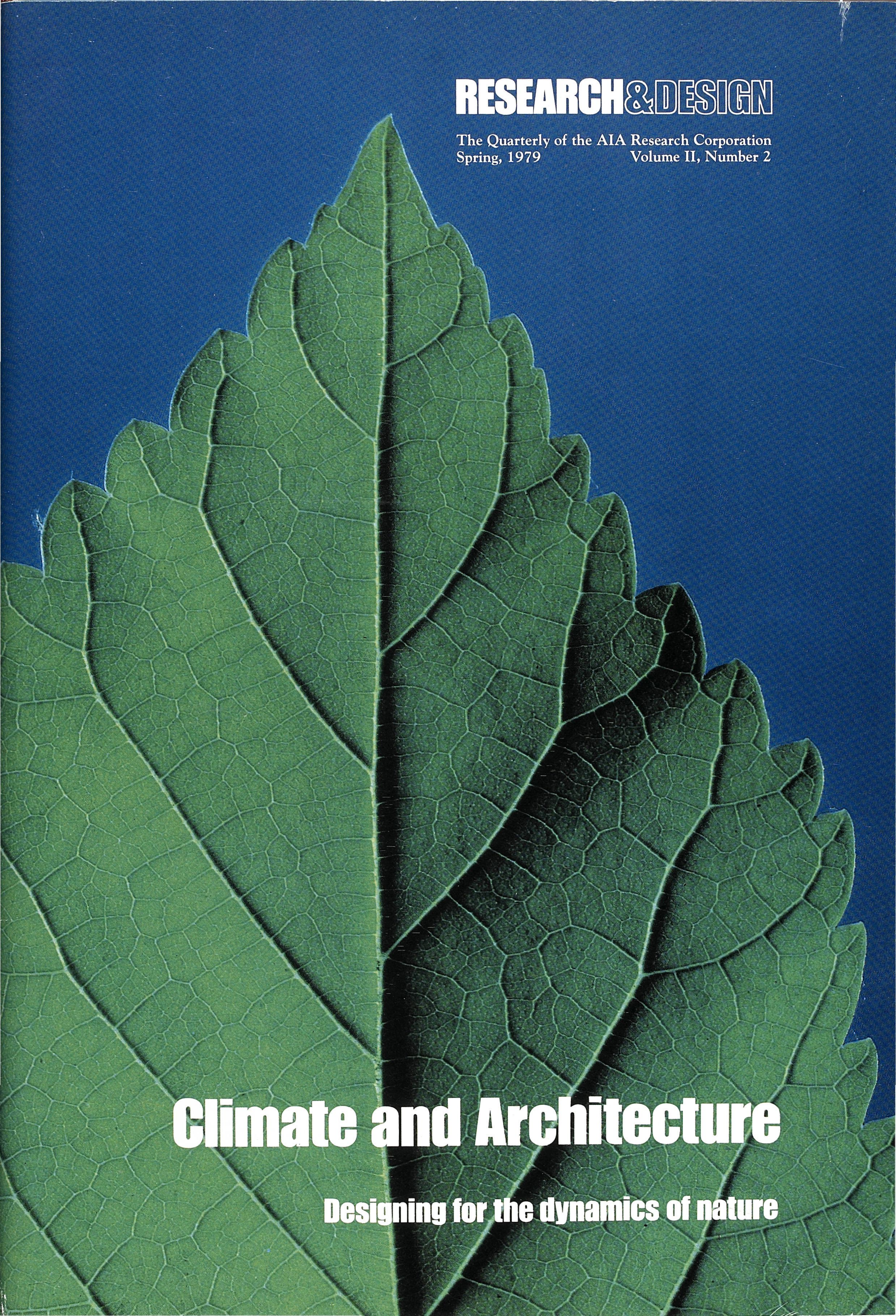
RESEARCH & DESIGN

The Quarterly of the AIA Research Corporation
Spring, 1979 Volume II, Number 2



Climate and Architecture

Designing for the dynamics of nature

COMMENTARY

In many ways, the current energy crisis is forcing us to reexamine our past. In an earlier day, homes were built to respond to climate. In the United States, this led to the small-windowed, low-ceilinged New England cottage, the airy, balconied southern mansion, and the adobe ranch house of the Southwest. We have since substituted cheap, abundant energy for climate common sense.

Today, most of our homes and offices are poorly designed, sited, and constructed in terms of climatic realities and energy conservation. To quote New York architect Richard Stein, too many buildings are "glass-skinned heat percolators." They admit and trap the heat of the summer sun and pass manmade heat outdoors in winter. We have been compensating for such climatically poor design by brute-force heating and air conditioning. We no longer can afford to waste so much energy.

A few years ago as much as one-third of all the energy used in the United States went to heat, cool, and operate homes and other buildings. Another 10 per cent went into their construction. Estimates are that this gross energy consumption could be cut by as much as 40 per cent if we designed, sited, and built by applying climatic data to minimize adverse environmental impacts and to maximize the impact of beneficial environmental elements. The climatic data needed to do this are available from the Environmental Data and Information Service's (EDIS) National Climatic Center in Asheville, North Carolina. One of the major objectives of the recent Climate and Architecture Conference was to identify the specific data needed by building professionals and to recommend forms and formats most useful for decision making.

EDIS and the AIA Research Corporation previously had cooperated in a pilot project to examine the influence of climate on design criteria for residential housing. The goal was to provide guidance to architects and homebuilders so that homes could be designed to be responsive to climate. The results of this effort are contained in AIA/RC's *Regional Guidelines for Building Passive Energy-Conserving Homes.*

The benefits of incorporating climatic factors into design decisions can be impressive. For example, according to an article in House Beautiful back in 1949, Henry Wright, an architect, reduced summer solar over-heating by 89 per cent in a small house he was designing simply by rotating the floor plan to take advantage of the fact that—contrary to popular belief—in summer the west side of a building, not the south side, is the hot one. Since solar heating may account for as much as 75 per cent of the load on home air conditioning systems, this is an excellent way to conserve energy.

The recommendations of the Climate and Architecture Conference will be used by EDIS to develop tailored climatic data summaries for major U.S. cities. These will provide the architect, builder, and engineer with the climatic information they need to design and construct energy-conserving buildings appropriate for the local climate. This return to climatic common sense is one of the simplest, yet most effective joint contributions the architect and the climatologist can make to the solution of our nation's energy problems.

"I could take the cold so much better before they discovered the wind-chill factor!"

Thomas S. Austin

Thomas S. Austin, Director
Environmental Data and Information Service

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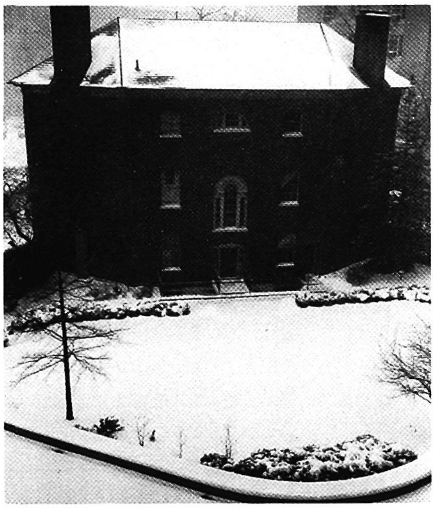

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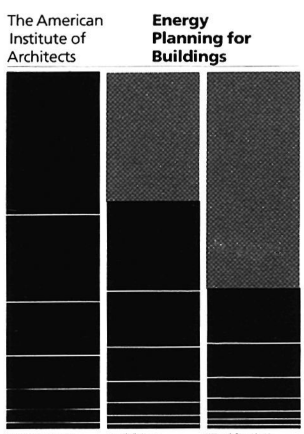
Cover: Photograph by Peter A. Garfield

NOTEBOOK



AIA's new guide to energy use planning in design and redesign

Today's clients expect their architects to produce buildings that are as energy-conservative as they are beautiful. If you've had difficulty translating energy theory into energy-conservative buildings, AIA has published a book that may solve your problem.

Authored by Michael Sizemore, Henry Clark, and William Ostrander—two architects and an engineer with hands-on experience in energy-conscious building design and redesign—*Energy Planning for Buildings* presents a practice-proven process for studying the actual or designed energy performance of a building, uncovering opportunities for energy-conscious improvements, evaluating those opportunities, and acting on them for maximum energy savings.

The book describes in detail a manual technique that designers can follow to calculate energy usage, showing in a sample problem how that technique can be applied. It also provides a basis for understanding computer-aided energy estimating, and should give you the information you need to evaluate any energy solution, including solar assisted alternatives.

In addition to basic concepts like HVAC systems, illumination and daylighting, and building envelope considerations, the authors discuss the impact energy planning has on user comfort, environmental impact, and visual appearance—considerations no less critical than energy to the average client.

With a glossary, practical reference list, and 120 charts and illustrations included in its 156 pages, *Energy Planning for Buildings* begins to fill the profession's serious need for practical direction on energy-conscious design. It's available from AIA Publications Marketing, 1735 New York Ave., N.W., Washington, D.C. 20006, for $40 to AIA members, $44 to others (order #4M-720).

Three new resources for passive solar design

The Department of Energy has three new design resources. *Passive Solar Design: A Survey of Monitored Buildings* is a 353-page compendium of data on 67 buildings coast-to-coast designed to make the most of natural energies. Photo reproduction is sometimes less than optimal and the monitoring procedures vary, but at $12.50 a copy, the wealth of information on climatic characteristics and design techniques may make the survey one of the best passive design resources available for the money. Order document HCP/CS 4113-2 from the National Technical Information Service (NTIS), 5285 Port Royal Rd., Springfield Va. 22161.

If you need access to more detailed information on discreet elements of passive design, *Passive Solar Design: An Extensive Bibliography* offers nearly 200 pages of titles on dozens of passive strategies, issues, and materials. If your access needs aren't that detailed, DOE has a short bibliography for practitioners with a refined list of titles on as many subjects as the larger volume. The short bibliography is available for $4.50 from NTIS (order HCP/CS-4113); the extensive (HCP/CS-4113-3), for $9.25. Both were prepared for DOE by the AIA Research Corporation, as was the passive survey.

A general tip for faster action from NTIS: Call toll-free on 800/523-2929 and order the document you want before putting your check in the mail; NTIS should be ready to ship your order as soon as your payment is received.

Wanted: Commercial and residential passive projects.

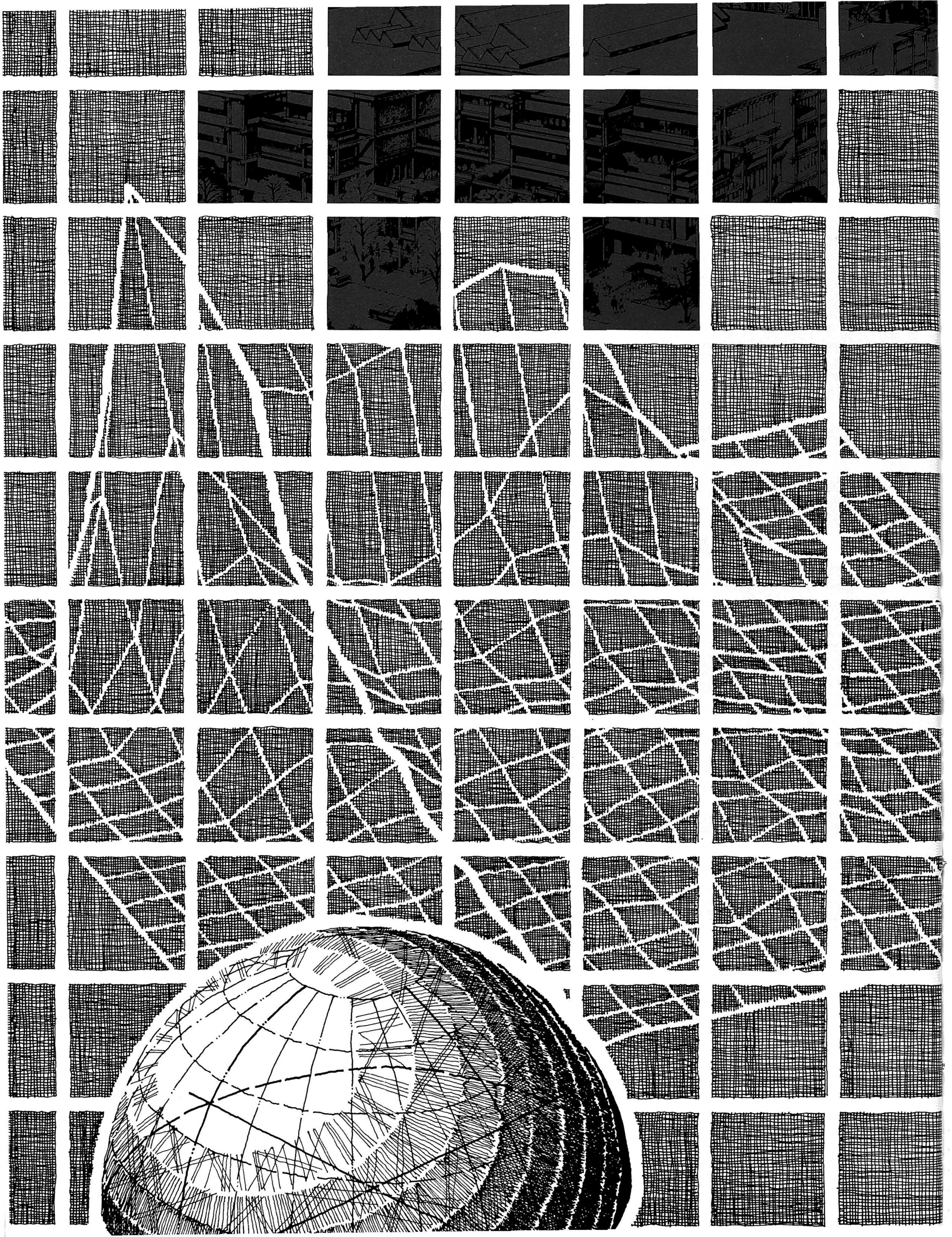
Under Department of Energy sponsorship, the AIA Research Corporation and New York's Ehrenkrantz Group are putting together a comprehensive survey of commercial buildings designed for passive heating and cooling. DOE and the Department of Housing and Urban Development are both sponsoring a parallel AIA/RC survey of passive residential buildings. While both efforts are well underway, designers of either residential or commercial buildings incorporating passive design techniques are invited to contact AIA/RC's George Royal about possible inclusion in the survey work. Write to Royal at AIA/RC, 1735 New York Ave., N.W., Washington, D.C. 20006. He'll send out a brief questionnaire by return mail for information on the project.

Journal of Architectural Research

Published by the American Institute of Architects
and the Royal Institute of British Architects

The Journal of Architectural Research, architecture's only international, interdisciplinary forum for advanced design research, is now being published in the United States with the support and assistance of the AIA Research Corporation. Subscriptions for the full 1979 volume, including the March issue just published and the upcoming July and November issues, may be obtained by sending check or money order for $15 to AIA Publications Marketing, 1735 New York Avenue, N.W., Washington, D.C. 20006.

March 1979 Volume 7 Number 1



Climate and Architecture

Last February, the energy crisis brought weather experts and building designers together for the first time in close to 30 years. Their mutual goal: Buildings that save energy by responding to the dynamics of climate.

"Weather Scientists to Tackle Building Problems at Parley Here." That was the headline 29 years ago, when 30 of the nation's leading "weather scientists, building technologists, and architects" converged on Washington, D.C. for the first federally-sponsored conference ever held on climate and architecture. And the last.

The National Academy of Sciences' Building Research Advisory Board (BRAB) sponsored that weekend gathering in 1950, and despite a general slant toward engineering the conference reflected a burgeoning interest in climate's influence on architectural design.

An architects' roundtable on the first evening was opened by James Marston Fitch, then architectural editor for House Beautiful. Fitch talked about the nation's first significant study of climate and design, completed only months earlier under the joint sponsorship of House Beautiful and the American Institute of Architects. After 27 months of research, House Beautiful was beginning to publish the results of the project, and for close to two years, from October, 1949 to June, 1951, virtually every issue of the magazine featured articles on climatic variations in the U.S., homes designed to take advantage of climate, and techniques for controlling climate "inside and outside the home." House Beautiful went on to publish the material in book form; AIA serialized it in the AIA Bulletin. Within three years, Progressive Architecture joined the movement, publishing Jeffrey Ellis Aronin's *Climate and Architecture,* calling it "the first book to *do* something about the weather."

And that, suddenly, was that. By 1953, the "technological miracles" to which House Beautiful had given a nod in its climate book—better construction technology, better conditioning systems, and, most important, cheap and plentiful energy—were firmly charting the course of American architecture. Climate consciousness was out; curtain walls, inoperable windows, and airconditioning were in, and thus, by and large, has it been ever since.

Until now. Two months ago more than 50 architects, engineers, homebuilders, and climatologists convened again in Washington for the first climate and architecture conference to be held since the BRAB event 29 years ago. Like their predecessors, these conferees were here at the behest of federal sponsors. The National Research Council (NRC) has been directed by Congress to develop a national research agenda linking climate and energy. The Department of Energy (DOE) and the National Oceanic and Atmospheric Administration (NOAA), where the nation's energy and climate research efforts are centered, called the conference to itemize the needs of the design community for that agenda.

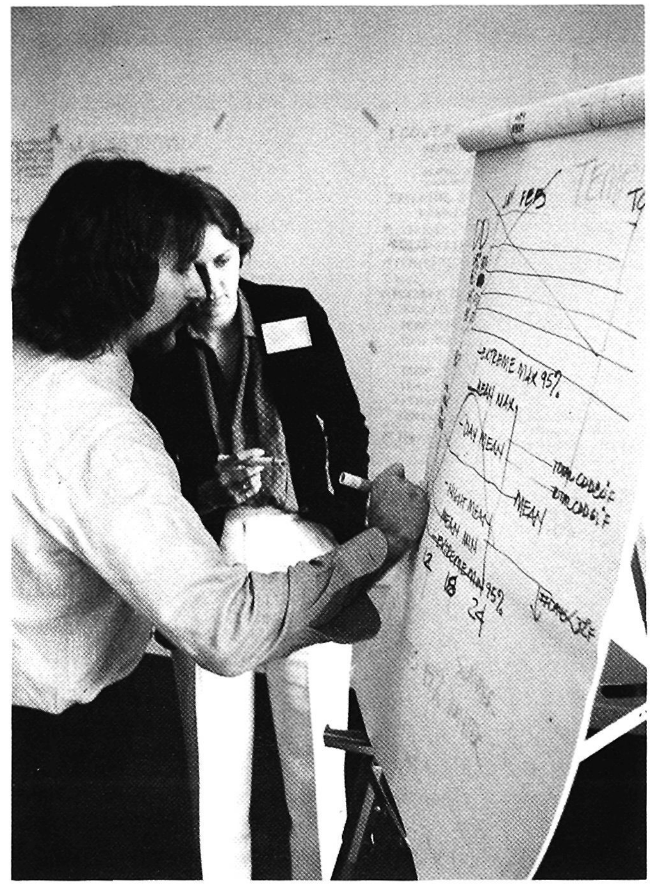
DOE is no stranger to the influences of climate on buildings and building design. In the recent research for the nation's approaching building energy performance standards, co-sponsored by DOE with the Department of Housing and Urban Development, architects cut energy consumption nearly in half by redesigning their buildings to adapt to local climatic conditions. One of the reasons the architects—together with engineers and homebuilders participating in the project—achieved such energy savings was that they approached climate as the first factor to be evaluated in their design problems. And their evaluations were made in terms of weighing climatic assets and climatic liabilities.

Four key elements of climate exert influence on buildings: temperature, humidity, sun, and wind. Depending on where a building is located and whether the comfort of its users depends more heavily on heating or cooling, each element may be either an asset to both comfort and energy consumption, or a liability.

The liabilities crop up when those elements make seasonal climatic conditions less tolerable for humans. Temperature is a liability when it is consistently too hot or too cold; wind, when it adds a wind chill factor to already chilled temperatures, or when, in hot, dry climates, it causes dehydration and overheating; humidity is a liability when it's so high the body can no longer sweat and evaporative cooling is prevented; sun, a liabil-

Illustration by Fred H. Greenberg

After exchanging views in a day-long plenary session (right), participants in the Climate and Architecture Conference broke into working groups (below, opposite page) to develop formats for a uniform "building climatological summary" that designers will be able to apply to virtually any site in the nation.



ity when it overheats already tropical conditions.

The same elements become climatic assets when they ease extreme seasonal conditions. Temperature becomes as asset when when its diurnal (day to night) swings are large enough that the thermal-lag inherent in massive construction can flatten out the diurnal curve, keeping days cooler and nights warmer. Wind becomes an asset in hot, humid climates, when natural ventilation can evaporate perspiration and dispel humidity. Humidity itself is an asset in dry climates; adding moisture to the air cools temperatures perceptibly. And in cold climates, the sun's energy can be trapped to provide heat.

Every location has its own climate, its own set of assets and liabilities. The differences from point to point within a given region are often slight, but the differences from region to region can be tremendous. In those differences lie the origins of regional architectural styles. New England's saltbox homes, with long sloping north-facing roofs that deflected winter winds and bore snowloads well, were ideal solutions to a harsh climate. New Mexico's adobe constructions provided the thermal lag necessary to ease the region's wide and uncomfortable diurnal temperature swings. The breezy piazzas of Charleston dispelled hot, humid conditions, while Nebraska's early sodhouses insulated themselves against the sweeping arctic winter winds of the Great Plains. But those were indigenous solutions to climate, reached intuitively. Today's designers can rely on climatic data that is lightyears ahead in its accuracy and precision.

NOAA's National Climatic Center in Asheville, N.C. coordinates the activities of 138 major weather stations around the nation, each one recording detailed (hourly or three-hourly) data on numerous climatic elements. Adjunct to those major stations are literally thousands of smaller recording points, collecting and reporting temperatures and precipitation levels. In addition, the U.S. Air Force and hundreds of airports maintain weather stations around the country, and many universities have similar, if smaller, climatic installations. All told, those sources generate more climate data than NOAA's Environmental Data and Information Service can handle, more data than most designers will ever need.

But do most designers know what they need, or how to use it? Those questions were first being asked back in 1950, and they weren't even partially answered until the energy performance standards research of the past three years. The designers involved in that research picked up quickly on what their forebears have been doing for centuries, adapting it to modern design techniques, building systems, and energy equations with general success. The process was so natural and the products so satisfactory in both energy and aesthetic terms that a good many designers came out of the project calling climate-conscious architecture—by some dubbed bed "neo-dynamism" for its renewed interest in natural energy flow—the logical successor to the fractious and fractured styles of post-modernism.

That assessment could turn out to be correct. But before climate-conscious design sweeps the nation, a nation of architects will have to learn to understand the often abstruse language and imagery of climate data, to extract from it the information they need to make intelligent design decisions, and to respond with techniques they weren't taught in school. Those were the problems put by DOE and NOAA to the climate and architecture conferees gathered in Washington last February.

The answers came back quickly. After a day of presentations from most of the 52 conference participants, each detailing a particular aspect of recent practice or research, the conference broke into six working groups charged with developing statements of the immediate, near future, and long term needs of the design community. After one long day there, they returned to plenary session in the circular board room of AIA's headquarters building and hammered out their differences, which were few.

Immediately necessary, they said, is a standard building climatological summary for each of the nation's 138 major weather stations. Their recommended format opens with a map and a narrative summation of climate, defining the regional parameters of the information and giving a quick picture of general trends; then the summary moves into specific data on sun, wind, temperature, humidity, and the constant interplay of those elements. Taken together, that information will give designers a quick and accurate tally of the assets and liabilities of local climate. When such summaries are developed for 138 areas across the nation—something the conference recommended for 1980 and which could occur by then—they will be invaluable for practitioners who can interpret them.

Interpretation, said the conferees, should be aided by published guidelines for architects, engineers, and homebuilders, another immediate need. The guidelines should cover everything from understanding climate data to designing solutions for specific problems.

Most important, the climate and architecture conferees agreed, is that designers understand the two fundamentals of climate-conscious architecture. Designs that respond to climate—and the research that supports such work—can't be approached as "solar" or "geothermal" or "underground construction," but as solutions that consider all the elements of climate in a holistic approach to energy-conservative design for human comfort. And, as important as this recognition of the interplay of climatic elements, designers must realize that the climatic matrix differs from region to region. The climate-conscious designer must be ready with flexible design strategies, applicable to changing conditions.

Given those fundamentals and the tools to implement them—design handbooks and climatological summaries—the conferees said the field will be ready for new research in a host of areas.

Some elements of climate have been inadequately researched to date. The illumination value of daytime sky, meaningless to meteorologists and relatively unimportant to airport weather collectors, can greatly influence lighting design and consequent energy load; the temperatures of groundwater and the ground itself, at the surface and at depths where it wavers minimally, can determine the viability of underground construction or subterranean storage of heat and "coolth." Neither has been rigorously researched in the U.S.

The exploration of techniques relatively new to design—dessicant cooling, induced ventilation, earth-air heat exchange, annual and diurnal thermal storage—will radically increase the number of design strategies available to climate-conscious designers. Understanding microclimatic variations and measuring them with compact recording units developed for use on actual design sites will permit finely tuned design responses. Understanding and measuring the effects of buildings themselves, on themselves and the exterior environment, may elevate building climatology to its most sophisticated level.

These long range research goals, however, have little to do with the current state of climate-conscious design. It is thriving, in a small way, and as energy conservation becomes a larger concern for architecture's avant garde and mainstream alike, it will grow. The federal government, architecture's single largest client, is already conferring most-favored status on projects that conserve maximum energy. In 1977, the office of California State Architect Sim Van der Ryn sponsored an energy-conscious design competition for a state office building, documenting Sacramento area climatic conditions in the program. The competition eventually generated *three* climate-conscious buildings for the state. It also developed the formats for climate documentation that Tennessee Valley Authority architects are using now in their sizeable development program. The same formats appear in the Climate and Architecture Conference's recommended building climatological summary, which is presented in the following pages.

Climate-conscious architecture gives all indication of being an idea whose time has come. With the world's oil-rich nations raising prices at regular intervals and America's own energy alternatives—gas, coal, nuclear—extremely uncertain, the need for energy conservative design solutions is as clear as a cloudless sky. With more buildings going up without benefit of an architect's services (if not without one's stamp) than with them, architects may also be in need of solutions that have more to offer than delight to the eye. What better solutions than those climate-responsive designs which, to quote Vitruvius, "remedy by art the harm that comes by chance"?

—Kevin W. Green

The chief aim of February's Climate and Architecture Conference, along with developing recommendations for future research, was to come up with a standardized Building Climatological Summary capable of giving designers the major climatic characteristics of more than 130 cities across the nation.

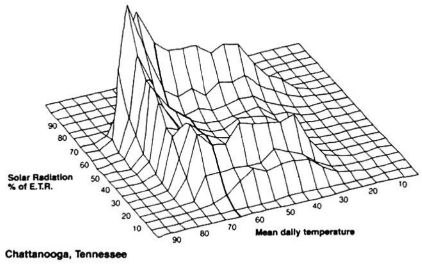
Basing their work on the long-recognized impacts of climate on design, and using data gathered by the National Oceanic and Atmospheric Administration, the U.S. Air Force, and literally thousands of minor meteorological research stations, the conferees developed a format that touches on most, if not all, of the climatic factors affecting human comfort–and thus designed energy performance–in buildings.

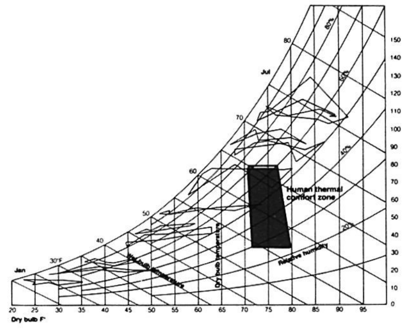
What follow on these pages are the key elements of that summary format. The summary begins with basic data locating a region and defining its climatic character, and progresses through precise graphic and tabular presentations of more detailed data. When produced for the nation's 130-plus major weather stations, it will be the data base energy-conscious designers turn to as their first resource.

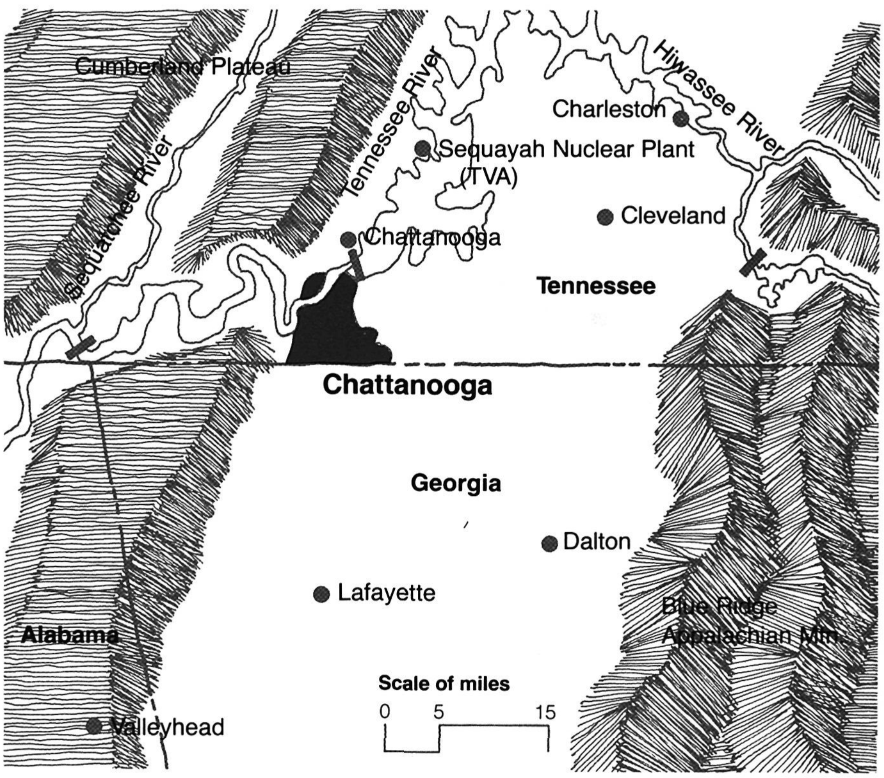
Narrative Climatological Summary: Chattanooga, Tenn.

Chattanooga is located in the southern portion of the Great Valley of Tennessee, an area of the Tennessee River between the Cumberland Mountains to the west and the Appalachian Mountains to the east. Local topography is complex, with a number of minor valleys and ridges giving a local relief of as much as 500 feet . . . Most of the city lies on the south side of the river. On the north and southwest sides, the terrain rises abruptly to about 1,200 feet above the river. This complex topography results in marked variations in air drainage, wind, and minimum temperatures within short distances. In winter, the Cumberlands moderate the climate by retarding the flow of cold air from the north and west.

Chattanooga enjoys a moderate climate, characterized by cool winters and quite warm summers. Because of the sheltering effect of the mountains, winter temperatures average about 3° warmer than at stations on the southern Cumberland Plateau . . . Summer temperatures are either in the high 80s or low 90s . . . Spring and autumn are very enjoyable seasons in Chattanooga, with many days being nearly ideal in temperature. To many, the fall months of September, October, and November are the most pleasant. Rainfall is at a minimum, sunshine at a relative maximum, and temperature extremes are practically nonexistent.







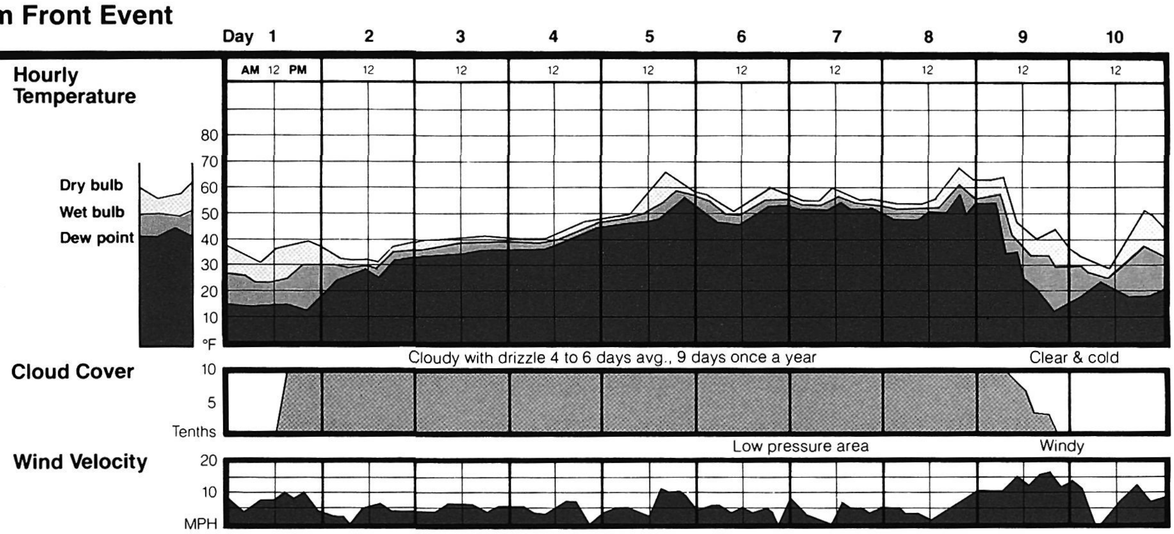
The opening page of the building climatological summary gives a quick sketch of an area's climate. A regional map (above) locates area topography and local weather stations, where climate data are actually recorded (and thus can differ from conditions on an actual design site). Graphic correlations (top) chart solar availability and temperature and humidity conditions in the region (see page 15 for more on correlations). And a narrative summary, usually longer than the excerpt (taken from a NOAA local climate summary) at left, briefly sums year-round climate and the region's meteorological history.

Representative events

A quick look at a few typical climatic events—series of simultaneously occurring climatic conditions—gives a surprisingly broad picture of a region's climate patterns, as the three events shown here for Chattanooga indicate. The winter warm front event (top), when warm winds driven out of a southern low pressure area bring lingering drizzle and cloud cover, accounts for more than a third of Chattanooga's winter weather. Skies clear, winds pick up, and temperatures drop (middle) when the northerly arctic air of a cold front—another third of the winter—follows the warm front through. The summer cycle (bottom) is a function of the Bermuda highs that send moisture-laden southerly winds through the region, saturating the air until a rainstorm breaks. Then the cycle begins again.

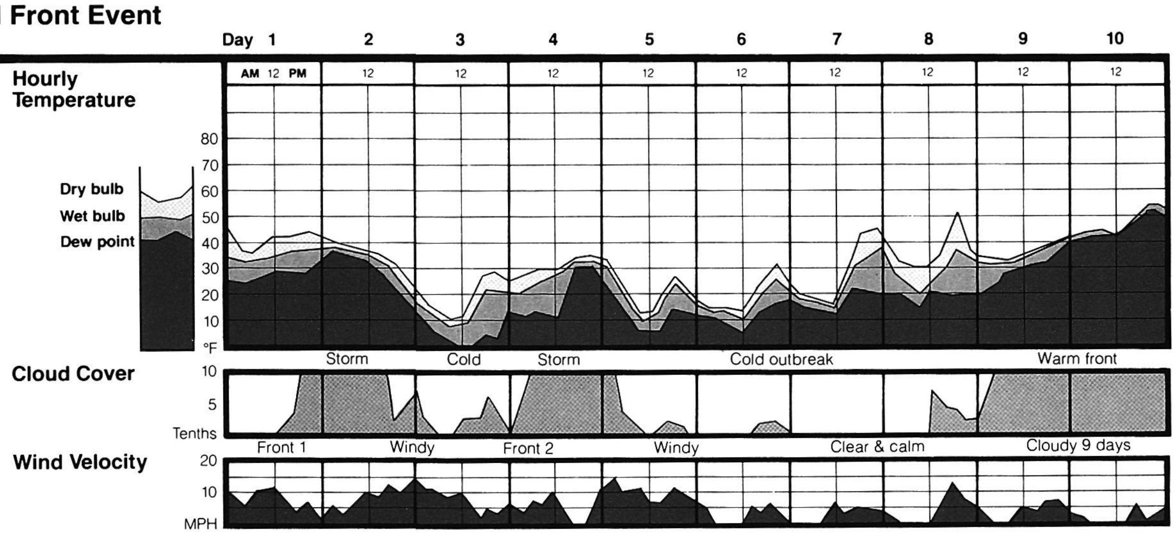
Winter Warm Front Event

1/26/69



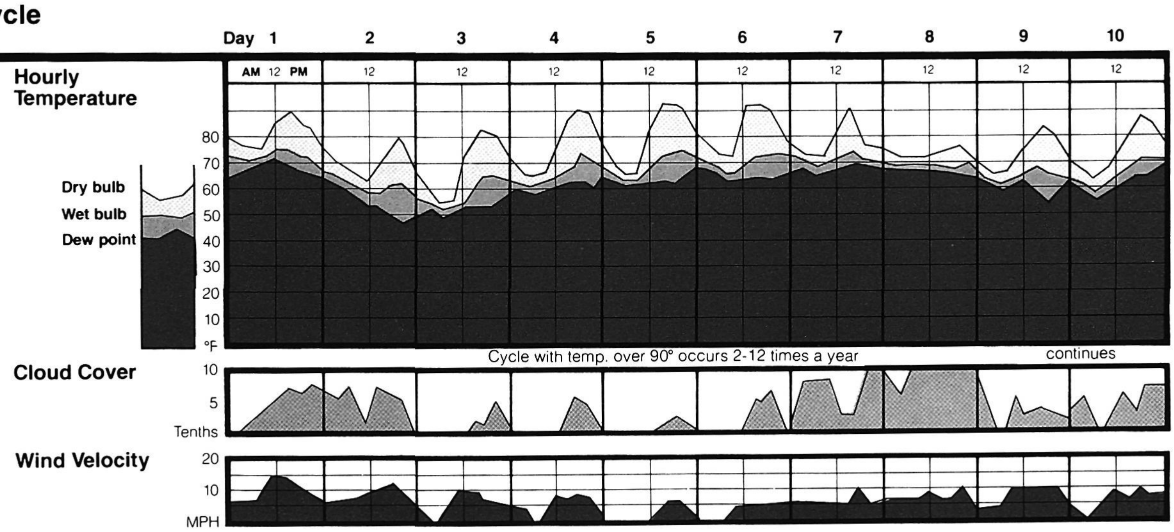
Winter Cold Front Event

1/29/65



Summer Cycle

6/26/68



Normals, means, and extremes

Climatic activity can be documented in both tabular and graphic form, and the Climate and Architecture conferees suggested that both forms be included in the building climatological summary. The tabular data shown immediately below for Chattanooga are actual normals, means, and extremes documented by the recording weather station. The graphic depictions document climatic conditions drawn on an "average day per month" basis, which sacrifices specific accuracy but gives an excellent picture of the year-round climate.

Meteorological Data for the Current Year

Station: CHATTANOOGA, TENNESSEE # 13882 LOVELL FIELD Standard time used: EASTERN Latitude: 35° 02' N Longitude: 85° 12' W Elevation (ground): 665 feet Year: 1977

Month	Temperature °F Averages: Daily maximum	Daily minimum	Monthly	Extremes: Highest	Date	Lowest	Date	Degree days Base 65 °F: Heating	Cooling
JAN	38.1	18.9	28.5	54	28	-2	17	1123	0
FEB	54.1	26.9	40.5	79	26	12	2	679	0
MAR	65.1	42.1	53.6	79	30	24	2	353	9
APR	75.9	50.2	63.1	87	17	33	6	111	60
MAY	81.5	59.5	70.5	90	30	45	10	17	194
JUN	89.0	66.1	77.6	98	12	48	8	0	384
JUL	94.6	72.1	83.4	104	8	64	3	0	578
AUG	91.9	71.7	81.8	97	6	65	21	0	532
SEP	83.7	66.8	75.3	95	3	55	29	5	320
OCT	68.9	46.6	57.8	86	1	33	17	233	15
NOV	61.2	44.7	53.0	74	1	24	26	359	3
DEC	50.3	30.8	40.6	70	5	13	7	753	0
YEAR	71.2	49.7	60.5	104	JUL 8	-2	JAN 17	3633	2095

Month	Precipitation in inches, Water equivalent: Total	Greatest in 24 hrs.	Date	Snow, Ice pellets: Total	Greatest in 24 hrs.	Date	Relative humidity, pct. (Local time): Hour 01	Hour 07	Hour 13	Hour 19
JAN	3.14	1.40	9	3.7	2.5	24	67	73	56	56
FEB	2.98	1.67	23-24	T	T	20	69	80	44	45
MAR	8.39	3.38	29-30	0.0	0.0		81	85	54	55
APR	9.10	2.65	22-23	0.0	0.0		87	94	51	57
MAY	2.55	0.62	24-25	0.0	0.0		92	93	59	63
JUN	2.44	0.73	17-18	0.0	0.0		85	88	53	56
JUL	1.01	0.42	25	0.0	0.0		82	89	51	55
AUG	3.53	1.55	17-18	0.0	0.0		83	89	56	61
SEP	14.18	6.62	6-7	0.0	0.0		88	92	65	72
OCT	6.21	3.52	25-26	0.0	0.0		88	91	56	68
NOV	8.66	1.84	4-5	T	T	27	84	87	66	74
DEC	2.37	0.73	24-25	T	T	30	78	81	62	65
YEAR	64.56	6.62	SEP 6-7	3.7	2.5	JAN 24	82	87	56	61

Month	Wind, Resultant: Direction	Speed m.p.h.	Average speed m.p.h.	Fastest mile: Speed m.p.h.	Direction	Date	Percent of possible sunshine	Average sky cover, tenths, sunrise to sunset
JAN	30	2.9	7.1	28	26	10	47	6.2
FEB	29	2.9	7.2	26	18	23	72	3.5
MAR	22	1.4	7.3	26	26	18	57	6.0
APR	25	1.3	5.5	32	18	18	57	5.4
MAY	07	0.8	4.3	33	29	18	57	5.6
JUN	28	2.0	5.7	28	31	13	66	5.5
JUL	19	0.9	5.7	20	36	1	60	5.1
AUG	20	1.7	5.4	23	32	9	54	6.2
SEP	17	0.8	4.8	21	31	25	48	6.6
OCT	36	1.5	5.8	18	35	12	51	5.8
NOV	30	0.8	5.5	21	19	9	35	7.1
DEC	28	2.3	7.1	23	32	6	42	6.6
YEAR	27	1.0	6.0	33	29	MAY 18	54	5.8

Month	Number of days, Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less.	Temperature °F Maximum: (b) 90° and above	32° and below	Minimum: 32° and below	0° and below	Average station pressure mb Elev. 688 feet m.s.l.
JAN	5	13	13	8	1	0	1	0	8	26	1	994.6
FEB	16	5	7	4	0	3	0	0	0	22	0	994.2
MAR	9	6	16	14	0	2	2	0	0	6	0	992.6
APR	10	8	12	9	0	7	2	0	0	0	0	994.6
MAY	10	9	12	13	0	13	5	1	0	0	0	992.9
JUN	8	12	10	11	0	10	2	15	0	0	0	991.2
JUL	9	14	8	7	0	8	2	28	0	0	0	993.9
AUG	4	18	9	12	0	12	0	27	0	0	0	993.9
SEP	7	7	16	14	0	10	4	7	0	0	0	992.2
OCT	9	7	15	6	0	2	6	0	0	0	0	994.2
NOV	8	2	20	14	0	3	3	0	0	6	0	993.6
DEC	9	5	17	12	0	2	3	0	1	17	0	993.6
YEAR	104	106	155	124	1	72	30	78	9	77	1	993.5

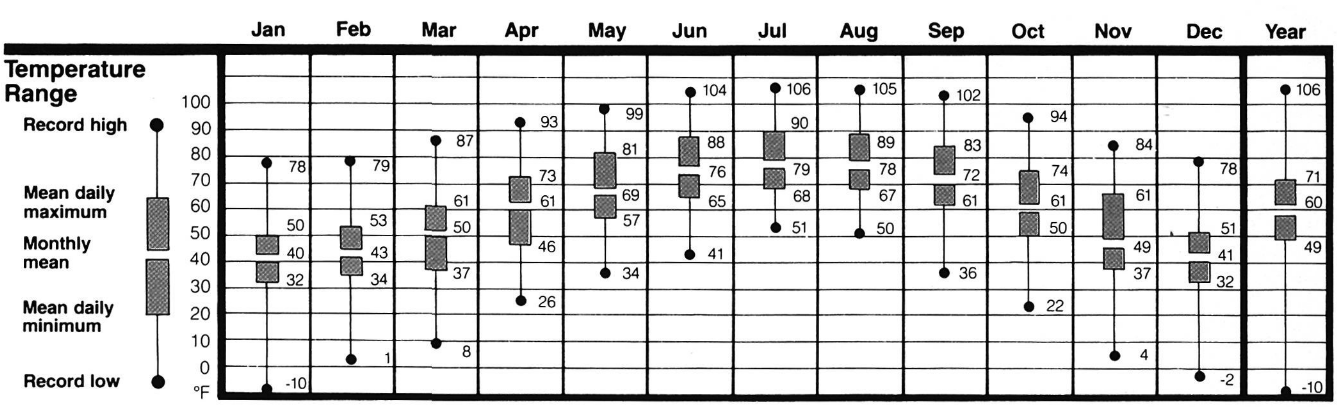
Normals, Means & Extremes

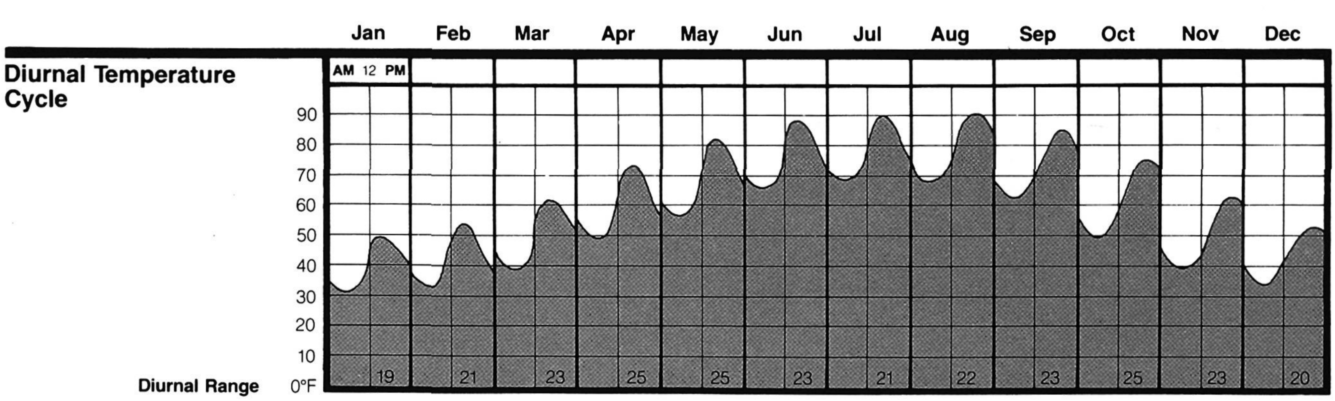
Month	Temperatures °F Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F: Heating	Cooling
(a)				38		38			
J	49.9	30.5	40.2	78	1949	-10	1966	769	0
F	53.4	32.3	42.9	79	1977	1	1958	625	6
M	61.2	38.4	49.8	87	1963	8	1960	483	12
A	72.9	48.1	60.5	93	1942	26	1973	165	30
M	81.0	56.0	68.5	99	1941	34	1971	51	159
J	87.5	64.5	76.0	104	1952	41	1972	0	330
J	89.5	68.1	78.8	106	1952	51	1972	0	428
A	89.0	67.0	78.0	105	1947	50	1946	0	403
S	83.4	60.4	71.9	102	1954	36	1967	9	216
O	73.5	48.1	60.8	94	1954	22	1952	182	52
N	60.7	37.1	48.9	84	1961	4	1950	483	0
D	50.9	31.4	41.2	78	1951	-2	1962	738	0
YR	71.1	48.5	59.8	106	JUL 1952	-10	JAN 1966	3505	1636

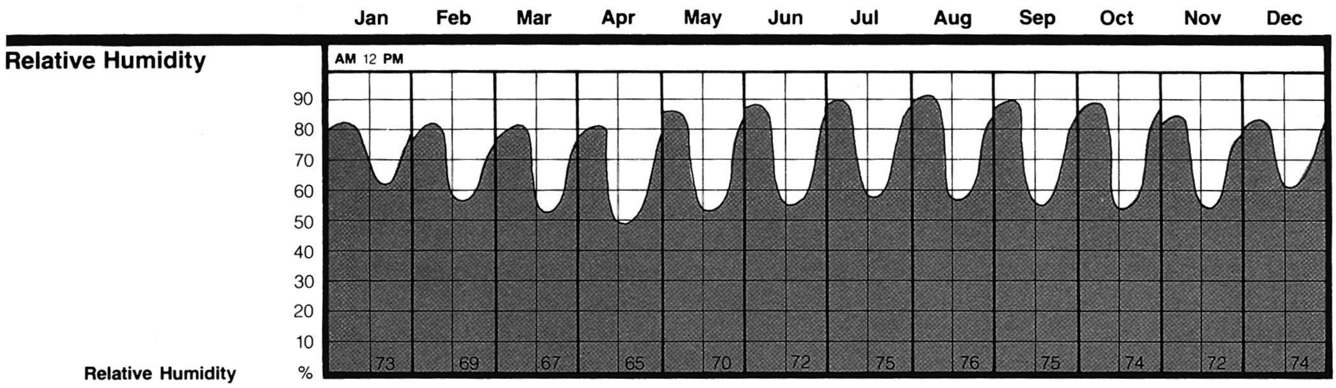
Month	Precipitation in inches, Water equivalent: Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets: Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)		38		38		38		47		47	
J	5.38	12.28	1947	1.13	1961	4.44	1949	8.4	1966	8.4	1966
F	5.19	11.03	1944	0.62	1941	3.93	1958	10.4	1960	8.7	1960
M	5.63	13.80	1973	1.17	1967	6.53	1973	10.1	1960	6.0	1960
A	4.42	11.92	1964	0.44	1942	3.07	1944	1.0	1971	1.0	1971
M	3.43	6.65	1946	0.54	1941	3.46	1964	T	1944	T	1944
J	3.68	9.40	1949	0.87	1968	4.85	1949	0.0		0.0	
J	5.14	11.54	1941	0.20	1957	4.79	1941	0.0		0.0	
A	3.22	7.54	1975	0.56	1963	3.70	1941	0.0		0.0	
S	3.69	14.18	1977	0.34	1941	6.62	1977	0.0		0.0	
O	2.95	9.91	1949	0.24	1963	3.52	1977	T	1954	T	1954
N	3.94	13.59	1948	0.93	1953	4.56	1948	2.8	1950	2.8	1950
D	5.25	13.68	1961	0.86	1965	5.25	1942	9.1	1963	8.9	1963
YR	51.92	14.18	SEP 1977	0.20	JUL 1957	6.62	SEP 1977	10.4	FEB 1960	8.9	DEC 1963

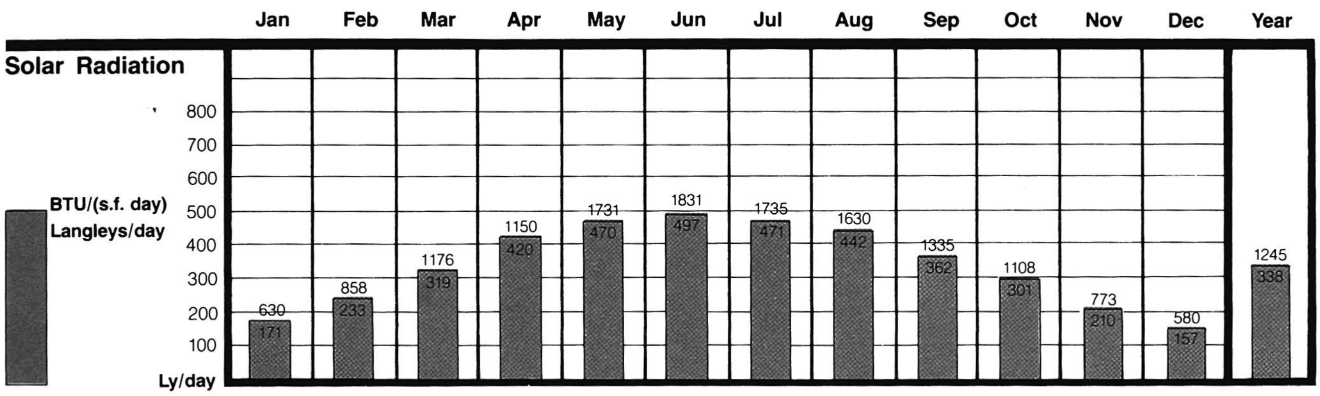
Month	Relative humidity pct. (Local time): Hour 01	Hour 07	Hour 13	Hour 19	Wind: Mean speed m.p.h.	Prevailing direction	Fastest mile: Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset
(a)	37	47	47	47	37	23	35	35		47	47
J	80	82	63	67	7.2	S	59	SW	1959	42	6.7
F	77	81	57	60	7.7	S	63	W	1952	48	6.4
M	77	81	53	56	8.2	S	82	W	1947	51	6.3
A	78	81	49	52	7.7	S	57	W	1957	60	5.8
M	86	85	52	57	6.1	S	63	NW	1951	65	5.7
J	88	86	54	60	5.5	S	67	NW	1953	65	5.7
J	89	89	57	64	5.1	S	48	NW	1952	61	6.0
A	90	91	57	66	4.7	S	62	W	1946	62	5.6
S	89	90	55	67	5.0	S	57	SW	1957	63	5.3
O	88	89	53	67	5.1	S	35	NW	1952	62	4.7
N	82	84	55	66	6.3	S	45	S	1961	53	5.6
D	82	84	62	69	6.7	S	42	SW	1953	42	6.6
YR	84	85	56	63	6.3	S	82	W	MAR 1947	57	5.9

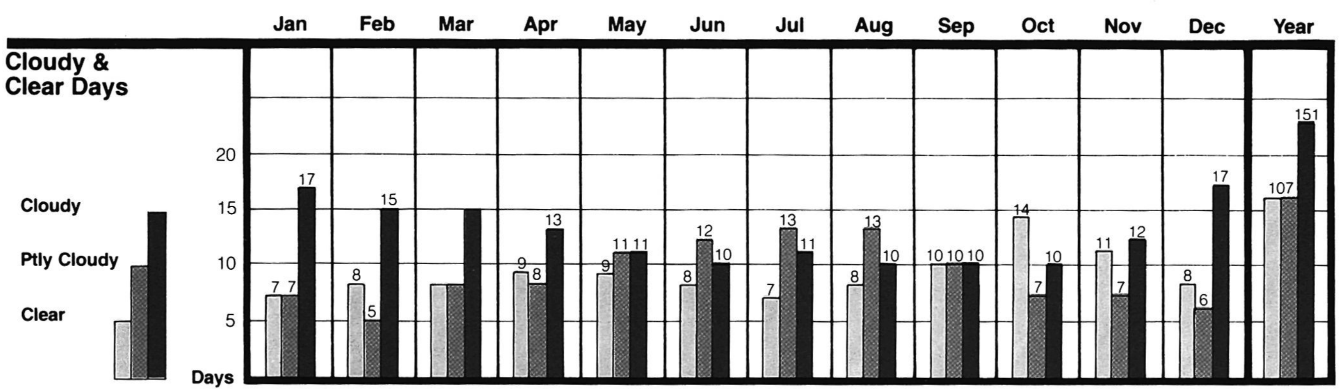
Month	Mean number of days, Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperatures °F Max.: (b) 90° and above	32° and below	Min.: 32° and below	0° and below	Average station pressure mb. Elev. 688 feet m.s.l.
(a)	47	47	47	47	47	47	47	37	37	37	37	5
J	7	7	17	12	1	1	3	0	2	19	*	995.8
F	8	5	15	11	1	2	2	0	1	15	0	994.0
M	8	8	15	12	*	4	2	0	*	9	0	992.0
A	9	8	13	10	*	5	2	*	0	2	0	993.2
M	9	11	11	10	0	7	2	3	0	0	0	990.6
J	8	12	10	11	0	10	2	11	0	0	0	991.6
J	7	13	11	12	0	11	2	16	0	0	0	992.7
A	8	13	10	10	0	9	3	14	0	0	0	993.8
S	10	10	10	8	0	4	4	5	0	0	0	993.0
O	14	7	10	7	0	1	6	*	0	1	0	995.3
N	11	7	12	9	*	1	4	0	*	11	0	995.3
D	8	6	17	11	*	1	4	0	1	18	*	994.7
YR	107	107	151	121	2	56	36	49	3	75	*	993.5

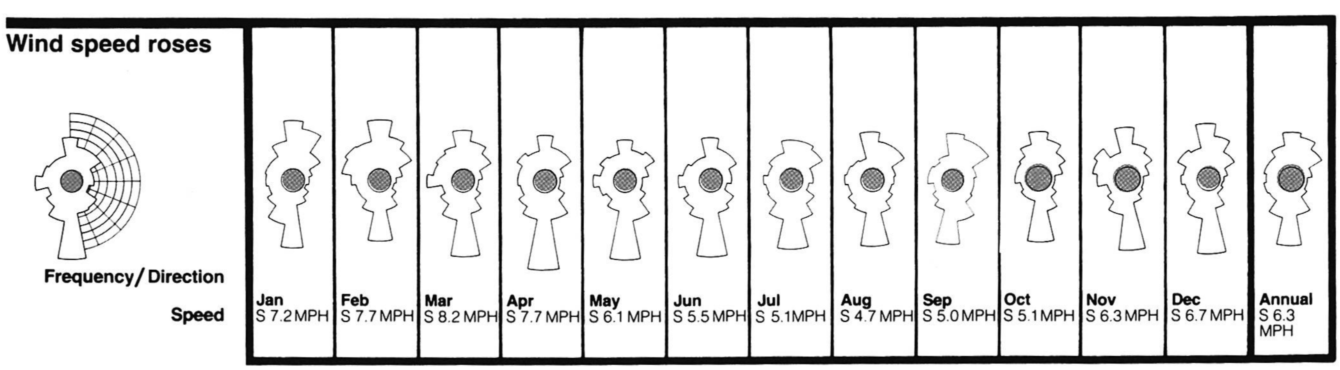





Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Relative Humidity
AM 12 PM
90
80
70
60
50
40
30
20
10
Relative Humidity
%
73
69
67
65
70
72
75
76
75
74
72
74


Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Year
Solar Radiation
800
700
600
500
400
300
200
100
BTU/(s.f. day)
Langleys/day
Ly/day
630
171
858
233
1176
319
1150
420
1731
470
1831
497
1735
471
1630
442
1335
362
1108
301
773
210
580
157
1245
338


Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Year
Cloudy & Clear Days
Cloudy
Ptly Cloudy
Clear
20
15
10
5
Days
7 7 17
8 5 15
9 8 13
9 11 11
8 12 10
7 13 11
8 13 10
10 10 10
14 7 10
11 7 12
8 6 17
107 151


Wind speed roses
Frequency/Direction
Speed
Jan S 7.2 MPH
Feb S 7.7 MPH
Mar S 8.2 MPH
Apr S 7.7 MPH
May S 6.1 MPH
Jun S 5.5 MPH
Jul S 5.1MPH
Aug S 4.7 MPH
Sep S 5.0 MPH
Oct S 5.1 MPH
Nov S 6.3 MPH
Dec S 6.7 MPH
Annual S 6.3 MPH

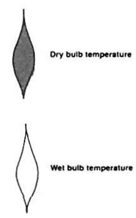
Pure information

Certain elements of climate demand more attention and more accurate calculations from designers. Daily and hourly temperature, humidity, wind, and sunlight have a tremendous bearing not only on human comfort but on buildings designed to shelter people and use energy wisely as well. With architects relearning the techniques of climate-conscious design at a rapid pace, the Climate and Architecture conferees recommended that the building climatological summary give designers "pure information" on the key elements of climate, to serve as a foundation for design. Since the information must be useful in the design process, the conferees sought clear and precise graphic images to accompany tabular data. The result was a format that is accurate, easily read, and enables comparison of climates from location to location.

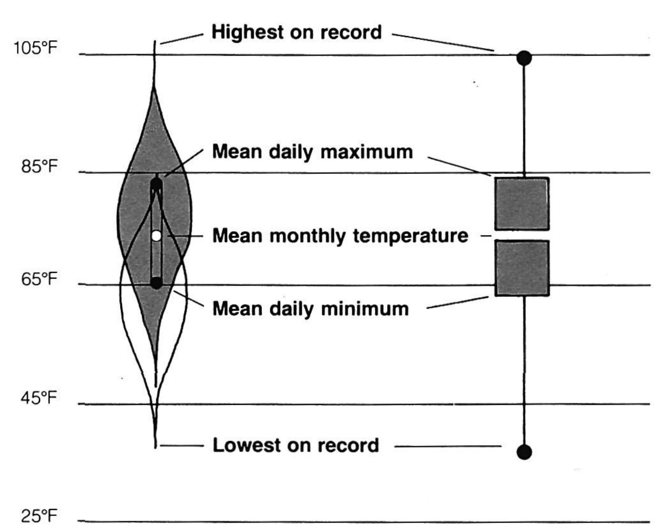
Temperature

It's the first thing one listens for on the weather report, the most common gauge of human comfort. While other factors influence its impact, temperature may also be the single most important climatic element for designers, and the simplest to understand.

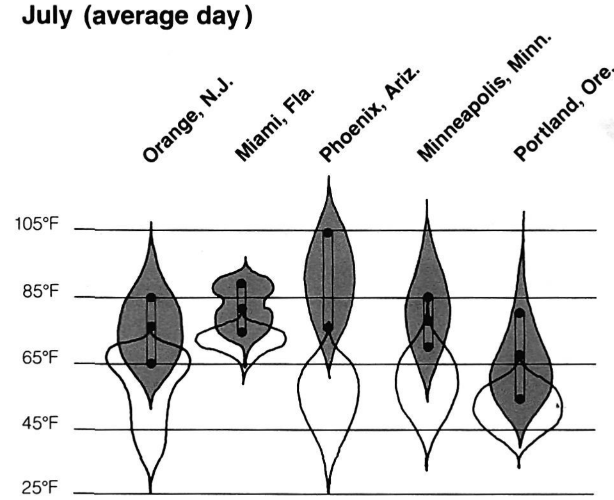
Dry bulb temperature is the air temperature read from a standard thermometer. **Mean daily temperature** is the center of a day's range of dry bulb temperatures. Match the mean daily temperature against a building's desired interior temperature and you find the average daily heating or cooling load. **Wet bulb temperature** is a measure of the heat held latent in water vapor in the air (and an indicator of dew point temperature). The more closely wet bulb temperatures match dry bulb temperatures, the more humid and latently heated the air, and the more appropriate natural ventilation becomes as a design technique for easing high temperatures. **Diurnal temperature swing** is the range of differential between day and night temperatures. A wide diurnal swing—hot days, cold nights—might call for massive construction to introduce thermal lag, keeping spaces cool in the daytime and warmer at night. Patterns of wide diurnal swing and high relative humidity rarely coincide, so a single design solution—ventilation or massing—will likely be indicated from regional temperature data. **Heating degree days** and **cooling hours** estimate seasonal conditioning loads as a function of the number of degrees of difference between outdoor temperatures and a design base of 65°, and the number of days (or hours) of the occurrence of a differential.

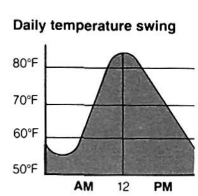


Chicago—July (average day)



July (average day)

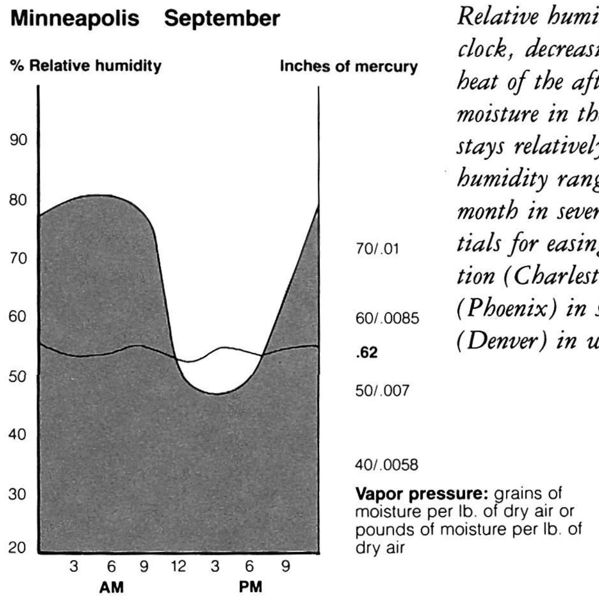




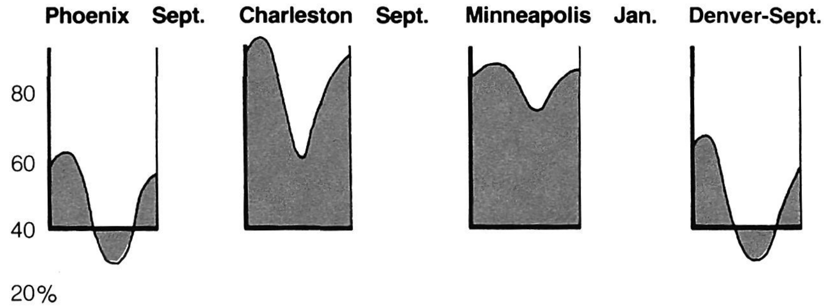
Two images can be used to graph temperatures (chart at top) but the teardrops used for the AIA/House Beautiful project in 1950 will likely prevail over the more recently developed bar graphs. The width of each drop indicates the duration of a temperature on an average day of a given month. The greater the overlap of wet and dry bulb drops, the higher the humidity, as comparison of Phoenix (dry) and Miami in July indicates above. The greater a region's diurnal temperature swing (left), the better thermal massing will ease temperature extremes.

Humidity

The crux of the humidity issue is sensible heat. Heat held latent in water vapor is insensible—not perceived as heat—so the amount of water in the air and the heat it can hold become crucial factors. **Relative humidity** is the amount of moisture in the air expressed as a percentage of the total amount of moisture the air can hold at a given temperature. **Vapor pressure** represents the amount of moisture actually in the air, regardless of temperature. The importance of that relationship can be seen in climates of low relative humidity, where humidification and evaporative cooling can draw sensible heat from the air, hold it latent in water vapor, and reduce temperature. High humidity—cause of condensation in winter, mildew in summer, and misery at high temperatures—suggests dessicant design solutions.

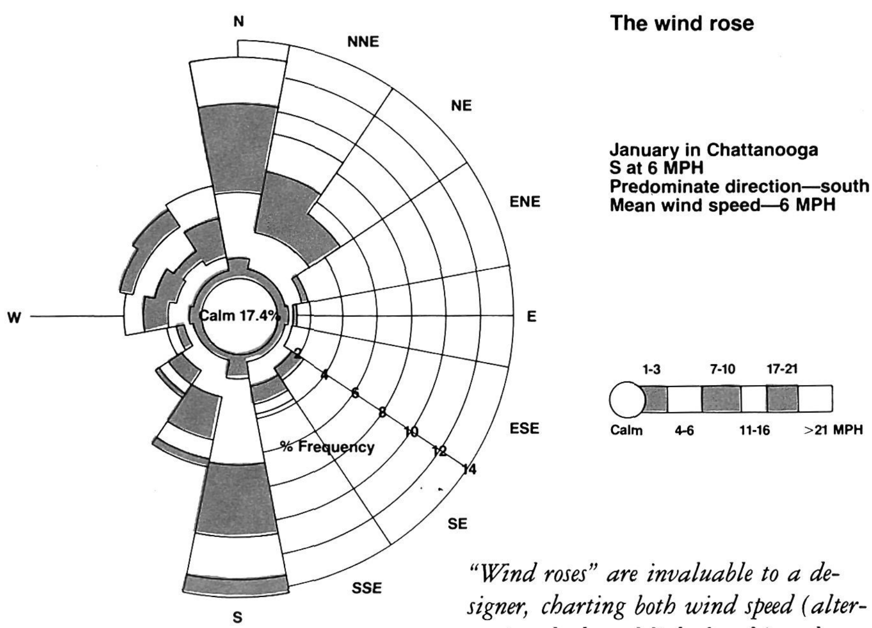


Relative humidity varies around the clock, decreasing substantially in the heat of the afternoon, but the amount of moisture in the air—vapor pressure—stays relatively constant. Checking the humidity ranges for an average day per month in several locations shows potentials for easing conditions with ventilation (Charleston) or evaporative cooling (Phoenix) in summer, humidification (Denver) in winter.

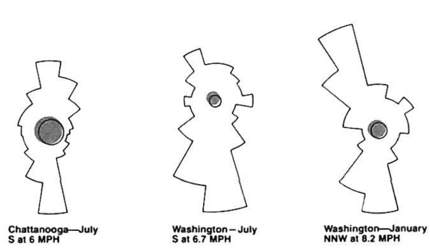


Wind

Wind figures on both sides of the energy-conscious design ledger. In winter, it infiltrates and overchills; in summer it cools. In humid climates, it can ease humidity by spurring evaporation, but in dry climates, its evaporative nature saps the air of comforting moisture. The extent to which a designer can modify and control those influences is determined by three key factors. **Wind direction**, at different times of day and night, in different seasons of the year, will dictate the way a building can deflect winter wind or accept summer's breezes. **Wind frequency** documents the occurrence of wind from any given direction, which influences static design. **Wind speed** states the utility of a breeze; regardless of frequency or direction, winds of less than 5 mph have minimal impact on comfort or conditioning.

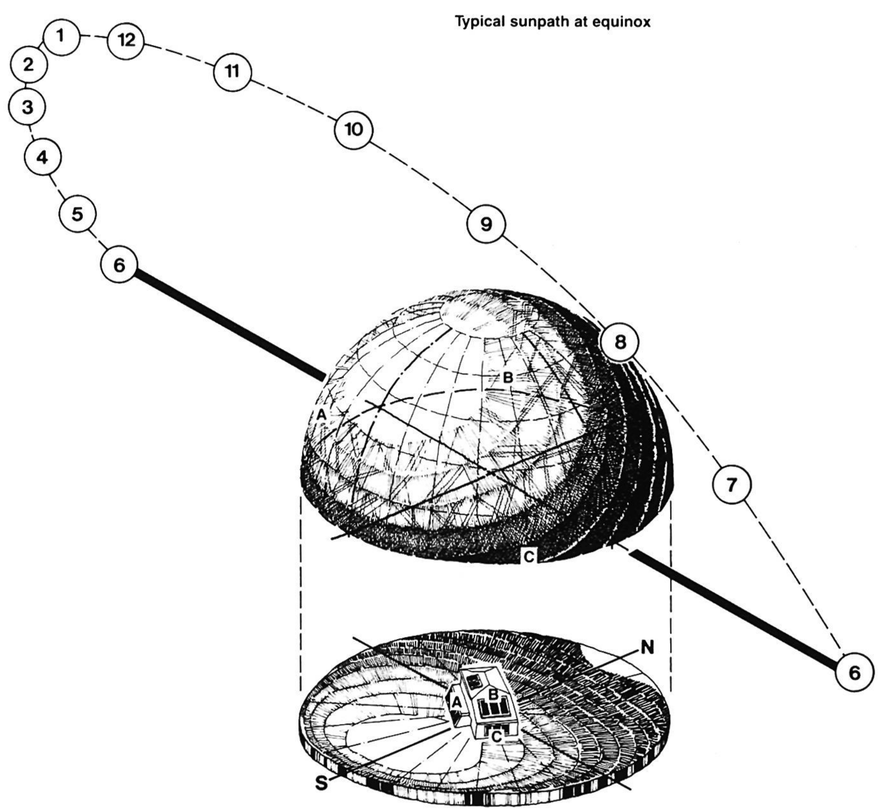


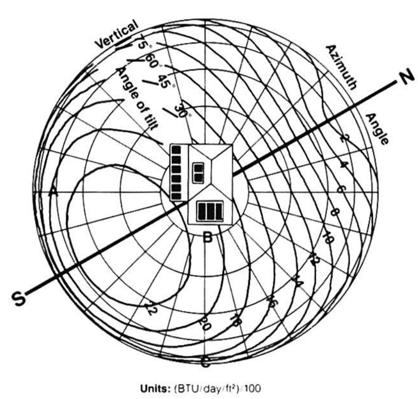
"Wind roses" are invaluable to a designer, charting both wind speed (alternating dark and light bands) and frequency of occurrence from a given direction (length of each vector). A glance at a regional wind rose can dispel the common notion that all winter winds are northwesterly—Chattanooga's are primarily southerly—and indicate which facades should be closed to winter wind infiltration, which opened to summer ventilation, and whether or not either is a significant issue in the region.



The sun

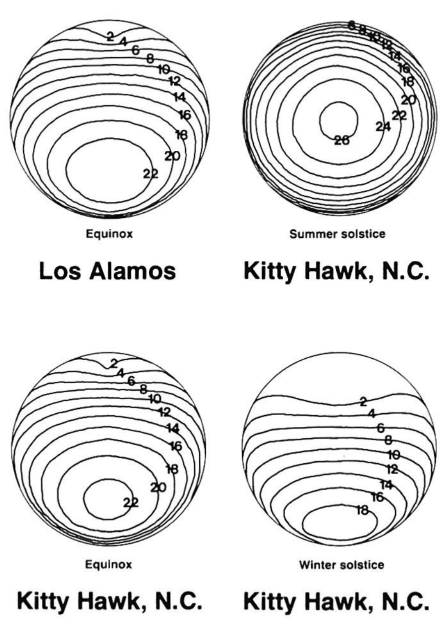
Responding to the energy of the sun—alternately known as solar radiation, beam radiation, irradiation, and insolation—can be relatively simple given an understanding of some fundamentals. **Solar intensity** is the sun's heat, usually measured in BTUs/sf/hour, day, or month on a horizontal surface; it's greater in summer and on clear days. **Solar availability** is the time the sun spends in a clear sky, measured in clear and cloudiness factors. **Altitude** and **azimuth** represent the sun's height on a vertical axis—higher in summer—and its location on the horizontal—a wider range in summer. A window that sees the sun receives **direct** sunlight; north windows generally receive bounced, **diffuse** light. Protecting against the intensity of summer sun—both direct and diffuse—with shading devices and welcoming winter insolation with open forms is the essence of passive solar design.





Daylighting

Daylighting can be the major factor in an energy-conserving design solution, and designers need more research in the field. A designer can significantly reduce the duration of artificial lighting in a building, if not the amount of equipment installed, by considering certain conditions. Direct sunlight, though it glares in task lighting, can be beamed (bounced) for general light. Clear sky diffuse light is optimal for task or general illumination. For both of the above, building openings and orientation should be carefully planned. Cloudy sky illumination is diffuse and evenly balanced—negating the influence of orientation—but requires greater auxiliary lighting.



The "Orientilt" diagram developed by New Mexico's The Architects Taos depicts the sun's altitude, azimuth, and intensity for a specific location and time of year—here, for Los Alamos, N.M. at the equinoxes. Locating a structure on the diagram, a designer can calculate insolation on a given surface. Here, the glazed greenhouse surface (A in the center diagram), tilted 60°, faces south-southwest. By following that axis out to the concentric 60° ring and following the intensity line intersected there (A on the lower diagram), the designer learns that insolation on the greenhouse surface will amount to 2,000 BTUs/sf for that equinocal day. Comparing the orientilt's plane projections for different cities and times of the year demonstrates the significant variation of insolation values on different building surfaces.

Correlations

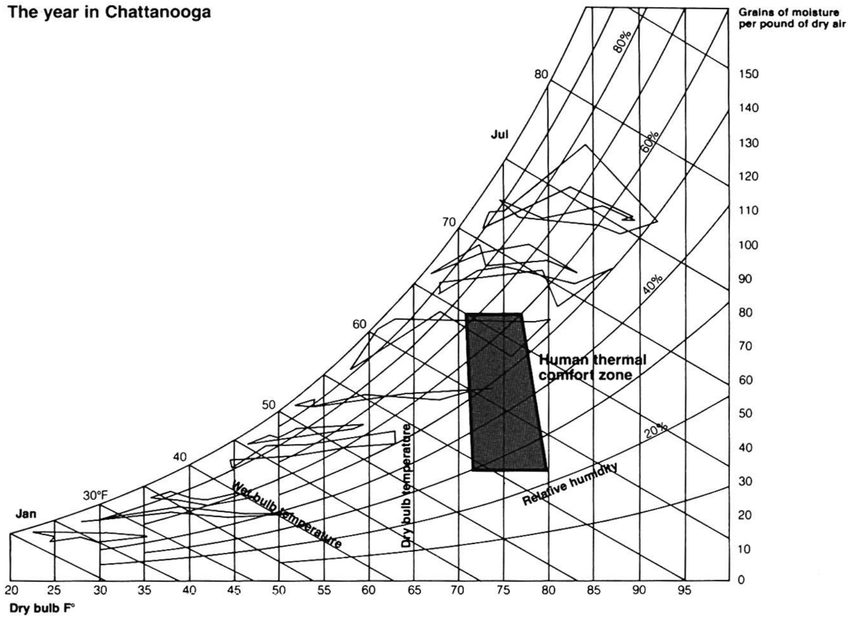
None of the climatic elements that affect design—and all do to some significant extent—do so independently. The wind chill factor, the warmth of sunlight on a winter day, the cool of a summer breeze are all indications of the impact one climatic element can have on another. To determine the extent of these moderating and exacerbating influences, designers can look at "correlations" of two or more elements and gain a better understanding of the design problem, as well as some clues to the right solution. Temperature, for example, rarely holds significance for comfort calculation until matched with humidity and vapor pressure. The phrase "92° in the shade" expresses the colloquial understanding that effective temperatures under direct insolation are always higher. Wind may be the most effective moderator of hot, humid conditions, but without knowing wind speed, direction, and the percentage of occurrence when those conditions prevail, its impact goes uncalculated. Designers have been working within particular climates for centuries, but only in the last 30 years—ironically, when conditioning technology has seemed to outmode climate-conscious design—have we developed the skill to make climatic correlation more than educated guesswork.

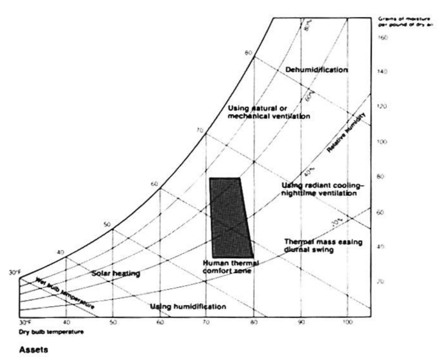
Temperature/Humidity

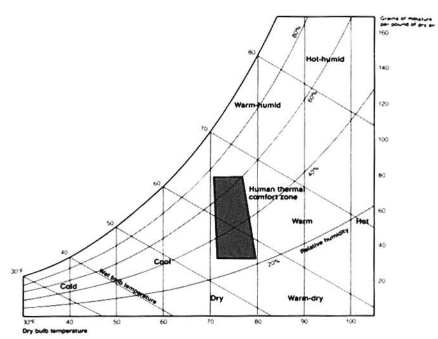
Temperature and humidity correlation is the keystone of designed comfort. The federally-adopted comfort zone plotted on a psychrometric chart for ASHRAE's Standard 90-75 defines the generally accepted ranges of temperature and relative humidity in which normally active humans are comfortable. The comfort zone, or envelope, also defines by association the ranges of hot-humid, hot-dry, cool, and cold conditions.

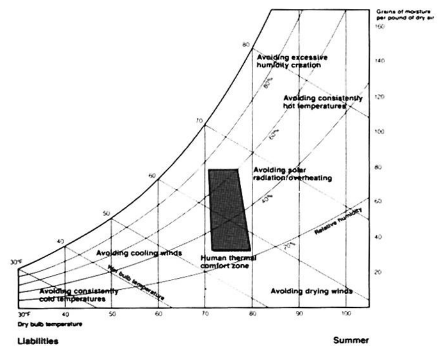
By plotting hourly temperature and humidity readings for an average day per month and linking the points plotted, one gets a graphic image of those conditions at a given location and time. If the "loop" is relatively level, vapor pressure stays close to constant. If the loop is long and open, temperature and humidity vary significantly throughout the day. A short, closed loop indicates minimal variation. A year of monthly loops gives quick indication of the region's general climatic assets and liabilities.

Correlating a third element with temperature and humidity can point out solutions to some of those liabilities. If hot-humid conditions prevail in an area, a wind rose documenting the winds that occur when those hot-humid conditions prevail will indicate, when juxtaposed, how effective designing for natural ventilation will be for easing those conditions.





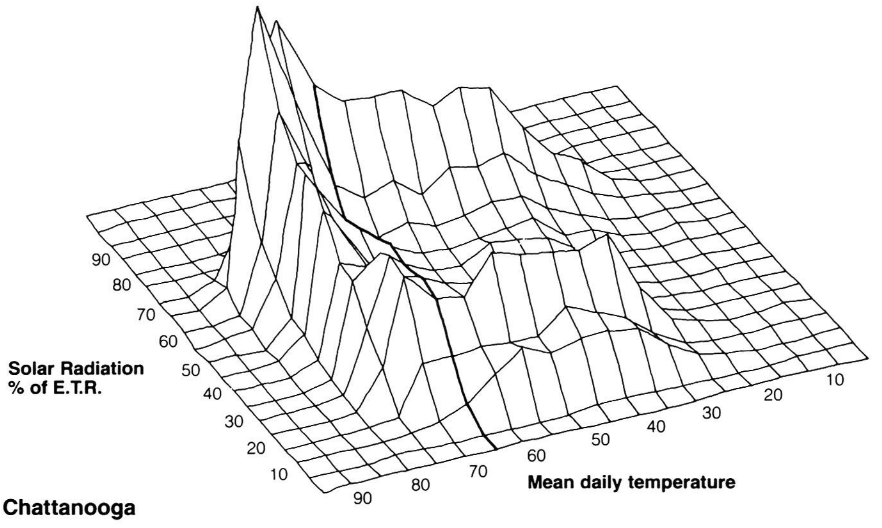


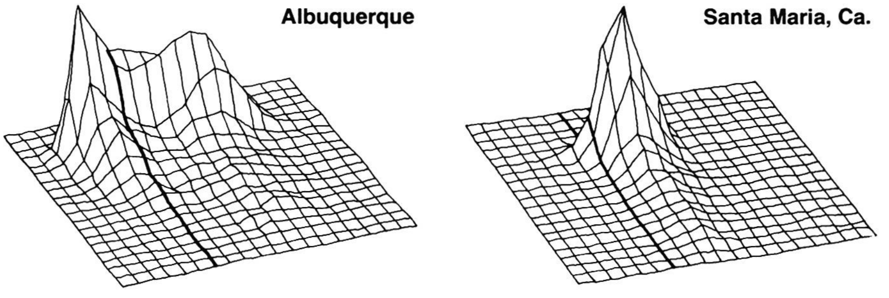


The temperature/humidity loops plotted for Chattanooga (top) show that the region's relative humidity is high year-round; temperatures range from 25-95°F. The psychrometric chart above illustrates climatic conditions in relation to ASHRAE's comfort zone; the charts at left, the climatic assets and liabilities that can dictate design strategy.

Sun/Temperature

The correlation of temperature and insolation can make clear where and when solar design techniques are appropriate. The "solar mountains" depicted here were computer-generated by the University of New Mexico's Raymond Bahm to chart active solar collector feasibility, but they apply to passive design as well. The correlation matches solar radiation striking the earth with mean daily temperature; the changing elevations document per cent of simultaneous occurrence. At temperatures above 65° heating is generally unnecessary, so elevations to the left of that line show a potential for solar overheating. Elevations below 30-40 per cent insolation show that solar heating—passive or active—won't contribute significantly. Elevations in the upper right quadrant—sunny days at lower temperatures—are the solar design optimum.



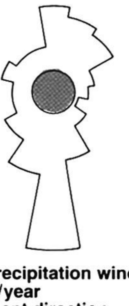


Chattanooga's "solar mountain" shows numerous cloudy days (low percentages of extraterrestial radiation) as well as sunny days—a difficult solar location. Albuquerque (left) gets consistently higher insolation across the temperature range—an ideal solar location. Santa Maria's moderate winters and sunny conditions present an excellent opportunity for passive design solutions.

Wind/Precipitation

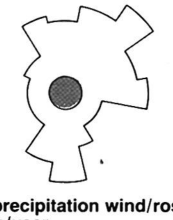
The Climate and Architecture conferees addressed non-thermal issues as well as those related to comfort and energy conservation. The correlation of precipitation and wind—which culminate in driving rain—affects entrance location, pedestrian shelter design, and window detailing. In a clear indication that climate-conscious design extends beyond thermal comfort considerations, the conferees also recommended that building climate summaries include such data as maximum inches of rain at a falling and maximum inches and weight of snow, so that such recent events as the leaking roof of Washington's Kennedy Center and the roof collapse at Hartford's civic center might be avoided by climate responsive architects.

Chattanooga Annual



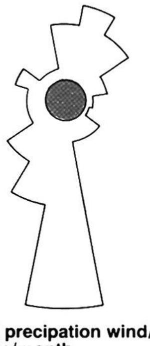
Annual precipitation wind/rose
8.6% rain/year
Predominant direction—south

Washington Annual



Annual precipitation wind/rose
8.5% rain/year
predominant direction—northeast

Chattanooga – January



Annual precipitation wind/rose
13% rain/month
predominant direction—south

Precipitation/wind roses pinpoint winds occurring when rainy conditions prevail. In Chattanooga (above left) southerly winds predominate for the 8.6 per cent of the year that rain falls there. In Washington, D.C. the rainfall percentage is similar, but wind direction varies significantly, prevailing northeasterly. The low percentage of calm on each rose, including Chattanooga's relatively blustery January (above right), shows that wind-driven rain predominates in both cities—an important factor for building detailing.

Climate and Architecture Conference

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