CONTROLLING AIR MOVEMENT

A MANUAL FOR ARCHITECTS AND BUILDERS

Terry S. Boutet

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Preface

Modern architectural practice embraces a wide field of information from building materials to behavioral science; consequently, reference books are the greatest tools available to conscientious designers. *Controlling Air Movement* is such a tool. It is a guide to air movement in residential structures and utilizes over 300 illustrations. Its objective is to present the variety of design options for air movement control that are available to designers and the impact those options have upon the final building form, total design image, solid-void relationships, and the structure's relationships to its site configuration, orientation, topography, and landscaping.

This book centers on implementing the positive effects of air movement as a way to improve the quality of living through optimum application to residential structures. The benefits include improved air quality, energy conservation with reduced operational costs, and superior human physical and mental comfort.

In addition, methods of studying air movement are compared and analyzed. Basic principles of air movement control are thoroughly described with an emphasis on building forms, openings, projections, and partitions.

From the data presented in this book, a thorough index, described and illustrated, of air movement control techniques is developed. Those techniques, tested with models in a kerosene smoke airflow chamber, consisted of designs by practicing architects and the author. Consistently, the focus of *Controlling Air Movement* is on the potential benefits of securing optimum air movement in residential structures through the application of proper control techniques.

To date, no single presentation of information on air movement control has covered all the possible site characteristics, building configurations, opening variations, and other design modifications, nor has any presentation documented the various probabilities. I have personally searched through thousands of books and articles in the engineering, architectural, medical, agricultural, and energy fields without finding a single document

that begins to contain the volume of information found in this book. Also, the format permits easy usage and quick reference.

Architectural designers cannot spend great amounts of energy and time resolving the climatic needs of each and every design problem, nor can they start with assumptions about important features of each building with regard to air movement control. Instead, they need ready facts upon which to base intelligent decisions. This book unites the explorations of past researchers and develops a relatively comprehensive guide of known air movement control techniques. In short, this book is a necessary tool for conscientious designers whether they are professional architects, architectural educators, intern architects, or architectural students.

Controlling Air Movement is a valuable reference for the professional architectural society as well as other building designers, and it will provide a needed service and be a wise investment for architectural designers. designers.

Terry S. Boutet

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Chapter

1

Air Movement

Architectural designers can no longer ignore the effects of climate on buildings; they must understand and use the fundamentals of air movement to improve their designs. Though the task is complex, they must consider the prevailing weather conditions to build durable, efficient, aesthetic, and economical structures.

Climate affects every design solution however sophisticated; prevailing weather conditions alter the environment in and around structures. Thermal and moisture distribution systems are the major factors, and thermal distribution has the greater effect on comfort. Since air movement distributes most of the earth's heat, architectural designers must use it to design for comfort. To do so requires a thorough understanding of basic principles.

Terminology

Some terms need clarifying; others will be defined as they are introduced. Various forces cause air to move across the earth. The types of air motion are defined by those forces.

Air, the atmosphere that surrounds the earth, is a mixture of gases. *Air movement* is a change in position of air regardless of the cause or degree.

Wind is the natural form of air movement; usually but not always the movement is horizontal.

Ventilation is the process of supplying unconditioned or conditioned air to and removing it from a given space by any method. For example, when wind enters a bedroom, it becomes ventilation, but it is always air movement.

Ventilation is classified by the force acting on the air: *Natural ventilation* depends on natural forces; *induced ventilation* depends on influencing natural forces to perform specific tasks as in a thermal chimney; *forced ventilation* depends on mechanical methods. *Cross-ventilation*, a loosely applied term, actually refers to air movement across a space connected by openings to both positive and negative pressure areas of the exterior.

Buoyancy, a force that creates air movement, is the tendency of air to rise because of thermal differentials (Figure 1.1). It is *positive*, *neutral*, or *negative* in reference to its ability to move air. High air density creates

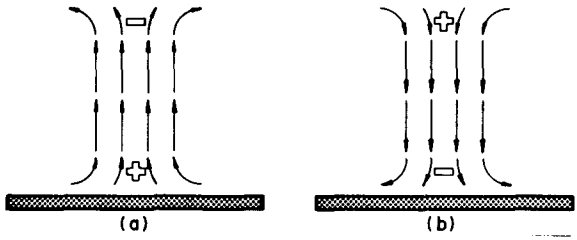

Figure 1.1 Variations in air density due to thermal differentials may cause air to (*a*) rise (buoyancy) or (*b*) fall (reverse buoyancy).

positive buoyancy; low air density creates negative buoyancy. Air moves from positive to negative through neutral buoyancy, in which the air density is neither high nor low. *Reverse buoyancy* may occur when the air tends to fall because of thermal differentials. Whatever the cause of buoyancy, air movement must be from positive to negative.

Pressure, a force that creates air movement, is the shifting of air caused by force differentials (Figure 1.2). It also is positive, neutral, or negative. Positive pressure occurs when the force and air density are high; negative

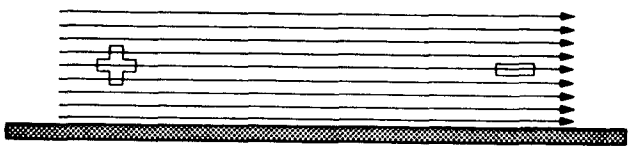

Figure 1.2 The action of force differentials on air movement is known as pressure. Air moves from positive to negative pressure zones.

pressure occurs when the force and air density are low. Air travels to negative from positive through neutral pressure, in which the force and air density are neither high nor low. Air movement always occurs in a positive-to-negative fashion.

Climate, the prevailing weather conditions of a given region, is commonly considered at three principal levels (Table 1.1). The *macro-climate* comprises the weather conditions of a large region such as a continent or country. The *meso-climate* comprises the weather conditions of a region that is neither large nor microscopic, such as a state, county, or city. The *microclimate* comprises the weather conditions of a very small, or microscopic, region such as a leaf, blade of grass, or sidewalk crack. A relatively new term is *micro-climate*, which is easily confused with microclimate. A micro-climate comprises the weather conditions of a small region such as a city block, acre, lot, or garden.

TABLE 1.1 Principal Climatic Scales

Climate	Scale	Example
Macro-climate	Extremely large	Continent Country
Meso-climate	Moderate	State County City
Microclimate	Small	City block Acre Lot Garden
Micro-climate	Extremely small	Leaf Blade of grass Sidewalk crack

Air Movement Systems

Air movement is created by uneven heating of the atmosphere. As the sun heats it, the air expands, rises, and is replaced by cooler air. The exchange of air creates a cycle known as the *general circulation*, the major wind system of the earth.

Occurring as it does over large portions of the earth, the general circulation creates prevailing air movement. It is affected by differences in heating qualities of land and sea and by the position of the sun. Land is heated by the sun quicker than water; water retains more heat for longer periods of time. Consequently, the land and water almost always differ in temperature, and that causes the air masses over them to move (Figure 1.3). The sun constantly changes its position, and so the angle of

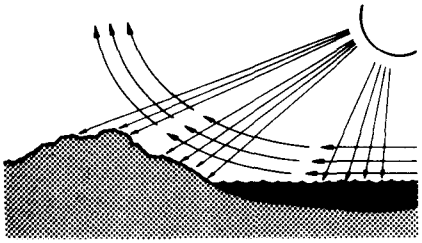

Figure 1.3 Temperature differences between land and sea cause air masses over land and sea to move. As the air rises over the warmer body, cooler air replaces it.

its rays varies through the year. The effect of the variation is to heat the earth unevenly and at varying rates. Because of that uneven heating, there are three main global belts of the general circulation in each hemisphere (Figure 1.4).

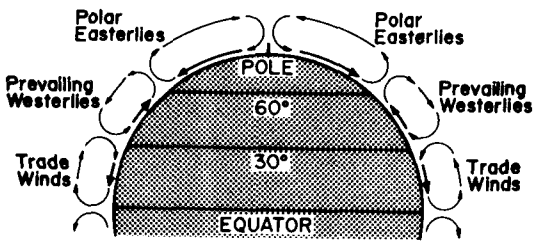

Figure 1.4 The prevailing air movement of the general circulation occurs in three main global belts within each hemisphere. The heavy arrows indicate the direction of air movement across the face of the earth.

The *trade winds* travel to the equator from approximately the 30° latitude in both hemispheres; in those regions the air moves from positive pressure to the equator's negative pressure zone. At the equator, the air rises, returns to the 30° latitude zone, and thereby creates a cycle.

The *prevailing westerlies* abut the trade wind belts in both hemispheres. Their cycles are opposite to those of the trade winds; the air moves to the negative pressure zones at 60° latitude from the positive pressure areas at 30° latitude.

The third global belt is the *polar easterlies*. The air moves from the north or south pole to the 60° latitude zone in a positive-to-negative pressure fashion. Where global belts abut, some air moves from one belt to another.

The global belts do not move in direct north-to-south or south-to-north fashion, however; instead they are curved. The cause of the curving, known as the Coriolis force, is the earth's rotating faster than the atmosphere, which is slowed by the friction of the earth's surface (Figure 1.5).

The force is zero at the equator, increases toward the poles, and has a magnitude proportional to the sine of the latitude.[1]*

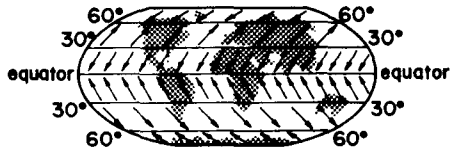

Figure 1.5 The earth's rotation creates a curving action of the global belts called the Coriolis force.

Secondary Circulation Systems

Within the general circulation system are several air movement patterns that have lesser intensities. They occur over small areas that usually involve positive and negative pressures (Figure 1.6). The air movement from positive to negative pressure areas is circular. Positive pressure areas are mountains of air as they rise above surrounding air because of increased air density, and the air movement spirals downward and outward. In negative pressure areas, the valleys of low air density, air movement occurs in a downward and inward spiral and causes the air in the center to rise. In these negative pressure areas, the rising air cools and condenses and often creates clouds, fog, and rain. These secondary circulation systems are unaffected by minor variations of the earth's surfaces, but they are affected by major land forms of the earth such as plains, mountains, valleys, plateaus, and seas.

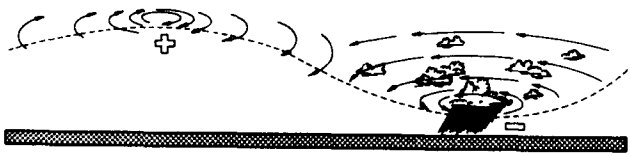

Figure 1.6 Air pressures of the secondary circulation systems vary as the air moves from positive to negative pressure areas.

Meso-climatic Systems

When the secondary circulation systems develop variations within themselves that are due to cities, housing developments, industrial centers, and so forth, meso-climatic systems are established. The driving forces at this

* Numbers in brackets are those of references listed at the ends of chapters.

level are pressure and buoyancy, which may work together or independently. Although their intensities vary, buoyancy is the weaker of the two, since thermal differentials are not as easily obtained as pressure differences. Buoyancy usually creates vertical air movement, whereas pressure creates horizontal air movement. Throughout the meso-climatic systems, a great variety of air movement may occur because of pressure, buoyancy, and terrain.

It is within the meso-climatic systems that architectural designers can begin to utilize air movement by controlling and altering the driving forces. On the micro-climatic scale, air movement can be transformed into ventilation traveling through architectural designs. A wealth of free energy is waiting to be used by the architectural designer.

REFERENCES

1. B. Givoni, *Man, Climate, and Architecture,* Applied Science, Ltd., England, 1976.

Chapter

2

Effects of Air Movement

Air movement, which influences air purity, temperature, and moisture, has a direct effect on human health, comfort, and well-being. Although occupant well-being is of primary concern, the building envelope must be considered as well. The way a residence relates to its microclimate determines the type of climatic environment within the structure. Consequently, air movement plays an active role in the quality of life.

Air movement in residences has three separate functions: *air quality*, *energy*, and *comfort*. B. Givoni called them "health ventilation," which refers to maintaining the air quality by replacing indoor air with fresh outdoor air, "structural cooling ventilation," which describes the method of cooling the structure when the indoor air temperature is higher than the outdoor air temperature, and "thermal comfort ventilation," which provides for a reduction of heat and moisture from the body into the surrounding air. [1]Although Givoni's categories are limited in scope, they are a basis for understanding the benefits of air movement with buildings.

Air quality, energy, and comfort describe the functions more thoroughly and are used in this book. *Air quality*, which describes the characteristics of the air, is a more suitable term than health ventilation. Not all health problems are caused by lack of air purity. The architectural designer must be concerned with both interior and exterior spaces. Ventilation starts where air enters the building, but its source of energy is the air movement of larger and more encompassing systems.

Energy involves both avoidance of heat gain and acceleration of heat loss, whereas Givoni's structural cooling employs only the release of gained heat.

Comfort encompasses both the physical and psychological aspects of human well-being. Givoni's thermal comfort, however, involves only the physical aspect.

Air Quality

Pollution arising from fuels used in homes to cook or create comfort and from human respiratory processes has always plagued humanity. Patricians of the Roman Empire complained about togas soiled by soot from "the heavy air of Rome and the stench of its smoky chimneys."[2] Air pollution, in residences as well as factories and plants, remains an important issue, and it is becoming more involved as technology advances. The solution is to stop air pollution at its source or to dilute pollutants so that the air can be cleansed naturally.

One of the easiest places to control residential air pollution is at its source within the home. Control must begin before the building is occupied. Many finishing materials used in construction, especially residential, introduce pollutants. Over 70 percent of a home's interior consists of materials that contain formaldehyde, which is suspected to be a human carcinogen (Figure 2.1). Even a concentration as low as one part in 100 million parts of air makes eyes water. In sufficient quantities, formaldehyde can cause lung irritation, nausea, vomiting, drowsiness, sore throat, headache, and fatigue.[3]

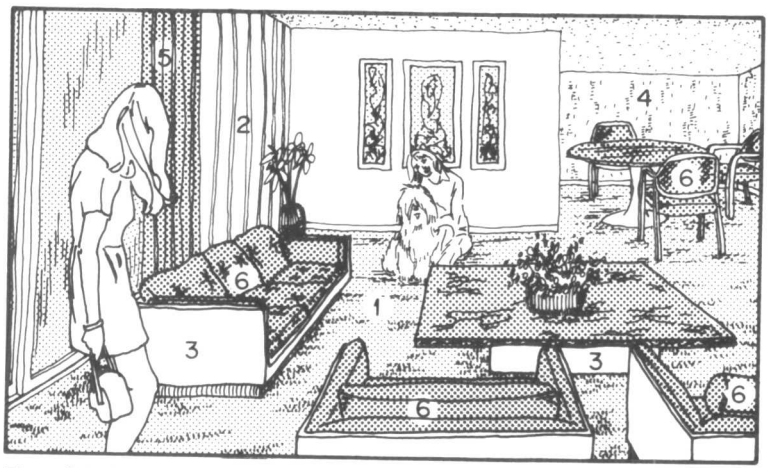

Figure 2.1 Formaldehyde from carpet (1), paneling (2), particleboard cabinets (3), wallpaper (4), curtains (5), and plastics (6) poses potential health threats unless the home is adequately ventilated.

The problem is not just with new building materials; it may last as long as 20 to 30 years.[3] Homeowners add still more formaldehyde in a variety of products: plastic appliances, permanent-press sheets, towels, soaps, plastic trash bags, hair spray, newspapers, cosmetics, clothing, disinfectants, plastic wraps, shampoo, and toothpaste. Nevertheless, the trouble can be reduced or eliminated by utilizing building materials with low

levels of formaldehyde, sealing the materials with a water vapor barrier, and providing adequate ventilation.

Radon, a byproduct of the radioactive decay of radium, cannot be avoided. It is found in soils and rocks, most commonly in Texas, Pennsylvania, Tennessee, Colorado, New Hampshire, Maine, Montana, and Florida and especially in residences built over old granite and phosphate mines (Figure 2.2). Radon was found in excessive levels in 15 percent of thousands of homes tested in eastern Pennsylvania, posing a high lung cancer risk.[3] "Indeed, health authorities now believe that exposure to radon is the second leading cause of lung cancer in the United States, accounting for some 5000 to 20,000 new cases per year."[4] Unfortunately, it cannot be completely eliminated, but its quantity can be reduced by as much as 90 percent by isolating the building from the soil and providing proper ventilation.

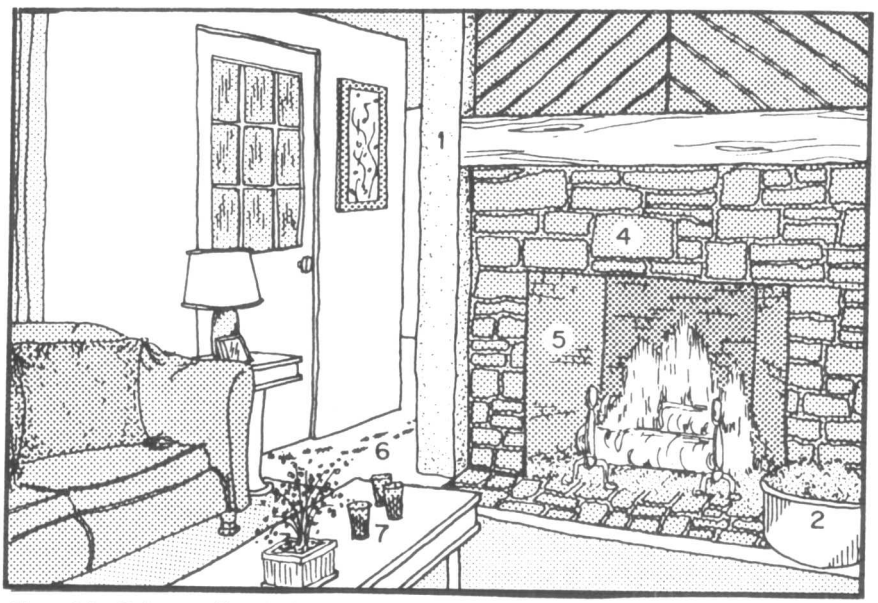

Figure 2.2 Radon, a radioactive byproduct found in concrete (1), sand (2), gravel (3), stone (4), brick (5), soil (6), and drinking water (7), may become confined within a closed house and concentrated to levels up to 10 times higher than those outdoors.

Household products introduce other interior pollutants. "In the home of Mr. and Mrs. Average American are 45 aerosol sprays."[3] Examining the home reveals a large number of other products that may cause pollution (Figure 2.3). A scented product adds substances to the air that may or may not be desirable. Furthermore, the problem of household product pollution is dual: pollution from the product's chemical content may