ARCHITECTURAL RESPONSE TO CLIMATIC PATTERNS

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1. INTRODUCTION

We have analysed several climates in terms of some basic recurring weather patterns, and then classified these patterns in terms of direct architectural response. This analysis allows the designer to organize and prioritize the vast array of architectural responses in a way that is appropriate for a particular climate.[1]

2. DATA CHARACTERISTICS

For a data base, we obtained computer tapes that recorded hourly insolation levels in addition to other climate variables. For these locations, only one year's data was used so we are less than certain that it is a true representative of the actual climate. However, we did have 9 years of information for one location and our analysis shows that the same major patterns (accounting for more than 70% of the year) recur each year, with only minor differences in their frequency of occurrence.

3. METHOD

Our work utilizes the thermal comfort zone as defined by Olgyay[2] which lies roughly between 21° and 27°C (70° and 80°F) and between 20-80% relative humidity. It assumes shading and still air but unregulated air changes. We defined the modified comfort zone (MCZ) to include those combinations of relative humidity, temperature, wind speed, and insolation which would result in a feeling of comfort even outside that narrow zone. For example, if the air temperature is below 21°C (70°F), the lower limit of the standard comfort zone (SCZ), but there is sufficient insolation to balance the body's heat loss and there is no

wind, then this point is within the MCZ. This larger zone, which includes the SCZ, can theoretically demonstrate comfort as low as 10°C (50°F) or as high as 32°C (90°F).

Outside the built environment, thermal comfort results from a delicate balance of the several climate variables. This balance occurs relatively rarely in North American climates. However, if some of the variables are manipulated architecturally, then the frequency of comfortable periods can be increased dramatically. The variables which can be controlled most easily architecturally are insolation and wind which can be blocked, filtered or admitted, when available. We were able to classify each hour of the year in terms of what would be architecturally necessary to produce comfort, and classify each climate on the basis of the frequency of these responses.

In order to facilitate pattern identification and comparison between different locations we have simplified the data by the smoothing technique of looking only at those codes which occur in two consecutive hours. Climate analysis for architectural design in the past has been based on the use of averaged data usually in combination with a description of the extremes for some time period. But the conclusions drawn from this data are misleading because a) it encourages the belief that weather changes seasonally instead of daily and ignores the subtle variation that climate-sensitive architecture might easily respond to; b) it ignores the interactive effect of the several climate variables which is of critical importance when designing for a dynamic climate.

4. THE CHARACTERISTICS OF FOURTEEN CLIMATES

While a very small proportion of the time in any climate falls within Olgyay's standard comfort zone (SCZ), a surprisingly high percentage of hours of the year fall in the MCZ (see Table 1).

[1] Brown & Novitski, "A Method for Analysing Climate in Terms of Architectural Response", Proceedings, Solar '79, Seattle, WA, August 1979.

[2] Olgyay, V., Design with Climate, Princeton University Press, Princeton, New Jersey, 1963.

Table 1. Per cent of time in Standard Comfort Zone (SCZ) and Modified Comfort Zone (MCZ)

Location	SCZ	MCZ	MCZ 8am-5pm
Dodge City, KS	0	28	29
Madison, WI	1	20	39
Medford, OR	1	22	42
Miami, FL	1	44	74
Phoenix, AZ	4	35	45
Seattle, WA	0	15	30
Santa Maria, CA	0	25	66
El Paso, TX	1	38	49
Fresno, CA	1	33	53
Albuquerque, NM	0	26	41
Charleston, SC	0	26	54
Bismarck, ND	1	20	36
Blue Hill, MA	1	19	36
New York, NY	1	22	39

Figure 1 shows the distribution of these potentially comfortable periods for the fourteen locations under consideration. It is important to note that all of the points plotted would be times of thermal discomfort without appropriate architectural or other controls.

The periods of MCZ are still greater if seen in a particular time frame: from 8 am to 5pm, for example, as one might do in designing an office building; or from noon to 1pm only, for a lunch room. Fig. 1 shows how thermal design criteria vary depending on the time frame under consideration.

Most of the climates shown are temperate, with the best weather occurring in the summer, but there are large differences between climates with this basic one-peak shape: the peak may happen as early as June (Fresno, CA) or as late as August (Blue Hill, MA); a rounded curve indicates a longer period of nice weather (Dodge City, KS) while a sharp point indicates a short summer (Seattle, WA): a tall peak shows periods where the MCZ occurs day and night (El Paso, TX) while a shallow peak indicates that even in the best weather, there are large parts of the day that are still uncomfortable (Santa Maria, CA).

Hotter climates have two peaks per year, spring and fall. The depth of the valley in between indicates the degree of overheating in the summer. While this is most marked in Miami, FL it is also evident in Phoenix, AZ and in Charleston, SC. This trend is also responsible for the small dips in the top of the curves in Medford, OR and Bismarck, ND.

The daytime MCZ is typically greater than the 24-hour MCZ in temperate climates because cold nights are responsible for much of the non-MCZ times, even in the summer. In hotter climates (El Paso, TX; Phoenix, AZ) when the curves for daytime MCZ fall below that of the total MCZ, this means that the days are over-

Fig. 1 Frequency of MCZ
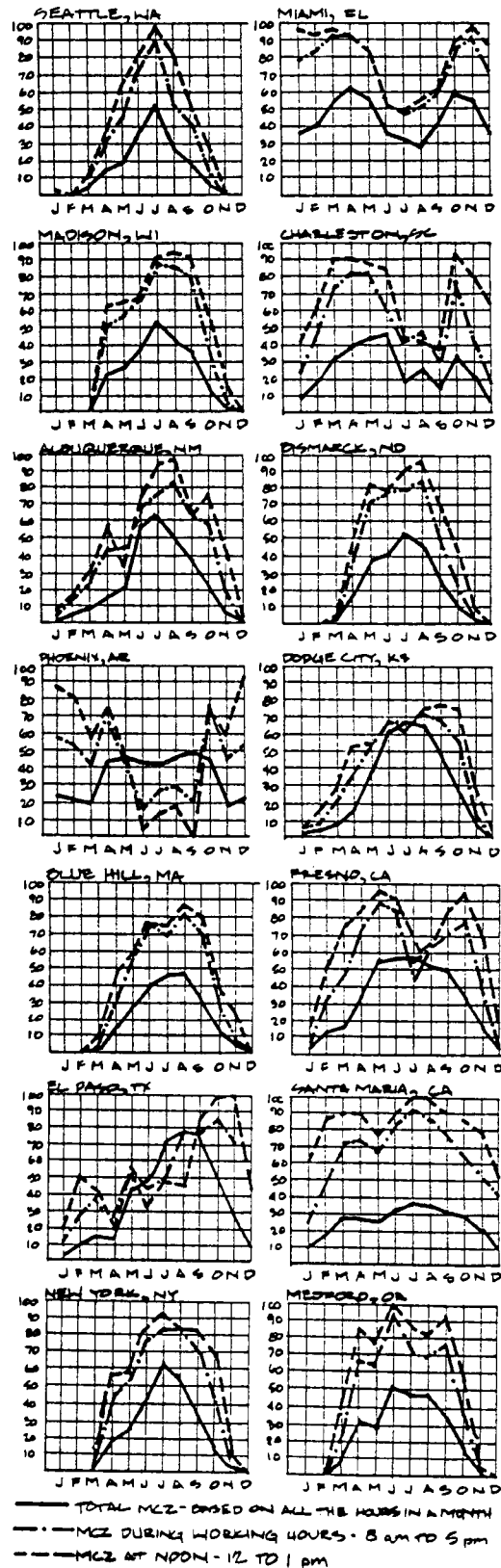
heated and the comfortable periods happen at
night. Miami is an interesting exception in
that the overheated periods in the summer
occur at night, while summer daytimes are
relatively comfortable.

We have catalogued the daily sequence patterns
that the various response types form through-
out the year. One frequently occurring pat-
tern is the "C-210-C" sequence: cold at
night (C); nice in the morning if the wind is
blocked and the sun admitted (210); and then
cold again in the evening (C). A second pat-
tern, occurring less frequently but still
shared by many climates is "C-210-020-C"
which is the same as the above but with nice
weather in the afternoon only if the sun is
blocked (020). A third pattern "C-210-020-
200-C" is similar to the last except that
after sundown comfort is still achievable by
blocking the wind (200) before the night be-
comes cold.

Figures 2-4 show the extent to which these
patterns are shared by the 14 climates. The
fourth pattern included, "C", means too cold
all day.

Figure 2 was constructed by selecting the
month for each place that showed the greatest
frequency of the pattern "C-210-C". Each bar
indicates the frequency of the other 3 pat-
terns as well. Similarities can be seen be-
tween climates in that these patterns are
shared although the similar climatic charac-
teristics occur at different times of the
year for different locations. Further simi-
larity can be shown in terms of the secondary
patterns which are common to several loca-
tions. For example, Santa Maria and El Paso
are similar in that there are no dominant
patterns besides "C-210-C". Albuquerque and
Charleston are similar in that, while C-210-C
is the dominant pattern for the month in
question, the secondary pattern "C" is also
significant. It can be argued that Bismarck
and Fresno are similar in that they share the
same three patterns even though the distribu-
tion of the three is greatly different. This
is because a building designed to respond to
these 3 patterns for a given month would have
to adjust its responsiveness from one day to
the next, so the exact frequency of each
response is not important.

Figure 3 was similarly constructed by select-
ing the month for each location which had the
highest frequency of the pattern "C-210-
020-C". Again, different months are represented
but similarities are evident relative to the
shared patterns (e.g., Phoenix in January and
Seattle in June).

Figure 4 shows the same for locations sharing
the pattern "C-210-020-200-C".

In these three figures, the amount of time
accounted for by shared patterns rarely

approaches 100%. The remainder is accounted
for by low frequency patterns.

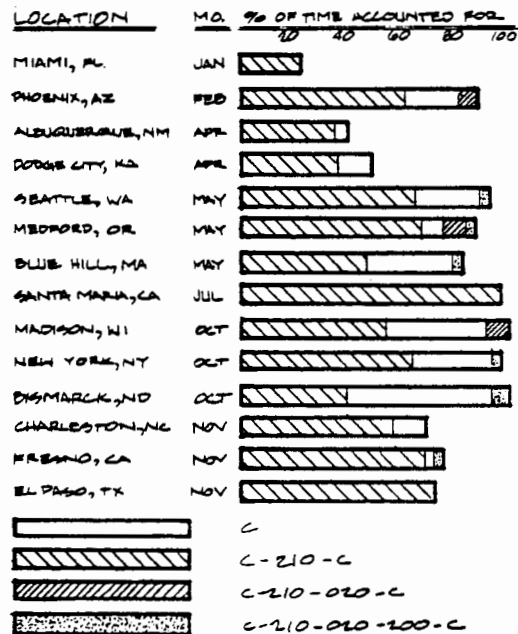Fig. 2 Maximum Occurrence of "C-210-C"
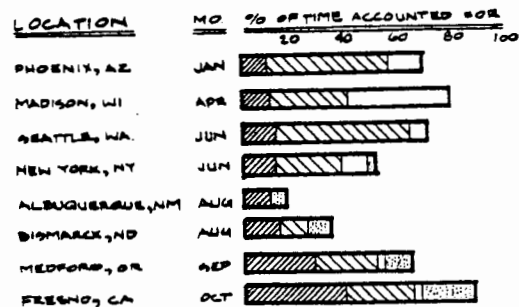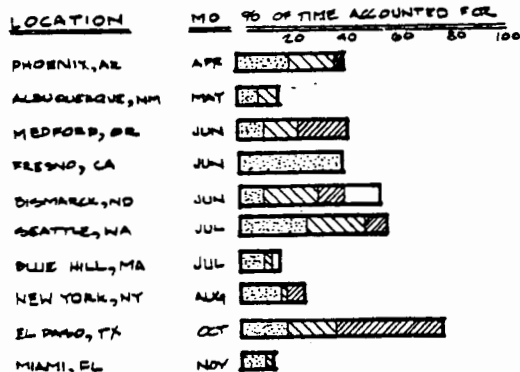

Fig. 3 Maximum Occurrence of "C-210-020-C"

Fig. 4 Maximum Occurrence of "C-210-020-200-C"

5. ARCHITECTURAL DESIGN IMPLICATIONS

The characterization of climate in terms of recurring daily and seasonal patterns is valuable to the designer because it organizes the larger array of architectural design techniques. An understanding of the set of patterns within a particular climate provides the designer with 3 important pieces of information:

First, what are the appropriate architectural responses to that climate; second, how important are they relative to each other; and third, when do they occur in terms of time of day and time of year.

One significant characteristic of the patterns we have looked at is that they are continuously changing, both daily and seasonally. An architectural response to these changes must also be dynamic, in order to remain in the MCZ. For example, on a daily level the pattern "C-210-020-C" suggests a change from complete architectural enclosure to control heat loss (C) to no enclosure required if shade is available (020). Like other patterns we have investigated, it shows a "reversal" from admit sun in the morning (210) to block sun in the afternoon (020).

Understanding and selecting the appropriate architectural design techniques for a given set of patterns is somewhat easier if the techniques are organized into 3 categories. (1) Static Form response, such as a roof for shading, do not change over time. Static forms can respond dynamically to those climate patterns which are themselves dynamic, but predictably so. For example, a south-facing roof overhang takes advantage of the predictable change in the sun's altitude from summer to winter by shading south-facing glass in warm periods and admitting sun in cool periods. Initial examination indicates that static forms are most useful for accommodating pattern reversals at the seasonal level.

(2) Dynamic Forms in architecture respond directly to diurnal pattern reversals by changing on an hourly basis. For example, an operable window can both block wind and admit wind in the same day; a venetian blind can be easily switched to block or admit direct insolation. Easily manipulable components are clearly desirable for daily changes.

(3) In Migration the inhabitants move from one comfortable place to another as the daily pattern changes. This response is frequently used to change from lots of architectural enclosure to little, and is exemplified by the pueblo dwellers in traditional architecture and by summer barbeques in modern times.

Climate-sensitive design techniques can also be organized in terms of scale. For example,

if the required response is to block wind, this may be accomplished at the site scale by using trees for a windbreak, at the cluster of buildings scale by creating wind shadows for outside areas, at the building scale with an enclosing envelope, or at the component scale with operable windows. The appropriate design response may be at one scale or at a combination of scales, depending on the behavior of the pattern in question, the nature of the building being designed, the characteristics of the site, etc.

Climate-sensitive design is therefore complex in that it simultaneously considers: (1) the issue of forms and migration, (2) several levels of scale, (3) the fact that optimally a particular element will satisfy more than one design requirement (e.g., a window will block wind while admitting sun).

Indigenous architecture has dealt with these complexities by virtue of an evolving understanding of a single climate/building relationship over a long period of time. In lieu of this ingrained experience, a designer must have access to a detailed description of the appropriate architectural responses for a particular climate in order to take best advantage of a site's natural energy to maximize human thermal comfort.

6. NOMENCLATURE

MCZ - modified comfort zone
SCZ - standard comfort zone

7. REFERENCES

Brown, G.Z. and B-J Novitski, "A Method for Analysing Climate in Terms of Architectural Response", Proceedings, Solar '79, Seattle, WA, August 1979.

Olgyay, Victor, Design with Climate. Princeton, New Jersey: Princeton Univ. Press, 1963.

A METHOD FOR ANALYSING CLIMATE IN TERMS OF ARCHITECTURAL RESPONSES

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INTRODUCTION

We have developed computer-aided techniques for analysing climates in terms of the combined effects of insolation, air temperature, wind speed, and relative humidity and have linked these to specific architectural responses in order to establish some passive building design techniques that can be used to achieve thermal comfort in various climatic regions, taking maximum advantage of available natural energies.

This analysis allows the designer to organize and prioritize the vast array of architectural responses in a way that is appropriate for particular climates. Even without using thermal lag techniques, the need for mechnical heating and cooling can be reduced by 15-45%, depending on location, solely by an architectural sensitivity to the immediate behavior of the sun and wind.

DATA CHARACTERISTICS

For a data base, we obtained computer tapes from the University of Wisconsin Solar Energy Laboratory because they recorded hourly insolation levels in addition to other climate variables. We therefore had concurrent information, on an hour-by-hour basis of the pertinent variables (air temperature, relative humidity, wind speed, and insolation) which interact to form a complete description of a micro-climate.

The tape contains hourly data for one year for fourteen locations around the country, including representative locations from the major climate zones.

For the purposes of this paper we have chosen 6 of those 14 locations to examine: 2 in the Northwest and 4 others which represent a broad range of climate types.

For these locations, only one year's data was used so we are less than certain that it is a true representative of the actual climate. However, we did have 9 years of information for one location -- Madison, Wisconsin -- and our analysis shows that the same major patterns (accounting for more than 70% of the year) recur each year, with only minor differences in their frequency of occurrence. A design based on the data from any single year may therefore be capable of responding to variations from one year to the next.

Further analysis of several years of data from each location will be necessary to determine exactly how much variation in patterns is likely to occur from year to year, and what the representative patterns for a particular location are.

At this point we are most interested in developing the method of analysis and cannot provide verified pattern descriptions for particular locations.

METHOD

Our work utilizes the thermal comfort zone as defined by Olgyay which lies roughly between 70° and 80°F and between 20-80% relative humidity. It assumes shading and still air but unregulated air changes. We defined the modified comfort zone (MCZ) to include those combinations of relative humidity, temperature, wind speed, and insolation which would result in a feeling of comfort even outside of that narrow zone. For example if the air temperature is below 70°F, the lower limit of the standard comfort zone, but there is sufficient insolation to balance the body's heat loss and there is no wind, then this point is within the modified comfort zone. This larger zone, which includes the standard comfort zone, can theoretically demonstrate comfort as low as 50°F or as high as 90°F.

Our definition of the modified comfort zone assumes that there are infinite air changes and that the cooling effect of the wind can be balanced by the warming effect of the sun.

There are, of course, conditions which are so extreme that they can be brought into the modified comfort zone (e.g., too hot, too cold, too humid, or too windy). Frequently, however, these conditions may be passively moderated by utilizing thermal lag techniques and controlled air change rates.

Outside of the built environment, thermal comfort results from a delicate balance of the several climate variables. This balance occurs relatively rarely in North American climates. However if some of the variables are manipulated architecturally, then the frequency of comfortable periods can be increased dramatically. The variables which can be controlled most easily architecturally are insolation and wind which can be blocked, filtered or admitted, when available. Humidity can also be modified to some extent. More complex architectural responses that utilize thermal lag for heating or cooling may also be used to moderate air temperature.

This data in this paper relies on Olgyay's comfort criteria however other definitions of comfort could easily have been used. Using a computer, we analyzed a year of six places' climate. For every hour in the year we looked at the combination of temperature, relative humidity, wind speed, and available insolation. On the basis of this data, and Olgyay's definitions, we were able to classify each hour of the year in terms of what would be architecturally necessary to produce comfort.

Here, as an example, is Medford, Oregon in June, as described by our computer program.

Table 1.   MEDFORD, OREGON

	15	16	17	18	19	20	21	22	23	24	25	26
0	C3	C2	C2	C2	C2	C2	C2	C2	C2	C2	C2	C2
1	C3	C3	C2	C2	C2	C2	C2	C2	C2	C2	C2	C2
2	C3	C3	C3	C2	C2	C2	C2	C2	C3	C2	C2	C2
3	C3	C3	C3	C3	C2	C2	C2	C2	C3	C2	C2	C2
4	C3	C3	C3	C3	C2	C2	C2	C3	C3	C2	C3	C2
5	C3	C3	C3	C3	C2	C3	C3	C3	C3	C3	C3	C2
6	C3	C3	C2	C2	C3	C2	C2	C2	C2	C2	C2	C2
7	C5	C5	C5	C5	C5	C5	C5	C5	210	210	210	C5
8	210	210	210	210	210	210	210	210	210	210	210	210
9	210	210	210	210	210	210	210	210	020	020	020	210
10	210	020	210	210	210	020	020	020	020	020	020	210
11	210	020	020	020	020	020	020	020	020	020	020	210
12	020	020	020	020	020	020	020	020	020	120	220	020
13	020	020	020	020	020	120	120	120	120	120	220	020
14	020	020	120	020	120	120	120	120	120	120	220	020
15	220	120	120	120	120	120	120	H1	120	120	220	020
16	020	120	120	120	H1	120	120	H1	220	120	220	020
17	220	02	120	120	H1	120	120	H2	120	120	220	020
18	020	000	000	01	120	120	120	120	120	220	000	000
19	200	200	200	200	200	200	200	120	120	120	210	200
20	210	02	210	210	210	200	200	200	200	200	C2	C2
21	C2	C2	C2	02	C2	200	C2	200	200	200	C2	C2
22	C2	C2	C2	C2	C2	C2	C2	200	200	C2	C2	C2
23	C2	C2	C2	C2	C2	C2	C2	C2	C2	C2	C2	C2

The 3-digit code indicates times when the weather, though not ideal, can be directly architecturally moderated to produce thermal comfort. The two-character codes represent extremes in temperature (too hot or too cold) during which time either the lag properties of buildings or mechanical equipment is required to achieve comfort.

What follows is an interpretation of the codes for and a qualitative description of the weather on June 22, in terms of architectural responses.

Until 7 a.m., temperatures are cold, and buildings require some heat source (natural or mechanical, and moderated if the inhabitants are absent or under blankets) (C2 and C3); from 7 a.m. to 8 a.m., it's still cold, but the sun has come up enough to make the insolation collectable (opened drapes on the south and east windows) (C5); from 8 a.m. to 10 a.m., chilly temperatures are tolerable as long as the wind is blocked and the sun is admitted (interior or protected spaces, with direct solar gain) (210); from 10 a.m. until 1 p.m. the wind has died down, but the air temperature is rising, so the sun must be blocked for comfort (overhangs on southfacing windows, or lunch under a deciduous tree) (020); from 1 p.m. to 3 p.m., the direct sun must still be blocked, and although the temperature is still rising, the wind speed has picked up again, and if admitted, will provide comfort (indoors: an opened window, with closed venetian blinds; outdoors: an open structure with an opaque roof but no walls) (120); from 3 p.m. to 6 p.m., it is simply too hot for comfort (either because the wind has died again or because the temperature is so high that no amount of wind can cool effectively) (H1 & H2); from 1 p.m. to 8 p.m., like from 1 p.m. to 3 p.m. earlier, comfort is possible by blocking the sun and admitting the wind (120); from 8 p.m. to 11 p.m., even though the sun has gone down, the evening is pleasant as long as the wind is blocked (indoors: closed windows; outdoors: a walled-in barbeque area) (200); finally at 11 p.m., the ambient air temperature drops below the comfort level and will stay there until sunrise the next day (C2).

In order to facilitate pattern identification and comparison between different locations we have simplified the data by the smoothing technique of looking only at those codes which occur in two consecutive hours. Initial inspection indicates that the smoothed patterns which result are not significantly different than the "real" patterns in terms of architectural response, however the resulting simplification greatly reduces the problem of translating patterns into architectural design criteria. Since the frequency of uncomfortable, unmodifiable weather outweighs the frequency of the "modified comfort zone" in every climate we've examined, error in this smoothing technique will tend to underestimate the hours which fall in the MCZ.

COMPARISON OF ANALYSIS TECHNIQUES

Climate analysis for architectural design in the past has been based on the use of averaged data usually in combination with a description of the extremes for some time period. This data is used to construct an average day or month which is then used as a basis for determining architectural response. While this information is at some levels valuable it does tend to disguise the dynamic character of climate. For example an average day could be constructed from a month's averages for each hour. The resulting "day" might exhibit one of several patterns that we have identified for that month. But the conclusion to draw from this "day", for the purposes of architectural design will be misleading beacuse a) it encourages the belief that weather changes seasonally instead of daily and ignores the subtle variation that climate-sensitive architecture might easily respond to; b) it ignores the interactive effect of the several climate variables which is of critical importance when designing for a dynamic climate.

A more common (and still more misleading) climate analysis technique is one in which averages are calculated for an entire month at a time, or even a whole year (e.g. annual degree days). Most climatic realities are washed out in the process, and the potential for balancing sun and wind with air temperature is lost.

THE CHARACTERISTICS OF SIX CLIMATES

We found that thermal comfort, except in extremes of weather, was possible to achieve with relatively little assistance from mechanical systems. While a very small proportion of the time in any climate falls within Olgyay's standard comfort zone, a surprisingly high percentage of hours of the year fall in the MCZ.

Table II.   POTENTIAL THERMAL COMFORT INCREASES THROUGH CLIMATE-SENSITIVE ARCHITECTURE FOR SELECTED LOCATIONS

| Location	% of time in standard comfort zone	% of time in modified comfort zone
1. Dodge City, Kansas	0	28
2. Madison, Wisconsin	1	20
3. Medford, Oregon	1	22
4. Miami, Florida	1	44
5. Phoenix, Arizona	4	35
6. Seattle, Washington	0	15

The following graphs show the distribution of these potentially comfortable periods for the six locations under consideration. As would be expected, the summer is most comfortable in temperate climates and the spring and fall in warmer ones. It is important to note that all of the points plotted would be times of thermal discomfort without appropriate architectural or other controls.

Of the several architectural response types that we have identified, two have emerged as the most important for most climates.

The first of these is the response to sunny but chilly weather such as is common in the Northwest on clear days in the spring and fall, and on summer mornings. Comfort is achieved from direct solar radiation as long as the wind is blocked. According to Olgyay, air temperatures as low as 50°F can be comfortable during these periods. This 210 "Block wind – admit sun" response can be put to one's advantage in any temperate climate, for much of the year, with a minimum of architecture (e.g. an unshaded wind break), and independently of any higher technology. Note that it is also appropriate in warmer climates, in the winter.

The second predominant response type is opposite the first:
when air temperatures go higher than normally comfortable
levels, thermal comfort can be achieved by blocking the sun
while admitting the wind (120). Most summer over-heating
problems in the Northwest fall in this category and can be
solved by a nice shade tree.

Fig.1. Frequency of MCZ, 120 & 210.

DODGE CITY   MADISON

MEDFORD   MIAMI

PHOENIX   SEATTLE
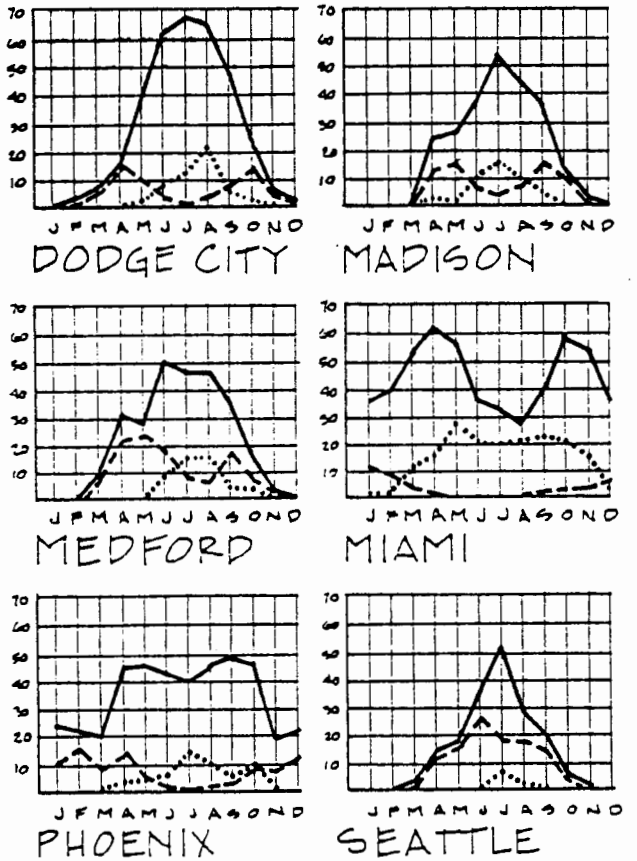
——————— MODIFIED COMFORT ZONE - MCZ
— — — — IN MCZ IF WIND BLOCKED & SUN ADMITTED-210
·········· IN MCZ IF SUN BLOCKED & WIND ADMITTED-120

In looking at how these responses and others combine into
recurring patterns throughout a day we found that many
pattern sequences were common to most or all locations --
but with distinct variations in seasonal frequency, depend-
ing on the location.

One of the most common patterns (C-210-C) is one in which
nights are cold but some portion of the day is comfortable
if the wind is blocked and the sun admitted. [These are
times when the passive collection of solar energy is possi-
ble and desirable.] This pattern occurs frequently in the
Northwest in the spring and fall, but also, to a lesser
extent in the winter in warmer climates.

Another "universal" but less frequent pattern (C-210-020-
200-C) is one in which again, nights are cold, and mornings
and evenings are comfortable if the wind is blocked, but
afternoons are so warm that the sun must be blocked, with
wind admitted, to achieve thermal comfort without air-
conditioning. In one day the weather changes from heating
phase to cooling phase and back again. [This "reversal"
shows how important it is to design environments which can
change from hour to hour as well as season to season.] And
it is clear that the potential for thermal lag to moderate
these extremes is enormous.

Fig.2. Frequency of C-210-C & C-210-020-200-C Patterns.

DODGE CITY   MADISON

MEDFORD   MIAMI

PHOENIX   SEATTLE
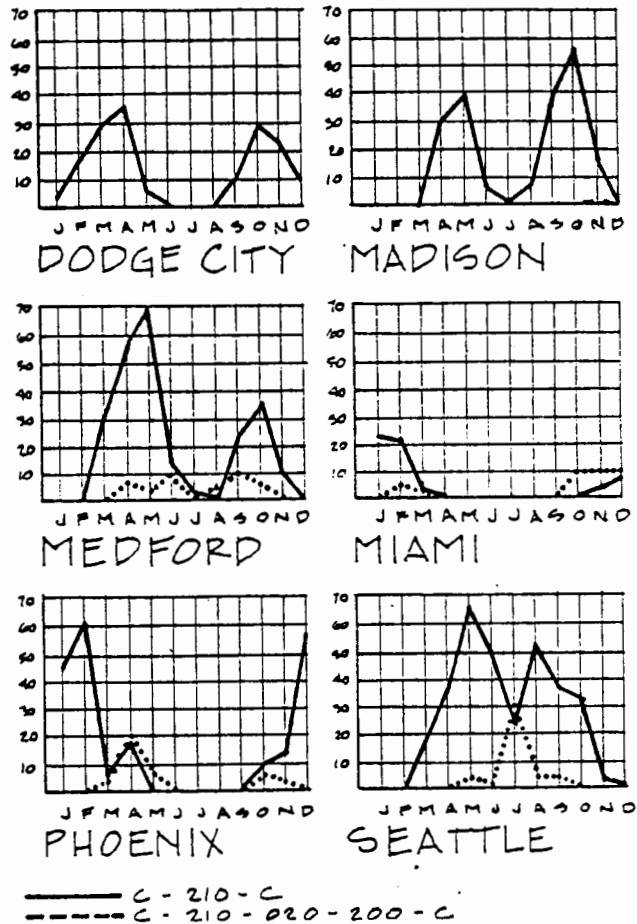
——————— C - 210 - C
— — — — C - 210 - 020 - 200 - C

We were surprised to discover that a similar daily climatic
pattern occurred in other locations we investigated, only
with calendar variations: Madison's summer, Miami's winter,
Phoenix's autumn, etc., are all like Medford's spring. We
speculate that similar architectural patterns could be
developed for these varied climates without neglecting the
particular problems each has in its extremes.

It may be that it will be more useful from a building design
standpoint to stress the similarities rather than the dif-
ferences between climates if we can identify universal con-
stants to investigate the differences.

ARCHITECTURAL DESIGN IMPLICATIONS

Looking at one of these places more closely, it becomes
immediately apparent why and when climate-sensitive architec-
ture is important.

Here is a breakdown by month of the standard and modified
comfort zones for Medford, Oregon. Note that in Table II,
Medford fares poorly, relative to other parts of the
country. Even so, in Figure 3, we show that even in
Medford, the number of potentially comfortable hours is far
higher (especially during the day) than is normally assumed.

This graph demonstrates how the periods of thermal comfort
can be substantially increased (except from November through
February) through direct architectural methods.

They also show how the reliance on mechanical systems can
be reduced still more if the design context is one in which
full conditioning is required primarily during waking
hours (housing) or primarily during working hours (office
buildings).

Fig.3. The Comfort Zone in Medford
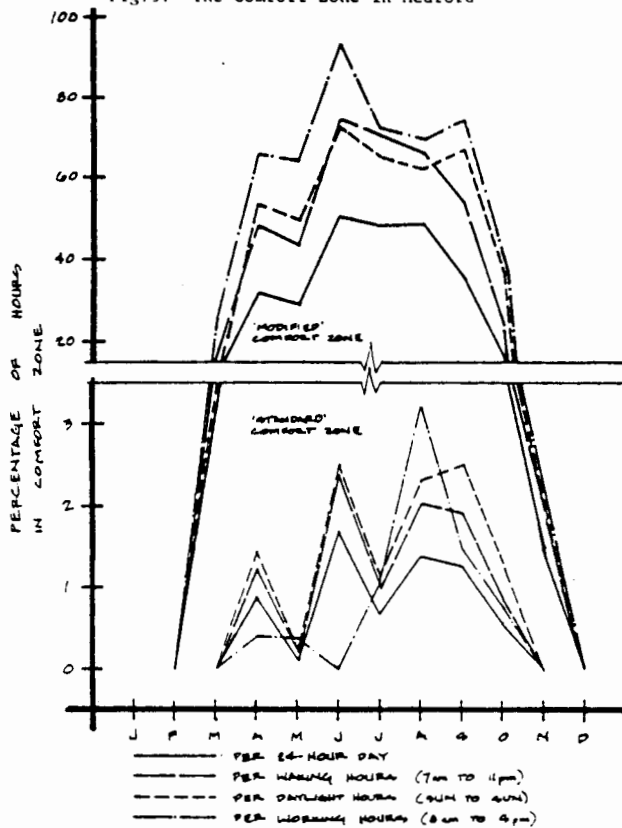
We have begun to look at how responses vary throughout the year. In the following example, the hour between noon and 1 p.m. is examined (as it might be by someone interested in designing a lunch room).

Each of the six identifiable "seasons" was found by choosing calendar intervals during which 95% of the climatic variation could be accounted for by 2 or 3 dominant responses. Table III shows a gradual shifting of these patterns through

Table III. MEDFORD AT NOON -- A SUMMARY OF A YEAR'S CLIMATE RESPONSE FROM NOON TO 1 P.M. (VALUES GIVEN ARE PERCENTAGES PER SEASON.)

Identifiable Seasons (#of Days)	Medford	Climate			Responses	
	C2	C8	210	120	H	TOT
Oct. 21 - March 4 (135)	29	70				99
March 5 - April 11 (38)		42	58			100
April 12 - June 6 (56)		14	71	11		96
June 7 - July 8 (32)			16	81		97
July 9 - Aug. 31 (54)				78	19	97
Sept. 1 - Oct. 20 (50)		6	48	42		96
Total # of Days	39	118	91	95	10	97

C2   Too cold; no collectable insolation
C8   Too cold, but with collectable insolation
210 In MCZ if wind is blocked and sun is admitted
120 In MCZ if sun is blocked and wind is admitted
H   Too hot, even with sun blocked and wind admitted
TOT Percent of hours accounted for

time. Within each season, a structure would ideally be capable of responding interchangeably to the several dominant responses, at least one of which would also be dominant in the season preceding and/or following.

This suggests a design which not only changes through time, but which has a number of changeable elements that can be controlled, on a day-to-day basis, independently of one another. Architectural variation throughout the year, then, takes on a more organic character in that no change is sudden; rather each season gradually introduces a new response while gradually phasing out an old one.

The characterization of climate in terms of recurring daily patterns is valuable to the designer because it organizes the existing array of architectural responses to climate (roof overhangs, operable windows, wind blocks, solar heating, etc.). The existence of a certain set of patterns within a particular climate tells the designer three important pieces of information. First, what are the appropriate architectural responses to that climate; second, how important are they relative to each other; and thirdly, when do they occur in terms of time of day and time of year.

A review of the patterns that characterize Medford, Oregon indicates that 85% of the year can be described by just four architectural response pattern types. These are, in order of importance:

1) Too cold all day, but with periods of collectable insolation.
2) Too cold at night, but in the MCZ during the day if wind is blocked.
3) Too cold at night but in the MCZ in the morning and evening if wind is blocked, and in the afternoon if sun is blocked.
4) Same as (3) but with overheating in the afternoon.

Fig.4. The Distribution of Pattern Types in Medford
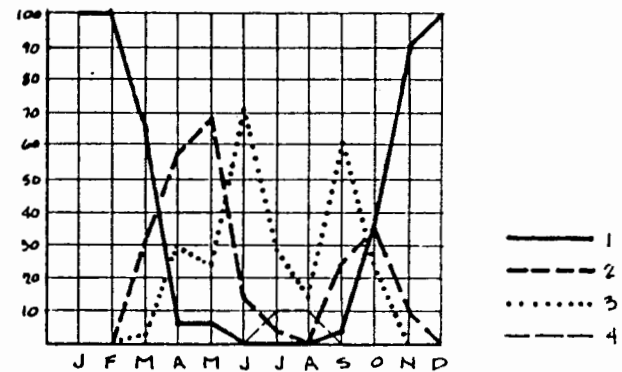
Using these response pattern types, with an understanding of sun position and wind direction, one can optimize a building which creates a large modified comfort zone and utilizes thermal lag for heating and cooling.

CONCLUSION

This method of climate analysis allows the designer to establish, for a particular location:

1) What architectural responses to climate are important.
2) How important these responses are relative to each other.
3) When the responses occur during the day and year.
4) How the responses are related to each other.

Preliminary analysis of six locations indicates that the patterns formed by these responses occur in all locations but at varying times and with different frequencies. Several of the architectural responses (not including a building shell) utilize the immediate behavior of the wind and sun, and can provide comfort for large portions of the year in each location.