate is mild enough for students to enjoy outdoor swimming at least six months of the year, the designers separated the pool from the main arena and put it under a separate but adjacent roof. During the summer the pool roof can be rolled back over its supporting cables. This has a practical advantage; a less expensive fabric can be used since it will be exposed to the harmful effects of sunlight only half the year. The locker rooms for all activities are located at the end of the main arena adjacent to the pool so that one facility serves both structures. The rooms are underneath a concrete mezzanine under the main airstructure roof. A smaller mezzanine is situated at the other end of the airstructure. Beneath it are squash courts and other physical recreation areas. Both mezzanines carry bleachers that can be folded away to leave space for a basketball court. With all seats in use, the main basketball court can accommodate 5,000 spectators.





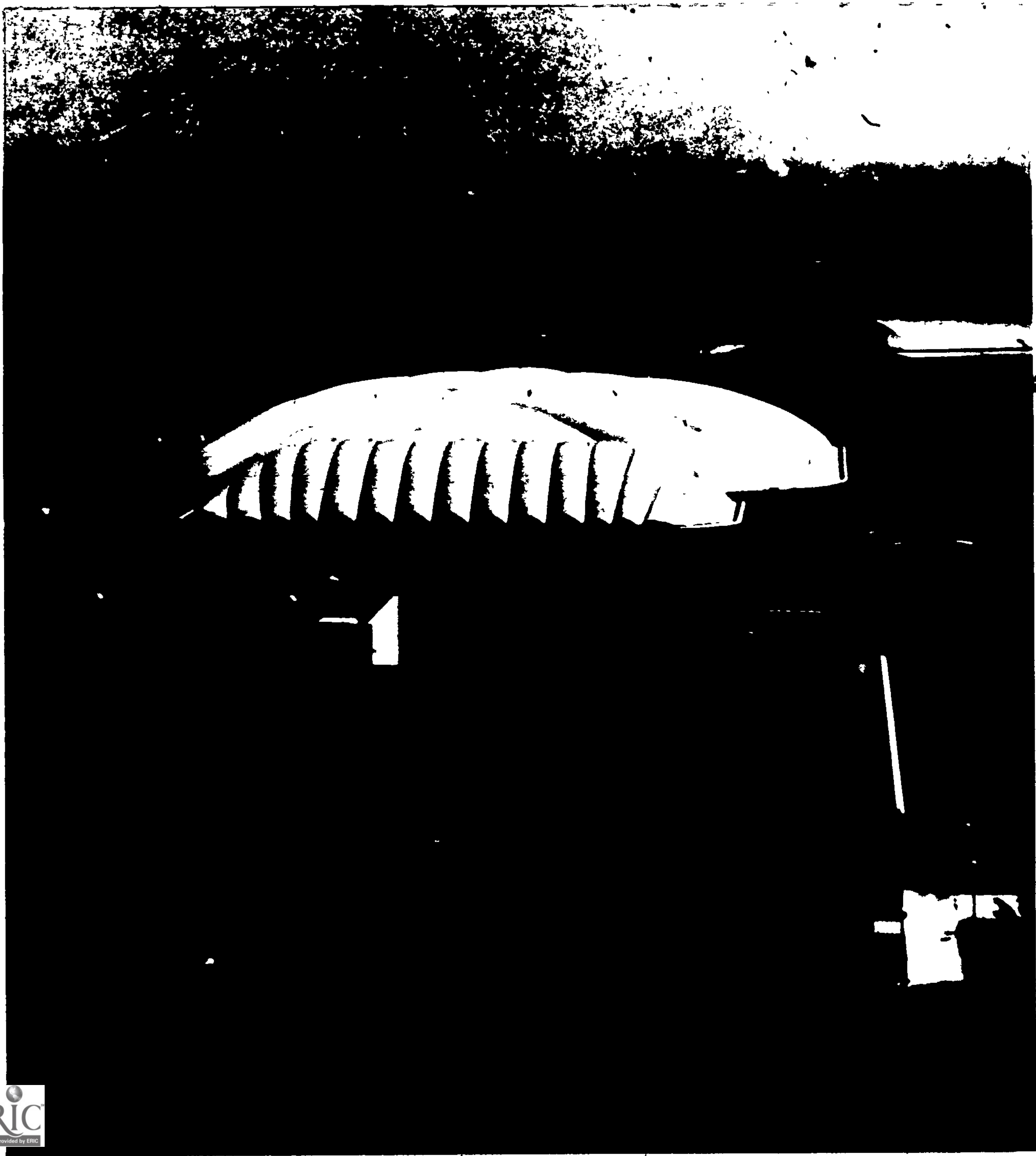
Hefty-looking steel trusses surround the basketball court to support the lighting, scoreboards, and television cameras. These trusses seem slightly incongruous under a lightweight roof of cables and fiberglass fabric, but they do serve one important additional function. if for any reason the roof drops, it will drape over the lighting trusses instead of collapsing on the floor.

Air for the large arena can be cooled or heated before it is blown in to support the roof. When the pool is enclosed, its roof is supported by air exhausted from the main structure. No outside air is blown into the pool structure. For safety reasons, a set of standby fans equaling the capacity of the regular fans is installed in the student activities center. The standby fans simply blow outside air into the structure without cooling or heating it. Engineers calculate that even with a 100-sq-ft hole in the roof, the combined fans would still keep the roof floating.

The roof fabric is translucent, and is expected to be more translucent when it is bleached by six months exposure in the atmosphere. It will then admit enough daylight to make artificial lighting unnecessary during the day. It also permits plants to grow because sufficient ultraviolet light penetrates the fabric. During the design period, landscape architects used a sample of the fabric to determine which plants will grow best on the interior faces of the earth berms.

Roof raising ceremony of Student Activities Center in March, 1975. Top photo was taken 15 minutes before bottom.

During the day when the sun is illuminating the interior of the structure, it is also heating the space. To counteract the solar heat gain, the air supporting the roof has to be chilled through airconditioning units before it is introduced to the interior. The architect says that the amount of heat created by the sun shining through the translucent roof is about the same as the heat given off by lighting units in a building with a traditional roof. He also points out that 5,000 spectators at a winter game will give off more heat than the summer solar heat gain, and the airconditioning system will have to be switched on. Operational costs calculated by the architects before the center was built indicate that it should be about the same to heat, cool, and light as a conventional building housing the same activities.



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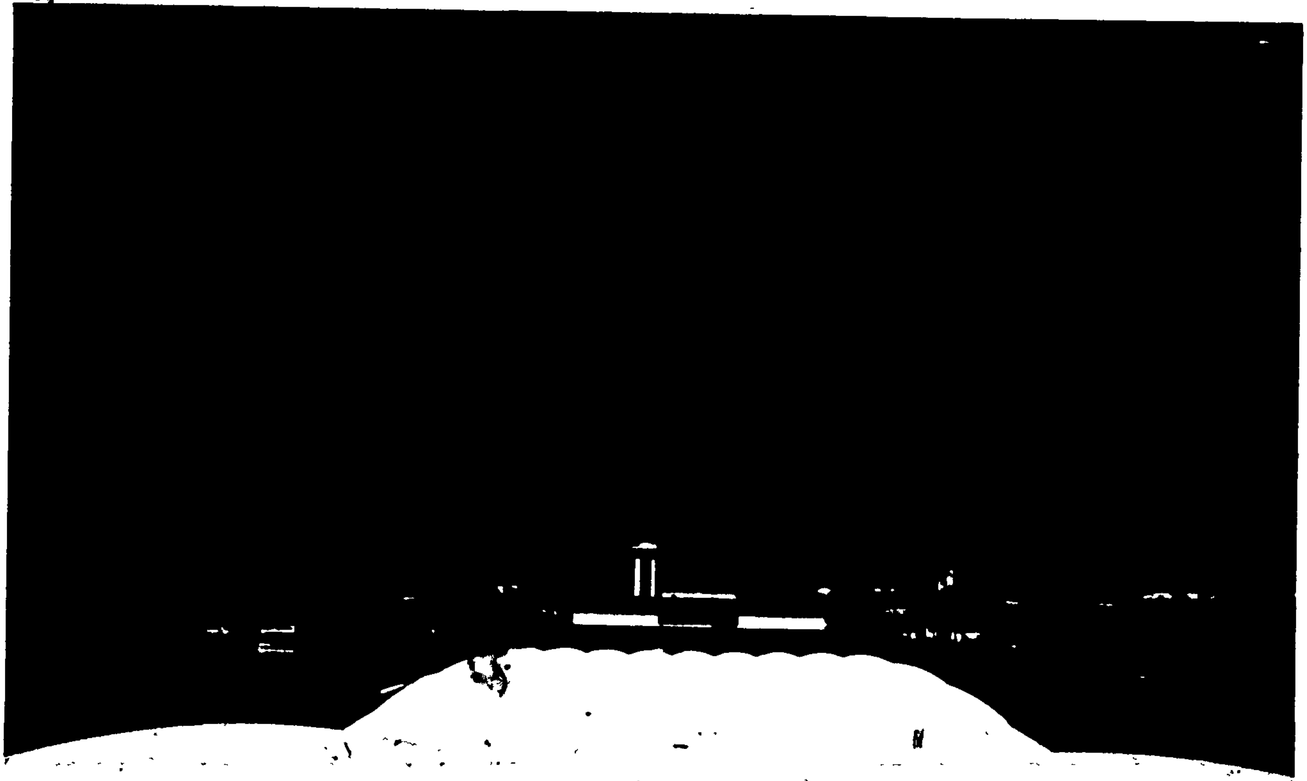
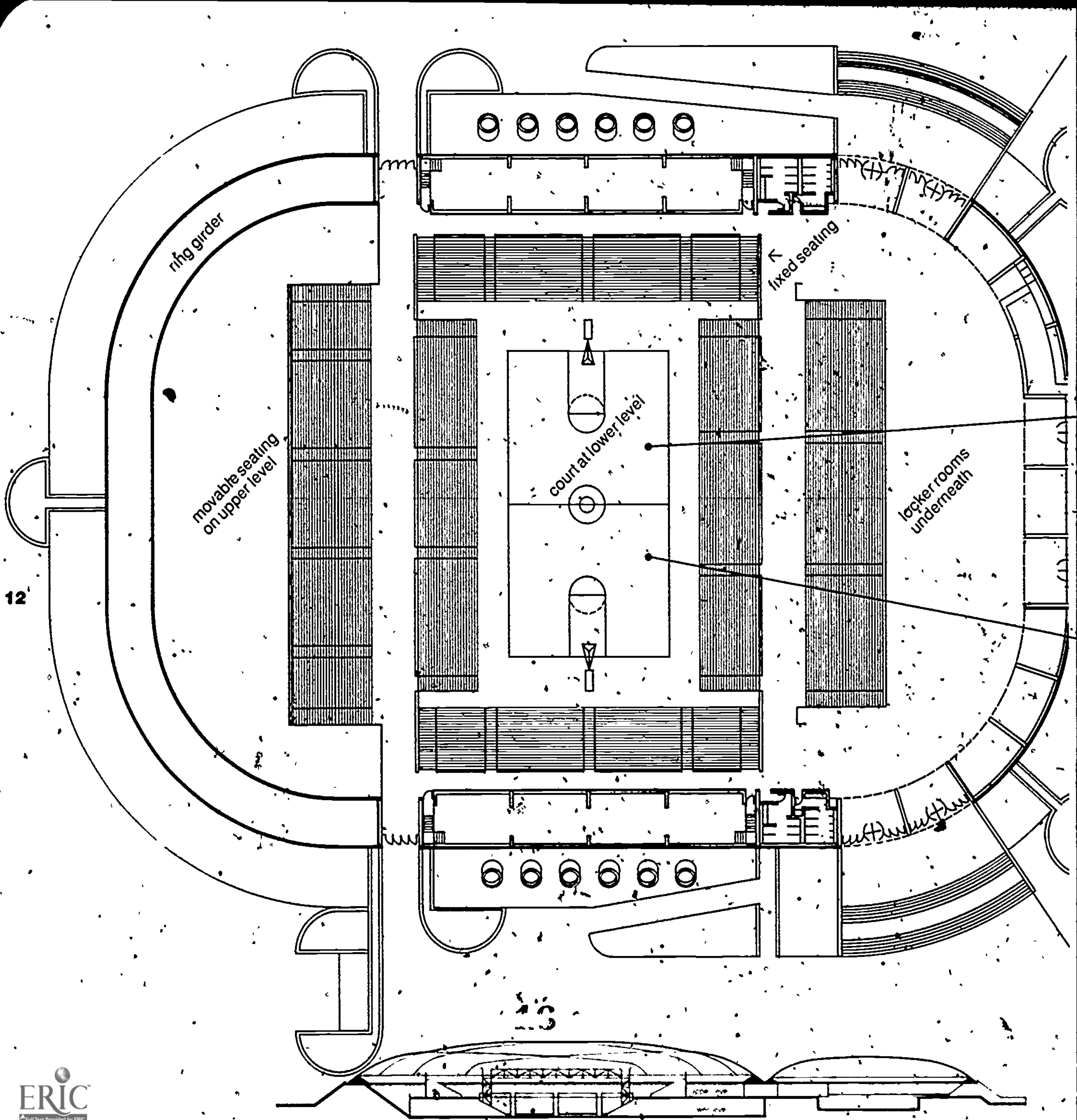
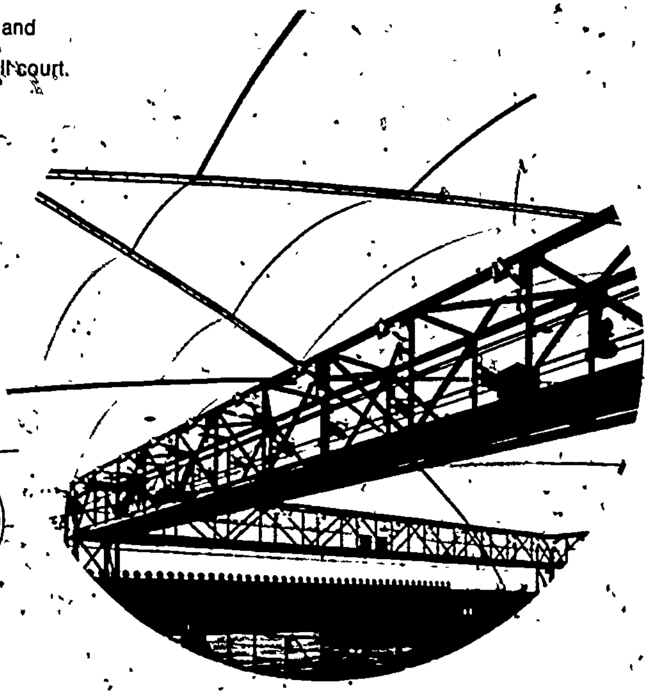


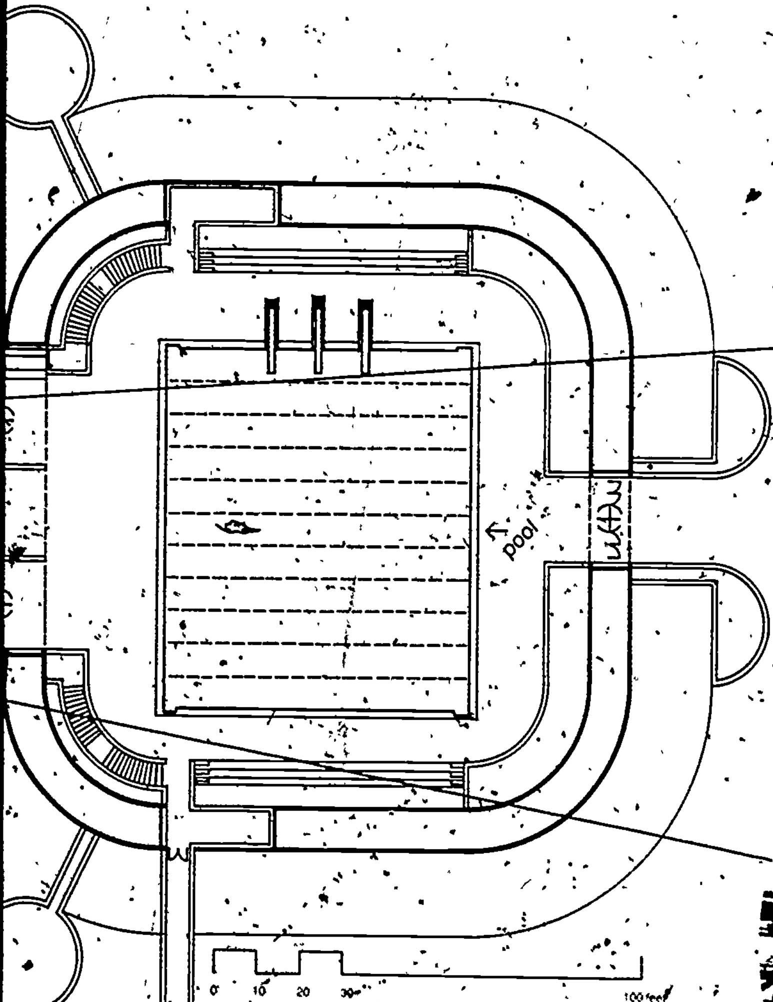
Despite large span, airstructure roof maintains low profile in keeping with older buildings on campus.


ring girder
fixed seating
movable seating on upper level
court at lower level
locker rooms underneath

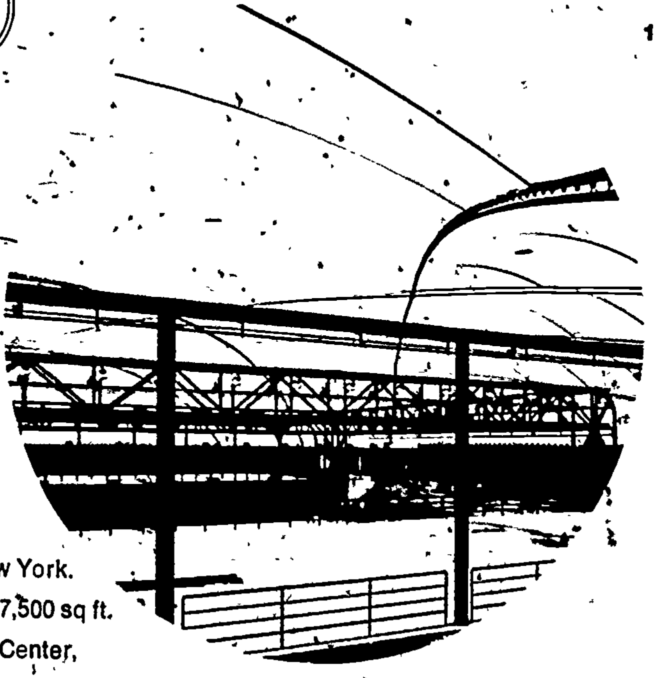
section

Steel trusses carry lighting and TV equipment for basketball court.





University of Santa Clara
Santa Clara, Calif 95050
Architects Caudill Rowlett Scott, Los Angeles, and Albert A. Hoover & Associates, Palo Alto.
Structural Engineer: Geiger Berger Associates, New York.
Area enclosed: Student Center, 65,000 sq ft, Pool, 17,500 sq ft.
Cost of fabric roof, cables, and ring girder: Student Center, $445,000; Pool, $121,000.
Total cost of project: $3,573,300.



Tall pipe rail in foreground will support nets separating ball-playing areas.

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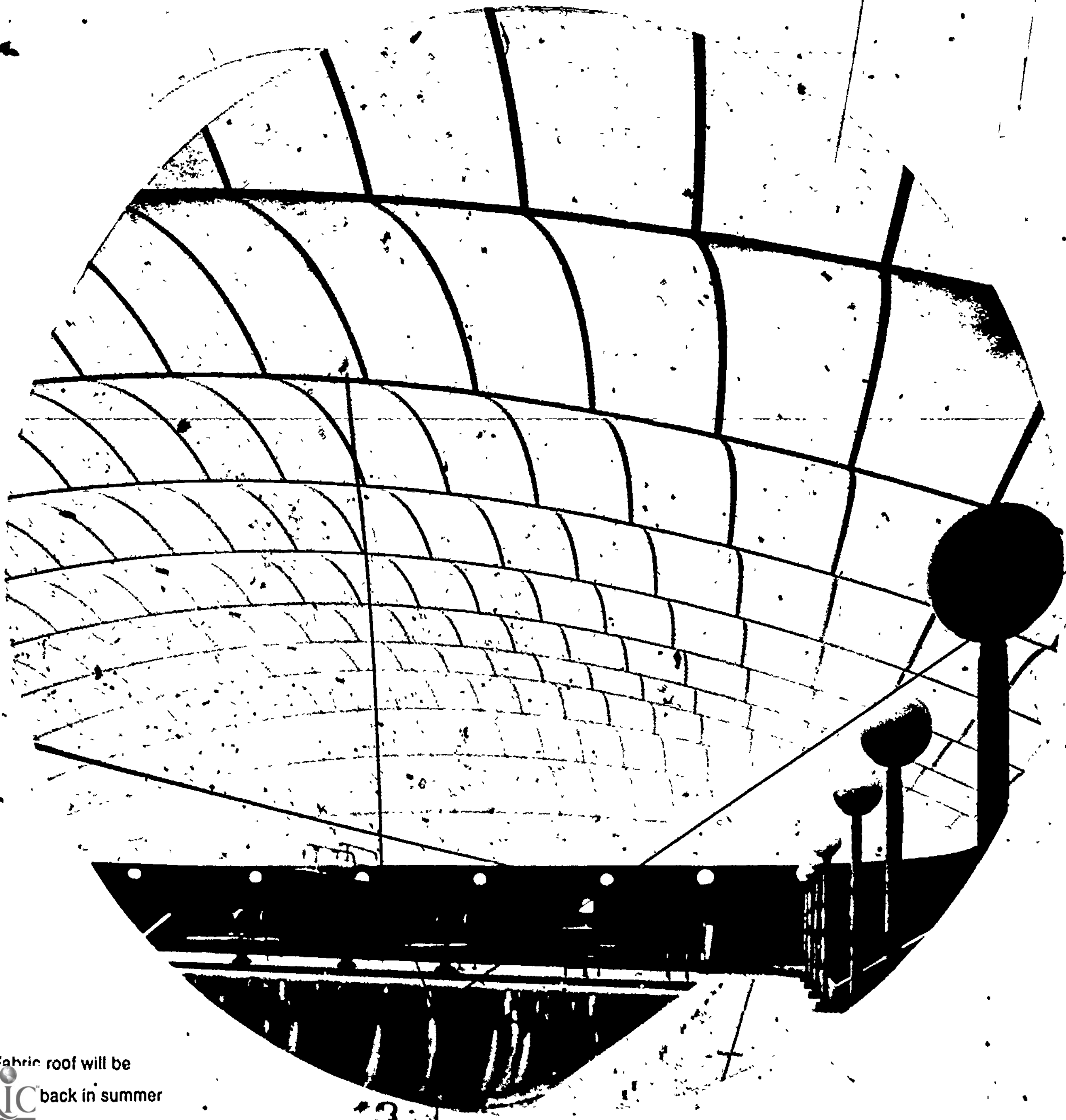
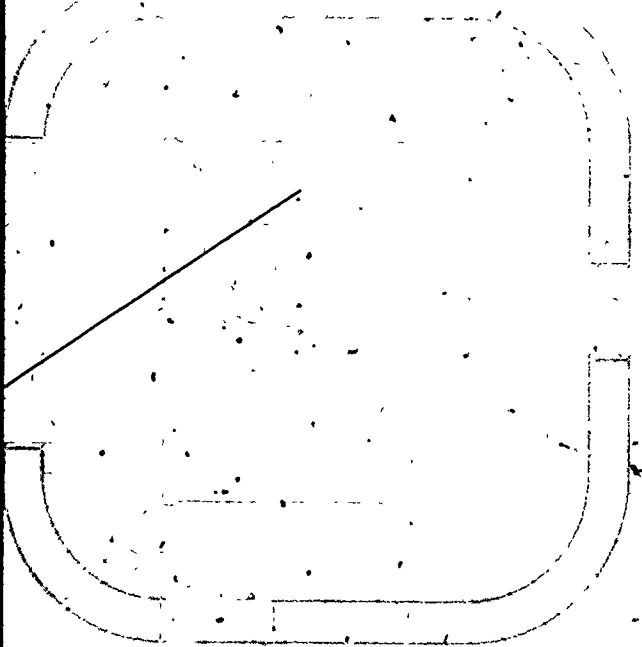
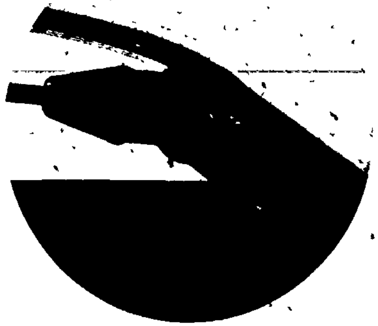


Fabric roof will be [illegible] back in summer months.





Roof cable anchor.

Charles Wright Academy

Charles Wright Academy, a private K-12 school in Tacoma, Washington, built a simple airsupported fieldhouse at an astonishingly low cost. The fieldhouse contains enough floor space for two basketball courts and two badminton courts, but there are no mezzanines or basements. Everything is on the ground floor under a 220-ft by 140-ft airsupported roof, except the locker rooms which are located in a concrete-block building at one end of the fieldhouse. When the school raises funds, it will build outdoor tennis courts next to the fieldhouse locker rooms. Because the interior is kept simple, the school had a head start in building a low-cost structure. Excluding the locker-room building, the completed facility cost $14 23 a sq ft. Two other design decisions contributed to the economy. to use a polyester fabric instead of fiberglass roof, and to use "economy model" hardware, finishes, etc.

The roof spans 140 ft across the fieldhouse, which according to the architect is about as far as polyester fabrics should be extended without support from cables. This also contributes to the low cost since there are neither cables nor anchorages to tie them down. The edge of the roof fabric is attached to a concrete ring beam cast integrally with a precast wall. Cables sewn into the fabric loop around the perimeter to help relieve the stress on the fabric.

Most air roofs are installed atop an earth berm (a mounded earth wall) but CWA's fieldhouse has a concrete wall sloping inward at about the same angle as an earth berm. This accomplishes three design functions. it maintains the aerodynamic profile of the roof so that winds deflect upward over the structure, it creates a large storage area under the wall, and it elevates the fabric beyond the reach of casual vandalism. Construction was simplified by precasting the wall slabs and supporting them on columns cast in place.

Tacoma experiences erratic winds from the Puget Sound that tend to blow in gusts but not at sustained intensity. Such conditions are not ideal for an airstructure but they are not insurmountable. For instance, Charles Wright's controls are set to raise the normal 2½ pounds per sq ft interior pressure to 5 pounds when winds reach 30 mph even though that airspeed does not require 5 psf. But, after the winds reach 30 mph, records show that much higher gusts can be expected, so the airstructure is prepared ahead of time. During the first few months, the staff is using a manual control to lower the interior pressure until a pattern of gusting can be established. This manual control is used to prevent the interior pressure from automatically going down during a lull in a gusty period that could leave the structure unprepared for a resurgence of high winds.

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Air pressure is maintained with four blowers, two of which are automatically shut off during normal operating conditions. These blowers are integrated with heating and cooling units so that they can maintain the interior temperature at 65F in winter and 10F below the outside air during summer. If an electrical failure stops the blowers, a standby blower fueled by propane gas will maintain the air pressure. All the mechanical equipment is standard components. None of it was designed foran airstructure.

Should the roof fail through lack of pressure or a catastrophic tear, it would not fall to the floor because lighting poles would hold it above the heads of any people in the building. If the walls had been high enough to support the draped fabric above the floor, the light poles would not have been required for this function.

Fabric roof sits atop concrete walls that slope inward to maintain aerodynamic shape of structure

Many of the 28 members of the school's board of trustees resisted the prospect of an airstructure. Aesthetics was not a problem says a member of the board, it was strictly a matter of getting value for money that has to be raised by the school. One of the strategies adopted by the supporters of the proposal was to always speak of the structure as a permanent building, and never refer to it as a bubble. Bubbles are used to enclose pools and tennis courts, and in nearby Seattle a bubble enclosing tennis courts at a country club had been ripped to shreds during a gale. The difference between a bubble and a permanent airstructure is significant. The whole of a bubble is fabric, and because the bubble is not bought to last forever, a low-cost fabric is used in order to keep the initial cost down. Therefore, when, or if, the fabric deteriorates in sunlight, from air pollution, or in high winds, the whole structure is lost. On the other hand, the school's fabric roof made of nondegradable materials accounts for only about 10% of the total cost of the structure, and if for some bizarre reason it is destroyed, 90% of the investment will remain intact. Without committing itself to build, the board appropriated $26,000 for a design fee to explore the concept, then appropriated more funds to produce working drawings. Not until bids were received on the final drawings did the board formally decide to build the airsupported fieldhouse.

During the exploration of the airstructure project, long discussions took place with local and state building officials about fire codes, flammability, occupancy limitations, etc. Finally, all problems were resolved and the proposed building was classified as a permanent structure.

Construction was divided into two contracts: a general and a roof contract. Obtaining bids for the roof was difficult, says the architect. In the first place there

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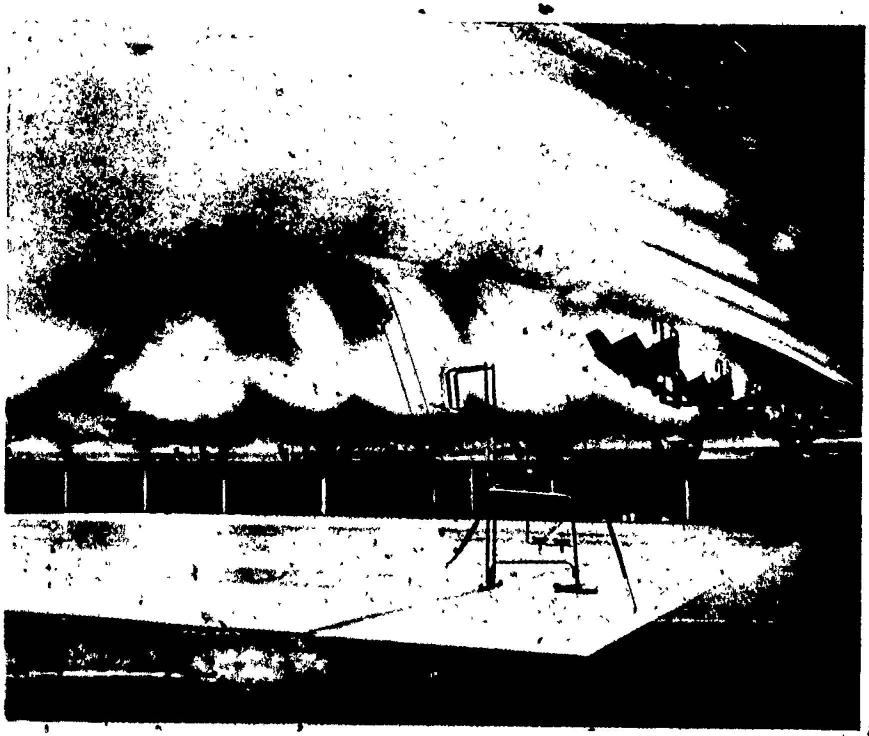
aren't many companies in the country that fabricate and erect fabric roofs, and those that do often prefer to design the structure themselves. Charles Wright Academy asked four contractors to bid on the roof one company refused because it wanted a design-construct contract, two offered substitute materials that did not comply with the specifications and were unacceptable to the architect. The fourth company met the specifications and its bid was accepted. The final cost of the completed fieldhouse was 0.4% more than the bid price. This, says the architect, is extremely close, considering that an average job runs about 5% over.

Cables sewn into fabric arc between column anchorages to relieve stress along the edges of the fabric.



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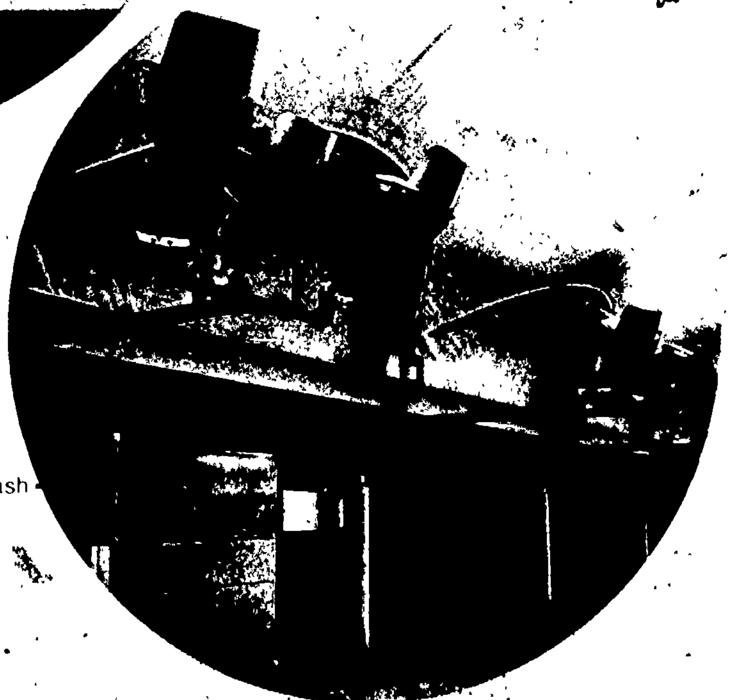


Charles Wright Academy

7723 Chambers Creek Road, Tacoma, Wash 98467

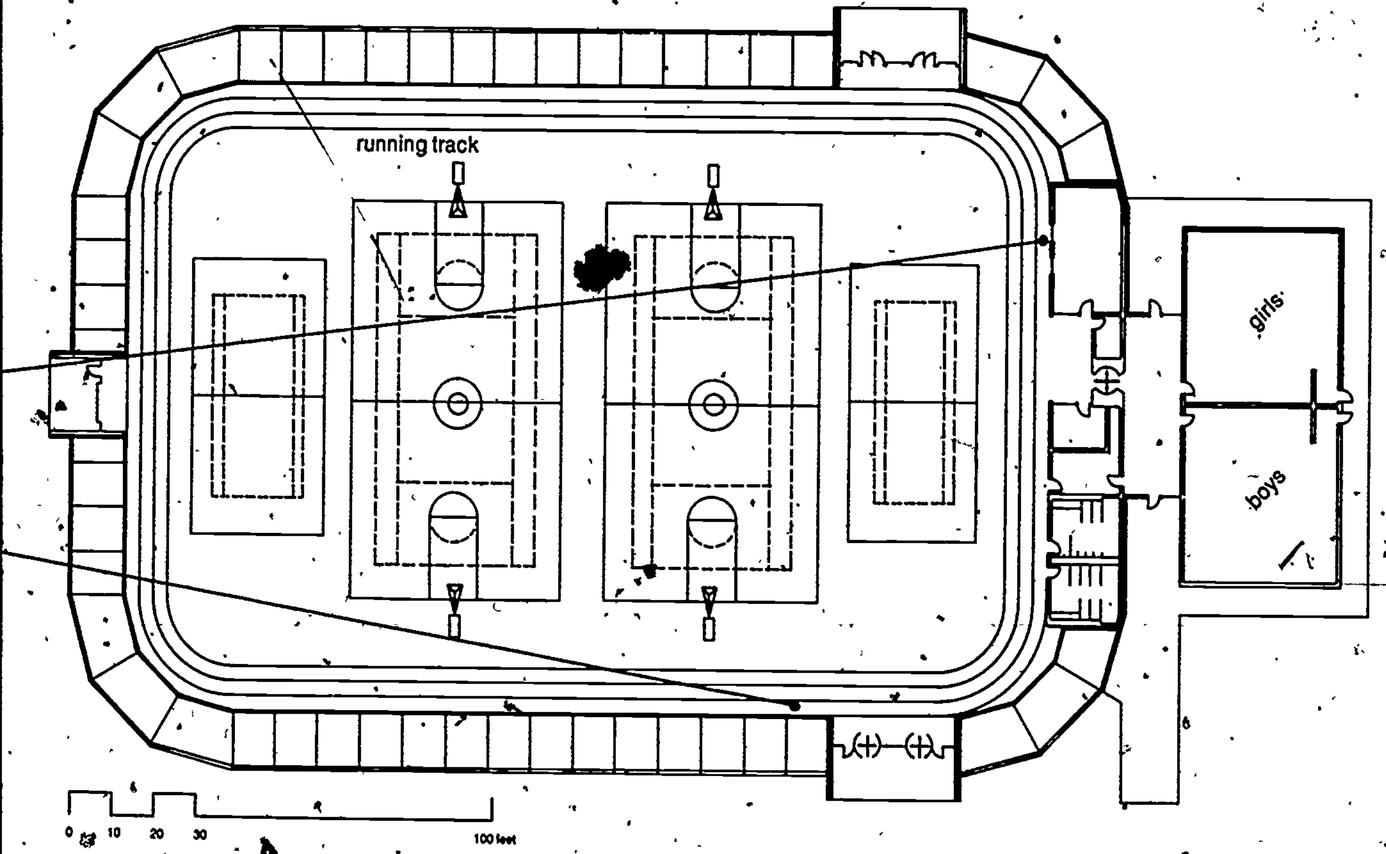
Architect Donald F. Burr & Associates, Tacoma, Wash

Structural Engineer ABAM Engineers, Inc., Tacoma, Wash

Area enclosed 30,400 sq ft

Cost of fabric roof $60,600

Total cost of project $588,000.



Pipe rail above lamps would prevent roof fabric draping on floor if air pressure is lost.

La Verne College

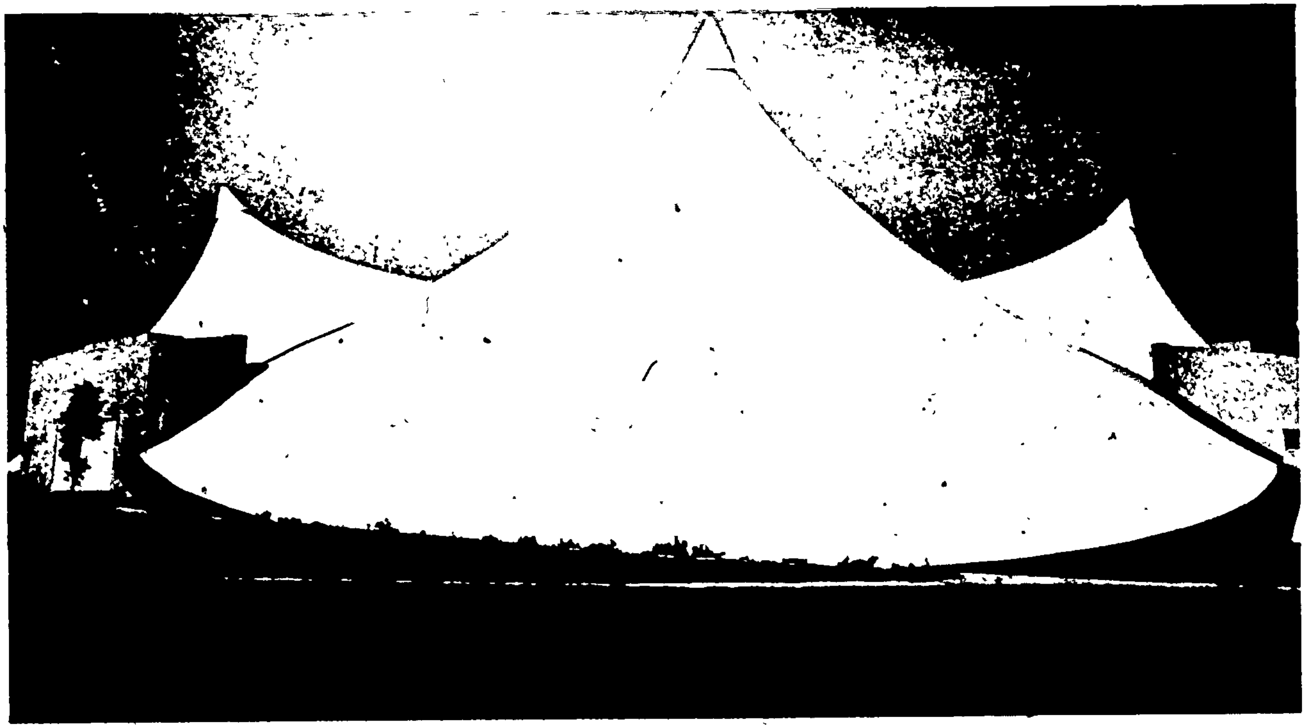
About 50 million people saw **La Verne College** on their television screens in the fall of 1974—and it wasn't because of a campus riot. What one quarter of the nation saw was a chemical corporation's commercial that appeared twice in prime time The commercial included shots of the sponsor's coated fabric on the roof of La Verne's new student center that looks like a Brobdingnagian Maidenformscape. La Verne has achieved two big breakthroughs: it's the first college with a permanent tent structure, and it may be the first to house such diverse activities under one roof. The program is as interesting as the shelter. Physical recreation, art, student health services, and a social center are all in one building with no doors separating activities. Nevertheless, each department's territory is firmly defined by the plan of the structure.

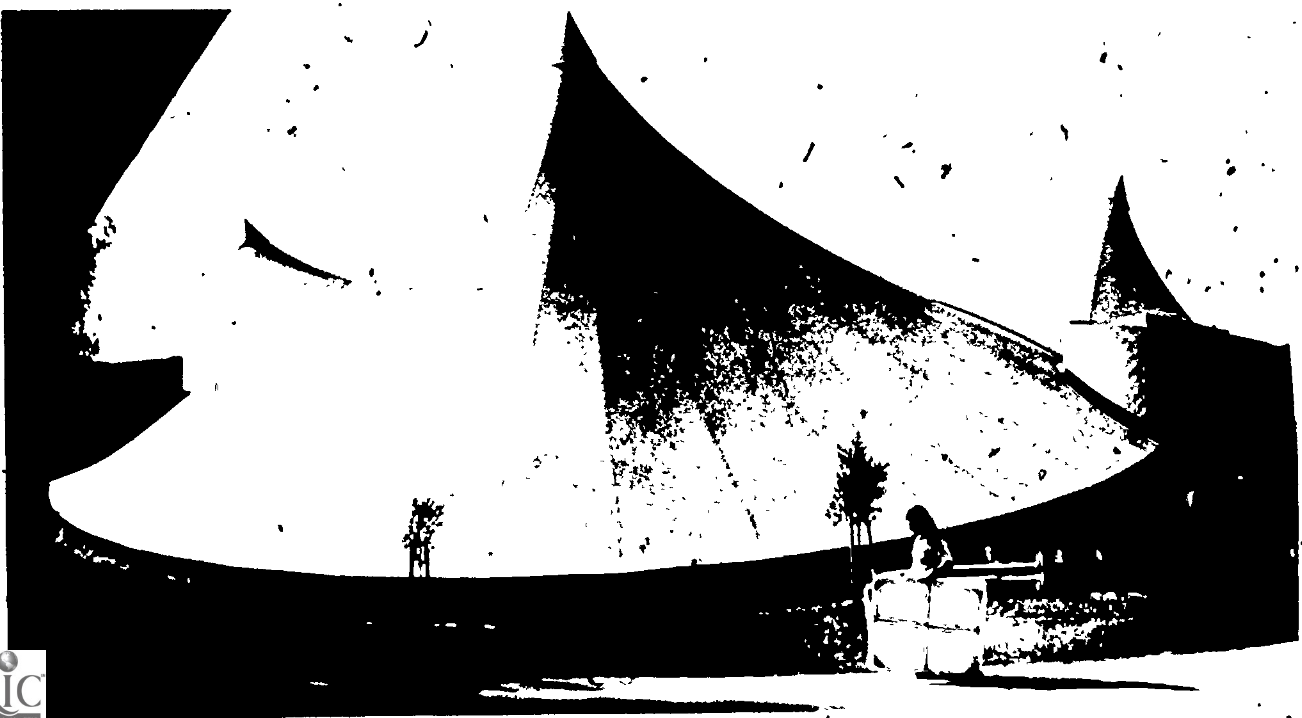
The building plan is based on a square with semicircular segments along each side of it. The square area has a mezzanine built above it that contains the main basketball court. Offices and a campus store are located underneath the mezzanine. Each of the four segments contains different activities. One is an art studio, another is gymnastics and body building, the third is for student health services and union activities, and the last contains food vending machines, seating, pool tables, and table tennis.

Four masts support the roof. Each base is at the midpoint of a side of the square containing the offices, and each leans outward. The four fabric roofs intersect at the center of the structure and create a large uninterrupted interior space. Toilets and stairs to the basketball court are located in four circular towers at the perimeter.

La Verne's roof structure consists of masts that can be raised with jacks, cables from the mast tops that stretch down to a perimeter beam, and fabric stretched over the cables Originally, the fabric was intended to be translucent so that in daylight the interior of the center would be flooded with natural light. Unfortunately, from an aesthetic standpoint, insulation added to the fabric to reduce the solar heat gain blocks out the daylight. A sense of what the roof would have been like if not insulated can be seen around the perimeter where uninsulated translucent panels admit daylight.

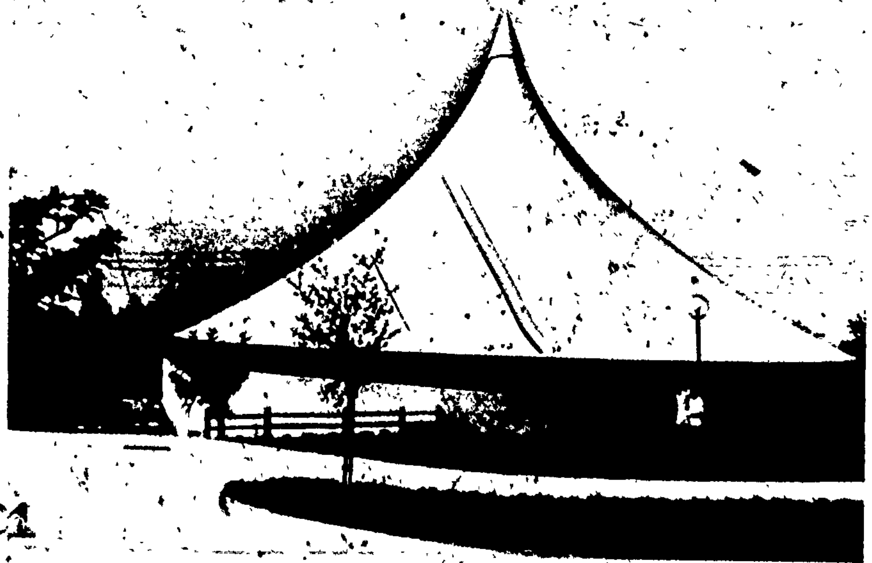
The fabric and its coating are both inert and flame resistant. They carry a 20-year life expectancy, just like some airsupported roofs. La Verne says the total cost of the center is $33 a sq ft, which includes a separate theater adjacent to the center that is a one mast version of the big tent. A La Verne spokesman contrasts the modest cost with $80 a sq ft for most college structures.

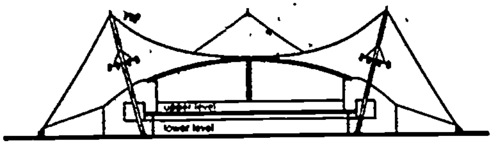




Being a private institution, La Verne had to raise its own construction funds through donations, pledges, and an unsecured loan for $2 million. There were no state or federal funds in the project. To relieve the financial burden, the college generates some revenue through selling memberships to students and nearby families to use the facilities during the summer vacation. High schools rent the basketball court for tournaments because the unusual surroundings attract more spectators to their games.

Four masts support roof of student center. Adjacent theater is supported with a single mast





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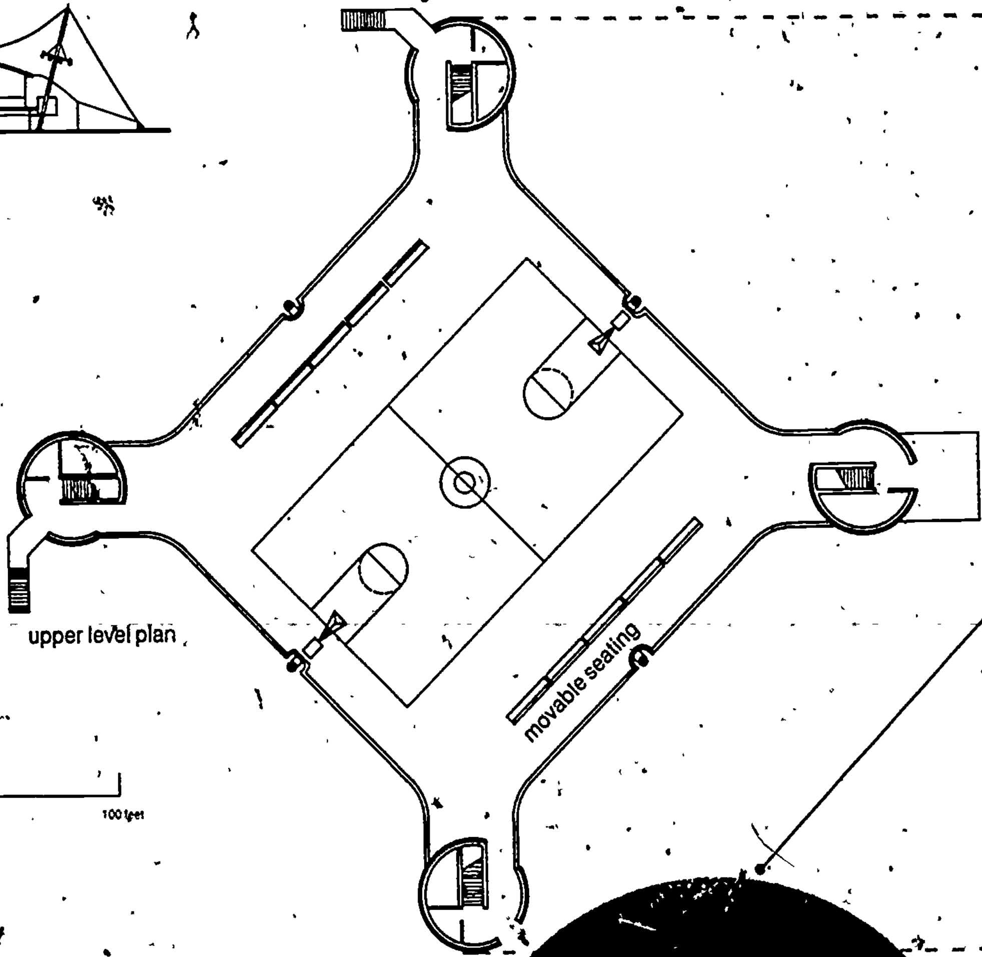
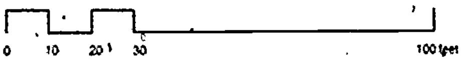
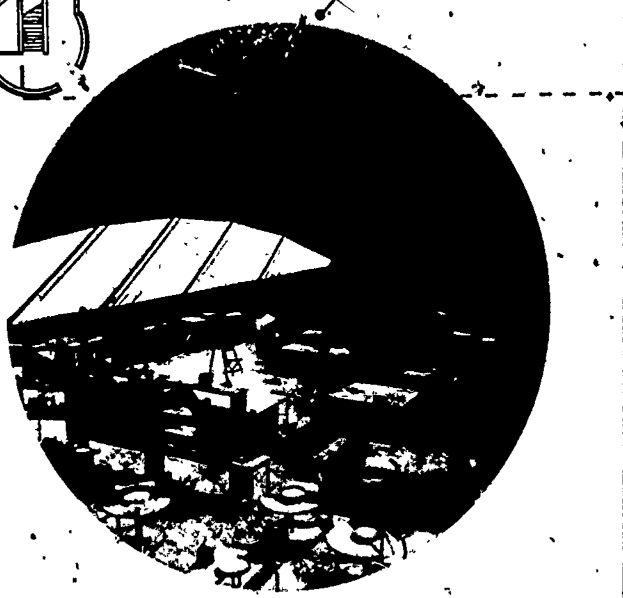


upper level plan





La Verne College

1950 Third Street, La Verne, Calif 91750

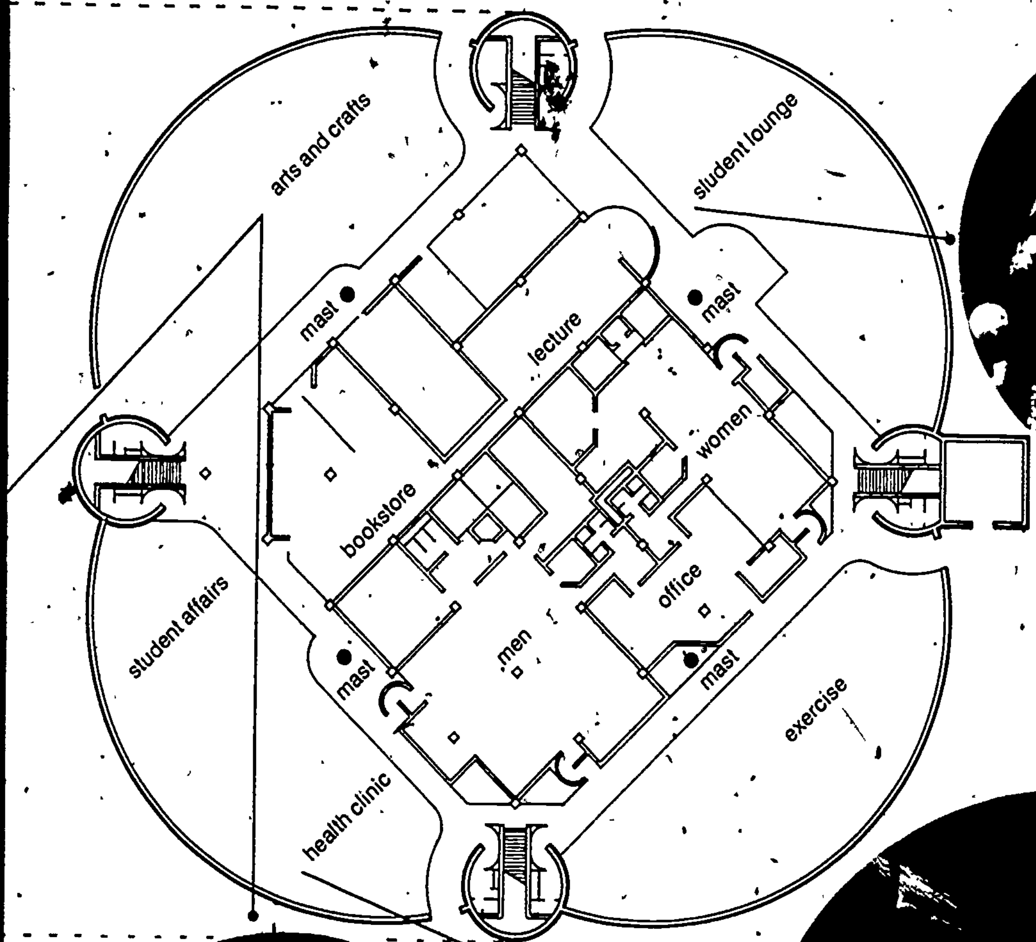
Architect The Shaver Partnership, Salina, Kan

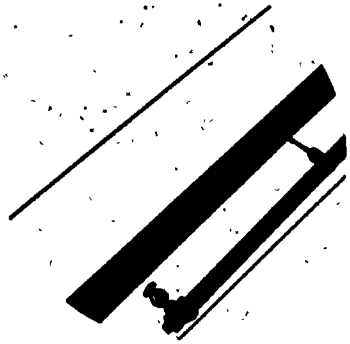
Structural Engineer Bob D Campbell & Company, Kansas City Mo and T. Y. Lin, Kulka, Yang & Associates, San Francisco

Area enclosed. Student Center, 57,000 sq ft, Theater, 11,000 sq ft

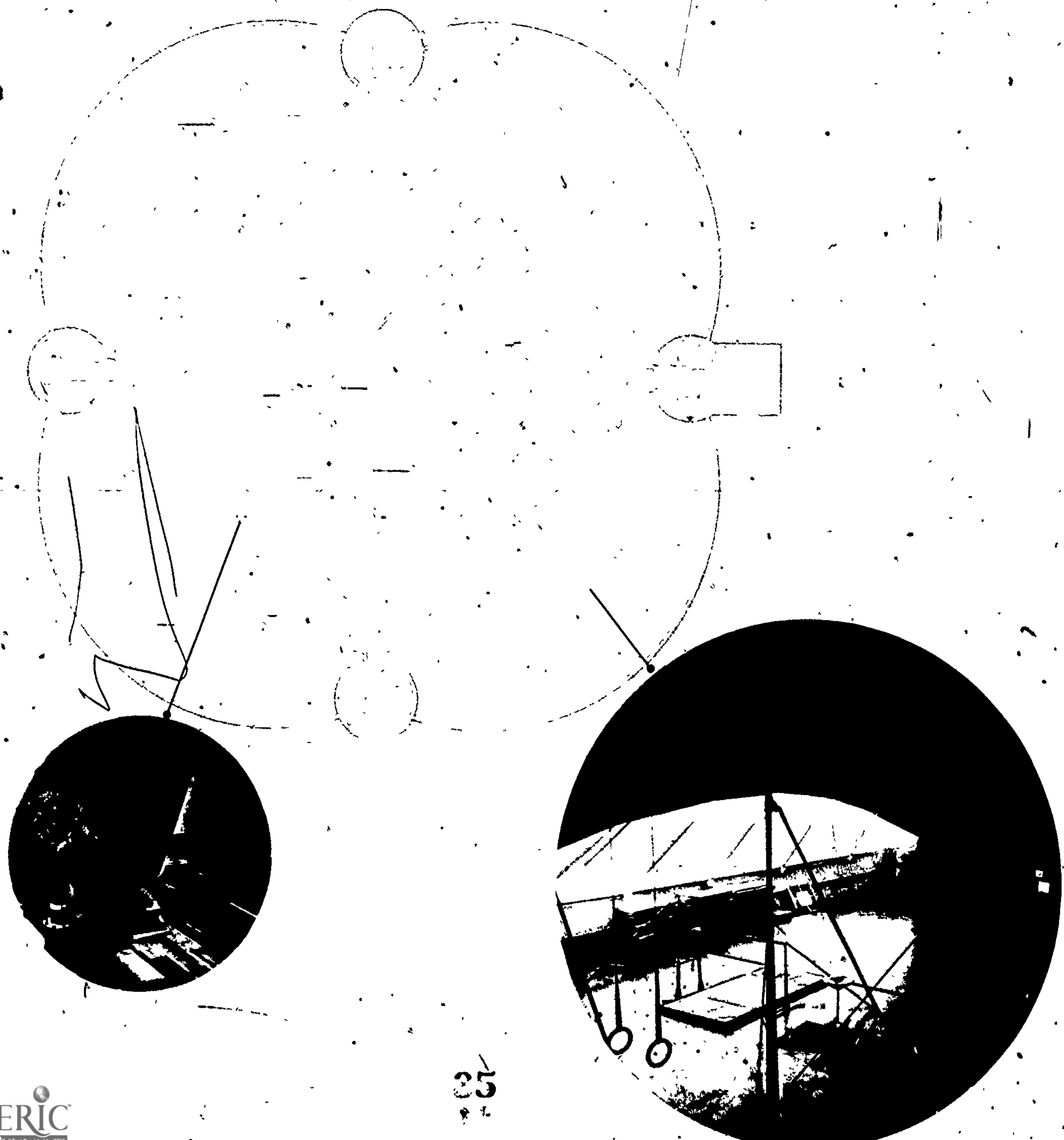
Cost of fabric roof, masts, and cables. Student Center, $510,000, ...ter, $90,000.

...cost of building: Student Center, $2,189,000, Theater, $386,000.


arts and crafts
student lounge
mast
mast
lecture
women
bookstore
student affairs
office
men
mast
mast
exercise
health clinic



Sprinkler attached to roof cable.



Milligan College

A small, church-oriented college in eastern Tennessee showed remarkable faith in technology when it committed itself to building the largest (at that time) airsupported structure in the United States. It ran into financial problems during construction, but it now has a fieldhouse under a 35,000-sq-ft fabric roof.

Milligan College wanted space for physical recreation, and in 1970 an architect who had just completed another building on the campus suggested that an airstructure would enable the college to build a large fieldhouse at about half the cost of a conventional structure. The first estimate of $1.2 million was accepted, and the college found a donor for the full amount. A revised estimate added $100,000 which the college agreed to raise. However, a series of unfortunate circumstances, including poor soil conditions and subcontractors resigning, delayed work and raised costs until the total reached $1,664,000.

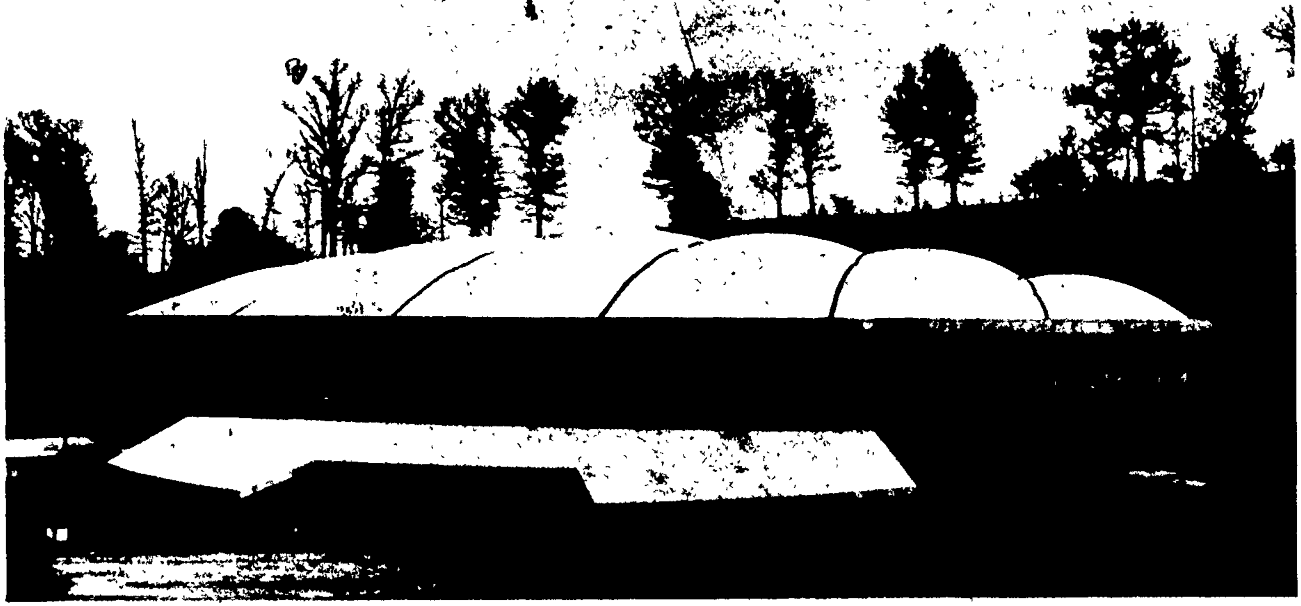
Another $200,000 was obtained from a foundation, leaving Milligan to find $264,000. In large colleges or universities, a quarter of a million dollars may seem an easy target, but for a rural college with an enrollment of 800 and an endowment of $1,162,000, it seems as elusive as winning the national intercollegiate basketball championship. Nevertheless, the unit cost of Milligan's fieldhouse is only $27.75 a sq ft, a modest figure for such a large arena.

Designers took advantage of the hilly terrain to locate the fieldhouse where it required a minimum of excavation. An earth berm encloses about three quarters of the circumference of the structure, columns are spaced around the remaining quarter to support the roof's ring girder that sits atop the berm. The girder forms an exterior wall that raises the ends of the roof cables high enough for them to hang without touching the floor when the roof has no supporting air pressure.

There is a large mezzanine that increases the usable floor space to 62,000 sq ft. Bleachers can seat 1,400 spectators for the main basketball court on the mezzanine. Beneath the mezzanine are a swimming pool, locker rooms and two open floor areas.

The pool environment has to be kept warmer than the rest of the fieldhouse. Most of the pool is under the mezzanine and is walled in with glass partitions, but the diving boards are not under the mezzanine and they had to be separated from the uninsulated fabric roof above. This is accomplished with a fabric canopy draped from the top of the ring girder down to the edge of the mezzanine.

The lower floor can be heated and cooled independently from the upper floor, although apart from the pool the areas are not isolated from each other. Three high pressure fans (two at a time in normal usage) support the roof, and each is



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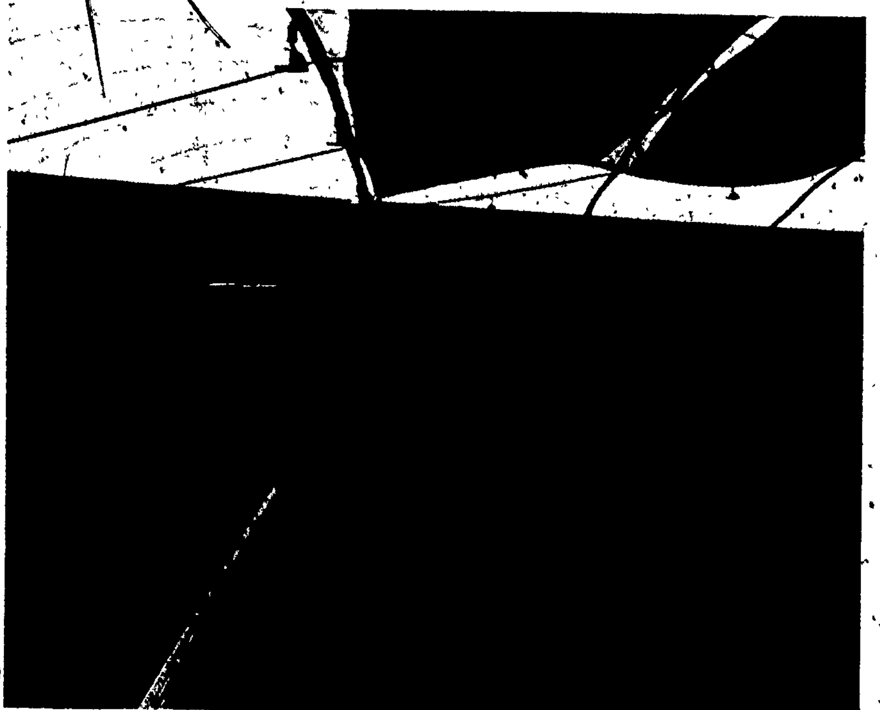
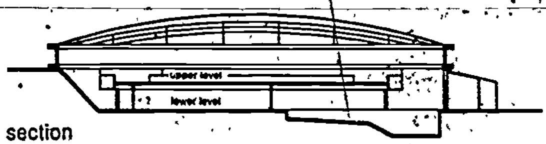
connected to heating and cooling equipment. Two low pressure fans also supply heating and cooling to the mezzanine.

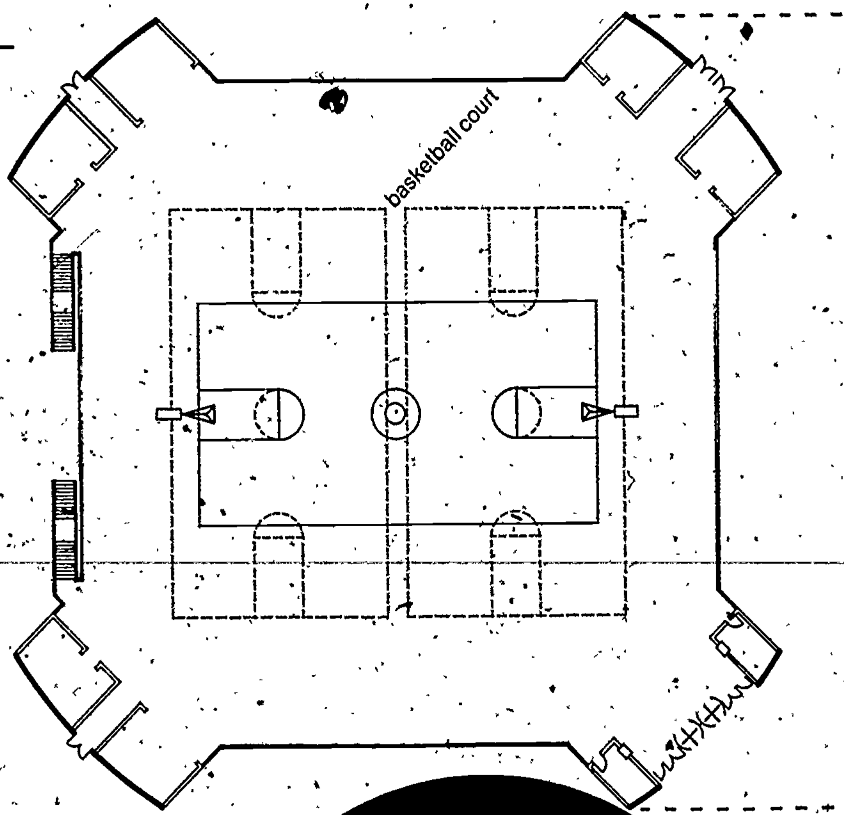
Most of the roof is insulated. Two layers of coated fiberglass fabric form a sandwich with 4-in.-thick blankets of fiberglass insulation between them. Air pressure that supports the roof pushes the inner layer of fabric and the insulation against the top layer of fabric. Relief vents in the top layer allow the air to escape from the sandwich. The insulated roof covers a square area leaving four segments with a single, uninsulated fabric. These segments are translucent, whereas the main insulated area is opaque. Lighting is hung from the roof cables—no additional structure is used to carry the basketball lighting fixtures.

Columns and brick walls support deep concrete ring girder on one side of building, top, *and earth berm supports girder on opposite side,* bottom. *Inside face of berm is covered in concrete,* left of photo at right.

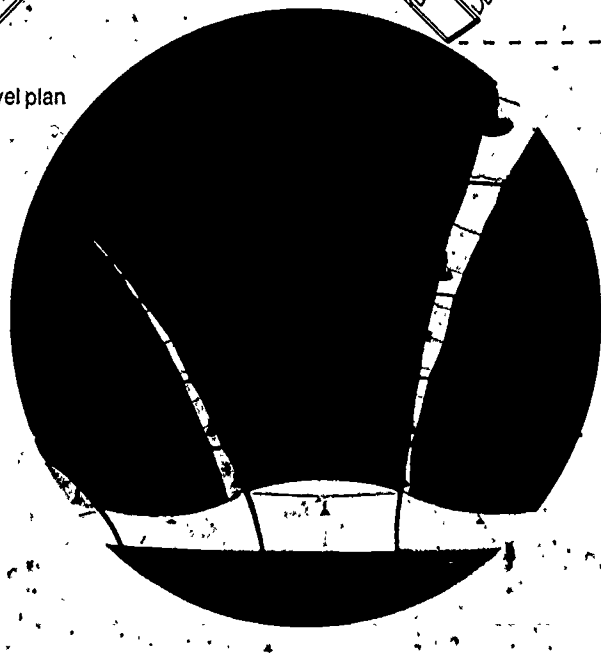




section



upper level plan



Milligan College

Milligan College, Tenn. 37682

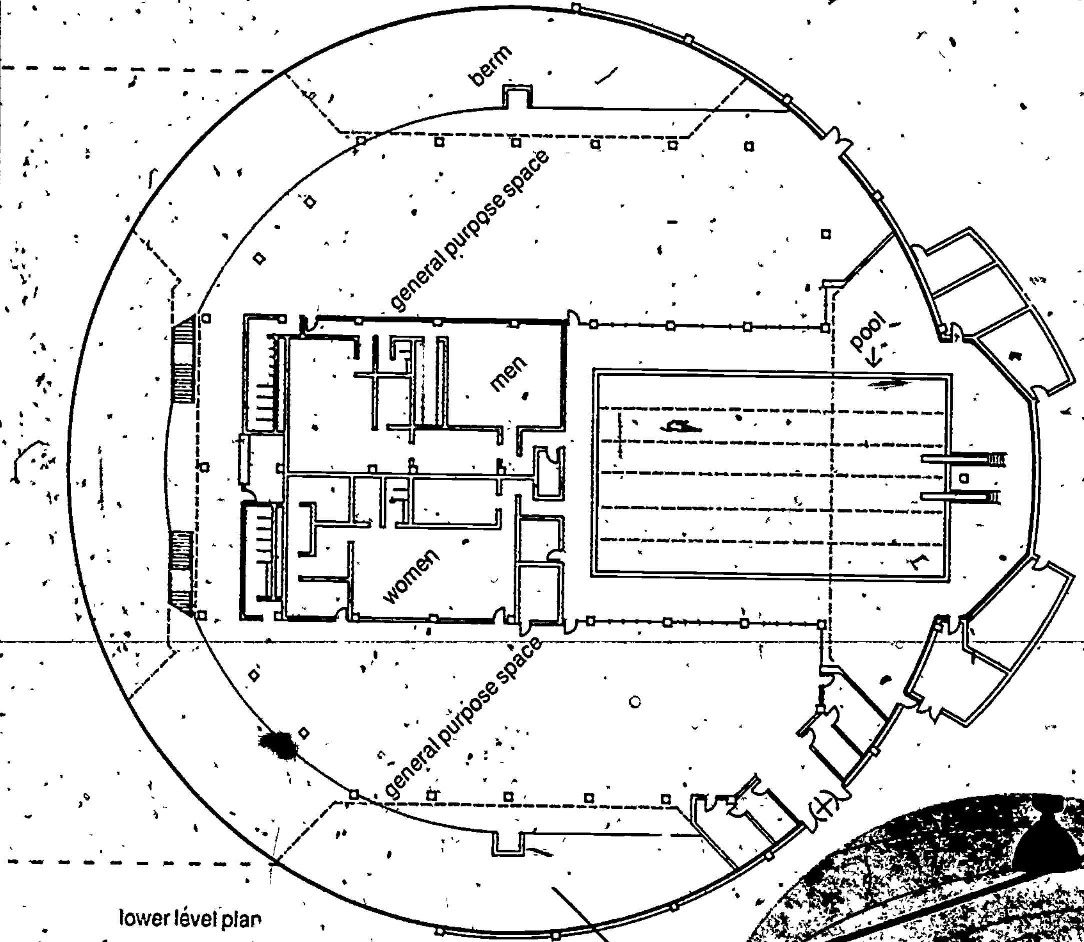
Architect: The Shaver Partnership, Michigan City, Ind.

Structural Engineer: Geiger Berger Associates, New York.

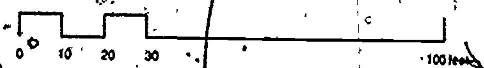
Area enclosed: 68,400 sq ft.

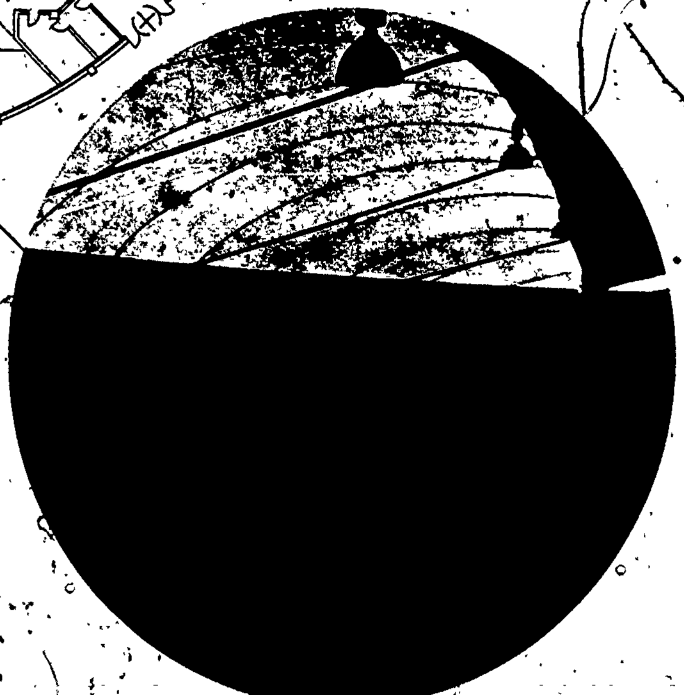
Cost of fabric roof, cables, and ring girder. $190,000.

Total cost of project: $1,664,000.

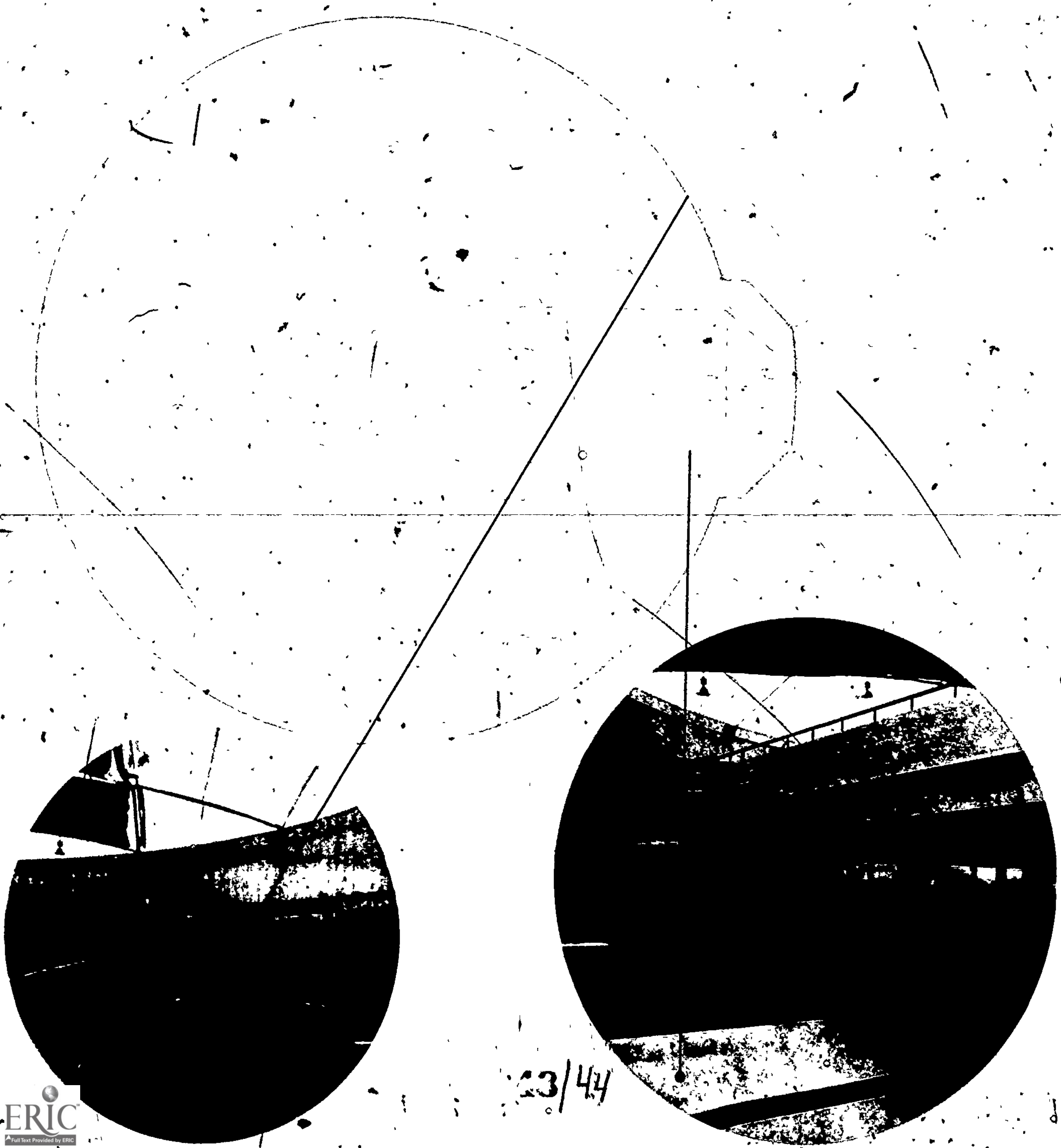


lower level plan





upper level plan



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Actual size
detail of fabric

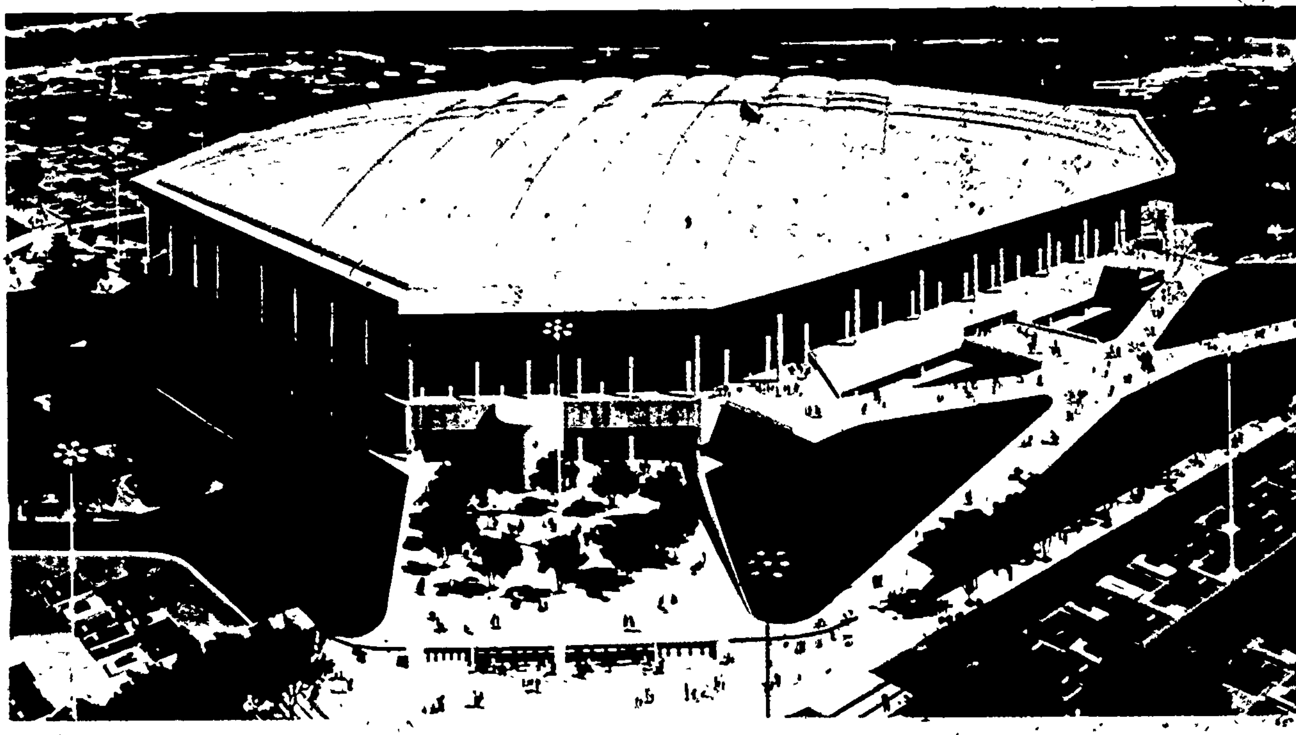
Five Other Structures

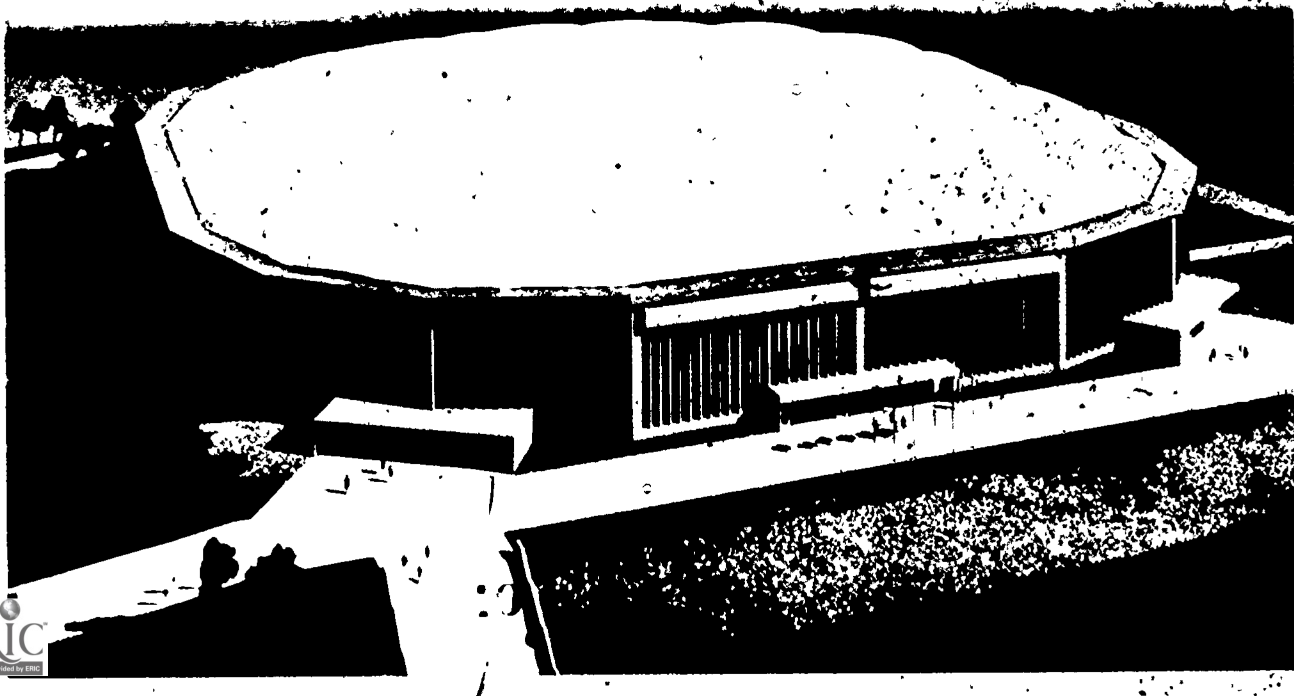
Some of the people involved with the four schools in this publication believe that they paid a penalty for being among the first to use fabric roofs. Manufacturers and contractors claim that costs will go down when they become more familiar with the materials and construction techniques because they will not have to make allowances for unknown contingencies. This may be overly optimistic since at present, a fabric roof, including its erection, costs about 12% of the total construction of a student activities center. Familiarity with the technology might reduce this cost by say 8%, which would lower the over all cost 1%—$30,000 on a $3 million center.

However, the main economic attraction of fabric structures is that they can be built for a great deal less than any other type of roof of similar spans. Owners themselves can help reduce costs by simplifying the uses of their airsupported or tent structures. For instance, if the structure of a fieldhouse is made only to house a field, it will be much cheaper to build than a fieldhouse containing offices, mezzanines, locker rooms, etc. Unfortunately, there's a temptation to increase the amenities inside a structure just because of the savings effected by a fabric roof. Of course, the extras inevitably outweigh the savings, and another expensive building is perpetrated.

There seems to be no maximum size for an airstructure. According to David Geiger there are no limits to roof spans, and only minor limitations to the economical shape of a roof. This leads planners with an eye to the future to sketch entire campuses underneath a fabric roof, and then to project the concept to an entire encapsulated city. Already, farsighted corporations are discussing the possibilities of building new industrial plants under airstructures so that trees, bushes, and water can be used to make the surroundings far superior to standard manufacturing plants.

Meanwhile, colleges and secondary schools have to find additional physical recreation facilities for female students. Federal laws demand that equal access be given to men and women students, and many institutions had previously relegated women to cheer leading. The old gymnasiums built only large enough for a basketball court and bleachers can't contain the diversity of programs that must now be offered. The alternative is a new fieldhouse, and it makes an ideal candidate for an airsupported roof.



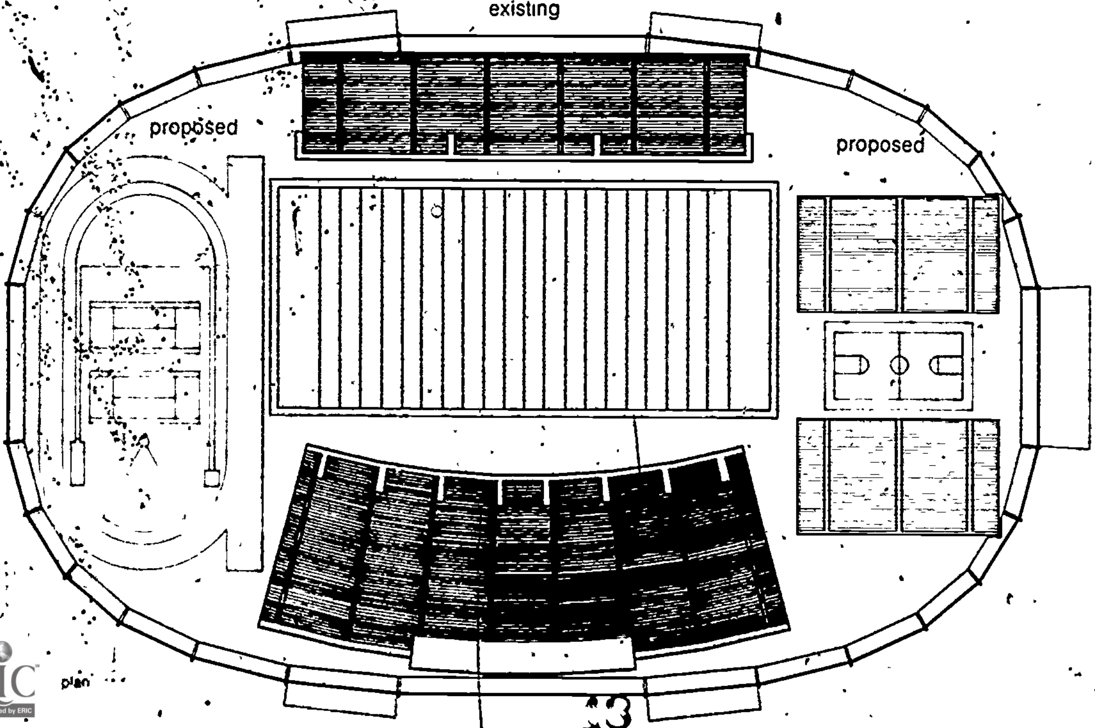


Pontiac, Michigan

Work is underway on an arena with an airsupported roof in Pontiac, Michigan, that will seat 80,000 spectators at professional football games. About half the seats will be below ground level so that the roof can be kept reasonably low. The construction schedule calls for the stadium to be opened to the public before the roof is installed. The roof will be added a few weeks later between games. Construction costs are projected to be $42 million. The stadium was designed by O'Dell/Hewlett & Luckenbach, Inc., architects, and Geiger Berger Associates, engineers.

The University of Northern Iowa

If an airsupported roof encloses a stadium built to accommodate large numbers of spectators, the structure cannot retain the low profile used at Milligan or Santa Clara. The University of Northern Iowa is currently building a coliseum at Cedar Falls that requires the roof perimeter to be elevated about 70 ft above the arena floor in order to accommodate the seating. An earth berm rises about half the height, and a vertical concrete wall encircles the building above the berm. The coliseum plan is a 450-ft square with rounded corners topped with a 168,000-sq-ft fabric roof. The cost was estimated at $6.2 million when work started in 1974. About 18,000 spectators will be seated for football games, and 5,000 more seats will be added for activities such as concerts. The stadium was designed by Thorson-Brom-Broshar-Snyder, architects, and Geiger Berger Associates, engineers.



plan

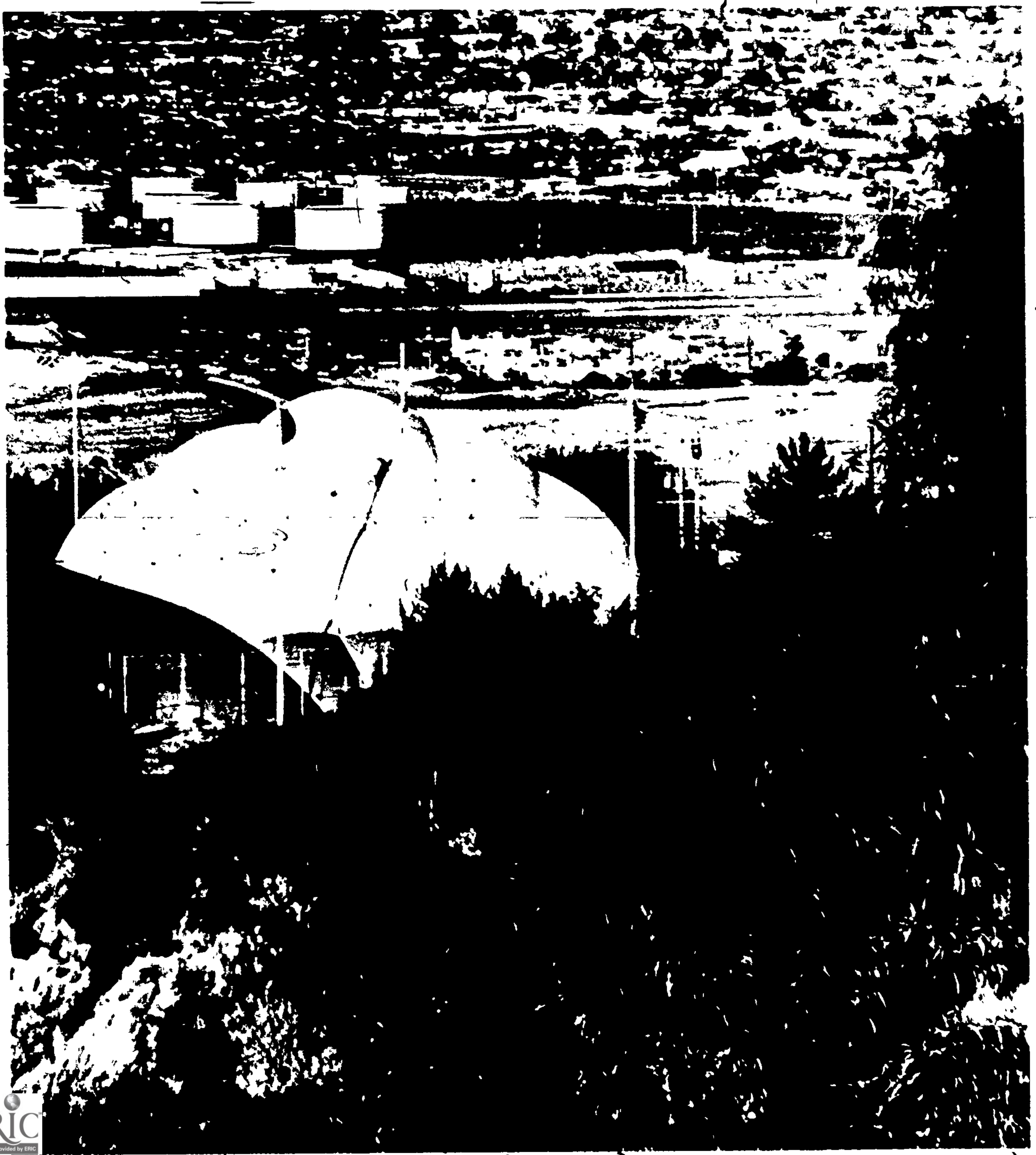
Hanover Park, Illinois

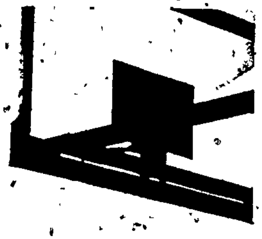
In addition to airstructures and tent structures, it is also possible to suppport fabric roofs with frames rather like covered wagons. Pipe frames have been developed that hold fabric taut over tennis courts, but in Hanover Park, Illinois, the technique has been advanced with steel arches that span 140 ft. The arches are to be spaced 50 ft apart, and coated fiberglass fabric will be stretched between them and pulled down so that the fabric forms a 'saddle' effect.

The Hanover Park Recreation Complex will house just about every activity considered to be recreational. On plan, the facility is shaped like an uneven cross. At the center, under a rigid roof will be the offices, locker rooms, shops, meeting rooms, etc., on three floors. Two short wings with fabric roofs will contain a gym and a small ice rink. Two main wings, also under fabric roofs, will contain tennis courts and a hockey rink. The Shaver Partnership is the designer.

Eastern Michigan University

A feasibility study for Eastern Michigan University shows that the existing football stadium could be roofed over with an airsupported fabric if the two ends of the stadium are extended to form an oval arena. The spaces at the two new ends could accommodate a running track and a basketball court. If football is played on artificial turf, the "turf" can be rolled away to expose nine basketball or tennis courts. The cost of a basic conversion (at 1974 prices) is about $10 million. If the university builds all the facilities it wants in the arena, the cost would be another $2 million. The feasibility study was made by Geiger Berger Associates, engineers, and O'Dell/Hewlett & Luckenbach, Inc., architects.





Chadwick School

Fabric structures don't have to be big and complex like the preceding examples—"off the shelf" models can easily be adapted to shelter recreational activities. An economy model airstructure enclosing a fieldhouse at the Chadwick School, a private school in Palos Verdes, California, was built for $173,000 plus $9,000 for sports equipment. The unit cost of the 102-ft by 120-ft fieldhouse was $14.90 a sq ft in 1974. The structure meets all the code requirements, but the designers had to make an interesting concession. Officials required masts inside the fieldhouse to support the fabric roof in case the air pressure should be lost. Masts, however, would have obstructed the playing area, so the designers offered to erect masts outside the structure and tether the fabric to them so that the roof could never sink to the floor. The masts serve as flagpoles that add a festive touch to the site.

EFL Publications

The following reports are available from EFL at 850 Third Avenue, New York, N.Y. 10022.

Campus in Transition Interprets demographic factors influencing college enrollments, discusses current academic trends, and describes how dozens of colleges are producing new income and/or providing new programs without building new facilities. (1975) $4.00

Career Education Facilities A programming guide for shared facilities that make one set of spaces or equipment serve several purposes. (1973) $2.00

Community/School: Sharing the Space and the Action How schools share facilities with other public agencies to provide improved social services. The book discusses financing, planning, building, staffing, and operating community/schools. (1973) $4.00

The Economy of Energy Conservation in Educational Facilities Recommendations for reducing energy consumption in existing buildings, remodeled projects, and future buildings. Explains the importance of including long-term operating costs and evaluating capital costs of electrical and mechanical systems. (1973) $2.00

Educational Change and Architectural Consequences A report on school design that reviews the wide choice of options available for planning new facilities or updating old ones. (1968) $2.00

Environmental Education/Facility Resources Illustrates where and how students learn about the environment by using existing facilities in schools, communities and natural sites. (1971) $2.00

Fewer Pupils/Surplus Space Looks at the phenomenon of shrinking enrollments, its extent, its possible duration, and some of the strategies being developed to cope with unused school space. (1974) $4.00

Five Open Plan High Schools Text, plans, and pictures explain how five secondary schools operate open curriculums in open spaces. (1973) $3.00

Generating Revenue from College Facilities Strategies used by institutions of higher education to produce income from their land and buildings. (1974) Single copies free, multiple copies 50 cents each.

The Greening of the High School Reports on a conference on how to make secondary school healthy Includes the life-styles of adolescents and ways to accommodate them, open curriculums, and alternative education programs. (1973) $2.00

High School: The Process and the Place A "how to feel about it" as well as a "how to do it" book about planning, design, environmental management, and the behavioral and social influences of school space. (1972) $3.00

Learning About the Built Environment A sourcebook of guides and resources for teachers, and mini-courses, activities, programs, games, simulations and films for students. Available from the National Association of Elementary School Principals, 1801 North Moore Street, Arlington, Virginia 22209. (1975) $3.00

One Out of Ten: School Planning for the Handicapped Implications of the new laws for the handicapped, and alternative methods of educating handicapped children in public schools. (1974) Single copies free, multiple copies 50 cents each.

Physical Recreation Facilities Illustrated survey of places providing good facilities for physical recreation in schools and colleges—air shelters, roofing existing stadiums, shared facilities and conversions (1973) $3 00

The Place of the Arts in New Towns Reports the experiences of arts in new towns and established communities. Gives insights and models for the support and planning of programs and facilities for arts in new towns. (1973) $3.00

Places and Things for Experimental Schools Reviews every technique known to EFL for improving the quality of school buildings and equipment. Found space, furniture, community use, reach out schools, etc. Lists hundreds of sources. (1972) $2.00

Reusing Railroad Stations Advocates combining commercial and public use of discarded railroad stations to preserve part of our heritage, keep urban centers alive, and provide facilities (including educational) for public services. (1974) $4.00

Reusing Railroad Stations: Book Two Extends the information in the first book, explains the business of development, and describes 30 federal agencies that can give financial aid. (1975) $4.00

Student Housing A guide to economical ways to provide better housing for students. Illustrates techniques for improvement through administrative changes, remodeling old dorms, new management methods, co-ops and government financing. (1972) $2.00

Films

The following films are available for rental at $9.00, or for purchase at $180.00 from New York University Film Library, 26 Washington Place, New York, N.Y. 10003. Telephone (212) 598-2250.

New Lease on Learning A 22-minute, 16mm color film about the conversion of "found space" into a learning environment for young children. The space, formerly a synagogue, is now the Brooklyn Block School, one of New York City's few public schools for children aged 3-5.

Room to Learn A 22-minute, 16mm color film about The Early Learning Center in Stamford, Connecticut, an open-plan early childhood school with facilities and program reflecting some of the better thinking in this field.

The City: An Environmental Classroom A 28-minute, 16mm color film, produced by EFL in cooperation with the New York City Board of Education, shows facilities and resources in and around the city in which effective programs of environmental education are underway. Such diverse sites as the Hudson River, an incinerator, Chinatown, Governors Island and a children's camp in a rural setting are analyzed for their contributions to the education of city children.

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15-39 Peter Green
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