IDEAL SITING, ORIENTATION, AND VENTILATION OF HOUSES IN RELATION TO THE CLIMATE OF DENTON COUNTY, TEXAS

THESIS

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By

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INTRODUCTION

The Problem

In the Denton County area the naturally breezy climate of summer, excluding areas near heat-collecting surfaces of pavement and masonry, is not usually uncomfortable out of doors unless one is directly exposed to the sun; but, as a result of improper orientation of houses, indoors one often feels a pressing still heat and a general discomfort. The writer's interest in the field of architecture led to a desire to find out how this condition could be alleviated; therefore, this study was undertaken: "Ideal Siting, Orientation, and Ventilation of Houses in Relation to the Climate of Denton County, Texas."

Definition of Terms

For the purpose of this study, orientation is used to mean the art and science of placing houses on sites to use the sun, wind, view, and natural complements of trees, hills, and other features of the landscape to the best advantage.[1] Climate is the long-term average of atmospheric

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[1] Elizabeth Gordon, "'Windbreaks' and 'Sunpockets,'" House Beautiful, LXXXV (August, 1943), 50.

conditions as determined by terrain, sun, and air. _Microclimate_ is used to mean the small climate of the individual lot.[2] _Insolation_ is solar radiation--composed of light rays, infra-red rays, and ultra-violet rays--that is received by surfaces which are exposed to the sun.

Importance of the Study

No laboratory statistics are needed to show the direct effects of heat and cold on personal comfort, since we noticeably feel the changes they make; but a physician has explained how climate expressly affects health and work:

> Studies during the past few years have revealed that climatic factors in life play a startling and dominating role in all we do. Man as an energy machine thinks and acts only because of the burning of food in his tissues; but the speed of this burning--and the intensity of his living--depends largely upon outside temperatures and how easily he can get rid of his waste heat. . . it need only be said here that the climatic influences are real and clear-cut. They affect man's rate of growth, speed of development, resistance to infection, fertility of mind and body, and the amount of energy available for thought or action. The heat of the tropics lulls people into a passive complacency and saps their vitality; residents of colder climates are driven onward into activity, since natural conditions permit their tissue fires to burn more brightly. 3

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[2] "Microclimatology: A Big Word for the Study of Small-size Weather," _Architectural Forum_, LXXXVI (March, 1947), 115.

[3] Clarence A. Mills, _Climate Makes the Man_, p. 6.

> Proper means of controlling the rate of body heat loss are vital in climates with marked seasonal swings in temperature. Cold-weather chilling must be avoided because it is likely to induce respiratory or rheumatic infections; severe summer heat is bad since it depresses general body vitality. [4]

Herrington, another outstanding physician, is quoted by Langewiesche as approving the latter's statement that

> A bad house is a drain, like constant under-feeding. It saps your productivity, your efficiency. Just like a poor diet, its effects are hidden and slow, but they are real. Home is where you come to recuperate from your work, to get rest, replenishment, relaxation. If the home doesn't give it to you, life cheats you. [5]

Purpose of the Study

The purpose of this study was to collect and compile data on the principal climatic factors of the Denton area which affect one's personal comfort and health, in order to show how a maximum of these commodities could be secured through manipulation and control of the climate of individual building sites.

Scope of the Problem

Since a greater geographic area would involve other and different factors which would make the study more complex, it was decided to limit this study to the area of

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[4] Ibid., p. 202.

[5] Wolfgang Langewiesche, "So You Think You're Comfortable!," House Beautiful, XCI (October, 1949), 222.

Denton County. Although neighborhood and city planning affect local climate--which in turn affects personal comfort and health--these aspects are not considered, this study being limited to the problems of building within the area of the conventional building lot as related to the natural climatic factors of terrain, sun, and air.

Geographical Background

Because the geography of any area is one of the determining factors of its climate, a brief geographical sketch of Denton County, Texas, is pertinent.

Denton County is between the parallels of north latitude 32 and 34; it has an elevation of from 500 to nearly 1,000 feet, with the highest area in the northwestern part, generally sloping toward the southeast; and it is composed mainly of a sandy prairie plain traversed by a number of small streams in shallow valleys. Most of the terrain ranges from undulating to very rolling, with a rapid surface-drainage. The topsoil is friable and the subsoil crumbly and readily penetrated by water.[6] This combination limits the advisability of below-the-surface building, since there are occasional torrential rains.

The air temperature of Denton County varies from extremes of 10° F. or lower in winter to 100° F. or above in

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[6] William T. Carter, The Soils of Texas, Bulletin No. 31, p. 9.

summer. There are about nine months of warm weather, from late March to early January; and for four of these months, from late May to early October, the temperature rises well above 90° F. almost daily, with an average temperature for the period of 83° F.[7] When combined with high temperatures, the usually high humidity produces an uncomfortable environment. In the spring and summer, occasional thunderstorms with hail or strong winds occur. Winter is a short three months; but bitter northers from the northwest--frequently accompanied by rain, which often changes to sleet or, sometimes, snow--cause sudden changes of temperature. An annual average of three light snowfalls deposits a total of one and one-half to two inches of snow during a season.[8]

Review of Literature

In 1924 the effect of microclimate on personal comfort and health in connection with architecture was examined by Mumford.[9] A good, but rather general, article which considered microclimate was published by the Architectural

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[7] United States Weather Bureau, Our Climate, p. 25.

[8] Records from the United States Department of Agriculture Soil Conservation Service, Texas A. & M. College, Agriculture Experiment Station No. 6, Highway 24, Denton, Texas.

[9] Lewis Mumford, Sticks and Stones, pp. 155-193.

Forum in 1947.[10] In 1949, research in this field was sponsored by House Beautiful; extensive studies were undertaken and data have been compiled on the orientation of houses for manipulating and controlling specific local climates. These data have been compiled for the areas of Columbus, Ohio;[11] New York, New York;[12] Miami, Florida;[13] Phoenix, Arizona;[14] St. Louis, Missouri;[15] New Orleans, Louisiana;[16] Philadelphia, Pennsylvania;[17] St. Paul and Minneapolis, Minnesota;[18]

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[10] "Microclimatology: . . . .," Architectural Forum, LXXXVI (March, 1947), 114-115.

[11] Paul E. Siple, "Have You Ever Seen the Portrait of a Climate?," House Beautiful, XCI (October, 1949), 162-63.

[12] Siple, "15,750,000 Americans Live in This Climate," House Beautiful, XCI (November, 1949), 202-03.

[13] Langewiesche, "Your House in Florida," House Beautiful, XCII (January, 1950), 70-1.

[14] "An Arizona House That Baffles the Western Sun," House Beautiful, XCII (April, 1950), 156-59.

[15] James M. Fitch, "If You've Too Much Climate, Try Climate Control," House Beautiful, XCII (May, 1950), 168-69.

[16] Buford L. Pickens, "How to Live at Peace with the Gulf Coast Climate," House Beautiful, XCII (July, 1950), 74-6.

[17] "The Philadelphia Story on Climate Control," House Beautiful, XCII (September, 1950), 119-25.

[18] Siple, "How to Live with America's Worst Climate," House Beautiful, XCIII (March, 1951), 96-101.

Washington, District of Columbia;[19] Oakland, California; and Portland, Oregon.[20] No attempt has been made heretofore to apply this body of available knowledge to building in the Denton area.

Procedure

The procedure used in presenting the data compiled is as follows: Chapter I includes a statement of the problem; a definition of terms; the importance, purpose, and scope of the study; the geographical background of Denton County, Texas; a review of literature; and the procedure followed in developing the problem. Chapter II deals with orientation of houses in regard to the terrain, with a discussion of the influence of local topography and vegetation on a site. The consideration of the influence of vegetation includes the effects of past and present mutilation and the potentialities for manipulation and control of the local climate by the use of trees, grass, and added plants. Chapter III considers orientation of houses in relation to

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[19] House Beautiful, XCIII (April, 1951), 129-35.

Fitch, "It's Cooler in the Suburbs," House Beautiful, XCIII (June, 1951), 132.

[20] Siple, "How Many Climates Do We Have in the U. S.?," House Beautiful, XCI (October, 1949), 136-137.

the sun in order to obtain its warming effects in the winter when wanted and to exclude them in summer when they are undesirable. Chapter IV explains how to orient house and site plans in relation to the air--its movement, temperature, and humidity. Chapter V summarizes the study.

CHAPTER II

RELATING THE BUILDING SITE TO TERRAIN

Influence of Local Topography on a Site

Although acutely conscious of the general climate, not many people know much about their microclimate. If we learn enough about our particular microclimate, we can make it work for, instead of against us, eliminating the need for many expensive building materials which an improper use of a site makes necessary.[1] Variations in the local topography, including its contours and water bodies, its soil conditions, and its vegetation cause the principal fluctuations in the microclimate. In addition, all the aspects of siting--whether the building site is on the crest of a hill or in a valley, whether it is near the sheltered or windward side of water, whether it is in the open or near trees, and whether it is on sandy, rocky, or dirt soil--are profound influences for good or bad. Thus, some plots of ground are more advantageous than others as building sites from the standpoint of microclimate.

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[1] "Knowing Climate Will Reduce Building Costs," Science News Letters, LVII (January 28, 1950), 61.

The rapidly-draining, sandy, dry soil generally found in Denton County tends to make the climate uncomfortable by causing higher temperatures and lower humidities.[2] If attempts are made to reduce the high summer temperature by sprinkling the surrounding ground, such efforts are offset by the rapidly-draining, dry soil. Thus, a movement of air will do more to alleviate the high summer temperature than will a wet ground.

In addition to the factor of soil composition, contour of the terrain influences the microclimate; with its rolling terrain, Denton County embraces many different microclimates. There are hot spots and frost hollows, smoky and clear places, rancid and fragrant areas, foggy valleys, and other locales of varying character.

If a site slopes as much as one foot in twelve, the direction in which it slopes makes a vast difference in its microclimate.[3]

The variations in microclimates make differences in problems of maintenance of a house; for example, in heating costs, in frequency of frozen water pipes, in persistence of rattling of doors and blinds. Microclimate causes the

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[2] "Microclimatiology: . . . ," Architectural Forum, LXXXVI (March, 1947), 115.

[3] Langewiesche," How to Pick Your Private Climate," House Beautiful, XCI (October, 1949), 148.

success or failure of a garden; it makes a house cheerful or gloomy; it determines the length of time people can live comfortably out of doors; and it affects the physical well-being of the occupants of a site.

In Denton, south or southeast is the best direction for a site to incline, because a south or southeast slope is not so hot in summer as one oriented oppositely. Figure 1, A and B, shows how a south or southeast slope is open for the prevailing summer breeze and how it is protected in winter from northers, while a north or northwest slope is not similarly protected. Even in the direct sun, a south or southeast slope is cooler than a north or northwest one, because the higher summer sun actually rises and sets in the northern half of the sky, not the southern. This means that the south or southeast slope has more protection from the hot summer sun for a longer period of time than does the north or northwest slope. Seven or eight hours of direct sun descend on the south or southeast slope as contrasted with fourteen hours of direct sun received by a north or northwest slope.[4]

An east or northeast slope is better than a west or southwest inclination mainly because the summer morning sun is not so objectionable as the sun in the afternoon,

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[4] _Ibid_., p. 215.

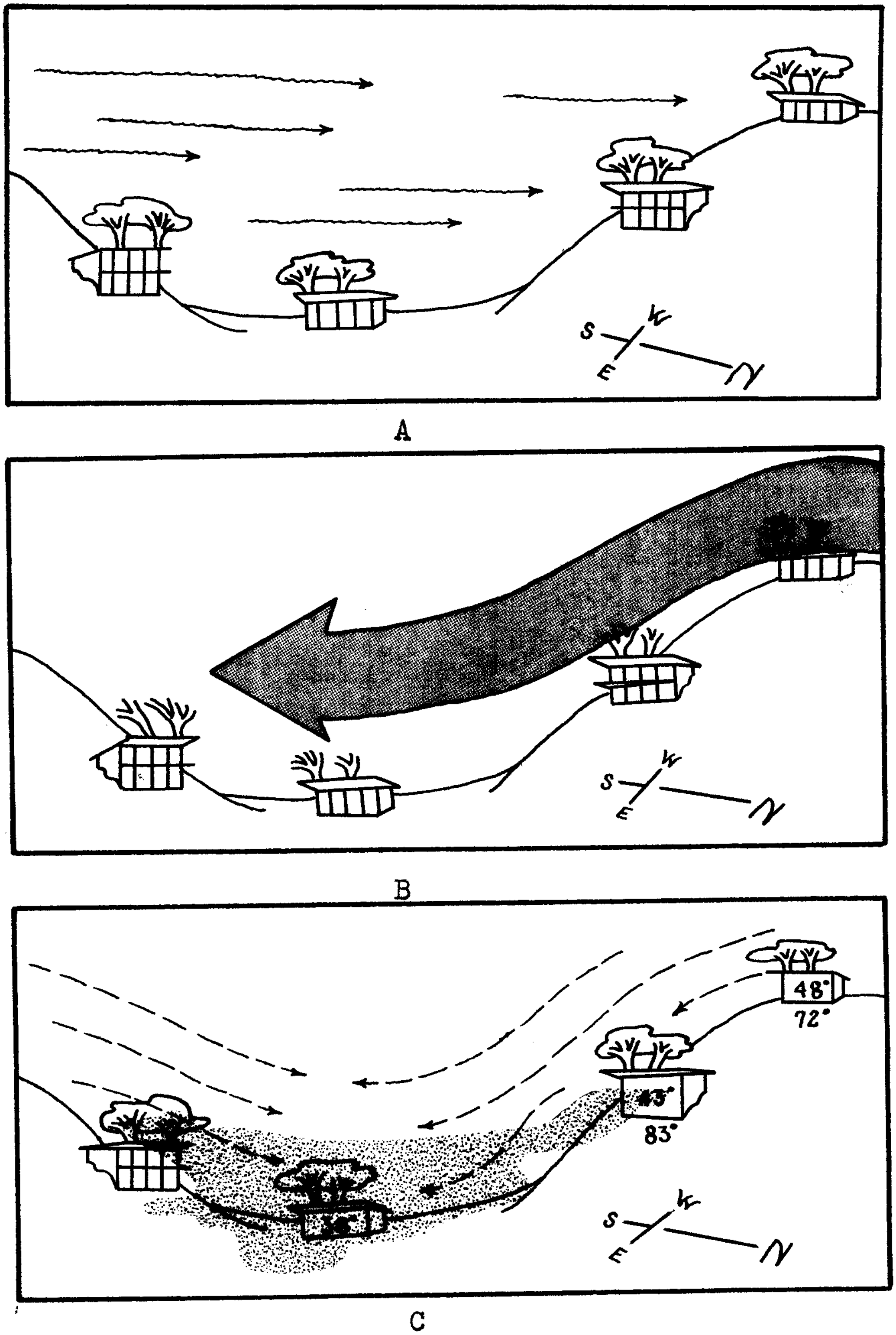

Fig.1.--Influence of an incline as to placement and exposure of a house for (A) prevailing southeasterly breezes, (B) northers, (C) heavy, cooler air or fog.

when the air is warmer. This orientation is more desirable in winter also since the warming effect of the winter morning sun occurs while the air is coolest. Also, an east or northeast slope would receive a little more of the cooling southeasterly breeze in summer and exclude more effects of the cold northers in winter.

Air temperature is affected by height as well as by sun and wind. Figure 1-C shows that with the difference in height of only a few feet there will be one microclimate at the top, one midway, and another at the base, especially at night.[5] Cold air, being heavier than warm air, sinks and causes the temperature to be lower, sometimes as much as 10 degrees, at the bottom of the slope. A site midway down an incline would work best in the Denton County area because it could be so oriented that it would benefit by the prevailing summer breeze; moreover, the air would be cooler at this level than at the top of the slope. Also, a site midway down an incline would be above the colder winter air of the lower levels and would be somewhat protected from winter winds.

The best position of a house on a flat lot is determined by the climate, also. Near the northwest end of a

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[5]"Microclimatology: . . . ," Architectural Forum, LXXXVI (March, 1947), 115.

level plot is a good placement in order to leave more open space to the south and east exposed to the prevailing summer breeze.

In relating new houses to existing buildings in a Denton County town, the south or southeast part of town would provide the best site because it would receive more of the prevailing southeasterly breeze of summer and be protected by the existing buildings from the sudden winter northers. In comparison, a site on the north or northwest side of town would exclude much of the needed summer breeze and give greater exposure to the winter northers.

In summarizing the effects of terrain on microclimate in Denton County, the following points are pertinent: (1) The undulating terrain, because of its effect on quality and quantity of wind and sun received and because of its determination of thermal layers of air, indicates that the most favorable building sites in the Denton area are located midway down a south or southeast slope. (2) In case of a flat lot, the northwest corner of the lot is the best location for a building. (3) Because of the barriers resulting from existing buildings in urban areas, the southeast section of a town offers the best building sites.

Influence of Vegetation on a Site

Past and Present Mutilation

Two factors profoundly altering our way of living, which had their beginning in the nineteenth century, are the machine and the industrialization of production that the machine made possible.[6] The country became obsessed with mechanization; and the practice in architecture of stripping a plot of ground, leveling it, and starting from nihility began. The nation turned away from the idea of adapting buildings to make the best use of the natural elements and began to contrive ever better artificial controls, almost completely ignoring the potentialities of natural factors. People still act as if comfort-making machines can take the place of proper orientation; or that the marvelous new materials are an adequate replacement for common sense about climate. The difference between what we could do and what we are doing makes the difference in our personal comfort.

Potentialities for Manipulation and Control

Regardless of the building practices of the past or present, we should consider the natural lot itself and its potentialities for manipulation and control of microclimate,

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[6] Ludwig Hilberseimer, The New City, p. 18.

because everything done to a site alters the microclimate of that particular plot of ground; for example, paving, excavating, cutting of trees, and placement of the house. Living vegetation maintains a cooler temperature in the sun than do inorganic elements. Vegetation absorbs a large part of the heat, light, and noise and actually manufactures coolness by its suspiration; whereas asphalt, brick, and stone collect far more of the sun's heat than any vegetation and hold it longer, slowly re-radiating it for hours after the sun has set.

Trees.--Every tree felled makes for a hotter and more glarey summer. A tall deciduous tree can shade a desirable area during the hot part of a day, thus modifying the temperature by blocking the sun's heat and glare. The leaves also manufacture coolness by suspiration. In the shade of a tree at midday in summer the air one to six feet above the ground is approximately 5 degrees cooler than that of the adjacent unshaded area.[7] The author of American Building has aptly summarized the effects of vegetation on climate:

> Above and beyond their beauty, the scientific use of deciduous trees will accomplish any or all of the following:

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[7] "Microclimatology: . . . ," Architectural Forum, LXXXVI (March, 1947), 116.

> Deflect, absorb, and reduce the heat radiation of sunheated roofs, walls, and paved areas in summer, while in the winter permitting fullest access of solar heat to these surfaces.
>
> Reduce the free air temperatures of contiguous areas (the shade effect) both by reduction of radiant temperatures and by the transpiration of the leaves, . . .
>
> Filter the atmosphere. Trees are themselves excellent air filters, catching and holding dust on the viscous surface of their leaves, . . .
>
> Reduce intensities and glare both indoors and out from sun, street lights, near-by windows. . . .
>
> Increase visual privacy in summer when more people spend much time out of doors, or with doors and windows open.
>
> Reduce the transmission of air-borne sound.[8]

Grass.--Another helpful factor in temperature control is a natural carpet of grass at least one and one-half inches thick, which cools the air by slowly evaporating moisture from the soil. Grass also traps dust and noise and kills the glare and re-radiation effect of the sun.[9] A difference in temperature of from 10 to 14 degrees occurs between the exposed soil, depending on its color, and the cooler surface of grass;[10] and a difference of 25 to 30 degrees occurs between adjacent asphalt and grass surfaces in the summer.[11] Even a paved terrace will be cooler if grass is

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[8] Fitch, American Building, pp. 293-294.

[9] "Good Lawns Keep You Cooler," House Beautiful, XCII (March, 1950), 108-109.

[10] "Microclimatology: . . .," Architectural Forum, LXXXVI (March, 1947), 116.

[11] Ibid., p. 114.

grown between the paving blocks.[12] Thus, trees and lawns have similar functions in climate control.

Other plants.--Other vegetation in the form of shrubs and vines can be added to a landscape to redirect summer breezes or winter northers and to increase sources of shade and coolness. A few evergreens properly oriented make an excellent wind shield for a site in winter (see Figure 2),

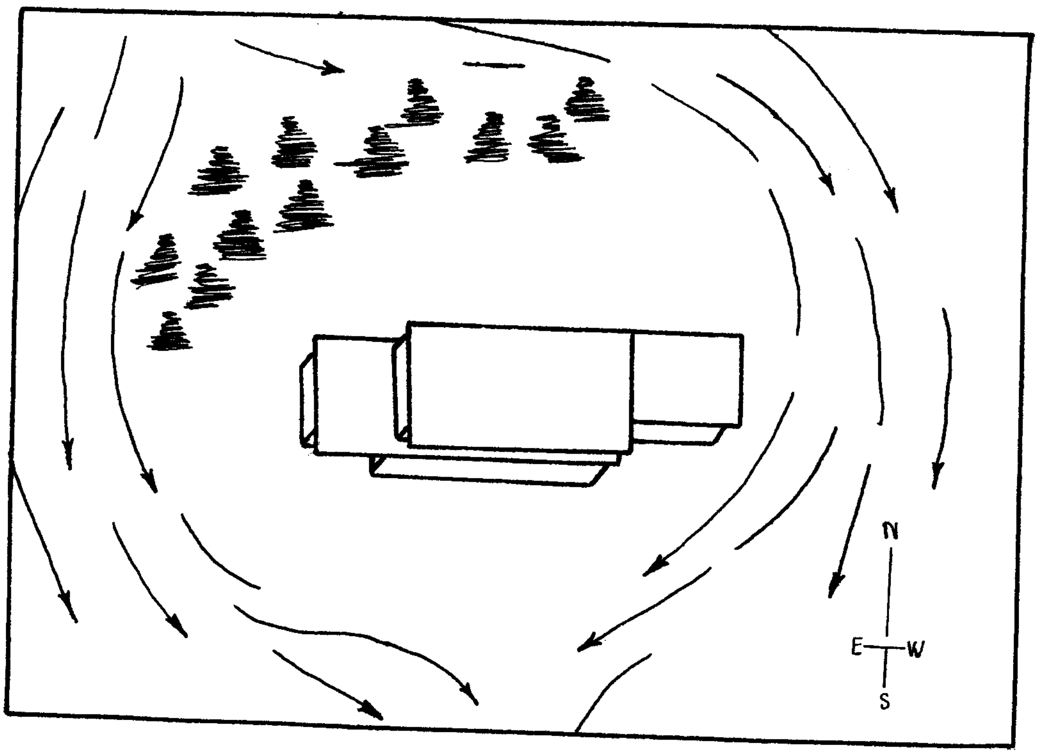

Fig. 2.--Effects of evergreen vegetation planted on the northwest side of the house.

raising the temperature 3 to 5 degrees, cutting the wind velocity 20 per cent, and reducing heating costs. Such

[12]Langewiesche, "How to Pick Your Private Climate," House Beautiful, XCI (October, 1949), 192.

barriers also procure privacy and conceal objectionable views; however, it must be remembered that plants or an artificial barrier, especially on a slope, can also cause an unfavorable change in microclimate by acting as a dam which holds a small volume of cold air.[13] Figure 3 illustrates one possible solution by having an opening on the lower side of the barrier through which the heavier cold air may drain.

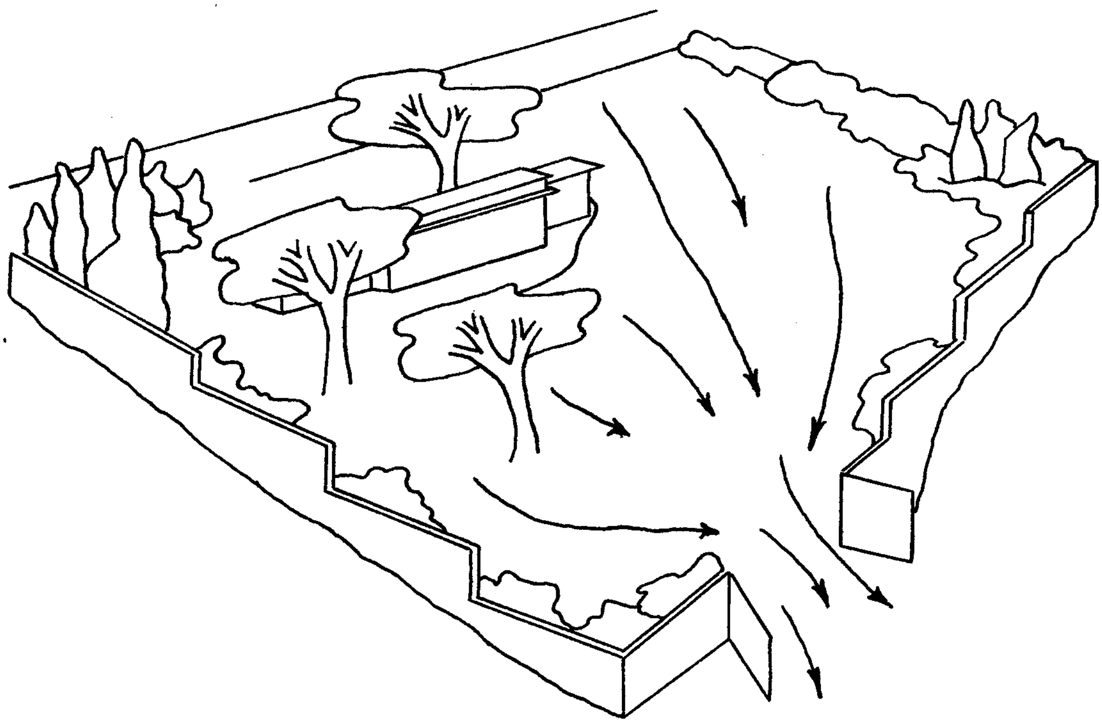

Fig. 3.--Opening on lower side of an inclosed plot as drain for heavy, colder air.

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[13] "Microclimatology: . . . ," Architectural Forum, LXXXVI (March, 1947), 116.

Some perennial and annual plants which were suggested by regional consultants for House Beautiful as being climatically adapted to this area are zinnias (Carduaceae), calendulas (Carduaceae), marigolds (Calendula officinalis), portulacas (Portulacaceae), fall asters (Aster ericoides), four-o'clocks (Mirabilis jalapa), irises (Iridaceae), chrysanthemums (Carduaceae), and sedums (Crassulaceae); and the shrubs cargana (Carboreseens), colutea (Fabacaea), Russian olive (Elaeagnus angustifolia), barberry (Berbaris), bush cinquefoil (Potenilla fruticosa), tamarix Tamaricaceae), sumac (Rhus and Toxicodendron), lilac (Syringa vulgaris), matrimony vine (Lycium halimifolium), leadplant (Amorpha canescens) and other amorphas (fabaceae), alpine currant (Ribes alpinum), buckthorn (Rhamnus), sandcherry (Prunus pumila), cotoneaster (Malaceae), rose acacia (Albizzia julibrissin), buffaloberry (Shepherdia argentea and shepherdia canadensis), sea buckthorn (Hippophae rhamnoides), aralia (Araliaceae), and rock spirea (Rosaces tomentosa).[14]

If one already has a badly oriented house and lot, much still can be done to manipulate and control the microclimate. In such a case, the south and east sides of the site could be opened as much as possible for admission of the prevailing

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[14] Joseph E. Howland, "How to Furnish a Sunpocket with Climate-hardy Plants," House Beautiful, XCII (November, 1950), 227.

summer breeze and the winter sun. Certain man-made surfaces could be replaced with grass; arbors, shade trees, and other vegetation could be strategically planted.

These alterations may be small, but combining them adds up to a momentous change in the microclimate and in one's personal comfort. These are basic factors, not additions or luxuries, and should never be overlooked in house and site planning. The use of more vegetation on a plot, if it is planned in connection with the topography and the path of the sun and prevailing winds, makes the microclimate more comfortable and reduces the need for artificial heating or cooling, thus reducing operation costs.

CHAPTER III

INSOLATING THE HOUSE

Properties of the Sun

The sun is the most important factor in climate. Its radiation is composed of three types of rays: the visible light rays, the heating infra-red rays, and the health therapy ultra-violet rays. These are the important factors of house insolation, and, along with terrain, and air, determine orientation of the house for health and personal comfort. The visible and infra-red rays are perceptible to sight and feeling, but the ultra-violet rays are invisible and can be perceived only through their effects.

Light Rays

The visible light rays are the luminous rays of the sun which cause daylight and enable us to see. They are the rays of which most people are conscious. Their presence usually denotes the presence of the other two. Insolation is calculated by the visible light rays.

Infra-red Rays

Infra-red rays are important hygienically and therapeutically. When they penetrate the body in winter and spring, they produce the added benefit of lasting warmth.

These rays travel through air without warming it appreciably; their warming effect occurs only when they hit solid surfaces which can absorb the rays. The absorbed rays cause a motion of kinetic energy which produces heat.

Body heat loss can be controlled through radiant channels, regardless of how hot or cold the surrounding air temperature may be, if the amount of radiant heat striking or leaving the skin surface is controlled. Even in zero air temperatures, the body can be kept warm by the radiant heat waves of the sun.[1] Radiant heat from warmed surfaces, whether they be human bodies, vegetation, or inorganic objects, passes to cooler surfaces without raising the air temperature between the source of the heat and the absorbing object. This means that body comfort can be achieved without too much change in surrounding air temperatures, if the nearby surfaces are cooler than the body in summer and warmer than the body in winter. The radiant temperature of interior surfaces of the house can be controlled to a great extent by insulation. Insulation intercepts the radiant sunheat of summer; the same insulation, also, stops the cooling effects of winter northers and keeps the interior heat from escaping.

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[1] Mills, Climate Makes the Man, p. 203.

Ultra-violet Rays

Ultra-violet rays exert chemical influences which are biologically important; their therapeutic values are acknowledged, but not definitely explained. Many types of air-borne bacteria are killed by them; and many kinds of diseases--rickets, tuberculosis, and respiratory disorders--develop in the absence of these rays. Ultra-violet rays are necessary in the production of vitamin.[2] From May until September such rays are especially active from eight o'clock in the morning until four in the afternoon.[3] Although ultra-violet rays do not appreciably affect personal comfort, houses that admit them are more healthful for their inhabitants.

Orienting Houses to the Sun

Orienting houses to the sun is not a new principle. In ancient Greece, Socrates suggested the same type of oriented plan as is being advocated by progressive architects today.[4] Most houses of today, since they are designed in relation to street layout, fail to take advantage of the sun and prevailing breeze. These houses of old-style planning average nine times more summer sun-heat

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[2] Fitch, American Building, p. 302.

[3] Hilberseimer, The New City, p. 81.

[4] Xenophon, Memorabilia and Oeconomicus, Vol. IV, pp. 221-222.

than houses utilizing solar planning, and in the new solar houses the average winter sun-heat is four times that of the old-style houses.[5] It has been proven that even as far north as New York a house which has large areas of glass in the south walls is cheaper to heat on a ten-year average.[6]

The orienting of houses in relation to the sun is a twofold problem. In winter, the sun's heat is desired and needed, but in summer it is very annoying and undesirable in relation to personal comfort. In winter, the sun is very low in the southern sky; in summer it is very high in the sky, even being in the northern sector part of the time (see Figure 4). Thus, it is possible, through proper orientation and installation of permanent and temporary shades to exclude the high summer sun from walls and windows while the low winter sun is freely admitted. Proper orientation in relation to the sun can change by 85 per cent or more the amount of sun heat, winter and summer, that a house receives.[7]

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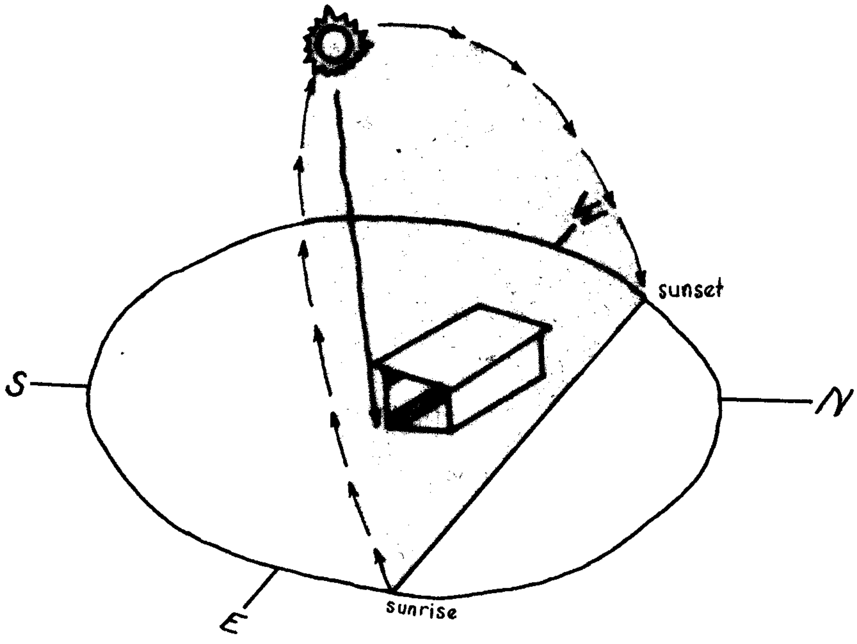
[5] "What a Big Difference a Little Reorienting Makes," House Beautiful, LXXXV (September, 1943), 64.

[6] George Nelson, Tomorrow's House, p. 178.

[7] "Climate and Houses," Scientific American, CLXXXI (November, 1949), 29.



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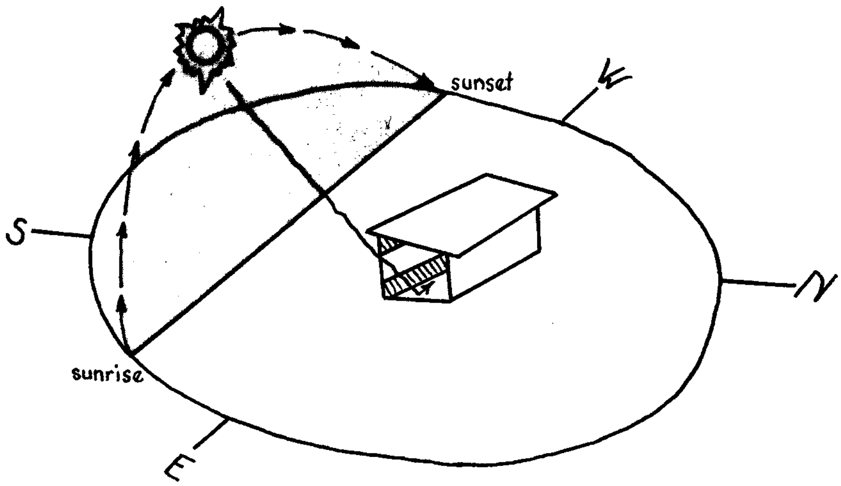

B

Fig. 4.--Relation of sun's path to insolation. (A) Summer sun. (B) Winter sun.

Windows

In the Denton area, as elsewhere, one of the principal determining factors in window placement and size should be the sun. Glass functions as a radiation trap because the solar rays penetrate it and do not return; thus, about 85 per cent of the summer sun-heat gets into the interior of a house through unprotected glass areas. Large window areas, properly oriented so as to be shaded in summer and unshaded in winter, as illustrated in Figure 5, by (A) movable blinds, (B) awning supplements to overhang, (C) ventilated metal awnings, (D) deciduous trees, and (E) deciduous trellises, reduce some of the cooling and heating loads put on mechanical equipment; admit more of the prevailing summer breeze; reduce the glare caused by excessive contrast between light and dark; take advantage of openness; and make possible the reduction of actual room sizes while visually minimizing the reduction.

It is not now desirable or necessary, as it was in the past, to use window areas divided into small panes of glass. In the early days windows had to be small and many-paned, regardless of the need for light in the interior, because of the nonexistence or high cost of large panes of glass; moreover, primitive heating methods and danger from Indians made large areas of glass a luxury and a liability. Today unlimited quantities of glass are at our disposal.

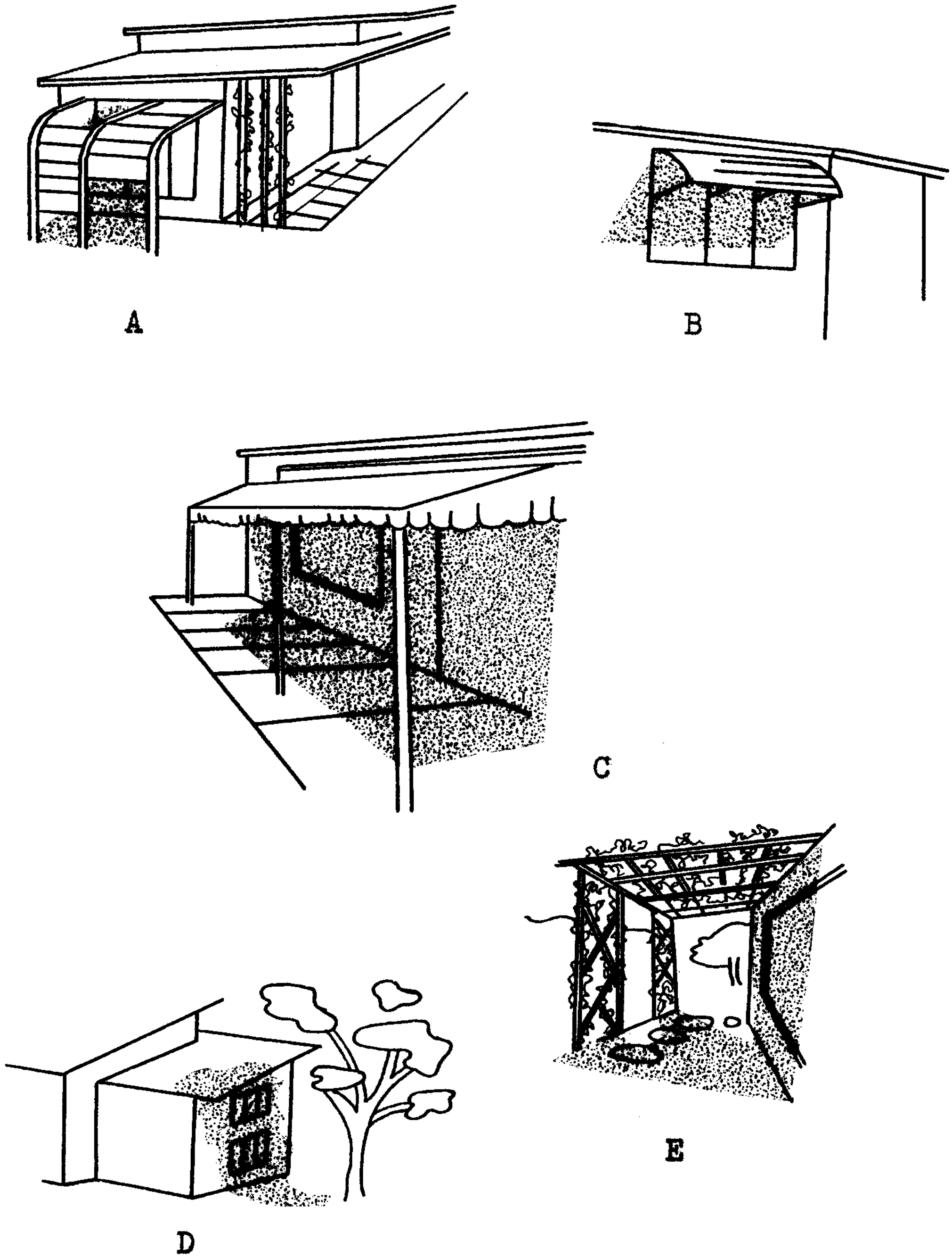

Fig. 5.--Suggestions for obtaining shade by natural and artificial sun barriers. (A) Movable blinds. (B) Awning supplements to overhang. (C) Ventilated metal awnings. (D) Deciduous trees. (E) Deciduous trellises.

Windows can be large, continuous, unbroken surfaces; they can even become walls of glass in order to obtain an even, glareless light, unbroken by the contrasting darkness of mullions. These areas of glass may be covered with heavy draperies for needed winter insulation.[8]

The altitude and azimuth angles of the sun for the different seasons in the Denton area are the key to orienting a local house to the sun. By knowing the number of degrees direction from the south horizon that the sun shines (the azimuth angle) in conjunction with the angle of altitude, insolation can be calculated for windows in buildings for any time of the day or year. As shown in the sun chart in Figure 6 A, in the Denton area the summer sun has an angle of altitude of 46° or higher from eight o'clock in the morning till four o'clock in the afternoon. In spring and fall the sun has an angle of altitude of 46° (see Figure 6 B) or higher from nine-thirty in the morning until two-thirty in the afternoon. As Figure 6 C shows, the winter sun has only a 34° angle of altitude at noon; thus, winter insolation would not be affected by any overhang constructed to exclude sun rays for a 46° angle of altitude.

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[8] Langewiesche, "How to Control the Sun," House Beautiful, XCII (March, 1950), 105.

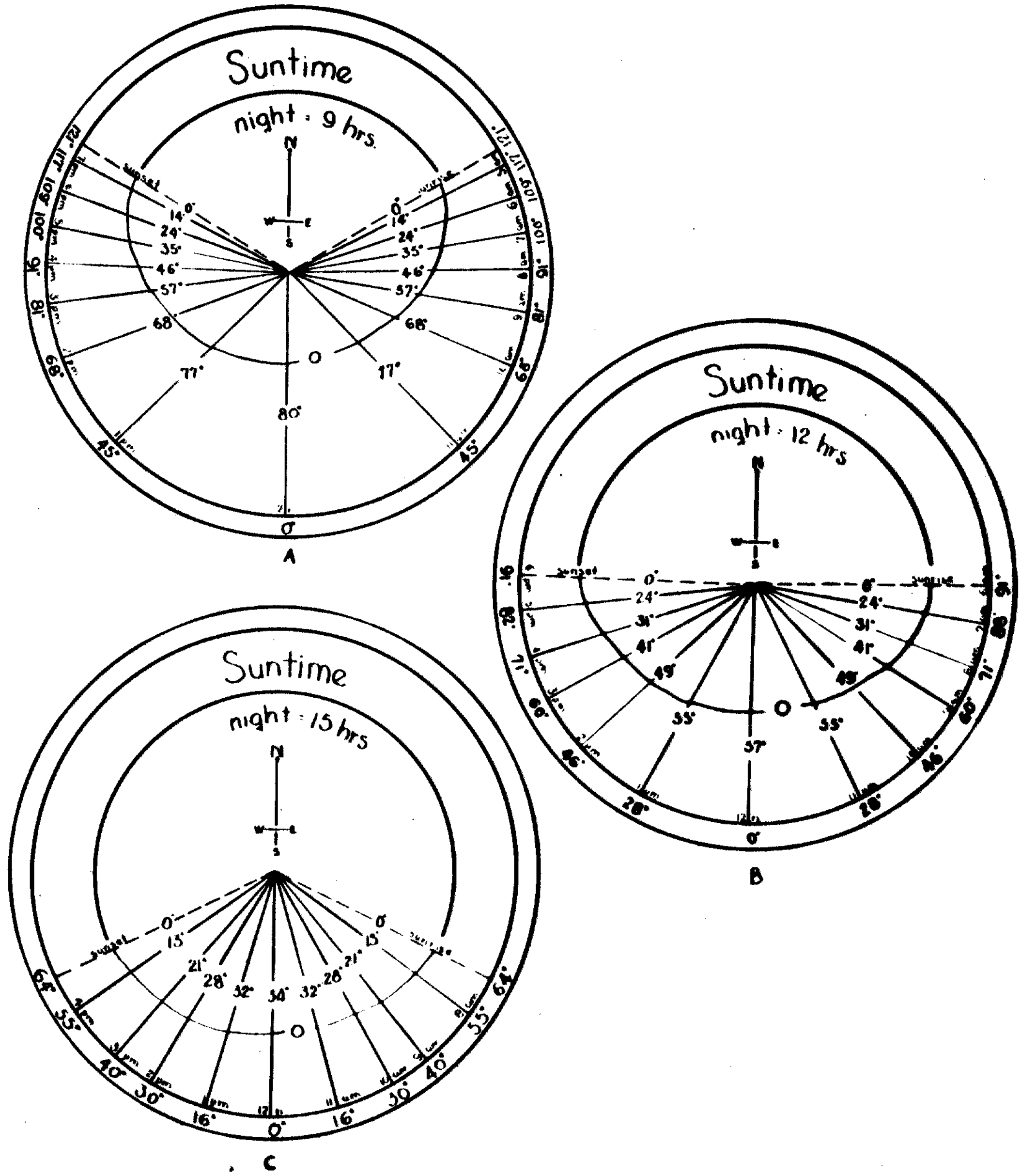

Fig. 6.--Sun chart, indicating the altitude and azimuth angles for Denton, Texas. (A) Summer soltice, June 21. (B) Spring and fall equinox, September 21 and March 21. (C) Winter soltice, December 21.

The duration of the insolation, which can be calculated from Figure 6, also is important, as is the size of the sun prism formed by sun rays coming through the window. Both duration and size of the sun prism depend on the size of the window, the orientation of the room, the time of day, and the season of the year. As the sun changes its course throughout the year, the form and size of the sun prism is also constantly changing.

North windows.--Large north windows are probably the least desirable, winter or summer, in this area. North windows do get sun in the summer, as Figure 7 illustrates.

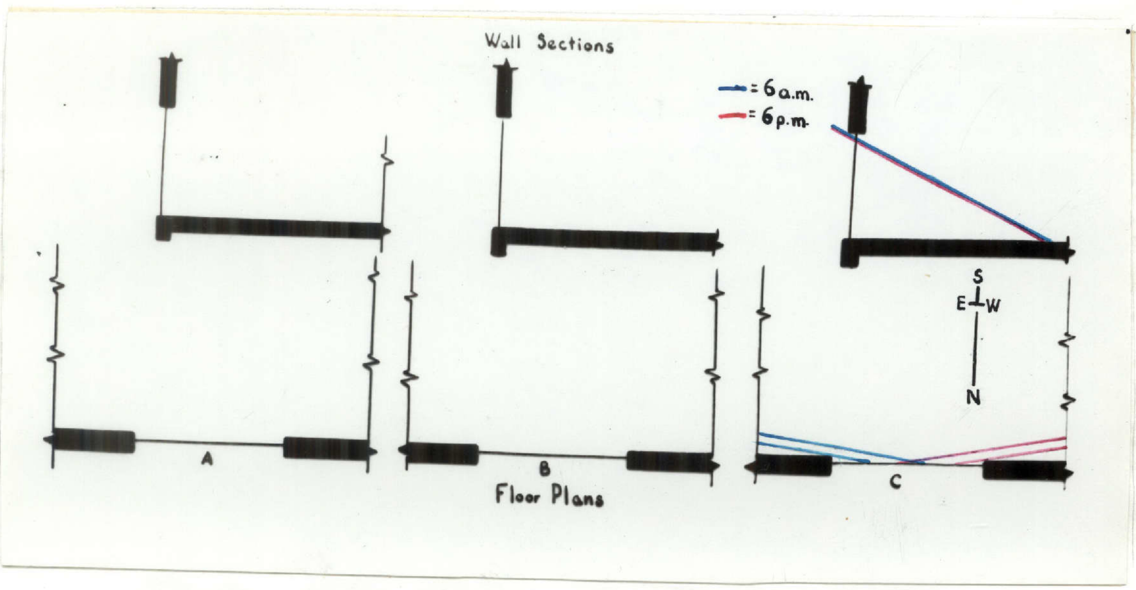

Fig. 7.--Sun's penetration into a north room through a seven-foot-high window with no overhang, calculated at two-hour intervals, beginning at six a.m. (A) Winter soltice, December 21. (B) Spring and fall equinox, September 21 and March 21. (C) Summer soltice, June 21.

Some morning sun strikes them from the northeast, which is not objectionable; but the hot evening sun from the northwest penetrates them, heating the house on summer evenings when it needs to be cooling off. Thus, north windows should be protected in summer by a vertical sun barrier. The winter sun never gets to north windows. These windows do not get any sun-heat in winter, but lose heat from the inside, which raises heating costs. Thus, for an easier-to-cool and easier-to-heat house only high, small windows, for cross ventilation, should be used on a north exposure.

South windows.--For purposes of insolation, south windows are most effective, as they collect much more sun in winter than in summer (see Figure 8).

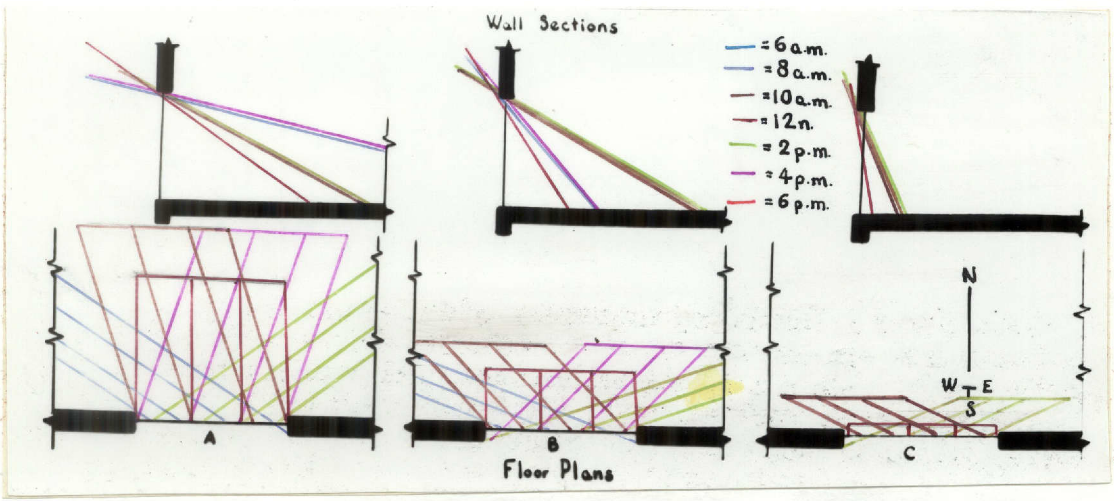

Fig. 8.--Sun's penetration into a south room through a seven-foot-high window with no overhang, calculated at two-hour intervals, beginning at six a.m. (A) Winter soltice, December 21. (B) Spring and fall equinox, September 21 and March 21. (C) Summer soltice, June 21.

Southerly orientation as discussed here, includes a southeasterly exposure (see Figure 9), as well as due south, because windows facing somewhat east of south take better advantage of the prevailing summer breeze from the southeast while still utilizing the winter sun-heat. The high

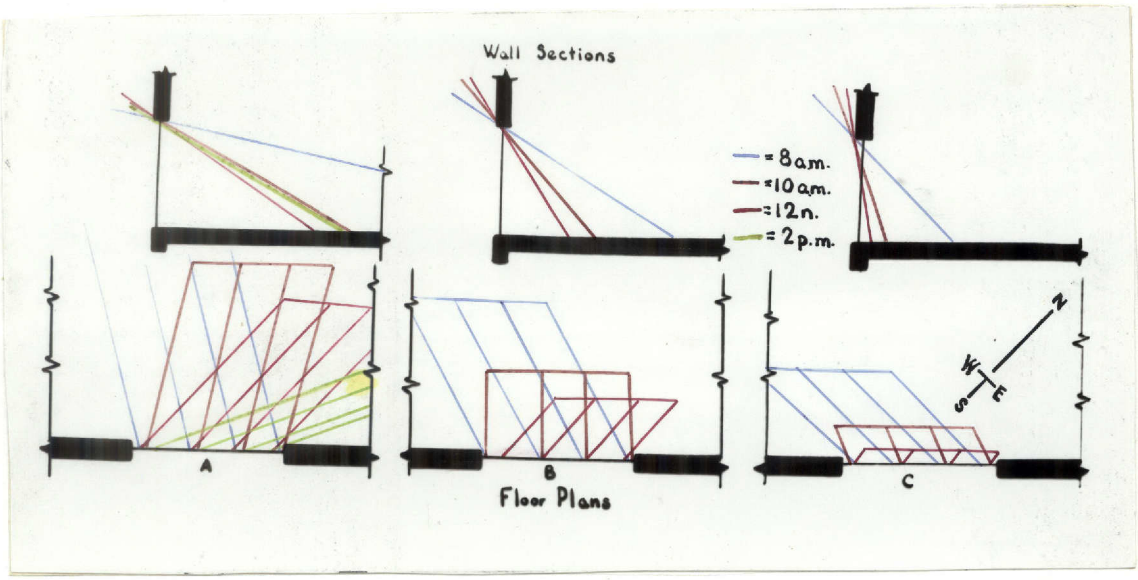

Fig. 9.--Sun's penetration into a southeast room through a seven-foot-high window with no overhang, calculated at two-hour intervals, beginning at six a. m. (A) Winter soltice, December 21. (B) Spring and fall equinox, September 21 and March 21. (C) Summer soltice, June 21.

summer sun strikes south windows at an acute angle; the low winter sun hits more squarely, shining deep into the interior. South windows, shaded in such a way as to cut off the high summer sun and to admit the low winter sun, function almost perfectly by letting in much sun-heat in winter, but practically none in summer. They will reduce the amount of artificial heat needed, rather than increase it, because, in this area when 76 per cent of the days are clear or partly clear, the sun-heat that penetrates into the house when the sun is shining is more than sufficient to balance the extra heat that leaks out through the glass and curtains at night or on cloudy days.

East windows.--Although they get more sunshine in summer than in winter (see Figure 10), east windows can be

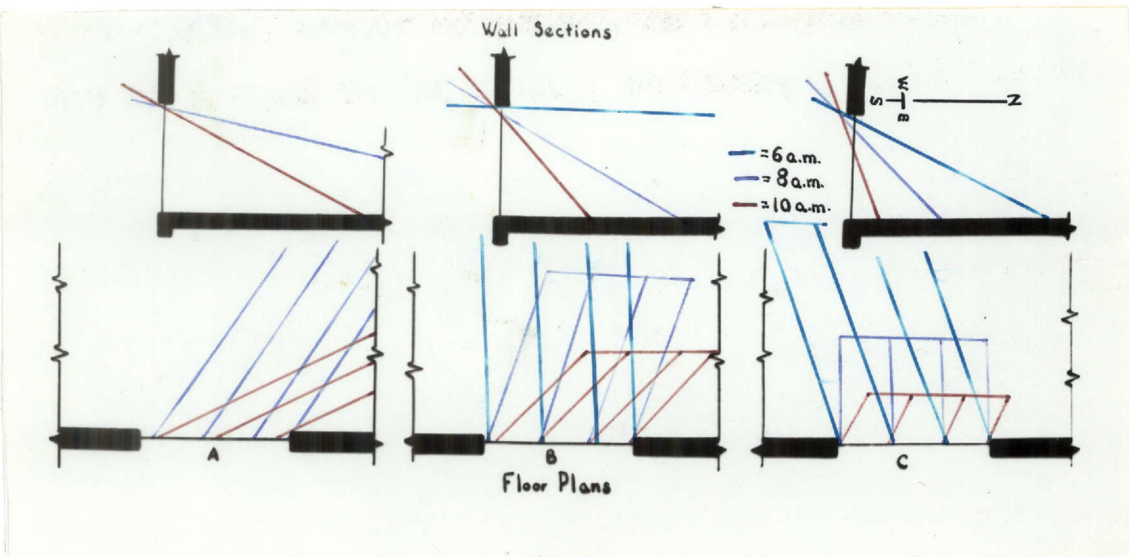

Fig. 10.--Sun's penetration into an east room through a seven-foot-high window with no overhang, calculated at two-hour intervals, beginning at six a. m. (A) Winter soltice, December 21. (B) Spring and fall equinox, September 21 and March 21. (C) Summer soltice, June 21.

left about average size, since the sun strikes them in the morning while the air is still cool. East windows are good much of the time, and rarely do serious harm; but they will not reduce heating costs.

West windows.--West windows are similar to east windows in that they get more sun in summer than in winter, as Figure 11 illustrates; however, at the critical time--in the hot afternoon--the low western summer sun is almost horizontal, penetrating the interior deeply to cause much

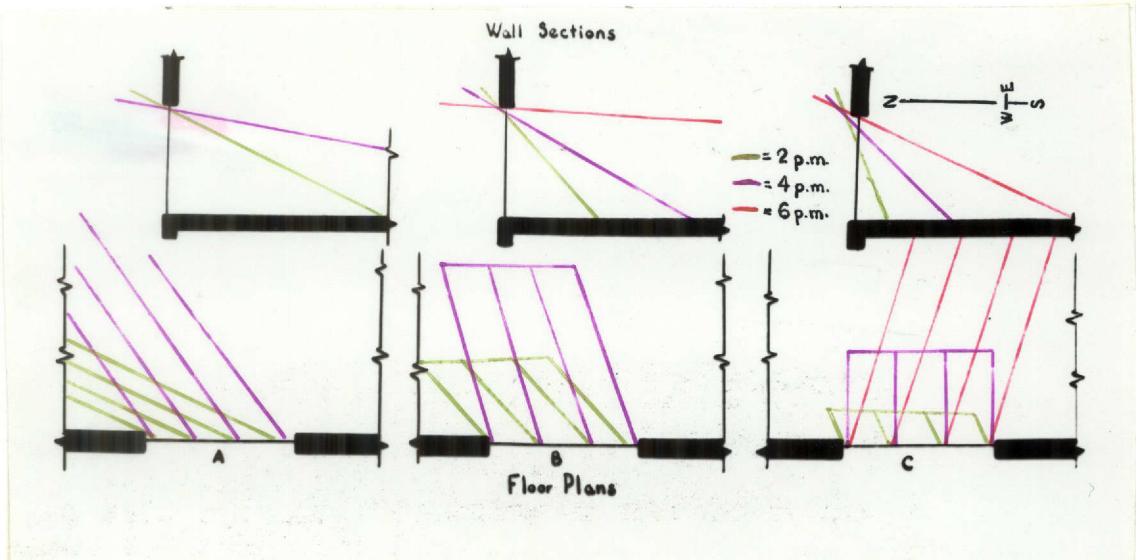

Fig. 11.--Sun's penetration into a west room through a seven-foot-high window with no overhang, calculated at two-hour intervals, beginning at six a.m. (A) Winter soltice, December 21. (B) Spring and fall equinox, September 21 and March 21. (C) Summer soltice, June 21.

discomfort. Overhangs or awnings will not satisfactorily shade west windows; vertical sun-barriers are needed outside to intercept the sun-heat. West windows admit sun at the wrong time of year and day; thus, west windows should be small, possibly omitted entirely, unless well protected.

The influence of windows upon temperature control in buildings in Denton County may be summarized as follows: South windows with proper shade exclude the hot summer sun, admit the prevailing summer breeze, and, contrasted with those differently oriented, save heating costs in winter. Large north windows are not especially desirable since they increase heating costs in winter, and raise the temperature in an already hot house on late summer afternoons. Sun coming through an east window is not objectionable in the mornings while the air is still cool, but west windows admit heat in summer and cold in winter and are generally undesirable unless they give access to a special view.

Walls

Walls derive the same effects from sun-heat as do windows similarly oriented. The John B. Pierce Foundation, in a study of orientation made in 1936 in the New York area, investigated the amounts of sun-heat received by walls of different aspect. It was determined that west and north walls receive six times as much heat in summer as in winter. East walls receive the early morning sun of summer before the air becomes heated by the sun. South walls receive almost five times as much heat from the low winter sun as from the high summer sun; in fact, south walls receive more heat per day in mid-winter than walls facing in any other direction at any season of the year. Except in subtropical regions, variation in these conditions would not be great.[9] In buildings in the Denton area, it is best, therefore, for most of the living areas to face south and east, with closets, bathrooms, stairs, and halls reserved for the north and west sides (Figure 12).

Owing to the effects of radiant heat, wall temperature is more important than air temperature in connection with body comfort. Walls directly exposed to the sun all day store heat and cool slowly, even in a cool breeze; hence, houses must be well insulated in addition to being properly oriented, to obtain the best results from solar radiation. If heat can enter through walls in summer and escape through them in winter, much of the value of planned orientation will be nullfied. In the Denton County area two layers of insulation should be used in southwest, west, and northwest walls, which are the ones exposed to summer sun and winter winds.

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[9] "Orientation for Sunshine," Architectural Forum, LXVIII (June, 1938), 18-22.

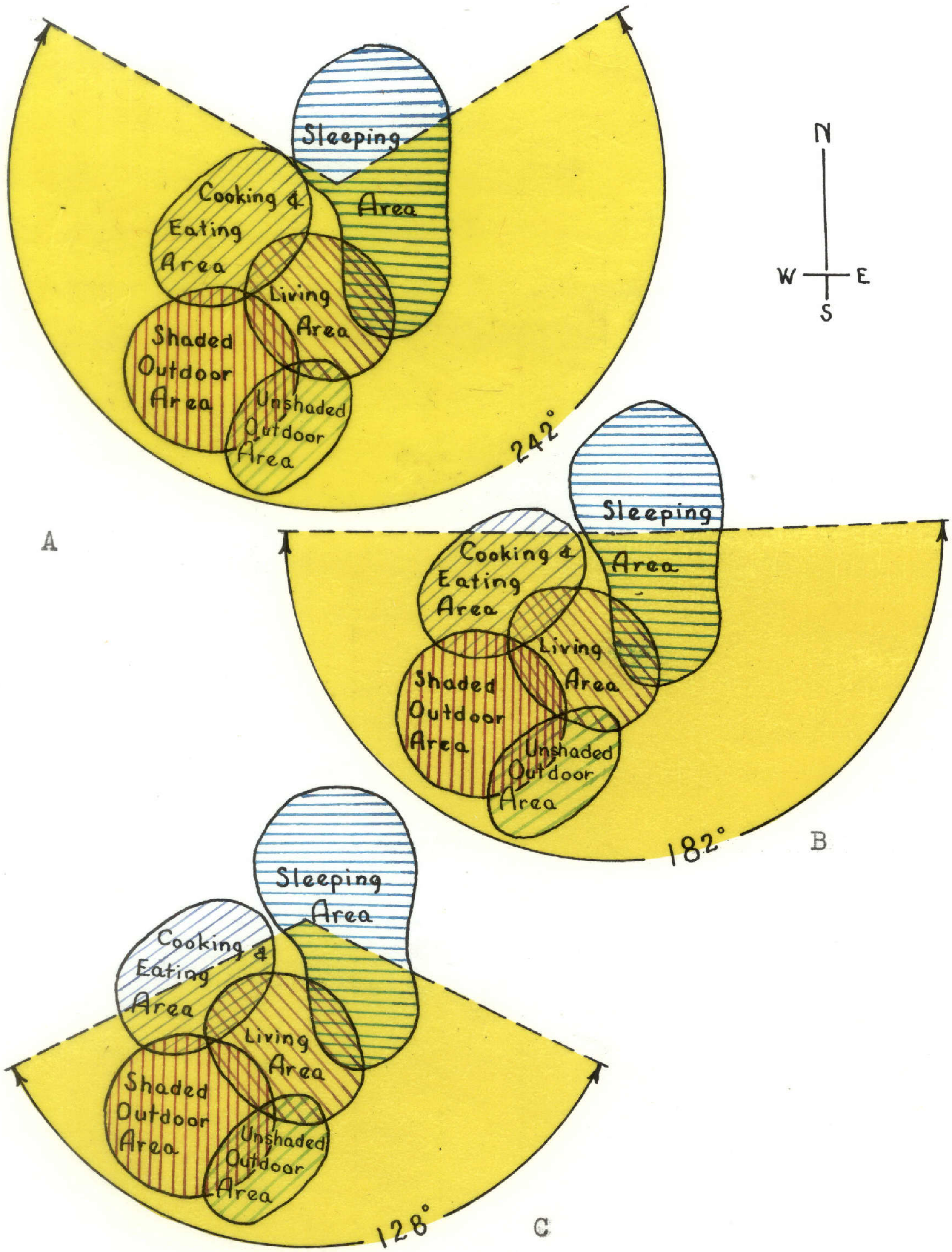

Fig. 12.--Orientation of living areas in relation to the sun. (A) Summer sun. (B) Spring and fall sun. (C) Winter sun.

Floors

All-wood solar houses tend to become overheated while the sun is shining and to cool off almost instantly when the sun is hidden.[10] With concrete floors the reverse occurs, since concrete has a greater capacity for absorbing and storing heat than does wood. The exposed concrete floors absorb much of the winter heat from the shining sun and reradiate it slowly for hours after there is no sun. Also, shaded concrete remains cooler in summer than does wood, which makes for a cooler microclimate.

Roofs

A roof gets twice as much sun-heat as does any wall;[11] hence, roofs must be protected from the direct summer sun in this area in order to have a comfortable microclimate. Sun-heat is reflected as light is reflected; it bounces off shiny and light-colored surfaces in the same manner as do light rays. A dark-colored roof with a film of chemically treated water or a water spray--the latter works equally well on flat or pitched roofs--will reflect sun-heat effectively in the summer; and without its film of water, it will absorb more winter sun-heat. Double insulation within

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[10] Nelson, Tomorrow's House, p. 179.

[11] "There Is More Than One Way to Beat the Heat," House and Garden, XCIX (June, 1951), 120-123.

the roof itself, one layer being of reflective metal foil, will markedly reduce the summer attic temperature and retain the inside winter heat.

Other methods of making houses cooler in summer are by protecting the roof by strategically placed deciduous trees and by air-washes immediately below the sheathing and above the insulation. These devices will not conflict with the absorption of the warming winter sun, since the trees will be leafless and the other devices will be shut off.

Solid overhangs are advantageous in this area. In addition to creating necessary summer shade, if they are of sufficient depth, they permit windows to be left open for adequate ventilation during sudden showers without fear of a water-soaked interior.

CHAPTER IV

VENTILATING THE HOUSE

Atmospheric environment, which is the basis for summer thermal comfort, is the product of three air factors: temperature, movement, and relative humidity.[1] These factors cannot be separated because a standard for one will change as another of the factors varies. Table 1 illustrates the effect that changes in wind velocity have on a comfortable air temperature. It shows how a warmer air temperature is required for body comfort as wind velocity increases.

TABLE 1

EFFECT OF WIND VELOCITY ON AIR TEMPERATURE NECESSARY FOR COMFORT *

Wind Velocity (miles per hour)	Air Temperature (degrees Fahrenheit)
1/10 mph	68 F.
1/2 mph	73 F.
1 mph	75 F.
2 mph	77.7 F.
3 mph	78.3 F.
5 mph	79.3 F.
10 mph	80.6 F.

* Langewiesche, "Can You Control the Wind," House Beautiful, XCII (June, 1950), 88.

Air Temperature

Air temperature in the daytime is cooler above the radiating surface of the ground, but nighttime air

[1] American Public Health Association, Planning the Neighborhood, p. 30.

temperature is cooler near the ground because the lighter warm air rises after the sun sets. A few feet above or below ground level makes a difference in the air temperature in the daytime (see Table 2) but the below-the-ground temperature cannot be utilized well in the Denton area because of the crumbly and friable soil characteristics (see page 4).

TABLE 2

EFFECT OF HEIGHT ON DAYTIME AIR TEMPERATURE*

Summer Temperature (degrees Fahrenheit)	Height (feet)	Winter Temperature (degrees Fahrenheit)
82	10	27
84	8	27
85	6	27
87	4	26
90	2	24
	ground level	
59	2	32
58	4	38
56	6	42
55	8	44
54	10	46

* Langewiesche, "There's a Gold Mine Under Your House," House Beautiful, XCII (August, 1950), 92.

Air Humidity

Humidity and air movement affect personal comfort more than actual air temperature. Humidity determines the amount of heat which can be carried off by evaporation. If there is too much humidity, as in the Denton area, perspiration will remain on the body unless the circulation is sufficient to evaporate it.[2] Humidity cannot be readily controlled except by some mechanical dehumidifying device; on the other hand, air movement can be controlled merely by proper orientation of a house to the prevailing breeze.

Air Movement

Because of the excessive humidity and high temperature which prevail locally, air movement is as important to atmospheric comfort as is shade. The aim is not a violent but a constant, general breeze. Moiryama, an observer participating in a field study of the Committee on the Hygiene of Housing of the American Public Health Association, held that indoor air movements of at least fifty feet per minute are essential to summer comfort.[3] Hence, a positive air change and air movement must be maintained within the house for personal comfort.

Air movement within the house is the product of two factors: velocity of outside air movement--which cannot be altered--and circulation of air through the house--which can be altered.[4] The problem is to facilitate the natural flow

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[2]Langewiesche, "Different Places Need Different Houses," House Beautiful, XCIII (January, 1951), 59.

[3]American Public Health Association, Housing for Health, pp. 78-80, citing American Public Health Association, Planning the Neighborhood, p. 31.

[4]Ibid., p. 30.

of summer air through a well-shaded, open house for effective cross-ventilation and upward-ventilation.

Air should flow into and through the house, and any obstruction--indoor or out--will cut down the effectiveness of this air movement. The prevailing southeasterly breeze should not be interrupted by any solid exterior barriers on the south or southeast of a site. If a sight-barrier is necessary, it needs to be one which will admit the breeze with as little interference as possible; for example, a trellis, which will cut the view but not all of the breeze. As few solid interior partitions as possible should be used for unobstructed interior air movement. Interior louvered doors and louvered sections in walls will aid interior air movement and at the same time give privacy.

Since air at different temperatures differs in weight, upward ventilation channels in a house will permit the warm air to flow up and out of the house (see Figure 13). This is advantageous, especially at night, if there are low openings near the ground for the cooler night air to enter while the warmer air is rising upward. This type of air movement does not require a breeze to push the cool air in and the hot air out; it depends only on the difference in weight. Thus, if a room has two openings at different levels--one low, the other high--the cooler air enters by the lower opening and floats the warmer air out by the higher opening, regardless of breeze.

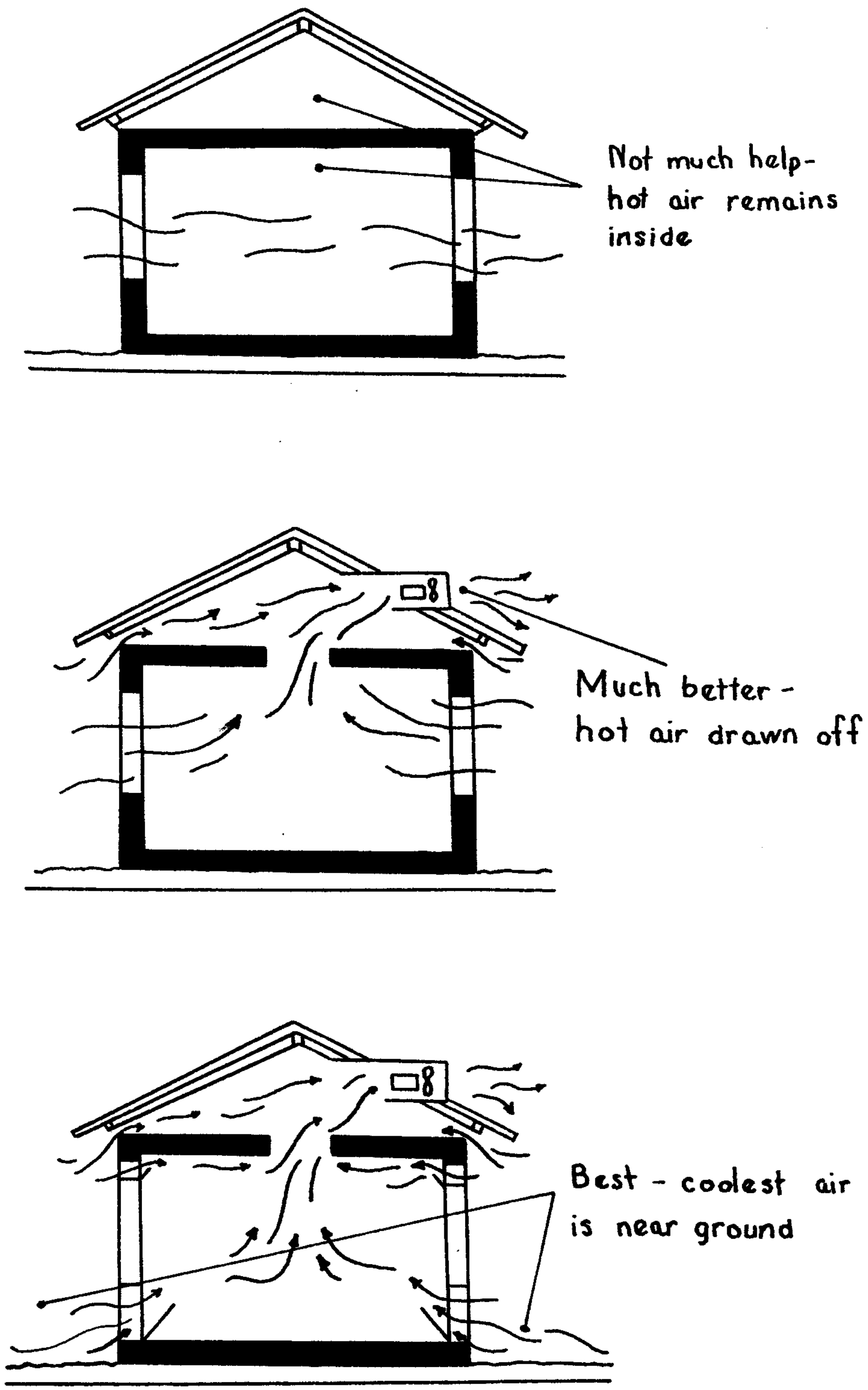

Fig. 13.--Suggestions for obtaining adequate ventilation.

Interior channels by which the warm air can flow up and out at the top of a house while the cooler night air enters near the ground level will help alleviate discomfort in the Denton area. Such channels can be made by open transoms which extend all the way to the ceiling, clerestory windows, registers in the ceilings, and open staircases for the air to flow into the attic and then out through attic vents (see Figure 13). If interior air channels are adequate and function properly, the need for the high twelve-foot ceilings of the Old South will be unnecessary; only a well-proportioned ceiling between eight and nine feet high will need to be used.

The exterior sources of light and air are usually considered together, though they need not be so considered in contemporary architecture. Air can enter through louvered sections of exterior walls, which may be above or below window areas or completely separated from light sources. If such louvers are properly placed and the house oriented to the prevailing summer breeze, ventilation will be adequate even on still days.

Large openings, windows, or windows and louvers on the south or southeast wall of a house will open the interior for the much needed prevailing breeze. The same large southeast windows recommended for orientation to the sun are best for air movement in the Denton area because it has been determined that buildings with openings that oppose the wind have a better average indoor air movement than buildings with openings that parallel the wind. It was found that buildings with openings which opposed the wind showed average indoor air movements of 7 per cent of outside velocities; while in buildings which paralleled the wind, indoor velocities averaged only 4 per cent of outside velocities.[5]

High, smaller windows on the north wall will make the air move faster through the interior as a result of what is known as the "orifice principle."[6] According to investigators, high windows under an overhang would exhaust air from the interior by a pumping action where a low or negative pressure area exists (see Figure 14).[7]

Because the winter winds come from the northwest and the summer breezes from the southeast or south, the same suggestions that applied for obtaining the summer breeze aid in winter wind control. The ceiling and attic vents can be closed. The southeast windows that admit the

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[5] Ibid., pp. 31-32.

[6] "The All Purpose Room," House Beautiful, XCI (November, 1949), 222.

[7] "Weather's Effect on Design Studied by Texas Colleges," Architectural Record, CVIII (August, 1950), 161.

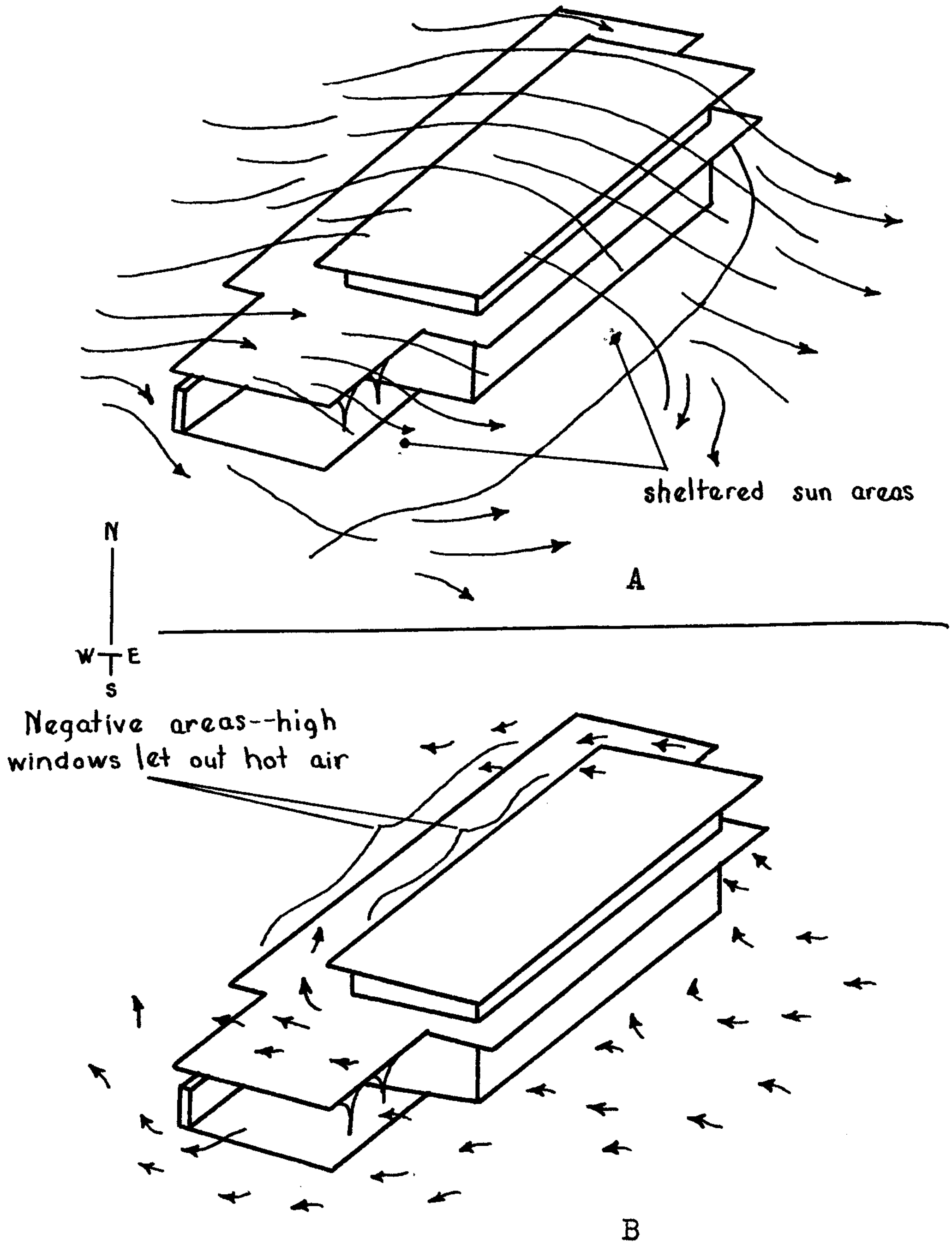

Fig. 14.--Relation of air circulation to house design. (A) Winter wind with the house itself as a windbreak. (B) Summer breeze and negative pressure areas.

prevailing summer breeze are protected from the cold northwest winds in winter; and, at the same time, they admit the winter sun to help heat the interior surfaces and air. A mean ceiling height of between eight and nine feet keeps the warm air from rising above a useful area. The outdoor summer breeze deflectors and the vertical west and northwest shade barriers will act as winter windbreaks and deflectors for the house. These protective devices also make possible the use of south and southeast outdoor areas for a late fall, winter, and early spring terrace and garden.[8]

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[8] Ibid.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

For the maximum of personal comfort and health, a house for Denton County, Texas, should admit a maximum of direct winter sun, a minimum of summer sun, the optimal amount of light at all times, a maximum of ultra-violet rays all year, and a maximum of the prevailing summer breeze. To incorporate all these features a house must be properly oriented in a controlled microclimate.

Denton County's soil conditions and extremes in atmospheric conditions combine at times to make an uncomfortable environment. This area has a varied humidity and a temperature which varies from cold in winter to very hot in summer. The atmospheric environment of the short winter is not a great problem; it can be controlled with windbreaks, sun areas, insulation, proper weather-stripping, and good heating. The atmospheric environment of the long, hot, and usually humid summer is the major problem for which protection must be planned. Fortunately, protective measures that help alleviate uncomfortable summer conditions work equally well in the winter because of the complementary nature of the prevailing summer breezes and the winter winds. Temperature can be cooled as much as 15 degrees F. in the summer and raised as much as 40 degrees F. in winter by good building practices.[1]

The south or southeast part of town, of a hill, and of a lot is the best place for building from the standpoint of microclimate. Especially, on a hill which has an incline of at least one foot in twelve, a site midway on the south or southeast side is the best. The southern slope actually receives fewer hours of the direct hot summer sun and gets more hours of the direct, warming winter sun. It is open for the prevailing southeasterly breeze of summer, is protected from the northwest winds in winter, and is above the heavier, cold winter air which settles to the base of the slope.

The practice in architecture of stripping a plot of ground, leveling it, and starting from nihility has been one of the causes for an uncomfortable atmospheric environment. A natural lot with trees and grass helps make a much more comfortable microclimate, since living vegetation maintains a cooler temperature in the sun than do exposed soil and inorganic elements. The living vegetation absorbs a large part of the heat, light, and noise and actually manufactures coolness by its suspiration. Then, in winter the cooling forces of the vegetation stop when the deciduous trees are leafless and the grass is dry and dormant.

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[1] "Can I Really Control Climate?," House Beautiful, XCI (October, 1949), 141.

If other vegetation is planted when the trees and grass are nonexistent or inadequate, the microclimate can be made even more comfortable. Deciduous trees and shrubs can be strategically planted on the south and southwest to create much-needed shade in the summer, which can reduce the temperature 5 degrees or more. Moreover, a few evergreen trees and shrubs planted strategically on the north and northwest will shade the site from the late afternoon sun in summer and make an excellent wind shield in winter. This shield may raise the temperature 3 to 5 degrees and cut the wind velocity 20 per cent, thus reducing heating costs. On the other hand, a lot which is completely inclosed either by plants or by an artificial barrier needs an opening at the lowest part; otherwise, the inclosure will act as a trap for the heavy, cold air in winter, causing an unfavorable change in the microclimate.

The sun, which is the most important factor in climate, is composed of three types of rays: the visible light rays, the heating infra-red rays, and the health therapy ultraviolet rays. These, along with terrain and air conditions, determine the orientation of the house for a more comfortable microclimate.

Orienting a house to the sun is a twofold problem: in winter, the sun's heat is desired; but in summer, it is very annoying and undesirable. Because of the seasonal variation in the angle with which the sun's rays strike the earth, a solution is possible. In winter the sun is very low in the southern sector of the sky and in summer it is high in the northern sector. Permanent and temporary shades can be installed so that the high summer sun is excluded from walls and windows while the low winter sun is freely admitted. Shades that are constructed to exclude the sun for a 46^{o} angle of altitude will protect the house during the hotter part of the summer day from eight o'clock in the morning until four in the afternoon, while admitting all of the low winter sun which has only a 34^{o} angle of altitude at noon.

Large window areas, properly protected, on the southern side of a house will function best for a more comfortable microclimate, both summer and winter, because the Denton County area has sunshine for 76 per cent of the time during the daylight hours of the year. Such windows, properly shaded and open in summer, will admit the needed prevailing breeze; and they will admit and trap more of the warming winter sun, while being protected from the cold northwest winds. North windows do little to further a better microclimate because they get the undesirable summer sun but not the needed warming sun in winter; so unless there is a special view, they should be small and high to cut down the area exposed to cold north winds in winter and to create cross ventilation in summer. East and west windows are similar in that they get more sun in summer than in winter. The east windows can be of average size because the sun strikes them in the cool morning; but, since west windows get the sun in the hot afternoon, they should be small or possibly omitted entirely, unless well protected by vertical exterior sun barriers.

Walls, floors, and roofs must be properly constructed and oriented to the sun, also, to help establish a desirable microclimate. Walls will be much cooler if they are shaded by overhangs and vegetation in the summer. For best results in a solar house, concrete floors should be used because shaded concrete remains cooler than wood in summer; and, unshaded in winter, it absorbs and stores more sun-heat than wood. As is the case with walls, a roof is cooler in summer when shaded; high, spreading trees provide the best shade. In the absence of shade, a light-colored roof reflects the sun-heat; a dark roof which has a film of chemically treated water or a water spray will reflect the sun-heat in summer. In winter, when the use of the spray has been discontinued, it will absorb more sun-heat.

Out-door areas can be adapted for more comfortable outdoor living both winter and summer in the Denton County area. A summer outdoor area which is well shaded but completely open to the southeasterly summer breeze will prove more usable than just any outdoor area. The same outdoor area will be sheltered from the winter winds; it will face the sun, and it can be used from six weeks to two months earlier and later than would otherwise be possible.

The Denton area has a hot and usually humid summer atmospheric environment. Air movement is the principal factor which can help alleviate the usually uncomfortable microclimate in the Denton area. An indoor air flow of fifty feet per minute has been deemed necessary to alleviate the hot, moist condition. This can be accomplished by building houses oriented to oppose the almost constant prevailing breeze. Even when there is no breeze, air movement can be maintained by providing means for heavier cool air to displace the light, warm air. Interior features of importance are open plans, many large, low, well-shaded openings on the south to admit the maximum of the prevailing breeze, small high openings on the north for cross ventilation, and attic vents to exhaust the warm air as it rises. Humidity cannot be readily controlled except by mechanical means.[2]

Comfort is much affected by the transfer of radiant heat between the body and surrounding surfaces. Cool surrounding surfaces in summer and warm surrounding surfaces in winter promote bodily comfort. By proper use of summer shade, insulation, and winter sun, the temperatures of

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[2] Elizabeth Gordon, "'Windbreaks' and 'Sunpockets,'" House Beautiful, LXXXV (August, 1943), 50.

these radiant surfaces may be controlled so as to promote comfort.

Conclusions

The microclimate of individual lots can be controlled. It is evident that consideration of siting, orientation and ventilation--if applied in planning and building of houses in the Denton County area--will result in much more comfortable year-round living. All need for additional cooling and heating aids will not be eliminated, but it will be greatly reduced.

BIBLIOGRAPHY

Books Cited

American Public Health Association, Planning the Neighborhood, Chicago, Public Administration Service, 1948.

Fitch, James M., American Building--The Forces That Shape It, Boston, Houghton Mifflin Company, 1948.

Hilberseimer, Ludwig, The New City, Chicago, Paul Theobald, 1944.

Mills, Clarence A., M. D., Climate Makes the Man, New York, Harper and Brothers Publisher, 1942.

Mumford, Louis, Sticks and Stones, New York, Boni and Liveright, 1924.

Nelson, George, Tomorrow's House, New York, Simon and Schuster, 1945.

United States Weather Bureau, Our Climate, Maryland, State Weatherservice, 1939.

Xenophon, Memorabilia and Oeconomicus, translated by E. C. Marchant, Vol. IV, New York, G. P. Putnam's Sons, 1923.

Bulletin Cited

Carter, W. T., The Soils of Texas, Bulletin No. 431, Austin, The University of Texas Press, 1931.

Articles Cited

"The All Purpose Room," House Beautiful, XCI (November, 1949), 222-223.

"An Arizona House That Baffles the Western Sun," House Beautiful, XCII (April, 1950), 156-159.

"Can I Really Control Climate?," House Beautiful, XCI (October, 1949), 138-141.

"Climate and Houses," Scientific American, CLXXXI (November, 1949), 29.

Fitch, James M., "If You've too Much Climate, Try Climate Control," House Beautiful, XCII (May, 1950), 168-169.

_____, "It's Cooler in the Suburbs," House Beautiful, XCIII (June, 1951), 132.

"Good Lawns Keep You Cooler," House Beautiful, XCII (March, 1950), 108-109.

Gordon, Elizabeth, " 'Windbreaks' and 'Sunpockets'," House Beautiful, LXXXV (August, 1943), 50-51.

House Beautiful, XCIII (April, 1951), 129-135.

Howland, Joseph E., "How to Furnish a Sunpocket with Climate-hardy Plants," House Beautiful, XCII (November, 1950), 226-227.

"Knowing Climate Will Reduce Building Costs," Science News Letter, LVII (January 28, 1950), 61.

Langewiesche, Wolfgang, "Can You Control the Wind?," House Beautiful, XCII (June, 1950), 88-89.

_____, "Different Places Need Different Houses, House Beautiful, XCIII (January, 1951), 58-61.

_____, "How to Control the Sun," House Beautiful, XCII (March, 1950), 104-107.

_____, "How to Pick Your Private Climate!," House Beautiful, XCI (October, 1949), 146-149.

_____, "So You Think You're Comfortable!," House Beautiful, XCI (October, 1949), 132-134.

_____, "There's a Gold Mine Under Your House," House Beautiful, XCII (August, 1950), 92-94.

_____, "Your House in Florida," House Beautiful, XCII (January, 1950), 70-71.

"Microclimatology: A Big Word for the Study of Small-size Weather," Architectural Forum, LXXXVI (March, 1947), 114.

"Orientation for Sunshine," Architectural Forum, LXVIII (June, 1938), 18-22.

"The Philadelphia Story on Climate Control," House Beautiful, XCII (September, 1950), 119-25.

Pickens, Buford L., "How to Live at Peace with the Gulf Coast Climate," House Beautiful, XCII (July, 1950), 74-76.

Siple, Paul E., "15,750,999 Americans Live in This Climate," House Beautiful, XCI (November, 1949), 202-203.

_____, "Have You Ever Seen the Portrait of a Climate?," House Beautiful, XCI (October, 1949), 162-163.

_____, "How Many Climates Do We Have in the U. S.?," House Beautiful, XCI(October, 1949), 136-137.

_____, "How to Live with America's Worst Climate," House Beautiful, XCIII (March, 1951), 96-101.

"There Is More Than One Way to Beat the Heat," House and Garden, XCIX (June, 1951), 120-123.

"Weather's Effect on Design Studied by Texas Colleges," Architectural Record, CVIII (August, 1950), 161.

"What a Big Difference a Little Re-orienting Makes," House Beautiful, LXXXV (September, 1943), 64.

Unpublished Material

Records from the United States Department of Agriculture Soil Conservation Service, Texas A. & M. College Agricultural Experiment Station, Substation No. 6, Highway 24, Denton, Texas.