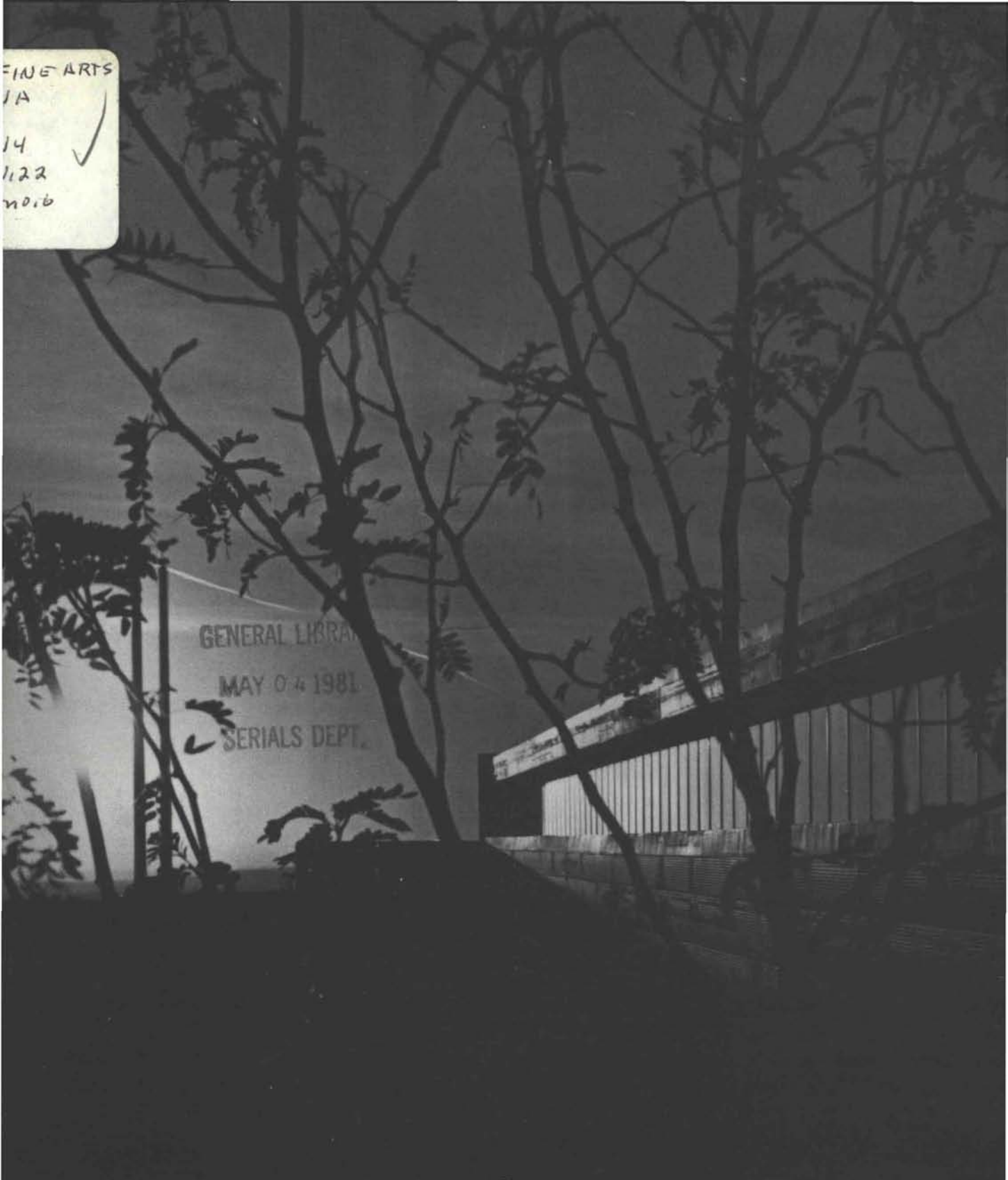

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November—December 1980

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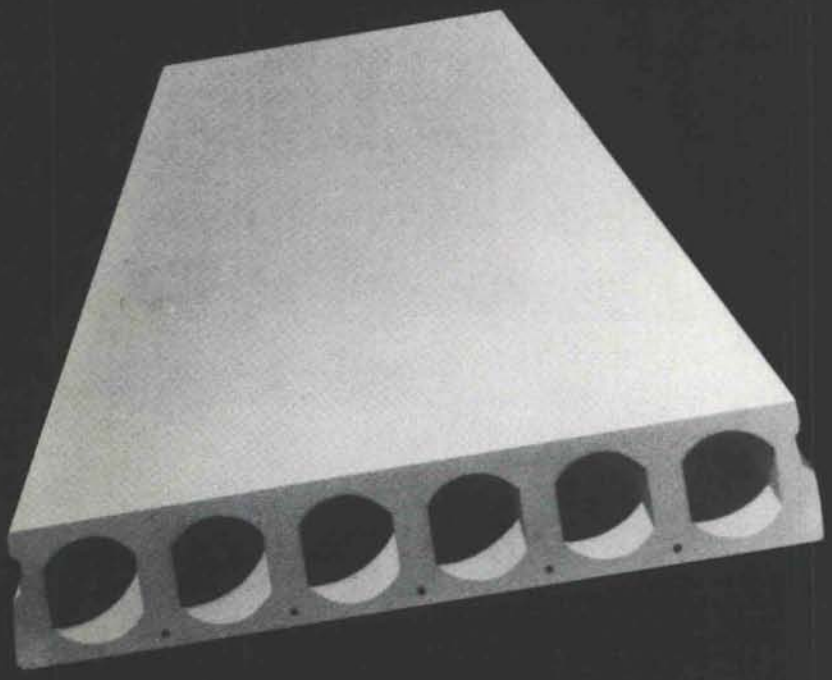

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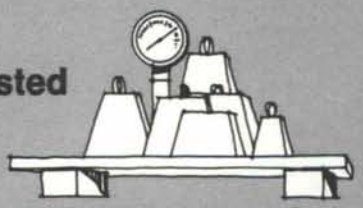

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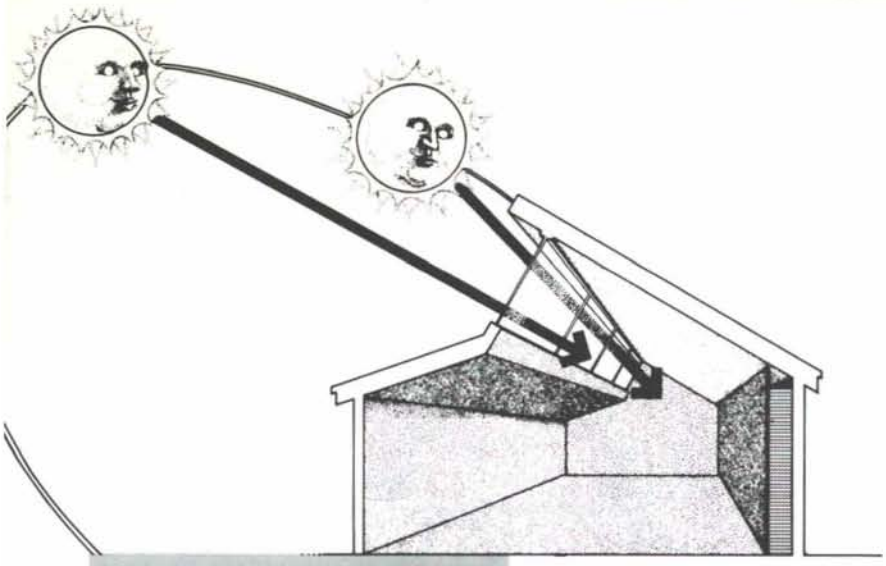

nma

• *vol. 22 no. 6* •

• *nov.-dec. 1980* • *new mexico architecture*

WITH THIS ISSUE we begin a series of articles and architectural projects Addressing the **ENERGY CRISIS.** The September/October issue of **NMA** hoped for a single special issue devoted to this timely subject. The financial basis to accomplish this goal did not happen! Rather than cut the number of articles that we have and eliminate several of the architectural projects to fit into a single issue, we elected to run the material in a series of issues.

We look forward to sharing the expertise that is amongst us here in New Mexico. We know that the authors write from experience and authority.

We invite the reader to respond with reactions and comments.—JPC

Because we are again a little late with this magazine, we can only **hope** that you **had** a very MERRY CHRISTMAS.

☐ ☐ ☐ ☐

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The **NMA** staff wishes to thank those members who have contributed to its growth.

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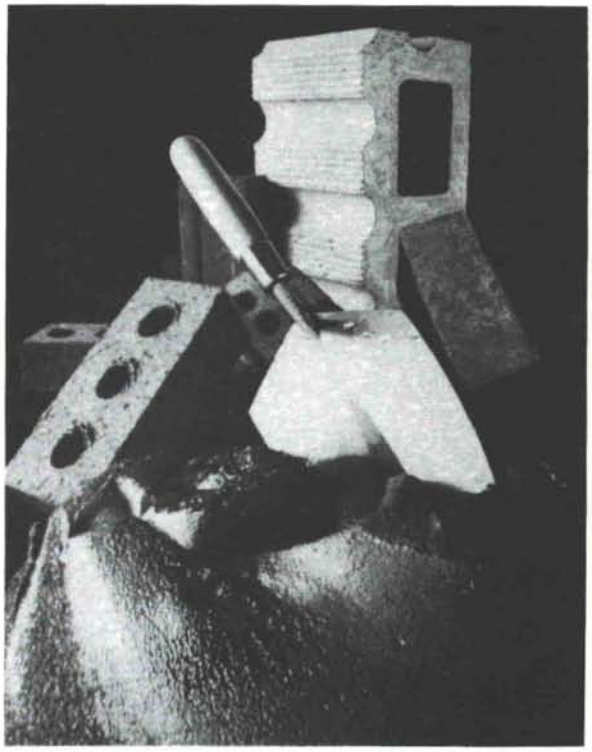

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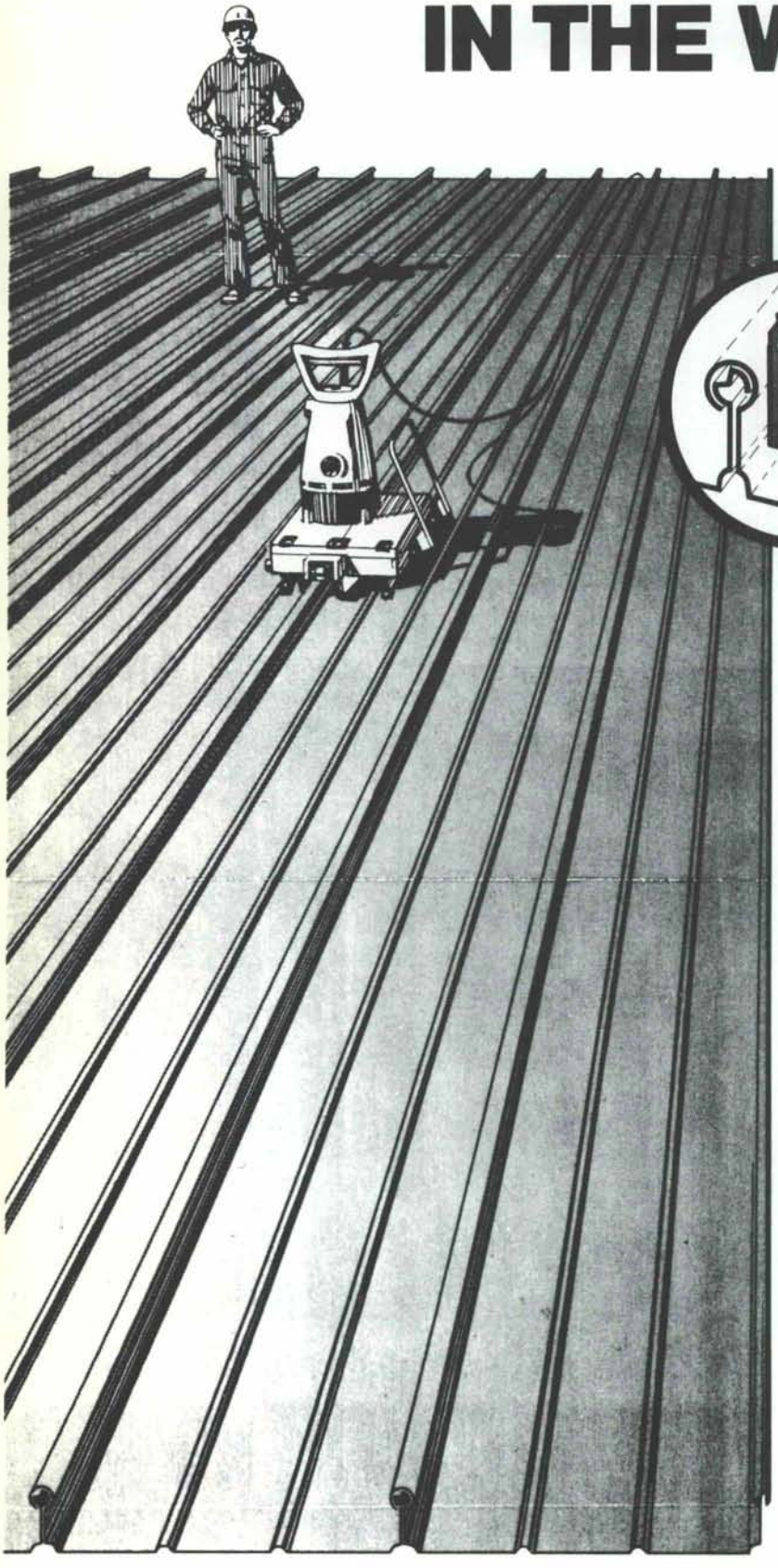

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THE CUMBRES & TOLTEC SCENIC RAILROAD

The Historic Preservation Study

Spencer Wilson and Vernon J. Glover

The narrow-gauge line known today as the Cumbres & Toltec Scenic Railroad is the sole remaining link to a bygone age of railroad history. The sixty-four miles of track through the San Juan Mountains between Chama, New Mexico, and Antonito, Colorado, is a "living museum"—original rolling stock operating on a route opened in the early 1880s. Built to tap a mining boom, the line underwent the first of several periods of hard times with the collapse of silver prices in 1893. In 1967 owners of the railroad announced plans to abandon it, at the same time that citizens and lawmakers in New Mexico and Colorado became concerned with preserving for posterity a functioning steam railroad. Today the two states jointly own the line, which is operated by the Scenic Railways Company on lease.

The C&TSRR now runs as both history and recreation, providing an unforgettable encounter with the steam railroad that helped open up the American West. This book, the only comprehensive study of the present operation of the C&TSRR, is invaluable for its inventory of the railroad's buildings and equipment. The text and photographs enable passengers to appreciate the stabilization and restoration that has occurred, while at the same time providing plans for the future conservation of the line as a unique part of America's frontier heritage.

The C&TSRR, in being preserved, affords the passenger of today a rare view of much that was typical of nineteenth-century railroad engineering and practices. After a century of operation, the great scenic beauty of the route still inspires awe in passengers, and the sound of the whistle cutting the calm of a high, mountain meadow never ceases to delight. The book captures the incomparable history that awaits today's passengers: the Lobato Trestle built in 1881, the water tank at Osier, Rock Tunnel and Mud Tunnel, and of course the mighty steam locomotives.

No one who has ridden the C&TSRR or who has an interest in railroading and industrial America will want to be without this book. People concerned with preserving our historic heritage will find this study an invaluable model.

Spencer Wilson is professor of history at the New Mexico Institute of Mining and Technology in Socorro. Vernon J. Glover is employed by the United States Air Force as a manufacturing engineer.

LC 79—67373
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SOCORRO

A Historic Survey

John P. Conron

The architecture of Socorro, New Mexico, has an unusually rich blend of Spanish, Territorial, and Victorian styles. Writing in the spirit of the Historic Preservation Act of 1966, the author surveys over sixty of the city's historic sites and reports on it preservation plans. Numerous photographs, in particular those of pioneer southwestern photographer Joseph E. Smith, will interest laymen and professionals alike.

John P. Conron, FAIA, is an architect in the Santa Fe firm of Conron and Lent.

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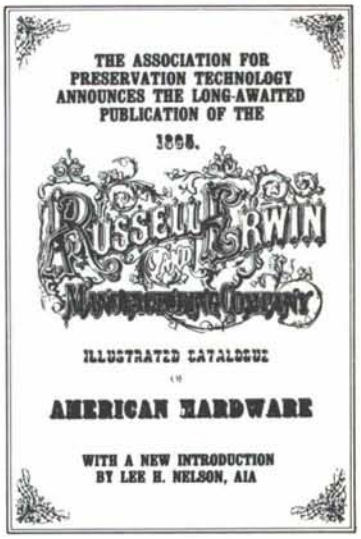

An important benchmark in the development of the American hardware industry, this encyclopedic catalog is an indispensible reference tool for architects, preservationists, and others. Over 450 pages long and containing 3300 line engravings, the volume contains valuable information on virtually every article of American hardware manufactured in the United States in 1865. Locks, latches, hinges, bell trimmings, nails, screws, bolts, handles, tools, chandeliers, scales, saws, traps, hollow ware, cutlery, sleighs and hundreds of other items in every conceivable size and shape are described and illustrated.

While this paperback reprint slightly reduces the format (the original being 12 by 17 inches), it is unabridged and there is no loss in quality regarding the original art of the engravers and printers.

A concise introduction by Lee H. Nelson, AIA, provides insights into the growth of the hardware industry in America and an appreciation of this remarkable catalog, together with mention of its English and American antecedents.

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The knowledge business

An NMA Series.....THE ENERGY CRISIS

Editorial By William L. Burns, AIA

BUILDING ENERGY CONSUMPTION

This issue begins a series devoted to the energy crisis and how it must impact building design. Energy usage by buildings today accounts for about 30% of this nation's total energy consumption. Most of this energy is generated from fossil fuels, which are becoming increasingly scarce and expensive. Everyone should be concerned about our country's dependence upon these energy sources, but architects and engineers can and must do something about the 30 percent consumed by buildings. State of the art energy conservation techniques can result in an energy savings of more than one-third, and this is just a start. It is paradoxical that throughout history designers have been striving to develop a central mechanical system that would allow any building to ignore outside influences and have a perfect indoor climate, yet today we find ourselves without the energy to maintain these mechanical systems. Buildings have become isolated from the natural environment, relying entirely upon mechanical space conditioning machines. Increasing the building's thermal envelope through insulation or double-glazing and better sealing it through weatherstripping are current techniques to save energy. What is needed, however, is a way to combine these techniques with alternative energy systems utilizing the natural environment.

EFFICIENT BUILDING FORM

Architectural form can be a powerful tool for achieving energy conservation by evaluating the building as a dynamic complete environment. The sucessful architect will accept the challenge of energy conscious design as opportunity for imaginative design rather than treat it as a design constraint. He will be a leader in developing innovative energy saving designs for his clients, rather than accepting prescriptive energy usage codes that may restrict building design options. With the current shortage of fossil fuels, buildings should be tailored to the surrounding environmental conditions rather than overpowering the natural climate with energy consuming machines. Buildings can be designed to respond to changing sun angles and to utilize natual daylight and ventilation. Necessary conventional mechanical and electrical systems should be chosen for their efficiencies and designed to accommodate future technologies.

NEW MEXICO'S OPPORTUNITIES

With it's abundant sunshine, cool days and clear sky, New Mexico is a natural area to utilize solar and other energy conserving systems. Simple, passive, direct solar gain was incorporated into the design of the earliest Indian Pueblos. Orientation for optimum solar gain and shading dictated the pueblo housing unit design as well as the master site plan. Our climate has low summer humidity and maintains about a 30°F diurnal swing. This creates the opportunity to utilize energy-saving cooling systems using evaporative, sky radiation or night cycle cooling techniques. Sunny winter days followed by cold nights allow use of both passive and active solar energy systems. We are fortunate in New Mexico to be able to utilize these solar energy heating systems coupled with simple low cost cooling systems.

This series will illustrate New Mexico's leadership in the field of enery conservation. the articles are all written by local professionals—all experts in their specialty and many are nationally recognized as such. The projects are varied in type of occupancy and energy saving techniques. I want to thank the authors and firms that submitted work to make this series possible. *W.L.B.*

ALTERNATIVE ENERGY SYSTEMS

by Don Felts

Don Felts, P.E.

Don Felts is a Registered Professional Engineer and principal owner of Don Felts and Associates, Designers, Engineers, of Albuquerque, New Mexico. His firm offers Mechanical and Electrical consulting services with an emphasis on energy conserving design, passive and active solar systems, natural lighting, and other alternative energy systems.

Felts received a Bachelor of Science degree from the School of Engineering and Technology, Southern Illinois University. Before forming his own firm in 1976, he was a Staff Engineer for a midwestern architectural firm. He has been involved in a wide variety of alternative energy projects.

Alternative energy systems, other than active and passive solar, available to building designers include: wind, biofuels, and photovoltaic solar conversion. These vary in complexity from the simple wood burning stove or fireplace to highly sophisticated large scale wind generators. Utilization of these alternative energy systems requires careful consideration by designers as well as additional capital outlays by the owner and investor.

The hardware and the technology for the implementation of these alternative energy systems are readily available. In some instances, these systems were widely used as energy sources before the advent of cheap fossil fuels. Windmills that pumped water and generated electricity were a common sight throughout rural areas. Hand fired boilers and furnaces that could accommodate a variety of fuels including coal, wood and trash were frequently used. In many instances, this energy hardware was very basic, somewhat inefficient and unreliable. With the advent of precision manufacturing and solid state electronics, reliability has been greatly improved, efficiency somewhat improved.

The rapidly changing economics and finite limits on the availability of fossil fuels are creating new markets for old technologies and new hope for the development and deployment of relatively new technologies such as photovoltaic solar conversion. It is essential that architects and engineers become aware of the alternative energy systems and consider them for use in the buildings they design.

Wind Energy

Wind is a non-polluting renewable solar energy resource. The potential for energy from the wind varies widely throughout the State of New Mexico (figure 1). The greatest potential is in the high plains of the northeastern part of the state. Other good areas include the plains east of the mountain ranges along the Rio Grande Valley and in southwestern New Mexico. The heavily populated areas of the central Rio Grande Valley have a low potential for wind energy.

Although figure one gives a good indication of wind potential in a given area, local microclimatic conditions that could generate favorable winds should not be overlooked. Geologic formations such as mountain ranges, and canyons provide natural paths for hot air to rise up from lowlands during the day and cold air to drop down from the highlands at night. Canyons and passes also focus low velocity winds, off the flatlands, through smaller areas thus greatly increasing the velocity and the potential for extracting useful energy. A good example of this is the Tijeras Canyon east of Albuquerque.

The power output of a wind generator is directly proportional to the cube of the wind velocity. This is graphically illustrated in Figure 2. In areas with

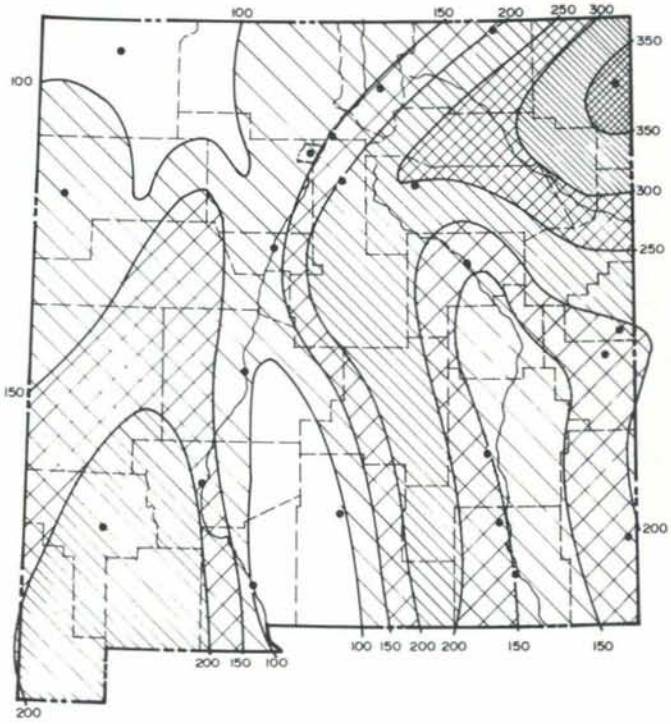


FIGURE 1 TOTAL POWER IN SURFACE WINDS, ANNUAL AVERAGE, IN WATTS PER SQUARE METER, IN FLAT OPEN AREAS FROM "ENERGYTIC NEW MEXICO---SECOND EDITION" BY ALBUQUERQUE INDUSTRIAL DEVELOPMENT SERVICE COOPERATIVE AND INDUSTRIAL FOUNDATION OF ALBUQUERQUE, NOVEMBER, 1977

average wind velocities of 10 mph such as Albuquerque, theoretical wind power densities on the order of 5 watts per square foot can be expected. If the wind speed were increased by 50% from 10 to 15 mph, the theoretical wind power density would increase by over 200% to over 16 watts per square foot. This fundamental principle is critical to the selection of wind generators as alternative energy sources.

Like all solar energy sources, the wind is intermittent. Therefore, a means must be provided to store the wind's energy for utilization as required by the building's systems and its occupants. A frequently used method is storage batteries. The batteries are charged when the wind is blowing and discharge as required to meet the building load. Disadvantages of this storage and utilization method are the cost of the batteries and the floor space that must be devoted to them. Also, most electrical equipment operates on alternating current. Thus inverters are often required to change direct current from the generator to alternating current for the electrical equipment.

Another method would be to operate the wind generator in parallel with the utility company interface. That is, when excess electricity was being generated by the wind, it could be fed into the utility company grid. When the wind was not meeting the electrical requirements of the building, electricity would be supplied from the utility company grid. Disadvantages of this method include the fact that excess wind energy may not always coincide with the utility company peak demand periods. Thus, the utility company may have no use for the wind energy.

A method that seems to offer a great deal of potential is thermal storage. This method would use the electricity generated by the wind to raise the temperature of water in a storage tank. The heated water could then be used as a heat sink for water to air heat pumps or fan coil units. It could also be used as domestic hot water. Advantages would include the elimination of expensive batteries and inverters. Also, the thermal storage could be used in conjunction with active and passive solar systems.

Where a public water supply is not available, wind is a viable energy source for pumping water from deep wells. However, in order to maintain adequate pressure at plumbing fixtures, elevated storage tanks from 50 to 60 feet above the fixtures would be required. Since elevated tanks could be quite expensive, an effective compromise might be to use wind energy to pump water to a grade level storage tank. Then, an electric pump and pneumatic pressure tank could be used to maintain pressure in the building's plumbing system.

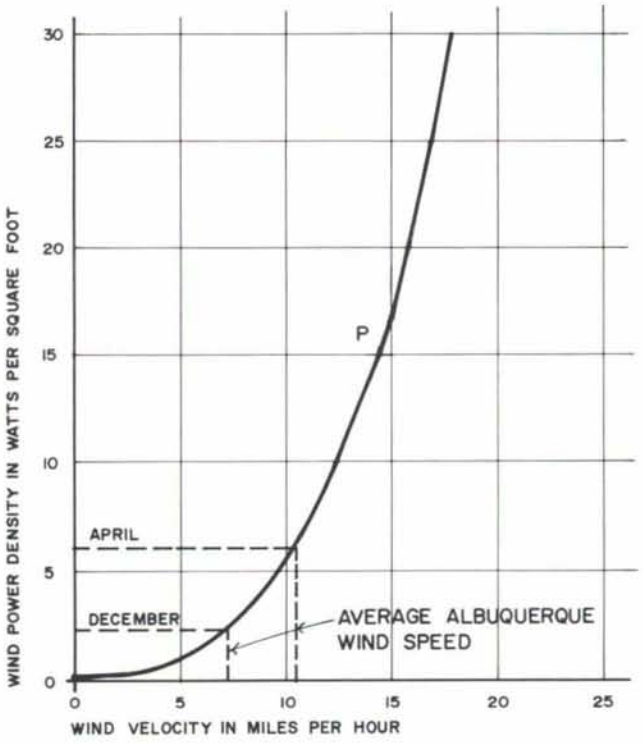


FIGURE 2

Biofuels

Biofuels are renewable solar energy resources obtained essentially from plants. Forms of biofuels that could be readily used as energy sources for building systems include methane, alcohol and wood. Biofuels are labor intensive and tend to have a low net energy output.

Methane gas can be produced on site from domestic sewage and waste. An average adult could contribute 0.25 lbs of volatile solids per day to a methane generator[1]. Each pound of volatile solids could produce as much as 15 cubic feet of methane with a heat content of 850 BTU per cubic foot.

A recent study done for the State of New Mexico's Turquoise Lodge Special Medical Hospital for the Treatment of Alcoholism indicate that the facility's equivalent full time population of 60 people could produce as much as 225 cubic feet of methane gas per day. This would yield enough energy to meet only a very, very small portion of the building's daily energy requirements.

Due to the small yield, on site methane production from domestic waste is probably not feasible. Instances where it might be feasible include buildings where large amounts of organic waste are produced such as food processing industries.

Alcohol fuel has been receiving a great deal of attention in the national press. It is a renewable resource that has the potential of providing a major portion of this nation's energy requirements. Ethanol or grain alcohol not only yields a high grade fuel but also yields a high protein mash that can be fed to cattle.

The *Mother Earth News* issue number 61 gives a complete description of a low cost ($500) still with a yield of 8 gallons per hour. With a heat content of approximately 90,000 BTU per gallon and a combustion efficiency of 50%, it would require approximately 400 hours of operation of the still to produce enough fuel to meet the space heating requirements of the aforementioned 10,000 square foot, 60 patient Turquoise Lodge Alcoholism Treatment Hospital.

Continued on page 14

Grants Branch Community College

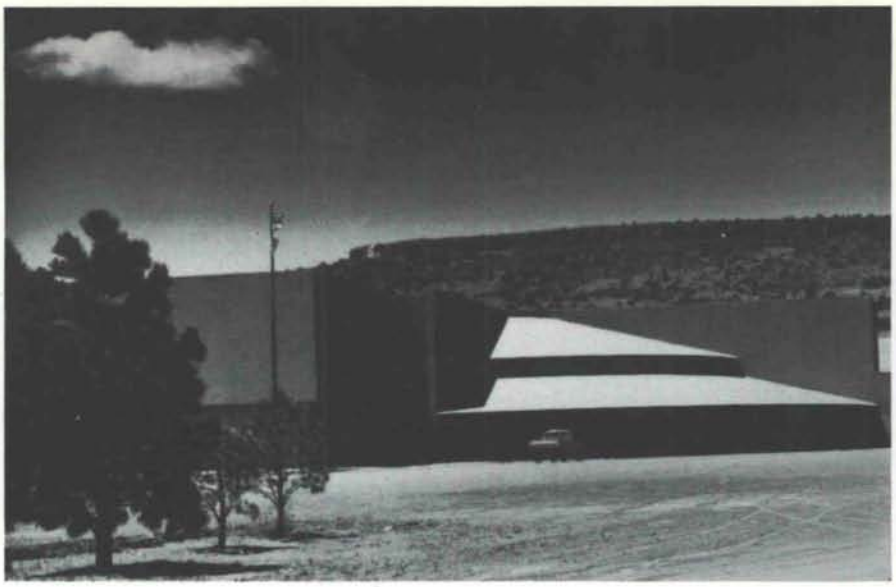
Phase II Architect:
Arthur W. Dekker
Phase II Consulting Architect:
Schaefer & Associates
Phase III Architect:
Alianza Arquitectos: An Architect's Alliance

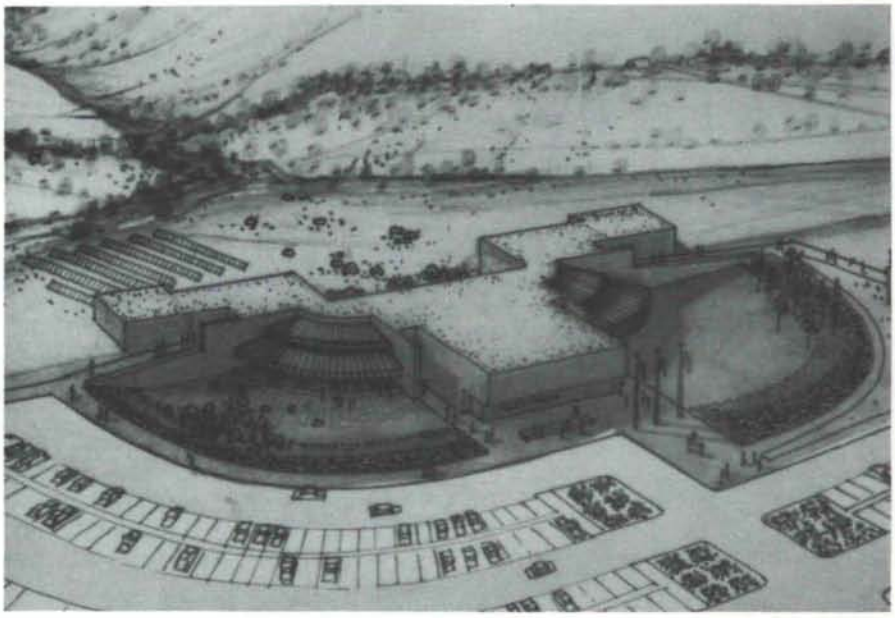
The project comprises Phases II & III of a community college branch of New Mexico State University, serving Western New Mexico. The site is at the edge of a small community impacted by growth generated by uranium mining, and consists of 39.5 acres at the foot of Black Mesa, forming a backdrop for the town. The site, at elevation 6500 ft., offers southeast views to the town and across the valley toward lava beds, while northeast views focus on 11,300 ft., Mt. Taylor.

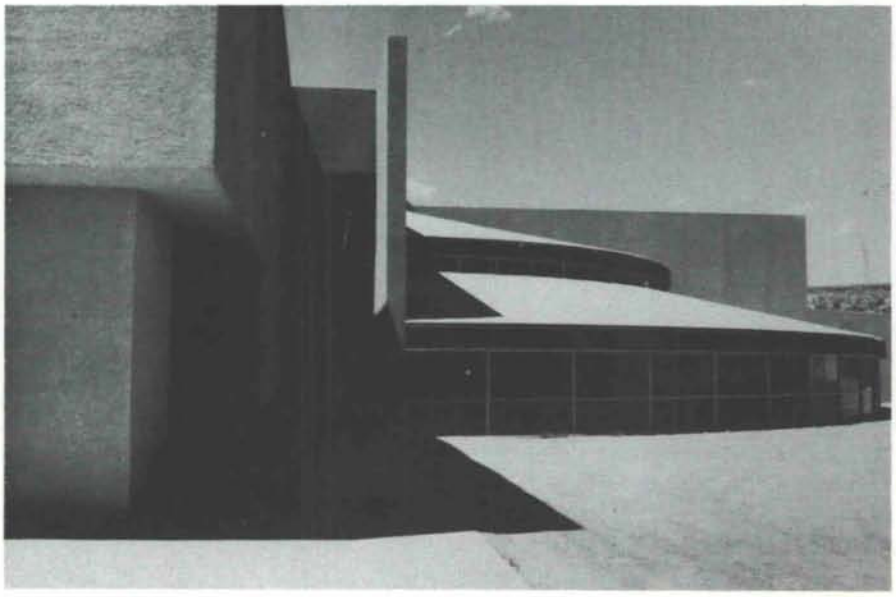
The initial campus core provides the first major cultural facility of Grants. To allow the institution, opened in 1969, to continue functioning, construction was in the central open space surrounded by 14 former Job Corps pre-fab structures, all but two of which were demolished or relocated later. Expansion along the north-south level axis will include replacement of remaining gym and shop structures.

A light steel frame provides flexible space within a thick-walled stuccoed block enclosure. Carefully oriented areas of transparency comprise 22% of vertical surface, 8% of total building envelope, well within ASHRAE standards for energy conservation. The zoned heat pump mechanical system includes storage tanks to which solar collectors have been added to provide a solar assisted heating cycle.

Slope of site allows a two level compact core, while curving sweep of parking area offers direct exterior access into either level. Students and citizens of the community enter according to their destinations, with community oriented facilities on the lower level.







Fast

United Bank Parking Addition
Denver, Colorado

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James Sudler & Associates
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General Contractor
Olson Construction
Denver
Structural Engineer
KKBNA Consulting Engineers
Denver

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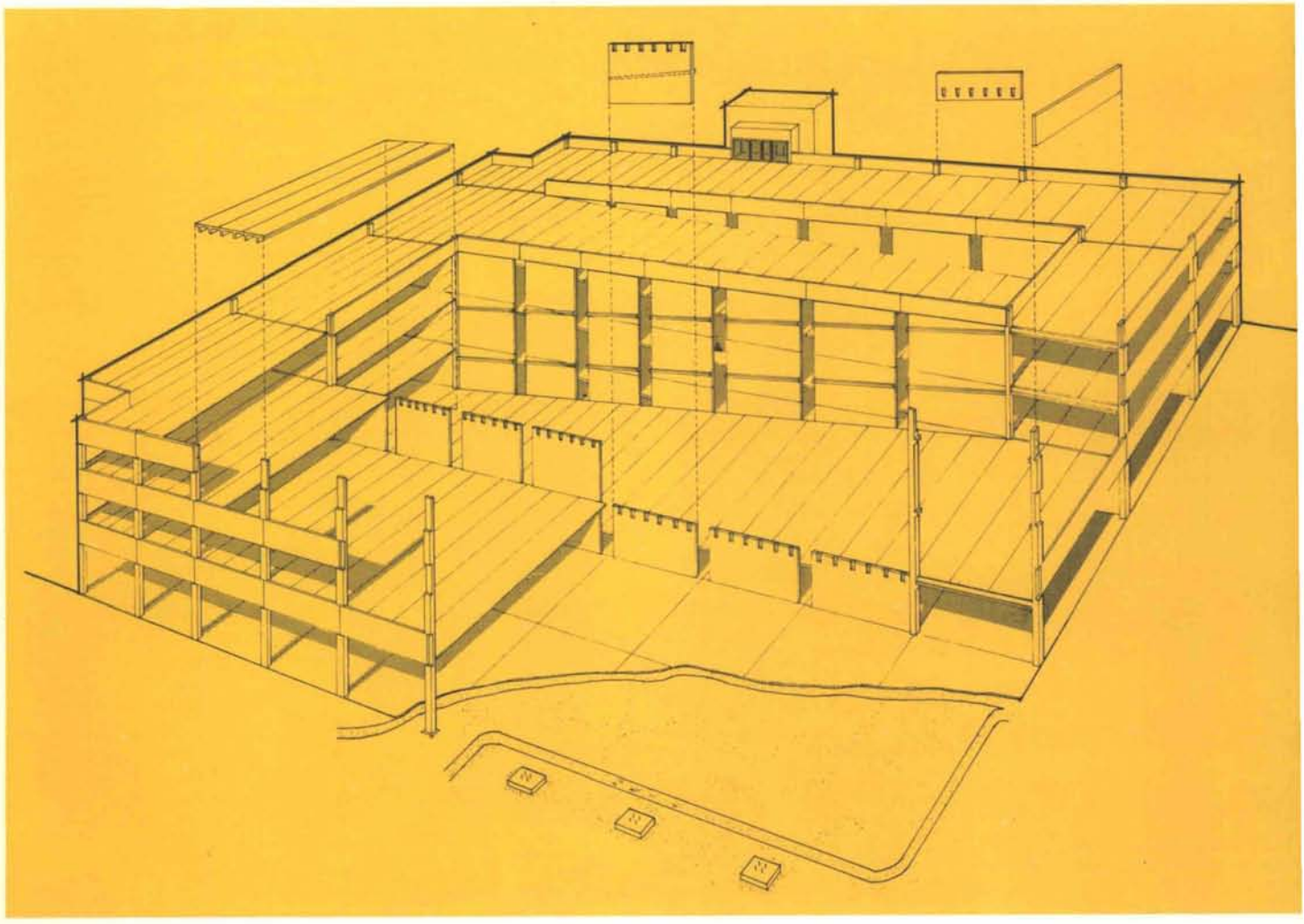

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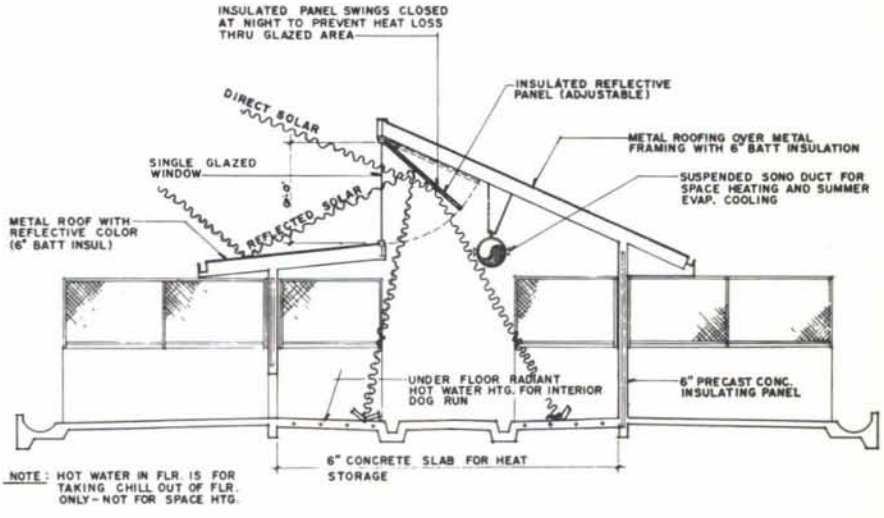
ALBUQUERQUE ANIMAL CONTROL CENTER

Owner:	**City of Albuquerque**
Architect:	**The Burns/Peters Group**
Solar Engineer:	**Bickle CM, Inc.**

The City of Albuquerque gave The Burns/Peters Group an almost perfect opportunity to blend energy conservation, active solar utilization, and passive design in this municipal animal control center. The site allowed for maximum southern exposure. The simplicity, open plans, and masonry construction typical of animal shelter design fit a passive approach. The economical underfloor radiant heating typically employed in kennels was compatible with active solar collection. A comfort range broader than the normal range for human comfort reduced peak demands on the solar system. Based on a preliminary feasibility study conducted by the project's designers, the federal Energy Research & Development Administration (ERDA) subsidized construction of the active system with a $39,250 demonstration grant. The long and relatively narrow geometry of the project capitalizes on its southern exposure. The 2,200 SF office area is heated primarily by the active solar system (48 rooftop tracking collectors and a 1,500 gallon water storage tank). Passive solar heat gain through the dark masonry walls and southern glazing (fascia-shaded in summer) supplies 15-20 percent of the offices's heat).

The 4,400 SF kennel and non-office spaces to the right of the offices are primarily passively heated through the 6-foot-tall single-glazed clerestory running the length of the space and the combination solar reflector/night insulation panel above it. The stained concrete floor of the kennel space absorbs both direct and reflected solar radiation. When temperatures exceed 65°F, a thermostatically-controlled ventilation fan cools the space; on a winter night or when summer temperatures reach 70°F, the reflecting panel closes to cut off the heat exchange. Hot water from the active system can be circulated underfloor to back up the passive system.

The building's massive construction, insulation, active system and passive features combine to answer not only 60 to 75 percent of its heating needs but 15 to 20 percent of its cooling load as well.



SECTION THRU DOG RUN — PASSIVE HEATED AREA

(Don Felts continued from page 11)

This process would require as much as 40 tons of corn for the mash and eight cords of wood for the distillation process (1) (2). It would be labor intensive and require storage space for the corn, the mash, the wood and the alcohol. Under these conditions, it is doubtful that on site production of alcohol fuel would be attractive to building owners. Alcohol would be a viable fuel if it were available from distributors and could be delivered to buildings just as fuel oil and propane are. Fuel oil burners can be converted to burn alcohol. Also, alcohol is a clean burning pollution free fuel.

Wood is commonly used as a fuel source on a residential scale in New Mexico. However, it is much less frequently used on a commercial-institutional-industrial scale. Boilers and furnaces with dual fuel, wood and natural gas or oil capabilities with firing rates of up to 500,000 BTU per hour are available (3). These units are usually hand fired, will handle unsplit logs up to 4'-0" in length and will go up to 12 hours on a single charge. In the event that the wood fire is not meeting the heating requirements, the boiler or furnace will automatically switch over to the alternate fuel.

Large scale boilers that utilize wood as a fuel are commonly used in the wood product and paper industry. These boilers burn the byproducts from the manufacturing and milling processes and require the sophisticated operation, maintenance, fuel handling and pollution controls typical to large scale power plants. Boilers such as these might find applications in large scale building complexes such as prisons, college campuses, etc.

Without proper combustion controls and adequate air supplies, wood burners release considerable amounts of smoke including particulate matter and unburnt creosote into the atmosphere. In urban areas, such as Albuquerque, this pollution can build up to intolerable levels. It can be expected that strict environment controls will be imposed upon wood burning if its current widespread usuage is continued.

Photovoltaics

Photovoltaic solar conversion holds the potential for low cost, decentralized generation of electrical power. The Federal government through the Department of Energy has plans to foster widespread use of solar electricity. The DOE photovoltaic budget for fiscal year 1980 is close to $140 million making it the best funded Federal solar initiative.

Photovoltaic electrical generating systems are much like flat plate solar collectors. They require fairly large areas of unshaded south exposure. For instance, a non-concentrating array large enough to provide the 8 to 10 kilowatts required for a typical house would cover as much as 500 square feet. The size of an array can be reduced by concentrating the sunlight and by keeping the array normal to the sun with tracking mechanisms. Whenever intense concentrations are used, the photovoltaic cell requires cooling in order to prevent overheating. Concentrators, tracking mechanisms, and cooling systems have a tendency to add to the complexity and detract from the reliability of a photovoltaical system.

Current cost of photovoltaic arrays range from $10 to $15 per peak watt. However, storage batteries, DC to AC convertors, additional floor space, and technical assistance increase the final cost to the user substantially. A good example of this is the photovoltaic installation at Schuchuli, Arizona for the Papago Indian Tribe. The cost of the photovoltaic equipment amounted to $109,000.00 or $1.76 per KWH. After the additional cost for equipment, fees, etc. were added in, the total amounted to over $330,000 or $5.30 per KWH (5).

Photovoltaic solar conversion is not competitive with utility company electrical service wherever power lines are readily available. However, at remote sites, where power line extension would be costly, photovoltaics should be considered. If the DOE timetable for economic photovoltaic cells is realized, they will be a common feature of building design, even in urban areas, by the end of this decade.

Conclusion

There are a number of technically and economically feasible alternative energy systems that can be used by architects and engineers to satisfy a building's energy requirements. In most instances, these alternatives are directly contrary to modern societies' automated plug-in and turn-on energy systems. They are decentraized and in many cases labor intensive. They tend to be a prominent part of a building both in terms of appearance and budget.

However, alternative energy systems are destined to play a vital role in the future of architecture. A viable alternative energy strategy would be to first reduce a building's energy requirements through energy conservation and passive design including passive heating, natural ventilation and natural lighting. Then, consider active solar, wind, biofuels, and photovoltaic energy systems. This strategy would minimize a building's requirements for utility company energy. *DF*

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Solar Heated Greenhouse
City of Albuquerque

Architect:
The Burns/Peters Group

Solar Consultant:
Bickle Division/CM, Inc.

A 3,000 SF greenhouse was a recent addition to the Arroyo del Oso Nursery of the City of Albuquerque. Many of the plants and shrubs that are located in parks and plazas throughout the City are grown by the City on this site, and the greenhouse was needed to work with seedlings, new transplants and other plants that need a warm growing enviornment.

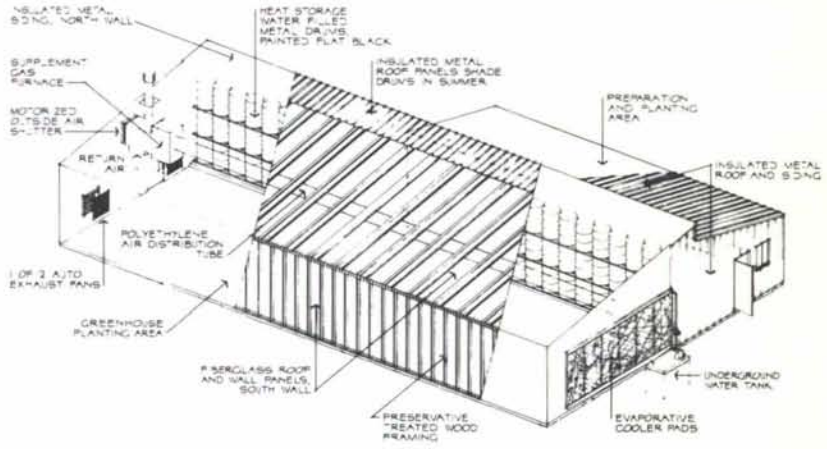
Because the traditional greenhouse is so energy wasteful, it was decided to develop an "energy conservative" greenhouse and heat it primarily with solar energy.

The entire translucent shell on the south side consists of an exterior fiberglass roof and wall panels and a layer of polyethylene film on the interior. This provides excellent lighting and solar gain, while greatly reducing heat loss over the conventional single layer of glass or plastic.

The heat storage system consists of water-filled metal drums, painted flat black, located along the north wall. These drums are shaded from the summer sun by insulated metal panels. Insulated metal roofs and sidings cover the north wall of the greenhouse building and entirely enclose the attached preparation and planting shed.

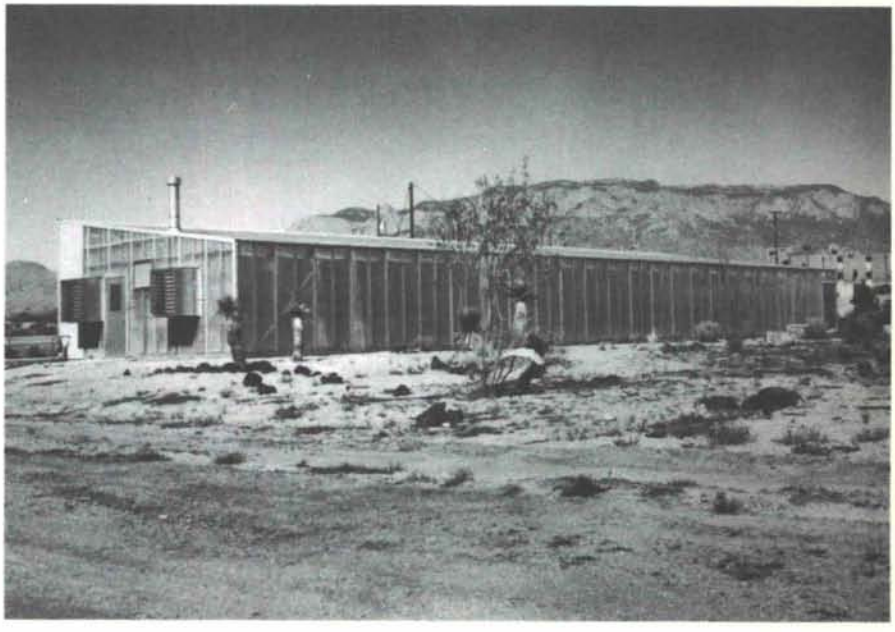
Auxiliary heating is provided by a gas-fired furnace and inexpensive flexible ductwork. Cooling is provided by evaporative cooling pads and two automatic exhaust fans. A manually operated shadecloth helps reduce heat gain in summer and sunburned plants.

The "energy conservation" greenhouse energy requirement is about 43% of that of a conventional greenhouse and much of this 43% will be supplied by solar heating. It is estimated that the payback on these features and the solar heating system is about 8½ years.



CITY OF ALBUQUERQUE
SOLAR HEATED GREENHOUSE

BURNS & PETERS
ARCHITECTS
& PLANNERS



A DESIGN AND SIZING PROCEDURE FOR PASSIVE SOLAR HEATED BUILDINGS

by Edward Mazria AIA

INTRODUCTION

Passive solar heating systems are integral to the architecture of a building, or, to put it another way, the building or some element of it *is* the system. Whereas conventional or active solar heating systems can be somewhat independent of the conceptual organization of the building, it is extremely difficult to add a passive system to a building once it has been designed.

All acts of building, no matter how large or small, are based on rules-of-thumb. Architects, contractors, mechanical engineers and owner-builders, design and build buildings based on the rules-of-thumb they have developed through the years of their own or other people's experience. For example, a rule-of-thumb to determine the depth of 2-inch floor joists is given as *1/2 the span of the joists (feet) in inches, plus two*, or to span a 20 foot space one would need roughly 2 x 12 inch joists. Calculations are used to verify and modify these rules-of-thumb after the building has been designed.

THE PROCESS

Passive systems demand a skillful and total integration of all the architectural elements within each space—glazing, walls, floor, roof and in some cases, even interior surface colors.

Two concepts are critical to understanding the thermal performance of a passively heated space. They are:

1. That the quantity of south glazing, insulating properties of the space, and outdoor climatic conditions will determine the average temperature in a space over the day, and that the size, distribution, material, and in some cases (Direct Gain systems) surface color of thermal mass in the space will determine the daily fluctuation above and below the average indoor temperature.

In the process of storing and releasing heat, thermal mass in a space will fluctuate in temperature, yet the object of the heating system is to maintain a relatively constant interior temperature. In a Direct Gain system, with masonry thermal mass, the major determinant of indoor air temperature fluctuations is both the amount of exposed surface area of masonry in the space and the distribution of sunlight over the masonry surface; in a Thermal Storage Wall system, it is the thickness of the material used to construct the wall; and in a Roof Pond system, it is the quantity of water in the pond.

DIRECT GAIN

Direct Gain systems are characterized by daily fluctuations of indoor temperatures which range from only 10°F to as much as 30°F. The heating system cannot be turned on or off since there is little control of natural heat flows in the space. To prevent overheating, shading devices are used to reduce solar heat gain, or excess heat is vented by opening windows or activating an exhaust fan.

Edward Mazia

The major glass areas (collector) of each space must be oriented to the south for maximum solar heat gain in winter. However, these windows can serve other functions as well, such as openings for light and views.

Each space must also contain enough thermal mass for the storage of solar heat gain. This implies a heavy masonry building, however, the masonry can be as thin as four inches. If an interior water wall is used for heat storage, then light weight (wood frame) can be used.

A. South Glazing:

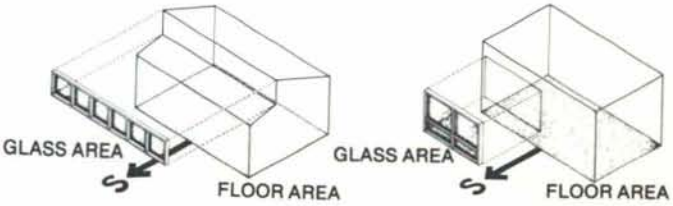
Our criterion for a well designed space is that it gain enough solar energy, on an average sunny day in winter, to maintain an average space temperature of 68°F ± over that 24 hour period. The following table lists ratios for various climates and locations that apply to a well-insulated residence:

TABLE 1

Average Winter (Clear-day) Outdoor Temperature[1]	36°NL	Glazing/Floor Area[2]
Cold Climates		
20°F	.24	(w/night insul.)
25°F	.22	(w/night insul.)
30°F	.19	
Temperate Climates		
35°F	.16	
40°F	.13	
45°F	.10	

Notes: [1]Temperatures listed are for December and January, usually the coldest months.

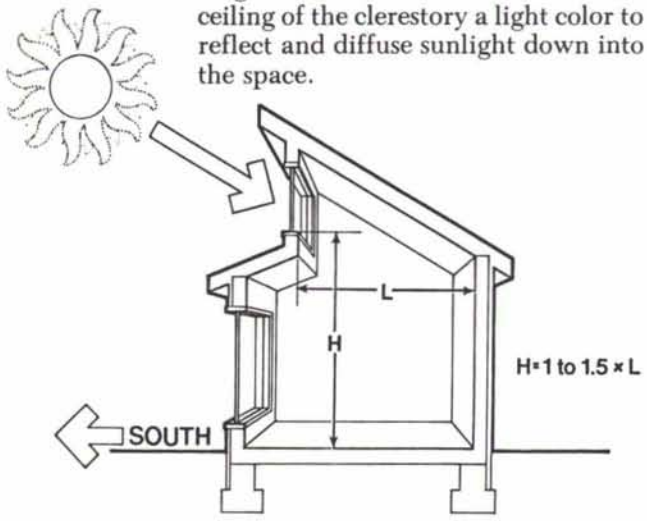
[2]These ratios apply to a well insulated space with a heat loss of 8 BTU/day/sq. ft. fl./°F. If space heat loss is more or less than this figure, adjust the ratios accordingly.



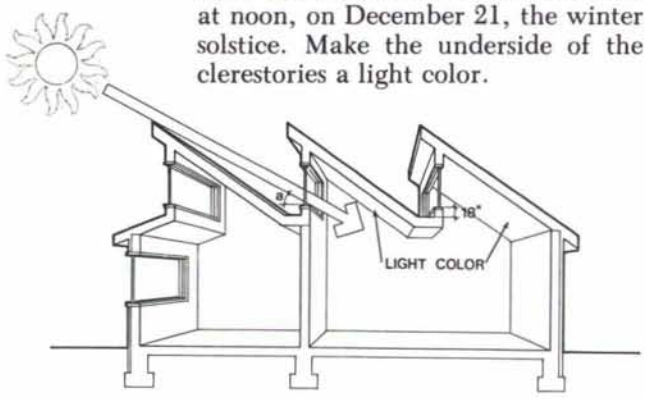
For example, in Denver, Colorado at 40°NL, with an average January temperature of 30°F, a well insulated space would need approximately 0.20 square feet of south-glazing for each one square foot of space floor area (i.e., a 200 square foot space needs 40 square feet of south-glazing).

In a Direct Gain System, sunlight can also be admitted into a space through clerestories and skylights, as well as through vertical south-facing windows. Use the following guidelines when designing clerestories and skylights:

Clerestory — locate the clerestory at a distance in front of an interior thermal storage wall of roughly 1 to 1.5 times the height of the thermal wall. Make the ceiling of the clerestory a light color to reflect and diffuse sunlight down into the space.



Sawtooth Clerestories — make the angle of each clerestory roof (as measured from horizontal) equal to, or less than the altitude of the sun at noon, on December 21, the winter solstice. Make the underside of the clerestories a light color.



Skylight — use a reflector with horizontal skylights to increase solar gain in winter and shade both horizontal and south-facing skylights in summer to prevent excessive solar gain.

B. Thermal Storage Mass:

The two most common materials used for storing heat are masonry and water. masonry materials transfer heat from their surface to interior at a slow rate. If direct sunlight is applied to the surface of a dark colored masonry material it will become uncomfortably hot, giving much of its heat to the air in the space rather than conducting it away from the surface for storage. This results in daytime overheating and large daily temperature fluctuations in the space. To reduce fluctuations, direct sunlight must be spread over a large surface area of masonry so that roughly 60% of the solar energy admitted into the space is stored as heat in ;the walls and/or floor and/or ceiling at sunset. To accomplish this:

Construct interior walls and floors of masonry at least 4 inches in thickness.

Diffuse direct sunlight over the surface area of the masonry by using either a translucent glazing material by placing a number of small windows so that they admit sunlight in patches, or by reflecting direct sunlight off a light colored interior surface first.

Use the following guidlines for selecting interior surface colors and finishes:

- masonry floors a dark color
- masonry walls any color
- lightweight construction (little thermal mass) a light color to reflect sunlight to masonry surfaces
- avoid direct sunlight on dark colored masonry surfaces for long periods of time
- do not use wall-to-wall carpeting over masonry floors

By following these recommendations, temperature fluctuations in the space on clear winter days will be approximately 10°F to 15°F.

For an interior water wall the volume of water in direct sunlight and the surface color of the container (Thin metal or plastic) will determine the temperature fluctuation in the space over the day (See Table 2). When using a water wall for heat storage:

Locate the wall so it receives direct sunlight between the hours of 10 a.m. and 2 p.m.

Make the surface of the container exposed to direct sunlight a dark color (at least 75% solar absorption.

Use roughly one cubic foot (7.48 gallons) of water for each one square foot of south glazing. Adjust the volume of water according to the temperature fluctuation desired in the space.

Note that when using an interior water wall there are few restrictions regarding other wall and floor materials and surface colors in the space. The water can be stored within an interior wall or in free standing containers, as long as the surface of the water wall is a thin material exposed to direct sunlight.

TABLE 2
DAILY SPACE AIR TEMPERATURE FLUCTUATIONS[1] FOR DIRECT GAIN WATER STORAGE WALL SYSTEMS[2]

Solar Absorption (Surface Color)	Volume[3] of Water Wall for Each One Square Foot South-Facing Glass			
	1 cu. ft.	1.5 cu. ft.	2 cu. ft.	3 cu. ft.
75% (Dark Color)	17°F	15°F	13°F	12°F
90% (Black)	15°F	12°F	10°F	9°F

Notes: [1]Temperature fluctuations are for a clear winter day with approximately 3 square feet of exposed wall area for each one square foot of glass. If less wall area is exposed to the space, temperature fluctuations will be slightly higher. If additional mass is located in the space (such as masonry walls and/or floor) then fluctuations will be less than those listed and therefore less water can be used.

[2]Assumes 75% of the sunlight entering the space strikes the mass wall.

[3]One cubic foot of water = 62.4 lbs. or 7.48 gallons.

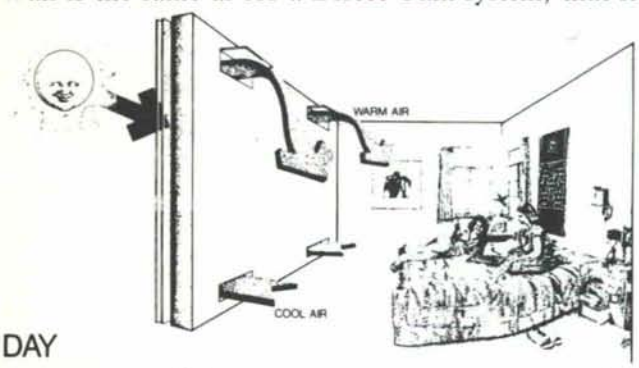
THERMAL STORAGE WALL

The predominant architectural expression is south facing glass. The glass functions as a collecting surface only, and admits no natural light into the space, unless desired.

Either water or masonry can be used for a thermal storage wall.

SOUTH-GLAZING

Our criterion for a double-glazed Thermal Storage Wall is the same as for a Direct Gain system, that it



DAY

transmit enough heat on an average sunny winter day to supply a space with all its heating needs for that day. To accomplish this use the following tables* as a guide for sizing the glazing of masonry or water wall:

*These tables apply to a well insulated space with a heat loss of 8 BTU/day/sq.ft. fl./°F. If space heat loss is more or less than this figure, adjust the ratios accordingly. The surface area of the wall is assumed to be the same size as the glazing.

TABLE 3

Average Winter (Clear-day) Outdoor Temperature	Masonry WALL/Space Floor Area[1] 36°NL
Cold Climates	
20°F	.71
25°F	.59
30°F	.50
Temperature Climates	
30°F	.40
40°F	.32
45°F	.25

Average Winter (Clear-day) Outdoor Temperature	Water Wall/Space Floor Area[1] 36°NL
Cold Climates	
20°F	.52
25°	.45
30°	.36
Temperate Climates	
35°	.28
40°	.23
45°	.17

Note: [1]For thermal walls with a horizontal specular reflector equal to the height of the wall in length, use 67% of the recommended rations. For thermal walls with night insulation (R-8), use 85% of the recommended rations. With both night insulation and reflectors, use 57% of the recommended rations.

For example, in Boston, Massachusetts, at 42°NL, with an average January temperature of 31.4°, a well insulated space will need approximately 0.41 square feet of double-glazed water wall for each one square foot of building floor area, (i.e., a 200 square foot space will need about 82 square feet of glazing).

WALL DETAILS

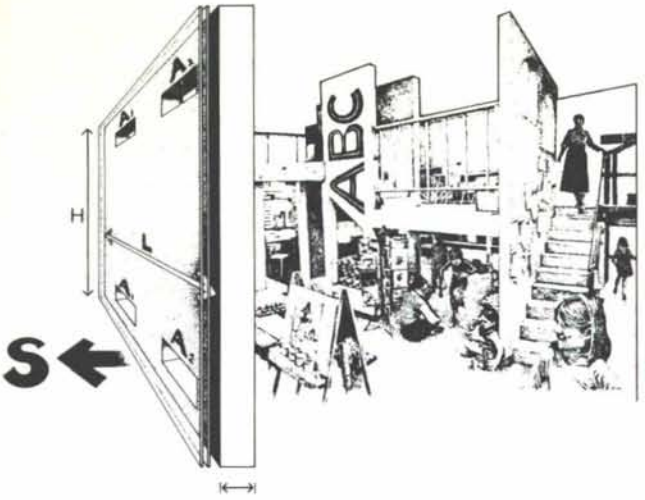
While the above procedure gives guidelines for the overall size (surface area) of a Thermal Storage Wall, the efficiency of the wall as a heating system depends mainly on its thickness, material and surface color.

Material	Recommended Thickness
Adobe	8 - 12 inches
Brick (common)	10 - 14 inches
Concrete (dense)	12 - 18 inches
Brick[1] (magnesium oxide additive)	16 - 24 inches
Water[2]	6 inches or more

Notes: [1]Magnesium oxide is commonly used as an additive to brick to darken its color. It also greatly increases the thermal conductivity of the material.

[2]When using water in tubes, cylinders, or other types of circular containers, use *at least* a 9½ inch diameter container or 1/2 cubic foot (31 lbs., 3.7 gallons) of water for each one square foot of glazing.

The choice of a wall thickness, within the range given for each material, will determine the air temperature fluctuation in the space over the day. Use the following table for selecting a wall thickness:



APPROXIMATE SPACE TEMPERATURE FLUCTUATIONS[1] AS A FUNCTION OF THERMAL STORAGE WALL MATERIAL AND THICKNESS

	Wall Thickness in Inches					
Material	4	8	12	16	20	24
Adobe	-	18	7	7	8	-
Brick (common)	-	24	11	7	-	-
Concrete (dense)	-	28	16	10	6	5
Water	31°F	18	13	11	10	9

Note: [1]Assumes a double-glazed thermal wall. If additional mass is located in the space, such as masonry walls and/or floors, then temperature fluctuations will be less than those listed. Values are given for clear winter days.

The greater the absorption of solar energy at the exterior face of a thermal wall, the greater the quantity of incident energy transferred through the wall into the building. Therefore:

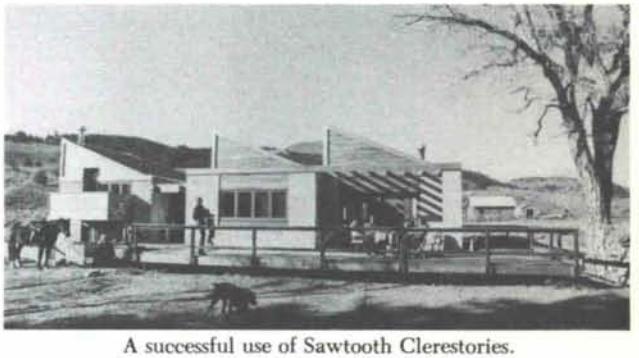
> Make the outside face of the wall a dark color (perferably black) with a solar absorption of at least 85%.

In cold climates, the addition of thermocirculation vents in a masonry wall will significantly increase the performance of the wall. In mild climates the vents are unnecessary since winter daytime temperatures are comfortable and heating is usually not needed at that time. To size the vents:

> Make the total area of each row of vents equal to approximately one square foot for each 100 square feet of wall surface area.
>
> Prevent reverse air flow at night by placing an operable damper over the inside face of the upper row of vents.

CONCLUSION

Since a building, or some element of it, *is* the passive system, the use of passive solar energy must be included in every step of a building's design. The format outlined here provides a method for including technical information in a way that can be applied by architects, builders and owner-builders. *E.M.*



A successful use of Sawtooth Clerestories.

Edward Mazria, AIA, is an architect and solar consultant with the firm of Edward Mazria and Associates, Inc., Albuquerque, NM. Information for this article was excerpted and condensed by the author from his book, ***THE PASSIVE SOLAR ENERGY BOOK****, published by Rodale Press, Emmaus, Pa. Some of the work was performed for the Department of Energy under a contract from Lawrence Berkeley Laboratories, Berkeley, Calif. This article was published in the May 1979 issue of SOLAR AGE MAGAZINE.*

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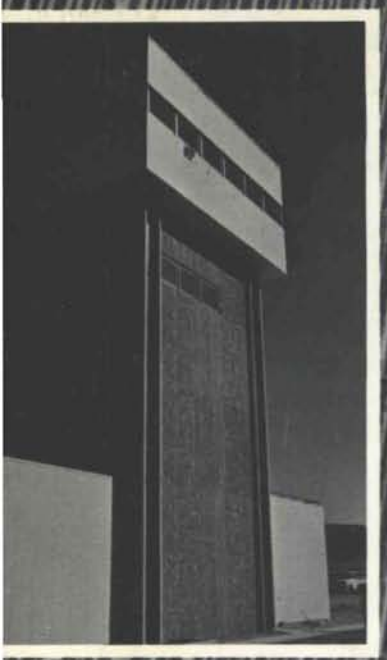

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