

MICROCLIMATIC DESIGN FOR ENERGY CONSERVATION

by

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A MASTER'S THESIS

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requirements for the degree

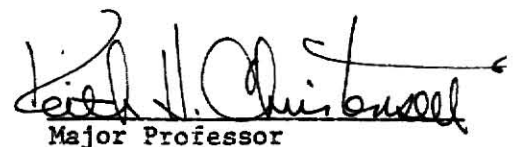
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## INTRODUCTION

A recent article in Nation's Business magazine examined the United States' current energy situation and discussed the state of current and developing technologies for decreasing our nation's dependence on imported petroleum products. Of all the alternatives presented, energy conservation was cited as the most practical and cost-effective measure. Daniel Yergin, co-editor of Energy Future and a lecturer at Harvard's Center for International Affairs, has maintained that the U.S. can cut down on energy usage by thirty to forty percent "with only modest adjustments to the way people live."<sup>1</sup> He has stated that an effective nation-wide energy conservation effort will save billions of dollars, remove pressure from a strained environment, decrease air pollution, reduce some of the economic pressure faced by the dollar, and lessen our dependence on OPEC oil.<sup>2</sup>

Architects today find themselves on the front lines of the battle against energy waste. This is the case due to the large quantities of energy consumed by the building industry in our nation. The ramifications of architects' decisions--in selection of materials, methods of construction, siting, systems, etc.--account for as much as forty percent of the energy produced in this country.<sup>3</sup> It has been estimated that one-third of our country's total energy consumption goes just for the heating, cooling and lighting of buildings.<sup>4</sup> Further, it has been determined that as much as fifty percent of that energy is wasted.<sup>5</sup> Architects have come to realize that this situation must change. Leo Daly, in "Energy and the Built Environment" has estimated that thirty percent of the energy used in older buildings, and sixty percent



in new ones could be saved through implementation of effective energy-conserving measures.<sup>6</sup> By 1990, such a program of energy conservation in buildings would be equal to that produced from 12.5 million barrels of oil.<sup>7</sup>

These figures point out why architects, as the designers of many of the buildings erected in our country, are increasingly anxious to produce structures which do not waste energy. At the same time, the more traditional design problems of aesthetics, function and cost are still part of the design-making process.

Many strategies have been promoted for designing buildings which use less energy. Among these are super-insulated buildings, double-shell designs, active and passive solar buildings, earth-sheltered buildings, and many more. The purpose of this paper is to provide yet another design tool for the energy-conscious architect.

Proposed in the following pages is a method by which an architect can act to improve the climate at a building site in order to decrease the amount of energy required to provide comfortable conditions within the building. Included is information that identifies factors which determine the comfort of the users of a proposed building, the elements of climate which affect design decisions, and the variables of a site which can be manipulated by the designer, and which can alter the microclimate at that site. Following presentation of this information, a method is presented by which architects can conduct a microclimatic site survey, analyze and evaluate the information obtained, and formulate recommendations for alterations at the site which will result in the creation of a more favorable microclimate.

The author recognizes that practising architects and architectural students usually do not have the time or inclination to spend a year or more gathering detailed data on the microclimate of a proposed building site.

What is needed by these groups is an understandable presentation of the concepts involved in microclimatic design, and a relatively quick and simple method for translating these concepts into effective design solutions. For this reason, no elaborate charts or challenging mathematical formulas will confront the reader. It is hoped that this paper can serve as a practical, usable tool for the energy-conscious designer.

The concept of "designing" the climate in which a building will be placed is not a new one, since the external environment has always placed stresses on humans and has caused them to act to control its effects. In the third century A.D., Vitruvius wrote on the importance of selecting "the most healthy site."<sup>8</sup> In the days of the Roman Empire, the use of overhangs was forbidden in the narrow streets of Pompeii because they would shut out light and air.<sup>9</sup> A third example of microclimatic concerns in early times occurred in the planning of the city of Puebla, Mexico, in 1534. The streets were laid out to prevent prevailing winds from sweeping the length of the city.<sup>10</sup> These examples are just a few of the many cited by such authors as Aronin (Climate and Architecture), Olgyay (Design with Climate), and Rudofsky (Architecture Without Architects and The Prodigious Builders). All of this evidence indicates that the designers of the past knew that the climate could be effectively manipulated, on a small scale, for the benefit of man.

As methods for heating and cooling buildings became more sophisticated and effective, concern by designers about adjusting their buildings for climatic fit declined. The ancients learned to design with the climate in order to survive its effects, but modern architects learned to overpower climate by the brute force of mechanical heating and cooling systems.

Today we are being forced to re-evaluate this attitude. Thankfully, we are not, at present, in a position where our survival is threatened by the forces of nature. The threat comes from the economic cost of the "brute

force" method of building design.

The potential for saving energy, and the dollars spent to obtain that energy are probably the most important and favorable arguments for the integration of microclimatic design into the planning of buildings. Since the external environment rarely provides the proper conditions for human comfort, it is necessary for us to conduct many of our activities within the controlled environment of a building. The common design practice of today is to make up the difference between external and internal environments with mechanical space conditioning. The objective of the microclimatic designer is to act to moderate the extremes of the external adjacent environment so that the differences between actual (outdoors) and ideal (indoors) are reduced and, therefore, less energy is consumed in the building.

A good example of the kind of energy savings one can expect from designing the microclimate is provided by Dr. John Palmer, Associate Professor of environmental sciences at Florida International University. Dr. Palmer has used landscape elements to alter the microclimate at a day care center in Miami, Florida, with the following results. The center, which is located in a modular "double-wide" building, has experienced a thirty percent reduction in total energy consumption and the occupants report a more comfortable environment. Additionally, the center manager has stated that the building "feels" more comfortable since the air conditioning units are now able to "keep up" with the hot Florida summers. Measurements have shown the exterior wall temperatures, which used to reach 115° regularly, now rarely exceed 85°. Due to this increased capacity to maintain comfortable conditions, the center now can operate year round rather than closing in the hottest months of the year.<sup>11</sup>

While the previous example deals mainly with savings in cooling a building, it is possible to moderate the microclimate to effect savings in

the heating of buildings as well. The cost of alterations for microclimatic design are generally minimal (\$1500 for our Florida example<sup>12</sup>) and the pay-back period, the time it takes for the initial investment to be returned in energy savings, is usually a relatively short period of time.

Microclimatic design can be advantageous to architects because of its versatility as a design tool. It can be used to help save on energy consumption in virtually any type of building using any form of fuel. The principles can be applied to homes utilizing solar design techniques or to buildings which ignore such concepts. It can be used in large, complex projects or on shelters as simple as an outdoor pay telephone station. The concepts can be applied effectively in planning for a new building or in energy conservation retrofit projects for existing structures. The ideas are adaptable to individual buildings, groups of buildings, and even to entire towns.

Besides versatility and energy savings, microclimatic design offers architects an opportunity to explore the aesthetics of truly site-integrated energy conscious design. The design of a building based on a specific site and microclimatic conditions in which it is placed can only lead to a type of architecture which is rich in form as well as substance. As James Marston Fitch has stated,

This successful interposition between man and his natural environment furnishes the material basis of all great architecture. To wrest the objective conditions for man's optimal development and well-being from a Nature which only seldom provides it, to satisfy his physiological and psychological requirements at optimal levels-- this beyond question is the objective basis of any architecture which is both beautiful and good.<sup>13</sup>

## FOOTNOTES

1. "Energy: Elusive Solutions," Nation's Business, August 1980, p. 24.
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3. Richard G. Stein, Architecture and Energy (Garden City, New York: Anchor Press/Doubleday, 1978), p. 5.
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7. Ibid.
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9. Ibid.
10. Ibid., p. 9.
11. Roger Rawlings, "Planting Shade in South Florida," New Shelter, September 1980, p. 34.
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## CHAPTER I

### COMFORT

The underlying goal of architects through the ages has been to provide an environment in which the occupants of a space can carry out their activities in physical comfort. Since early man began to alter the conditions in which he lived by sheltering himself in a cave and building fires for warmth, he has been trying to achieve a comfort goal.

It may seem rather basic, but even today we consistently fail to provide comfortable environments or to perceive the elements required to achieve a state of physical comfort. In order to moderate the microclimate of a building location and to conserve energy, designers must first have an understanding of the comfort criteria or parameters of the building's users.

Comfort has been defined as "when the current level of the varying microclimate equals the current level of the varying requirements of the person exposed to it."<sup>1</sup> This definition indicates the two variables in the comfort equation: the environment and the people. The major elements of the environment which affect human comfort are air temperature, radiation, air movement, and humidity.<sup>2</sup> Major human factors affecting comfort are activity, clothing, nutrition, age, general body build, degree of acclimatization, respiratory rate, and sex.<sup>3</sup>

#### Human Factors Affecting Comfort

The designer of a building should take into account the human variables in the comfort equation. By knowing as much as he can about the occupants of

his building, the designer can more accurately predict and provide the comfort requirements of the occupants. In most cases, he will not know much about the nutrition, body, degree of acclimatization or respiratory rate of a building's occupants. The designer will, however, be able to make fairly accurate assumptions about the physical activities and clothing of the building's occupants, and probably about their age and sex. A brief discussion of these four elements follows.

The activity in which a person is engaged has a very real bearing on his feelings of comfort. The more one senses the imbalance of comfort criteria when performing a task, the more likely he or she will be to express feelings of discomfort. Figure 1 indicates the metabolic rate of the "average" man for different levels of activity. As one proceeds from light to heavy work, the requirement for warmth diminishes. Occupants of a building engaged in strenuous physical activity have need for more cooling than those engaged in more sedentary pursuits. The architect should be aware of this and respond with adjustments in temperature, air movement, and humidity levels.

The amount and type of clothing one wears can also have a marked effect on one's feelings of comfort. Fitch has referred to architecture as the "third environment,"<sup>4</sup> following the environments created by nature and by clothing. He recognized that man was using clothing to assist in achieving feelings of comfort long before he began to erect architectural barriers between himself and the natural environment. Clothing acts basically as an insulator, and its effects vary according to how much and what type clothing we wear. To help categorize the insulating value of clothing, a basic unit of insulation known as the "clo" has been developed. Arbitrarily, the clo value of 1.0 has been assigned to the insulating value of a man's business

KIND OF WORK	ACTIVITY	METABOLIC RATE	
		BTU / HOUR	K. CAL. / HOUR
LIGHT WORK	SLEEPING	250	63
	SITTING QUIETLY	400	100
	SITTING, MODERATE ARM AND TRUNK MOVEMENTS DESK WORK, TYPING.	450-550	113-140
	SITTING, MODERATE ARM AND LEG MOVEMENTS ORGAN PLAYING, DRIVING A CAR IN TRAFFIC.	550-650	140-165
MODERATE WORK	STANDING, LIGHT WORK AT MACHINE OR BENCH MAINLY ARM MOVEMENT	550-650	140-165
	SITTING, HEAVY ARM AND LEG MOVEMENTS	650-800	165-200
	STANDING, LIGHT WORK AT MACHINE OR BENCH SOME WALKING ABOUT.	650-750	165-190
	STANDING, MODERATE WORK AT MACHINE OR BENCH SOME WALKING ABOUT.	750-1000	190-250
HEAVY WORK	WALKING ABOUT, WITH MODERATE LIFTING AND PUSHING	1000-1400	250-350
	INTERMITTENT HEAVY LIFTING PUSHING OR PULLING PICK AND SHOVEL WORK	1500-2000	380-500
	HARDEST SUSTAINED WORK.	2000-2400	500-600

NOTE: RATES DO NOT INCLUDE REST PERIODS AND ARE FOR A 145 LB. MALE. ( AFTER A.S.H.R.A.E. )

Fig. 1 - Approximate Metabolic Rates For Activities



suit of a fairly heavy fabric. The value of a pair of slacks is about .44, and a bikini is .15.<sup>5</sup> The insulating value of clothing also depends upon fabric type (synthetic or natural) and tightness or looseness of the weave, but a building designer would rarely be aware of the occupants' preferences in this regard. Still, some knowledge by designers as to the clothing that will be worn by a building's occupants can help determine what will be required to achieve a desired level of comfort.

The age and sex of a building's occupants can also play a part in their perception of comfort. The age factor has long been known with regard to safety, such as the increased incidence of falls as age increases, but it has also been shown that older persons are more likely to experience discomfort as wind speed increases,<sup>6</sup> and as temperature decreases. Over the age of 40, people prefer temperatures on the order of one Fahrenheit degree higher than their younger counterparts.<sup>7</sup> Females will experience more discomfort in windy or cool environments than will males. It has been observed that females are generally more comfortable where air temperatures are one to two Fahrenheit degrees higher than those preferred by men.<sup>8</sup>

The architectural implications of these variations of human perception of comfort seem obvious. The designer should strive to know as much as possible about the people who will be using the building. By knowing the users, the designer can more clearly define the types of environments which will be needed to obtain comfortable conditions.

#### Environmental Factors Affecting Comfort

Temperature, radiation, air movement and humidity, the four basic variables of the environment which affect our feelings of comfort, act on us in a complex relationship. An increase in one factor can offset what would normally be a deficiency in another area while maintaining a comfortable environment.

The state of being comfortable can be defined as the point where the heat gain of a body is balanced with the body's heat loss. The human body exchanges heat with its surroundings in four ways: radiation, conduction, convection, and evaporation. Approximately 44 percent of body heat loss is from radiation either to the sky or colder adjacent surroundings. Heat loss from convection generally accounts for 32 percent of the total; evaporation causes about 21 percent of normal heat loss, and three percent is due to conduction.<sup>9</sup> The body gains heat by producing its own through basal processes, activity, digestion, muscle action, etc.; by absorption of radiation from the sun or other warm objects; by heat conduction of warm air circulating about the body; and sometimes from condensation of atmospheric moisture.<sup>10</sup>

Movement of air affects us by either heating our bodies if the air is very warm, or by cooling us due to heat loss by convection air currents and, thus, increased evaporation. It has been shown that as the velocity of air movement increases, the upper limit of temperatures perceived as "comfortable" also increases. There is a limit to the increase of air movement for comfort, since beyond a certain point the movement of air itself is seen as uncomfortable, regardless of air temperature. Figure 2 illustrates the desirable range of air velocities.

Under certain circumstances, humidification of the air can have a cooling effect. When atmospheric conditions are very dry and air temperatures are too high for effective cooling by air circulation alone, adding humidity to the air can be a good strategy for achieving comfortable conditions. The use of plant materials, pools, fountains, roof ponds or evaporative coolers can be very beneficial in such situations.

As air temperatures decrease, people will remain comfortable if the body's heat loss is counteracted with an increase in exposure to the radiation of the sun. Within a limited range, a drop of one degree Fahrenheit can be

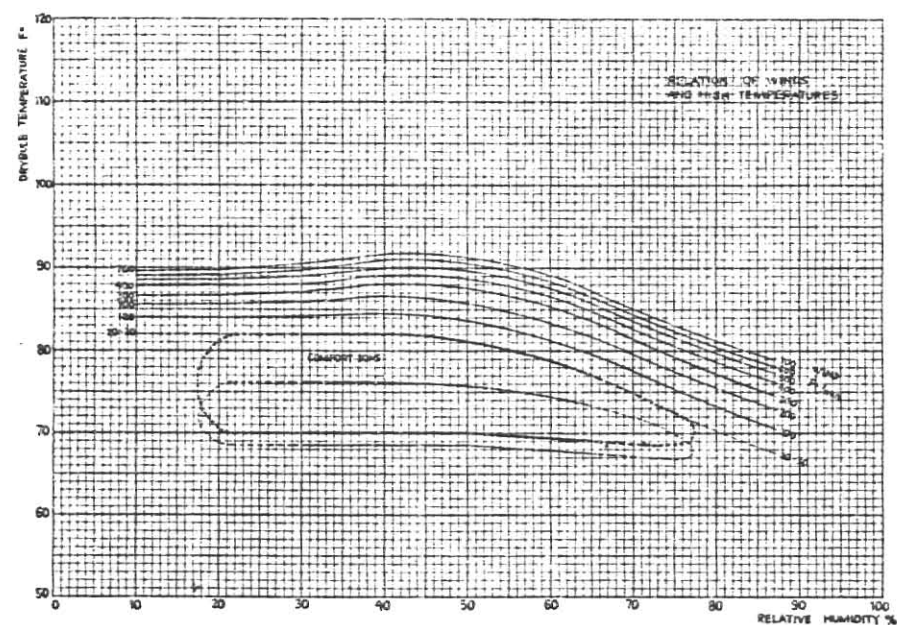


Fig. 2.--Relation of winds and high temperatures

counteracted by elevating the mean radiant air temperature by  $0.8^{\circ}\text{F}$ .<sup>11</sup> Translated into BTUs, the terminology by which most weather information concerning radiation is presented, a  $3.85^{\circ}\text{F}$  drop in temperature can be offset by a 50 BTU-per-square-foot increase in solar radiation.

The following chart from Olgyay's Design with Climate presents graphically information correlating temperature, air movement, evaporation and radiation. It shows a "comfort zone" which shifts as the environmental factors affecting comfort change or vary.

The bioclimatic chart shown in Figure 3 is applicable to people in the temperate zone of the United States, at an elevation below 1000 feet, wearing customary indoor clothing, and engaged in light muscular work. To apply to latitudes other than  $40^{\circ}$ , elevate the lower line of the summer comfort zone by about  $3/4^{\circ}\text{F}$  for every  $5^{\circ}$  change toward lower latitudes. The upper line can be raised at the same rate, but should not be raised above  $85^{\circ}\text{F}$ .<sup>12</sup>

The bioclimatic chart can be very useful to architects who are concerned with climate and energy conservation. By plotting data concerning the exist-

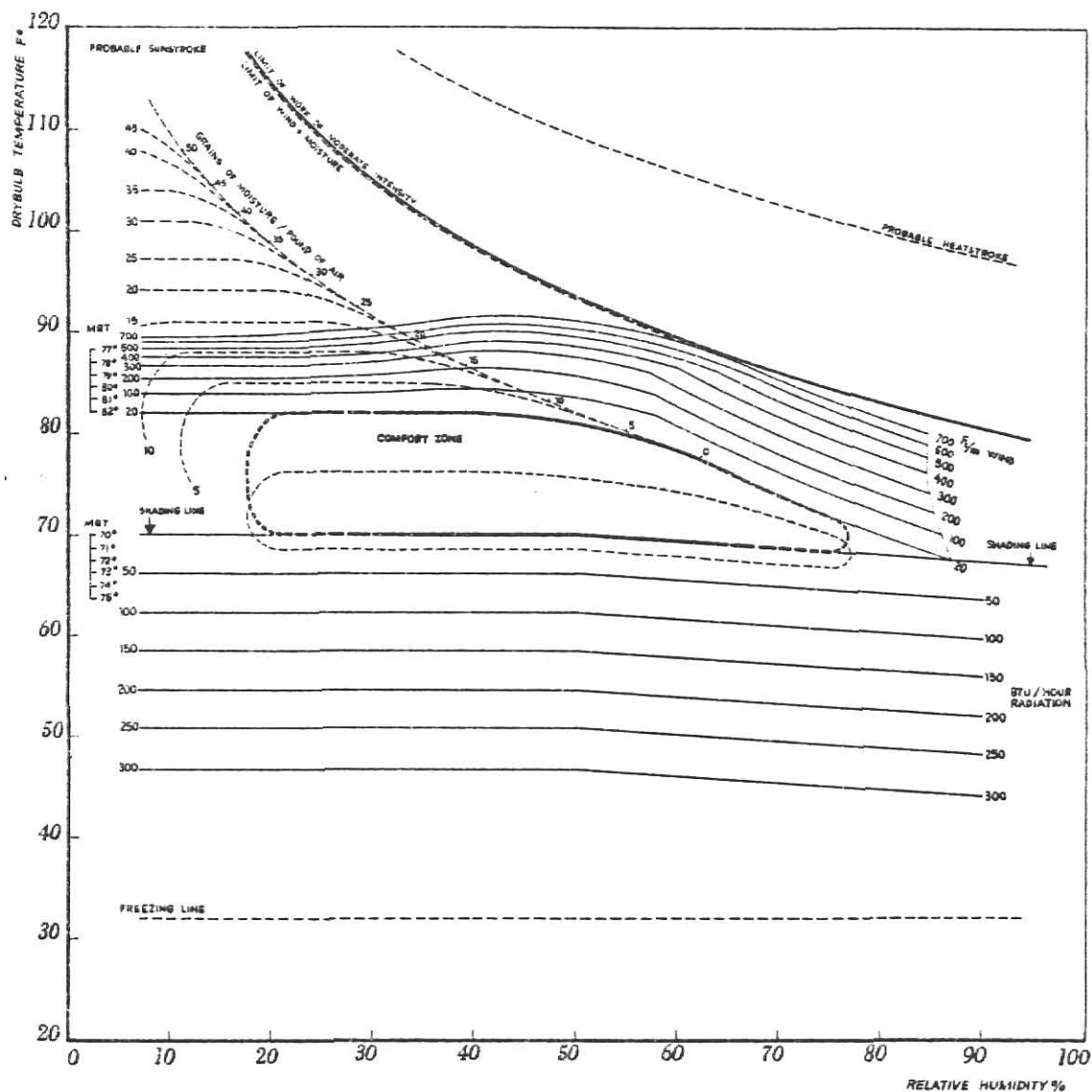


Fig. 3.--Bioclimatic chart

ing climate at a site on the chart, and then taking into account the human factors of comfort, a designer can determine how existing conditions compare with producing a "comfortable" environment. He can also discover areas where physical improvements can occur that will bring existing site conditions closer to the desired comfort zone. Study of the chart can show when to increase air movement, when to add moisture to the air, and when to add or reduce shading. All of these adjustments can be made, at least to a degree, through manipulation of the natural elements at the site to alter the microclimate of the site.

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- Fig. 2. Victor Olgyay, Design with Climate (Princeton, N. J.: Princeton Univ. Press, 1963), p. 20.
- Fig. 3. Ibid., p. 22.

## CHAPTER II

### CLIMATE ZONES OF THE UNITED STATES

It is important for a designer to understand the basic characteristics of the climatic region in which a building will be placed before he can begin to "fine tune" his building to a particular site's conditions. This chapter will discuss the characteristics of the four basic climatic zones which occur in the continental United States.

The climate of a place has been defined as the long-term normal weather for that place. It can be described in terms of temperature, pressure, humidity, sunshine, winds, clouds, and precipitation.<sup>1</sup> It is controlled by such factors as latitude, continentality and sources of moisture, prevailing winds, ocean currents, elevation, and mountain barriers.<sup>2</sup>

Our country is unique in that within its borders occur four basic different climatic zones. The British climatologist F. K. Hare has stated, "In their quality of dramatic changeability, the climates of North America have no rival; nor is there any continent in which greater differences exist between region and region . . . ."<sup>3</sup> The main reason for this is that, while the air moves through our latitudes along a basic east-west axis, the mountain ranges are arranged on a north-south orientation which affects climate on a regional scale.

The four zones of climate which occur in our country are cool, temperate, hot-arid, and hot-humid. Figure 4 shows the general boundaries of these areas.

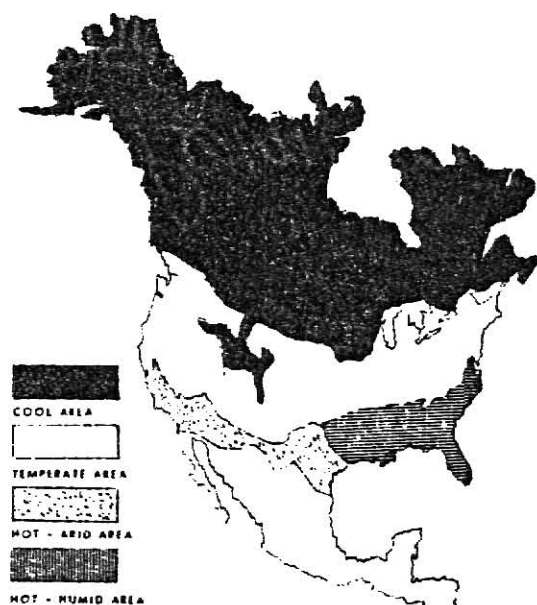


Fig. 4.--Regional climate zones of North America

The lines of division between climatic zones are, of course, somewhat arbitrary. It is not unusual for one region to exhibit, on occasion, the characteristics associated with the other climatic regions. However, in general, each region exhibits a commonality of climatic conditions which distinguish it from the others. Characteristics of these regions are:<sup>4</sup>

**Cool regions:** Hot summers to  $+100^{\circ}\text{F}$  occasionally, cold winters to  $-34^{\circ}\text{F}$  common. Persistent winds year round, generally out of the NW and SE. Being generally in the north, these regions receive less solar radiation than do the others.

**Temperate regions:** Characterized by an equal distribution of overheated and underheated periods. Seasonal winds are from the NW and S. High humidity and large amounts of precipitation are common traits, along with intermittent periods of clear, sunny days, followed by extended periods of overcast, cloudy days.

**Hot-arid regions:** These areas are characterized by clear sky, dry atmosphere, extended periods of overheating, and large diurnal temperature swings. The wind is generally along an E-W axis, with variations between day and evening.

**Hot-humid regions:** Consistent vapor pressure, high humidity, and high temperatures are the major characteristics of these regions. Wind velocities and direction vary throughout the year and throughout the day.



It is obvious from these descriptions that designers working in the different climatic regions should be dealing with different objectives and solutions. A building with a proper climatic "fit" in the cool regions would not work efficiently if placed in a hot-humid area. The basis of a regional design approach is that a building should respond to the particular constraints and opportunities presented by the characteristics of the climate of the region in which it is placed. As shall be shown later, the micro-climate at a specific site will be somewhat different from that of the region as a whole, but the basic objectives of the designer are determined by the characteristics of the regional climate.

Following is a summary of objectives of the energy-conscious designer, broken down by region:<sup>5</sup>

Cool: Maximize warming effects of solar radiation. Reduce impact of winter wind and avoid "cold pockets."

Temperate: Maximize warming effects of the sun in winter, but block it out as much as possible in summer. Reduce the impact of winter wind but allow air circulation in summer.

Hot-arid: Maximize humidity, air movement, and shade from late morning through the afternoon.

Hot-humid: Maximize shade and air movement.

There is really no substitute for a little research when it comes to determining the actual characteristics of the climate of an area in which a building will be placed. The National Weather Service has been gathering data in certain areas for over 100 years; this information is available from them, as well as from local radio stations, airports, university weather stations, etc. Most of this information has been gathered for the benefit of the aviation and agriculture industries. It should not be interpreted as being the actual climate in which buildings would be placed, since wind, temperature, humidity and radiation measurements are taken away from the earth, trees,

buildings and other elements which constitute a building site. The information does, however, give a designer a better "feel" for the climate of the area in which he lives, which can be called the macro-climate.

For those designers to whom macroclimatic information is not available, or where time constraints preclude the acquisition of such information, Appendix A contains a series of detailed maps which will help the architect in determining the local area climate in which a building site is located.

After identifying regional and macroclimatic conditions of an area, the architect can begin to develop objectives to which his microclimatic design will aspire. The next chapter will point out how certain site elements cause variation of the microclimate at each site and, at the same time, begin to suggest strategies by which the designer can alter the microclimate to reach his design objectives.

## FOOTNOTES

1. John L. Baldwin, Climates of the United States (Washington, D.C.: U.S. Dept. of Commerce, 1973), p. 1.
2. Ibid., p. 2.
3. Robert Claiborne, Climate, Man and History (New York: Norton and Co., 1970), p. 378.
4. Gary Robinette, Landscape Planning for Energy Conservation (Reston, Virginia: Environmental Design Press, 1977), p. 66.
5. Ibid., p. 69.

## ILLUSTRATION CREDITS

Fig. 4. Olgyay, Design with Climate, p. 4.

### CHAPTER III

#### SITE CHARACTERISTICS WHICH CAUSE VARIATIONS IN MICROCLIMATES

It is essential that an architect involved in microclimatic design have an understanding of how certain characteristics of a site can affect that site's climate. In site surveying, he should be able to recognize areas that may pose potential problems or offer energy-saving opportunities. In site analysis, he should be able to identify areas of variation from the regional climate and understand why these variations occur. During microclimatic design, he should be able to develop alternate proposals for site alterations for energy conservation. All of these skills can be developed through the study and application of the material presented in this chapter and by reading the material cited in references and the bibliography.

There are basically five aspects which can affect the climate of a site. These are topography, vegetation, earth surface conditions, bodies of water, and man-made structures. On any site, some of these variables may be present and in some sites they will all act to alter the climate. Each has its own effect on the four aspects of climate (solar radiation, air temperature, wind and humidity/precipitation), but at any particular site they act together to make up the microclimate at that location. For the purpose of clarity, each of these variables will be examined separately, however, along with the way each impacts on the four aspects of climate.

### Topography

The shape and form of the land can have a marked effect on the climate on a "macro" as well as a "micro" scale. The mountains of our nation--the Cascades, Rockies, Sierra Madres, and Appalachians--all have a dramatic climatic impact. In much the same way, local land forms have an impact on the microclimate.

Topography and Solar Radiation.--The amount of radiation to strike the land depends upon the inclination and direction of the land's slope, season of the year, degree of cloudiness, time of day, and latitude.<sup>1</sup> The difference caused by slope variations can be marked. While the differences in radiation received on the land's surface are more dramatic in direct sunlight conditions,<sup>2</sup> studies in Germany have shown that a surface inclined at 20° facing toward the south will receive, even accounting for cloudiness, about twice as much solar radiation as a horizontal surface.<sup>3</sup> Figure 5 shows how solar radiation can differ on different slopes. Radiation amounts are shown as a percentage for the north, east and south sloping surfaces with slope gradients

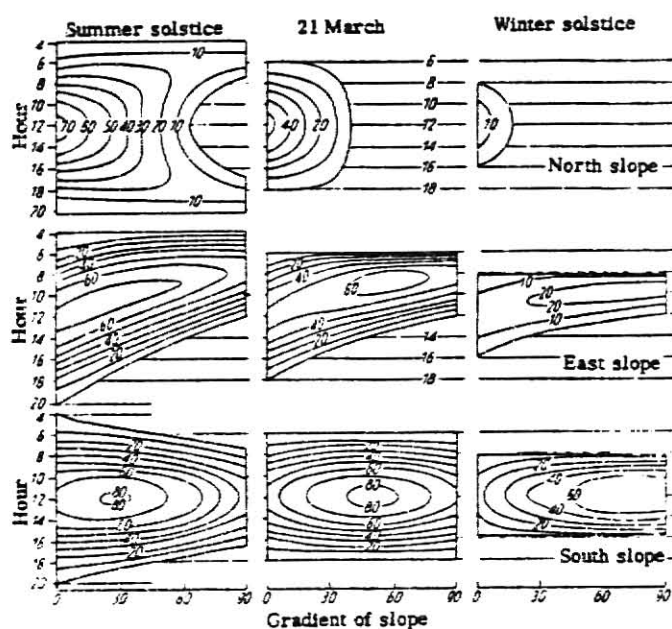


Fig. 5.--Direct solar radiation ( $\text{cal cm}^{-2}\text{hr}^{-1}$ ) on inclined surfaces

of  $0^{\circ}$  to  $90^{\circ}$ . It is readily apparent how much more sun reaches the south sloping surfaces. Figure 6 shows the results of an actual survey which takes into account cloudiness and other weather variations.

		January	February	March	April	May	June	July	August	September	October	November	December	Total
Level ground		107	179	380	585	740	819	893	788	569	294	107	82	5544
10° slope	N	52	116	296	510	690	774	827	703	462	205	58	31	4724
	NE (NW)	66	133	319	528	696	784	847	728	486	226	69	45	4928
	E (W)	104	178	375	577	731	812	877	778	555	281	102	74	5446
	SE (SW)	142	218	426	620	764	836	908	828	612	341	137	106	5938
	S	158	238	446	636	773	841	925	852	650	372	155	125	6171
20° slope	N	4	52	204	417	611	702	744	596	342	114	7	0	3793
	NE (NW)	36	92	256	462	633	725	774	644	402	165	41	21	4251
	E (W)	104	176	366	559	705	778	841	752	540	279	102	74	5274
	SE (SW)	175	253	466	646	764	825	909	846	649	382	165	134	6214
	S	203	289	501	677	790	847	927	884	723	442	193	160	6638

Fig. 6.--Monthly totals ( $10 \text{ cal cm}^{-2} \text{ hr}^{-1}$ ) of direct solar radiation, Vienna, 1930-1932.

Topography and Air Temperature.--The simple fact that warm air rises is enough to lead us to believe that air temperature is affected by topography. On the large scale, air temperature decreases with altitude. In summer this decrease is  $1^{\circ}\text{F}$  for each 330 foot rise in elevation, and in winter,  $1^{\circ}\text{F}$  for each 440 foot rise.<sup>4</sup> This accounts for the generally cooler temperatures in mountainous areas. On a more localized scale, however, there is a noticeable tendency for cool air to flow down into ground depressions, as shown in Fig. 7 by the illustration of a series of temperature readings taken at a right angle to the shore of Lake Ontario by Dr. Helmut Landsberg. The extreme drop in temperature at the right represents the Don River Valley. The cold air flow down into this area caused this difference of  $34^{\circ}\text{F}$  only seven miles from the lake.

At the smaller scale of a given site, the rule holds true that concave surfaces are cool at night and convex surfaces are warm. This can have dra-

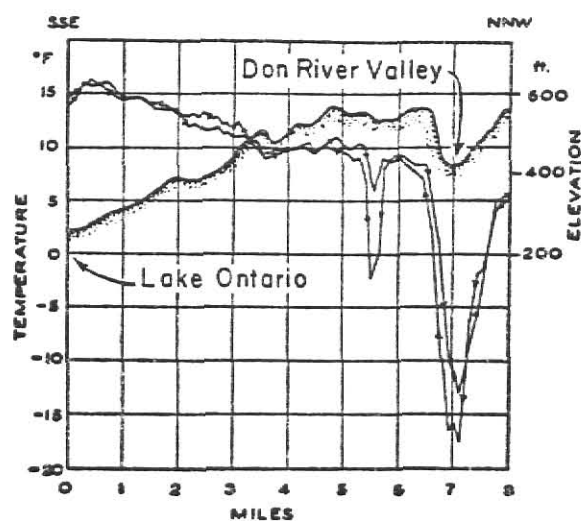


Fig. 7.--Temperature profile at right angles to shore of Lake Ontario

matic effects in frost and freeze damage to vegetation. This phenomenon is illustrated in Figure 8, which shows night temperatures in Celsius degrees measured over nearly level ground. As can be seen, even at an elevation difference of 1.6 meters, the average temperature difference was 1.1°C and, during the growing season, this proved to be a difference of five frost nights.

Nights with frost, 1939	Elevation (m)				
	36.1	36.1	36.3	36.6	37.7
23-24 May	-7.6	-6.9	-5.4	-5.1	-3.7
2-3 June	-9.4	-7.9	-8.2	-6.7	-5.0
2-3 July	-2.1	-1.3	-1.1	0.0	+0.1
11-12 July	-2.5	-1.4	0.0	+1.6	+1.9
Mean of 30 coldest nights	-0.6	-0.4	+0.1	+0.7	+1.7

Fig. 8.--Night minimum temperature (°C) over nearly level ground

Topography and Wind.--That the lay of the land has an effect on wind direction and speed is a fact which is readily apparent. Part of the cause of varying wind or air flow in relation to topography is the temperature differential over sloping ground. Generally, these air flows are downward in

direction at night and upward during the day. Downslope breezes at night which are caused by temperature differences are generally in the range of 1 to 1.5 meters per second at 5 to 10 meters above the earth's surface. Upslope breezes during the day are usually in the 2.3 to 2.9 meter-per-second range.<sup>5</sup> Figure 9 illustrates the general pattern of upslope valley winds during the day. Dots at the bottom of the valley represent breezes flowing perpendicular to the page up the valley.

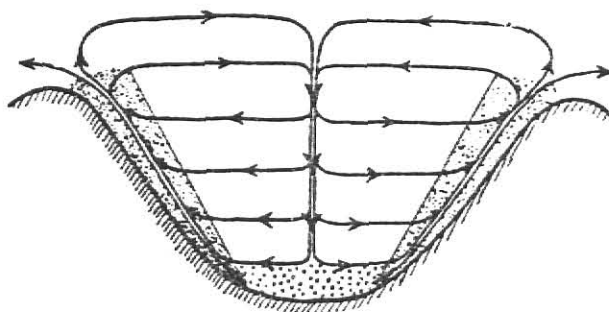


Fig. 9.--Diagram of upslope and valley winds

In addition to upslope and downslope winds, the general prevailing winds of an area are modified by the local terrain or the presence of manmade structures. Figure 10 indicates how topography tends to deflect the wind, increase its speed in areas, and change its direction. The same holds true for wind in the plan view as it flows around hills and topographic irregularities, generally causing the areas on the lee side of a hill to be more protected from the prevailing winds.

Topography and Humidity.--In this paper, precipitation levels will be considered along with humidity. The climate of slopes facing in different directions is affected by moisture distribution, which is not uniform but varies with topography. A portion of this is determined by the wind flow variations. On a macroclimatic scale, as in mountain ranges, precipitation



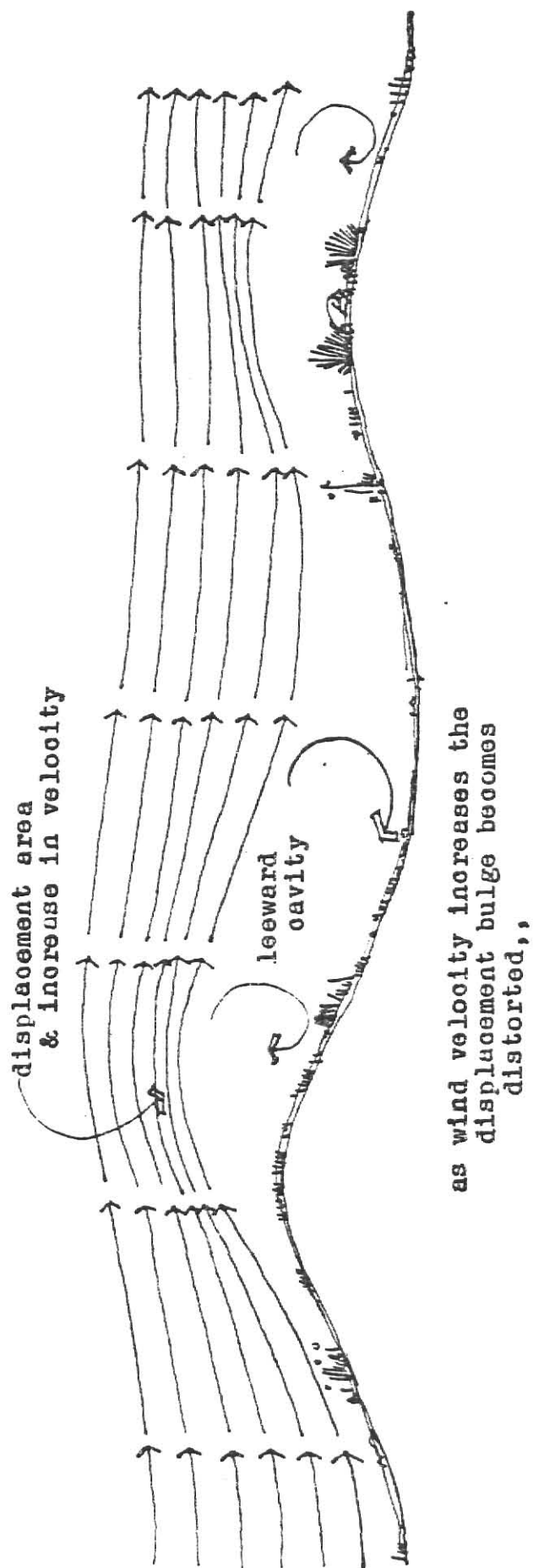


Fig. 10.--Wind displacement due to topography

is heavier on the windward side of slopes, as illustrated in Figure 11. On a more microclimatic scale, however, precipitation is usually carried to the



Fig. 11.--Rain distribution in mountainous terrain

lee side of hills, where precipitation levels can be five to ten percent higher, as shown in Figure 12. This is an illustration of actual measurements of precipitation on a hill by Victor Olgyay.<sup>6</sup> This phenomenon is readily apparent in winter when snow drifts can be observed on the lee side of sloping ground. The difference in the amount of moisture received depends upon direction of the slope, its gradient, the angle at which the moisture is falling, and type of precipitation, i.e., rain, snow, hail, etc.

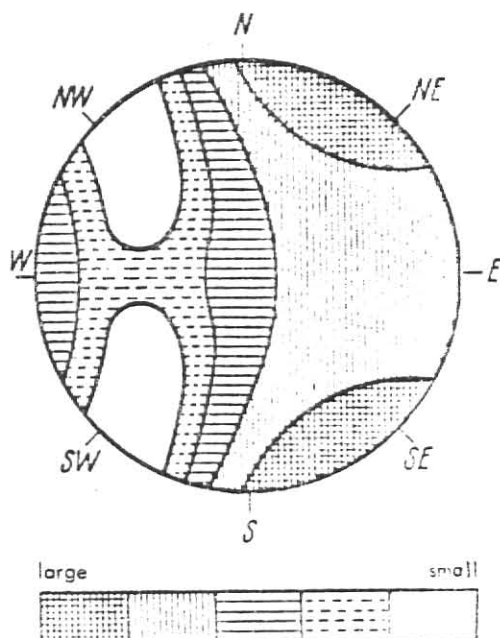


Fig. 12.--Precipitation distribution on a hill

### Vegetation

The varieties, amounts and position of vegetation at a site can have a pronounced impact on the local climate. When speaking of plant materials and their use in climate modification, one should always be aware of a dichotomy that exists concerning vegetation and climate. While vegetation modifies the microclimate, only certain types of plants can grow in certain areas. The range of plant materials open to the use of the designer is always limited to those which can be successfully grown in a particular area.

Vegetation and Solar Radiation.--The effect of vegetation on the solar radiation at a site depends upon the type of vegetation, time of year, time of day, and placement of the vegetation. Vegetation affects the amount and quality of solar shading which reaches the ground. Plant species provide varying shade patterns because of the variation in their shapes, leaf shapes, and leaf configurations. Evergreens, for example, tend to be thicker and block out more of the sun than do deciduous varieties. Figure 13 illustrates a comparison of light intensities beneath different types of tree canopies.

Type of tree (old stand)	Without foliage	With foliage
Deciduous trees		
Red beech	26—66	2—40
Oak	43—69	3—35
Ash	39—80	8—60
Birch	—	20—30
Evergreen trees		
Silver fir	—	2—20
Spruce	—	4—40
Pine	—	22—40

Fig. 13.--Light intensity (percent of outside) in stands of trees

The time of year is also important in determining vegetation effects on solar radiation. Deciduous trees lose their foliage in the winter, which has a dramatic impact on the shadow pattern they provide. Coniferous species, on

the other hand, retain their foliage year round and, therefore, cast basically the same sorts of shadows throughout the year. Of course, shadow patterns also vary with the difference of the sun's position in the sky as the seasons change.

In much the same manner, the shadow pattern of a group of trees varies as the sun moves across the sky during the day. A portion of a site can be in full sun at 10:00 a.m., and in deep shade at 4:30 p.m. due to the position of plants and the changing location of the sun.

To this point, our discussion has been limited to trees and large shrubs; however, low-growing plant cover also has an effect on the solar radiation at the site. The amount of radiation which reaches the soil surface in a grassy meadow, for example, is only about one-fifth that received on bare ground, as illustrated in Figure 14. One would expect the earth in a grass-covered field to gain heat more slowly during the day and lose heat more slowly at night.

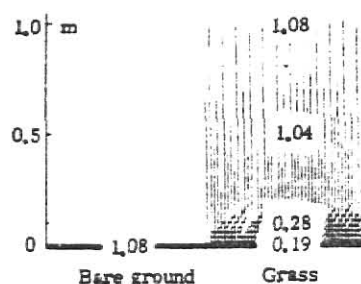


Fig. 14.--Solar radiation levels on bare ground and in tall grass

Vegetation and Air Temperature.--Vegetation can have a dramatic impact on temperature conditions at a particular location. The ability of vegetation to absorb, reflect, radiate and transmit solar radiation can reduce daytime temperatures, in some cases, by as much as 15°F. Obviously, this can have a significant impact on the heating load of a building. By shielding the ground from direct solar radiation, planted areas will normally be cooler



Low-growing vegetation has basically the same influence on air temperature, although to a lesser degree. Figure 16 shows how different low-growing plant types affect temperature in relation to bare ground at sunrise and at mid-day. As can be seen, the temperature difference in the 50 cm closest to the ground is marked. If the graph were to include temperature readings over concrete or asphalt paving, the difference at mid-day would be striking.

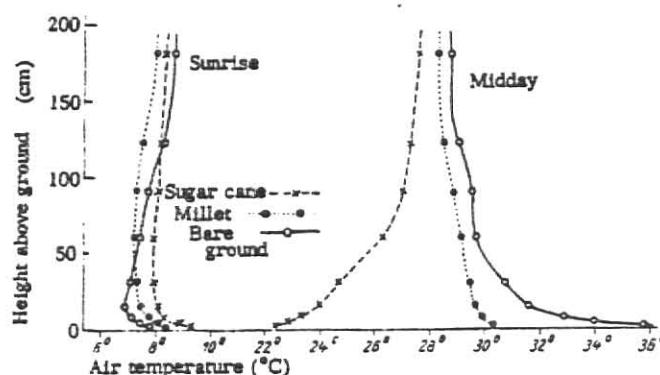


Fig. 16.--Stratification of temperature over differing plant materials

Figure 17 shows how a combination of high and low plant growth can affect temperature in a realistic type situation.

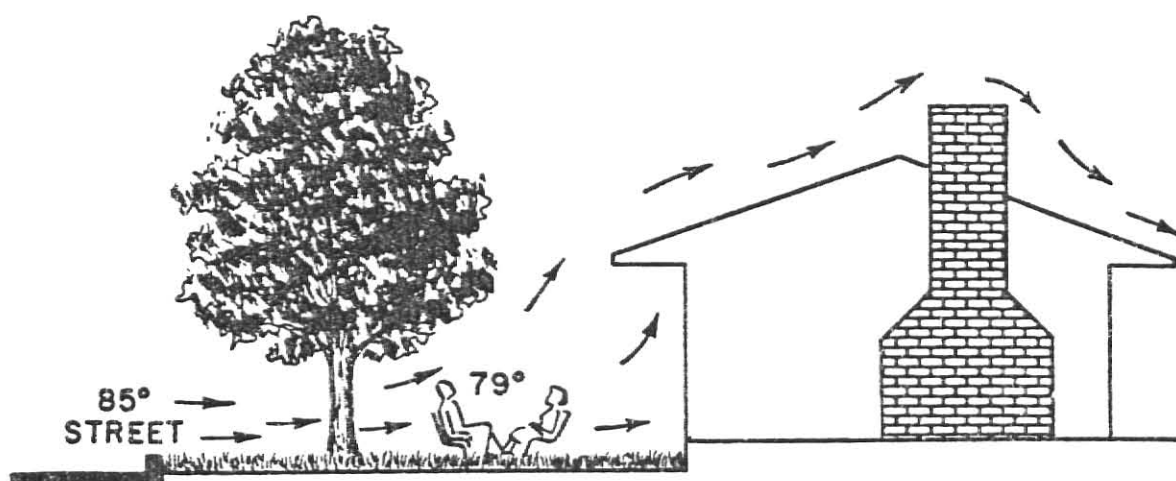


Fig. 17.--Temperature variations in typical residential setting

Vegetation and Wind.--Vegetation can serve to direct, deflect, slow down, speed up, or filter local winds. The effect of vegetation is dependent upon vegetation type and placement and on wind speed and direction.

On a large scale, the presence of vegetation on the earth's surface tends to break up the wind, create turbulence, and lower the wind velocity at ground level. Figure 18 illustrates this effect, and explains why wind speed readings at ground level are generally lower than those recorded by weather stations, which read wind speeds from locations above vegetation and other turbulence-creating factors. In Figure 19 can be seen the result of actual measurements of wind velocity at a forest floor; this illustrates how much difference trees and plants can make on wind speed.

Wind can be deflected by vegetation in both a vertical direction, as indicated in Figure 20, and in a horizontal direction, Figure 21.

Wind breaks are a relatively common wind control tool used by farmers in the United States who recognize the deflection value of vegetation. Figure 22 shows the result of research on the effects of wind breaks. Wind velocity is shown to be substantially reduced on the leeward side of plantings, as well as on the windward side to a lesser extent. The area protected from the wind and the degree of wind speed reduction depend on the height and density of the wind break.

Wind can be directed to flow in a certain direction by plant groupings, as indicated in Figure 23. This type of funneling and directing of the wind is known as the Venturi effect, and is accompanied by an increase in wind speed through the funneled area. Venturis can be a useful design tool to direct and increase winds for ventilation, odor control, wind generating systems, and other purposes. Figure 24 shows how a Venturi effect can be created by leaving a gap in a wind break.

Note - "SP" = separation point

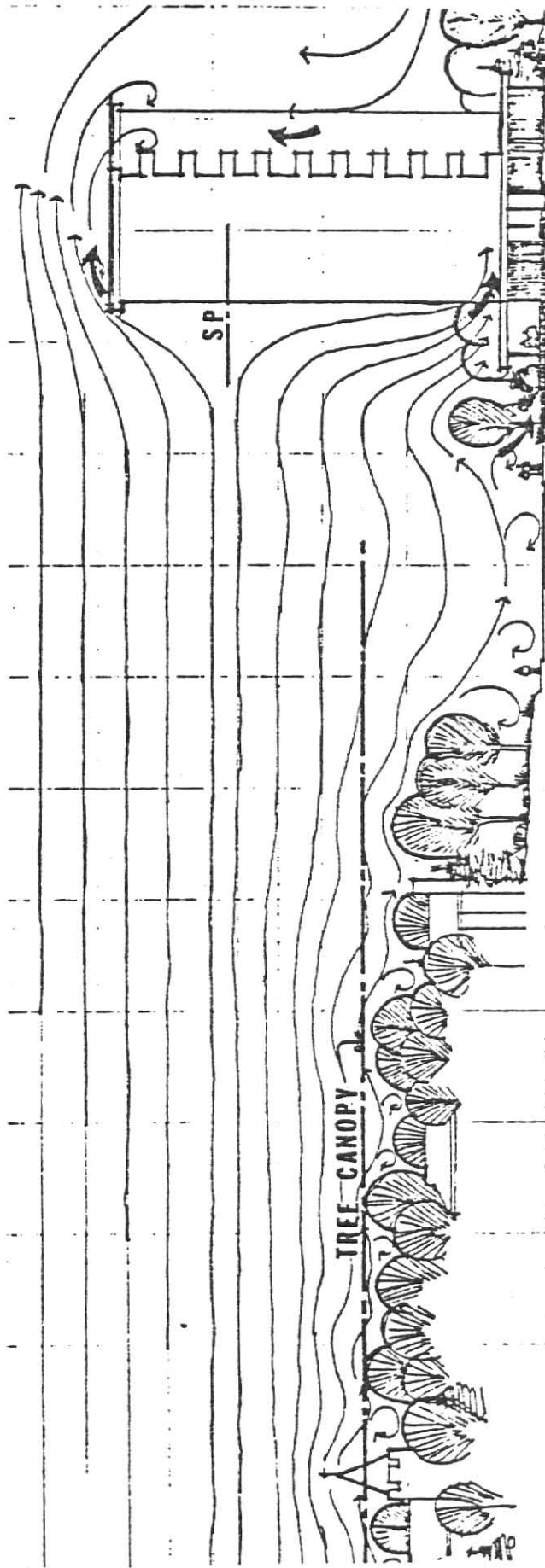


Fig. 18 - Effect of Tree Canopy on Wind

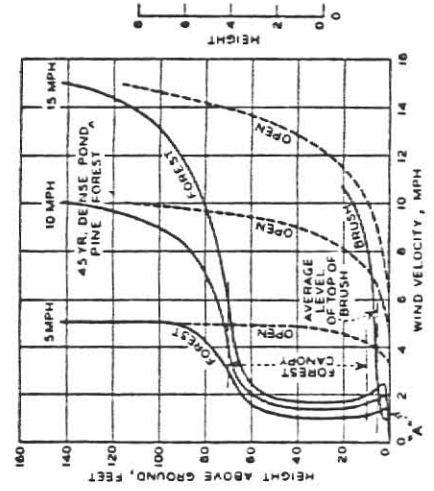


Fig. 19 - Vertical Gradients of Wind Velocities



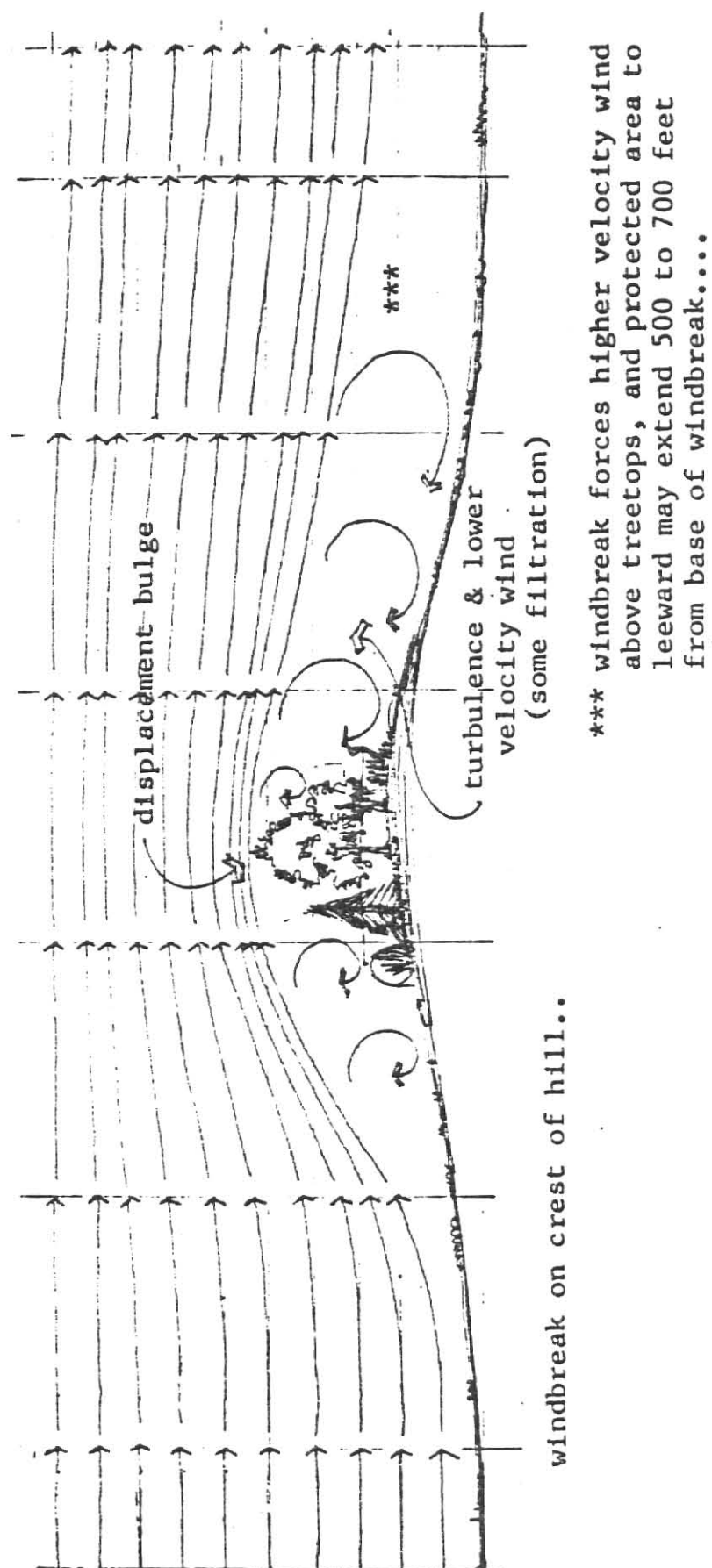


Fig. 20 - Vertical Displacement of Wind by Vegetation

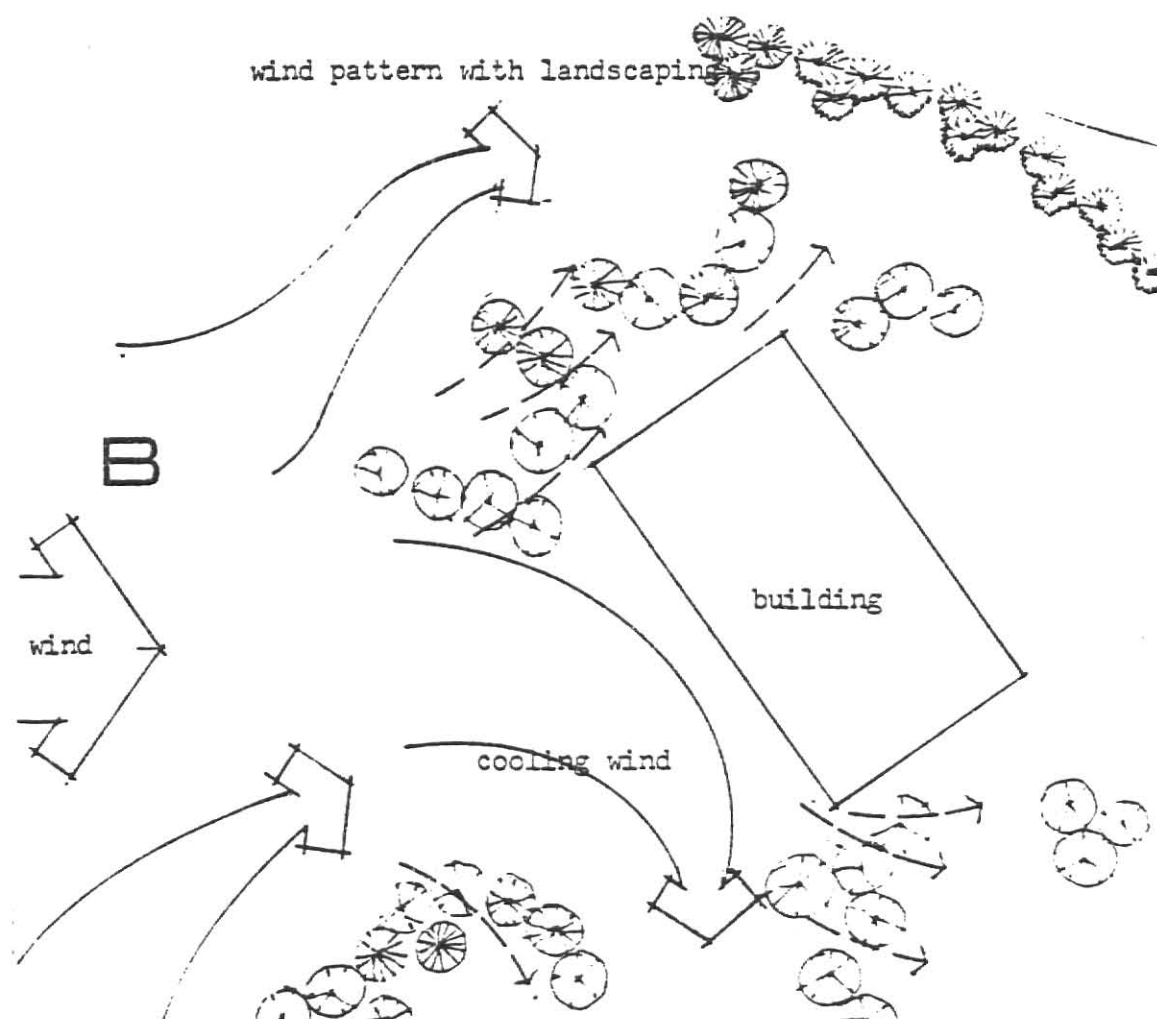


Fig. 21 - Horizontal Displacement of Wind by Vegetation

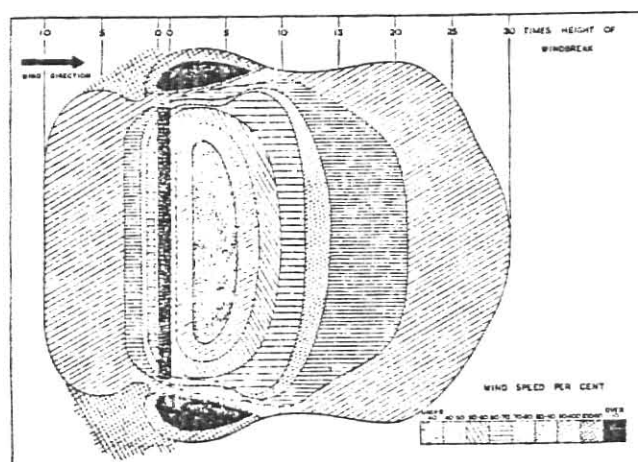


Fig. 22 - Plan of Wind Conditions at Moderately Dense Shelterbelt

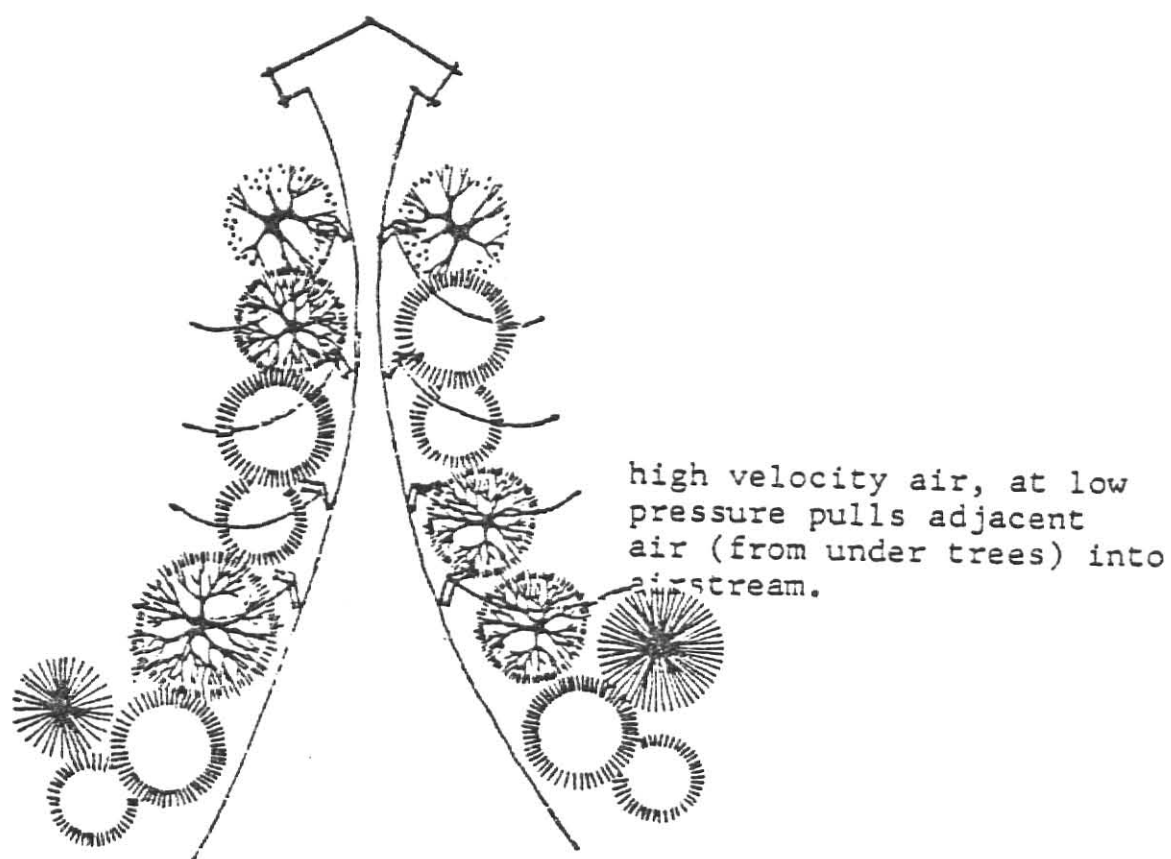


Fig. 23 - Venturi Created by Plant Materials

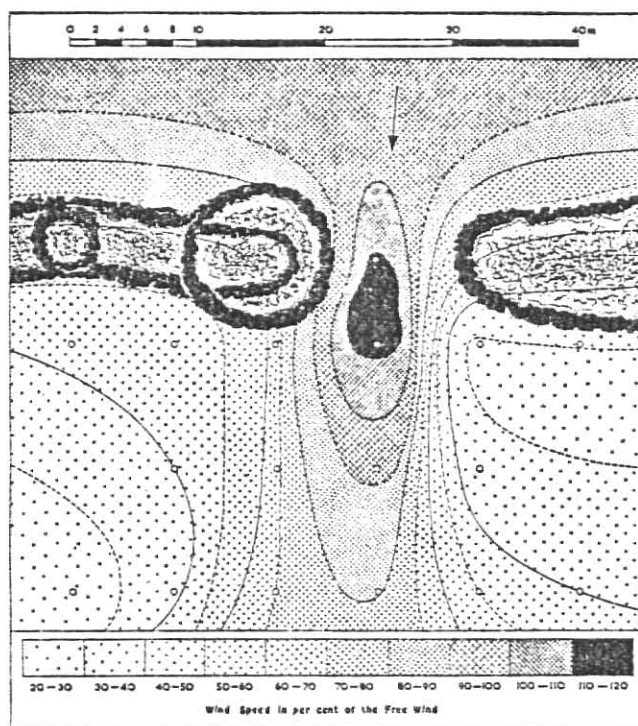


Fig. 24 - Venturi at Gap in Shelterbelt

Vegetation can also act as an air filter. For example, fog has been shown to dissipate more rapidly in areas of heavy concentrations of pine needled trees. The fog condenses on the leaves and drips to earth, allowing sunshine to penetrate to the ground.<sup>7</sup> Additionally, it has been shown that planted areas tend to filter pollutants and odors from the air.

Low-growing vegetation has similar effects on winds at ground level. Figure 25 shows how wind speed is reduced over low plant growth, in this case a beet field. Depending on height, roughness and thickness of the planted surface, this effect is seen to some degree in all planted areas.

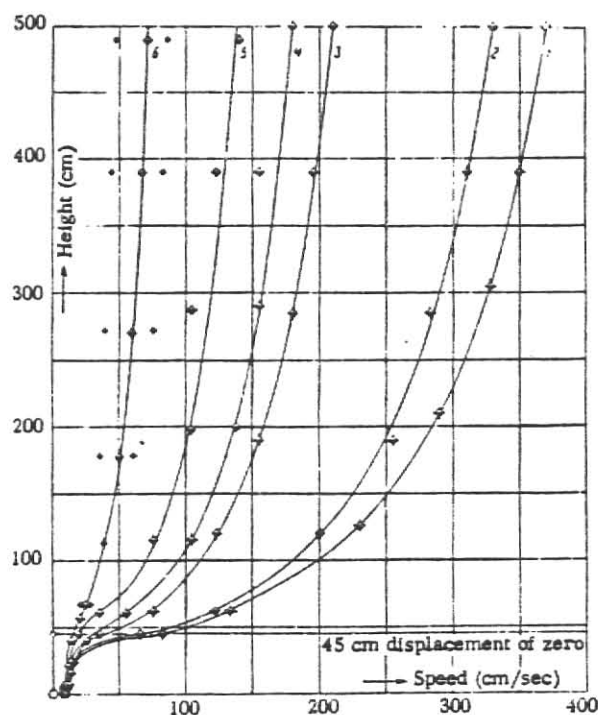


Fig. 25.--Wind profiles in and above a beet field

Vegetation and Humidity.--Vegetation acts in two ways with regard to humidity and precipitation. First, plants intercept water falling on its way to earth. Second, plants draw moisture from the soil and release humidity into the atmosphere.

In rainy conditions, not all of the rain reaches the ground in treed

areas. For example, only 60 percent reaches the floor of a pine forest, and 80 percent reaches the ground beneath a hardwood forest canopy.<sup>8</sup> The moisture reaches the ground in two ways: raindrops which fall freely through the tree canopy, and dripping rain from leaves which had previously intercepted the rain. The amount of rainfall reaching the ground is influenced by the intensity and duration of the rainfall, the tree type, and the structure of the tree canopy. While less moisture reaches the ground, that which does is retained longer than moisture falling on exposed soil.

Transpiration of water into the air, along with the lower temperatures in planted areas, causes the relative humidity in such areas to be higher than in the open. Figure 26 illustrates how humidity at the forest floor is higher than above the forest canopy for three conditions: a cloudy day, a clear night, and a windy day.

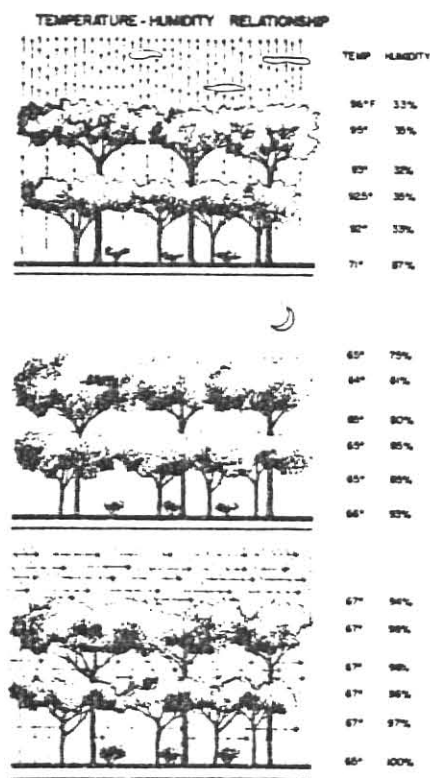


Fig. 26.--Humidity levels in a forest setting

### Earth Surface Conditions

The condition and composition of the soil or other material which forms the site's surface can have a significant effect on the climate of that site.

Surface Conditions and Radiation.--Different types of soils and ground materials affect the amount of the sun's radiation which is absorbed or reflected. In general, lighter, less moist surfaces reflect more and absorb less of the sun's radiation. Reflection of the sun's rays from light surfaces can be very useful to architects for bouncing light into buildings when the architecture is properly integrated with outdoor surfaces. Figure 27 illustrates the various reflective capacities of different types of ground surfaces.

Fresh snow cover	75-95
Dense cloud cover	60-90
Old snow cover	40-70
Clean firm snow	50-65
Light sand dunes, surf	30-60
Clean glacier ice	30-46
Dirty firm snow	20-50
Dirty glacier ice	20-30
Sandy soil	15-40
Meadows and fields	12-30
Densely built-up areas	15-25
Woods	5-20
Dark cultivated soil	7-10
Water surfaces, sea	3-10

Fig. 27.--Albedo of various surfaces

In addition, soil type and configuration can affect the radiation pattern. Rough surfaces such as tilled soil, and loosely packed soils tend to bounce less radiation back to the atmosphere.

Surface Conditions and Air Temperature.--Closely tied in with the effects on radiation of various surfaces is the effect on air temperature. Soils or other materials which tend to absorb more radiation also show an increase in temperature. Soils with the least air content absorb the most solar radiation; thus it has been found that the greatest change of air temperature is over soils with a high moisture content.<sup>9</sup> Rough or disturbed soils tend to be cooler during the day than smooth surfaces, since incoming radiation is bounced

off at odd angles and not received straight on.<sup>10</sup>

Since daytime temperatures are hottest in the air layer next to the ground,<sup>11</sup> and this is also the coolest location at night,<sup>12</sup> it can easily be seen that surface composition, color, and configuration can have a strong influence on the temperature at a site. Figure 28 illustrates how the temperatures of different surface materials can be markedly different.

Type of ground	June			January		
	Max.	Min.	Variation	Max.	Min.	Variation
Tar macadam	35.4	10.0	32.6	8.1	1.2	6.9
Earth	35.1	10.4	25.0	7.1	1.7	5.4
Sandy soil	31.1	9.1	26.0	7.4	2.0	5.4
Gravelly soil	42.6	9.9	21.2	7.1	1.4	5.7
Under grass	29.3	13.3	16.0	6.2	2.9	3.3
Loam	24.6	13.1	11.5	6.7	1.7	5.0
(Air temperature)	21.8	7.6	14.2	8.3	1.7	6.6

Fig. 28.--Variation of subsurface temperature (°C) with soil type

Surface Conditions and Wind.--Surface conditions can have an effect on local wind patterns, usually due to the roughness of the ground or temperature variations of different surface materials. This effect is usually quite small, however, and can be disregarded for our purposes.

Surface Conditions and Humidity.--Different types of soil have different capacities for moisture absorption and retention. Architecturally speaking, these variations are usually small, except in extreme cases such as the mud slide areas of California. Figure 29 shows how, in a normal situation, soil moisture can vary for different soil types. The most common and significant aspect of soil moisture is in its ability to sustain plant growth, and in that respect it is an important factor to be considered.

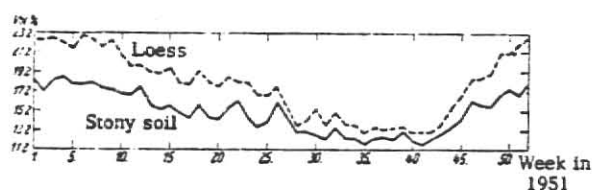


Fig. 29.--Annual moisture variation in two different types of soil

### Bodies of Water

The proximity of a particular site to a body of water, be it ocean, lake or river, can have an effect on the climate of that site.

Water and Radiation.--The effects of water on the incoming solar radiation depend mostly upon color and depth of the water. Deep or dark colored water has a low albedo, or reflectivity factor. Shallow water bodies, such as reflective pools, tend to be in the light color spectrum and, therefore, reflect high percentages of solar radiation. The smooth surface of water allows for a predictable pattern of bounce of the sun's light.

Reflective properties of water can be quite useful to the designer. For example, in temperate climates where reflected sunlight can be useful in winter but undesirable in summer, reflecting pools can be a good feature. The dark, low reflective surface cuts down on summer radiation, and in winter when the water is frozen and possibly covered with snow, a highly reflective surface is presented.

Water and Air Temperature.--The most striking aspect of a body of water with respect to microclimate is its ability to moderate the air temperature of an area. This is due to the fact that water stores a large amount of incoming radiation and reflects little. The result is that sites near water bodies, if the water body is large enough, will be cooler in hot weather and warmer in cold weather.

On the macro side, large land areas are affected by this moderating



influence. Coastal sites benefit from the moderating effect of the oceans and the winds which blow in over them. During the course of an entire year, the surface of an ocean may vary no more than  $18^{\circ}\text{F}$  and less than  $1^{\circ}\text{F}$  from day to night.<sup>13</sup>

Inland lakes have the same effect on surrounding areas, though to a lesser extent. The moderating effect of Lake Michigan enables a large fruit growing industry to thrive in the area. Figure 30 shows graphically the effect of a lake on air temperature near the shore. Readings were taken at a height of one meter and for a distance of 100 meters horizontally on either side of the shoreline.

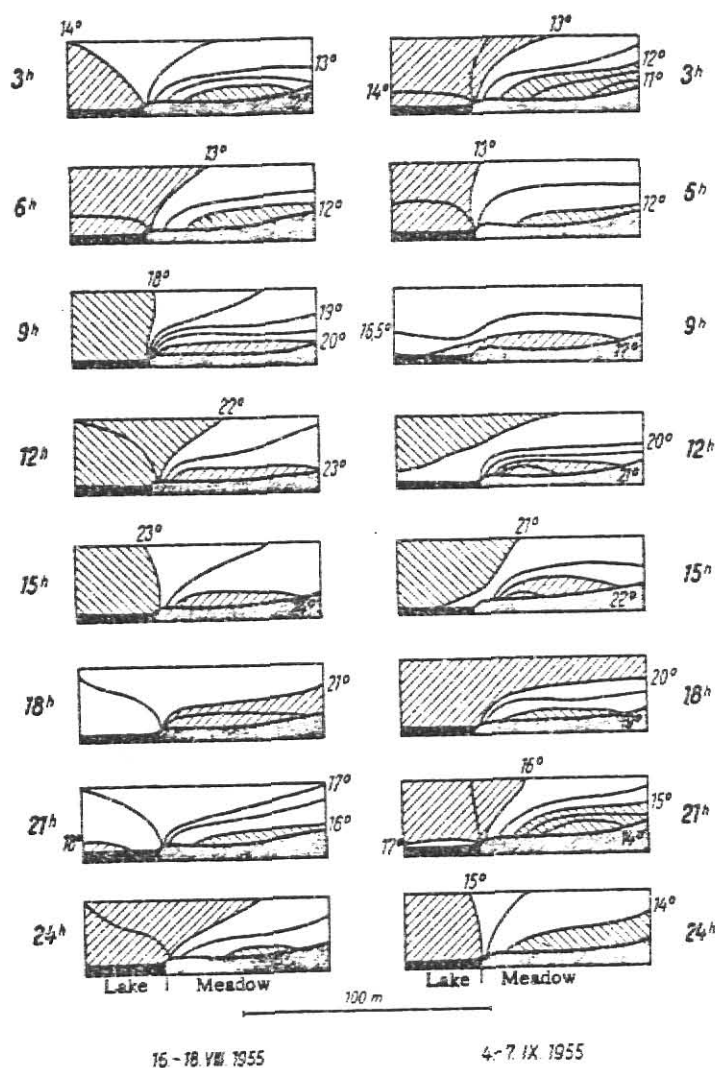


Fig. 30.--Temperature field near a large lake

Rivers and streams can also have an impact on the microclimate. These flowing bodies of water are generally cooler than the air in warm weather, with temperature depending upon distance from the source, depth and width of the stream, the amount of shading of the stream, and the influence of heat exchange with the river bed. Figure 31 shows how temperature near the surface differs over water with that of the bank, eight meters away. As can be seen, at a height of about 40 centimeters this difference is all but eliminated. Further study on the influence of rivers and streams on the microclimate could prove to be quite helpful to designers.

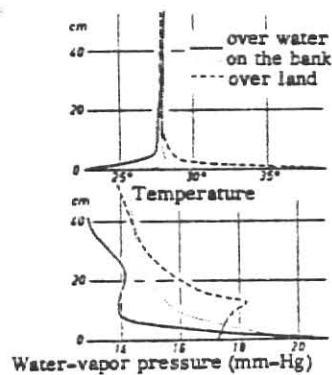


Fig. 31.--Temperature and pressure at water's edge

Water and Humidity.--Humidity levels tend to be higher in areas where water is present. This is a function of the evaporation of water from the water's surface. Since water evaporates more when the temperature is hottest,<sup>14</sup> it can be a helpful design element for evaporative cooling. Designers should be careful, however, to keep water moving to prevent stagnation and insect breeding.

#### City Environments

Sites which are located within cities deal with a particular set of conditions which affect climate. While architects are rarely in a position to

manipulate these elements, an awareness of them is important.

Solar Radiation in Cities.--Generally, city sites receive significantly less solar radiation than do their rural counterparts. This is usually due to the increased number of particles suspended in air from dust, smoke, automobile emissions, and other sources. Studies have indicated that the average annual amount of solar radiation received on a horizontal surface in a city is 15 to 20 percent less than in the country.<sup>15</sup>

Besides the particles in the air, sites in cities are often in deep shadow due to the proximity of nearby tall buildings. Shadow patterns of buildings block out much more sunshine than do most tree groupings, and should be of great concern to the designer with an urban site.

Air Temperature in Cities.--Probably the most documented and widely known difference between urban and rural environments is the difference in temperatures. In general, there are two processes which cause the city to become a "heat island." In summer the mass of building materials of the city--concrete, asphalt, masonry, etc.--which go into buildings, streets, and parking lots, absorb large amounts of solar radiation. This increases heat both in daytime and during the night. In winter, heat which leaks from buildings and that which is given off by automobiles and manufacturing processes has the same effect. Figure 32 indicates the results of a temperature study in London in May of 1959, showing a 12°F difference between temperatures at the edge of the city and the city center.

Wind in Cities.--The average wind speed in cities has been found to be lower than that in rural areas. This is basically due to the presence of so many obstructions to the general wind flow. There are, however, many instances where wind speed is increased in certain areas of a city, sometimes to a point that dangerous conditions are created. The presence of many tall buildings on either side of a street can create a channel for winds, creating a Venturi



Fig. 32.--Minimum temperature distribution, London, May 14, 1959, in °C with °F in brackets

effect. The path of wind around a building creates areas of high speed due to the action of wind flow around a bluff body, as illustrated in Figure 33.

In addition to the channeling effect and changing of wind speed and direction in the horizontal plane, vertical winds are created by the flow of air striking a tall building. Figure 34 illustrates these wind patterns which should be, but too often have not been, of prime consideration to urban designers.

Humidity and Precipitation in Cities.--While relative humidity in cities is generally slightly lower than in rural areas, the average annual precipitation tends to be higher. This is probably due to the particle content of the air, which causes more favorable conditions for cloud formation and rainfall.

Figure 35 shows the results of rainfall measurements in Washington, D.C.

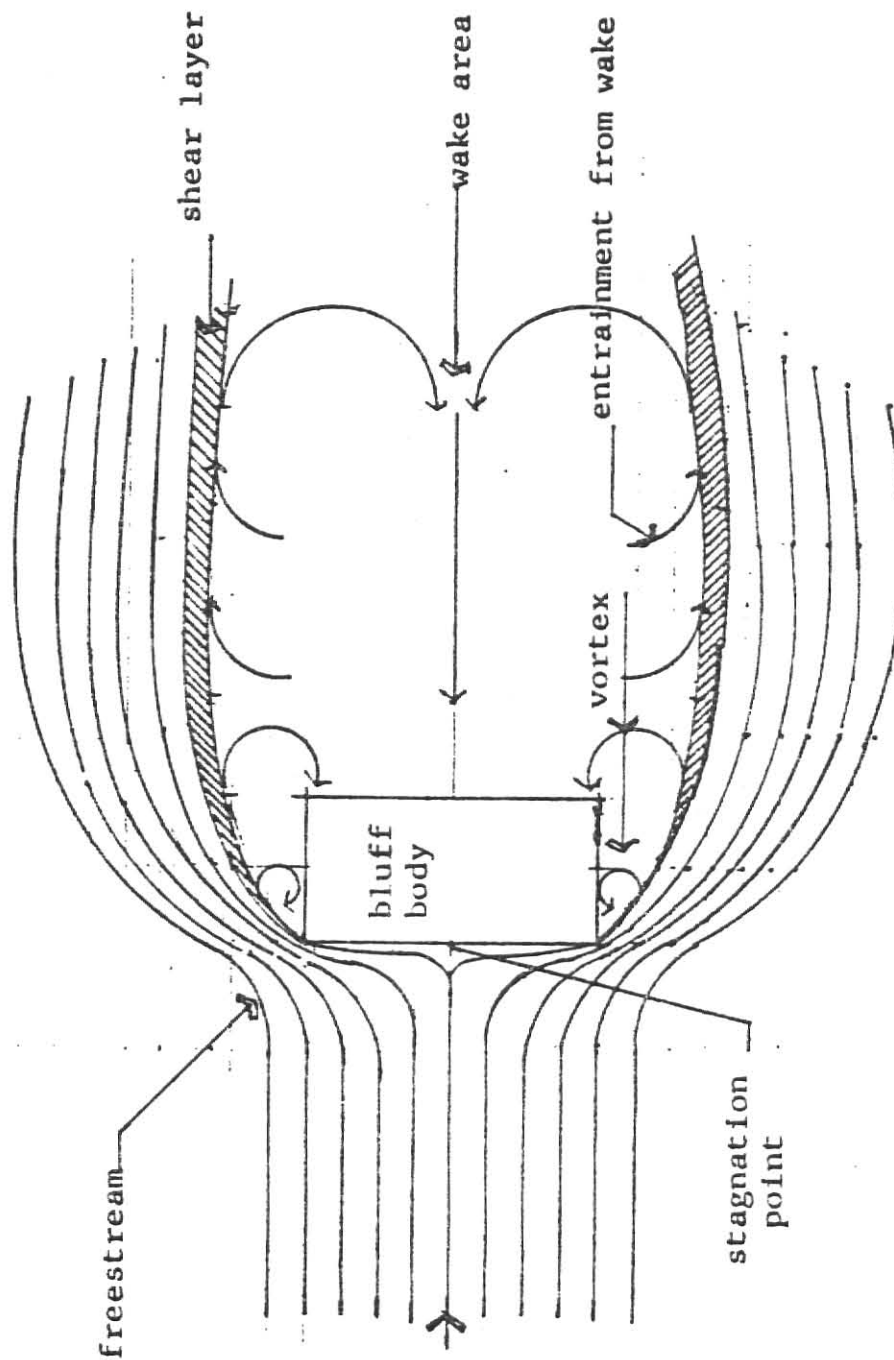


Fig. 33 - Windstream Flow Field About a Bluff Body

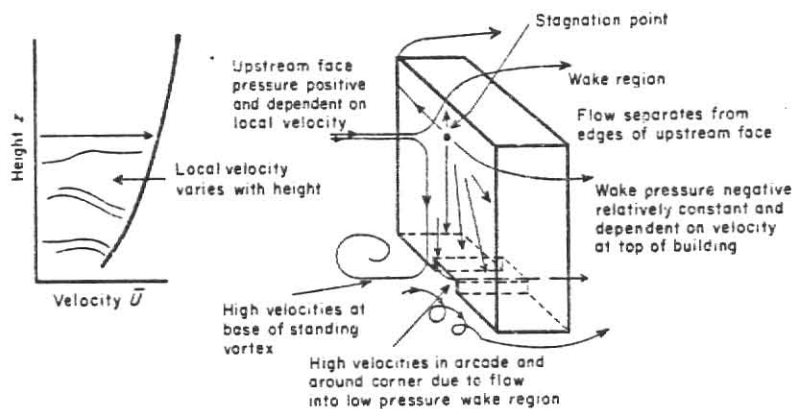


Fig. 34.--Wind flow field around a building

Areas of the most precipitation, which are pushed slightly northward by the southerly breezes, verify the conclusions of others on this subject.

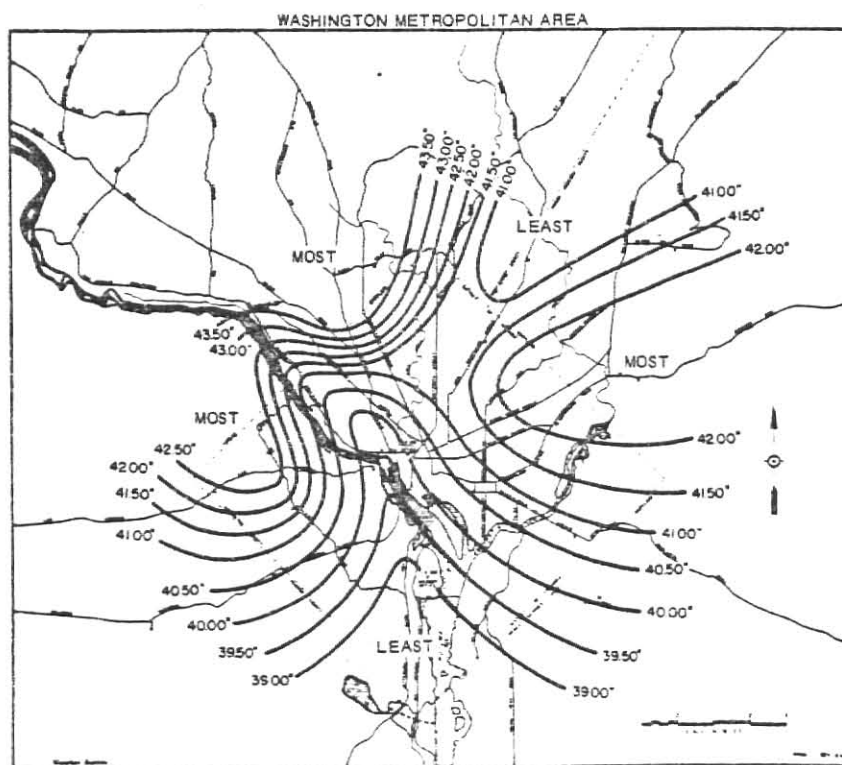


Fig. 35.--Mean annual precipitation (inches), Washington, D.C.

Figure 36 gives a summary of the effects of cities on climate, based on the research of Dr. Helmut Landsberg. The microclimatic designer working in an urban area would do well to note these effects and take them into account in the design process.

Element	Comparison with rural environs
Temperature	
Annual mean	1.0 to 1.5 °F higher
Winter minima	2.0 to 3.0 °F higher
Relative humidity	
Annual mean	6 % lower
Winter	2 % lower
Summer	8 % lower
Dust particles	10 times more
Cloudiness	
Clouds	5 to 10 % more
Fog, winter	100 % more
Fog, summer	30 % more
Radiation	
Total on horizontal surface	15 to 20 % less
Ultraviolet, winter	30 % less
Ultraviolet, summer	5 % less
Wind speed	
Annual mean	20 to 30 % lower
Extreme gusts	10 to 20 % lower
Calms	5 to 20 % more
Precipitation	
Amounts	5 to 10 % more
Days with < 0.2 inch	10 % more

Fig. 36.--Climatic Changes Produced by Cities

## FOOTNOTES

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2. Jeffrey Ellis Aronin, Climate and Architecture (New York: Reinhold Publishing Corporation, 1953), p. 57.
3. Rudolph Geiger, Climate Near the Ground (Cambridge, Mass.: Harvard University Press, 1966), p. 370.
4. Olgyay, p. 44.
5. Geiger, p. 404.
6. Olgyay, p. 50.
7. Gary Robinette, Landscape Planning for Energy Conservation (Reston, Virginia: Environmental Design Press, 1977), p. 99.
8. Ibid., p. 39.
9. Aronin, p. 140.
10. Ibid., p. 141.
11. Ibid., p. 136.
12. Ibid., p. 137.
13. Aronin, p. 146.
14. Robinette, p. 159.
15. James T. Peterson, Climate of Cities (Raleigh, N.C.: U.S. Dept. of HEW, 1969), p. 25.



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- Fig. 5. Rudolph Geiger, Climate Near the Ground (Cambridge, Mass.: Harvard University Press, 1966), p. 374.
- Fig. 6. Ibid., p. 376.
- Fig. 7. Groff Conklin, The Weather Conditioned House (New York: Reinhold Publishing Corp., 1958), p. 11.
- Fig. 8. Geiger, p. 393.
- Fig. 9. Ibid., p. 408.
- Fig. 10. Keith Christensen, handouts for course "Environmental Dynamics," Kansas State University, Fall 1979.
- Fig. 11. Gary Robinette, Landscape Planning for Energy Conservation (Reston, Virginia: Environmental Design Press, 1977), p. 12.
- Fig. 12. Olgyay, p. 50.
- Fig. 13. Geiger, p. 301.
- Fig. 14. Ibid., p. 291.
- Fig. 15. Ibid., p. 318.
- Fig. 16. Ibid., p. 286.
- Fig. 17. Conklin, p. 12.
- Fig. 18. Christensen, handouts.
- Fig. 19. Robinette, p. 23.
- Fig. 20. Christensen, handouts.
- Fig. 21. Ibid.
- Fig. 22. Robinette, p. 37.
- Fig. 23. Christensen, handouts.
- Fig. 24. Robinette, p. 37.
- Fig. 25. Geiger, p. 274.
- Fig. 26. Robinette, p. 41.
- Fig. 27. Geiger, p. 15.

- Fig. 28. Ibid., p. 144.
- Fig. 29. Ibid., p. 169.
- Fig. 30. Ibid., p. 245.
- Fig. 31. Ibid., p. 244.
- Fig. 32. James T. Peterson, Climate of Cities (Raleigh, N.C.: U.S. Dept. of Health, Education and Welfare, 1969), p. 8.
- Fig. 33. Christensen, handouts.
- Fig. 34. R. M. Aynsley, W. Melbourne and B. J. Vickery, Architectural Aerodynamics (London: Applied Science Publishers Ltd., 1977), p. 151.
- Fig. 35. Peterson, p. 34.
- Fig. 36. Ibid., p. 1.

## CHAPTER IV

### THE MICROCLIMATIC SITE SURVEY

The purpose of site surveying for microclimatic design is to gather raw data at the site which will be needed to develop design strategies for climate moderation. Two basic types of data are needed: physical information which can be gathered in the initial visit to the site, and information on the climatic conditions at the site. Data required for the climatic survey demand repeated visits to the site, or the placement of recording instruments which constantly monitor and record base data information.

The economics of architectural practice dictate that time devoted to a microclimatic survey be held to a minimum. Time which is feasible to allow will vary with the size and complexity of the site, building budget, building function, and amount of time allowed for the development of architectural contract documents. For most projects, a period of four to six weeks could be allowed for microclimatic surveying. Much of the schematic design and design development could be carried on at the same time as the site survey. Any information and conclusions gathered at the site could be incorporated into the design if this time frame is adhered to.

By collecting proper data at the site, the designer can begin to make proper decisions which will complement the design process. Gary Robinette has stated:

Proper gross site selection prevents problems in discrete site selection, proper discrete site selection prevents problems in site planning--proper site planning prevents problems in site design and detailing--proper site design prevents problems in

architectural design--and proper architectural design prevents problems in mechanical design.<sup>1</sup>

### Physical Site Survey

The physical site survey consists of gathering and recording the information which can be accomplished in an initial site visit. Information included should be site dimensions, topography, vegetation, earth surface materials, bodies of water, if any, and surrounding buildings, if any.

Dimensions and contours of the site can be obtained from private surveys, city or county records, or dimensions and surveys performed at the site by the architect. Other information which can be of use from these documents includes utility locations, property lines, and street locations.

Even though some surveys indicate vegetation, the architect should inspect the site and record and update this information himself. Many surveys are inaccurate in this regard, and vegetation is important enough to micro-climatic design that the architect must be certain of his information. In addition to the location and types of shrubs and groundcovers, the survey should accurately locate all trees on the site, including their location, height, height to bottom of foliage, foliage spread, and type. This information will be important when plotting shadow patterns on the site plans. Such information is also useful in any model simulation studies which may be planned for the project.

Earth surface materials are another area of information which should be recorded. Streets, walks, parking areas, paved paths, areas of different surface materials such as rocks and other earth surface materials should be located and noted.

Additionally, bodies of water and surrounding buildings, including size, shape and spacing, should be accurately located and noted in the survey.

Information such as views, potential odor problems, pollution sources, Venturi wind effects, and other items which may affect design should be recorded.

Information gathered in the physical site survey can be recorded on a site plan with supporting schedules and charts, as needed. This plan should be drawn to scale with the compass directions indicated, as well as information gathered concerning topography, vegetation, earth surface conditions, water bodies, and man-made structures. A photographic survey can also be quite helpful. During later analysis, the photographs can be referred to for verification of items and for details which may have gone unnoticed in first surveys. A site section may also prove to be useful in the later stages of analysis and site design. An example of the physical site survey, including site plan, schedules and photographs are included in Chapter VI.

#### Climatic Site Survey

While the information contained in the physical site survey is familiar to most architects, climatic site surveying is a relatively new concept, and will be discussed in more detail. Most articles concerning "climate-based design" discuss regional or area climate, as determined by records of weather stations, airports, or other traditional information-gathering agencies. As has been stated, these weather records may not coincide with conditions at a particular site, and may be too general in nature to be useful. Because of this, it is necessary for the architect to gather his own information concerning wind, temperature, solar radiation, and humidity at each particular site.

Gathering the required climatic information entails the use of some instruments and methods not familiar to most architects. This data should be collected at the site in the area where the building will most likely be located. On some sites, this location will be obvious, but in some cases where large sites are involved, there may be more than one potential location

for the building. If this is the case, the climatic data should be gathered at each possible building location. Additionally, the architect should determine if there are any potential problem areas on the site, and gather climatic data at these locations, as well. Such problem areas could include snow drift zones, unpleasant wind turbulence, or locations where unusually high velocity winds might occur.

Measuring the Wind.--Wind conditions at a site can vary in many respects from the conditions recorded for an area. Both wind speed and direction at the site should be recorded by the architect. Instrumentation available for recording wind conditions can range from the very simple and inexpensive to costly automated devices.

At the low end of the cost scale, wind directions can be determined by streamers and poles, and a simple compass. The cost for these items should range from ten to twenty dollars. Direction of the wind can be recorded by observation of streamers as they are affected by passing breezes. The architect who chooses to record wind direction in this manner sacrifices some accuracy in order to save money. Additionally, wind direction readings can be recorded only by direct observation at the site. This means that someone must be at the site to record information and, therefore, lose time that could be spent in the office if automatic recording devices were used that were more expensive. Placing a series of streamers over the site does, however, provide the architect with wind direction information at more than one place simultaneously, and can give the designer a better insight into how wind travels over a site.

Wind vanes which automatically record wind direction on a strip chart are available on the market, often as part of a wind-speed and direction-recording unit. Such devices are much more expensive than the compass and

streamers method, sometimes costing several thousand dollars. They offer the architect a greater degree of accuracy and convenience, however, and are well worth the consideration of the designer who is seriously interested in microclimatic design, energy conservation, and human comfort, and whose office does a volume of work large enough to absorb the initial expense. They are generally referred to as anemometer-wind vane units, or anemographs. Such units can be placed on a site and left for a period of time, often the entire month allotted for microclimatic surveying. During this time, these instruments record wind speed and direction simultaneously and continuously on a chart or other device. After the survey period, this chart can be retrieved by the architect and used for analysis purposes. Automatic units can be powered by AC or DC electrical current, batteries, or spring-wound mechanisms. The convenience to the designer is obvious; he can be in the office performing other tasks and be recording wind conditions at the site at the same time. Disadvantages of such units are the possibility of vandalism to an unprotected device, initial cost, and the lack of a "feel" for the site which can be gained through on-site observations. Examples of such units are contained in the manufacturers' literature in Appendix B.

It should be pointed out that no amount of automation can entirely replace direct observation. The insights gained from time spent at the site by the architect should not be underrated.

For the architect who chooses to forego automatic devices in favor of less expensive wind direction recording, the question of how to record wind speed must be answered. Anemometers for measuring wind speed vary in type, cost, and accuracy. At the low end of the cost scale are hand-held devices which show wind readings as a result of wind pressure felt on the face. Such units are generally accurate enough for the purpose of architects when wind

speeds are over five miles per hour. Costs for these devices are currently in the \$25 to \$50 range. For wind speeds below five miles per hour, hand held devices designed for measuring air velocity in ductwork can be quite useful. Another type of anemometer is the cup-type, which depends upon the rotation of three or more wind cups due to the wind's velocity. Wind speed is indicated by the electrical current generated by these moving cups; the greater the current, the higher the wind velocity. Selected examples of cup anemometers are shown in Appendix B, with costs ranging from a few hundred dollars to considerably more. Two main advantages of cup anemometers are their accuracy even at very low velocity breezes, and their ability to record wind speeds from any direction without having to be pointed into the wind.

A third type of anemometer is known as a wind-run accumulator. These devices record only the total amount of wind passing the anemometer in miles or fractions of a mile of wind.<sup>2</sup> Average wind speed is computed by dividing the distance of wind recorded by the time that the recorder was in operation. Wind-run accumulators with anemometers can be purchased for less than \$200, and have the advantage of giving a wind speed reading unaffected by gusts or other short term aberrations.

For firms that can afford the cost, an anemograph system that records wind speed and direction continuously from sensors set on three or four locations at the site would be ideal in terms of accuracy and convenience. However, less expensive systems can provide data which is almost as easy to use, and as accurate. For the cost-conscious, a hand-held cup anemometer, a series of pole-mounted streamers and a compass, along with the investment of some time and effort, can produce data which is useful and relatively accurate for under \$200.

Once the decision is made about instrumentation for wind recording,



what information to record and how to gather it should be addressed. First, it must be remembered that the microclimatic survey data will be compared with area weather data gathered by the Weather Bureau at the same time. Therefore, it is essential that the architect know where and how wind data for the area is gathered, and how to gain access to that information. For example, wind information, reported as the conditions in a given city, may be gathered at an airport every hour of the day at five minutes before the hour, with wind speed being averaged for one minute. A microclimatic survey wind reading should be taken to correspond with this schedule, i.e., at five minutes before the hour. This point is especially important for designers not recording wind conditions continuously with an automatic data logger.

Locations of wind recording instruments should be shown on the site plan and numbered. A schedule can then be made which indicates the date, time, location of reading, wind speed in miles per hour, and wind direction. It is also advisable to include spaces for wind speed and direction readings of the local weather station for the same time and date. Information gathered during the survey period can be easily entered on the schedule to be analyzed later against corresponding area weather data. The objective during the survey period is to record winds at the site which correspond to the major directions of wind in the area. If the prevailing summer winds are from the south and winter winds from the north, then site data should roughly correspond to or be interpolated to correspond with area readings of winds from these directions. It may be that a prevailing north wind, as recorded by the local weather station, will actually cross the site in a more westerly direction, or in some other unexpected way. The architect must be sure to be at the site to record such significant findings. In most locations, winds will be recorded, at one time or another during a four-week period, from all directions.

The microclimatic surveyor should be aware of wind direction changes and be prepared to go to the site to record wind conditions when a shift in direction is likely. Local weather forecasts can serve to alert designers to impending weather changes. This willingness to invest the effort to gather useful data will repay the architect in a more accurate assessment of conditions at the site, and a more effective energy-conserving design. Chapter VI includes examples of wind measuring and data recording during a microclimatic survey.

Measuring Temperature.--The variance of air temperatures recorded at a site with those recorded for the area are less likely to affect the final design or to contrast as sharply as wind readings. Temperature readings are important, however, as indicators of the physical characteristics at the site which effect the microclimate. A temperature reading significantly above or below that recorded at the local weather station should indicate to the designer that something--topography, wind, vegetation, or other physical factor--is acting to alter the microclimate of the site. An inquiring eye and mind should then be cast about to ascertain the nature of this characteristic and to use it to the designer's advantage.

As with wind instruments, a range of unit price and complexity are available for temperature recording. Thermometers which send impulses to a recording unit, for later retrieval, are available either alone or as part of a more complex weather collection array. Such automatic devices are generally accurate to within about  $1^{\circ}\text{C}$  and offer the convenience of continuous data recording without requiring the presence of a site surveyor. Such devices range in price at the present time upwards from about \$200. At the other end of the price scale, a simple mercury thermometer can be obtained for a few dollars, and probably offers the accuracy necessary for a microclimatic survey. The main drawback to the use of these instruments is the necessary

presence of the surveyor to read and record the instrument data.

It would appear that, for most architects, a group of mercury thermometers set up at strategic locations on the site would be an economical temperature recording installation. These thermometers could record the effects of shade, upslope and downslope wind flows, surface materials and other temperature aspects of the site. Some care should be taken to shade simple thermometers to achieve the greatest degree of accuracy.

Acquisition of a continuously recording thermographic device, such as those illustrated in Appendix B, would be a better choice for the designer when upgrading site surveying instrumentation. This unit could be set at the probable building location and would provide, in conjunction with other thermometers at the site, a good indication of temperature patterns.

As with wind recording, it is wise for the architect to find out about temperature recording methods of the local weather station. Most weather station temperatures are recorded by a device shielded from the effects of sun and wind. At the site, however, the architect should record conditions as they exist, with the exception of placing thermometers in direct sun, and this will cause some of the variation between the two temperature readings. If temperatures are read only at certain times by the local weather reporters, then the site survey temperatures should be read at similar time intervals. If the weather station records data continuously, this requirement is not as important for the architect's readings.

Temperature data gathered at the site should be recorded in much the same fashion as wind data. Numbered locations of thermometers should be recorded on a site plan, and data should be entered on a schedule which includes location of the thermometer, date, time, temperature reading, general sun conditions at the thermometer, i.e., shaded, cloudy, etc., and general wind conditions at the thermometer. A space for the recording of weather

station temperature data is also advisable. Examples of temperature recording are included in Chapter VI.

Measuring Solar Radiation.--In most instances, the amount of solar radiation falling on a site, in BTUs per square foot, will not differ dramatically from solar radiation measurements obtained by the local weather bureau. Shading and topography can have the most dramatic effects on solar radiation at a site, and the knowledgeable designer can estimate these effects with reasonable accuracy without actual monitoring. In some cases, however, where smog, heavy fog, mists, or other factors that can cause a substantial difference in solar radiation occur, site measurement may be necessary. Also, if active solar collectors will be employed to a great extent in the building design, solar radiation measurements are advisable to determine the effectiveness and extent to which the sun will provide energy for the building.

Instruments for measuring solar radiation are called pyranometers. As with all instruments for weather recording, there is a range of prices of pyranometers coinciding with the sophistication and convenience of the various models. A pyranometer coupled with a monitor which gives instantaneous readouts and stores information for later retrieval can be obtained for about \$750, and on up to over \$1,000. The designer who opts for the purchase of such a system should carefully consider the various models, features and options available. Appendix B contains examples of currently available solar monitoring systems.

As with wind and temperature measurements, solar monitoring should be carried out in the location(s) where the building will probably be placed. A system of continual recording of solar radiation would preclude the need for keeping a running log of measurements. If such a system is not used, then a record listing location of the instrument, date, time, and measurement, usually in BTUs per square foot, at both the site and the local weather station,

should be kept during the microclimatic survey period.

Measuring Humidity and Precipitation.--Humidity and precipitation levels, as with solar radiation levels, are not likely to differ substantially from the local weather service information. The presence of heavy growth of vegetation or bodies of water at a site do affect humidity levels, but these can be estimated, in most cases, without harmful consequences.

There are many instruments on the market which can be used to measure humidity, should the designer feel the need for such information, or if no area humidity/precipitation records are available. Usually these devices are manufactured in conjunction with thermometers to measure temperature, and are called hygrothermographs. They can be purchased for about \$65, if no recording capacity is required. Devices which record temperature and humidity on a chart continuously for up to seven days or more can be obtained for about \$300. Examples of these instruments are included in Appendix B. Rainfall can be recorded in a simple rain gauge, available in most hardware stores for under \$5.

The recording instrument should be placed in the most likely area where the future building will be located. A log showing location of the instrument, date, time, and measurements both at the site and at the local weather station should be kept if no automatic data recorder is used.

#### Summary

Following is a checklist for the designer to use when carrying out a microclimatic site survey. Information from the site survey will be recorded on the site plan photographs, vegetation schedules, building schedule, wind information data log or automatically recorded data, and temperature log or automatically recorded data. Optional information concerning solar radiation levels and humidity/precipitation levels will be kept on a log or on automati-

cally recorded tapes or printouts. Each of these items is listed here, along with the information which should be recorded on each one.

### Physical Site Survey Checklist

#### SITE PLAN

1. General size and shape of the site, compass directions, drawn to scale.
2. Site topography.
3. Location of trees and vegetation (numbered).
4. Location of buildings and man-made structures (numbered).
5. Location of bodies of water.
6. Location of different surface materials.
7. Location of climate-monitoring instruments (numbered).

#### PHOTOGRAPHS

1. General conditions at site and surroundings.
2. Buildings on and around site.
3. Vegetation on and around site.

#### VEGETATION SCHEDULE

1. Number of shrub or tree.
2. Type: deciduous or evergreen.
3. Overall height, including foliage.
4. Overall diameter, including foliage.
5. Height to bottom of foliage.
6. Remarks: health, species, etc.

#### BUILDING SCHEDULE

1. Number of building.
2. Name.
3. Eave height.
4. Ridge height, if applicable.
5. Remarks.

Climatic Site Survey Checklist

## WIND INFORMATION LOG\*

1. Instrument number
2. Date
3. Time
4. Wind speed
5. Wind direction
6. Wind speed recorded at local weather station.
7. Wind direction recorded at local weather station.

## TEMPERATURE LOG\*

1. Instrument number
2. Date
3. Time
4. Sun conditions
5. Wind conditions
6. Temperature reading
7. Temperature reading at local weather station.

## Optional: SOLAR RADIATION LOG\*

1. Instrument number
2. Date
3. Time
4. Instrument reading
5. Instrument reading at local weather station.

## Optional: HUMIDITY/PRECIPITATION LOG\*

1. Instrument number
2. Date
3. Time
4. Instrument reading
5. Instrument reading at local weather station.

\* Can be omitted if required information is recorded automatically.

## FOOTNOTES

1. Gary Robinette, Landscape Planning for Energy Conservation (Reston, Virginia: Environmental Design Press, 1977), p. 70.
2. Paul Gipe, "Clocking the Wind," Solar Age, October 1980, p. 31.



## CHAPTER V

### MICROCLIMATIC SITE ANALYSIS, EVALUATION, AND DESIGN

In order to develop a site design which will help to reduce energy consumption in a proposed building, it is first necessary to analyze the data previously gathered and evaluate the existing site for areas of potential benefits or problems. The analysis phase involves the development of site-specific diagrams and charts showing shadow patterns throughout the year and a climate profile of the site. This climate profile will indicate expected average yearly wind patterns, temperature ranges, solar radiation levels, and humidity and precipitation patterns at the site.

The evaluation phase builds on information generated in data analysis to identify, in a general way, strengths and weaknesses of the site as a location for an energy-conscious building. In site evaluation the designer will establish goals for microclimatic site design.

The microclimatic design phase involves the determination of specific design strategies based upon the information presented in Chapter III, which can be integrated into the site plan to help meet goals established in the evaluation phase.

#### Microclimatic Site Analysis

To conduct a proper microclimatic site analysis, the designer will require the following information:

1. Physical site survey
2. Climatic site survey

3. Climate information recorded by the local or area weather station for the same time period as the climatic site survey.
4. Climate information for the area expressed as "average" conditions.

The physical site survey and climatic site survey are explained in detail in Chapter IV. Local weather information for the time corresponding with the climatic site survey data may be available from a number of sources, depending upon the site location. In many areas the best source of weather information is the National Oceanic and Atmospheric Administration's Environmental Data and Information Service at the National Climatic Center in Asheville, North Carolina. They offer, for a yearly subscription fee, a detailed monthly weather summary and yearly weather summary for many locations in the United States. Monthly summaries present information at three-hour intervals throughout the day for wind speed and direction, temperature, relative humidity, and cloudiness. The yearly summary includes information for each month of that year, and averages based upon weather observations in all previous years of data collection. The yearly summary also contains a narrative climatological summary of the area which can be helpful to the microclimatic designer. On the following pages are examples of these NOAA documents. Figures 37 and 38 illustrate a sample monthly summary, in this case for Toledo, Ohio, for January, 1979. Figures 39 through 42 show the yearly summary for Toledo for 1979.

It should be pointed out that the designer who wishes to use NOAA information for microclimatic analysis should collect data at the site in a compatible format. This means that three-hour averages are best for comparison with the three-hour averages presented in NOAA summaries.

In many instances local sources of weather information are available. Often, local weather data are collected by radio stations, television stations,

Fig. 37 - Monthly Climatological Summary -  
Toledo, Ohio - January 1979 - Sheet 1

OBSERVATIONS AT 3-HOUR INTERVALS									
HOUR	DATE	TIME	TEMPERATURE	WIND	WIND	TEMPERATURE	WIND	WIND	TEMPERATURE
1	2	3	4	5	6	7	8	9	10
01	10	1	30	10	10	30	10	10	30
02	10	2	30	10	10	30	10	10	30
03	10	3	30	10	10	30	10	10	30
04	10	4	30	10	10	30	10	10	30
05	10	5	30	10	10	30	10	10	30
06	10	6	30	10	10	30	10	10	30
07	10	7	30	10	10	30	10	10	30
08	10	8	30	10	10	30	10	10	30
09	10	9	30	10	10	30	10	10	30
10	10	10	30	10	10	30	10	10	30
11	10	11	30	10	10	30	10	10	30
12	10	12	30	10	10	30	10	10	30
13	10	13	30	10	10	30	10	10	30
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15	10	15	30	10	10	30	10	10	30
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17	10	17	30	10	10	30	10	10	30
18	10	18	30	10	10	30	10	10	30
19	10	19	30	10	10	30	10	10	30
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23	10	23	30	10	10	30	10	10	30
24	10	24	30	10	10	30	10	10	30
25	10	25	30	10	10	30	10	10	30
26	10	26	30	10	10	30	10	10	30
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35	10	35	30	10	10	30	10	10	30
36	10	36	30	10	10	30	10	10	30
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83	10	83	30	10	10	30	10	10	30
84	10	84	30	10	10	30	10	10	30
85	10	85	30	10	10	30	10	10	30
86	10	86	30	10	10	30	10	10	30
87	10	87	30	10	10	30	10	10	30
88	10	88	30	10	10	30	10	10	30
89	10	89	30	10	10	30	10	10	30
90	10	90	30	10	10	30	10	10	30
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92	10	92	30	10	10	30	10	10	30
93	10	93	30	10	10	30	10	10	30
94	10	94	30	10	10	30	10	10	30
95	10	95	30	10	10	30	10	10	30
96	10	96	30	10	10	30	10	10	30
97	10	97	30	10	10	30	10	10	30
98	10	98	30	10	10	30	10	10	30
99	10	99	30	10	10	30	10	10	30
100	10	100	30	10	10	30	10	10	30

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Fig. 38 - Monthly Climatological Summary -  
Toledo, Ohio - January 1979 - Sheet 2

# Local Climatological Data

Annual Summary With Comparative Data

1979

TOLEDO, OHIO



## Narrative Climatological Summary

Toledo is located on the western end of Lake Erie at the mouth of the Maumee River. Except for a bank up from the river about 30 feet, the terrain is generally level with only a slight slope toward the river and Lake Erie. The City has quite a diversified industrial section and excellent harbor facilities, making it a large transportation center for rail, water, and motor freight. Generally rich agricultural land is found in the surrounding area, especially up the Maumee Valley towards the Indiana State line.

Rainfall is usually sufficient for general agriculture. The terrain is level and drainage rather poor; therefore, a little less than the normal precipitation during the growing season is better than excessive amounts. In 1894 the total precipitation was only 21.34 inches, making it the driest year on record, and 1950, with almost two and one-half times as much, was the wettest. Snowfall is generally light in this area, distributed throughout the winter from November to March with frequent thaws. The greatest total snowfall for any winter was 73.1 inches in 1977-78, and the least 6.0 inches in 1889-90. The average number of days per winter with a tenth of an inch or more of snowfall is twenty-seven. The earliest record of snow in the fall occurred on September 27, 1942, and the latest in the spring on May 24, 1925.

The nearness of Lake Erie and the other Great Lakes has a moderating effect on the temperature, and extremes are seldom recorded. On the average, there are only fifteen days a year when the temperature reaches 90° or higher, and only eight days when it drops to zero or lower. The absolute maximum ever recorded here was 105° in July 1936, and the minimum was -17° in January 1963. The growing season averages 160 days; the longest was 224 days in 1910 and the shortest was 125 days in 1961. The average date of the last freezing temperature in the spring is April 27. The date of the last killing frost averages near May 2 and the last light frost about May 15. On the average, the first frost in the fall occurs on September 24, the first killing frost on October 12, and the first freezing temperature on October 15.

Humidity is rather high throughout the year in this area, and there is an excessive amount of cloudiness. In the winter months the sun shines during only about 30 percent of the daylight hours; December and January, the cloudiest months, sometimes have as little as 16 percent of the possible hours of sunshine.

Severe windstorms, causing more than minor damage, occur infrequently. There are on the average twenty-three days per year having a sustained wind velocity of 32 mph or more.

Flooding in the Toledo area is produced by several factors. Heavy rains of an inch or more will cause a sudden rise in creeks and drainage ditches to the point of overflow. The western shores of Lake Erie are subject to flooding when the Lake level is high and prolonged periods of east to northeast winds prevail.

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ENVIRONMENTAL DATA AND  
INFORMATION SERVICE

NATIONAL CLIMATIC CENTER  
ASHEVILLE, N.C.

Fig. 39 - Yearly Climatological Summary -  
Toledo, Ohio - 1979 - Sheet 1

# Meteorological Data For The Current Year

Station	TOLLEDO, OHIO E 33830		ELEVATION: 610 feet		Longitude: 81° 36' W		Latitude: 41° 42' N		ELEVATION: 610 feet		Year: 1979	
	Temperature °F		Precipitation in inches		Relative humidity, per cent		Wind		Number of days		Average	
	Average		Maximum		Minimum		Direction		Direction		Maximum	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
Jan	31.1	15.4	0.00	0.00	61	31	46	31	0.00	0.00	0.00	0.00
Feb	32.0	16.0	0.00	0.00	61	31	46	31	0.00	0.00	0.00	0.00
Mar	33.0	17.0	0.00	0.00	61	31	46	31	0.00	0.00	0.00	0.00
Apr	34.0	18.0	0.00	0.00	61	31	46	31	0.00	0.00	0.00	0.00
May	35.0	19.0	0.00	0.00	61	31	46	31	0.00	0.00	0.00	0.00
Jun	36.0	20.0	0.00	0.00	61	31	46	31	0.00	0.00	0.00	0.00
Jul	37.0	21.0	0.00	0.00	61	31	46	31	0.00	0.00	0.00	0.00
Aug	38.0	22.0	0.00	0.00	61	31	46	31	0.00	0.00	0.00	0.00
Sep	39.0	23.0	0.00	0.00	61	31	46	31	0.00	0.00	0.00	0.00
Oct	40.0	24.0	0.00	0.00	61	31	46	31	0.00	0.00	0.00	0.00
Nov	41.0	25.0	0.00	0.00	61	31	46	31	0.00	0.00	0.00	0.00
Dec	42.0	26.0	0.00	0.00	61	31	46	31	0.00	0.00	0.00	0.00
Year	35.0	19.0	0.00	0.00	61	31	46	31	0.00	0.00	0.00	0.00

## Normals, Means, And Extremes

Month	Temperature °F				Precipitation in inches				Relative humidity, per cent			
	Average				Maximum				Minimum			
	High	Low	Mean	Range	High	Low	Mean	Range	High	Low	Mean	Range
Jan	31.1	15.4	23.3	15.7	0.00	0.00	0.00	0.00	61	31	46	31
Feb	32.0	16.0	24.0	16.0	0.00	0.00	0.00	0.00	61	31	46	31
Mar	33.0	17.0	25.0	16.0	0.00	0.00	0.00	0.00	61	31	46	31
Apr	34.0	18.0	26.0	16.0	0.00	0.00	0.00	0.00	61	31	46	31
May	35.0	19.0	27.0	16.0	0.00	0.00	0.00	0.00	61	31	46	31
Jun	36.0	20.0	28.0	16.0	0.00	0.00	0.00	0.00	61	31	46	31
Jul	37.0	21.0	29.0	16.0	0.00	0.00	0.00	0.00	61	31	46	31
Aug	38.0	22.0	30.0	16.0	0.00	0.00	0.00	0.00	61	31	46	31
Sep	39.0	23.0	31.0	16.0	0.00	0.00	0.00	0.00	61	31	46	31
Oct	40.0	24.0	32.0	16.0	0.00	0.00	0.00	0.00	61	31	46	31
Nov	41.0	25.0	33.0	16.0	0.00	0.00	0.00	0.00	61	31	46	31
Dec	42.0	26.0	34.0	16.0	0.00	0.00	0.00	0.00	61	31	46	31
Year	35.0	19.0	27.0	16.0	0.00	0.00	0.00	0.00	61	31	46	31

Means and extremes shown are from existing and comparable temperatures. Annual extremes have been rounded at other than 10% intervals. Highest temperature 45° in July 1979, maximum monthly precipitation 8.45 in October 1979, minimum monthly precipitation 0.00 in November 1979, maximum precipitation in 24 hours 5.50 in September 1979, maximum snowfall in 24 hours 0.00 in February 1979, lowest wind speed 0 in March 1979.

(a) Length of record, years, through the current year unless otherwise noted.  
(b) 70° and above at station.  
(c) 70° and above at station.  
(d) 70° and above at station.  
(e) 70° and above at station.  
(f) 70° and above at station.  
(g) 70° and above at station.  
(h) 70° and above at station.  
(i) 70° and above at station.  
(j) 70° and above at station.  
(k) 70° and above at station.  
(l) 70° and above at station.  
(m) 70° and above at station.  
(n) 70° and above at station.  
(o) 70° and above at station.  
(p) 70° and above at station.  
(q) 70° and above at station.  
(r) 70° and above at station.  
(s) 70° and above at station.  
(t) 70° and above at station.  
(u) 70° and above at station.  
(v) 70° and above at station.  
(w) 70° and above at station.  
(x) 70° and above at station.  
(y) 70° and above at station.  
(z) 70° and above at station.

Fig. 40 - Yearly Climatological Summary - Toledo, Ohio - 1979 - Sheet 2

## Average Temperature

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1900	17.4	27.8	35.2	44.0	57.0	70.2	78.2	71.3	63.4	54.4	39.8	26.8	54.6
1901	27.4	25.4	31.4	42.4	54.4	67.4	74.4	72.0	64.4	56.4	42.4	30.2	52.0
1902	26.1	33.4	38.4	43.4	51.4	61.4	67.4	74.4	70.4	61.4	50.4	37.4	53.2
1903	22.4	26.4	33.4	42.4	57.4	71.4	73.2	71.1	60.4	50.4	37.4	24.2	48.2
1904	27.4	26.2	31.4	42.4	57.4	71.4	73.4	72.4	64.4	51.4	41.4	21.4	49.4
1905	16.7	27.4	37.7	50.2	57.4	65.4	70.2	70.7	61.4	50.4	37.4	21.0	48.1
1906	37.4	26.7	36.5	47.4	58.4	67.4	72.4	67.2	55.2	43.4	31.4	20.0	51.0
1907	10.7	22.0	31.2	43.4	55.2	66.2	72.4	77.2	65.2	54.4	42.4	29.2	49.0
1908	18.0	25.4	36.0	47.0	58.0	67.0	73.0	71.2	60.0	49.0	36.0	21.0	49.0
1909	22.0	32.4	36.4	47.0	60.0	70.0	77.0	73.1	59.0	48.0	35.2	22.1	52.1
1910	13.9	27.4	37.4	52.3	59.4	68.2	70.4	69.4	67.0	56.1	35.9	22.1	48.4
1911	27.0	27.0	38.2	46.1	56.2	66.4	72.4	69.4	62.0	50.4	37.7	27.7	49.1
1912	35.0	30.4	35.4	44.0	57.0	67.4	74.4	71.4	63.0	52.0	39.0	27.0	51.0
1913	13.4	25.4	35.4	44.0	54.4	64.4	71.4	73.2	64.4	54.1	43.2	32.1	52.1
1914	27.2	25.4	36.1	45.4	58.4	67.4	72.1	70.1	60.7	50.2	36.9	20.2	50.4
1915	25.4	26.0	36.7	45.1	57.4	67.2	74.4	74.4	64.4	53.4	36.7	26.3	50.4
1916	23.4	26.4	32.7	45.4	57.4	67.4	72.1	71.0	59.4	48.4	35.1	24.1	49.1
1917	25.1	31.4	38.4	48.4	57.4	67.4	72.4	70.4	62.4	51.4	38.2	26.2	49.2
1918	19.0	22.1	28.4	40.4	50.4	58.2	67.2	72.2	64.4	53.2	42.4	31.1	48.4
1919	21.4	26.4	35.1	46.7	57.7	67.0	73.2	76.1	66.7	56.4	44.4	31.1	49.9
1920	29.7	27.5	35.7	46.2	57.3	67.3	74.4	74.4	64.4	52.4	40.4	23.4	50.2
1921	22.4	31.2	34.4	41.4	54.4	64.2	70.1	65.2	57.4	47.4	36.9	26.5	48.4
1922	21.4	26.4	35.0	46.2	55.4	64.4	69.4	70.4	61.2	50.2	38.2	27.7	49.1
1923	14.4	18.1	27.0	37.4	47.4	57.4	67.4	72.4	61.7	51.2	38.2	26.4	47.2
1924	18.4	25.4	35.4	46.4	57.4	67.4	72.4	67.4	62.4	51.4	37.4	26.4	48.4
1925	27.7	27.5	35.7	46.2	57.3	67.3	74.4	74.4	64.4	52.4	40.4	23.4	50.2
1926	22.4	31.2	34.4	41.4	54.4	64.2	70.1	65.2	57.4	47.4	36.9	26.5	48.4
1927	21.4	26.4	35.0	46.2	55.4	64.4	69.4	70.4	61.2	50.2	38.2	27.7	49.1
1928	14.4	18.1	27.0	37.4	47.4	57.4	67.4	72.4	61.7	51.2	38.2	26.4	47.2
1929	18.4	25.4	35.4	46.4	57.4	67.4	72.4	67.4	62.4	51.4	37.4	26.4	48.4
1930	27.7	27.5	35.7	46.2	57.3	67.3	74.4	74.4	64.4	52.4	40.4	23.4	50.2
1931	22.4	31.2	34.4	41.4	54.4	64.2	70.1	65.2	57.4	47.4	36.9	26.5	48.4
1932	21.4	26.4	35.0	46.2	55.4	64.4	69.4	70.4	61.2	50.2	38.2	27.7	49.1
1933	14.4	18.1	27.0	37.4	47.4	57.4	67.4	72.4	61.7	51.2	38.2	26.4	47.2
1934	18.4	25.4	35.4	46.4	57.4	67.4	72.4	67.4	62.4	51.4	37.4	26.4	48.4
1935	27.7	27.5	35.7	46.2	57.3	67.3	74.4	74.4	64.4	52.4	40.4	23.4	50.2
1936	22.4	31.2	34.4	41.4	54.4	64.2	70.1	65.2	57.4	47.4	36.9	26.5	48.4
1937	21.4	26.4	35.0	46.2	55.4	64.4	69.4	70.4	61.2	50.2	38.2	27.7	49.1
1938	14.4	18.1	27.0	37.4	47.4	57.4	67.4	72.4	61.7	51.2	38.2	26.4	47.2
1939	18.4	25.4	35.4	46.4	57.4	67.4	72.4	67.4	62.4	51.4	37.4	26.4	48.4
1940	27.7	27.5	35.7	46.2	57.3	67.3	74.4	74.4	64.4	52.4	40.4	23.4	50.2
1941	22.4	31.2	34.4	41.4	54.4	64.2	70.1	65.2	57.4	47.4	36.9	26.5	48.4
1942	21.4	26.4	35.0	46.2	55.4	64.4	69.4	70.4	61.2	50.2	38.2	27.7	49.1
1943	14.4	18.1	27.0	37.4	47.4	57.4	67.4	72.4	61.7	51.2	38.2	26.4	47.2
1944	18.4	25.4	35.4	46.4	57.4	67.4	72.4	67.4	62.4	51.4	37.4	26.4	48.4
1945	27.7	27.5	35.7	46.2	57.3	67.3	74.4	74.4	64.4	52.4	40.4	23.4	50.2
1946	22.4	31.2	34.4	41.4	54.4	64.2	70.1	65.2	57.4	47.4	36.9	26.5	48.4
1947	21.4	26.4	35.0	46.2	55.4	64.4	69.4	70.4	61.2	50.2	38.2	27.7	49.1
1948	14.4	18.1	27.0	37.4	47.4	57.4	67.4	72.4	61.7	51.2	38.2	26.4	47.2
1949	18.4	25.4	35.4	46.4	57.4	67.4	72.4	67.4	62.4	51.4	37.4	26.4	48.4
1950	27.7	27.5	35.7	46.2	57.3	67.3	74.4	74.4	64.4	52.4	40.4	23.4	50.2
1951	22.4	31.2	34.4	41.4	54.4	64.2	70.1	65.2	57.4	47.4	36.9	26.5	48.4
1952	21.4	26.4	35.0	46.2	55.4	64.4	69.4	70.4	61.2	50.2	38.2	27.7	49.1
1953	14.4	18.1	27.0	37.4	47.4	57.4	67.4	72.4	61.7	51.2	38.2	26.4	47.2
1954	18.4	25.4	35.4	46.4	57.4	67.4	72.4	67.4	62.4	51.4	37.4	26.4	48.4
1955	27.7	27.5	35.7	46.2	57.3	67.3	74.4	74.4	64.4	52.4	40.4	23.4	50.2
1956	22.4	31.2	34.4	41.4	54.4	64.2	70.1	65.2	57.4	47.4	36.9	26.5	48.4
1957	21.4	26.4	35.0	46.2	55.4	64.4	69.4	70.4	61.2	50.2	38.2	27.7	49.1
1958	14.4	18.1	27.0	37.4	47.4	57.4	67.4	72.4	61.7	51.2	38.2	26.4	47.2
1959	18.4	25.4	35.4	46.4	57.4	67.4	72.4	67.4	62.4	51.4	37.4	26.4	48.4
1960	27.7	27.5	35.7	46.2	57.3	67.3	74.4	74.4	64.4	52.4	40.4	23.4	50.2
1961	22.4	31.2	34.4	41.4	54.4	64.2	70.1	65.2	57.4	47.4	36.9	26.5	48.4
1962	21.4	26.4	35.0	46.2	55.4	64.4	69.4	70.4	61.2	50.2	38.2	27.7	49.1
1963	14.4	18.1	27.0	37.4	47.4	57.4	67.4	72.4	61.7	51.2	38.2	26.4	47.2
1964	18.4	25.4	35.4	46.4	57.4	67.4	72.4	67.4	62.4	51.4	37.4	26.4	48.4
1965	27.7	27.5	35.7	46.2	57.3	67.3	74.4	74.4	64.4	52.4	40.4	23.4	50.2
1966	22.4	31.2	34.4	41.4	54.4	64.2	70.1	65.2	57.4	47.4	36.9	26.5	48.4
1967	21.4	26.4	35.0	46.2	55.4	64.4	69.4	70.4	61.2	50.2	38.2	27.7	49.1
1968	14.4	18.1	27.0	37.4	47.4	57.4	67.4	72.4	61.7	51.2	38.2	26.4	47.2
1969	18.4	25.4	35.4	46.4	57.4	67.4	72.4	67.4	62.4	51.4	37.4	26.4	48.4
1970	27.7	27.5	35.7	46.2	57.3	67.3	74.4	74.4	64.4	52.4	40.4	23.4	50.2
1971	22.4	31.2	34.4	41.4	54.4	64.2	70.1	65.2	57.4	47.4	36.9	26.5	48.4
1972	21.4	26.4	35.0	46.2	55.4	64.4	69.4	70.4	61.2	50.2	38.2	27.7	49.1
1973	14.4	18.1	27.0	37.4	47.4	57.4	67.4	72.4	61.7	51.2	38.2	26.4	47.2
1974	18.4	25.4	35.4	46.4	57.4	67.4	72.4	67.4	62.4	51.4	37.4	26.4	48.4
1975	27.7	27.5	35.7	46.2	57.3	67.3	74.4	74.4	64.4	52.4	40.4	23.4	50.2
1976	22.4	31.2	34.4	41.4	54.4	64.2	70.1	65.2	57.4	47.4	36.9	26.5	48.4
1977	21.4	26.4	35.0	46.2	55.4	64.4	69.4	70.4	61.2	50.2	38.2	27.7	49.1
1978	14.4	18.1	27.0	37.4	47.4	57.4	67.4	72.4	61.7	51.2	38.2	26.4	47.2
1979	18.4	25.4	35.4	46.4	57.4	67.4	72.4	67.4	62.4	51.4	37.4	26.4	48.4
1980	27.7	27.5	35.7	46.2	57.3	67.3	74.4	74.4	64.4	52.4	40.4	23.4	50.2
1981	22.4	31.2	34.4	41.4	54.4	64.2	70.1	65.2	57.4	47.4	36.9	26.5	48.4
1982	21.4	26.4	35.0	46.2	55.4	64.4	69.4	70.4	61.2	50.2	38.2	27.7	49.1
1983	14.4	18.1	27.0	37.4	47.4	57.4	67.4	72.4	61.7	51.2	38.2	26.4	47.2
1984	18.4	25.4	35.4	46.4	57.4	67.4	72.4	67.4	62.4	51.4	37.4	26.4	48.4
1985	27.7	27.5	35.7	46.2	57.3	67.3	74.4	74.4	64.4	52.4	40.4	23.4	50.2
1986	22.4	31.2	34.4	41.4	54.4	64.2	70.1	65.2	57.4	47.4	36.9	26.5	48.4
1987	21.4	26.4	35.0	46.2	55.4	64.4	69.4	70.4	61.2	50.2	38.2	27.7	49.1
1988	14.4	18.1	27.0	37.4	47.4	57.4	67.4	72.4	61.7	51.2	38.2	26.4	47.2
1989	18.4	25.4	35.4	46.4	57.4	67.4	72.4	67.4	62.4	51.4	37.4	26.4	48.4
1990	27.7	27.5	35.7	46.2	57.3	67.3	74.4	74.4	64.4	52.4	40.4	23.4	50.2
1991	22.4	31.2	34.4	41.4	54.4	64.2	70.1	65.2	57.4	47.4	36.9	26.5	48.4
1992	21.4	26.4	35.0	46.2	55.4	64.4	69.4	70.4	61.2	50.2	38.2	27.7	49.1
1993	14												



## STATION LOCATION

TOLEDO, OHIO

Location	Completed from	Completed to	Airline distance and direction from previous location	Latitude North	Longitude West	Elevations above										Type H = AMOS T = AUTOS	Remarks
						Sea level	Ground at temperature site	Wind instrument	Extensive observations	Psychrometer	Exhaustive Smith	Typical Smith at same spot	Weighting rate gauge	8" rain gauge	Hygrometer		
<b>CITY</b>																	
C. A. King Building Water Street	11/01/70	3/01/71		41° 40'	83° 34'												
Chamber of Commerce Building, Corner of Isaac & Madison Sts.	3/01/71	2/01/88	1 block NW	41° 40'	83° 34'	602	114	65	65					105			
Government Building Corner St. Clair & Madison	3/01/88	7/12/06	1 block NW	41° 40'	83° 34'	603	127	120	120					112			
Nicholas Building Corner Huron & Madison	7/12/06	6/20/32	2 blocks NW	41° 40'	83° 34'	591	243	208	208					201			
New Federal Building Civil Center Spaulding Avenue	6/20/32	7/01/49	4 blocks NE	41° 39'	83° 32'	589	87	79	79				74	72			All observations made at Air- port beginning 2/1/43.
<b>AIRPORT</b>																	
Toledo Municipal AP Transcontinental Hanger 9 miles SE of Federal Building	6/03/28	9/08/38		41° 34'	83° 28'	621	47	5	5								VS observations to 11/2/33, CAA character.
Toledo Municipal AP Administration Hanger	9/08/38	1/12/55	350 feet W	41° 34'	83° 28'	622	47	5	5			aa	aa	a3	c		CAA observations to 1/1/59, VS thereafter. a - Detailed 2/1/43. c - Telechronometer (5" 37/1/49- 1/12/55; 19" 1/12/55 until 10/1/59; 44" 1/12/59. d - 72 feet to 11/8/58 and 20 feet to 11/1/58. g - Standby after 10/1/59. h - 476 feet to 10/1/59. i - Effective 4/1/76.
Toledo Express Airport Administration Building	1/12/55	Present	15 miles W	41° 34'	83° 48'	6669	430	g19	g19	74	18	18	18	ca	ha		

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I certify that this is an official publication of the National Oceanic and Atmospheric Administration, and is compiled from records on file at the National Climatic Center, Asheville, North Carolina 28801.

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Fig. 42 - Yearly Climatological Summary -  
Toledo, Ohio - 1979 - Sheet 4



airports or colleges. The designer should check into such possibilities to determine the type and extent of information available. If sufficient data are not available locally, the nearest recording weather station of the NOAA should be used for analysis purposes. A listing of weather station locations in each state is available from the NOAA.

Once the weather station data have been collected, the architect's first step is to compare site-collected climatic information with the weather station's information recorded at the same time. In many instances variations between the two will be observed. For example, a wind speed of 15 miles per hour from the north at the weather station may correspond to a northwest wind of eight miles per hour at the site. The same sort of variations may be observed in temperature, humidity, and solar radiation measurements. By comparing weather station data with site-collected data, certain patterns of variation should begin to appear. From these patterns the architect can start to formulate some assumptions about how weather at the site differs from that at the weather station. For example, north winds at the weather station may correspond to northwest winds at the site; wind speeds may be consistently five percent lower than at the weather station, temperatures may be one or two degrees higher, and solar radiation and humidity levels may be similarly different.

From these observed variations of the weather pattern, an overall site climate profile can be formulated. This climate profile, based upon interpolation of the average weather for the area, may be a chart or series of graphs indicating expected weather patterns at the site for an "average" year. The climate profile, a document developed specifically for the individual site, is used by the designer for microclimate evaluation and site design. An example of a climate profile is included in Chapter VI.

The next step in microclimatic site analysis is to plot the information on the climate profile on the bioclimatic chart discussed in Chapter I. It is probably not necessary that this be done for each month of the year, but it should be done for the times of extreme conditions, usually the hottest and coldest months. This plot will indicate graphically how the climate at the site varies from the comfort requirements of the proposed building's occupants. An example for an actual site is included in Chapter VI.

The final step of site analysis is to produce a shading pattern and wind pattern diagram for the site. Usually this will be superimposed on a copy of the site plan, or shown as a series of overlays. Wind patterns can be indicated by arrows which show wind directions, as determined on the climate profile. Shading patterns, showing which areas would be in shade due to the location of buildings or vegetation at selected typical times of the day and year, can be produced by a number of methods. If the designer is fortunate enough to live near a university or other institution with a heliodon, or artificial sky for simulation of the sun's movement, a simple model can be constructed and the shadows traced or photographed in that facility. This method also enables the architect to test different design strategies and building schemes in model form. An example of a heliodon-produced shadow plot and photographs taken during the production of the plot are included in Chapter VI.

Other methods can be used by designers without access to such facilities. A knowledge of the sun's position with relation to the site, simple geometry, and the shape and types of site obstructions should be all that is necessary for an architect to draw a shadow plot. Also, there are a number of devices for solar access measurement which can be purchased on today's market. Figure 43 lists some of these devices, along with pertinent information about each one.

Instrument	Sighting Principle	Months Covered	Recording Procedure	Documentation Supplied	Accessories Included
<b>Shadow Mapper™</b> Campbell Engineering 1302 Toney Drive Southeast Huntsville, Ala. 35802  (205) 883-9866 Price: \$450.00	Shading objects are observed through a sighting tube. Mechanical scales provide readings of latitude, azimuth, elevation angle and solar time.	12	The date, time and duration of each shadow are recorded on a separate chart.	Instruction manual and plotting charts for observed shadow patterns.	Combination carrying case and adjustable mounting platform.
<b>Sun Machine™</b> Teamworks Manufacturing Company Post Office Box 711 Cambridge, Mass. 02139  (617) 661-2081 Price \$250.00	A viewing scope traces the sun's path across the sky at any latitude. Solar time, shading-object altitude and the azimuth are read directly.	12	Successive observations are recorded separately.	Instruction manual with charts to facilitate sunpath understanding and recording of shadow patterns.	Carrying case.
<b>Solar Pathfinder™</b> Solar Pathways, Inc. Valley Commercial Plaza 3710 Highway 82 Glenwood Springs, Colo. 81601  (303) 945-6503 Price: \$144.00	The reflected image of all shadow-casting objects is displayed on the surface of a transparent, reflecting dome. The sunpath diagram beneath the dome assigns solar-time and energy values to each obstruction. The full year's data is contained in a single image.	12	Access to the sunpath diagram beneath the reflecting dome enables direct tracing of shadow boundaries. Multiple sunpath diagrams and frosted mylar (reusable) tracing overlays provided.	Instruction manual. Horizontal and sloped surface sunpath diagrams in six-degree latitude increments for contiguous U.S. "Percentage of Monthly Total" solar radiation figures printed within each ½ hour period on sunpath diagram. Printed worksheets and solar radiation at 250 U.S. locations for conversion of percentage data to incident solar energy on collection surfaces of varied angles.	Aluminum tripod. Optional sunpath diagrams and solar radiation data for north surfaces and customer specified locations.
<b>Sunbloc™</b> Pacific Sun, Inc. 437 Tasso Street Palo Alto, Calif. 94301  (415) 328-4588 Price: \$125.00	A Brunton hand-held transit is supplied to enable the angle of elevation of each shading object to be observed. Sequential readings at various azimuth angles enable measurement of all shadow patterns.	12	Each observation is recorded on the site assessment sheet provided. Sunpaths and solar time values are printed on each recording chart.	Instruction book and pad of site assessment, sheets, unique to each 2.5° latitude band.	Pocket transit carrying case.
<b>Solar Site Selector</b> Lewis & Associates 105 Rockwood Drive Grass Valley, Calif. 95945  (916) 272-2077 Price: \$79.50	Sunpaths for seven months are printed on transparent grid. Sighting through a "distortion optic" enables coincident viewing of shading objects and winter sunpaths. Sighting grid covers 2° latitude band.	12	A clear, plastic overlay is mounted in front of the transparent grid. Tracing of observed shadow boundaries preserves all data. An extrapolation method is provided to determine summer shading.	Instruction manual detailing procedures for estimating Prime Solar Fraction from observed shading patterns.	Canvas carrying bag and wooden handle.
<b>Sun Angle Calculator™</b> Zomeworks Post Office Box 712 Albuquerque, N.M. 87103  (505) 242-5354 Price: \$63.50	Shading objects and transparent sunpath grid are coincidently sighted in a plane mirror, horizontally mounted at the center of the instrument. Successive sightings at various azimuth angles enable construction of a "horizon plot."	12	Observations are separately recorded.	Instruction manual.	Elevation-angle scale pivots on centered spindle to enable the instrument's use as a desk-top sun angle calculator.

Fig. 43 - Leading Devices for Solar Access Measurement

The shadow plot should include shadow patterns for morning, noon, and afternoon for the summer solstice, June 22; the winter solstice, December 22; and one or two readings for spring and fall days. This will give the range of area on the site where shadows will fall at some time of the year, and will prove helpful in site design.

#### Microclimatic Site Evaluation

The purpose of microclimatic site evaluation is to develop a set of goals for improvement of a site's microclimate for energy conservation. These objectives are derived from an evaluation of the site's existing climate and how it relates to comfort requirements of a proposed building's occupants. The plot of the site's climatic characteristics on a bioclimatic chart will prove to be very beneficial during site evaluation. The goals are, by design, rather general and unspecific. During site design specific strategies will be developed to provide the desired climatic modification.

Goals developed during microclimatic site evaluation can be divided along the same lines as the characteristics of climate: solar radiation, temperature, wind, and humidity/precipitation. Further objectives can be developed concerning the auditory and olfactory characteristics of the site. For each of these divisions a goal would be either to amplify or diminish that characteristic's influence; that is, to increase or decrease the amount of solar radiation, raise or lower temperature, and so on. In most areas of the country it is necessary to develop a different set of parameters for summer and winter conditions. In tropical or arctic regions, one set of goals may hold true for producing comfort throughout the year. The climate plot on the bioclimatic chart should indicate graphically what the goals of the microclimatic designer should be. The following chart lists some types of goals which can be developed during the site evaluation phase.

### SAMPLE MICROCLIMATIC DESIGN GOALS

Increase amount of solar radiation  
Decrease amount of solar radiation  
Increase temperature  
Decrease temperature  
Increase wind velocity  
Decrease wind velocity  
Increase humidity levels  
Decrease humidity levels  
Diminish unwanted odors  
Diminish unwanted noises

#### Microclimatic Site Design

Microclimatic site design involves the selection of a number of design options which, when incorporated into the site plan, will alter the site's climate as established by the objectives set earlier. The architect's decisions during this phase are based upon a knowledge of the microclimatic effects of certain site features, aesthetics, building type and function, circulation patterns at the site, costs, local tradition and culture, and a number of factors. This paper will deal only with the microclimatic effects of certain site modifications, though it must be remembered that in actual practice many other factors affect decision making.

In Chapter III the physical characteristics which can cause variations in microclimates were discussed. These characteristics were divided into five classifications: topography, vegetation, earth surface conditions, bodies of water, and the surrounding built environment. Adjustments to one or more of these characteristics can be identified by the architect for each design goal formulated during site evaluation. This design process can also be useful in locating the building on the site. In many cases, a site is large enough to accommodate a proposed building, parking areas, walks, drives, people areas, etc., in more than one area. Proper location of a new building with respect to the microclimate is usually more economical than altering the

site to "fit" with an arbitrarily placed building, as well as being a more logical design concept.

The following series of charts may serve as an aid to the microclimatic designer in formulating a design strategy for a particular project. These charts summarize information contained in Chapter III, and relate that information to the most commonly identified microclimatic design goals. In many cases the designer will formulate other objectives or identify different ways to achieve his goals. This is to be expected since each project and each site offer unique problems and opportunities. Not all items listed on the charts as methods for accomplishing an objective may be used on the same project. Many items are mutually exclusive, and some will not be appropriate to a specific project for any of a number of reasons. It is the function of the architect to choose appropriate options from these charts or add options to them as necessary, and develop a "package" of solutions which will achieve the desired microclimatic modifications.

Microclimatic Design Charts

GOAL: Increase amount of solar radiation.

POSSIBLE SOLUTIONS:

A. Topography

1. Locate building on southerly slope.
2. Alter topography around building to be more perpendicular to sun's rays.

B. Vegetation.

1. Locate building in unshaded areas of site.
2. Provide plants which lose leaves when solar radiation is desired.
3. Minimize low-growing vegetation when solar radiation is desired.

C. Earth Surface Conditions

1. Use light colored surface material for reflection of sun's rays.
2. Use dark colored surface material for absorption of sun's rays.
3. Use smooth surfaced materials to increase reflection.
4. Use rough surfaced materials to decrease reflection.

D. Bodies of Water

1. Locate building near a shallow pool or body of water for increased reflection.
2. Provide a reflection pool to the south of the building.

E. City Environment

1. Locate building where shade from surrounding buildings will not strike it.

GOAL: Decrease amount of solar radiation.

POSSIBLE SOLUTIONS:

A. Topography

1. Locate building on northerly slope.
2. Alter topography around building away from perpendicular to sun's rays.

B. Vegetation

1. Locate building in shaded areas of site.
2. Provide plants with heavy leaf cover when solar radiation is not desired.
3. Provide maximum amount of leafy ground-cover type vegetation.

C. Earth Surface Conditions

1. Use light colored surface materials for reflection of sun's rays.
2. Use smooth-surfaced materials to increase reflection.
3. Use rough-surfaced materials to decrease reflection.

D. Bodies of Water

1. Avoid location of building near shallow bodies of water. Location of building near deep water with low albedo is more acceptable.
2. Provide deep or dark-colored pool to absorb radiation.

E. City Environment

1. Locate building in shadow of neighboring structures.



GOAL: Increase temperature.

POSSIBLE SOLUTIONS:

A. Topography

1. Locate building at top of slopes to take advantage of rising warm air.
2. Slope ground away from building to provide cool air "channels."
3. Slope ground to shield building from cold winds.

B. Vegetation

1. Limit shading effects of trees and low-growing vegetation.
2. Locate vegetation to shield building from cold winds.
3. Provide vegetation "channels" to direct downhill cold air flow away from building.

C. Earth Surface Conditions

1. Provide dark-colored surface materials where exposed to sun for greater heat gain.
2. Provide smooth surface materials where exposed to sun.
3. Provide surface materials with high density.

D. Bodies of Water

1. Locate building near large body of water for modification of temperature extremes.

E. City Environment

1. Locate building near an adjacent large building to take advantage of the heat given off.
2. Locate building to receive maximum amount of solar radiation.

GOAL: Decrease temperature.

POSSIBLE SOLUTIONS:

A. Topography

1. Locate building in valley or depression to take advantage of downhill cool air flow.
2. Slope ground to direct cool air flow downhill toward building.
3. Slope ground to maximize building exposure to cool breezes.

B. Vegetation

1. Maximize shaded areas at site with both trees and low-growing vegetation.
2. Locate vegetation so that breezes will flow through planted areas and cool off prior to reaching building.
3. Provide vegetation channels to divert cool air flowing downhill toward building.

C. Earth Surface Conditions

1. Provide light colored surface materials where exposed to sun.
2. Provide rough surface materials where exposed to sun.
3. Provide loose, low density materials with high air content.

D. Bodies of Water

1. Locate building near large body of water for modification of temperature extremes.

E. City Environment

1. Avoid close proximity to nearby buildings.
2. Locate building in shadow area of nearby buildings.
3. Maximize vegetation around building.

GOAL: Increase wind velocity.

POSSIBLE SOLUTIONS:

A. Topography

1. Locate building at high point of site to increase exposure to wind.
2. Locate building in areas of highest wind speed.
3. Alter topography to channel wind and increase wind speed in area of building.

B. Vegetation

1. Locate building away from vegetation which blocks path of prevailing breezes.
2. Remove or thin vegetation which blocks path of prevailing breezes.
3. Plant vegetation in a manner which will direct and increase wind velocity in building location.

C. Earth Surface Conditions

1. Provide smooth surface materials in breeze path to reduce "drag" effect.

D. Bodies of Water

1. Locate building near a large body of water to facilitate breeze patterns due to temperature differential between water and adjacent surroundings.

E. City Environment

1. Locate building to take advantage of wind patterns influenced by surrounding buildings.

GOAL: Decrease wind velocity.

POSSIBLE SOLUTIONS:

A. Topography

1. Locate building away from high points to minimize exposure to winds.
2. Locate building in area of lowest wind speeds.
3. Alter topography to shelter building from winds.
4. Alter topography to deflect winds away from building.

B. Vegetation

1. Locate building in area where vegetation blocks path of prevailing winds.
2. Plant vegetation to block, deflect, or reduce speed of prevailing winds at building.

C. Earth Surface Conditions

1. Provide rough surface materials in wind path to increase "drag" effect.

D. Bodies of Water

1. Avoid location of building adjacent to large body of water.

E. City Environment

1. Locate building to take advantage of shelter from wind afforded by surrounding buildings.

GOAL: Increase humidity levels.

POSSIBLE SOLUTIONS:

A. Topography

1. Locate building on lee side of hill to increase precipitation.
2. Alter topography to slow drainage and increase retention of precipitation.

B. Vegetation

1. Locate building in or near, and preferably downwind from, an area of thick vegetation.
2. Plant vegetation around near, and especially to the windward side of, the building.

C. Earth Surface Conditions

1. Provide surface material with a high capacity for moisture retention.

D. Bodies of Water

1. Locate building near a body of water.
2. Make maximum use of pools, fountains, etc.

E. City Environment

GOAL: Decrease humidity levels.

POSSIBLE SOLUTIONS:

A. Topography

1. Locate building on windward side of hill to decrease precipitation.
2. Alter topography for rapid site drainage.

B. Vegetation

1. Avoid location of building near thick growths of vegetation, especially downwind.
2. Minimize use of vegetation in landscape plan.

C. Earth Surface Conditions

1. Provide surface material with low capacity for moisture retention.

D. Bodies of Water

1. Avoid location of building near a large body of water.
2. Avoid use of pools, fountains, etc., in the design.

E. City Environment

GOAL: Diminish unwanted odors.

POSSIBLE SOLUTIONS:

A. Topography

1. Alter topography to deflect breezes from odor source away from building.
2. Alter topography to deflect breezes to building from areas other than odor source.

B. Vegetation

1. Plant vegetation between building and odor source to "filter" the air.
2. Plant vegetation to deflect breezes from odor source away from building.
3. Plant vegetation to deflect breezes to building from areas other than odor source.

C. Earth Surface Conditions

D. Bodies of Water

E. City Environment

GOAL: Dimish unwanted noise.

POSSIBLE SOLUTIONS:

A. Topography

1. Alter topography to provide a screen or barrier between building and source of noise.
2. Alter topography to deflect winds over noise source away from building.

B. Vegetation

1. Provide vegetation screen or barrier between building and source of noise.
2. Use vegetation to deflect winds over noise source away from building.

C. Earth Surface Conditions

1. Provide rough, loose textured surface material to break up and absorb sound.

D. Bodies of Water

1. Make use of running water elements, i.e., fountains, waterfalls, etc., to mask unwanted noises.

E. City Environment



## ILLUSTRATION CREDITS

- Fig. 37. U.S. Department of Commerce, "Monthly Climatological Summary, Toledo, Ohio--January 1979," National Climatic Center, Asheville, North Carolina.
- Fig. 38. Ibid.
- Fig. 39. Ibid.
- Fig. 40. U.S. Department of Commerce, "Annual Climatological Summary, Toledo, Ohio--1979," National Climatic Center, Asheville, North Carolina.
- Fig. 41. Ibid.
- Fig. 42. Ibid.
- Fig. 43. Robert S. Clarke, "Shadows at the Site: Solar Access Measurement," Solar Age, October 1980, p. 14.

## CHAPTER VI

### EXAMPLE OF MICROCLIMATIC SITE SURVEY, ANALYSIS, EVALUATION AND DESIGN

This chapter contains an example of a microclimatic design analysis developed for an actual site using the methods previously outlined. The example is the microclimatic site design analysis for a hypothetical 2,000 square foot office building.

#### Microclimatic Site Survey

The site chosen for this sample study is located at the corner of Humboldt and Juliette Streets in Manhattan, Kansas (see Fig. 44), and was designated as Site "A". The city of Manhattan, with a population of around 30,000, is situated in east central Kansas, approximately fifty miles west of Topeka, the capital city. The climate of Manhattan is represented on the climatic summary (Fig. 45) distributed by the Weather Data Library of the Department of Physics at Kansas State University in Manhattan. These figures are, for the most part, based upon records from 1941-1970 gathered by the Kansas Agricultural Experiment Station in Manhattan. The exception to this is the data for wind speed and direction, which is compiled from records of the National Weather Service station in Topeka. No official wind readings have been recorded in Manhattan. The physical characteristics of the site are recorded in Figures 46 through 50 of the following pages.

A lack of funds and available equipment necessitated the use of inexpensive instruments and repeated site visits for the gathering of climatic infor-

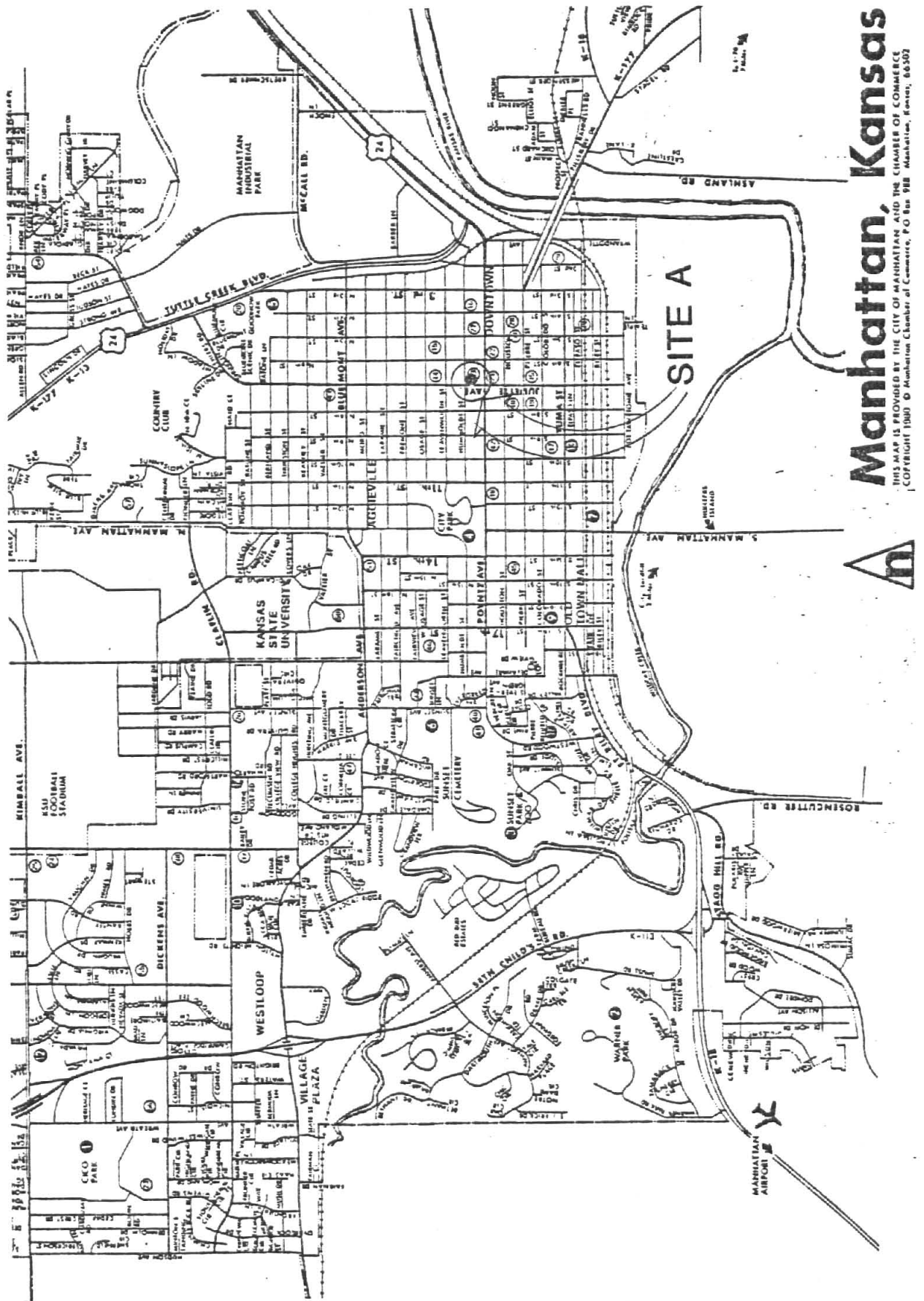
mation at the site. Temperature, wind speed, and wind direction are the climatic factors which were surveyed throughout the month of December, 1980. Instruments used for recording wind velocity were a Dwyer Instruments, Inc., "Vaneometer" for recording low velocity breezes, a Dwyer "Wind Meter" for higher wind velocities, an Airguide "918" wind speed indicator for high wind velocities, and a Taylor "Comfortmeter" thermometer for recording temperature. For this site it was assumed that humidity and solar radiation levels would conform to those listed in the city climatic summary. Instruments used for the survey, shown in Fig. 51, can be obtained at a total cost of less than \$50.

The center of the site was assumed to be the most probable building location. Temperatures and wind readings taken at that point will serve as the site conditions for comparison purposes. The site plan showing instrument locations (Fig. 52) indicates the central location as instrument station number one. Stations two through thirteen were used to determine wind flow patterns over the site during different types of wind conditions. The Temperature Log and Wind Information Log (Figs. 53 through 59) indicate the number of visits made to the site and the information gathered.

Wind direction was determined by smoke or hand-held streamers, as conditions dictated. Due to the relatively small size of the site, wind conditions at stations two through thirteen were taken by walking over the site rather than by mounting streamers on a series of poles. Numbers indicating wind direction on the Wind Information Log follow the format established by the National Weather Service. Each number indicates a ten-degree swing in a clockwise direction; a true north wind corresponds to 36, east is 9, south is 18, and west, 27.

Climatic information was gathered on eleven different days. Each read-

ing took approximately ten minutes to gather and record, and the overall time spent actually on the site was approximately ten hours. Including preparation of the various site plans, measuring and other tasks, the microclimatic site survey took a total of approximately 24 hours of the four-week survey period.



CLIMATIC SUMMARY  
Manhattan, Kansas

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(From Data Collected by Kansas Agricultural Experiment Station,  
Room 401, Cardwell Hall, Kansas State University)

\* From Topeka NWS Station

# From Climate of Kansas, Kansas State Board of Agriculture - figures  
represent averages from 1937 - 1945 at Topeka, KS at 12:30 PM.

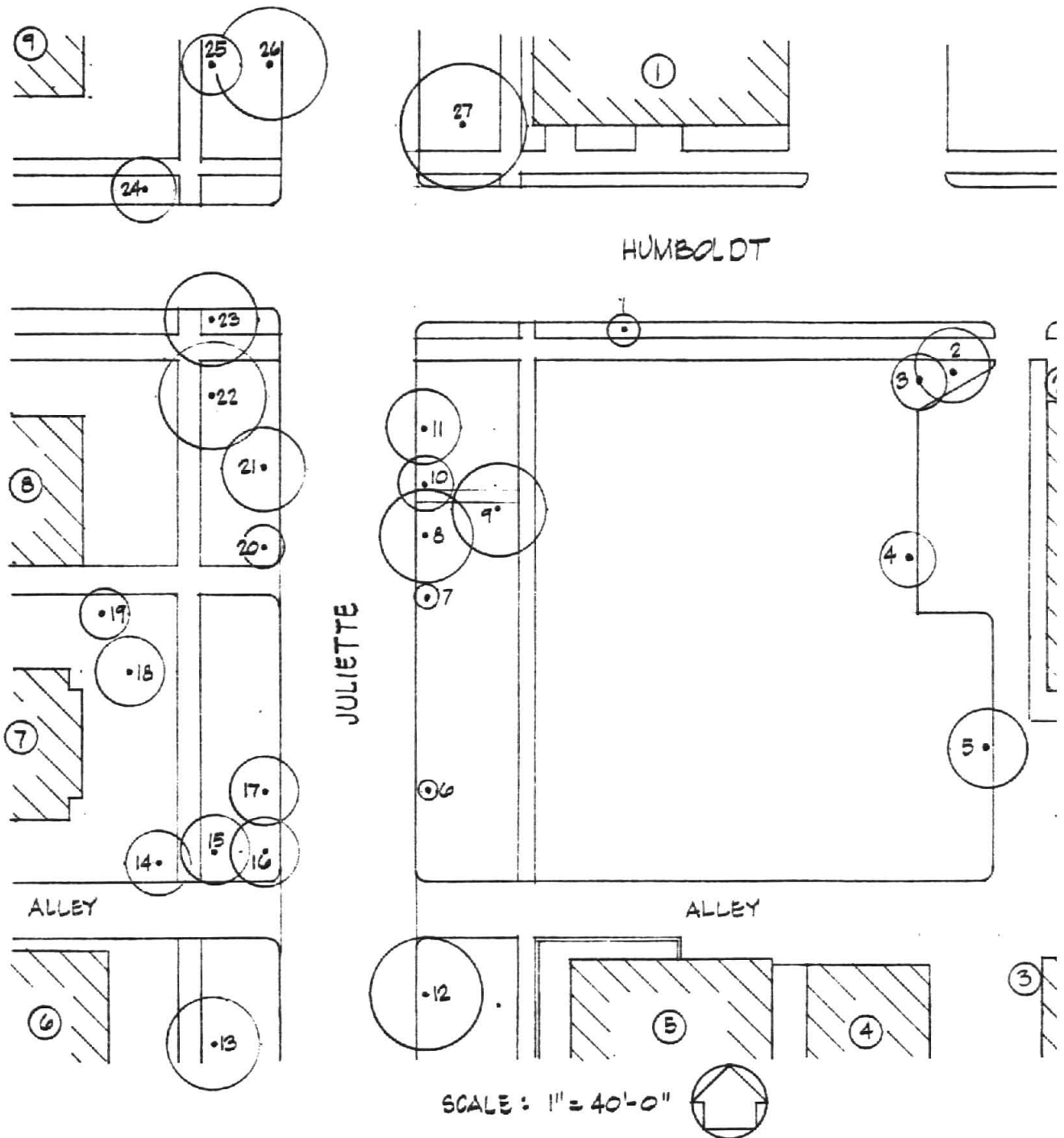
Month	Average Max. Temperature	Average Min. Temperature	Mean Temperature	Wind Direction *	Wind Speed *	Average Rel. # Humidity
JAN	39.6	17.5	28.7	N	10.5	64.0%
FEB	45.5	22.6	34.0	N	10.9	60.3%
MAR	54.1	29.8	41.9	S	12.7	56.6%
APR	68.1	42.8	55.5	S	12.7	53.4%
MAY	77.2	53.3	65.0	S	11.3	52.1%
JUN	85.5	63.0	74.3	S	10.4	56.9%
JUL	91.1	67.1	79.1	S	8.8	47.0%
AUG	90.6	66.2	78.4	S	8.9	53.6%
SEP	81.9	56.2	69.0	S	9.3	49.7%
OCT	71.9	45.3	58.6	S	9.7	50.1%
NOV	55.4	31.6	43.5	S	10.4	58.0%
DEC	43.0	21.8	32.4	S	10.4	66.1%

Figure 45

# SITE A

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## JULIETTE AND HUMBOLDT MANHATTAN, KANSAS



### PHYSICAL CHARACTERISTICS

TOPOGRAPHY: FLAT

VEGETATION: SEE PHOTOS AND SCHEDULE

SURFACE MAT'Ls.: GRASS, CONC. WALKS & STREETS (EXCEPT JULIETTE IS BRICK  
& ALLEY IS ASPHALT)

BODIES OF WATER: NONE

BLDGs.: SEE PHOTOS AND SCHEDULE

Figure 46



View Across Site A Looking West



View Across Site A Looking East

Figure 47  
Photographs of Site A





View Across Site A Looking South



View Across Site A Looking North

Figure 48  
Photographs of Site A

# SCHEDULE OF VEGETATION

NUMBER	TREE	SHRUB	TYPE	HEIGHT	DIAMETER OF FOLIAGE	HEIGHT TO BOT. OF FOLIAGE	REMARKS
1	✓		DECIDUOUS	9'	8'	3'	YOUNG - WILL GROW
2	✓		"	30'	20'	8'	
3	✓		"	15'	15'	5'	
4	✓		"	25'	15'	12'	SPARSE FOLIAGE - MAY DIE
5	✓		"	40'	20'	20'	
6	✓		"	7'	4'	3'	YOUNG - WILL GROW
7	✓		"	7'	6'	3'	WILL REMAIN SMALL
8	✓		"	30'	25'	20'	
9	✓		"	33'	25'	18'	
10	✓		"	15'	15'	10'	
11	✓		"	25'	20'	18'	
12	✓		"	30'	30'	15'	
13	✓		"	28'	25'	18'	
14	✓		"	35'	18'	12'	
15	✓		"	35'	18'	12'	
16	✓		"	35'	18'	12'	
17	✓		"	35'	18'	12'	
18	✓		"	35'	18'	12'	
19	✓		EVERGREEN	25'	12'	7'	
20	✓		DECIDUOUS	30'	10'	10'	
21	✓		"	40'	23'	15'	
22	✓		"	35'	30'	15'	
23	✓		"	35'	25'	10'	
24	✓		"	33'	15'	16'	
25	✓		"	35'	15'	20'	
26	✓		"	35'	30'	20'	
27	✓		"	32'	35'	8'	

Figure 49 - Schedule Of Vegetation

## SITE A

# SCHEDULE OF BUILDINGS

NO.	NAME	EAVE HGT.	RIDGE HGT.	REMARKS
1	SAVINGS & LOAN	14'	N/A	FLAT ROOF
2	JOB SERVICE	13'	N/A	FLAT ROOF
3	ELECTRIC. CONTR.	14'	N/A	FLAT ROOF
4	GARAGE	8'	16'	NORTH-SOUTH SLOPE
5	HOUSE	10'	20'	EAST-WEST SLOPE
6	CHURCH	40'	N/A	MULTIPLE ROOF SLOPES - BASICALLY BLOCK SHAPED
7	HOUSE	18'	N/A	"
8	HOUSE	34'	N/A	"
9	HOUSE	24'	N/A	"

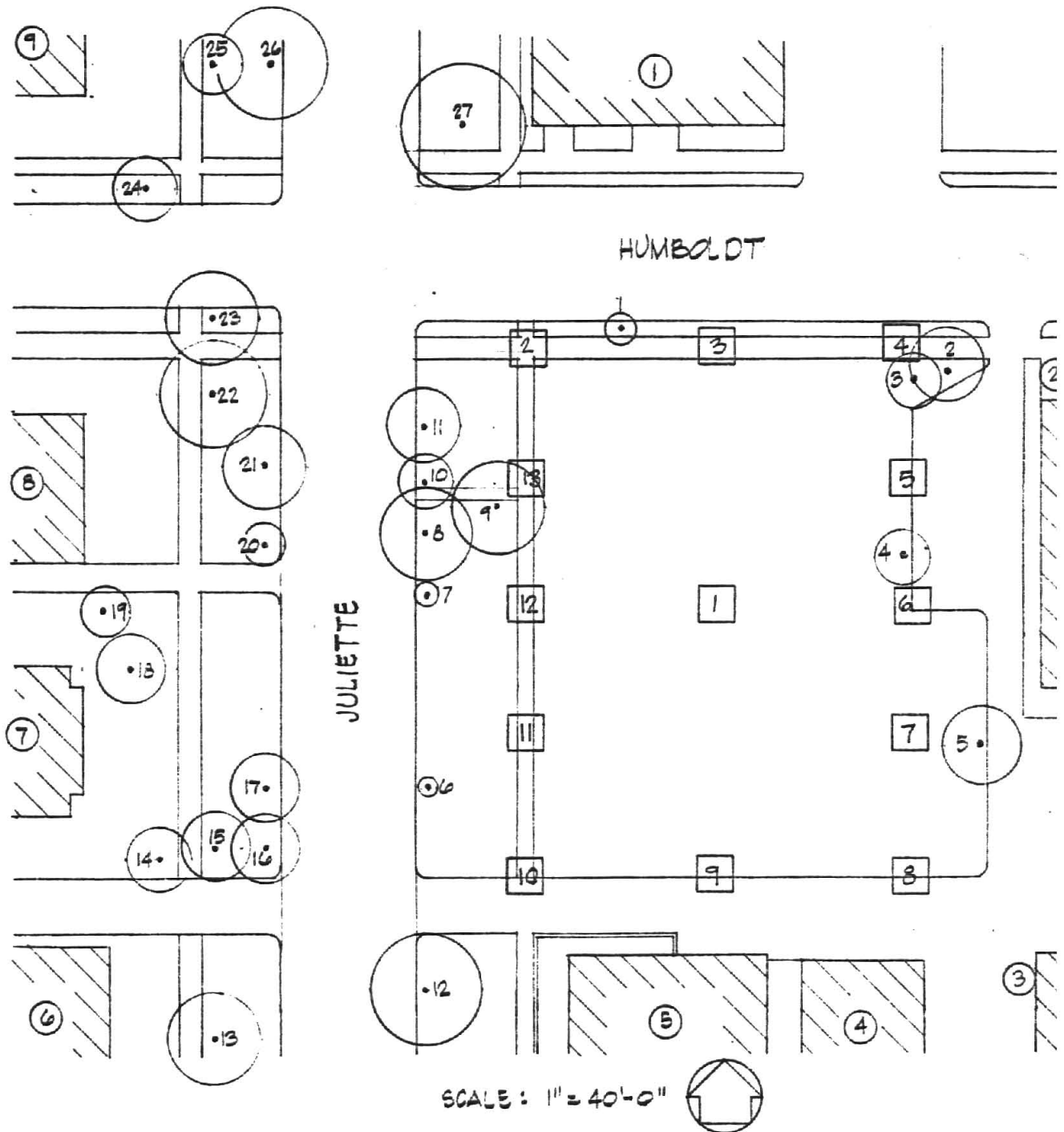
Figure 50 - Schedule Of Buildings



Figure 51  
Climate Data Collection Instruments

(l. to r. - Dwyer "Vaneometer," Dwyer "Wind Meter,"  
Airguide "918," Taylor "Comfortmeter")

## JULIETTE AND HUMBOLDT MANHATTAN, KANSAS



PLAN - LOCATIONS OF INSTRUMENTS

- 1 TEMPERATURE AND WIND MONITORING
- 2 THRU 13 WIND MONITORING ONLY

Figure 52

## TEMPERATURE LOG

DATE	TIME	INSTR. NO.	SUN CONDITION	WIND CONDITION	TEMP.	TEMP. AT WEATHER STATION
12/3/80	12:40 PM	1	SUNNY	GUSTY	50°F	47°F
"	4:51 PM	1	DUSK	LIGHT	46°F	45°F
12/4/80	12:44 PM	1	SUNNY	LT. GUSTS	73°F	60°F
12/11/80	8:19 AM	1	"	CALM	23°F	34°F
"	11:12 AM	1	"	"	47°F	50°F
"	2:06 PM	1	"	LIGHT	51°F	58°F
"	3:42 PM	1	"	"	50°F	57°F
12/12/80	8:00 AM	1	"	"	33°F	45°F
"	9:21 AM	1	"	"	46°F	47°F
"	1:15 PM	1	"	"	63°F	67°F
"	2:52 PM	1	"	"	60°F	71°F
"	4:02 PM	1	DUSK	CALM	57°F	71°F
12/15/80	9:21 AM	1	PT. CLOUDY	LIGHT	33°F	44°F
"	10:26 AM	1	CLOUDY	"	39°F	46°F
"	11:21 AM	1	"	"	40°F	50°F
12/16/80	7:49 AM	1	CLEAR	"	41°F	47°F
"	11:08 AM	1	SUNNY	"	47°F	54°F
"	12:45 PM	1	"	"	54°F	57°F
"	1:43 PM	1	"	MODERATE	51°F	58°F
"	3:37 PM	1	"	LIGHT	51°F	59°F
12/18/80	8:00 AM	1	CLOUDY	MODERATE	34°F	43°F
"	8:53 AM	1	"	"	35°F	43°F
"	10:18 AM	1	"	"	37°F	44°F
"	11:14 AM	1	"	"	37°F	45°F
"	12:56 PM	1	"	"	39°F	45°F
"	2:02 PM	1	"	"	38°F	45°F
"	2:59 PM	1	"	"	36°F	44°F

Figure 53

SITE A**TEMPERATURE LOG**

DATE	TIME	INSTR. NO.	SUN CONDITION	WIND CONDITION	TEMP.	TEMP. AT WEATHER STATION
12/18/80	3:50 PM	1	CLOUDY	MODERATE	36°F	44°F
12/19/80	11:17 AM	1	SUNNY	"	20°F	25°F
"	12:16 PM	1	"	"	19°F	26°F
"	1:47 PM	1	P/CLDY.	"	19°F	23°F
12/22/80	7:58 AM	1	CLEAR	LIGHT	32°F	40°F
"	8:58 AM	1	P/CLDY.	MODERATE	34°F	42°F
"	9:52 AM	1	CLOUDY	MODERATE, GUSTY	36°F	43°F
"	12:35 PM	1	"	"	40°F	46°F
"	12:57 PM	1	"	"	40°F	46°F
"	1:57 PM	1	"	LIGHT	40°F	49°F
12/29/80	7:59 AM	1	DAWN	"	34°F	44°F
"	8:58 AM	1	SUNNY	"	36°F	44°F
"	10:01 AM	1	"	"	41°F	49°F
"	11:11 AM	1	"	"	44°F	52°F
"	12:04 PM	1	"	"	47°F	54°F
"	1:58 PM	1	"	MODERATE	49°F	57°F
12/30/80	7:57 AM	1	P/CLDY.	LIGHT	39°F	50°F
"	9:00 AM	1	"	MODERATE	41°F	51°F
"	10:10 AM	1	"	"	46°F	54°F
"	10:56 AM	1	SUNNY	"	50°F	57°F
"	12:38 PM	1	"	"	51°F	57°F
"	1:54 PM	1	"	LIGHT	52°F	60°F
"	2:55 PM	1	"	"	53°F	60°F

Figure 54

# SITE A

## WIND INFORMATION LOG

DATE	TIME	INSTR. NO.	WIND SPEED	WIND DIR.	WEATHER STATION READINGS	
					SPEED	DIRECTION
12/3/80	12:21 PM	1	10	15.5	23	19
"	"	2	NOT RECORDED	"		
"	"	3	"	"		
"	"	4	"	"		
"	"	5	"	"		
"	"	6	"	"		
"	"	7	"	"		
"	"	8	"	9		
"	"	9	"	9		
"	"	10	"	18		
"	"	11	"	18		
"	"	12	"	18		
"	"	13	"	16		
"	12:40 PM	1	5	15.5	23	19
"	1:45 PM	1	5	16	19.6	18
"	3:23 PM	1	4.5	16	18.4	18
"	4:31 PM	1	6	21	9.2	18
12/4/80	12:32 PM	1	4	21	16.1	18
"	"	2	NOT RECORDED	21		
"	"	3	"	23		
"	"	4	"	23		
"	"	5	"	18		
"	"	6	"	13		
"	"	7	"	18		
"	"	8	"	CALM		
"	"	9	"	33		
"	"	10	"	19		

Figure 55



## WIND INFORMATION LOG

DATE	TIME	INSTR. NO.	WIND SPEED	WIND DIR.	WEATHER STATION READINGS	
					SPEED	DIRECTION
12/4/80	12:32 PM	11	NOT RECORDED	21		
"	"	12	"	21		
"	"	13	"	21		
12/11/80	3:19 AM	1	1.5	20	3.4	26
"	11:12 AM	1	2.3	15	6.9	28
"	2:06 PM	1	3.4	20	6.9	31
"	3:42 PM	1	1.7	20	5.8	8
12/12/80	3:00 AM	1	1.9	18	8	26
"	9:21 AM	1	1.5	23	11.5	27
"	1:15 PM	1	2.9	31	6.9	26
"	2:52 PM	1	2.9	34	10.4	25
"	4:02 PM	1	CALM	CALM	8	26
12/13/80	9:21 AM	1	3.4	20	3.5	18
"	10:26 AM	1	1.7	20	5.8	26
"	11:21 AM	1	4.0	22	6.9	28
12/16/80	7:49 AM	1	2.0	33	12.7	32
"	11:08 AM	1	4.6	33	11.5	34
"	12:39 PM	1	5.7	2	11.5	34
"	"	2	5.7	5		
"	12:40 PM	3	5.7	4		
"	"	4	5.0	3		
"	12:41 PM	5	4.6	2		
"	"	6	4.6	2		
"	12:42 PM	7	4.0	1		
"	"	8	4.0	1		
"	12:43 PM	9	4.5	1		
"	"	10	5.7	2		

Figure 56

## WIND INFORMATION LOG

DATE	TIME	INSTR. NO.	WIND SPEED	WIND DIR.	WEATHER STATION READINGS	
					SPEED	DIRECTION
12/16/80	12:44 PM	11	6.8	2		
"	"	12	6.2	3		
"	12:45 PM	13	5.8	4		
"	1:43 PM	1	3.9	3	9.2	33
"	3:37 PM	1	1.7	3	4.6	4
12/18/80	8:00 AM	1	8	6	11.5	4
"	8:53 AM	1	6	6	15	5
"	10:18 AM	1	7	7	21.9	6
"	11:14 AM	1	7	7	20.7	5
"	12:56 PM	1	7	4	20.7	3
"	2:02 PM	1	5	6	20.7	2
"	2:59 PM	1	6	5	18.4	2
"	3:50 PM	1	5	5	20.7	1
12/19/80	11:17 AM	1	6	34	17.3	35
"	12:09 PM	2	5	34		
"	"	3	4	35		
"	12:10 PM	4	8	2		
"	"	5	6	2		
"	12:11 PM	6	7	1		
"	"	7	6	33		
"	12:12 PM	8	5	34		
"	"	9	4	3		
"	12:13 PM	10	7	2		
"	12:14 PM	11	4	35		
"	12:15 PM	12	3	0		
"	"	13	7	34		
"	12:16 PM	1	7	3	16.1	36

Figure 57

# WIND INFORMATION LOG

DATE	TIME	INSTR. NO.	WIND SPEED	WIND DIR.	WEATHER STATION READINGS	
					SPEED	DIRECTION
12/19/80	1:47 PM	1	6	34	17.3	35
12/22/80	7:58 AM	1	3	22	15	18
"	8:58 AM	1	4.6	22	18.4	18
"	9:52 AM	1	4	20	18.4	19
"	12:35 PM	1	7	15	15	18
"	12:57 PM	1	5.5	21	15	18
"	1:57 PM	1	3	22	15	19
12/29/80	7:59 AM	1	.9	31	4.6	32
"	8:58 AM	1	1.7	32	5.8	28
"	10:01 AM	1	2.9	32	6.9	36
"	11:11 AM	1	3.4	32	11.5	34
"	12:04 PM	1	3.4	32	11.5	34
"	1:58 PM	1	6	32	12.6	32
12/30/80	7:57 AM	1	2.3	21	15	19
"	9:00 AM	1	5.7	22	12.6	18
"	10:14 AM	1	6	22	11.5	20
"	10:56 AM	1	6	22	17.3	20
"	12:38 PM	1	5	25	15	22
"	"	2	6	18		
"	12:39 PM	3	5	25		
"	"	4	5	22		
"	12:40 PM	5	6	24		
"	"	6	7	24		
"	12:41 PM	7	8	25		
"	"	8	5	27		
"	12:42 PM	9	2	36		
"	12:43 PM	10	5	18		

Figure 58

# WIND INFORMATION LOG

[illegible]

Figure 59

### Microclimatic Site Analysis

The first step of the analysis phase was to gather area weather data collected during the survey period which corresponds to the site-gathered data. Temperature information was obtained from tapes of a continuous temperature recording device operated by the Kansas State University Physics Department. This information was recorded on the Temperature Log. Wind information was obtained from records of the National Weather Service in Topeka, Kansas.

It is unfortunate that there is no source of appropriate wind information nearer to the site. The Weather Service office in Topeka is far enough from Manhattan that some question could be raised about the validity of using their data. Only a prolonged study to see if there is a consistent correlation between Manhattan and Topeka winds could answer this question. For purposes of illustrating the concept of microclimatic analysis, it is assumed here that using Topeka data is valid. It is hoped that most architects would not face this problem of a lack of local data.

A visit to the Topeka National Weather Service office, adjacent to Billard Airport, was necessary to acquire the required wind information. Wind readings, in knots, are recorded at the Topeka location hourly, at approximately ten minutes before the hour. Readings are taken from a strip chart attached to an anemometer mounted thirty feet above ground and located in an open area next to the airport. These figures are recorded and, every two weeks, sent to the NOAA in North Carolina, where they are verified and entered into the local climate summaries such as the one illustrated in Chapter V. Every third reading appears on these summaries, which are distributed by the NOAA. Since hourly readings were desired, the visit to the Weather Station was made, and the information was located and recorded, in miles per hour, in the appropriate

spaces on the Wind Information Log. Where wind readings corresponded closely with the timing of site-gathered information, the numbers were simply transferred to the log. Averages of the two hourly readings which bracketed the site-gathered information were used when timing did not correspond. Note that readings from Topeka are only entered on the lines for instrument location "1" since this is taken as our average site location.

In order to determine temperature and wind figures for Site A's climate profile, an analysis of the variation between site and weather station data was performed. Except for the first two days of data collection, when the thermometer was inadvertently placed in direct sunlight, temperatures at the site were consistently lower than those recorded by the KSU Physics Department. The average difference was determined to be  $7.4^{\circ}\text{F}$ . To determine how much of this variation was due to the instruments, a series of five readings were taken at the site of the Physics Department's temperature recording device. These readings averaged out at  $6.8^{\circ}\text{F}$  above the thermometer used for gathering site data. This figure, subtracted from the average difference of the readings, indicate site temperatures to be an average of  $0.6^{\circ}\text{F}$  below those recorded by the Physics Department. This is indicated on the site climate profile.

An analysis of wind speeds recorded at Site A shows a significant variation with wind speeds recorded by the National Weather Service in Topeka. Wind speeds at the site were consistently lower than those recorded by the National Weather Service, with the average determined at 66% lower. This is probably due to the fact that site readings were taken closer to the ground where trees and buildings tend to shelter the instrument. For wind direction analysis, it was necessary to determine site wind directions for a "north" and a "south" wind. To do this, a circle was plotted with the top facing north. This circle was divided into eight segments, each centered on the eight major compass directions: N, NE, E, SE, S, SW, W and NW. Any wind

direction reading from Topeka in the segment encompassing true north or south was taken as a wind from that direction. An analysis of the wind information log shows 17 readings during south wind conditions. Of those 17, twelve site readings were shown to be crossing the site from a more westerly direction. This was believed to be a significant number and those twelve readings were, therefore, averaged. The result indicated that a wind recorded as from the south in Topeka corresponds to one crossing Site A in a direction from  $28^{\circ}$  further west. A similar analysis was performed for the eleven north wind readings. Of those readings, five site winds blew from further east, and six from further west. There seemed to be no clear-cut directional variation, the average being only  $2.7^{\circ}$  east of the Topeka data. For this reason, north in Topeka is taken to be the same direction at Site A.

Temperature and wind figures determined in the previous analysis were used for compiling the climate profile of Site A illustrated in Figure 60.

From the site climate profile, figures representing the site's weather conditions throughout the year appear on the bioclimatic chart, Figure 61.

For this study, shadow patterns at the site, illustrated in Figures 62 through 67, were produced photographically in the heliodon at Kansas State University. A small scale model of the site was constructed including buildings and trees, with a fairly accurate simulation of size and shape of foliage. Shadow patterns of tree foliage should be disregarded on the photographs representing a winter day.

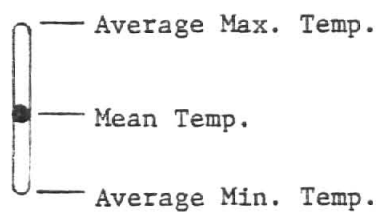
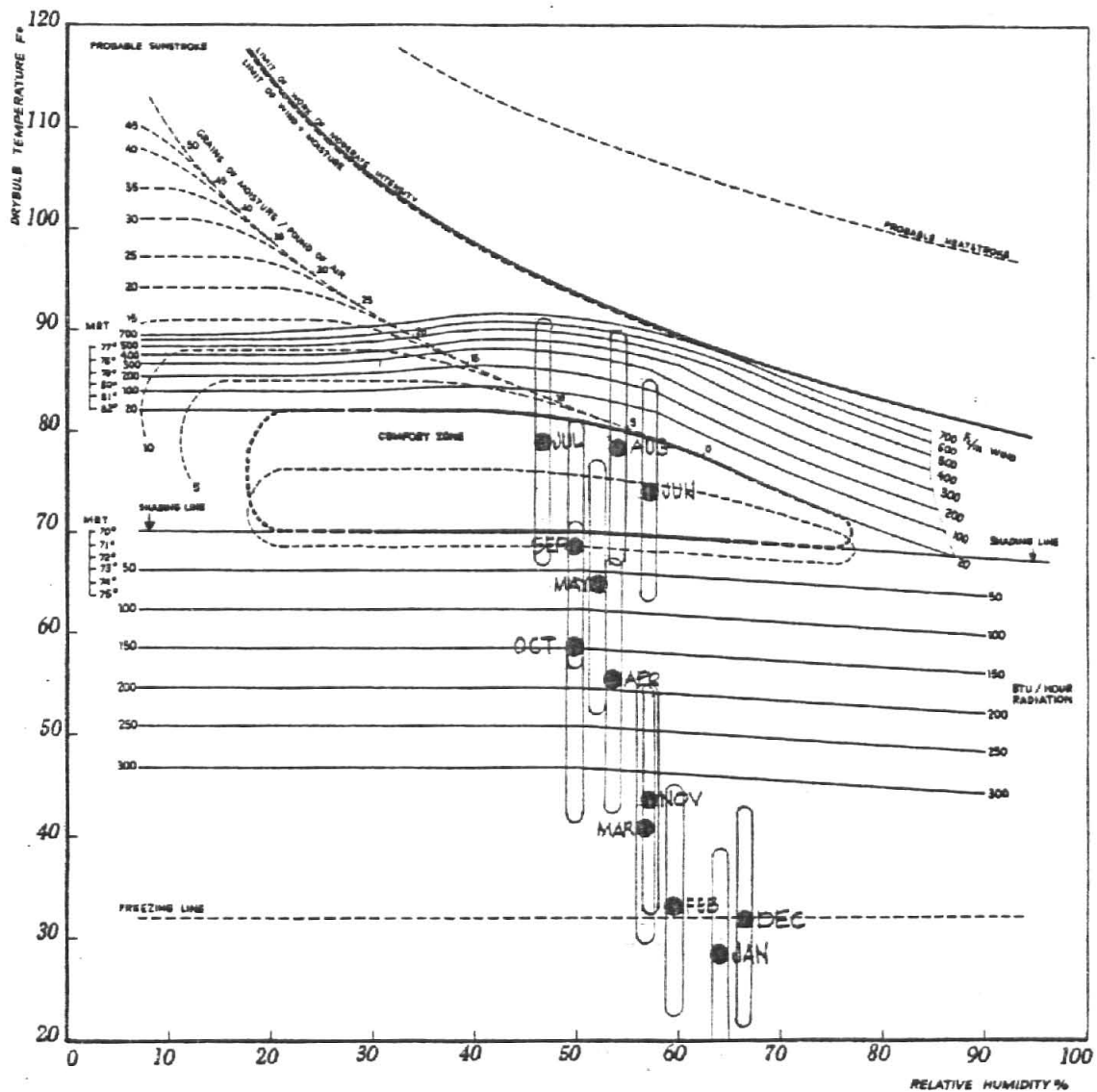
Wind pattern plans, Figures 68 and 69, were produced from data collected at the site by recording wind directions at instrument stations two through thirteen around the perimeter of the site.

## CLIMATE PROFILE - SITE A

Month	Average Max. Temperature	Average Min. Temperature	Mean Temperature	Wind Direction	Wind Speed	Average Rel. Humidity
JAN	39.0	16.9	28.1	N	3.6	64.0%
FEB	44.9	22.0	33.4	N	3.7	60.3%
MAR	53.5	29.2	41.3	SW	4.3	56.6%
APR	67.5	42.2	54.9	SW	4.3	53.4%
MAY	76.6	52.7	64.4	SW	3.8	52.1%
JUN	84.9	62.4	73.7	SW	3.5	56.9%
JUL	90.5	66.5	78.5	SW	3.0	47.0%
AUG	90.0	65.6	77.8	SW	3.0	53.6%
SEP	81.3	55.6	68.4	SW	3.1	49.7%
OCT	71.3	44.7	58.3	SW	3.3	50.1%
NOV	54.8	31.0	42.9	SW	3.5	58.0%
DEC	42.4	21.2	31.8	SW	3.5	66.1%

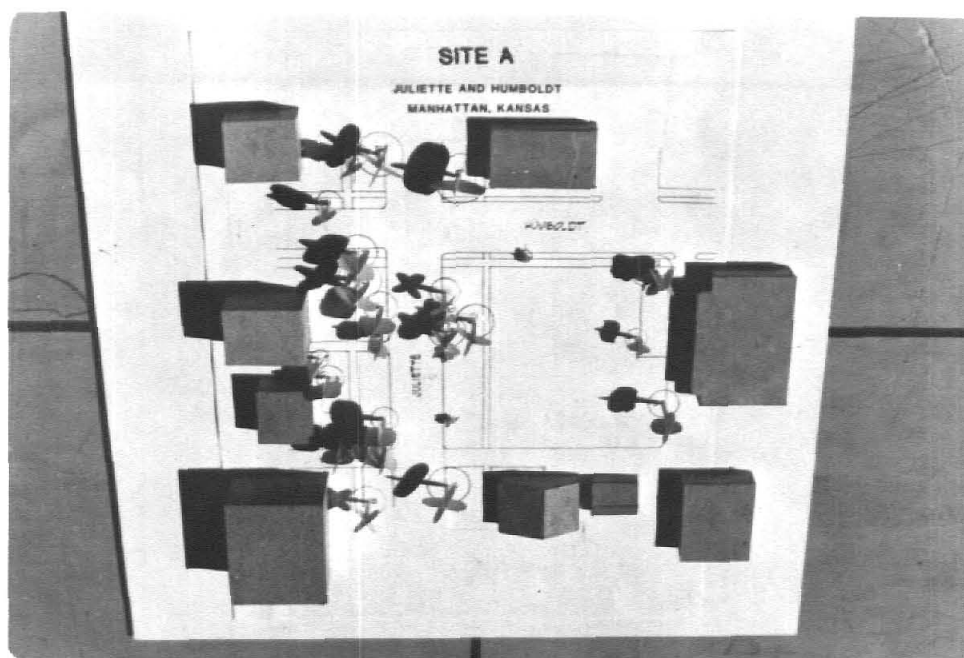
Figure 60



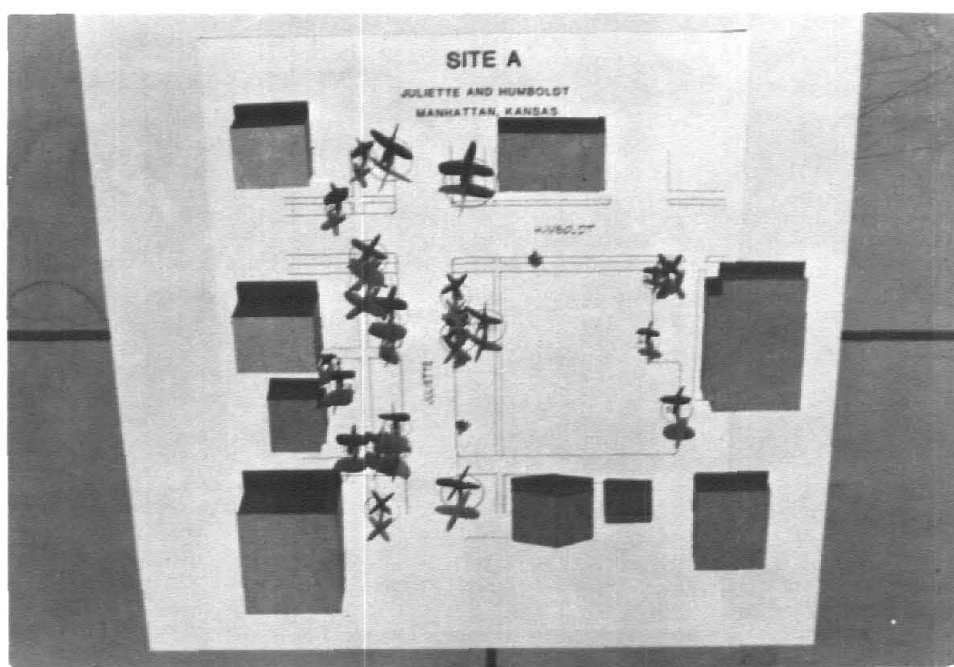


Note: Since the hypothetical office building will only be occupied During the day, temperatures in the upper area of the bar should be considered when developing goals for microclimatic design.

Figure 61 - Bioclimatic Chart - Site A

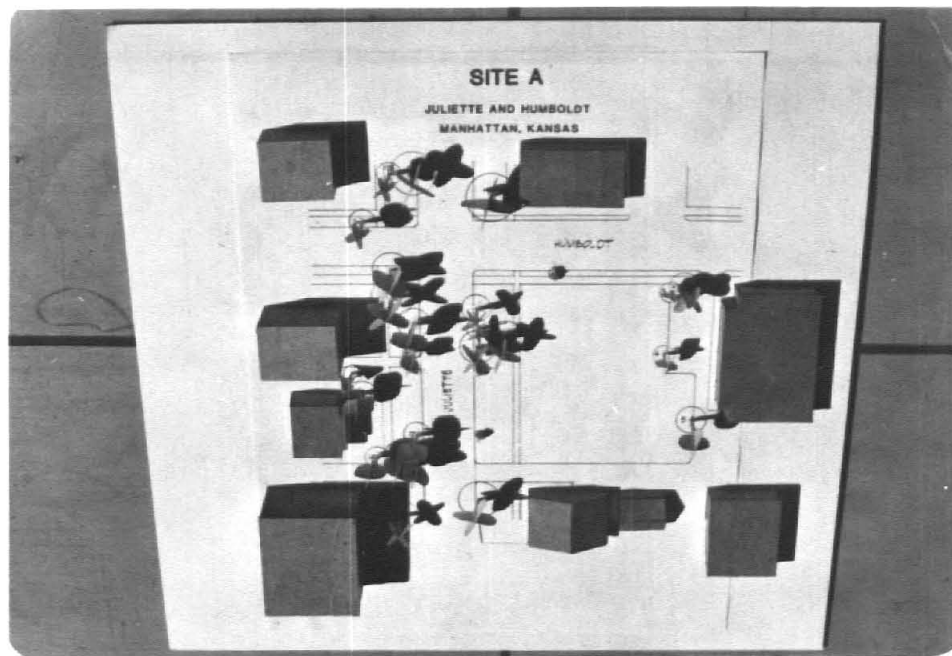


June 21, 9 AM

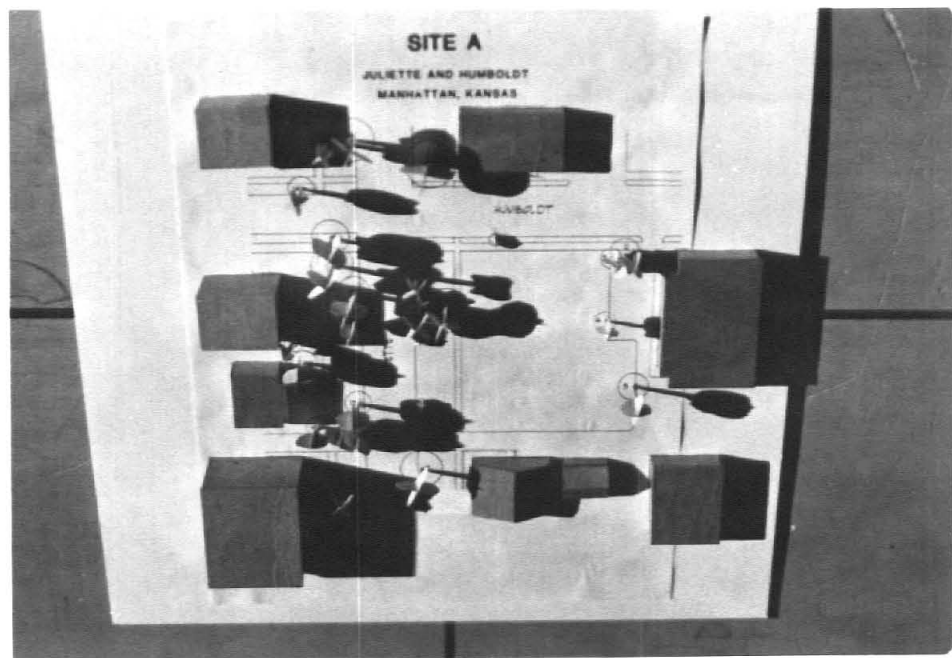


June 21, 12 Noon

Figure 62 - Site Shadow Patterns

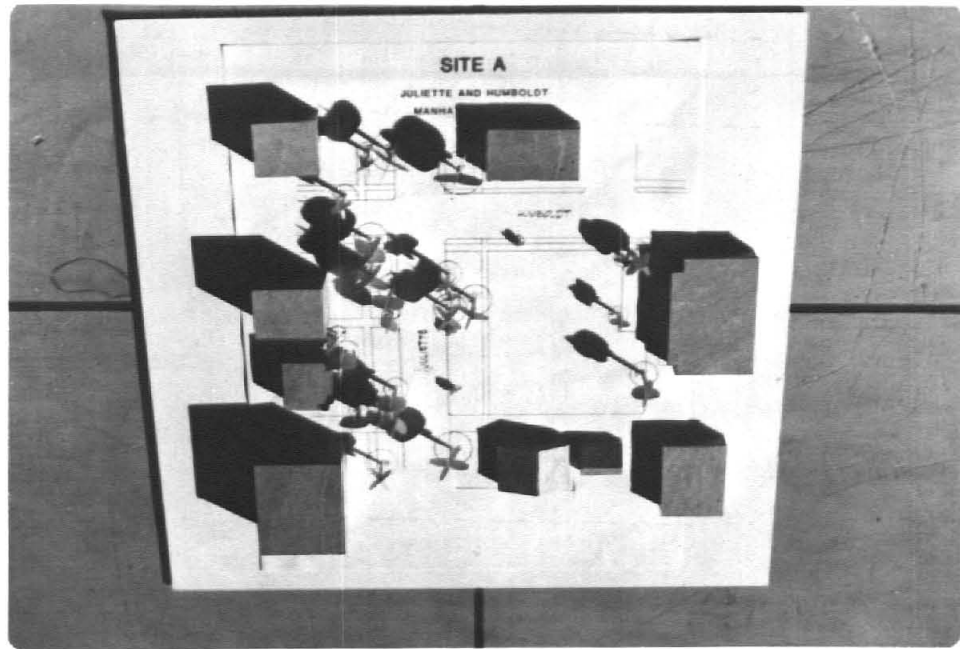


June 21, 3 PM

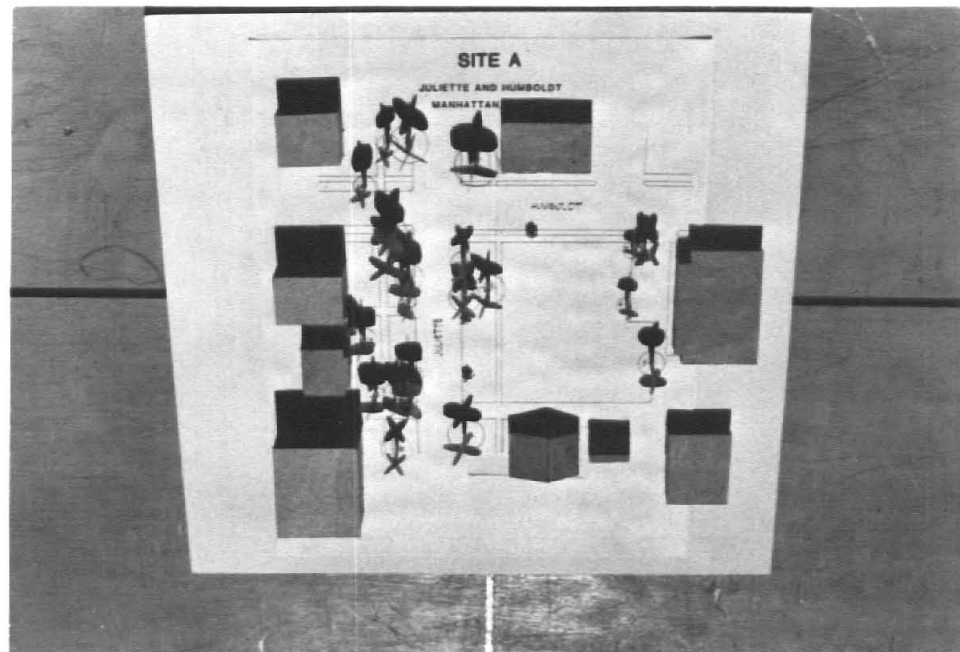


June 21, 5 PM

Figure 63 - Site Shadow Patterns

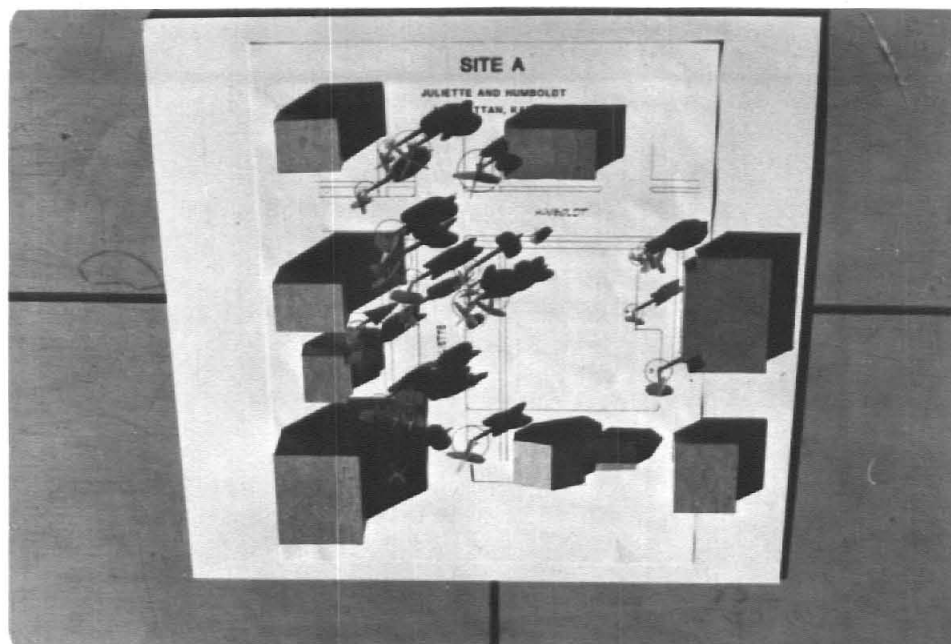


March, Sept. 21, 9 AM

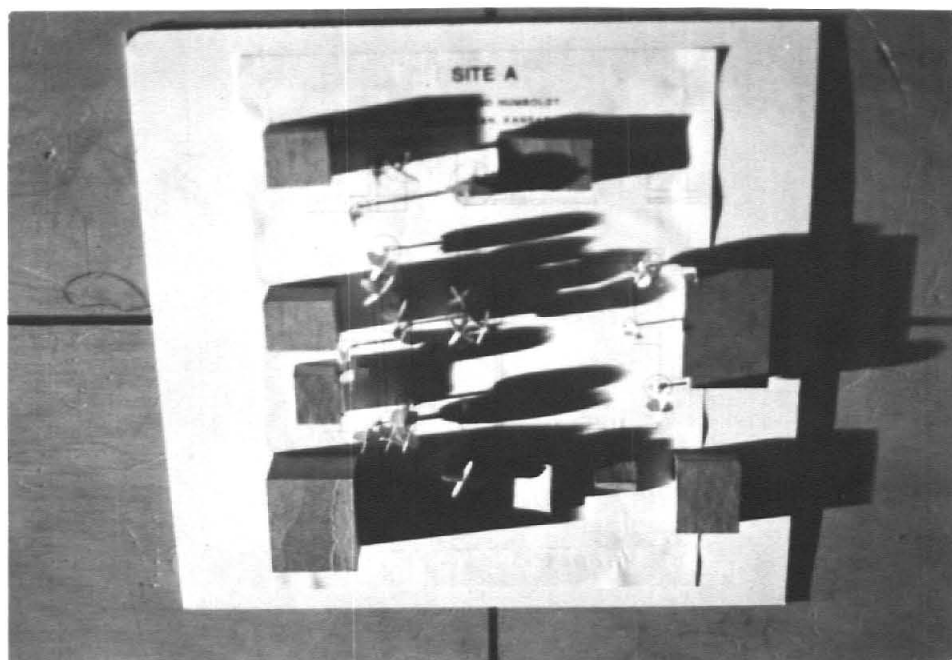


March, Sept. 21, 12 Noon

Figure 64 - Site Shadow Patterns

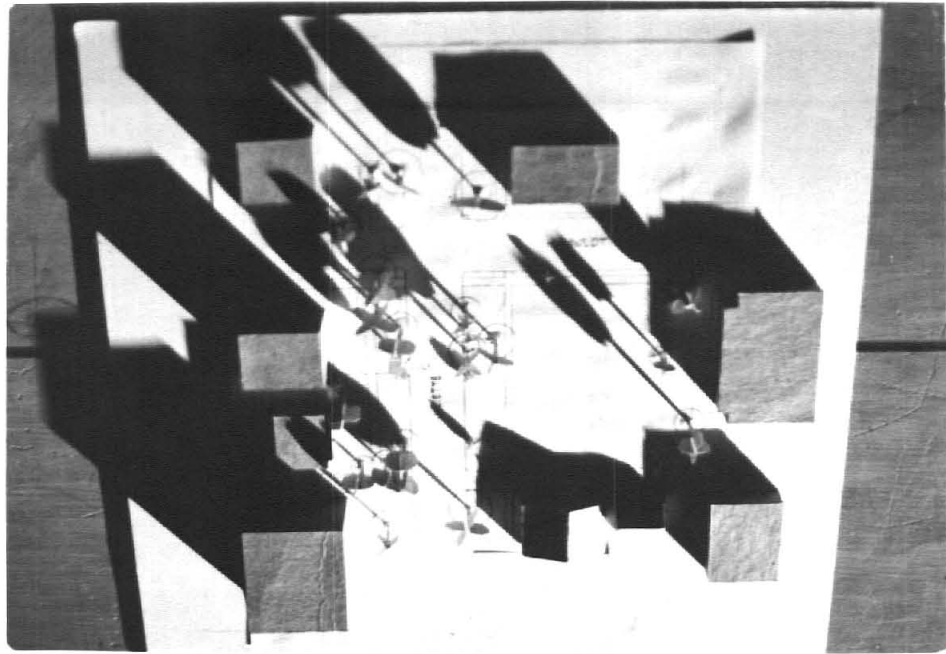


March, Sept. 21, 3 PM

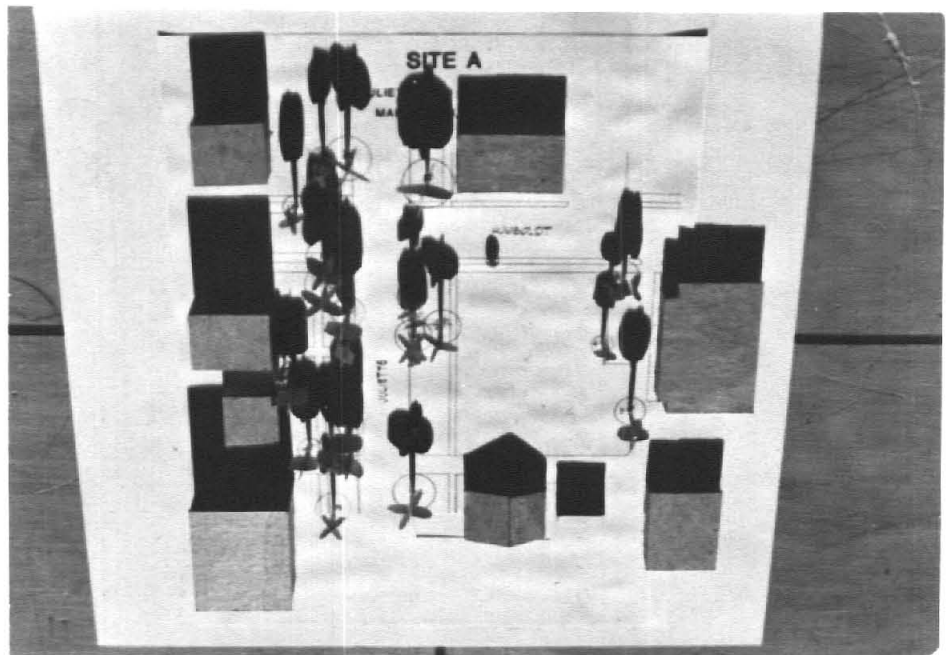


March, Sept. 21, 5 PM

Figure 65 - Site Shadow Patterns

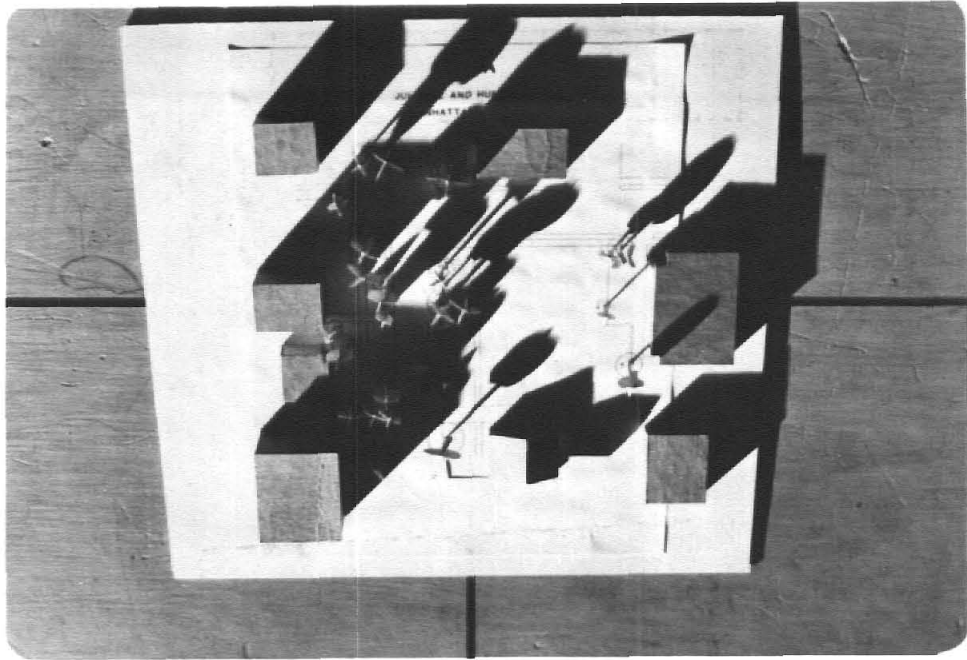


Dec. 21, 9 AM



Dec. 21, 12 Noon

Figure 66 - Site Shadow Patterns



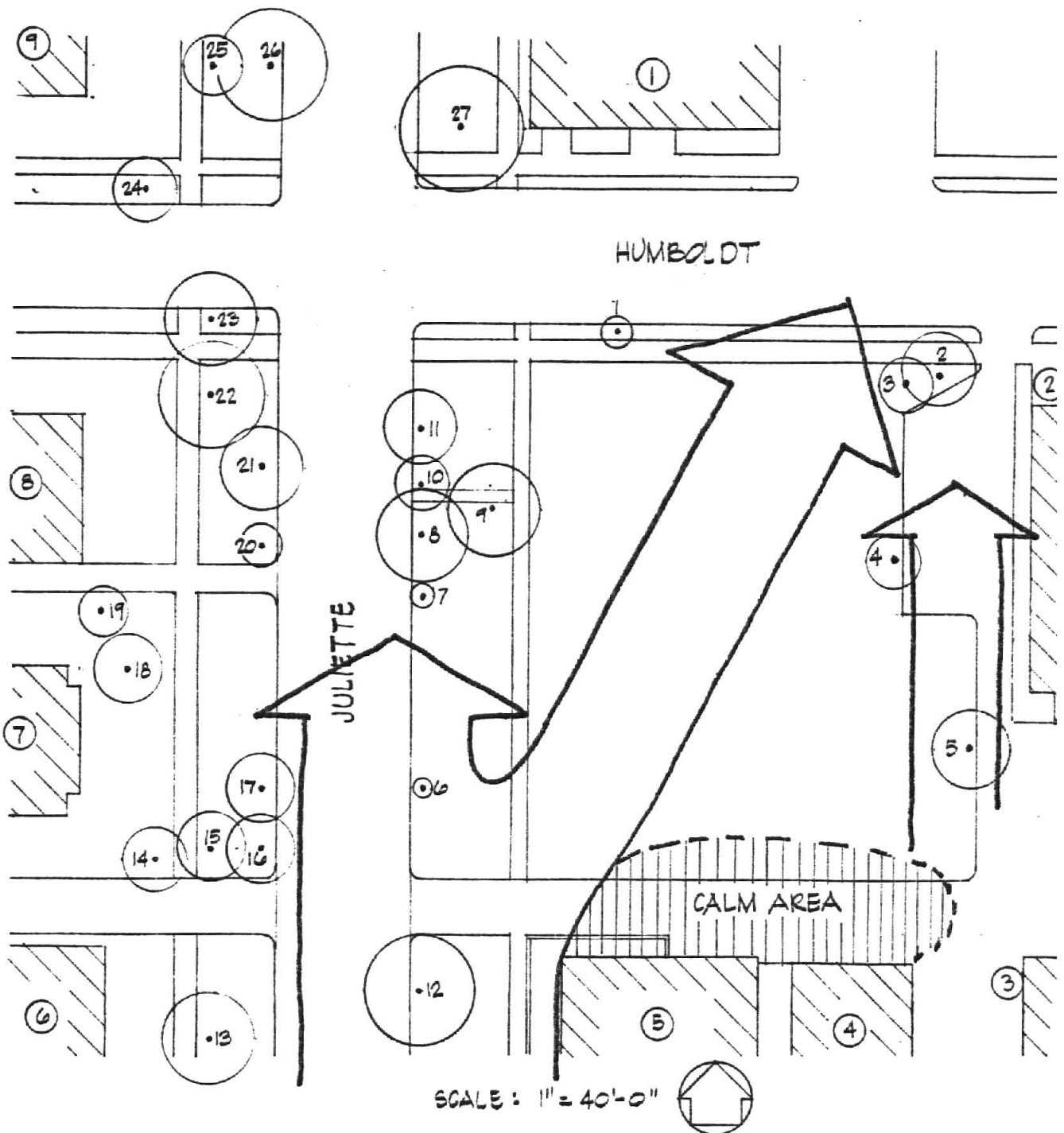
Dec. 21, 3 PM

Figure 67 - Site Shadow Patterns

# SITE A

121

## JULIETTE AND HUMBOLDT MANHATTAN, KANSAS



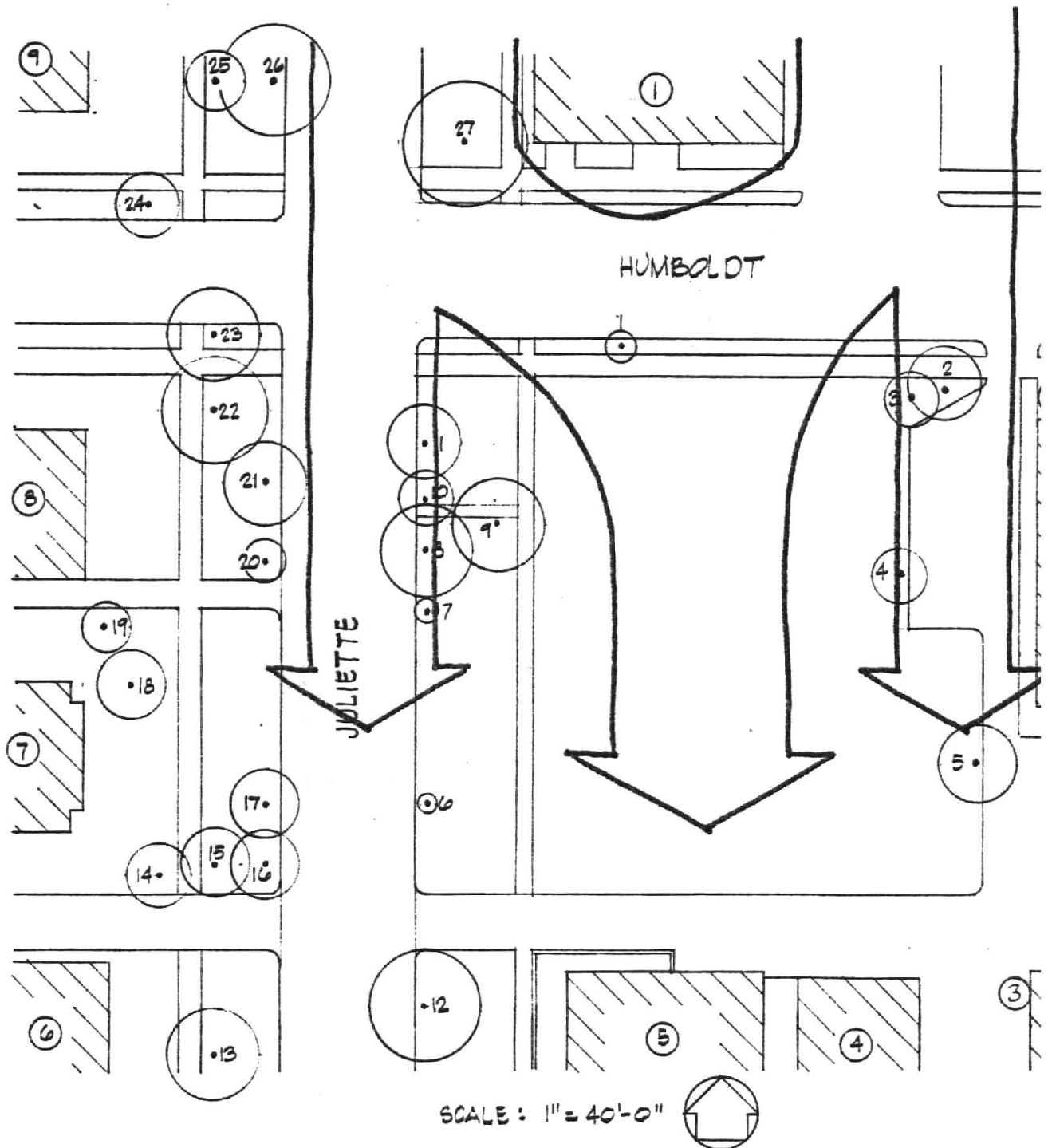
WIND PATTERN PLAN  
SOUTH WINDS - MARCH THRU DEC.



# SITE A

122

## JULIETTE AND HUMBOLDT MANHATTAN, KANSAS



WIND PATTERN PLAN  
NORTH WINDS - JAN. & FEB.

Figure 69

### Microclimatic Site Evaluation

Figure 70 lists goals for the microclimatic site design at this site. These were developed by an analysis of the bioclimatic chart plotted against climate conditions at the site.

### Microclimatic Site Design

The list of possible strategies to achieve design goals, Figure 71, was developed from design charts illustrated in Chapter V. The site plan developed for Site A appears in Figure 72. This plan features the following microclimate modifying elements.

A dense planting of conifers to the north of the building serves to slow down and deflect winter winds. The north and west sides of the building are bermed and covered with dense ground cover to provide further winter wind protection. A double row of conifers to the southwest of the building will tend to deflect and direct southwestern summer breezes toward the building.

The building shape was developed to expose a maximum of south wall surface to the sun in winter, and also to intercept southwest breezes for natural ventilation in the summer. The area immediately to the south of the building and a portion of the roof is shaded in summer by a vine-covered pergola structure which would lose most of its leaves in winter. Beneath the pergola is a concrete patio area which would serve as an outdoor lounge space in the summer. The smooth concrete surface of the patio would not hinder the passage of summer breezes toward the building. In winter, the light color of the patio concrete would tend to reflect sunlight into the building and its high mass would absorb some solar radiation and warm up slightly during the daytime.

Deciduous trees to the south and southwest provide additional summer shade. The foliage of these trees would be high enough that summer breezes,

cooled in the shade, could pass relatively unhindered toward the building. Keeping the grass mowed short in these areas would further facilitate the passage of southwest breezes.

The parking area is located far enough from the building that cars will not block summer breezes, and heat build-up in the pavement will have minimum impact on the building.

The site plan developed in Figure 72 is just one of many schemes that could have been developed from goals and strategies formulated in the micro-climatic design process. The design method presented in this paper allows the architect a great deal of freedom in design. It also provides him with the information required for making intelligent decisions which will affect the energy consumption of a proposed building.

## GOALS FOR MICROCLIMATIC SITE DESIGN

## SITE A

## MANHATTAN, KANSAS

SUMMER

Decrease amount of solar radiation  
Decrease temperature  
Increase wind velocity  
Decrease humidity

WINTER

Increase amount of solar radiation  
Increase temperature  
Decrease wind velocity

Figure 70 - Design Goals

## SITE A

## MANHATTAN, KANSAS

SUMMER

To decrease amount of solar radiation:

Provide trees to shade building from sun.

Provide leafy ground cover to south side of building.

Use dark, rough surface materials to decrease reflection of solar radiation toward building.

To decrease temperature:

Locate trees to southwest of building to cool breezes traveling toward building.

Provide low density surface materials near building.

To increase wind velocity:

Plant vegetation to direct and increase wind velocity toward building.

Provide smooth surface materials in breeze path.

Locate building to take advantage of existing breeze pattern for natural ventilation.

To decrease humidity:

Provide for good site drainage.

Provide surface material with low moisture retention.

Avoid use of pools or fountains.

WINTER

To increase amount of solar radiation:

Locate building in unshaded area.

Provide deciduous trees which lose leaves in winter.

Minimize low-growing vegetation to increase solar radiation on building.

Use light-colored surface materials to reflect sun into building.

Use smooth material to reflect sun into building.

To increase temperature:

Slope ground away from building.

Slope ground to shield building from cold winds.

Locate vegetation to shield building from cold winds.

Provide high density surface materials.

To decrease wind velocity:

Alter topography to deflect winds away from building.

Plant vegetation to block, deflect, or reduce speed of wind at building.

Provide rough surface materials in wind path.

Figure 71 - Possible Strategies To Achieve Design Goals

# SITE A

127

## JULIETTE AND HUMBOLDT MANHATTAN, KANSAS

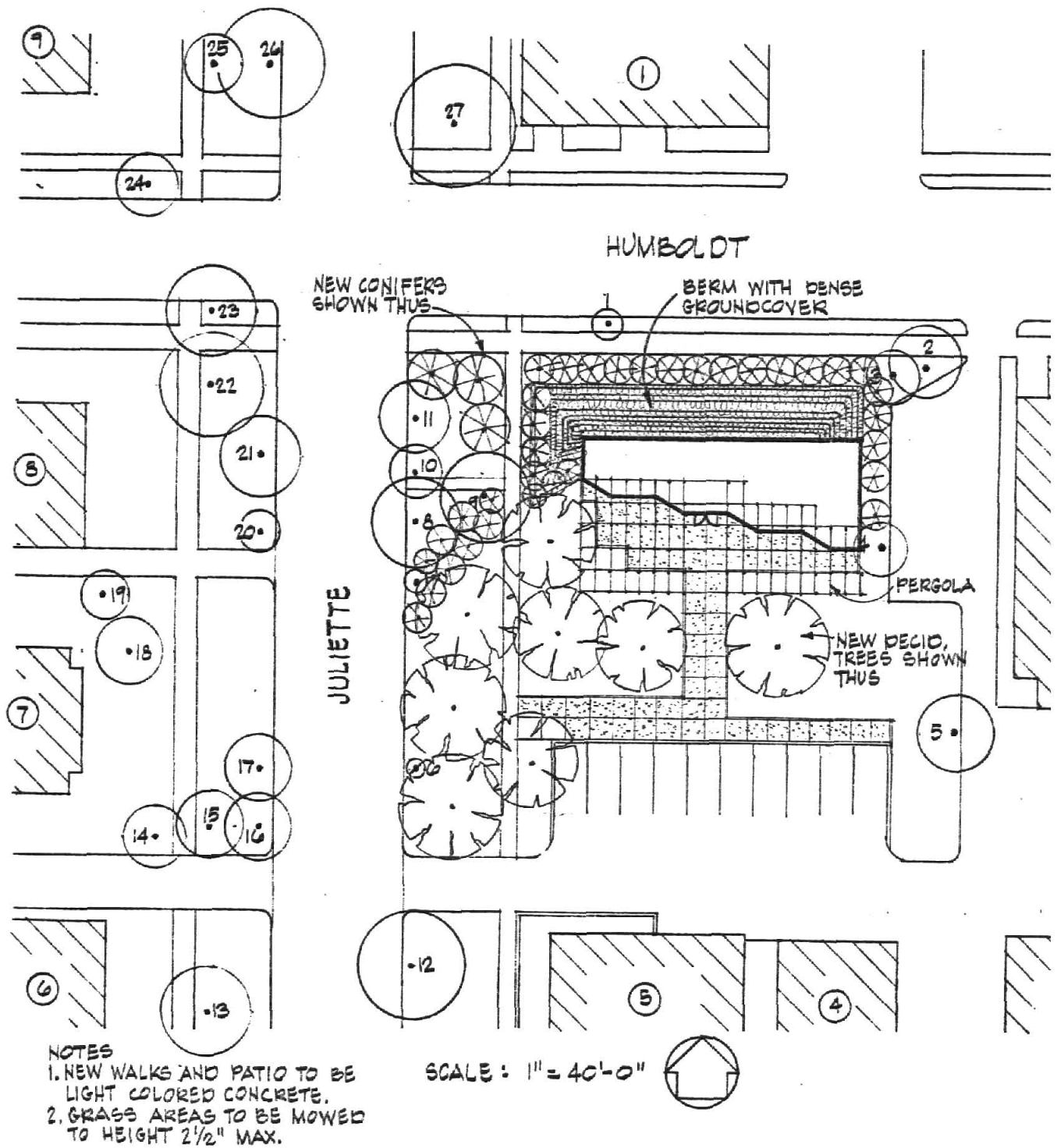


Figure 72 - Site Plan

## ILLUSTRATION CREDITS

Fig. 44. Manhattan Chamber of Commerce, "Map of the City of Manhattan,"  
P.O. Box 988, Manhattan, Kansas.

Fig. 45 - Fig. 60. Author.

Fig. 61. Victor Olgyay, Design with Climate (Princeton, N.J.:  
Princeton Univ. Press, 1963), p. 20.

Fig. 62 - Fig. 72. Author.

## SUMMARY

Microclimatic design for energy conservation is a subject which has been largely ignored by the architectural profession. Most architects, if they consider climate at all in building design, think only in terms of regional climates. It has been shown in this paper that this regional approach to climate-based design, while certainly better than no consideration at all of climate, is largely an oversimplification.

The climate at a particular site can vary to a significant degree from that of the area in general. The designer who is genuinely interested in producing energy-conscious architecture must look to the climate at the site as the source of form-generating data. To this end, he must include a more vigorous process of site surveying, both physical and climatic, than is common practice today.

A method has been presented here which illustrates a format for microclimate-based site planning and design. Due to the realities of the economics of architectural practice, this method depends upon the drawing of conclusions based upon assumptions. The determination of a climate profile for a particular site is, essentially, an assumption based upon extrapolation of a relatively small amount of data and a comparison with data from established sources.

The only way to prove the validity of a particular climate profile is to leave climate-monitoring equipment at that site for a number of years and compare actual measurements with assumptions previously made. It is hoped that such research will be carried out in years to come. The addition of a



large data base would improve the method presented for microclimatic site surveying, and elevate the confidence of architects employing it. The addition of computer technology to the process of data evaluation, climate simulation, and decision making would be a beneficial development. Model simulation studies performed in heliodons and boundary layer wind tunnels are another valuable method for expanding the base of knowledge in this area.

Having raised the question as to the validity of basing a design on unproven assumptions, one must ask whether the effort required in a microclimatic design is worthwhile. In this writer's opinion, the answer is yes. Even though one cannot be assured of 100% accuracy of assumptions, it is clear that the results of a microclimatic survey will yield an understanding of the interaction of site features and microclimate data which is more accurate than a quick analysis of weather bureau statistics. In essence, the microclimatic designer cannot be sure of absolute correctness, but he can be relatively certain that his assumptions are more correct than those he would have drawn without a microclimatic survey.

While this paper deals only with site planning and design, it must be recognized that the design of the building has a major impact on overall energy usage. Information generated during microclimatic site design can be very valuable for decision making during the building's design. The shape of the building, location of functions, fenestration, location of entrances and circulation spines, and many other items can, and should, be influenced by the site's climate.

The architect should be aware that the placement of a building on a site automatically alters the climate at that site. Wind patterns, shade patterns and other factors change with the addition of a building. The architect should take this fact into account during design, and temper his decisions

accordingly. Model studies in a heliodon and a wind tunnel can be invaluable in studying the microclimatic effects of building placement.

Further research on microclimate and design would be most valuable to expand the body of knowledge in this area. Because of the importance of energy conservation in the built environment and the rich aesthetic possibilities of a microclimate-based design approach, it is hoped that such research will soon begin.

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## APPENDIX A

WEATHER MAPS, CONTINENTAL U.S.









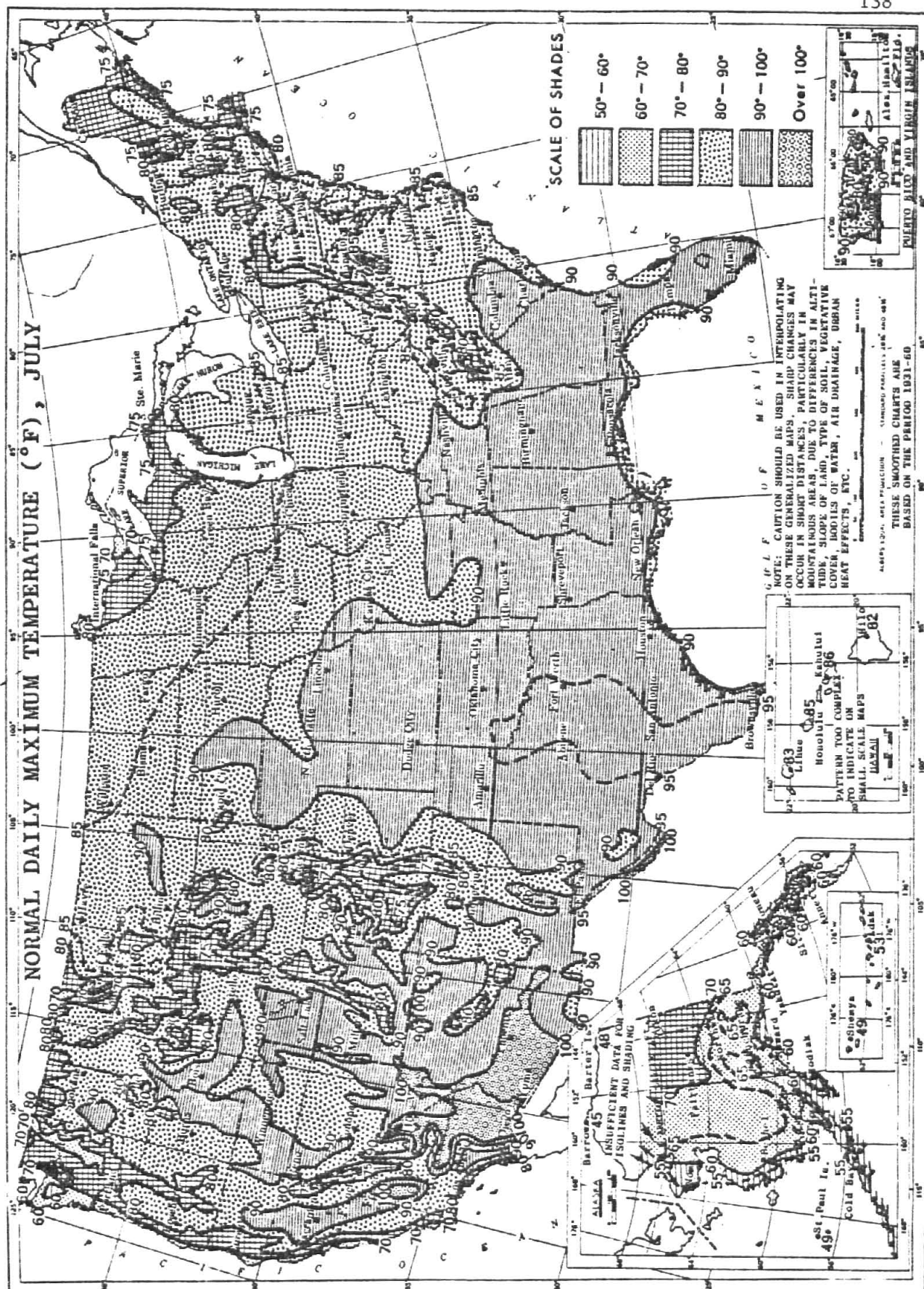


Figure A3

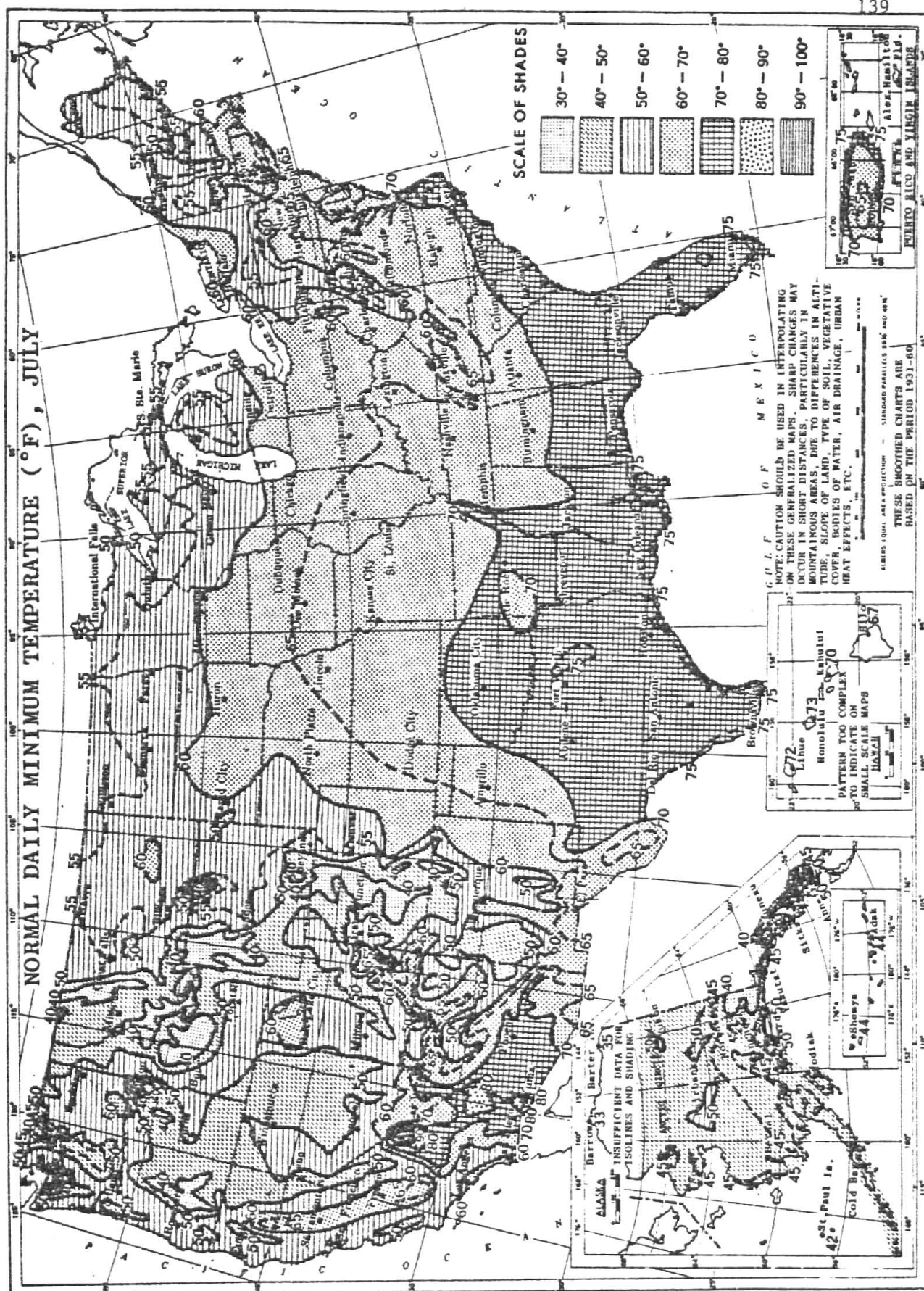


Figure A4







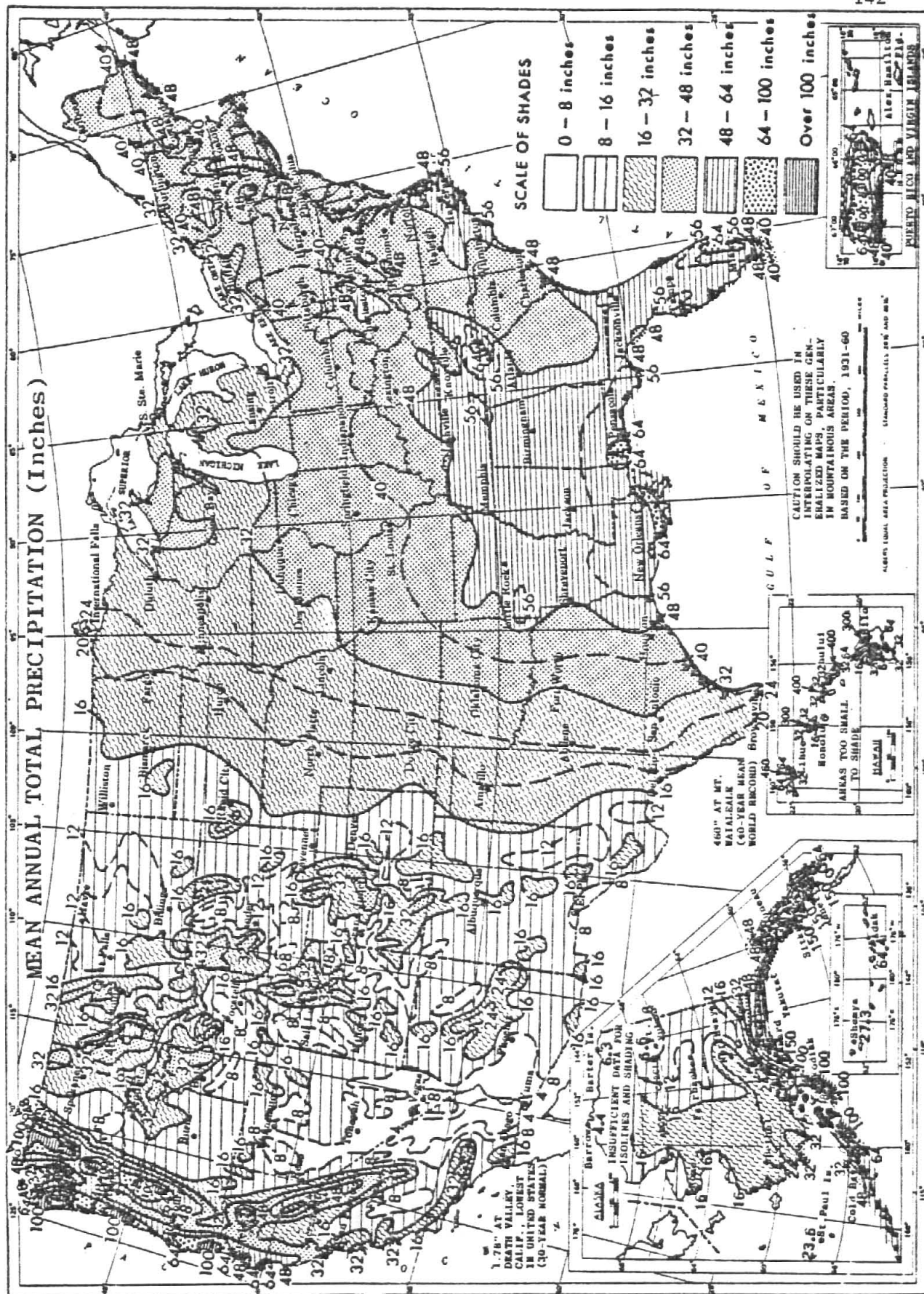


Figure A7





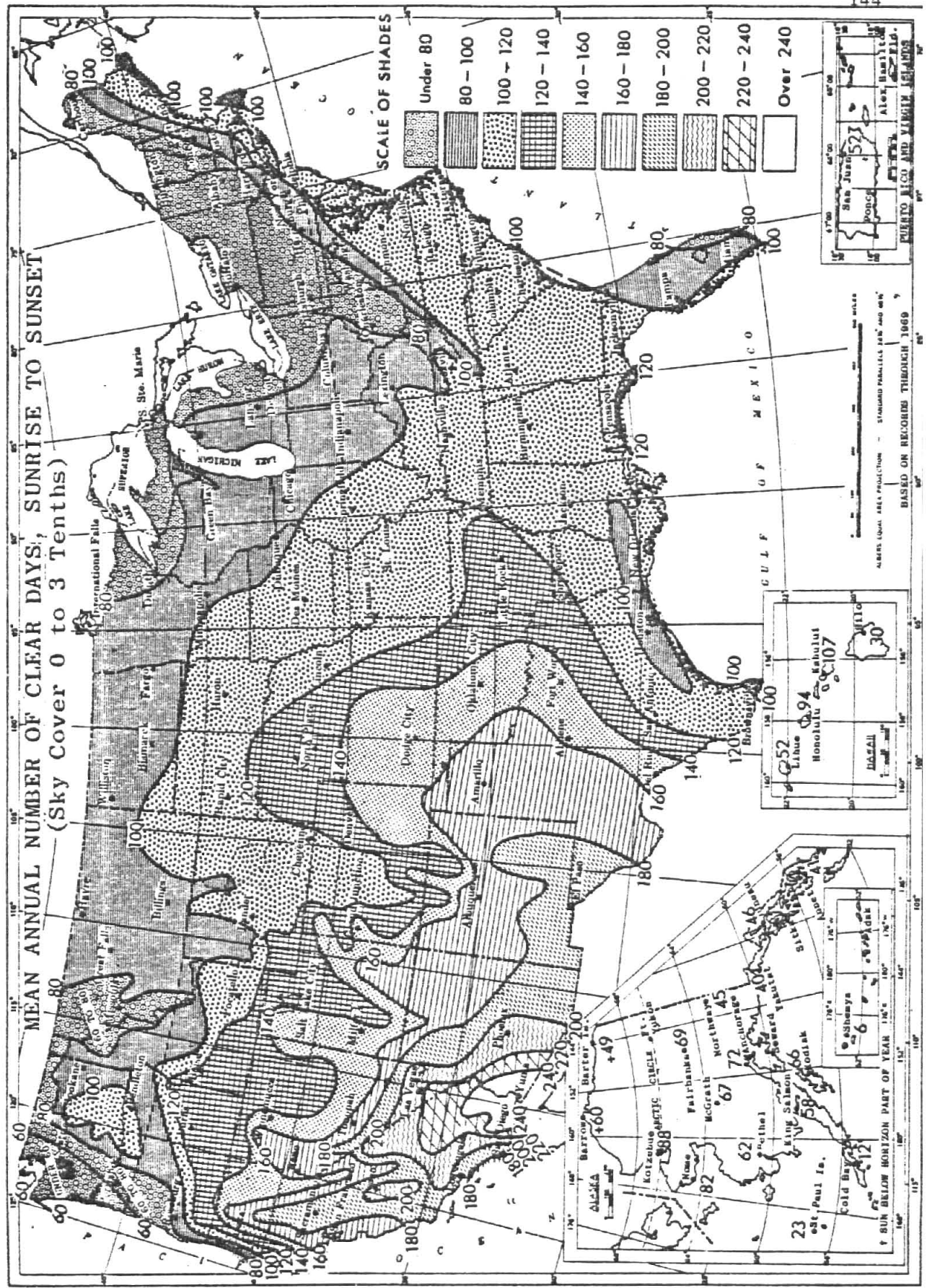


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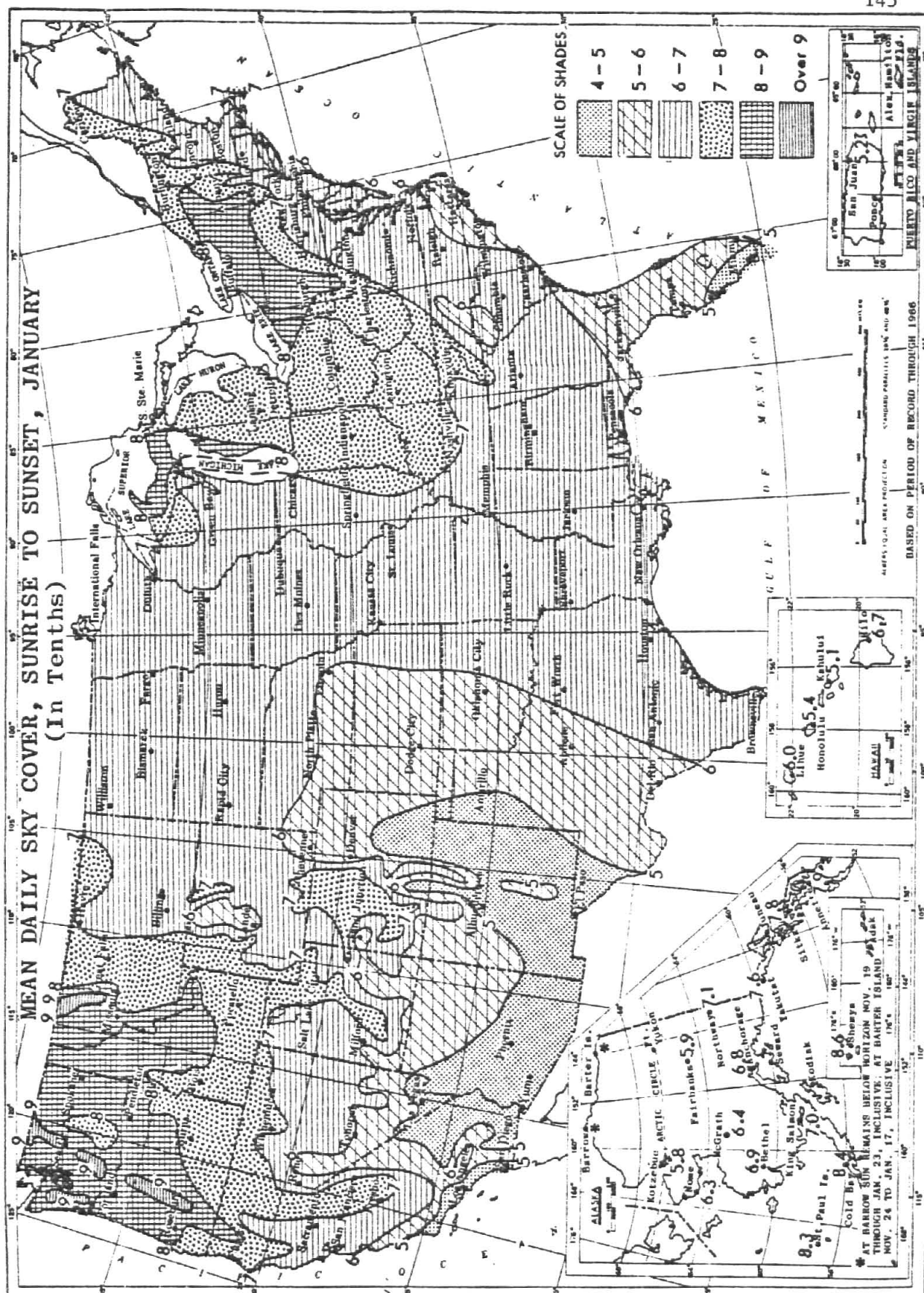


Figure A10











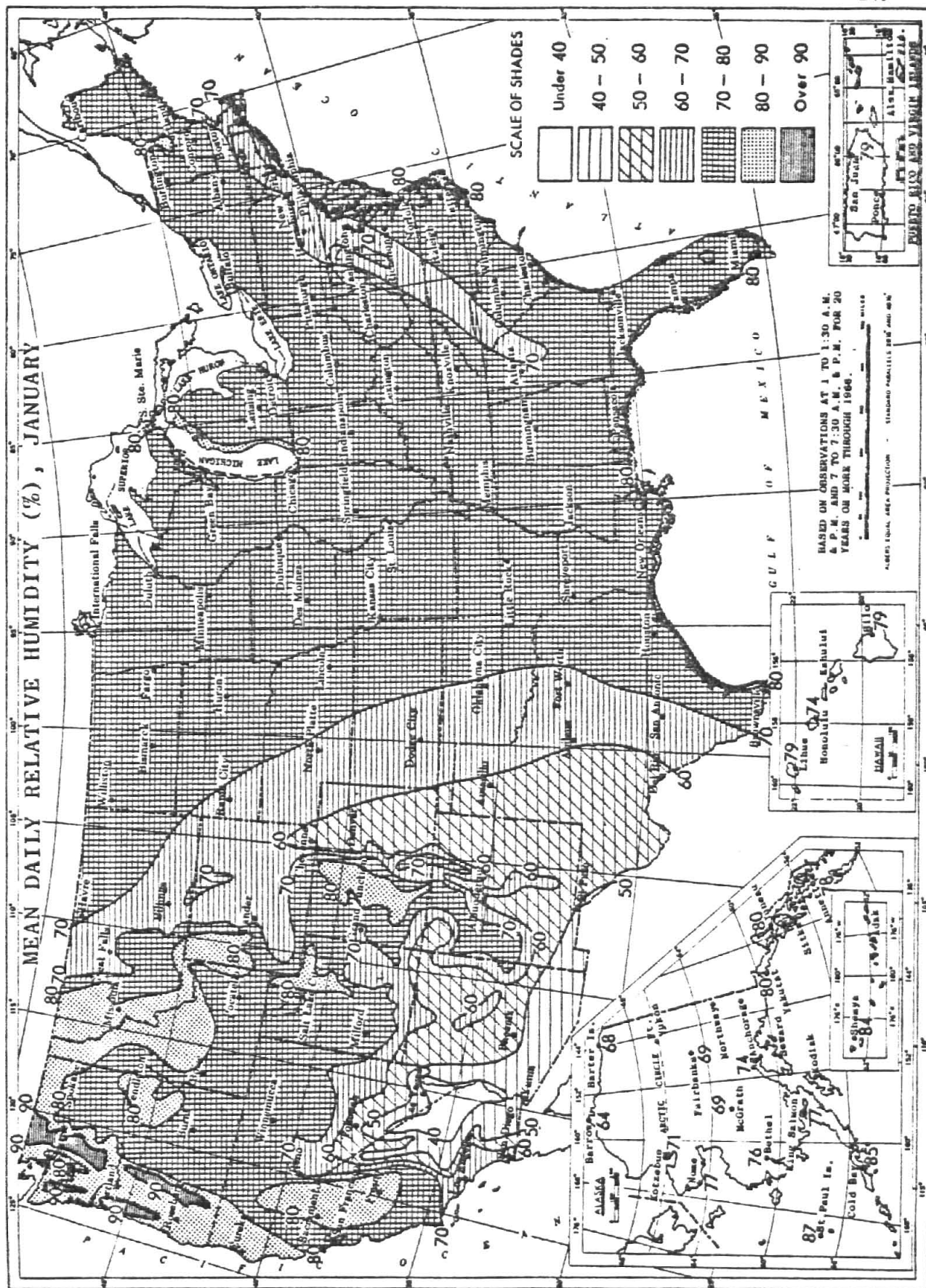


Figure A14

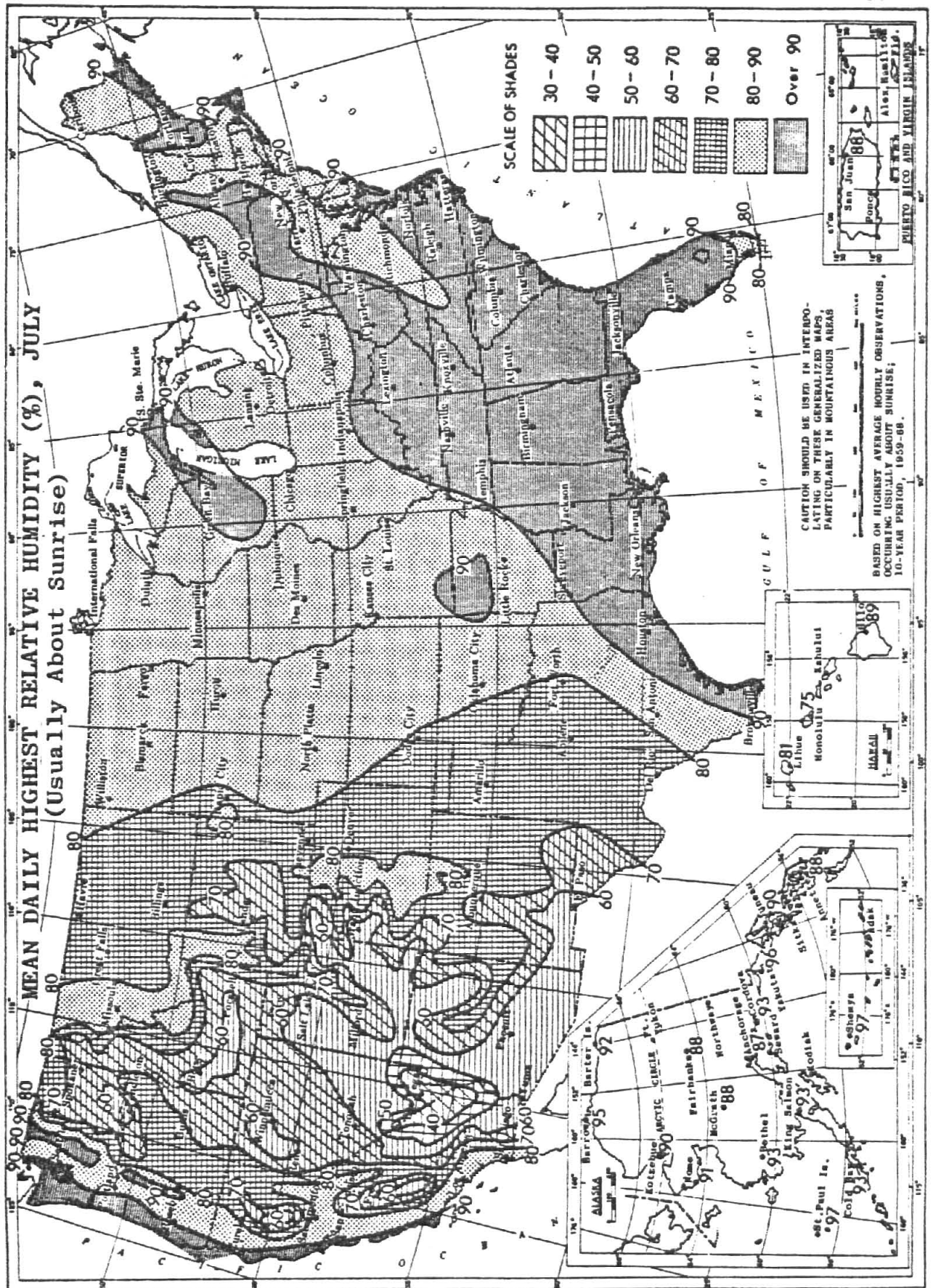


Figure A15

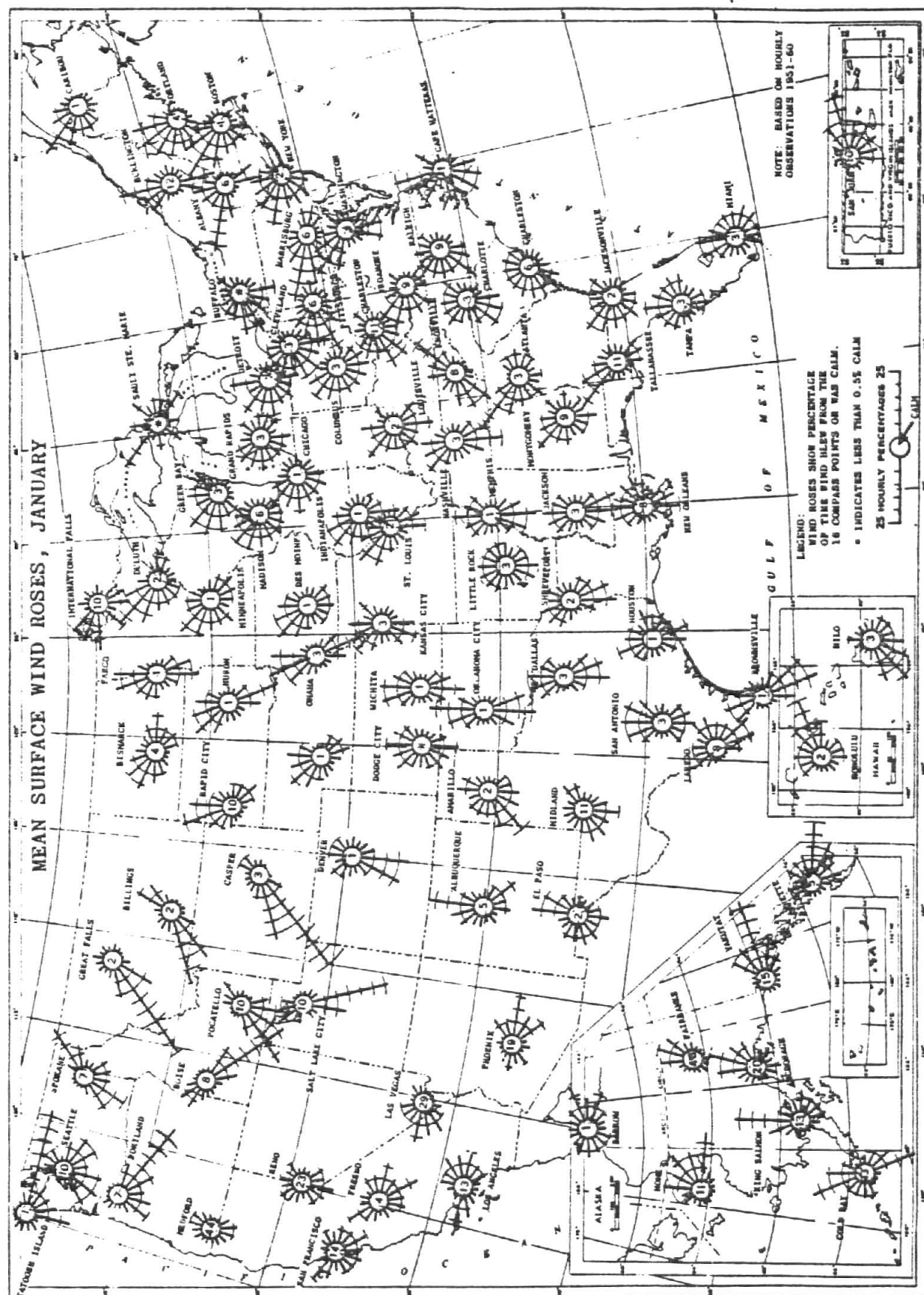


Figure A16





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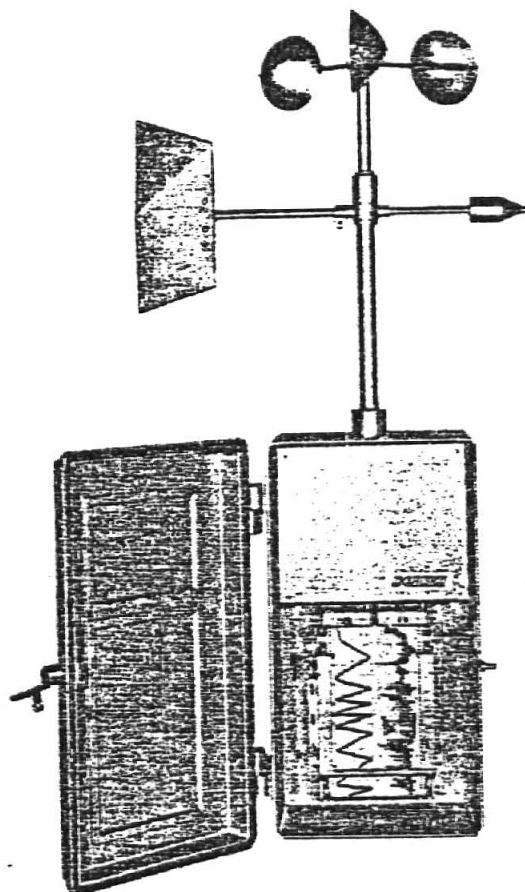


APPENDIX B

CATALOG OF INSTRUMENTS  
FOR  
CLIMATOLOGICAL SURVEYING

## KAHL SCIENTIFIC INSTRUMENT CORPORATION

P.O. BOX 1166, EL CAJON (San Diego), CALIFORNIA 92022  
 Telephones: (714) 444-2158 and 444-5944      Factory: 737 W. Main St., El Cajon, Calif.



BULLETIN 02M40

MECHANICAL 60-DAY ANEMOGRAPH

No. 02AM300 MECHANICAL 60-DAY ANEMOGRAPH

This completely mechanical KAHLSCO Anemograph has integral sensors and a weathertight housing. It scribes the cumulative passage of the wind (average instantaneous wind speeds can be obtained using the nomograph supplied) and its direction on an electro-mechanical strip-chart recorder. The compactness, robust construction and light weight of this device makes it ideal for long-time, unattended, environmental surveys, especially in remote locations. The sturdy housing has a large, hinged front door, fully gasketed for weathertightness, with a lockable handle and mounting lugs at top and bottom.

EXPORT  
DIVISION:



P.O. BOX 947, EL CAJON, CALIF. 92022, U.S.A.

TELEX: 697906  
CABLE: KAHLSCO SANDIEGO



Figure B1.  
Mechanical Anemograph

**TECHNICAL DATA:**

**TYPE:** Wind speed sensor with 3 cups, Robinson type; wind direction sensor with twin-plate vane and counter-balance weight.

**SCALE:** Total Wind for each excursion, from one end of its chart segment to the other, equals 10 km (or 5 miles, as ordered); Wind Direction: 0° to 360°.

**RANGE:** Unlimited.

**SENSITIVITY:** 0.5 m/sec (1.64 ft/sec).

**RECORDER:** Electro-mechanical, battery-rewound clockwork drive, strip-chart type for up to 60 days of recording. Chart paper speeds of 12.5 mm (0.5") per hour or 25 mm (1") per hour, depending upon gears used. Knife-edged helical runners, on both the cumulative wind (speed) and wind direction recording cylinders, individually and simultaneously mark the waxed paper chart at the appropriate value. Available with hand-wound clockwork drive for 8-day use.

**CHART:** Inkless, pressure-sensitive waxed paper, 100 mm (4") usable width, two separate sections for cumulative wind (speed) and wind direction, vertically divided approximately every 4.5 mm (0.18") for cumulative wind and every 3.8 mm (0.14") for wind direction (marked N, E, S, W, N and 0°, 90°, 180°, 270°, 360°).

**ACCURACY:**

**CUMULATIVE WIND:** Better than 0.5 m/sec (1.64 ft/sec).

**WIND DIRECTION:** Better than  $\pm 5^\circ$ .

**CLOCKWORK:**  $\pm 5$  minutes/30 days (battery-rewound),  $\pm 15$  minutes/30 days (hand-wound).

**POWER SUPPLY:** Self-contained, pack of three 1.5-volt, size D, flashlight batteries for electrically re-wound clockwork drive, none required for hand-wound spring clock work drive.

**AMBIENT OPERATING CONDITIONS:**

**TEMPERATURE:** -25° to +60° C (-13° to +140° F), under ice-free conditions.

**HUMIDITY:** 0 to 100% RH.

**ALTITUDE:** Unlimited.

**MATERIALS:** Corrosion-resistant materials are used externally wherever possible. Weatherproof housing with mounting lugs for installation.

**OVERALL DIMENSIONS:** Housing: 50 x 26.5 x 19 cm (20" x 10.5" x 7.5"). Wind sensor extends approximately 50 cm (20") above the housing.

**NET WEIGHT:** 19 kg (42 lbs).

**SHIPPING WEIGHT:** Approximately 40 kg (90 lbs).

**SHIPPING VOLUME:** Approximately 0.25 m<sup>3</sup> (9 ft<sup>3</sup>).

**ACCESSORIES FURNISHED:** Nomograph, set of three 1.5-volt batteries, 5 rolls of chart paper.

**INSTRUMENT DESCRIPTION:**

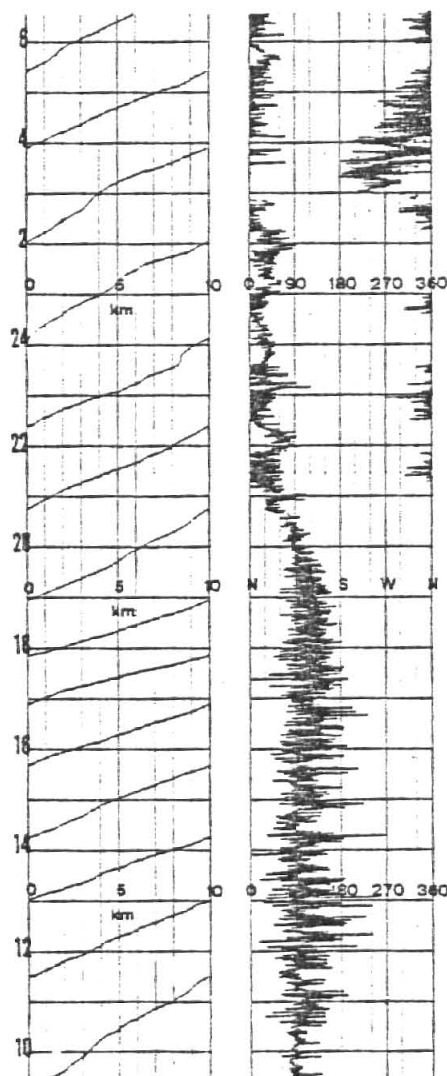
This KAHSICO Anemograph is a lightweight, portable, mechanical instrument for continuous, 60-day recording of the cumulative (total) wind and its direction on a strip-chart. The battery-rewound clockwork permits 2 months of continuous registration. An optional, hand-wound clockwork paper drive provides one month of operation. This anemograph has been designed for unattended field work, especially in isolated areas where electrical power is not available. The set of batteries is normally installed within the recorder housing; however, when extremely cold or hot ambient operating temperatures exist, a special battery-pack with wiring and connectors for the housing can be ordered with the anemograph, to be buried in the ground for thermal protection. The sensor and the recorder form a compact unit, easily transported and installed. No connecting shafts or cables are necessary.

**METHOD OF OPERATION:**

The metal wind vane with counterbalance, for direction indication, and the three Robinson-type, lightweight, metal cups for cumulative wind measurement are built to withstand gusts. The specially shaped and aerodynamically balanced cups attached to the ends of the three spokes of a wheel have beaded edges to reduce the effects of turbulence. Wind blowing past the anemograph causes the cup-wheel to rotate. Its hub is attached to a shaft, mounted on precision bearings, that terminates in a gearing system inside the housing which slowly rotates a cylinder, with a raised helical runner, horizontally supported in a framework above the chart paper. The wind vane has specially designed, twin plates in

Figure B2  
Mechanical Anemograph

order to obtain the best response to and tracking of the wind as it varies direction, with a self-damping feature. The adjustable counterbalance weight at the opposite end of the vane assembly is shaped to reduce turbulence. As the wind changes its direction of incidence, the vane moves until it aligns itself with the air flow. This assembly is attached to a shaft mounted on precision bearings, coaxial with the cup-wheel shaft, that terminates in a gearing system which slowly rotates a second, horizontally supported cylinder with a raised helical runner. This stylus is so designed that only its knife-edge touches the chart paper; its weight alters the wax surface so that a fine line appears. The single-turn helical shape allows the mark to be produced anywhere along the chart width, permitting rapid recording from one end of the measuring span to the other. The average wind speed can be interpolated from the slope of the cumulative wind recording.



TYPICAL SAMPLE OF RECORD CHART

Figure B3  
Mechanical Anemograph

# KAHL SCIENTIFIC INSTRUMENT CORPORATION

P.O. BOX 1166, EL CAJON (San Diego), CALIFORNIA 92022  
 Telephones: (714) 444-2158 and 444-5944      Factory: 737 W. Main St., El Cajon, Calif.

## No. 03AM120 KAHLSCO HAND ANEMOMETER, WIND SPEED AND DIRECTION

This is a small, precision, hand held anemometer for determining wind speed and direction. It is unaffected by time, temperature or humidity as it is carefully constructed using quality components. The three Robinson cups are of metal, not plastic, and will not deform with age. The handle, containing a direction alignment device, can be affixed to a threaded shaft for permanent mounting.

### TECHNICAL DATA

TYPE: Self-indicating; electro-magnetic and mechanical.

RANGE: Wind speed; 0 to 70 miles/hr. and 0 to 100 ft./sec., or, 0 to 60 knots and 0 to 30 meters/sec.

Direction: 0° to 360° in 5° divisions.

INDICATORS: Cylindrical dial type; wind speed scale is approximately 4" (10 cm.) long, with moving pointer; direction, 9.4" (24 cm.) long, read from index on housing.

### ACCURACY:

Wind Speed  
 =1.6 ft./sec. (0.5 meters/sec.).

Direction  
 Better than =5°.

SENSITIVITY: 1.6 ft./sec. (0.5 meters/sec.) is the minimum wind speed for indication.

POWER SUPPLY: None required.

CALIBRATION: Each instrument is furnished with a factory wind tunnel calibration certificate. (At an additional charge)

### AMBIENT OPERATING CONDITIONS:

Temperature: -13° to +140°F. (-25° to +60°C.)  
 under ice free conditions.

Humidity: 0 to 100% R. H.

MATERIALS: Noncorrosive metals are used including sealed, precision, stainless steel ball bearings. Weather-tight housing has internal 3/8-16 thread at lower end of handle for mounting shaft.

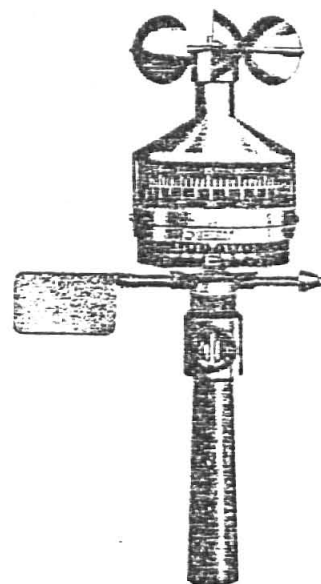
ALIGNMENT DEVICE: Compass indicator in handle, to facilitate alignment with North, has a locking device to avoid damage when not in use.

	Anemometer	Carrying Case
DIMENSIONS:	3.5" x 11" x 3.5" (9 x 27.5 x 9 cm.)	5" x 13" x 5.5" (13 x 33 x 14 cm.).
WEIGHT:	2.6 lbs. (1.2 kg.)	4.8 lbs. (2.2 kg.).

ACCESSORY FURNISHED: Finished wooden carrying case with compartments for anemometer and vane.

## 03AM120 HAND ANEMOMETER

These KAHLSCO cup type anemometers use a system with three cups. This is superior to the four-cup style sensor as greater torque is exerted, more uniformly, during a revolution. The specially shaped cups have beaded edges to reduce the effects of wind turbulence. The rotating cups produce a magnetic drag, proportional to the wind speed, which activates the sensitive measuring-indicating system. This has a needle pointer which moves across a wide angle scale, fully visible through a 180° plastic window. A small wind-vane, fitted in the wooden case, is easily attached to the counter-balanced shaft. An index on the housing indicates the direction on a scale which has 5° division, numbered every 10°, and is marked with cardinal and intermediate points. Normal wind scale divisions are: 5 mph, 5 fps; 1 mps, 5 knots. Other increments can be supplied upon request. The housing has two projections at the rear, to prevent rolling when placed on a flat surface. Other scales and ranges are available upon request.



BULLETIN 03M04 INDICATING ANEMOMETERS (CUP, VANE), PITOT TUBES, ETC.

EXPORT  
 DIVISION:



P.O. BOX 947, EL CAJON, CALIF. 92022, U.S.A.

TELEX: 697906  
 CABLE: KAHLSCO SANDIEGO



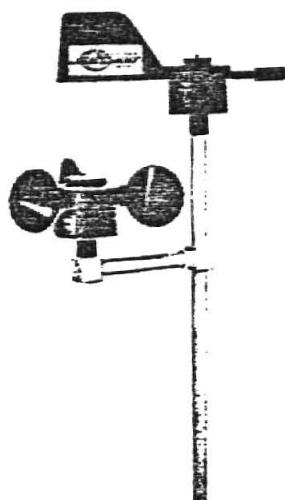
Figure B4  
 Hand Anemometer

# KAHL SCIENTIFIC INSTRUMENT CORPORATION

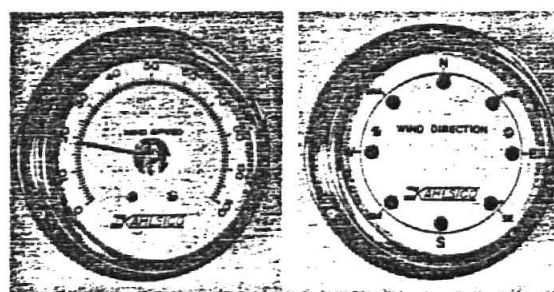
P.O. BOX 1166, EL CAJON (San Diego), CALIFORNIA 92022

Telephones: (714) 444-2158 and 444-5944

Factory: 737 W. Main St., El Cajon, Calif.



No. 03AM010 WIND MEASURING SYSTEM



BRASS CASE DIAL METERS  
FOR No. 03AM010 WIND MEASURING SYSTEM

BULLETIN 03AM5/1 WIND MEASURING SYSTEMS, BAROMETER, THERMOMETER, WIND GAUGES

In addition to rugged and sophisticated anemometers for meteorological research, KAHLSCICO also offers units to meet the need for reliable, inexpensive wind measuring systems. These well-built devices, which give long-time service, have an attractive appearance and are easy to install. The equipment is constructed from carefully chosen, sturdy materials. The 15-cm (6") diameter rotating-cup assembly for wind speed measurements is molded from polycarbonate, which does not exhibit the distortion and change in response found with other plastics, especially with exposure to strong sunlight, extreme cold and similar harsh environmental conditions. This KAHLSCICO system is thus lightweight and responsive to very low wind speeds, starting rotation at about 1.5 MPH (0.2 m/sec). The housing for the transducer, which generates AC power in relation to the wind speed by magnets mounted on a highly-polished stainless steel shaft and does not have any brushes or rings to wear out, is also of corrosion-resistant polycarbonate and its special surface finish inhibits adherence and build up of snow, grime, dust etc. Synthetic bearing materials are used to eliminate the need for lubrication and allow operation at high and low temperatures without maintenance problems. The wind speed sensor is calibrated with its matching 500-microampere meter movement used to display the measurement on the linear 0 to 100 MPH (miles per hour) scale (0 to 45 m/sec scales are available on special order). The wind direction sensor has a counterbalanced, V-shaped vane and is fabricated from anodized aluminum for lightness and quick response. It uses a waterproof potentiometer in a control circuit for the direction indicator, which has a pointer and scale marked with the cardinal and intermediary points, and may be battery or line powered. The alternative direction indicator with 8 lamps at the marked cardinal and intermediary points uses magnetically activated, hermetically sealed, dry-reed switches to light the appropriate bright, over-rated, low-voltage powered lamp (if two lamps are illuminated the actual wind direction is midway between those indicated (allowing 16 points of the compass to be determined).

EXPORT  
DIVISION:



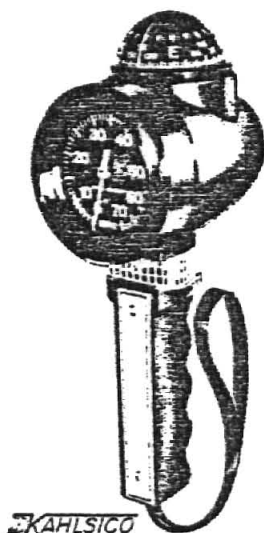
P.O. BOX 947, EL CAJON, CALIF. 92022, U.S.A.

TELEX: 697906

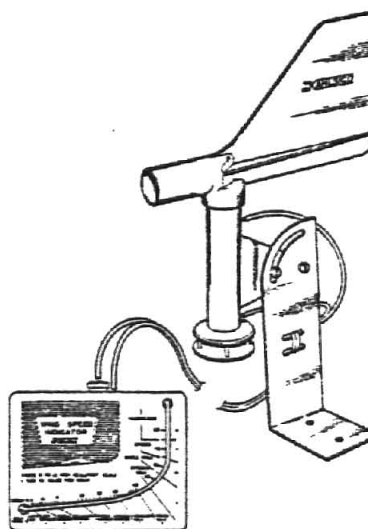
CABLE: KAHLSCICO SANDIEGO



Figure B5  
Wind Measuring Systems



No. 03BM015 WIND SPEED INDICATOR



No. 03BM020 WIND SPEED INDICATOR

No. 03BM010 KAHLSICO PRESSURE-PLATE WIND SPEED INDICATOR is direct reading, for use anywhere on land or sea. It is hand-held, perpendicular, with its grid-protected pressure-plate facing into the wind, the force of which moves the hinged plate, which is between the handle and indicator dial, forward, toward the observer. The red pointer allows the wind speed to be read directly, from the 5 to 70 miles per hour (with 1 mph scale of the dial divisions), which is protected by a glass window, not easily scratched or affected by the sun. This KAHLSICO wind indicator will provide reliable and proper readings even if it is pointed as much as 25° away from the exact direction of the incident wind. The handle has a comfortable hand grip and a carrying strap. This indicator is accurate and rugged, to provide long-time, useful service. It is 20 cm long, 8 cm in diameter (8" x 3") and is supplied complete with instructions which include 8 scales of measures and symbols relating to wind speed, as well as a wind chill factor chart.

No. 03BM012 METRIC WIND SPEED INDICATOR is like No. 03BM010 but has ranges of 2 to 25 meters/second, with 1 m/s divisions, and the Beaufort Scale of 2 to 10.

No. 03BM015 WIND SPEED and DIRECTION INDICATOR is like KAHLSICO No. 03BM010 but also has a compass scaled 0° to 360° in 5° and marked with the cardinal and intermediate points (N, NE, E, etc.). Measures mild breezes to gale-force winds and shows the direction from which they come.

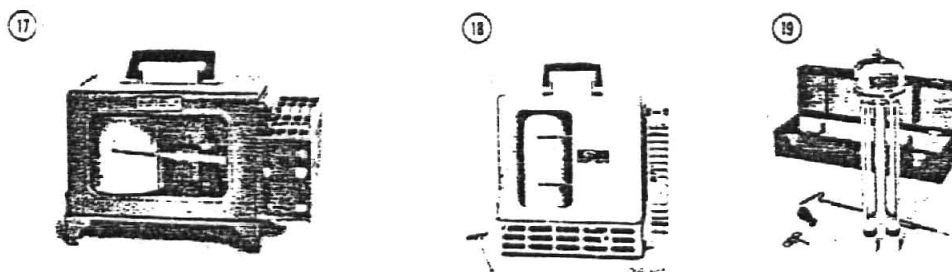
No. 03BM020 KAHLSICO WIND SPEED INDICATOR, completely mechanical, pitot-tube type with remote sensor. The indicator, which uses easily seen red liquid inside a curved, clear-plastic manometer tube, is of molded plastic with 2 mounting holes and is scaled from 0 to 80 miles per hour with corresponding Beaufort scale of 0 (calm) to 12 (hurricane). The sensor, molded of weather-resistant plastic, has a vane to align the movable top section into the wind and allow the dynamic wind pressure to be conducted by a connecting tube to the indicator. Dust plates, at the bottom of the sensor, protect the static (ambient) air pressure to be conducted by the second member of the connecting tube to the indicator. The indicator thus shows the difference between static and dynamic pressures at the sensor and has a zero adjustment for the liquid level, resulting in an accurate measurement of the wind speed. Wind direction can be noted by observing the position of the sensor vane. The color coded, 2-conductor connecting tube is supplied in a 15-m (50-ft) length and can be readily cut shorter, if desired. A mounting bracket for the sensor, all necessary mounting and securing screws and the red liquid for the manometer are supplied, as well as installation instructions.

MCMLXXIX

Subject to change without notice

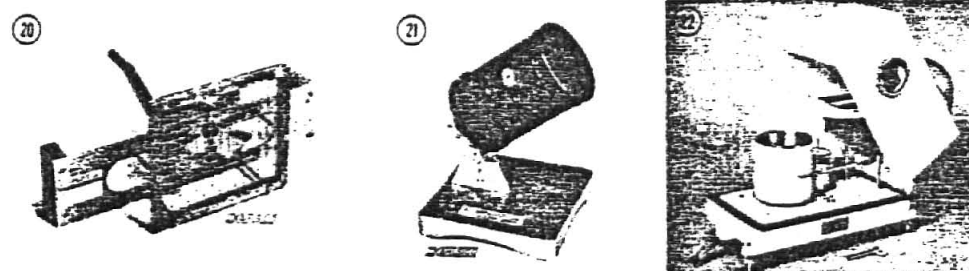
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Figure B6  
Wind Speed Indicators



17. HYGROGRAPH, No. 17AM080, has a sensor comprised of a bundle of specially selected and treated human hairs mounted outside the housing, for maximum sensitivity, and protected by a screen. This hygrometer is calibrated to provide an accuracy of 3% over the prevalent range of 20 to 80% relative humidity; with an accuracy of 5% at the extreme ends of the 0 to 100% scale.
18. HYGROTHERMOGRAPH, No. 19AM240, has two sensors, a bimetallic element for temperature and a hair-bundle for relative humidity. The temperature chart has 55 divisions, covering a range of  $-10^{\circ}$  to  $45^{\circ}$  C, in  $1^{\circ}$  C with  $0.5^{\circ}$  C accuracy (models with  $0^{\circ}$  to  $110^{\circ}$  F, in  $2^{\circ}$  F, are also available). The 0 to 100% relative humidity scale has the same accuracy as KAHLSICO No. 17AM080 Hygrograph.
19. ASSMANN PSYCHROMETER, No. 27AM570, has a heavy-duty, spring-wound clockwork for the turbine fan that aspirates air, at a speed of 2.5 meters per second, past the wet and dry thermometer bulbs, which have dual radiation shield tubes. A matched pair of porcelain scale thermometers (range:  $-30^{\circ}$  to  $+50^{\circ}$  C, in  $0.2^{\circ}$  C), assures high reliability and accuracy in measurement. The psychrometer has a wooden carrying case with bulb wicks, distilled water dropper, book of hygrometric tables, a suspension rod and a removable shield, which allows the fan to operate properly when used under windy conditions outdoors.

(Note: Assmann Psychrometers are available with electric motors and Fahrenheit or Celsius scales, with subdivisions in  $0.5^{\circ}$ ,  $0.2^{\circ}$  and  $0.1^{\circ}$ , as desired. The KAHLSICO motorized psychrometer is designated in the A.S.T.M. specifications as the Standard Instrument for humidity determinations.)



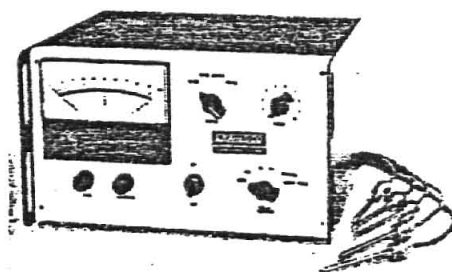
20. GEARED HAND-FAN, No. 27AM700, is mounted on a wall inside an instrument shelter to circulate air past the thermometers, hygrometers, psychrometers, etc. The 15-cm (6") diameter fan, with a guard-screen and wooden bracket, is normally installed inside a U.S.W.B. Cotton-region Shelter, with its handle outside. Mounting screws and a screw-hook for suspending a wet- and dry-bulb psychrometer, are furnished.

Figure B7  
Assorted Climate Measuring Instruments

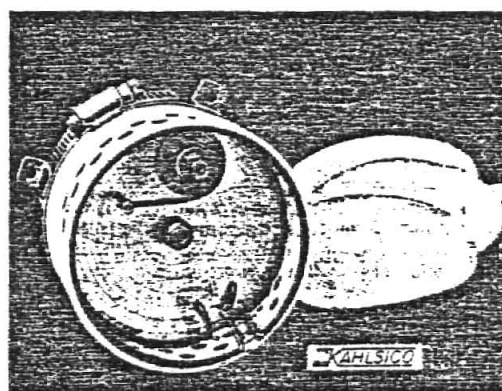


No. 36AM350 KAHLISCO PRECISION THERMISTOR THERMOMETER, like No. 36AM340 but having 3 interchangeable probes with plug in connectors for Control Unit which has a probe selector switch. (Other probe assemblies are available on a custom-fabrication basis. Please stipulate the number of thermistor probes and the cable lengths desired. Also, other temperature scales can be supplied; state desired range and subdivisions.)

No. 136WA120 PRECISION TEMPERATURE MEASURING SYSTEM, is similar to No. 36AM340 except it has a  $0^{\circ}$  to  $+100^{\circ}$  C measuring range in  $1^{\circ}$  divisions with 20 subranges divided in  $0.05^{\circ}$  C that permit readings to  $0.025^{\circ}$  C. This electrical thermometer is extremely useful for geo-thermal, bore-hole, power-plant outfall, as well as other environmental studies in rivers, lakes, reservoirs, estuaries, etc.



No. 36AM40/5 MULTI-PROBE TEMPERATURE SYSTEM



No. 38AM410 MINI-THERMOGRAPH

No. 38AM410 KAHLISCO MINIATURE BIMETAL THERMOGRAPHS are compact, portable devices, ruggedly built for field use. The instrument is intended for outdoor measurements and is designed to withstand harsh environmental conditions but should be protected against precipitation. It can be mounted in any orientation without adverse effect. The temperature sensor is specially processed, conditioned, aged and tested for permanent calibration; it maintains an accuracy of  $\pm 2\%$  of the scale range. The dependable clockwork has a high-grade mechanism with jewelled balance and is dust and moisture protected. It is made for either 24-hour or 7-day recording and will operate over a temperature range of  $-40^{\circ}$  to  $+110^{\circ}$  C ( $-40^{\circ}$  to  $+220^{\circ}$  F). The clock movement is spring-powered, operating for 8 days with one winding. Each clock is electronically timed for accuracy and can be supplied with a mechanism to stop rotating after approximately 30 hours.

If exposed directly to wet or corrosive environments, the thermograph should be protectively encased in the polyethylene bag supplied with the instrument. The bag does not impair the record accuracy but does slightly increase its response time. A chart-retaining ring is furnished to prevent curling of the paper when used under highly humid conditions. The circular, 9-cm (3.5") diameter paper chart is white, plastic-coated, with time and temperature graduations printed in blue ink, and it is securely attached to the clockwork by a knurled nut. The stylus effects a temperature-time trace in black color, providing easy readability and eliminating problems such as spilling, freezing, etc. when pen and ink are used to mark the chart. The stainless-steel, spring-loaded stylus need not be sharpened or changed, providing life-time service. Both the clockworks and the temperature sensing element assemblies are interchangeable and spares can readily be obtained. This unique feature allows various range temperature sensors to be readily used with any thermograph. It is only necessary to release the spring-clamp on the window to remove it and its attached bi-metal sensor for replacement with another. The white-painted, anodized aluminum housing measures 10 x 8.2 cm (3.9" x 3.3") and it weighs 0.4 kg (14 oz). An accessory stainless-steel mounting bracket with 3 extending lugs is included. The Thermograph is supplied with 100 charts.

Figure B8  
Temperature Measuring Instruments

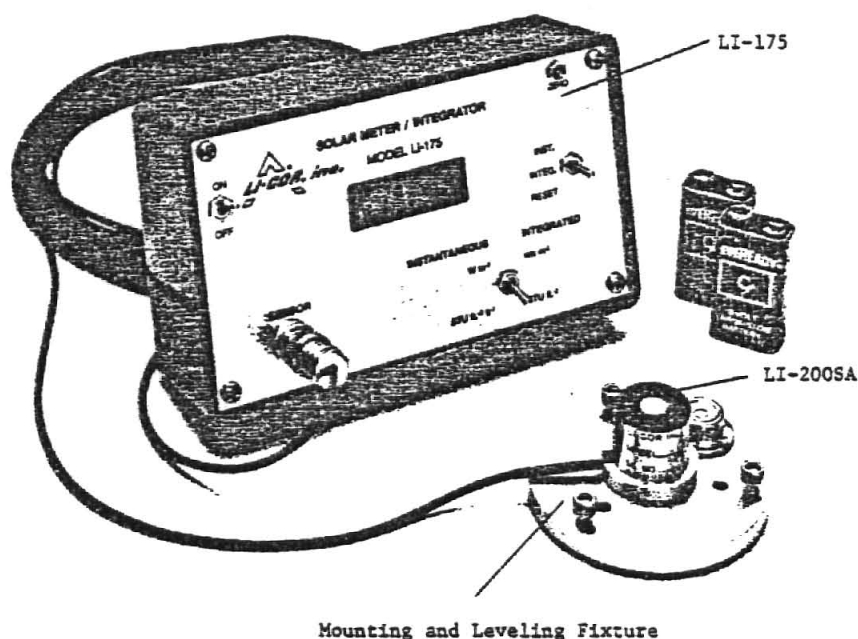
RM3-779

**LI-COR, inc.***Instrumentation for biological and environmental sciences*

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 TWX: 910-621-6116

## PRELIMINARY PRODUCT INFORMATION

Specifications for the LI-175 Solar Meter/Integrator System (Pat. Pend.)



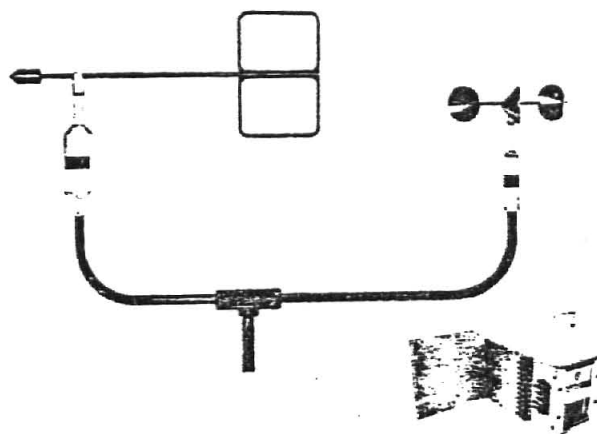
The LI-175 Solar Meter/Integrator System provides a low cost means for solar measurements of instantaneous and totalized (integrated) solar energy. There are no conversions to make or correction factors to apply. The readout is direct. This system which includes the widely acclaimed LI-200S Silicon Pyranometer was designed for solar engineers and architects.

## System Features

- Pyranometer performance approaching 1st class thermopiles at 1/10 the cost as substantiated by government laboratories (NOAA, SERI).
- Precisely calibrated to an Eppley PSP under clear daylight conditions
- Highest quality silicon photovoltaic detector - not inexpensive solar cells
- Fully cosine corrected - 1% linearity error - weatherproof sensor
- Small size pyranometer - ideal for use in solar collectors and remote areas
- Integrated and instantaneous measurements - rugged pyranometer -0 tilt error
- Temperature independent circuitry and sensor

Figure B9  
 Solar Meter/Integrator

# Bendix Wind Vane & 3-cup Anemometer System



The Bendix Wind Vane and 3-Cup Anemometer were designed to interface with the Bendix Air Monitoring Equipment. These units were developed to provide very low to moderate wind velocity indicating and recording. They have starting speeds of less than 0.5 mph, yet are rugged enough to be operated for extended periods of time without maintenance. The cups are formed from an anodized aluminum alloy to permit operation in all environments and eliminate problems such as the ultraviolet decay experienced with plastic cups.

The system provides the degree of accuracy and response required in making meaningful air pollution studies, wind data analyses and meteorological forecasts.

The Wind Vane and 3-Cup Anemometer are available as matched pair sensors for measurement of horizontal wind velocity and direction information. When ordered together they can be supplied with a mounting arm which locates the vane and anemometer in proper relationship to each other and provides a single mounting to allow easy removal for inspection and service. Complete data for each component of the system, including a CV-3 Wind Signal Adapter and complete ordering information are provided in the specific data sheets.

- VERY LOW VELOCITY WIND MEASURING SYSTEM
- USE WITH BENDIX AIR MONITORING SYSTEM
- USE WITH AEROVANE MODEL 135 INDICATOR OR MODEL 141 RECORDER
- USE WITH COMPUTERIZED SYSTEMS
- USE WITH BENDIX EPID POWER PLANT MONITORING SYSTEM

## SPECIFICATIONS

The standard Bendix wind vane provides a synchro signal output. Sine-cosine output units are available.

The standard Bendix 3-Cup Anemometer provides a linear DC voltage output.

## ORDERING INFORMATION

Ordering information for the Wind Vane and 3-Cup Anemometer System is given on the individual description sheets.

Wind Vane, P/N 2416970-0001.

3-Cup Anemometer, P/N 2416914-0001

CV-3 Signal Adapter, P/N 2417753(1).

MAST Support, P/N 2416994-0002, for mounting sensors on 1" O.D. MAST.

Transmitter Support, P/N 2414318-0006, for mounting sensor assembly on standard tripod MAST assembly.

7-Conductor Cable, P/N 508372.

ESD-026C-9

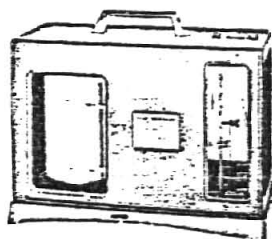


**Environmental &  
Process Instruments  
Division**

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Figure B10  
Wind Measuring System

# Hygro-Thermograph Model 594



- TEMPERATURE AND HUMIDITY ON SAME CHART
- DAILY OR WEEKLY RECORDING.
- MADE TO MEET WEATHER BUREAU SPECIFICATIONS.
- HUMAN HAIR HUMIDITY ELEMENT.
- 3-DAY SPRING DRIVEN MECHANISM.
- LIGHTWEIGHT.
- COMPACT 6"W, 10-1/8"H, 12-1/4"L

The Bendix Model 594 Hygro-Thermograph has established itself as a reliable standard in all applications where records of ambient temperature and relative humidity are required.

Portable, functional design, sturdy construction, and ease of operation are major features.

Research laboratories, colleges and universities, department of the government and industry in general have accepted this instrument as a leader in the field of recording instruments.

Charts interchangeable without recalibration (daily or weekly) (Centigrade or Fahrenheit).

Temperature is recorded on upper two-thirds of 5-inch chart and relative humidity on the lower portion. All instruments are calibrated to cover a chart scale range of 0 to 100% relative humidity.

Precalibrated completed with special recording ink, an instruction book, and a set of charts.

Temperature responsive element comprised of a highly polished gold plated bourdon tube. The Humidity element is a specially treated multiple strand hygroscopic element of human hair. Both elements are located within the case but are separated from the recording mechanism by a vertical partition.

Jeweled anchor escapement spring-driven mechanism which operates for eight days with one winding. Time scale gears to provide full chart movement either daily

(29 hours) or weekly (176 hours) are available on special order.

The Hygro-Thermograph is portable and may be moved from one location to another. Outdoors it should be protected from direct precipitation and shielded from thermal radiation and direct sunlight by a suitable shelter or other device designed to permit free circulation of air through the measuring element section of the instrument. A standard weather instrument shelter is recommended for this purpose.

## SPECIFICATIONS

<b>SIZE</b>	6" W x 10-1/8" H x 12-1/4" L
<b>CLOCK DRIVE</b>	Spring wound, 8-day clock
<b>ESCAPEMENT</b>	Jeweled Anchor
<b>SENSORS</b>	Temperature: Bourdon tube Humidity: Human Hair
<b>ACCURACY</b>	Temperature: $\pm 1^\circ$ full scale Humidity: $\pm 3\%$ @ 30%-70%
<b>CHARTS</b>	Daily or weekly Centigrade or Fahrenheit (Interchangeable without recalibration)
<b>DRUM ROTATION</b>	Daily (29 hours) Weekly (176 hours) Depending upon gears used
<b>SCALE RANGES</b>	Chart No. 207 series: $+10^\circ\text{F}$ to $+110^\circ\text{F}$ Chart No. 208 series: $-12^\circ\text{C}$ to $+43^\circ\text{C}$ Chart No. 209 series: $-30^\circ\text{F}$ to $+70^\circ\text{F}$
<b>HUMIDITY</b>	0-100%
<b>CHART SCALE</b>	1/32" of chart = 2% RH 1/16" of chart = $2^\circ\text{F}$
<b>FINISH</b>	Beige enamel
<b>WEIGHT</b>	8 pounds (approximately)
<b>OPTIONAL ACCESSORIES NOT INCLUDED</b>	Alternate set of gears for daily or weekly recording, spare pen, extra ink, chart binder

## ORDERING INFORMATION

BENDIX MODEL 594, P/N 500054-3

When ordering, please specify the recording period preferred (daily or weekly)

Chart No. 207 series:  $+10^\circ\text{F}$  to  $+110^\circ\text{F}$

Chart No. 208 series:  $-12^\circ\text{C}$  to  $+43^\circ\text{C}$

Chart No. 209 series:  $-30^\circ\text{F}$  to  $+70^\circ\text{F}$

ESD 016C Printed in U.S.A.



**Environmental &  
Process Instruments  
Division**

Figure B11  
Hygro-Thermograph

# Developments<sup>®</sup>

May, 1980

## Cole-Parmer's new Hygrothermograph ... for accurate RH and temperature recording

Get a continuous record of temperature and relative humidity changes over a 1-day or 7-day period for permanent reference. Our hygrothermograph lets you measure Fahrenheit and Celsius temperatures with one instrument by simply changing chart papers. Use it indoors or outdoors in a weatherproof shelter.

The newly designed case lets you view the chart, pens and mechanism through a clear plastic window. You have complete access to all moving parts by unlocking and lifting off the whole cover. All parts are corrosion resistant: duraluminum alloy, brass and stainless steel.

Relative humidity is measured by two human hair bundles which expand and contract. Changes are magnified by a unique lever system. A sensitive, curved bimetal strip is used to measure temperature. The recording mechanism consists of an 8-day spring-wound clock, external pen lifter, and gears for both 1-day (26 hours) and 7-day (172 hours) chart rotation. Two disposable pen cartridges included. Order chart paper below.

8368-00 Hygrothermograph. Shpg wt 15 lbs .... \$395.00

### Accessories

8368-10 Charts. +14° to +122°F. 1-day rotation ..... \$10.95/100

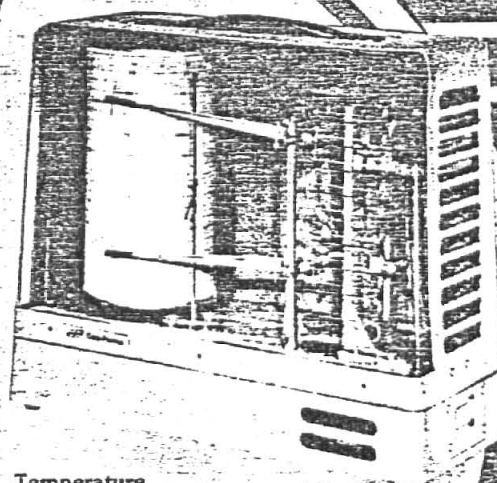
8368-20 Charts. +14° to +122°F. 7-day rotation ..... \$10.95/100

8368-30 Charts. -10° to +50°C. 1-day rotation ..... \$10.95/100

8368-40 Charts. -10° to +50°C. 7-day rotation ..... \$10.95/100

8368-75 Replacement pens. Blue felt-tip cartridges. Package of 5 ..... \$12.00/pkg\*

\*Save 10% on two or more packages.



### Temperature specifications

Accuracy:  $\pm 1.0^\circ\text{C}$  Sensor: Aged bimetal strip  
Temperature ranges:  $-10^\circ$  to  $+50^\circ\text{C}$ ;  $+14$  to  $122^\circ\text{F}$

### Relative humidity specifications

Accuracy:  $\pm 3.0\%$  Range: 0 to 100% RH  
Sensor: Human hair bundles

Chart scale divisions: 1% RH

### General specifications

Chart rotation: 1-day (26 hours) and 7-day (172 hours); gears supplied for both

Drive: Spring-wound clock, lasts 8 days

Recording pens: 2 disposable blue ink cartridges included

Case: Aluminum;  
12 $\frac{1}{4}$ "W x 5 $\frac{1}{4}$ "D x 11 $\frac{3}{4}$ "H

Chart size: 11 $\frac{1}{4}$ "L  
L7H

See our  
new pH section  
after page 16!

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Instrument Company

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Cole-Parmer Instrument Company 7425 North Oak Park Avenue Chicago, Illinois 60648

Represented in New England by Mr. Don Santo, No. 1 Washington Street, Woburn, MA 02181 (617) 235-0340

Figure B12  
Hygro-Thermograph

## Humidity and temperature indicators

### (A) RH & temperature indicator

Comparable to more expensive instruments. Temperature range:  $-10$  to  $+190^{\circ}\text{F}$ . Relative humidity range:  $0$ - $100\%$ , effective up to  $230^{\circ}\text{F}$ . Easily calibrated on the lower left side of its housing. Solid brass  $6"$  diameter case has three holes for wall mounting. Easy-to-read  $5"$  dial. Shipping weight is  $2$  lbs.

3310-00 Relative humidity and temperature indicator ..... \$59.50

### (B) Certified relative humidity indicator

This hygrometer indicates  $0$ - $100\%$  relative humidity. The instrument is certified accurate to within  $\pm 2\%$  by the Federal Republic Test Society. Each hygrometer is tested at three dial positions at temperatures from  $32$  to  $230^{\circ}\text{F}$ . Solid brass  $6"$  diameter case has three holes for wall mounting. Black  $5"$  dial has white numerals and letters, red-tipped pointer for easy reading. Shipping weight is  $2$  lbs.

3310-20 Certified relative humidity indicator ..... \$60.00

### (C) Certified RH & temperature indicator

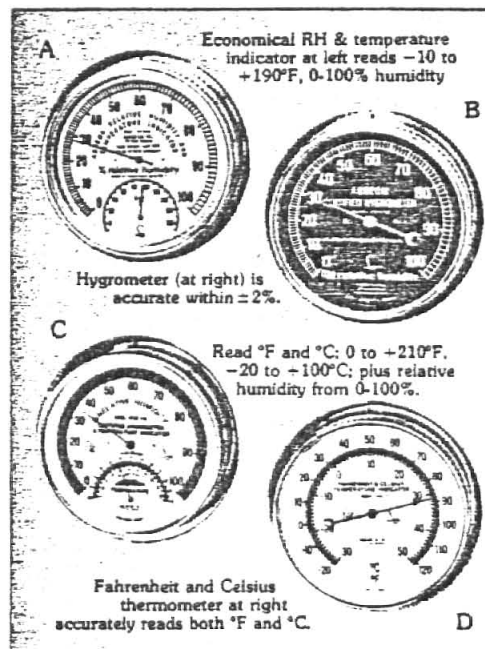
Provides relative humidity and both Fahrenheit and Celsius temperature readings. Temperature range:  $0$  to  $+210^{\circ}\text{F}$  ( $-20$  to  $+100^{\circ}\text{C}$ ). Relative humidity range:  $0$ - $100\%$ . Certified accurate to within  $\pm 2\%$  by the Federal Republic Test Society. Solid brass  $6"$  diameter housing is drilled for wall mounting. Color-differentiated  $5"$  dial has black markings, red-tipped pointer. Supplied with test certificate. Shipping weight is  $3$  lbs.

3310-40 Certified RH & temperature indicator ..... \$82.45

### (D) Fahrenheit & Celsius thermometer

Wall-mount  $6"$  thermometer indicates both Fahrenheit and Celsius temperatures. Scale ranges:  $-20$  to  $+120^{\circ}\text{F}$ ,  $-30$  to  $+50^{\circ}\text{C}$ . The mechanism is activated by a bimetal strip and is guaranteed accurate to within  $1\%$  of the range. Easy-to-read  $5"$  dial is printed in three colors with large numerals. Gleaming solid brass case. Shpg wt  $4$  lbs.

3310-60 Thermometer ..... \$52.00



## Digital psychrometer

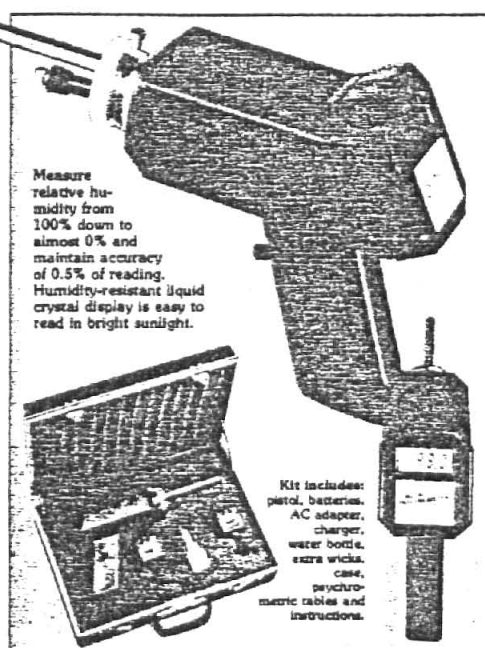
For relative humidity determination, our hand-held digital LCD psychrometer gives accurate dry and wet bulb readings only  $30$  seconds after you turn on aspirator motor and fan. Subsequent readings are almost instantaneous since the wet bulb is already cooled. Humidity-resistant liquid crystal display extends battery life, and is easy to read in bright sunlight.

With accuracy of  $0.5\%$  of reading, the digital psychrometer offers the precision of two fine-wire type K thermocouples. When you start the aspirator fan, air is drawn into the thermocouple chamber. Push a button, and the first thermocouple (the dry bulb) gives you a standard reading of air temperature. The second thermocouple (the wet bulb) is covered with a thin cotton wick kept wet by a water reservoir. The flow of air past the wick causes evaporation and commensurate cooling of the wet bulb. The drier the air, the cooler the wet bulb temperature. Push a second button to get the instrument-calculated difference between dry and wet bulb temperatures (wet bulb depression). Determine RH measurements with wet-dry readings and accompanying tables. Use dry bulb and depression data with supplied tables for dew point, enthalpy, and other psychrometric information.

Kit includes pistol, rechargeable batteries (one each for aspirator fan and circuitry),  $2$  AC adapter/battery chargers for simultaneous recharging, water supply bottle, extra wicks, carrying case, tables and graphs, and operating instructions. Choose Fahrenheit or Celsius,  $115$  or  $230$  VAC models.

Cat. no.	$^{\circ}\text{F}/^{\circ}\text{C}$	Recharger	Shpg wt	Price
3311-10	$^{\circ}\text{F}$	115 VAC	$8$ lbs	\$495.00
3311-20	$^{\circ}\text{C}$	115 VAC	$8$ lbs	495.00
3311-30	$^{\circ}\text{F}$	230 VAC	$8$ lbs	495.00
3311-40	$^{\circ}\text{C}$	230 VAC	$8$ lbs	495.00

3311-01 Extra wicks ..... \$4.00/10 wicks

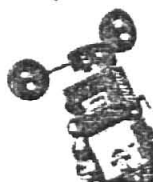


Developments, May, 1980

Figure B13  
Humidity And Temperature Indicators



## Sims' ANEMOMETERS

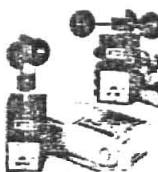


### MODEL BTC

Ranges: 0-35 and 0-70 MPH  
0-30 and 0-60 KNOTS

- CUP TYPE folding rotor
- No batteries required
- Compact
- Rugged
- Accurate

JUST HOLD IN THE WIND  
READ WIND VELOCITY ON SCALE.  
NON-DIRECTIONAL. SUSTAINED.  
SMOOTH READINGS.



### CUPS FOLD FOR STORAGE

The Sims Model BTC hand-held anemometer is a professional wind instrument. Cups open or close for storage instantly. Available with other dial calibrations shown at right. Supplied with protective vinyl case. An excellent instrument for on-the-spot wind observations. Cup and vane type rotors are not interchangeable, but are equally accurate.



### MODEL BT

Ranges: 0-35 and 0-70 MPH  
0-30 and 0-60 KNOTS

- VANE TYPE rotor removes for storage
- No batteries required
- Compact
- Rugged
- Accurate

The only difference between the various Sims hand-held anemometers is meter dial calibration and rotor type. Vane equipped anemometers are available with other dial calibrations as shown at right. The vane type rotor is suitable for laboratory use or in any general wind observation situation. Supplied with vinyl case. Cup and vane type rotors are not interchangeable.

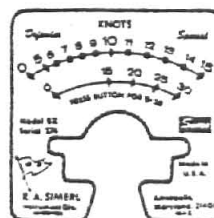
**VANE AND CUP TYPE INSTRUMENTS ARE EQUALLY ACCURATE.** General specifications for all Sims hand-held anemometers:

Generator/meter case and rotors are high impact ABS. Case is 1 1/2" x 2" x 3 1/4". Weight 7 ounces. Vane rotor is 2 1/2" in diameter by 1 1/2" high. Cup rotor is 5 1/2" in diameter. Rotor shafts spin on 2 sets of precision stainless steel radial ball bearings. Wind velocity of approximately 5 M.P.H. is required to overcome mechanical and electrical inertia and start instrument registering. Instruments can withstand hurricane winds. Hand-held anemometers are not waterproof. All instruments are designed and manufactured in the United States with premium, custom built components.

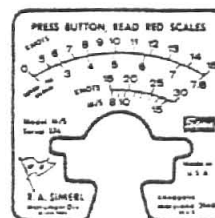
**QUALITY OF LABOR AND MATERIALS GUARANTEED.**

## Sims' HAND-HELD ANEMOMETERS

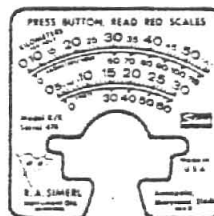
Available with all international combinations of wind speed designations. Illustrations below are full size reproductions of meter dials. Select cup or vane type rotor anemometers from illustrations at left.



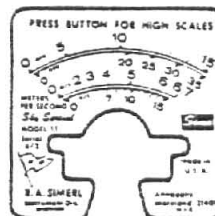
MODEL SKC with cup rotor  
MODEL SK with vane rotor  
Ranges: 0-15 knots  
0-30 knots



MODEL MSC with cup rotor  
MODEL MS with vane rotor  
Ranges: 0-15 knots  
0-30 knots  
0-7.5 meters/sec.  
0-15 meters/sec.

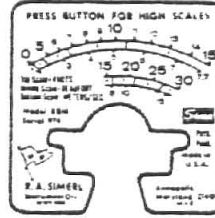


MODEL K/KC with cup rotor  
MODEL K/K with vane rotor  
Ranges: 0-30 knots  
0-60 knots  
0-54.5 kilometers/hr.  
0-112 kilometers/hr.



MODEL SSC with cup rotor  
MODEL SS with vane rotor  
Ranges: 0-6.7 meters/sec.  
0-15 meters/sec.  
0-15 M.P.H.  
0-35 M.P.H.

**EVERY Sims ANEMOMETER** described in this brochure uses a Simerl patented precision electric generator to convert air velocity (energy) to electric energy. This current is then measured on high quality pivot and jewel analog meters having an accuracy of  $\pm 2\%$ . Meters will not be damaged in winds exceeding dial ratings. Push buttons on sides of hand-held anemometers are used when wind velocities are greater than low range readings. With button depressed, readings of high scales are noted.



MODEL KSMC with cup rotor  
MODEL KSM with vane rotor  
Ranges: 0-15 knots  
0-30 knots  
0-7.7 meters/sec.  
0-15 meters/sec.  
Beaufort Forces 1-7

**Sims' ANEMOMETERS**  
Instruments for Professionals

Figure B14  
Hand Anemometers

## ILLUSTRATION CREDITS

- B1. 1977 Catalog, Kahl Scientific Corporation, P.O. Box 1166, El Cajon, California.
- B2. Ibid.
- B3. Ibid.
- B4. Ibid.
- B5. Ibid.
- B6. Ibid.
- B7. Ibid.
- B8. Ibid.
- B9. 1979 Catalog, Li-Cor Inc., P.O. Box 4425, Lincoln, Nebraska.
- B10. 1977 Catalog, The Bendix Corporation, Environmental & Process Instruments Division, 1400 Taylor Avenue, Baltimore, Maryland.
- B11. Ibid.
- B12. May 1980 Catalog, Cole-Parmer Instrument Company, 7425 North Oak Park Avenue, Chicago, Illinois.
- B13. Ibid.
- B14. 1980 Catalog, R.A. Simerl, Instrument Division, 238 West Street, Annapolis, Maryland.



MICROCLIMATIC DESIGN FOR ENERGY CONSERVATION

by

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B.Arch., Kansas State University, 1974

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF ARCHITECTURE

Department of Architecture

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

1981

Conservation of energy in the built environment is one of the most important concerns of architects today. It has been estimated that at least one third of the energy currently consumed in the United States goes into the heating, cooling and lighting of buildings and that at least 50% of this energy is wasted. Microclimatic design, or the alteration of the physical characteristics of a site to modify that site's climate, can be a valuable energy conserving design strategy.

In order to develop an effective microclimatic site design, the architect should be familiar with the environmental and human factors affecting the comfort perceptions of building occupants, the relationship of regional climate to human comfort, and the site characteristics which cause variations in microclimates. Among these characteristics are the site's topography, vegetation, earth surface materials, proximity to bodies of water and relationship to man-made structures.

A proposed method for microclimatic design involves a microclimatic site survey, analysis and evaluation. The site survey involves the gathering of facts concerning the physical and climatic conditions at a particular location. Microclimatic site analysis is the process by which the survey data is translated into charts and diagrams that amplify existing site conditions. The evaluation phase consists of the formulation of goals for climate modification based on the variance of the climatic conditions at the site with the comfort requirements of a proposed building's occupants. During the process of microclimatic design, the architect develops specific design strategies for site alteration to achieve climate modifying goals and to lower the energy requirements of a building placed at the site.