ANALYSIS OF HISTORIC AND CONTEMPORARY PASSIVE SOLAR DESIGN ELEMENTS

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ANALYSIS OF HISTORIC AND CONTEMPORARY

PASSIVE SOLAR DESIGN ELEMENTS

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CHAPTER I

THE RESEARCH PROBLEM

Introduction

Man has sought shelter from the elements since the beginning of time. This shelter took many forms. The architecture of a particular region was based upon the materials and tools available, the site, climate and orientation to the sun. Homes were designed climatically--to take advantage of nature and in particular the sun to provide comfort. For this reason, design varied from one climate to the next. This regionalism was a factor in all architecture until the mid 20th century, when technology developed mechanical systems that harnessed fossil fuels in such a way as to provide artificial heating and cooling of the interior environment. This coupled with the development of new tools and materials changed the nature of architecture. It was no longer necessary to consider the environment of a region when designing a building. Nor was it necessary to consider the buildings orientation to the sun. The interior environment could be controlled mechanically. Fuel for these mechanical systems was inexpensive and generally assumed to be available in an endless supply. This assumption proved to be in error.

Today we are faced with some undeniable facts. Our buildings alone consume about twice the electricity that was used twenty-five years ago for all purposes. Our fossil fuel supplies, far from being endless, are dwindling rapidly. Technology has yet to discover any new, safe replacement for the natural resources being used at such an astonishing rate.

Significance of Problem

Most residential buildings are overheated in winter, overcooled in summer, and underinsulated. They are, in fact, inordinately wasteful of fuel (Skurka, 1976). Faced with the fact that energy sources currently utilized to maintain comfort are limited, it would be irresponsible, if not suicidal to continue building homes such as those described above. Except for the energy that is supplied daily by the sun, the earth has only the energy resources that are already there (DiLavore, 1984). These energy resources are irreplaceable. Once used, they are gone forever. It is important, therefore, to find ways to conserve these resources or to seek other resources.

Though current housing wastes energy, it is possible to build houses that utilize the energy of the sun to maintain comfort. Until this century, virtually all shelter man built for himself was designed to utilize the natural energy sources of the sun and the wind to maintain comfort (Wright, 1978). It would be unacceptable to revert back to primitive building techniques, and it would also be unacceptable to continue building dwellings that are gluttenous consumers of valuable energy.

It is important, then, to synthesis all that technology has to offer with all that history has to offer, and to arrive at a responsible solution to housing energy comsumption.

Purpose of Study

It is the purpose of this study to illustrate the similarities and differences between passive solar design elements of primitive and vernacular architecture and contemporary passive solar architecture. Because primitive and vernacular architecture differs widely from region to region, it is necessary within the framework of this study to choose one region for analysis. The region chosen for this study will be Oklahoma, as defined by current state boundaries.

Specific objectives for this study include:

1. To analyze passive solar design elements of five primitive and vernacular dwellings constructed in Oklahoma between 1874 and 1916.
2. To analyze passive solar design elements of four contemporary passive solar dwellings constructed in Oklahoma between 1984 and 1985.
3. To compare passive solar design elements of selected primitive and vernacular dwellings to passive solar design elements of selected contemporary passive solar dwellings in Oklahoma.
4. To analyze the role of interior design in selected contemporary passive solar dwellings in Oklahoma.

Assumptions

1. The material collected from primary and secondary sources is representative of Oklahoma's primitive and vernacular dwellings and it's orientation to the environment.
2. Specific buildings chosen are representative of typical primitive and vernacular dwellings in Oklahoma.
3. Photographs and plans are appropriate media for analysis.

Limitations

Literature regarding primitive and vernacular dwellings in Oklahoma was limited to that found in the Oklahoma State University Library, the Oklahoma State University Architectural Library, the University of Oklahoma Library, the Western History Collection at the University of Oklahoma, Norman, Oklahoma, the Oklahoma Historical Society Library and Archives Division, and the Library of the American Institute of Architects, Oklahoma City, Oklahoma. Photographs of existing structures were limited due to accessability of private dwellings.

Definitions

In order to have a clear understanding of this study, the following definitions are relevant.

PRIMITIVE OR VERNACULAR DWELLINGS

Structures referred to as primitive or vernacular dwellings will refer to those dwellings built prior to 1930 that developed identifiable regional or local characteristics.

PASSIVE SOLAR DWELLINGS

Passive solar dwelling refers to any dwelling that is designed to take advantage of the favorable contributions of the sun to the comfort of the building and to restrict the impact of the sun when it is undesirable from a comfort point of view. is a solar building. (Stein, 1977)

DEGREE DAY

A commonly used measure of how much heat will be needed in a given locale.

RADIATION

Transmission of heat through space by wave motion.

COMFORT ZONE

The ASHRAE 55-74 comfort zone extends from 72° F to 78° F on the most recently developed effective temperature scale.

THERMAL COMFORT

For building and engineering purposes, human thermal comfort is defined as the state of mind which expresses satisfaction with the thermal environment.

CONDUCTION

Heat transferred through a substance in such a way that there is no gross displacement of the particles of the substance.

CONVECTION

The transfer of heat by the motion of air molecules.

CHAPTER II

REVIEW OF LITERATAURE

Introduction

In the early twentieth century technology developed ways to harness fossil fuels in such a way as to provide an artificially manipulated interior environment. When the technology was new, only the very wealthy could afford this luxury. It was several years later that the mechanical systems and the energy to run them became available and affordable to the general population. This energy revolution brought with it many changes in the way people live. One of the most striking changes can be seen in the architecture of the 1900's.

Prior to 1930, the main consideration in the design and construction of buildings was the climate and topography of the region in which the building was located. The building was oriented and built in such a way as to provide protection from the elements and to utilize climatic factors such as sun, shade and wind to provide comfort. With the ability to 'create' an artificial environment within the building, these environmental aspects ceased to be a consideration. Environmental factors have been neglected in most architecture since the early part of the 20th century.

Residential design ignores all aspects of orientation and topography that could work with the environment to heat and cool the structure (Skurka, 1976). Buildings and designers were 'freed' from environmental constraints. Most buildings constructed after 1930 are totally dependant upon mechanical systems powered by fossil fuels to maintain comfortable interior temperatures. Consequently, the built environment consumes a great deal of fossil fuel energy.

Energy: Consumption and Crisis

The United States is one of the most technologically advanced nations in the world. It is also one of the largest energy consumers. Presently, the United States consumes 35% of the world's energy while comprising only 6% of its population (Davis and Schubert, 1974). The demand for energy in less developed countries is increasing even more rapidly than in the United States (McKetta, 1972). This is not surprising considering that these countries started with a lower energy base. They have had to accelerate their energy use in an effort to catch up with other more technologically advanced nations. Clearly, however, the demand for energy is outrunning the supply. The fossil fuel resources on this planet are finite. Except for the energy supplied by the sun, the only resources of energy the earth has are those that are already here (DiLavore, 1984).

According to Davis and Schubert (1974), energy is vital to a nation's growth even in the face of fierce competition. For years the United States was not overly concerned about competing for energy supplies. It was meeting its own demand and even exporting some energy. Today, however, the U. S. is no longer self sufficient. In 1970 the American oil industry peaked and began to decline. Demand, however, continued to surge. The United States met this demand by importing oil from the middle east (Stobaugh and Yergin, 1979). DiLavore (1984), reports that oil consumption has tripled in the United States in the last 30 years and that the U. S. now imports one half of the oil it uses. In a matter of years the United States went from self sufficiency to dependency and vulnerability.

America is clearly in the midst of an energy problem. There is a growing demand for energy resources that are dwindling in supply. The energy problem is not just immediate but long term as well. It involves providing energy for the near future and ensuring that future generations have a sufficient source of energy to meet their needs as well. Simply finding new energy sources and using it as quickly as it is found will not solve the long term energy problem (DiLavore, 1984).

Energy Conservation

For many years, the American public was unaware, or unconcerned about its rate of energy consumption. The general assumption was that energy was cheap and available in seemingly endless supplies. In 1973, the Arab oil embargo changed this perception drastically. Though political in nature, and not due at that time to demand outstripping supply, the embargo foreshadowed a fuel shortage that was not far off and that was not being taken seriously by the American public (Curran, 1976).

In the years that followed the embargo, the price of energy rose, bringing the impact of the energy shortage home to the consumer. By 1978, the cost of fuel oil used in heating homes had almost tripled, while natural gas and electricity had doubled from their 1967 levels (Lindamood and Hanna, 1979). With the cost of energy affecting every American household, the economic impact of the energy situation on the United States became increasingly apparent.

The United States began considering solutions to the energy problem in earnest. One alternative being explored was the potential use of nuclear energy to produce electricity. Though a powerful source of energy, nuclear power met with opposition from individuals and groups who believed that nuclear power plants were unsafe, uneconomical or both. Critics claimed that the industry had failed to develop safe and acceptable methods to dispose of radioactive waste materials (Stobaugh and Yergin, 1979). Opposition to nuclear power slowed the projected development of this energy source. As a result, the United States began exploring ways to reduce the rate of energy consumption while continuing to explore other energy options.

According to Stobaugh and Yergin (1979), one inexpensive, productive and safe approach to slowing the rate of consumption is through conservation. The law of conservation states that in an isolated system, the total energy used remains the same. The 'idea' of energy conservation, however, is one of efficiency or of using as little energy as possible for needed tasks (DiLavore, 1984).

For the last 50 years the United States has not used energy efficiently. Davis and Schubert (1974), concluded with the following: Architects are responsible for over one third of all energy consumed by the United States, and 50% of that energy is being used inefficiently. The residential sector alone accounts for 20% of direct energy used in the United States. Because of the large amount of energy involved, and the inefficient way in which it is used, there is a large potential for conservation in this area (Burby and Marsden, 1980).

A Study by Newman and Day (1975), found that the basic level of household energy used for heating is determined by the structure of the dwelling itself. In order to insure that a structure does not use more energy than necessary, it must be designed and constructed in such a way as to need as little energy as possible to maintain a comfortable interior environment. Conklin (1982), reports that efficient heating involves preventing heat that is introduced into the structure from escaping outdoors while at the same time minimizing the infiltration of cold air into the structure.

Some conservation measures that will help achieve this minimal loss of heat or infiltration of cold air are as follows: caulking, weatherstripping around windows and at construction joints and careful insulation of the building envelope, airlock vestibules around entryways, double or triple glazed windows, minimizing windows on the north elevations and placement of unheated spaces as buffers against infiltration on the north side of the house (U. S. Department of Housing and Urban Development, 1982). While many of these conservation practices can be introduced into existing homes, others are a function of the initial building design and will only be viable in future construction. For purposes of conservation, future construction should also consider orientation of the structure to the environment, design, engineering and environmental integration as basic elements in its conception (Conklin, 1982).

A further component of conservation that is gaining attention in the United States is the use of passive solar systems to heat and cool the home. As homes become better insulated and more energy conserving in other ways, less energy is needed to maintain a comfortable interior environment. The less energy a building requires, the greater the significance of the solar energy input into that building (Curran, 1976). Stoubaugh and Yergin (1979) also found that for solar design to be effective, these underlying fundamentals are necessary: improved insulation, weatherstripping and other similar conservation pracatices to minimize the heating needs of the building. Consequently, the solar heating required is less than if these conservation elements had been ignored.

The use of passive solar techniques combined with other energy conservation practices will reduce the energy required to maintain a comfortable interior environment. One of the most effective ways to conserve energy is to isolate the interior of the building from the negative aspects of the environment through insulation and open up the same interior to the positive aspects of the climate through passive solar techniques (U. S. Department of Housing and Urban Development, 1982).

By building in response to the outside environment instead of in spite of it, the need for mechanical systems and fossil fuel energy sources is reduced. Davis and Schubert (1974), report that design which considers such factors as orientation, climate, site, a building's configuration to the site, and the use of passive energy sources such as the sun and wind could result in the conservation of as much as 50% of the energy consumed under current building standards. The basic concept of passive solar design is to synthesize the built environmment with nature. Well sited homes are sheltered from the north winds and open to summer breezes flowing from the south. In winter, solar heat is collected through large south facing glazed areas and is stored in massive walls, floors, or water filled containers. Heat is distributed by natural convection flowing from warm to cool areas. In the summer, the design minimizes the flow of sunlight and heat into the house by various shading techniques and promotes natural ventilation of living space (U. S. Department of Housing and Urban Development, 1982).

The use of conservation techniques including passive solar elements would greatly reduce dependance on mechanical systems and fossil fuel energy sources. There are, however, other benefits of using passive solar elements. Watson and Lab (1983), point out some of these benefits in the following:

> "Rather than imposing "brute force" tasks upon a mechanical system, the buiding itself can do the work, quietly, without fans or other machines and without adding to the peak demands of control power systems. And because we build buildings not only to survive the rigors of climate, but to grace our lives, and to give the places we live an expression of beauty, it is by means of climatic design techniques that a building responds to the natural environment, whether through a window, a skylight, a greenhouse, a covered porch or a protected courtyard. These establish the settings, the places of balance between ourselves and the outside world" (p.4).

Building homes to conserve energy by utilizing passive solar input offers several advantages. The most important of these is the potential to conserve 30% to 40% of the energy now being used without penalty to current lifestyles. In order to realize this savings, however, a substantial majority of U. S. households would have to adopt this type of housing (Shama, 1982). The initial cost of a home with these systems is not significantly higher than the cost of a conventional home and the potential for energy conservation is far greater. Yet, despite the low cost of the system and the potential for energy savings, utilization of passive solar buildings techniques has been limited (Weber and McCray, 1981).

Perceptions of Passive Solar Housing

Basic research suggests that one reason consumers are hesitant to adopt passive solar housing is that they perceive it to be an innovation. According to McCray and Weber (1981), consumers generally go through a multi-stage process prior to adopting an innovation. The process usually consists of the following stages: awareness or initial knowledge, interest, evaluation, trial, and finally adoption. This process necessarily takes time, and needs to be initiated on a large scale to be effective. Shama (1982), suggests that it is the government's failure to initiate this adoption of innovation framework that has led to such a low level of adoption of passive solar housing. A public education campaign would almost certainly be a positive step toward increasing the rate of adoption of passive solar housing. According to Weber and McCray (1984), some of the most predominant perceptions of passive solar housing are that they are more complex and expensive to build than conventional homes and that consumers are not knowledgeable enough about the systems to recognize the positive aspects of passive solar homes when considering purchasing such a housing system.

Educating the consumer about passive solar design would change many of these perceptions. A thorough education program including a historical perspective of passive solar design could even change the basic perception that it is an innovative type of housing, and as such, expediate or even circumvent several stages of the adoption of innovation process.

History of Passive Solar Housing

There is a large body of literature that supports the theory that passive solar design, far from being innovative, is simply a return to the common sense building techniques practiced by man since the beginning of time. According to Stoubaugh and Yergin (1979), passive solar design is not a new technology at all, but returns to the fundamentals of design used by all previous human cultures, the incorporation of the sun itself into the design of architecture. Skurka (1976), also reports that the natural energy sources, the sun and the wind have been used by mankind in the design of his dwellings since antiquity.

Contemporary passive solar systems have no mechanical parts. They, too, use the sun and the wind to heat and cool the structure. According to Stein (1977), primitive passive solar design and contemporary passive solar design are virtually the same thing. Primitive and vernacular architecture was designed to take advantage of the favorable contributions of the sun for comfort within the building and to restrict the impact of the sun when it was unfavorable to comfort. These buildings were also designed to store heat from the hot part of the day and to release it to the space or to the outdoors during the cooler hours. This is the basis for passive solar systems, past and present.

Passive solar buildings are not complex. They are simply homes built to utilize the natural energy flows of the environment as opposed to mechanically creating artificial environments using fossil fuel energy. Watson and Lab (1983), define passive solar design as simply building techniques that serve to reduce heating and cooling costs by using natural energy flows to maintain comfortable interior environments. Far from being innovative or complex, this is simply a return to the common sense techniques used by cultures in the past. These techniques enabled man to survive and be comfortable long before he had the mechanical systems and technology to manipulate the interior environment.

Though technology has developed materials and techniques to enhance passive solar design elements, the basis for these elements remain the same. Skurka (1976), details passive solar design elements found in early houses on the great plains. These houses typically had windows on the south facing exposure, while the walls to the north where winter winds prevailed were mostly unbroken. The dwellings were built of fieldstone, masonry, adobe, or wood framing stuffed with a mud and straw mixture which served to insulate the structure. The thermal mass of the walls stored heat during the day and released it at night when it became cooler. Shutters, deep window recesses, the roof overhang, awnings and other devices helped to shade the house and keep it cool in the summer. Although some of the construction materials have changed, the basic principles described by Skurka as found in historical dwellings could as easily be a description of passive solar dwellings of today.

Several accounts of typical houses found on the Great Plains attest to the comfort provided by these passive solar building techniques. According to Merideth (1984), half-dugouts and sod houses were cooler in summer and warmer in winter than conventional frame houses. The use of earth as a building material offered mass to store heat and insulate against heat loss in winter as well as protecting the dwellings from cold northern winds. Goins (1980), supported this theory. He reports that sod shantys, adobe houses and dugouts were naturally insulated against the heat and cold. Log cabins were also typically designed to utilize passive solar energy. They usually faced south and had shed additions on the north to protect against winter winds (Oklahoma Historical Society, 1984). In addition, trees were planted soon after the house was built to provide shade in summer and serve as windbreaks in the winter (Goins, 1980). Though technology has given us a wider variety of materials from which to choose, historical building techniques have much to offer todays energy concious world.

Climatic Elements

The climate of a particular region is the basis for passive solar design within that region. The United States Department of Housing and Urban Development (1978) describes Oklahoma's weather as it relates to passive solar design. Though located in the southwestern United States, Oklahoma's climate can be cold enough in winter that the discomforts of winter outweigh those of summer. Summer heat is, however, still a design problem. Despite its helpfulness in winter, the sun can cause overheating in summer, spring and fall. The sun should be allowed in during the winter months and kept out during summer months.

As summer humidity in Oklahoma can be uncomfortably high, it is fortunate that there is a good deal of wind as well, because humidity generally drops significantly in the afternoon. Natural, evaporative cooling can replace mechanical air conditioners during those hours. In spring and fall, temperature swings are significant. Temperatures soar on sunny days but fall into the 40's and 50's at night. This allows for time-lag heating and cooling. Daytime heat is stored within the dwelling and released to the space as darkness arrives and temperatures fall. The nighttime coolness is stored within the dwelling and released into the space as daytime temperatures rise.

In the winter season, Oklahoma has a good deal of solar radiation available for use. The percentage and intensity of sunlight in winter is significant enough to allow climatically responsive passive solar buildings to take advantage of the sun's heat for warmth (U. S. Department of Housing and Urban Development, 1978).

Summary

This chapter outlined some of the basic issues upon which this research was formed. An overview of the existing energy problem in the United States was presented, indicating the increasing importance of energy conservation. The chapter also outlined possible conservation techniques, the historical basis from which these techniques stem and the importance of that historical basis. This research is designed to analyze and compare current conservation techniques with their historical basis, and to illustrate the simplicity of these energy conserving techniques.

CHAPTER III

METHODOLOGY

Introduction

The previous chapter discussed the current energy situation in the United States and gave a brief overview of several conservation measures being considered. Chapter III presents the research methods and procedures of this study. Included are methods of data collection and analysis.

Type of Research

Historical research involves critical analysis of data that already exists. The data is not created or controlled as in experimental research. The research of history can only show from the existing evidence that it is likely or probable that something happened in the way the researcher says that it happened (Skjelver, 1971). This study deals with design and construction elements of pre-1930 houses in Oklahoma, as well as design and construction elements of contemporary passive solar houses in Oklahoma. The data exists in the form of photographs and literature relating to those structures and is not manipulated in any way. This research, therefore, is historical in nature.

There are three steps involved in the methodology of historical research. The first step involves the search for data, or sources of information with which to work. The second step involves a critical evaluation of that data to determine its authenticity and to extract evidence that is credible to the research. The third step is the process of assembling the data into an exposition revealing its significance (Benjamin, 1983).

Data Collection

Data collection for this study began with a period of orientation reading to determine the scope of the research in this area and to define the types of dwellings that were typical in Oklahoma in the late 19th and early 20th centuries. The type of dwellings defined as typical included dug-outs, soddies, log cabins, plains cottages and plantation or ante bellum homes.

Photographs of these types of dwellings were obtained from collections housed in the Okahoma Historical Society Archives and the Western History Collection at the University of Oklahoma, Norman. These collections are considered the largest and most thorough collection of authentic photographs from Oklahoma's history. All photographs relating to housing in Oklahoma and contained in these collections were reviewed, and one example of each typical dwelling was chosen for use in this study. Photographs were chosen for the study based on the amount of information they portrayed regarding structure and orientation to the environment. Any written data contained in the collection regarding the houses was noted at the time of selection. Prints of each photograph were purchased and permission to use them in the study was obtained from the currator of the collection.

Photographs of contemporary passive solar dwellings were taken on site by the researcher. Plans of these homes were obtained from the owners as was permission to use the photographs and plans within the content of the study. An interview with the owner and or builder of each dwelling was conducted to determine environmental orientation and construction techniques involved in the passive solar and energy conservation systems of the dwelling that the researcher was unable to determine from the photographs. Photographs and data regarding historical dwellings as well as photographs, plans and data regarding contemporary dwellings were used in analysis of the specific objectives of the study.

Data Analysis

Historical and contemporary photographs and plans were analyzed according to the definition of passive solar systems provided by the United States Department of Housing and Urban Development in cooperation with the United States Department of Energy (1982). This definition states that an effective passive system includes and can be recognized by five clearly defined elements. These are: collector, absorber, storage, distribution and control. The explanations below provided the basis for analysis of these elements within the content of this research.

Collector: Refers to the glazed areas of a structure through which solar radiation enters the dwelling. The primary areas of collection should face within 30 degrees of true south. These collectors should not be shaded during the heating season between 9:00 a.m. and 3:00 p.m., the peak hours of solar radiation.

Absorber: In most passive systems, refers to the hard darkened surface of storage elements. This surface, which is usually a masonry wall or floor, or a water container, must receive direct solar radiation. As sunlight strikes the absorber it degrades to heat, which is absorbed by the surface.

Storage: Storage refers to the materials used in the construction of the dwelling that are intended to hold the heat produced by sunlight. This material is referred to as thermal mass and is usually masonry or water. Though absorbers and storage elements are often the same wall or floor, the absorber is the surface of the material while the storage element is the mass or material below the surface.

Distribution: Distribution refers to the method by which the collected heat is circulated from the point of storage to the different areas of the dwelling. Passive systems use the three natural modes of heat transfer; conduction, convection, and radiation. The air in the structure becomes cooler at night when there is no solar radiation and is warmed by the conduction and convection of heat from the storage materials as it naturally moves from warmer to cooler areas.

Control: Control is essential to a passive system and refers to the elements of the dwelling that prevent over or under heating and heat loss. Control devices include: operable windows on different sides of the house to promote ventilation, roof overhangs, shutters, blinds, awnings, or vegetation that prevent radiation from entering the dwelling during the summer months, and moveable insulation which can be placed inside the collector at night to prevent heat loss in winter or to prevent solar radiation from entering the dwelling during the daylight hours in summer. To be effective in most climates, a passive solar system should contain some combination of all five elements of a passive solar system as described above (United States Department of Housing and Urban Development, 1982).

Also included in the analysis of this data were conservation techniques that serve to enhance the effectiveness of a passive solar system. These include: the shape of the structure and its orientation to the environment, the topography and vegetation surrounding the structure, the insulation of the building envelope and the layout of interior spaces. The explanations below provided the basis for analysis of these elements within the content of this research.

The shape of a building is important in a passive solar system because it affects the rate of heat loss and solar gain. The most effective shape for a passive solar dwelling is compact, as this provides a low exterior surface to interior volume ratio. The orientation of the building should promote solar gain. A dwelling with a long east/west axis allows a large south facing collection area that will access most of the living spaces in the building.

The topography of a site and its vegetation can reduce heat loss from the building in the winter and help to shade the building from solar radiation in the summer. Building on the south facing slope of a hill or berming the earth on the north, east and west sides of the structure serve to insulate the building from heat loss during the winter months, and to shade or keep the structure cooler in the summer months. In addition to earth berming, evergreen trees on the north of the building serve to redirect cold north winds away from the building in winter. Low growing shrubs on the east and west sides of the building serve to shade them from the heat of morning and afternoon sun in summer months. Deciduous trees on the south are also desireable. They help to shade the collection area in the summer months without hindering collection in the winter season. While some of these elements may be present on a chosen site initially, others can be added to enhance the effectiveness of the passive solar system as well as add beauty and interest to the site.

Conservation techniques involved in the insulation of the building envelope are essential in a passive solar system. Some methods used to achieve this include: weatherstripping and caulking around windows and doors and caulking of the construction joints to reduce heat loss; the use of double glazed windows and the reduction of windows on the north, east and west walls to reduce heat loss; the use of adequate and properly installed insulation around the walls, ceilings and floors of the building to prevent heat loss through construction materials; the use of vapor barriers to reduce infiltration and to keep moisture away from insulation; and the use of an "air-lock" vestibule that is unheated to reduce heat loss when opening doorways.

The layout of interior spaces can also enhance the energy converving potential of a structure. Living spaces should be organized in such a way as to take direct advantage of solar heat gain and natural circulation patterns. Low use and unheated areas such as storage, pantries, closets, vestibules, utility rooms and garages should be located along the north wall to serve as a buffer to the living spaces. This will decrease the load on the passive solar heating system

The more conservation measures a building employs the more effective the passive solar system is. Therefore, the data targeted for this research was analyzed to determine which passive solar and energy conserving elements were contained in each structure.

CHAPTER IV

FINDINGS AND DISCUSSION

Introduction

This chapter examines the data analysis for this study. The study analyzes individual photographs of primitive and contemporary dwellings for passive solar elements of collection, absorption, storage, distribution, control and conservation. The study also compares elements found in primitive dwellings to elements found in contemporary dwellings and analyzes the role that interior design plays in these elements.

Analysis

Analysis is based on the procedures outlined in Chapter Three. Each objective along with its analysis follow.

Objective One: To analyze passive solar design elements of primitive and vernacular dwellings in Oklahoma. Five photographs of primitive dwellings are analyzed under this objective. Each photograph is analyzed individually for the existence of the passive solar elements of collection, absorption, storage, distribution, control and conservation.

The first photograph of a primitive dwelling this study analyzes is that of a Sod home, located southeast of Alva, Oklahoma and constructed sometime before 1894. (Fig. 1.)

The passive solar elements this home contains are outlined in Table 1. The solid sod walls and south facing windows of this home serve to collect heat from the sunlight that strikes its face or enters the dwelling directly through the windows. The surface of the sod walls, roof and floors absorb the sunlight that degrades to heat when striking their surface. The mass of these same walls, roof and floors store the heat absorbed by their surface. Heat is distributed to the interior spaces by the three natural modes of heat transfer, radiation, conduction and convection. The space is heated directly by radiation when the sun enters the dwelling directly. When radiation is not directly available or is insufficient, the space is heated by natural conductive and convective flows of the heat stored in the massive materials. The roof overhang serves to control heat gain into the dwelling. The overhang shades the south face of the dwelling in the summer months when the angle of the sun is high. The overhang allows maximum infiltration of the sun onto the south face of the house and into the dwelling through the windows in the winter months when the angle of the sun is lower in the sky. The inherent insulating properties of the thick sod walls conserve energy within the house by reducing heat loss in winter and heat gain in summer.

South Elevation

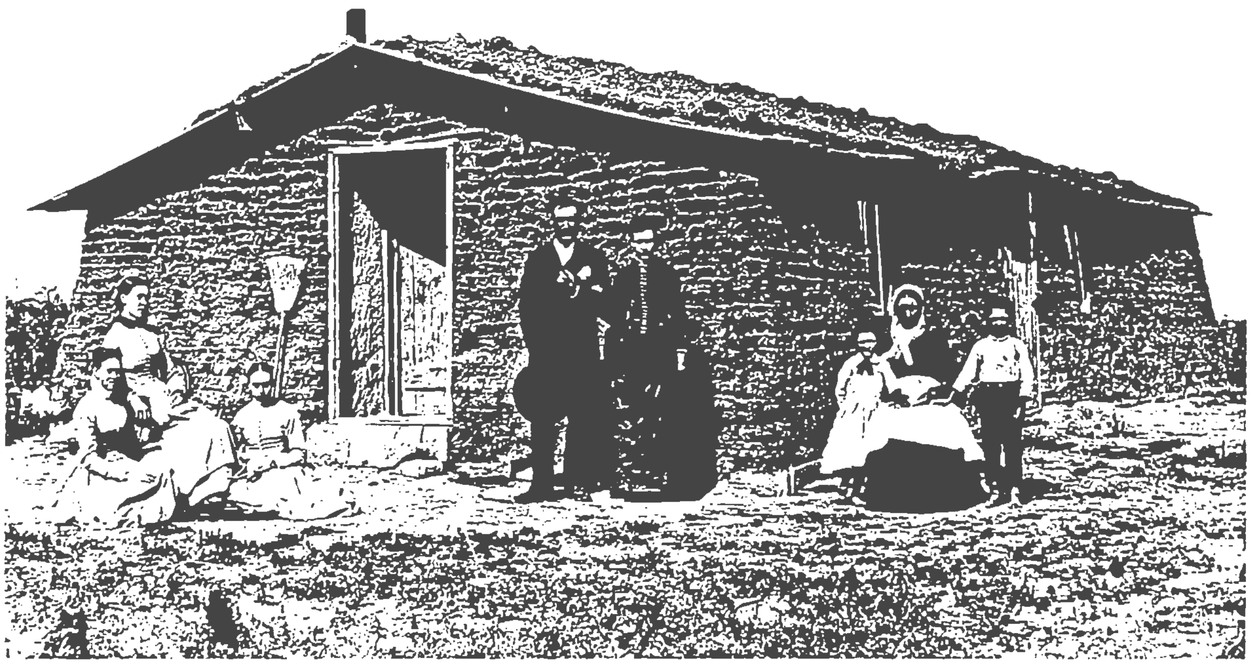

Figure 1. Sod Home

TABLE I

PASSIVE SOLAR COMPONENTS OF A SOD HOME

Passive Solar Design Element	Construction Application
Collection	Solid Sod Walls South Facing Windows
Absorption	Sod Walls Sod Floor Sod Roof
Storage	Sod Walls Sod Floor Sod Roof
Distribution	Radiation Conduction Convection
Control	Roof Overhang
Conservation	Solid Sod Walls

The second photograph of a primitive dwelling this study analyzes is that of a half dugout, frame and sod home, belonging to the Matt Dizney family and located in Shawnee, Oklahoma (Fig. 2). The dwelling was constructed before 1900.

Table II outlines the passive solar elements this home contains. The sod walls and south facing windows of this home serve to collect heat from the sunlight that strikes their face or enters the home directly through the glass. The surface of the sod walls, roof and floor of the dwelling absorb the heat that degrades from the sunlight that strikes their surface directly. The mass of the sod stores the heat absorbed by its surface. Heat is

South Elevation

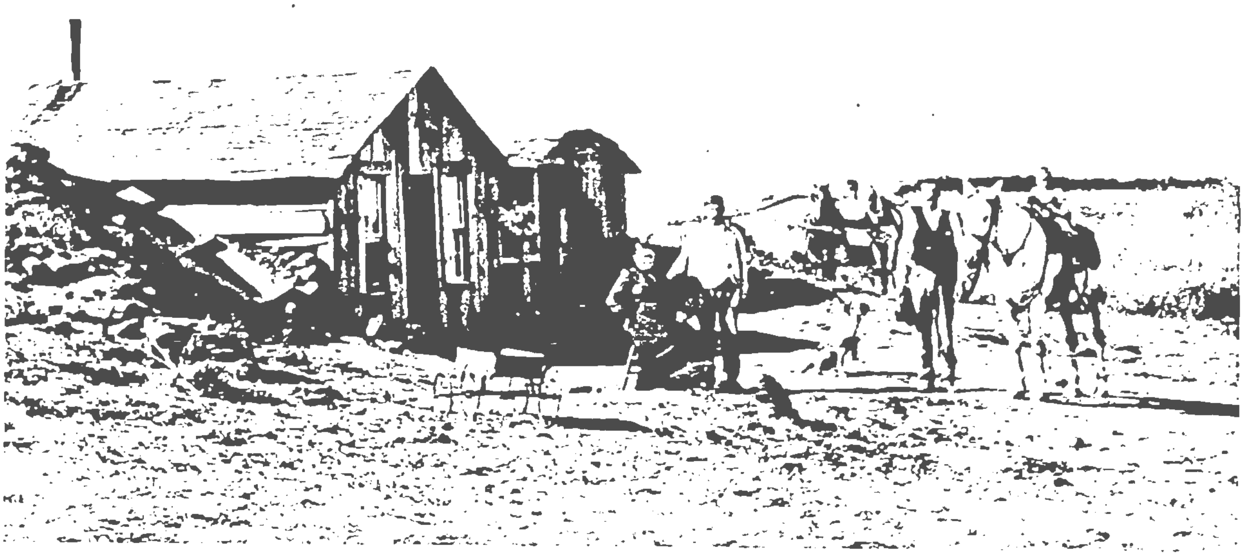

Figure 2. Dugout

distrubuted to the interior spaces by radiation, conduction and convection. The white, reflective window coverings control heat gain by reflecting sunlight back outside the dwelling in summer months when heat is undesireable to the comfort of the interior. The energy conserving elements that enhance the passive solar system of this dwelling are the sod berm on the west of the house and the sod room addition to the east. The inherent insulating properties of the sod help reduce infiltration of cold air and heat loss in winter, while reducing heat gain in summer. The location of the stove pipe in the photograph indicates that the kitchen/cooking area of the house is located on the north side and serves as a buffer between the north wall and the living spaces on the south. This reduces the amount of heat needed to maintain a comfortable temperature in the living spaces.

TABLE II

PASSIVE SOLAR COMPONENTS OF A DUGOUT

Passive Solar Design Element	Construction Application
Collection	South Facing Windows Solid Sod Walls
Absorption	Sod Walls Sod Floor Sod Roof
Storage	Sod Walls Sod Floor Sod Roof
Distribution	Radiation Conduction Convection
Control	White Reflective Window Treatment
Conservation	Sod Berm on West Sod Wall on East

The third photograph of a primitive dwelling this study analyzes is that of a Log Cabin, located in eastern Oklahoma and constructed before 1900 (Fig 3).

The passive solar elements this home contains are outlined in Table III. The south facing windows and sod insulation between the logs of this dwelling collect solar radiation from the sunlight that enters the dwelling through the windows or strikes the surface of the insulation. The dark surface of the sod insulation absorbs the heat from the sunlight and stores it within its mass. The heat is distributed to the interior of the dwelling by the natural modes of heat transfer, radiation, conduction and convection. The roof overhang and deciduous trees on the south of the house control heat flow into the dwelling. These elements shade the south glass and south wall of the building in the summer, reducing the heat gain into the building. In winter the overhang and trees do not impede the sun's light from striking the south wall or entering the dwelling through the windows. The conservation elements that enhance this passive solar system are the sod berm and storage buildings located north of the building. These elements serve to reduce infiltration of cold north winds into the living space in winter, thus reducing the amount of heat the passive solar system must supply for comfort.

South Elevation

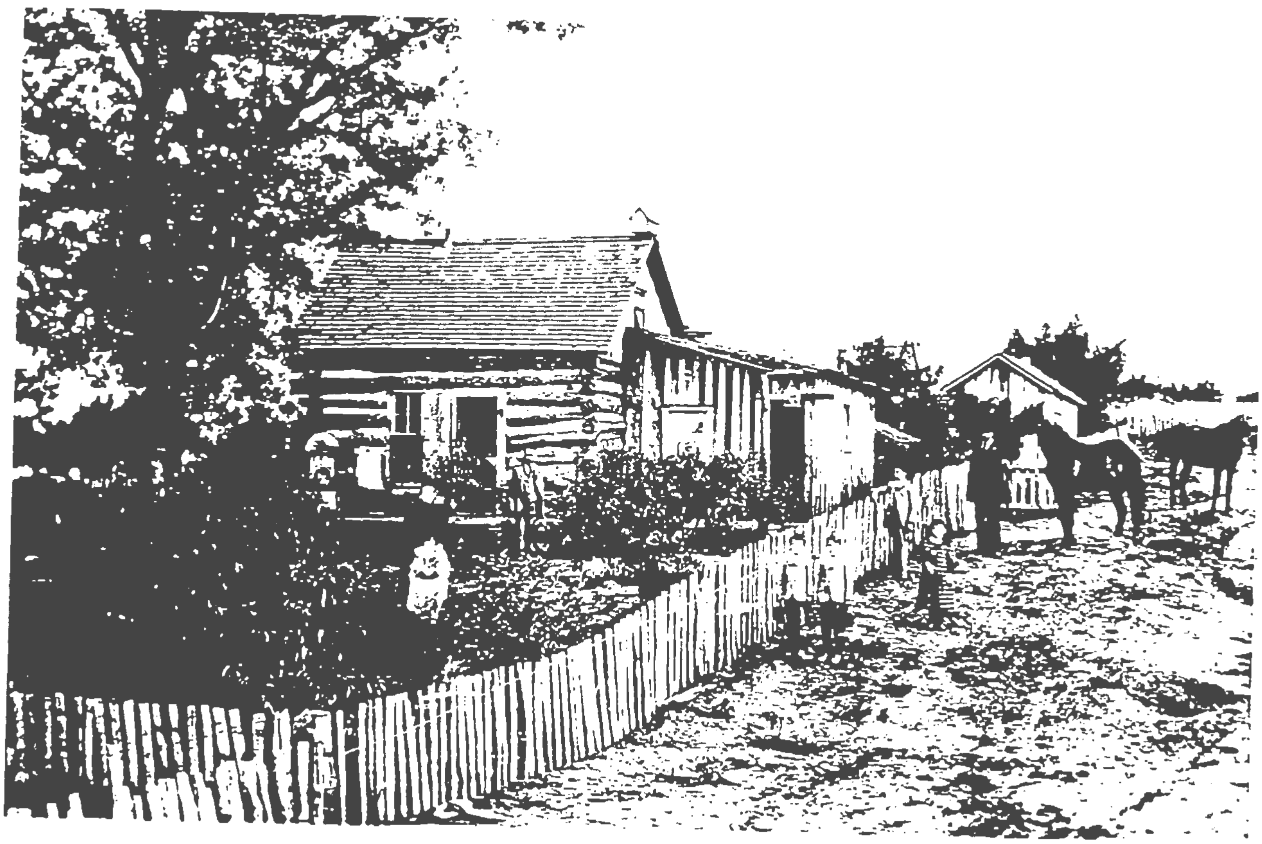

Figure 3. Log Cabin

TABLE III

PASSIVE SOLAR COMPONENTS OF A LOG CABIN

Passive Solar Design Element	Construction Application
Collection	South Facing Windows Sod Insulation
Absorption	Sod Insulation
Storage	Sod Insulation
Distribution	Radiation Conduction Convection
Control	Roof Overhang Deciduous Trees on South
Conservation	Sod Berm on North Storage Buildings on North

The fourth photograph of a primitive dwelling this study analyzes is that of a plain's cottage belonging to Mr. and Mrs. L. M. Cunningham and located in southeast Oklahoma (Fig. 4). The dwelling was constructed sometime before the date of this photograph, November, 1916.

The passive solar elements this home contains are outlined in Table IV. The south facing windows collect heat from the sunlight that enters the dwelling during the daylight hours in the winter months. The photograph does not indicate the existence of absorption or storage elements. Heat is distributed throughout the dwelling by direct radiation of the sunlight that enters into the home through the windows. Control of heat gain is provided by the porch roof overhang and deciduous shade trees on the south. These elements allow solar radiation to penetrate into the building in

South Elevation

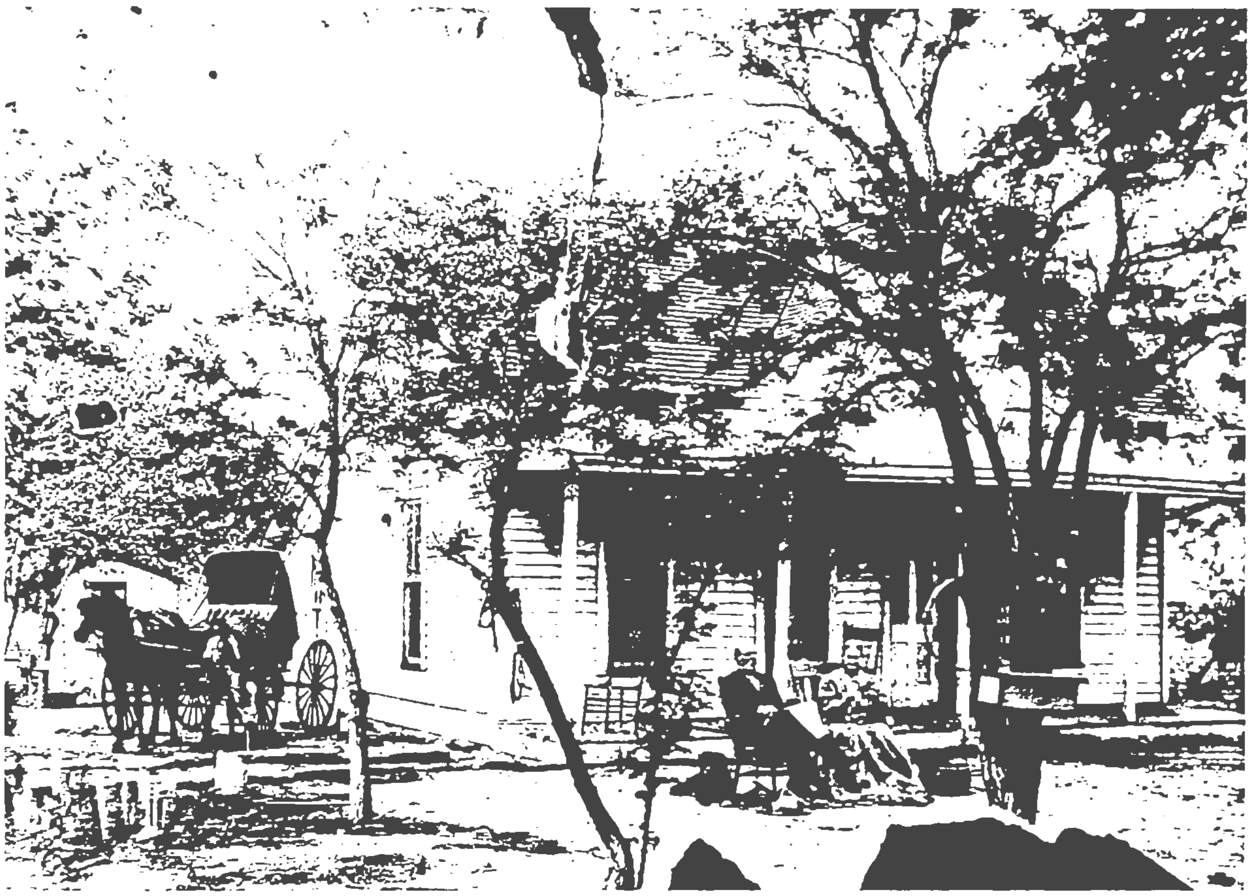

Figure 4. Plains Cottage

the winter months when the sun is low in the sky, while shading the south facing windows from the sun during the summer months when the sun's angle is higher in the sky. The salt box shape of this dwelling is an energy conserving element. The short north wall and the long sloping roof on the north side of the building help minimize infiltration of cold air by directing cold north winds up and over the dwelling, thus reducing the heat required to maintain a comfortable interior temperature.

TABLE IV

PASSIVE SOLAR COMPONENTS OF A PLAIN'S COTTAGE

Passive Solar Design Element	Construction Application
Collection	South Facing Windows
Absorption	Unable to Determine
Storage	Unable to Determine
Distribution	Radiation
Control	Porch Roof Overhang Deciduous Trees on South
Conservation	Salt Box Shape

The fifth photograph of a primitive dwelling this study analyzes is that of an Ante Bellum home located in Atoka, Oklahoma and built by Joseph Murrow in 1874 (Fig. 5). The passive solar elements this home contains are outlined in Table V. The south facing windows allow sunlight to enter the dwelling and function as a collector of solar radiation in this building. The photograph does not provide evidence of any absorption or storage elements

South Elevation

Figure 5. Ante Bellum Home

within this dwelling. Heat is distrubuted by direct radiation of the sun's heat into the interior spaces through the south facing windows. The roof overhang, awnings and deciduous trees on the south side of the home control heat gain in summer by shading the south facing glass from the sun's heat. The energy conserving elements that enhance this passive solar system are the shrubs and vegetation on the east and west sides of the house. This vegetation shades these walls from the heat of the early morning and late afternoon sun in summer and aids in reducing infiltration of cold winds in winter.

TABLE V

PASSIVE SOLAR COMPONENTS OF AN ANTE BELLUM HOME

Passive Solar Design Elements	Construction Application
Collection	South Facing Glass
Absorption	Unable to Determine
Storage	Unable to Determine
Distribution	Radiation
Control	Roof Covering Awnings Deciduous Trees on South
Conservation	Vegetation Surrounding Dwelling

Objective Two: To analyze passive solar design elements of contemporary passive solar dwellings in Oklahoma. Floor plans and photographs of four passive solar dwellings are analyzed under this objective. Each dwelling is analyzed individually for the existence of the passive solar elements of collection, absorption, storage, distribution, control and conservation.

The first plan and photographs of a contemporary dwelling this study analyzes are those of a speculative home built by Don Krahl Construction in 1985, and located at 2112 Shorewood, Edmond, Oklahoma (Fig. 6, 7, & 8). Table VI outlines the passive solar elements this home contains.

TABLE VI

PASSIVE SOLAR COMPONENTS OF 2112 SHOREWOOD, EDMOND, OKLAHOMA

Passive Solar Design Element	Construction Application
Collection	Large Area of South Facing Windows
Absorption	Quarry Tile Floor Brick Trombe Wall
Storage	Quarry Tile Floor Brick Trombe Wall
Distribution	Radiation Conduction Convection
Control	Roof Overhang Sun Screens Reflective-Insulated Window Treatment
Conservation	Highly Insulated Caulked Construction Joints Minimal North, East and West Windows

The south facing windows of this dwelling serve to collect solar radiation from the sunlight that strikes them during the day. The tile floors in the living and kitchen area and a half height brick trombe wall in the bedroom serve to absorb and store the heat collected from the sunlight striking their surfaces. Heat is

Floor Plan

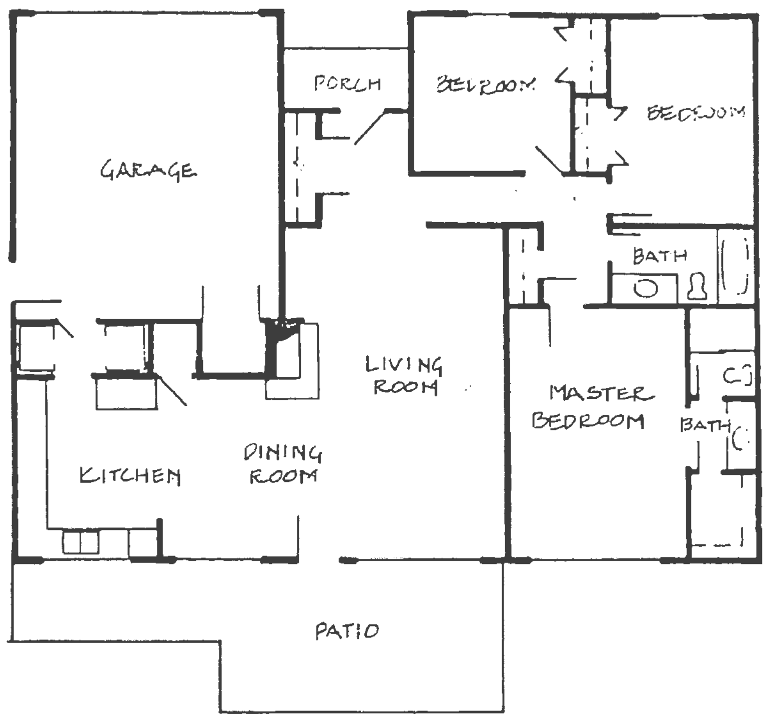

Figure 6. 2112 Shorewood

South Elevation

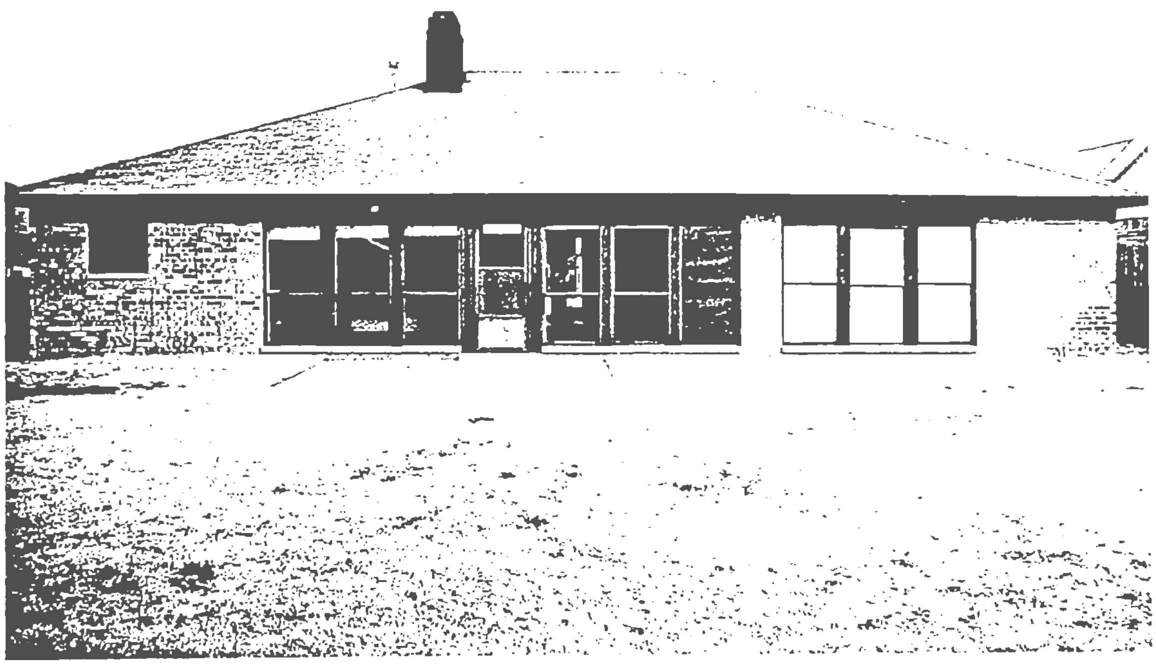

Figure 7. 2112 Shorewood

North Elevation

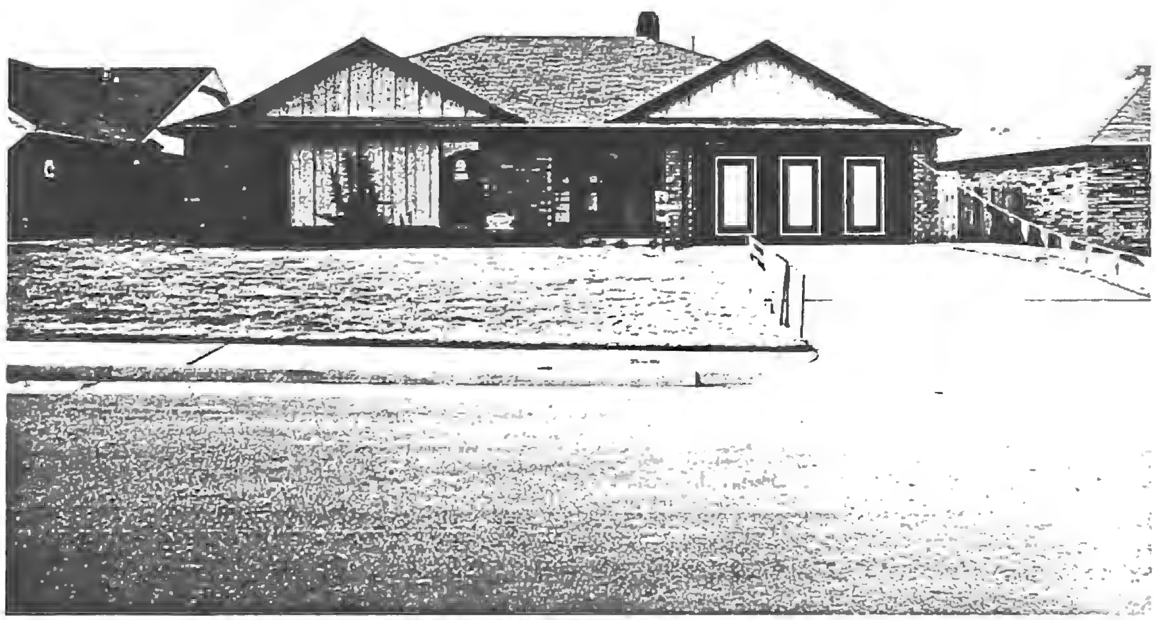

Figure 8. 2112 Shorewood

distributed throughout this dwelling by the three natural modes of heat transfer; radiation, conduction and convection. The elements of control this dwelling contains include a roof overhang that shades the south facing glass in summer but allows maximum penetration of sunlight into the dwelling in winter. Insulated window shades reduce heat loss from the interior in winter and their reflective exterior surface directs heat back outdoors in summer reducing undesireable heat gain. There are several elements of conservation that serve to enhance the passive solar system of this dwelling. The building is highly insulated with an insulative R-value of 26 used in the walls and an insulative R-value of 30 used in the ceiling. Vapor barriers were used around all insulation. The construction joints and the joints around door and window installations were caulked to prevent infiltration and heat loss. The windows on the north, east, and west sides of the house were minimized to reduce infiltration and heat loss as well.

The second plan and set of photographs of a contemporary dwelling this study analyzes are those of a speculative home built by Don Krahl contruction in 1984 and located at 2816 Pinto Trail, Edmond, Oklahoma (Fig. 9,10 & 11). The passive solar elements this home contains are outlined in Table VII.

Floor Plan

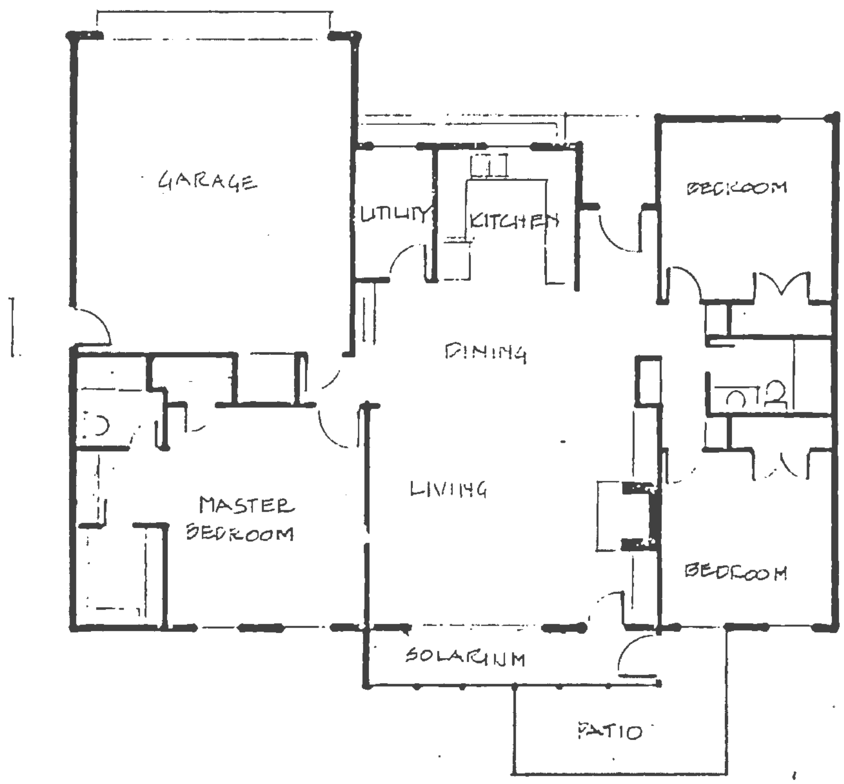

Figure 9. 2816 Pinto Trail

South Elevation

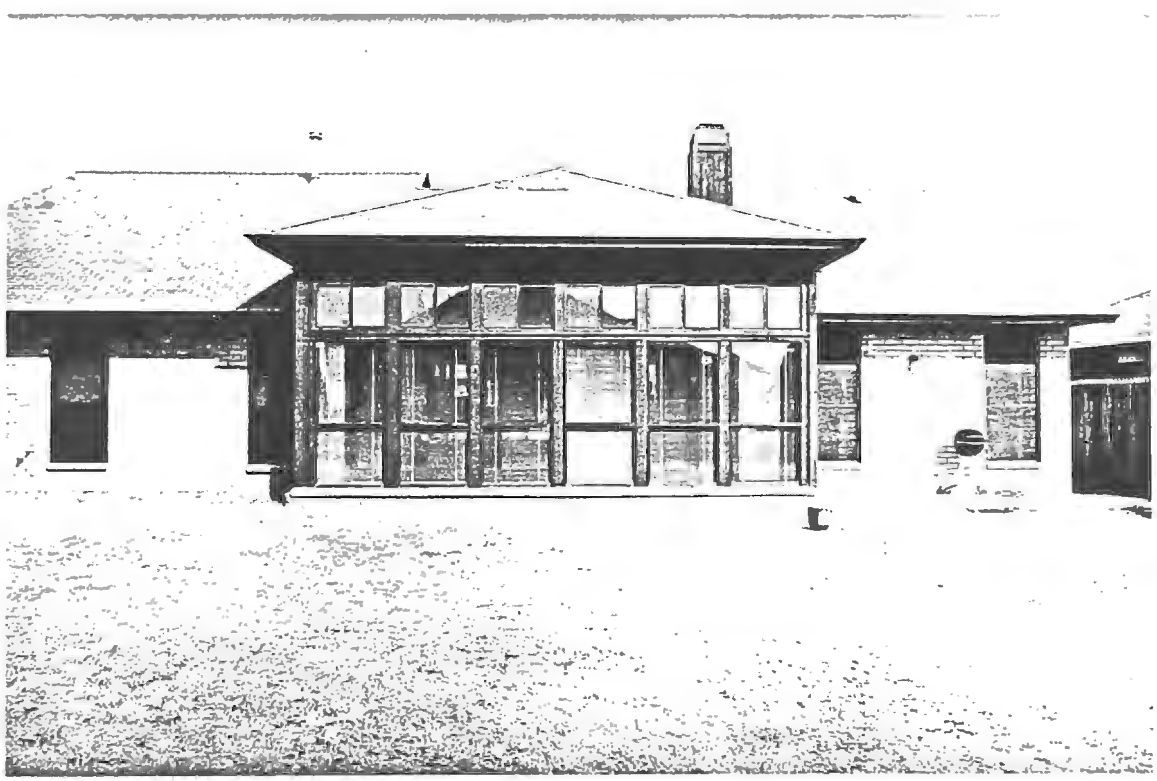

Figure 10. 2816 Pinto Trail

North Elevation

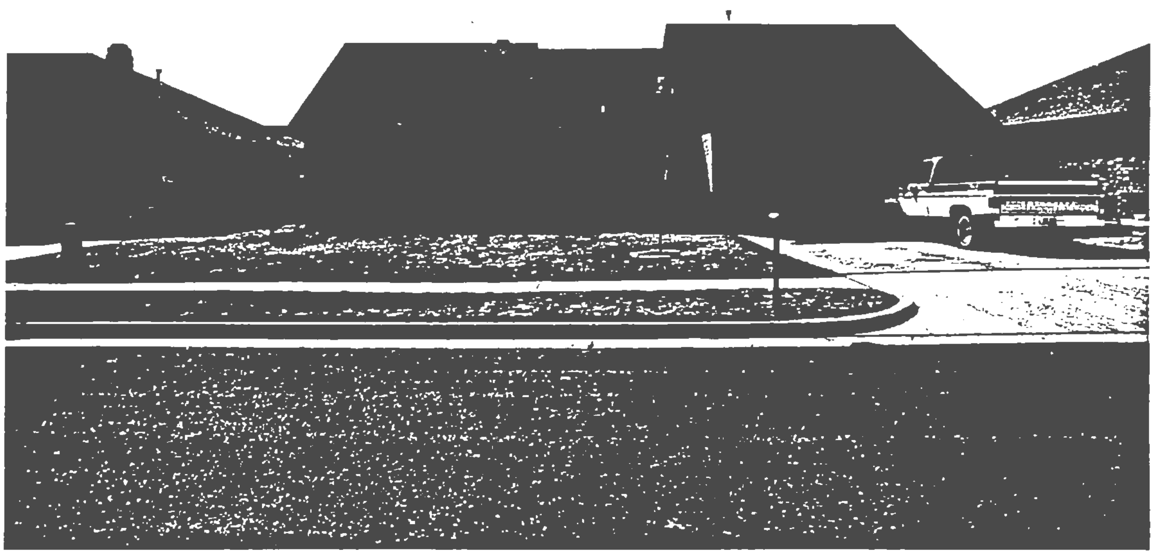

Figure 11. 2816 Pinto Trail

TABLE VII

PASSIVE SOLAR COMPONENTS OF 2816 PINTO TRAIL, EDMOND, OKLAHOMA

Passive Solar Design Element	Construction Application
Collection	South Facing Windows Solarium on South
Absorption	Quarry Tile Floor Brick Trombe Wall
Storage	Quarry Tile Floor Brick Trombe Wall
Distribution	Radiation Conduction Convection
Control	Roof Overhang Sun Screens Reflective Insulated Window Treatments
Conservation	Highly Insulated Caulked Construction Joints Minimal North, East, and West Windows

The south facing windows of the solarium as well as the conventional windows this dwelling contains serve to collect heat from sunlight to utilize in the passive solar system. The tile floor in the solarium and the half-height trombe wall in the bedroom absorb the heat that degrades from sunlight striking their surfaces and stores that heat within their mass. The heat is distributed throughout this dwelling by the three natural modes of heat transfer, radiation, conduction, and convection. Heat loss and gain is controlled in this system by the roof overhang which shades the south facing glass in summer while allowing sunlight to penetrate into the dwelling in winter. The doors separating the solarium from the living area also provide control of heat gain from the solarium into the living space. This dwelling utilizes reflective blinds in the solarium to reduce heat gain in summer. Insulated reflective shades are used on the conventional south facing windows to reduce heat loss in winter and heat gain in summer, providing another element of control to the passive solar system. This dwelling contains several elements of conservation that enhance the potential of the passive solar system. The building is highly insulated, with an insulative R-value of 26 in the walls and an insulative R-value of 30 in the ceiling. The construction joints and the joints at window and door installations were caulked to prevent infiltration and heat loss. There are minimal north, east, and west windows in this dwelling to further reduce infiltration and heat loss in the passive solar system.

The third plan and set of photographs this study analyzes are those of a custom home built by Jack Shelton for Margaret and Joe Weber in 1984. The home is located southwest of Stillwater, Oklahoma (Fig. 12, 13, 14 & 15). The passive solar elements this home contains are outlined in Table VIII.

Floor Plan

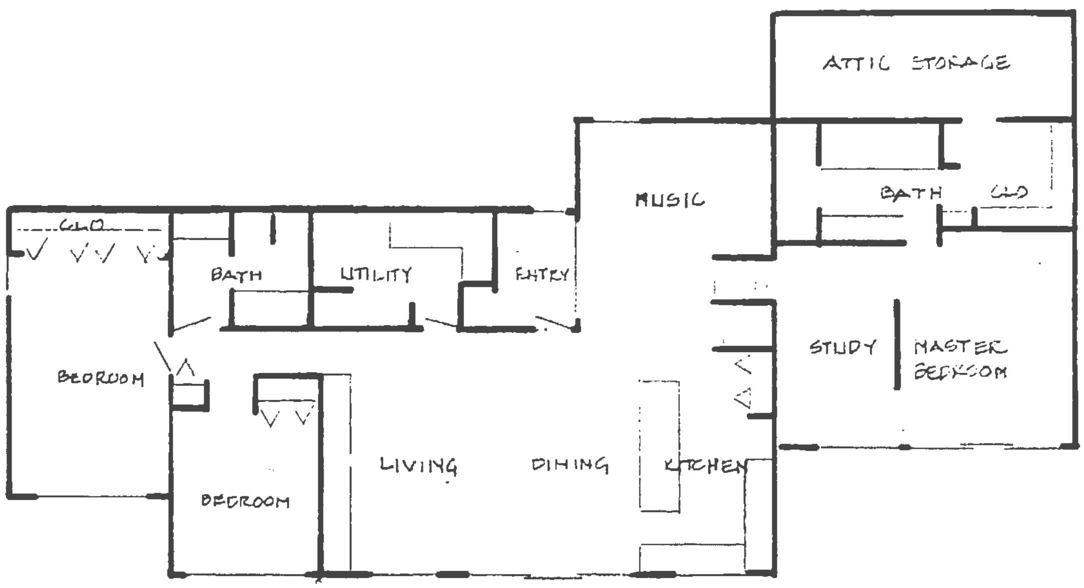

Figure 12. Weber Home

South Elevation

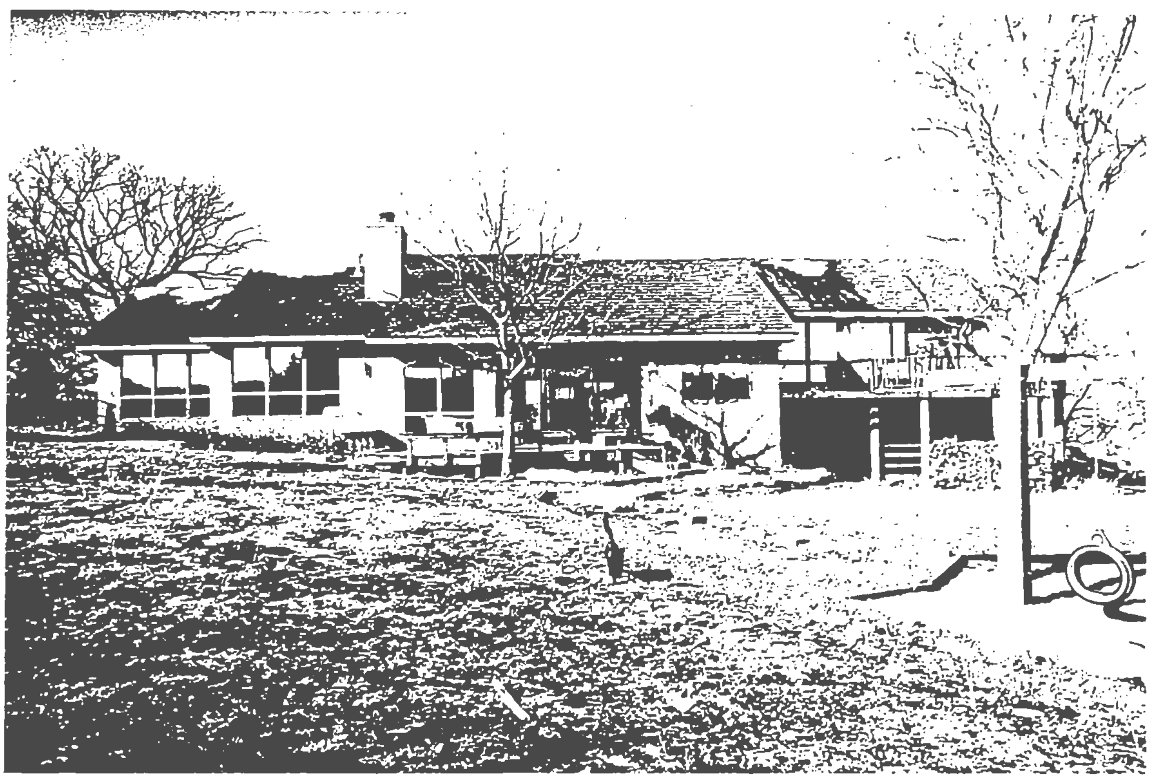

Figure 13. Weber Home

North Elevation

Figure 14. Weber Home

East Elevation

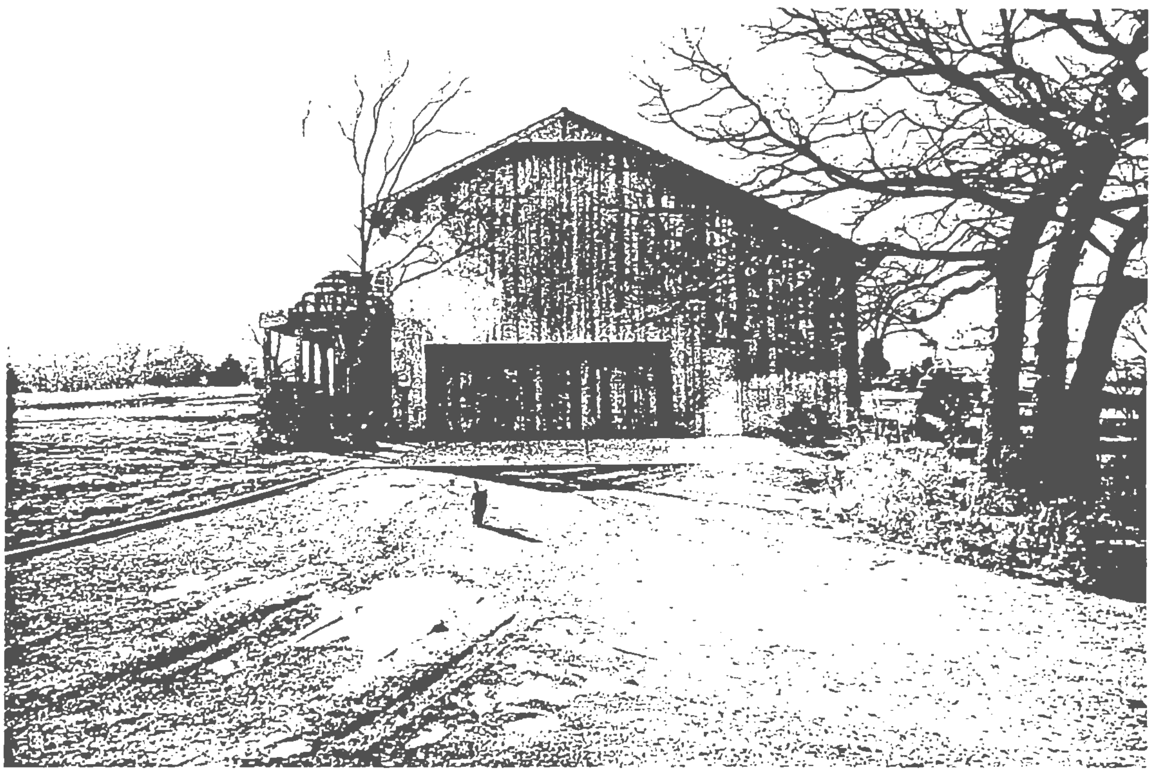

Figure 15. Weber Home

TABLE VIII

PASSIVE SOLAR COMPONENTS OF THE WEBER HOME, STILLWATER, OKLAHOMA

Passive Solar Design Element	Construction Application
Collection	Large Area of South Facing Windows
Absorption	Quarry Tile Floor on Concrete Slab
Storage	Quarry Tile Floor on Concrete Slab
Distribution	Radiation Conduction Convection
Control	Roof Overhang
Conservation	Highly Insulated Caulked Construction Joints Minimal North, East, and West Windows Airlock Vestibule-Entry on North

The south facing windows of this home collect solar radiation from the sunlight that strikes their surface in the winter months. The surface of the tile floors absorb the heat that degrades from sunlight when it strikes that surface. The mass of the tile floor and the concrete floor below stores the heat absorbed by the surface of the floor. Heat is distrubuted throughout this dwelling by the three natural modes of heat transfer, radiation, conduction, and convection. Control of heat gain in this home is provided by the roof overhang. The overhang is engineered to shade the entire south face of the windows in summer, while allowing maximum penetration of sunlight into the dwelling during the cold winter

The south facing windows of this home collect solar radiation from the sunlight that strikes their surface in the winter months. The surface of the tile floors absorb the heat that degrades from sunlight when it strikes that surface. The mass of the tile floor and the concrete floor below stores the heat absorbed by the surface of the floor. Heat is distributed throughout this dwelling by the three natural modes of heat transfer, radiation, conduction, and convection. Control of heat gain in this home is provided by the roof overhang. The overhang is engineered to shade the entire south face of the windows in summer, while allowing maximum penetration of sunlight into the dwelling during the cold winter months. This dwelling contains several energy conserving features that enhance the passive solar system of this dwelling. The structure is highly insulated, with an insulative R-value of 19 in the walls and an insulative R-value of 35 in the ceiling. The construction joints and the door and window installation joints are caulked to prevent infiltration and heat loss. There are minimal windows on the north and west sides of the house and no windows on the east side of the house. This reduces infiltration and undesirable heat loss and gain. The airlock vestibule entry on the north side of this dwelling serves to control heat loss from passage in winter.

The fourth plan and set of photographs this study analyzes are those of a custom home built by Jack Shelton for Ken and Shirley Larson and located on Redbud Lane, Stillwater, Oklahoma (Fig. 16, 17, 18, 19, & 20). The passive solar elements this home contains are outlined in Table IX.

Floor Plan

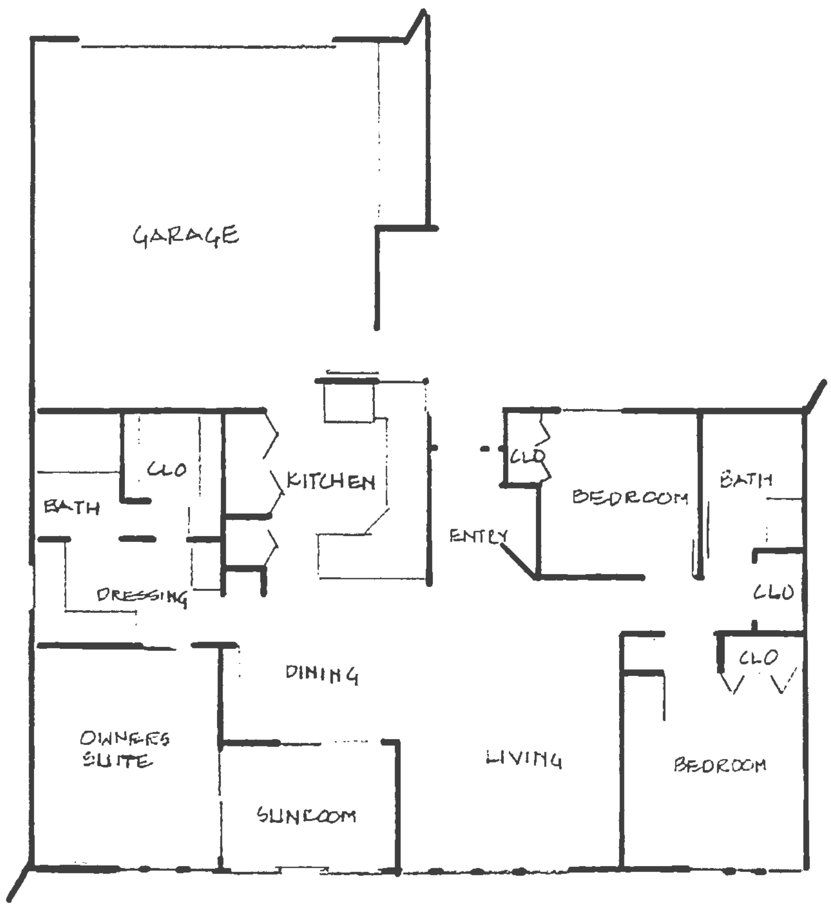

Figure 16. Larson Home

South Elevation

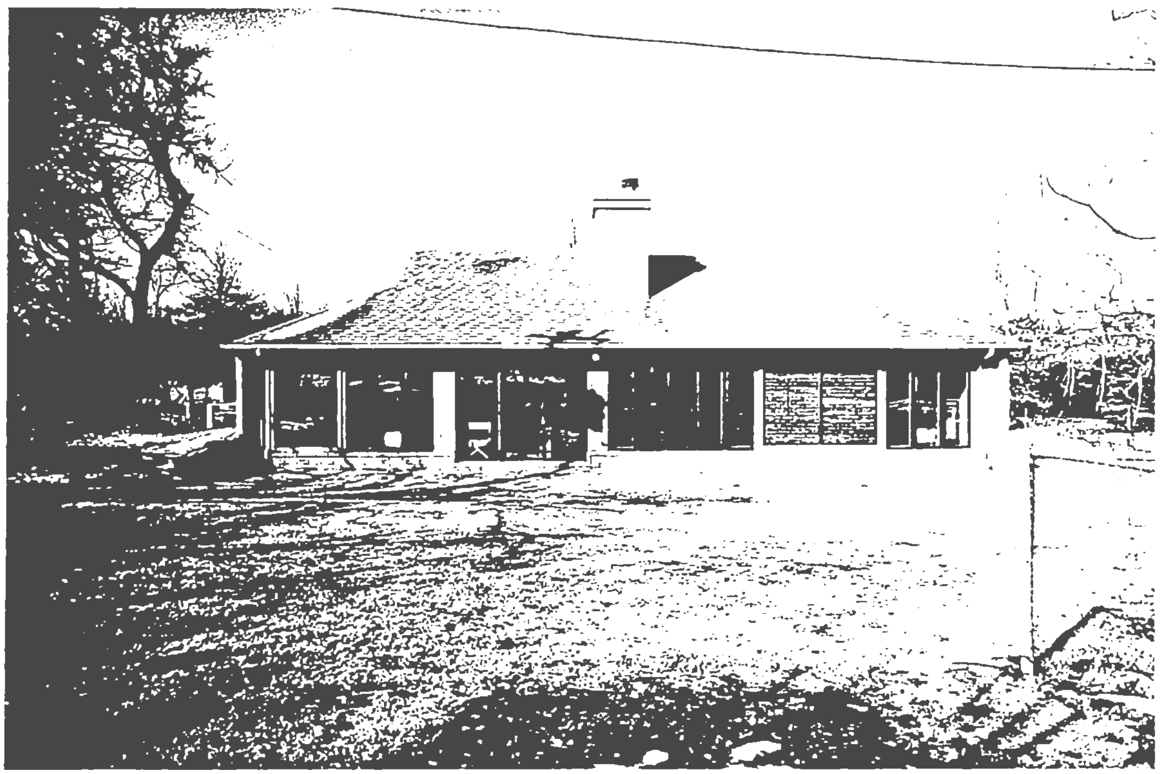

Figure 17. Larson Home

North Elevation

Figure 18. Larson Home

East Elevation

Figure 19. Larson Home

West Elevation

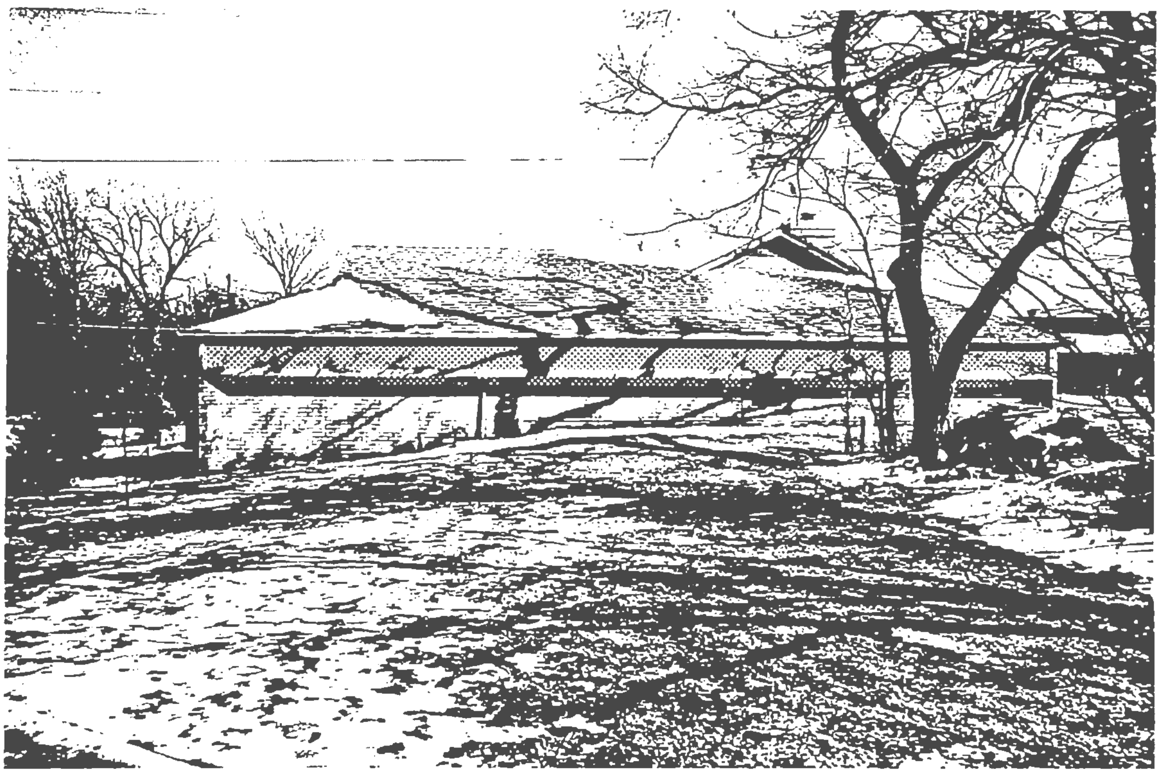

Figure 20. Larson Home

TABLE IX

PASSIVE SOLAR COMPONENTS OF THE LARSON HOME, STILLWATER, OKLAHOMA

Passive Solar Design Element	Construction Application
Collection	Large Area of South Facing Windows
Absorption	Quarry Tile Floor Interior Brick Wall Brick Trombe Wall
Storage	Quarry Tile Floor Interior Brick Wall Brick Trombe Wall
Distribution	Radiation Conduction Convection
Control	Roof Overhang Sun Room Doors Lattice Work Shading Earth Berm on East and West
Conservation	Highly Insulated Caulked Construction Joints Minimal North, East and West Windows

The south facing windows of this home collect solar radiation from sunlight that strikes their surface during the daylight hours in winter months. The surface of the tile floor and brick partition wall in the living area and the surface of the brick Trombe walls in the two south facing bedrooms absorb the heat that degrades from sunlight as it strikes the surface of these elements directly. The mass of the tile floor, the concrete sub-floor and the brick of the Trombe wall and interior partition wall serves as storage for the absorbed heat. Heat is distributed throughout the dwelling by the three natural modes of heat transfer, radiation, conduction, and convection. Control of heat gain is provided by an engineered roof overhang that shades the south facing windows in summer but allows maximum penetration of sunlight into the interior of the home in winter. The lattice work trim on the east and west sides of the structure shade the upper portions of these walls in summer, controlling undesireable heat gain. Earth berms on both the east and west sides add a further measure of control to this system. These berms reduce undesireable heat gain in summer by insulating the exterior of the wall from the sun's heat. The insulating quality also controls loss of heat from the interior in winter.

The doors that seperated the sunroom from the living, dining, and bedroom areas provides a manual means to control heat gain from the sunroom into the additional living spaces. This dwelling also contains several conservation features that enhance the passive solar system of the home. The structure is highly insulated with an insulative R-value of 24 in the walls and an R-value of 48 in the ceiling. Vapor barriers were used around all insulation and construction joints were caulked to reduce infiltration and heat loss. There is a minimum of windows on the north, east and west sides of this dwelling to further reduce infiltration and undesireable heat loss and gain.

Objective Three: To compare passive solar design elements of primitive and vernacular dwellings in Oklahoma to passive solar design elements of contemporary passive solar dwellings in Oklahoma. Table X outlines the elements compared in this study.

All dwellings, both primitive and contemporary, this study analyzes have at least one identifiable element of collection. Each of the nine dwellings utilizes south facing glass to collect solar radiation from the sun.

Three of the five primitive dwellings have identifiable elements of absorption and storage. All four contemporary dwellings have identifiable elements of absorption and storage. Two of the primitive dwellings and all four of the contemporary dwellings utilize massive floors to absorb and store heat collected from the sun.

All dwellings this study analyzes utilize radiation as a method of heat distrubution. Three of the five primitive dwellings and all four of the contemporary dwellings utilize conduction and convection of stored heat as an additional method of heat distribution.

Each dwelling this study analyzes contains at least one element of passive solar control. The roof overhang is the most common control this study identifies. Four of the five primitive dwellings and all four contemporary dwellings use some form of roof overhang to shade the south facing collector from heat gain during the summer months.

Objective Four: To analyze the role of interior design in contemporary passive solar dwellings in Oklahoma. This study analyzes plans of contemporary dwellings in Oklahoma to determine

TABLE X

PASSIVE SOLAR DESIGN COMPONENTS OF NINE SELECTED DWELLINGS IN OKLAHOMA

Design Component	Selected Dwelling								
Collection	Sod	Dougout	Log Cabin	Plains Cottage	Ante Bellum Home	2112 Shorewood	2816 Pinto Trail	Weber Home	Larson Home
South Facing Windows	*	*	*	*	*	*	*	*	*
Solid Massive Walls	*	*	*						
Absorption									
Massive Int/Ext Wall	*	*	*						*
Massive Int Wall	*	*				*	*		*
Masonry Floor	*	*				*	*	*	*
Storage									
Massive Int/Ext Wall	*	*	*						*
Massive Int Wall	*	*	*			*	*		*
Massive Floor	*	*				*	*	*	*
Distribution									
Radiation	*	*	*	*	*	*	*	*	*
Conduction	*	*	*			*	*	*	*
Convection	*	*	*			*	*	*	*
Control									
Roof Overhang	*		*	*	*	*	*	*	*
Dec. Shade Trees			*	*	*				
Ref. Window Treat.		*				*	*		
Sun Screen						*	*		
Conservation									
Highly Insul.	*	*				*	*	*	*
Calk. Const. Joints						*	*	*	*
Double Glz. Windows						*	*	*	*
Strg. Area on North						*	*	*	*
Living Area on South						*	*	*	*

what role interior design plays in the passive solar elements of collection, absorption, storage, distribution, control and conservation. Table XI outlines the interior construction elements that play a role in the passive solar systems this study analyzes.

TABLE XI

PASSIVE SOLAR DESIGN CONSIDERATIONS IN INTERIOR DESIGN

Passive Solar Design Element	Interior Design Application
Collection	Large Area of South Facing Windows
Absorption	Tile Floor Brick Interior Wall Trombe Wall
Storage	Tile Floor Brick Interior Wall Trombe Wall
Distribution	Living Area on South Storage Area on North
Control	Living Area on South Storage Area on North Window Treatment
Conservation	Minimal North, East, and West Windows Window Treatment

The large areas of glass on the south wall of the homes serve to collect solar radiation. These windows also influence interior design. The windows open up the living spaces to the outside, making the interior space seem larger. The large window area affects furniture arrangement within the interior and the choice of window treatments can enhance or detract from the ability of the windows to collect solar radiation in winter and to deter solar radiation in summer.

The elements of absorption and storage are necessary for passive solar systems to be effective. In the four contemporary dwellings this study analyzes, the elements of absorption and storage are integeral parts of the interior design of the spaces. Tile floors on concrete slab are one effective absorption and storage element found in these dwellings, as the masonry properties of the tile absorb heat and the mass of the tile and concrete store that heat. The floors must be placed in the interior so that sunlight strikes their surface directly. Area rugs or carpet can be used over these surfaces to provide softening acoustic or asthetic qualities, however, care must be taken in the placement of these rugs. Covering too large an area of the absorption and storage elements with carpet or rugs can cause overheating in summer months and can hinder collection of enough heat to warm the house at night or on cloudy days during the months of winter. The brick interior or trombe walls used in three of the homes this study analyzes are also effective elements of absorption and storage. The interior brick face of these walls affects the asthetic quality of the spaces. A brick wall usually gives the interior a casual appearance, which should be taken into consideration when placing these walls inside a home.

The layout of interior spaces is a critical element in the passive solar process of heat distrubution. In the contemporary dwellings this study analyzes, major living spaces are located on the south side of the house, with areas of least use such as storage and utility rooms located on the north. This serves to buffer living spaces from the north wall, reducing the heat necessary to maintain comfort in the living space as well as reducing the distance heat must travel in distribution.

The element of control in a passive system can have a great deal of effect on the interior design of the house. As with heat distribution, the layout of interior spaces also serves to control heat loss and gain. In all of the contemporary dwellings this study analyzes, the major living spaces are located on the south side of the house, while storage and other low use spaces are located on the north. This reduces the heat required to maintain a comfortable interior by reducing infiltration of cold air from the north. All four dwellings minimize window areas on the north, east and west walls of the homes. This reduced heat loss and undesireable heat gain also affects the interior design of the house. Natural light entering the dwelling is primarily from the south. Rooms requiring a great deal of natural light must, therefore, be primarily concentrated on the south facing side of the dwelling. The issue of control also affects the choice of window treatments. In the dwellings this study analyzes, reflective insulated shades are used in two of the four homes. These shades control both heat loss and gain in the passive solar system. The outward face of the shades are white to reflect unwanted radiation. The interior face of the shades are covered in a material of the owner's choice, and can be coordinated with other interior fabrics and finishes. The shades are quilted over an insulating fabric called approtex, a material that creates a sealed air cavity, which reduces conductive, convective and radiant heat transfer through their surface.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

The purpose of this study was to illustrate the similarities and differences between passive solar design elements of primitive and vernacular architecture and passive solar design elements of contemporary passive solar architecture. The following four objectives were explored: (1) to analyze passive solar design elements of primitive and vernacular dwellings in Oklahoma; (2) to analyze passive solar design elements of contemporary passive solar dwellings in Oklahoma; (3) to compare passive solar design elements of primitive and vernacular dwellings in Oklahoma to passive solar design elements of contemporary passive solar dwellings in Oklahoma; (4) to analyze the role of interior design in contemporary passive solar dwellings in Oklahoma.

Summary of Findings

In this study, three of the five primitive dwellings studied contained all five elements of a passive solar system; collection, absorption, storage, distribution and control. The two remaining primitive dwellings contained the elements of collection, distribution and control, however, there was no evidence of absorption or storage elements in these two dwellings.

All five primitive dwellings used south facing windows as the passive solar collector. Three of the five primitive dwellings utilized massive walls and or floors to absorb and store the solar radiation collected from the sun. All five primitive dwellings utilized radiation to distribute heat, while three of the five also utilized conduction and convection of stored heat as well. Four of the five primitive dwellings this study analyzed utilized a roof overhang to control heat gain from solar radiation by shading the south facing windows in summer. Three of the five primitive dwellings utilized decidous trees on the south side of the house to control heat gain. One primitive dwelling utilized a white reflective window treatment while one dwelling utilized exterior awnings to shade the south facing windows, thus controlling heat gain.

Three of the five primitive dwellings studied utilized massive sod insulation in the form of walls or berming as an energy conserving element. Surrounding vegetation was also an identifiable energy conservation measure in three of the five primitive dwellings analyzed. All five primitive dwellings analyzed utilized construction techniques and passive solar design elements to maintain a comfortable interior living space.

All four contemporary dwellings this study analyzed utilized south facing windows to collect solar radiation. All four contemporary dwellings utilized quarry tile floors on concrete slabs to absorb and store solar radiation. Three of the four contemporary dwellings utilized Trombe walls for additional absorption and storage of solar radiation. All four contemporary dwellings analyzed utilized the three natural modes of heat transfer, radiation, conduction, and convection for distribution of heat. All four contemporary dwellings studied utilized an engineered roof overhang to shade the south windows in summer, thus controlling heat gain. Two of the four contemporary dwellings used sun screens and reflective window shades as additional elements of controlling heat gain. One of the four contemporary dwellings utilized a lattice work trim and earth berms on the east and west sides of the dwelling to control undesireable heat gain in summer and heat loss in winter.

All four of the contemporary dwellings this study analyzed utilized several energy conserving measures to enhance the passive solar system of the structure. All four dwellings were very well insulated, and the building envelope was tightly sealed with caulk at construction joints and at door and window installations. Energy efficient double glazed windows were utilized by all four of the contemporary dwellings analyzed. One of the four dwellings utilized an air lock vestibule on the north entry to reduce heat loss due to passage. In all four contemporary dwellings analyzed in this study the storage areas and areas of least use were situated on the north while living areas were concentrated on the south to conserve heat gain and loss. All contemporary dwellings analyzed utilized construction techniques and materials as well as passive solar design elements to maintain a comfortable interior environment with low energy resource use.

Several similarities in passive solar design components were found between the primitive dwellings and the contemporary dwellings analyzed in this study. The use of south facing windows to collect solar radiation was the most apparent similarity. All five primitive dwellings and all four contemporary dwellings studied utilized south facing windows as solar collectors.

Three primitive and one contemporary dwelling utilized solid massive interior/exterior walls to absorb and store heat. Three primitive and three contemporary dwellings used massive interior walls as absorption and storage elements. Two of the five primitive dwellings and all four contemporary dwellings utilized massive floors to absorb and store heat.

All five primitive dwellings utilized radiation to distribute heat throughout the space. Three of the five primitive dwellings and all four contemporary dwellings utilized conduction and convection as additional modes of heat distribution.

Four of the five primitive dwellings and all four contemporary dwellings utilized a roof overhang to shade the south facing windows and control heat gain. One of the five primitive dwellings and two of the four contemporary dwellings used reflective window treatments to control the amount of solar radiation that enters the dwelling.

Two of the five primitive dwellings and all four contemporary dwellings utilized high levels of insulation to prevent infiltration and to conserve energy within the building. All four contemporary dwellings also utilize the conservation elements of caulked construction joints, double glazed windows, storage areas on the north and living areas on the south. The primitive and contemporary dwellings this study analyzed utilized similar passive solar design elements to maintain a comfortable interior environment.

Interior design was found to play a large role in the passive solar systems analyzed in this study. The large areas of south facing glass that serve to collect solar radiation found in all the dwellings analyzed also serve to open up and enlarge the spaces visually.

In the four contemporary dwellings analyzed, the interior floors and some interior walls served as absorption and storage elements. These elements were necessarily massive materials such as brick, tile or concrete, and their location and appearance was a consideration in the interior design of the space.

The layout of interior spaces has a great deal of bearing on distribution of heat in passive solar systems. In all four contemporary dwellings analyzed the living areas were concentrated on the south, with storage and utility areas on the north to serve as a buffer between the cold north wall and the living spaces. This interior layout reduced the distance that heat has to travel in distribution, as well as controlling heat loss.

Window treatments also play a role in both interior design and passive solar design. Two of the contemporary dwellings analyzed had window treatments that served as control elements of the passive solar system, controlling heat loss and gain. These window treatments also face the interior and are a consideration in the overall appearance of the space.

All four contemporary dwellings analyzed had a minimal number of windows on the north, east, and west walls of the home, which aided in controlling heat loss and gain. This also had an affect on the interior design of the space. Views and natural light were limited on these sides of the house and affected the optimal layout of interior spaces. Interior design played a major role in each of the passive solar elements in all four of the contemporary dwellings this study analyzed.

Recommendations

With depleting energy resources and the rising cost of energy, housing that uses less energy is becoming increasingly important to the American consumer and the United States as a whole. However, acceptance of energy efficient housing has not been widespread. In view of these observations and the experience with this project, the following recommendations are made:

1. A more in-depth study into the history of energy efficient passive solar design. This would aide in educating the consumer about the past successes of passive solar energy systems.

2. An in-depth study to determine specific questions about and objections to passive solar housing by the American consumer. This data could be utilized in future passive solar housing developments.

3. A large scale study comparing existing passive solar housing to existing conventional housing to determine energy savings realized by passive solar design elements. This would be a useful tool in marketing energy efficient housing.

4. A study utilizing a large sample that examines the interface of passive solar design and interior design. This data could then be used in the future with passive solar housing design.

5. A study to determine consumer satisfaction with passive solar housing. Demographic data should be included. This information could then be used to target passive solar housing consumers.

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