ENERGY CONSERVATION AND COST CONTROL IN PREFABRICATED HOUSING

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ABSTRACT

Energy Conservation and Cost Control in Prefabricated Housing

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Submitted to the Department of Architecture on January 28, 1976 in partial fulfillment of the requirements for the degree of Master of Architecture

The purpose of this thesis is to investigate ways in which a low-cost prefabricated building system can be modified at the climate/building interface to enrich the quality of the living environment through energy-conscious design. These principles are reflected in two ways: by their effect on building design and by their effect on controlling costs of long-term maintenance requirements. In addition, control of initial capital outlay through financing and through prefabrication will also be studied to develop an overall methodology for using cost constraints as a positive factor in improving living spaces.

This approach seeks relevance within the framework of practical constraints imposed by the construction industry and by current available materials. In addition, this approach seeks to be useful as a "manual" within an educational context since the methodology will include organization and clarification of the technical principles used as well as all necessary confirmatory and explanatory data.

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Organization of the Thesis

The thesis is composed of three sections. In the first section, the four specific considerations which have formed the background for the development of this thesis are discussed. They are the energy crisis, the cost crisis in economic planning, prefabrication as a planning alternative, and the consideration of the possibilities of "house" versus "home". At the end of this section, these factors are synthesized in order to present the basic direction of the thesis: the clarification of the design implications of these four determinants.

The second section examines more closely the design implications of climatic conditions and technical principles that stem from the energy crisis, the cost crisis, and "home" considerations. The fourth determinant, prefabrication, is not discussed in Section II since it is a design and building organization method more applicable to Section III. This section may be used as a "manual" of thermal comfort related to design for Boston and vicinity in particular, although the principles are similar for the northeastern United States in general. The methodology, which is to analyze environmental factors from the viewpoint of design, may be useful in any climate.

The third section is a discussion of design possibilities and proposals that are based on the determinants of Sections I and II. These proposals are planned according to a prefabrication module, and seek acceptability to the "projected" family-buyer as well as to the cautious banker. The proposals attempt to lower continuous upkeep and maintenance costs by advantageously employing the technical principles that help maintain a more comfortable interior living space.

SECTION I

BACKGROUND ISSUES:

- Energy Crisis
- Cost Crisis
- Prefabrication
- "Home"

SYNTHESIS OF BASIC DETERMINANTS

BACKGROUND ISSUES

The Energy Crisis

The conflict between the rising demand for energy-intensive goods and services and the depletion of the non-renewable sources of this energy has resulted in what may be called a crisis of availability. In addition, increased awareness of the environmental impact of energy-related usage has further intensified the atmosphere of a crisis condition. Federal alphabet agencies, speculative commercial products, academic research directions, and glossy photographs of backwoodsy, homegrown solutions have proliferated, giving the average citizen the hope that much is being done and that, at last, overall energy independence may be attained by the end of the decade. However,

> the President's appeal for US energy self-sufficiency by 1980 cannot be regarded as realistic. . . .Conceivably, this might be achieved by combining the strict conservation of energy with the ruthless exploitation of all the energy resources tappable within the short span of 6 years. That would mean a sharp curtailment in the booming demand for oil (recently growing at 7 per cent per year), the accelerated depletion of known oil fields, intensified drilling offshore in the hope of a major oil strike, the relaxation (if not the total abandonment) of environmental quality standards, unrestricted strip mining and a wholesale shift from oil and natural gas to coal, particularly for electric power generation. Between now and 1980, it will be virtually impossible to build more nuclear power plants than those already on the drawing boards.[1]

Not only does this assessment delineate a grotesque image of a frantic society scraping the bottom of the barrel quite literally in its search to find energy sources that will be depleted by the growth of demand for that very energy, it also indicates a search that has no goal other than immediate retrieval. Even the planning involved in nuclear energy research is not directed towards developing an approach for wise energy usage: again, it is an example of intense effort to produce a given product for a given period in time without thought for long-term future consequences. A comparison of efforts in energy provision versus energy utilization planning and conservation shows that the $1.5 billion budget under federal and private development is devoted entirely to provision, that is, immediate retrievability (see chart, p.10). Closer inspection reveals that "about a fifth of this entire sum is devoted to work on a single mechanism, the liquid-metal fast breeder."[2] The impression emerges of a sense of "fashionability" in research funding. Fast breeders are intensively studied now; other equally highly technological systems may be more popular in the future. Moreover, inefficiencies in current systems include problems that may occur whenever large-scale solutions are sought. Losses in captured energy occur between the generating or receiving station and its end point through transportation or delivery inefficiencies. Current utilities, themselves, have not yet been able to resolve this:

> . . .the inefficiency with which energy is consumed ranges from less than 5% for the ordinary incandescent lamp to perhaps 75% for a well-maintained home furnace. The automobile engine (particularly since the installation of emission controls) has an efficiency of less than 20%. Modern fossil fuel plants are more than twice as efficient. On the average, probably less than 35% of all the Btu consumed end up as comfort heat, useful work, or visible light.[3]

The singular attitude that emerges from this entire approach towards energy resources is that it should be "used and used up" rather than used and re-used wisely and efficiently. Attention to utilization planning and conservation would enable the unbalanced provision side of the diagram to have a more logical meaning.

1973 ALLOCATION OF FEDERAL AND PRIVATE DEVELOPMENT FUNDS[4]

Energy Utilization and Conservation: NONE

Energy Provision:

- Industry
- Commercial and Domestic
- Transportation
- Electricity:
  - Winds
  - Tides
  - Geothermal
  - Hydro
  - Solar:
    - Photosynthesis
    - Direct Conversion
  - Fossil:
    - Shale
    - Gas
    - Oil
    - Coal
  - Nuclear:
    - Fusion
    - Fission:
      - Converters:
        - Light-water
        - Gas-cooled
      - Breeders:
        - Gas-cooled
        - Liquid-metal

20% of the $1.5 billion budget is devoted to only one mechanism in the diagram: the liquid-metal breeder.

In exploring ways of implementing energy-saving methods, an active or a passive approach can be taken, each of which should be used in its appropriate context. The active energy approach uses ancillary energy sources to direct or convert primary energy sources through mechanical or other means. An oil-burning furnace would be a type of conventional active energy system; flat-plate solar collectors using cadmium-sulfide cells would also be considered an active intervention since they convert one energy form (light) to another (electricity).

The passive approach uses the building itself to collect and store available energy by utilizing its form, materials, and configuration. Historical examples include wind scoops on roofs in Pakistan that catch prevailing breezes and force the cooler air downward through the building[5] as well as solar shading devices such as deep overhanging roofs used in the American West to shade the interior completely while still allowing breezes to ventilate the rooms. A commonly seen contemporary example is the florist's or horticulturist's nursery greenhouse that catches most rays of warming daytime sun for sunrise-to-sunset heating requirements, only requiring supplementary heating on sunless days and during the night.

Energy delivery systems can also be differentiated by the way technology is used to enable the system to function. "High technology" solutions require, as the name suggests, highly technologically oriented material, collection, and delivery systems. Regional electric generating stations would be an analogue for futuristic "high tech" regional solar collection stations which would distribute solar energy transformed into electricity. "Low technology" systems seek solutions that are readily available at the individual or neighborhood level in the form of common building materials, or that are found in the form of indigenous approaches to architecture. Protection from exposure to the wind in mountainous regions occurs when each house builder takes the huddling formation of previous buildings into account when siting a new house: highly sophisticated understanding of wind patterns is exhibited and yet, "low tech" answers solve the problem.

High technology active systems are undergoing rapid changes in conceptual thinking and hardware. Excitement is being generated over the idea of intervening on a large scale at the solar level. In fact,

> . . .the idea of converting solar energy to electric power in space and beaming it down to earth at microwave frequencies would provide energy around the clock, fair weather and foul. Nevertheless, to be economically feasible, the cost of available components would have to be reduced by a factor of about 100 and the cost of putting the components in orbit by a factor of about 10, over and above the economies promised by the space shuttle. Beyond that, there is the worry about the long-term effect of low-level microwave power on life near the receiving antennae, which would have to cover tens of square kilometers.[6]

Many alternative approaches are seeking acceptability before adequate testing and experimentation has taken place. This includes the problems of the rudimentary state of current "solar energy" hardware, often prematurely claimed as nearly ready for complete mass availability. In addition, new schemes often outdate older ones that are already under construction. The state-of-the-art is in a state of flux. As a consequence, total reliance on highly technological solutions often results in premature investment of hopes, resources, and money. Public expectations are raised by the promise of technological magic that, at this stage of early research into alternative modes of energy investigation, science cannot yet fulfill.

On the other hand, low technology passive systems, used by builders since the beginning of history, represent an approach to design that may hold answers that will not only be useful during these decades of search for highly efficient mechanisms, but that also will not become "old fashioned" as better methods are found. With careful use of design principles, using known and non-changing environmental and climatologic facts, future systems may be able to be retrofitted in the same way that other "modern" appliances, such as refrigerators and home furnaces, have been retrofitted. In other words, once design principles that require sensitivity to climatologic constants are applied in dwelling design, such as solar heating alternatives, orientation-responsive fenestration, waste-water and waste-heat recovery, etc., future sources of energy control will be able to enhance, not disrupt or outdate, established patterns of prudent energy use.

Commitment to conservative measures that do not disturb the large-scale balance of life on earth can be seen as an attitude for design determination. This approach, which is the basic attitude of this thesis, pre-empts notions of future technologies that are capable of providing large-scale energy requirements with too instant solutions.

Whereas, it is hoped that technological research will be constantly searching to provide more comfortable living conditions for all people, nevertheless, solutions that are seen as continually stop-gap measures from one decade's crisis to the next are always potentially dangerous for future generations. Affirmation and encouragement of thoughtful use and conservation of resources will allow reasoned application of energy benefits.

The Cost Crisis

In the past ten years, the average cost of new homes has almost doubled, while carrying charges have nearly tripled. Interest rates are more than 1½ times the 1965 rate. Even at these high rates, in many banks in the Northeast, money has simply been unavailable for mortgages. Some banks have established waiting lists of preferred customers for when money would become available, that is, long-term depositers would be preferred over new depositers. People who were not depositers but just looking for mortgage money, would not even be considered for the waiting lists. Costs of materials have gone up, especially for materials dependent on petrochemicals for production. Land prices have reached inflation heights. The cost of labor, to keep pace with the national inflation, has also risen. This has resulted in what may easily be termed a "cost crisis."

THE CURRENT BREAKDOWN OF EXPENSES FOR NEW SINGLE-FAMILY HOMES, BASED ON INFORMATION FROM THE DEPARTMENTS OF COMMERCE AND HOUSING AND URBAN DEVELOPMENT, IS:[7]

	1965	1975
Buying Price	$23,000	$42,000
Down-payment, 20%	4,600	8,400
Mortgage, 25 years	18,400	33,600
Interest rate	5.75%	9%
Percent rise: 83%		
Monthly Payments		
Principal and interest on mortgage	$ 116	$ 282
Taxes	28	70
Heat and utilities	26	60
Maintenance	11.50	25
Hazard insurance	4.50	14
Total	$ 186.00	$ 451.00
Percent rise: 142%		

Banks usually require that a person seeking a mortgage earn each month an amount equal to four times the monthly PITI (Principal-Interest-Taxes-Insurance) payment he will have to pay back, although sometimes only the PI is required. This means that the homeowner in the chart "typical new single-family home" will have to earn $366.00 x 4 or $1,464.00 per month (or $17,568 per year). The homeowner, in budgeting his monthly expenses, must also include the remaining $85 for maintenance and heating. The cost of the house should be broken down into land and building, since land can be financed separately and at lower interest rates than new structures. This division would yield an average of $8,000 for land and $34,000 for the building. Since each $1,000 borrowed for twenty-five years at 9% equals $8.40 per month, then it can easily be seen that any savings in the cost of construction would equal $8.40 each month per $1,000 saved.[8] Consequently, if a construction system could provide living space at $25,000, the net monthly saving at 9% would be $75.60, or a new PITI payment of $290.40. This would now be available to someone earning almost $4,000 less each year.

There is also a slight monetary advantage to be found within the financing structure itself: a potential borrower does not have to earn the entire mortgage payment equivalent each week to be eligible for the money. He or she must only earn annually the mortgage payment x four weeks x twelve months, or forty-eight times the mortgage payment annually. It is often erroneously thought that what must be earned is the mortgage payment x fifty-two weeks.

It is also quite critical to understand the meaning of the small percentage points differences that various banks announce. Over twenty-five years, each $1,000 borrowed represents:

a monthly cost of: $8.40 at 9%
$8.23 at 8^{3}/4%
$8.06 at 8^{1}/2%
$7.89 at 8^{1}/4%
$7.72 at 8%
$7.56 at 7^{3}/4%
$7.39 at 7^{1}/2%

This means that between 7^{1}/2% and 9%, there is a monthly difference of $1.00 per $1,000 borrowed. For the "typical new single-family home", this would represent almost $34.00 x four weeks x twelve months, or $1,632 for the lower amount a prospective homeowner would have to earn if the interest rate were $7^1/2\%$ instead of 9%. In addition, the $34.00 reduction in interest represents a yearly saving of $408.00, or $10,200 for a twenty-five year mortgage.

The remaining monthly costs due to "heat" and "maintenance" may also be reasonably reduced. These total $85.00 per month. Costs of replacing materials, costs of related effects of condensation and rot, and costs of weathering to materials can be minimized by careful choice of materials before construction as well as by employing good construction techniques. In addition, heating and utility costs should be reduced through energy-conserving methods. Plumbing runs can be installed in the warmer interior of the house instead of in cold outside walls, natural light can provide illumination for all daytime needs, and most importantly, heating bills can be substantially reduced by careful siting, choice of materials, and adequate southern glazing and shading for appropriate heat gain in winter and heat reduction in summer. The $85.00 bill should be reduced by a reasonable 50%, equalling an additional saving of $42.50. This would change the total monthly outlay of the "typical" homeowner from $451.00 to $332.97 for the "conserving" homeowner, a net difference of $118.03.

There is still another area of saving that can result from the very techniques employed in a well-constructed house, that is, the insurance may be lower. Even more importantly, the competitive financing market may look more favorably at an "investment" that will probably still be standing long after the end of the borrowing period. Energy-conserving features, rather than being "eyesores" or blatantly "experimental", would have to incorporate designs for client acceptability in order to be part of a total package that must have minimal risk for the lender. Furthermore, even though banks sometimes do not look at a borrower's ability to meet total monthly costs, including upkeep, the borrower may be able to find more favorable treatment due to lower total house-related costs either in being considered competitively for the loan, in having quarter-percentage points shaved, or in lengthening the time to thirty years for repayment. The longer repayment period would result in a lower monthly PITI cost as well as a lower required salary that the borrower would have to be earning per year than the "typical" example. Savings, of course, would be much greater if, indeed, accumulated economies in construction and maintenance and resulting favorable financing treatment were able to be realized.

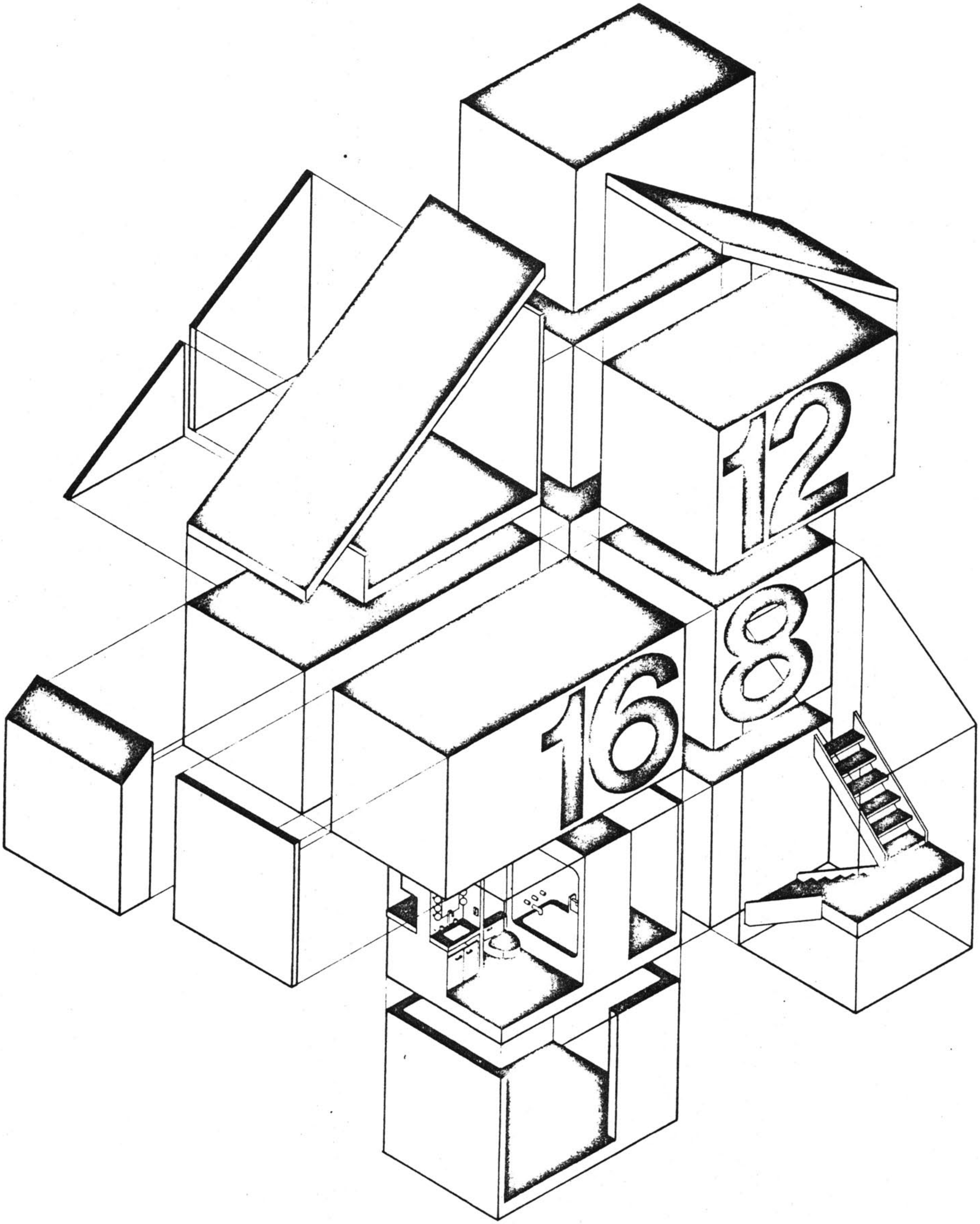
Prefabrication

Prefabrication can be understood by comparing a privy to a porcelain toilet. The privy required someone to figure out where best to place it, how far away from other living beings to hide it, how best to dig it, how deep to dig it, which tools to use, and what kind of seat to build over it. The site builder today regards the prefabricated porcelain toilet with uncomplicated affability. He orders the "part" and the plant sends it.

Modern prefabricating plants offer products ranging from a component such as a toilet, furnace, or plywood sheet to a whole living unit, such as a mobile home. One can order prefabricated concrete slabs, prefabricated wood stud wall panels, plastic components from bathtubs to entire walls, steel and aluminum components, and even prefabricated fireplaces "with the look of stone".

Use of prefabrication techniques with close cooperation between the prefabricator and the contractor offers several possibilities for controlling many costs of building with the exception of the cost of land itself. Even when a prefabricating plant's efforts are carried out on a small scale, some economies of scale in materials' ordering can be realized. Workers, who can be unionized or non-unionized, in well-organized plants have job security advantages over on-site workers due to the control management can exercise over year-around planning of unit output; on-site labor suffers more from the vagaries of weather and site conditions, materials' delivery, and possibilities of poorly planned scheduling of the work of various building trades. Costly repetitive work on the part of designers, engineers, and those responsible for preparing working drawings can be eliminated by carefully designing from the beginning a unit that can be prefabricated on a mass scale and yet that might retain the flexibility and adaptability necessary for buyer acceptability. In addition, the prefabrication designer can work out all the requirements and eccentricities of the building codes of the localities in which he wishes to sell, an advantage the custom designer or builder cannot imagine. It can be seen, then, that prefabrication acts to control costs by taking advantage of total package planning and organization more than by construction cost leverage.

The GEOCOM, or Geometric Components, system is a prefabricated wood panel system developed by an architect, Dan Leuchauer, to assist


12
8
16

design decision-making and production. It is particularly suitable for study and modification because of its simple basic units, its flexibility, its predictable cost control for total living space design, and because of the developer's interest in energy-conserving design innovation. As it is now available, it is made up of stud wall panels forming a sandwich of insulation and sheathing supported by 2" x 4" framing members 16" on center. Corner joining posts are 4" x 4". It is based on a planning system of multiples of 4 feet: 4 foot wide sheets of plywood cover panels in sizes of 8' x 8', 8' x 12', 8' x 16', etc. Back-to-back bathroom/kitchen modules save expensive plumbing runs. Roof panels can incline at several angles and window units are available in modules to fit into the various slopes. Many other adaptable units can also be arranged.

As an inexpensive wood panel system, GEOCOM employs useful concepts that can easily be modified for on-site construction. This means that variations that permit energy-conserving changes will also be more readily applicable for on-site builders who, while they cannot take advantage of prefabrication cost controls, would be interested in practical examples of energy conservation as applied to homebuilding.

"Home"

The basic assumption is that the living space or house must become a "home". Explorations of "home" must include the flexibility necessary for accommodating differing lifestyles. A home must be able to be "territorialized" by a young couple with or without children, by larger families, and by retired couples. In short, it must "fit" people who see themselves, not as part of an easy classification of types of people, but as human beings seeking to live a personalized life. Living space must have growth possibilities. It must be able to be enlarged or modified on the inside, and relations to outdoor space must be changeable. The conflict between the "shell" and the "finished space" must be resolved. People who can begin with a shell of a house have almost limitless opportunities for personalizing the space they will make into their home. But people who are not interested in building or finishing a non-completed space nevertheless still need to be able to "imprint" themselves on their living space. If no ways are found to enable residents to personalize their house, it will never become a home for them. Various possibilities or "clues" for accomplishing this must be searched for and provided.

SYNTHESIS OF BASIC DETERMINANTS

Design principles must be explored that answer to the cost and energy crises and that will emphasize the importance of "home" rather than "house configuration". These principles should partially be derived by respecting constraints that are imposed by economic and environmental considerations as discussed above. A prefabricated living space that is shaped by environmental constraints should enable its residents to incur lower maintenance and utility costs and usually lower overall costs than the standard non-energy conscious house. By providing prefabricated individual "enlargement add-on" parts, the residents will also be able to feel a sense of individualism that is not usually the goal of non-custom buildings. In addition, the use of passive, rather than active, energy controls will keep the house "up-to-date" by using timeless constants; thus, while being somewhat experimental in nature, the space will nevertheless have market financing acceptability.

"Back to Basics"

One method to accomplish these goals will be found by using a prototype that goes "back to basics". The prototype should provide basic needs for shelter, without including "fringe benefits", such as luxury appliances and extra rooms. By using a "back to basics" concept for a one thousand square foot living space, the potentially higher initial costs of energy-conserving design will be more than offset by the lowered costs of the total package, thus competing favorably with the $42,000 average price of the larger "typical single-family house" available in America today. The prototype will be aimed primarily at the large group of young couples with one or two young children, who cannot afford and do not yet need the standard three to four bedroom house usually offered.

An approximate area program can be derived:

2 bedrooms	400 square feet
living area	250 square feet
kitchen and eating	200 square feet
bathroom and linen storage	60 square feet
storage	90 square feet
Total:	1,000 square feet

It will be necessary to plan types and varieties of future additions and rooms to the basic prototype so that present energy-conserving elements will not be disrupted at the time of future construction.

The target price for prefabrication will be $25.00 per square foot, or $2,5,000 for the 1,000 square foot prototype. The net result of these savings should enable living space using these principles to become available to a family with a gross pay of approximately $12,000. This pay scale should include teachers, hospital employees, union workers, etc. The price of land cannot be included, but landscaping must be included since it plays such an important role in environmental controls. While the single-family detached house will form the basis for this program, viable alternatives for clustering and aggregation should also be explored to examine possibilities for lowering the price further and for making the units available to retired citizens as well as developing the possibility of renter-plus-owner inhabited units.

The scope of the thesis, then, will be to organize and present technical principles that will facilitate the modification of the GEOCOM system in order to develop criteria for inexpensive prototypical living spaces that will reflect a sense of harmony with the environment.

SECTION II

"MANUAL" OF THERMAL COMFORT AS RELATED TO DESIGN

CONTRIBUTION OF CLIMATIC VARIABLES TO THERMAL COMFORT CONTROL

This section of the thesis relates climatic conditions and space conditioning principles to human thermal comfort needs. The goal of this section is to enable the reader to use these factors as a basis for design.

The "Comfort Zone"

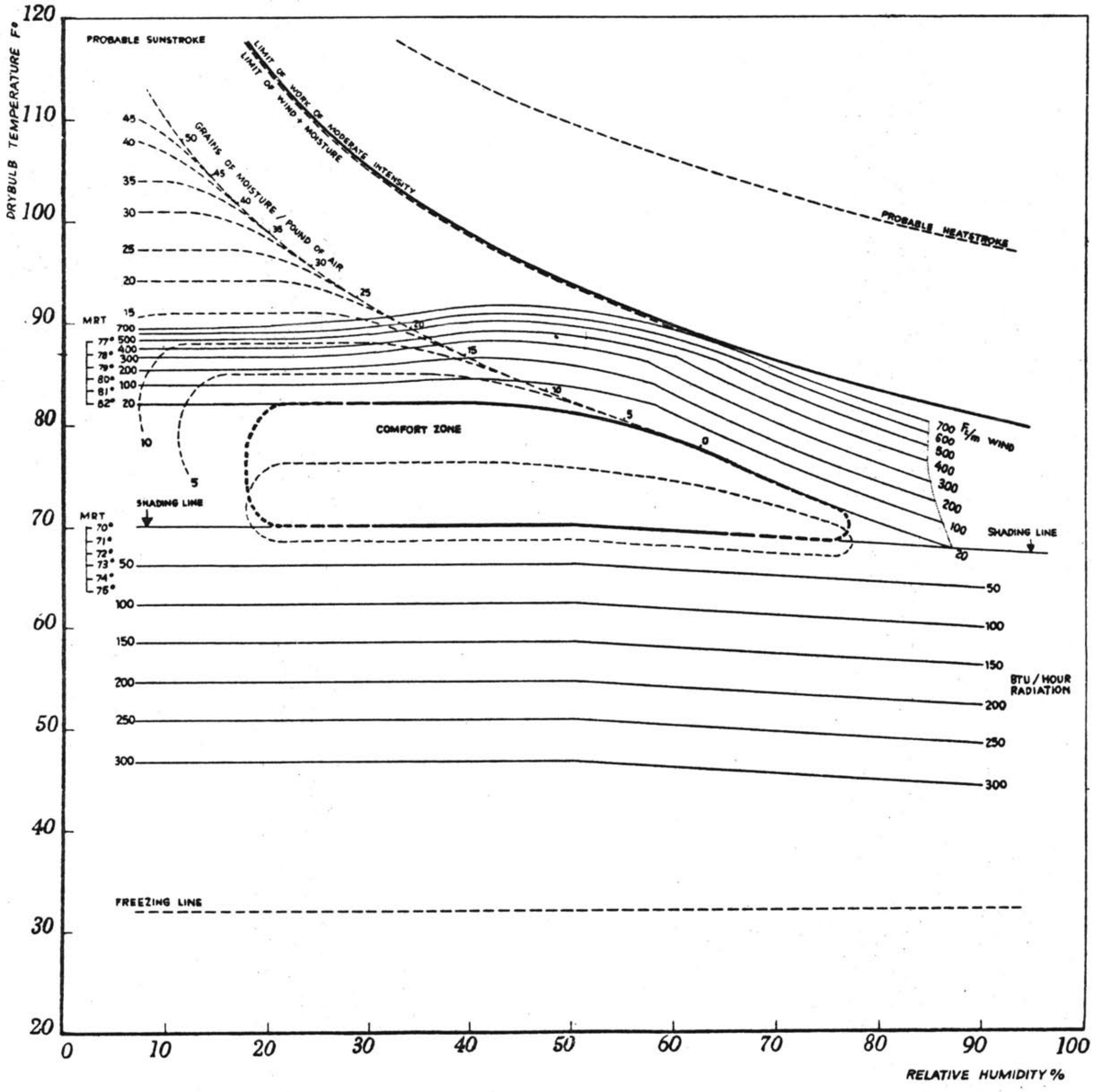
Many experiments have been done in attempts to determine methods of predicting human comfort under given conditions.[9] Three main variables have repeatedly been seen as important determinants for feelings of comfort: temperature, relative humidity, and air flow. Temperature can be understood as the potential of a space to transfer heat to surrounding colder surfaces or spaces, as measured by a dry-bulb thermometer. Relative humidity, which affects the cooling mechanisms of the human body, is the ratio of the amount of water vapor in the air to the total amount of water the air can contain at that temperature. Air flow affects resistance to heat flow and is expressed as a velocity.

These variables have been compiled in relation to each other by Victor Olgyay in the useful Bioclimatic Chart. It enables the designer to compare climatic conditions at any time of the year with an ideal comfort zone. Thus, shelter construction can be modified during the design phase to include variations that will permit the living space to meet its environmental needs as optimally as possible.

The Chart can also be used retrospectively. Feelings of discomfort may be noticed; to ameliorate the condition, temperature and relative humidity as well as air flow are measured. Correcting influences needed to restore a balanced climatic state, such as more air moisture or increased breezes, are then recommended by the Chart.

Bioclimatic Chart:

comfort chart for inhabitants of United States moderate zone[10]



Annual weather conditions play a determining role in comfort zone control and weather predictions can be made for seasonal variations. Specific data in this section are for Boston and vicinity.

Sun Angles

Sun paths can be predicted absolutely accurately. The sun follows a prescribed path across the sky and its radiation direction toward the earth is constant, interrupted only by cloudy overcast:

Season	Direction of Sunrise	Direction of Sunset
Winter	Southeast	Southwest
Spring	East	West
Fall	East	West
Summer	Northeast	Northwest

In addition, the maximum altitude of the sun at latitude 42°N varies with the season: from very low in the sky in the winter at 24.55° to very high in the sky in the summer at 71.45°. This causes the shadows cast by a building as a result of direct sunlight to vary: very short shadows will be cast by a high sun and long deep shadows will be cast by the low winter sun. Furthermore, changes also take place in the amount of sunlight available to reach the earth each day by season. The sun rises about three and a half hours earlier in the summertime than in the winter and sets about two and a half hours later.

This suggests simple ways to use solar radiation to advantage. Wintertime heating needs can be met at least partially by allowing the

Sun Angles, Altitudes, and Shadows Cast for Latitude 42°N

Date	Time AM	PM	Bearing Angle B x° from South*	Altitude a*	Tangent a	Shadow Length per 10 feet**	γ
June 22						x'	
sunrise 4:22	6	6	107.87	15.44	0.268	37.3	75
sunset 7:38	7	5	98.78	26.28	0.488	20.5	64
	8	4	89.19	37.38	0.754	13.3	53
	9	3	77.96	48.45	1.111	9.0	42
	10	2	62.79	58.95	1.664	6.0	31
	11	1	38.62	67.64	2.475	4.0	22
	12		0	71.45	2.904	2.9	19
March 22	7	5	79.84	11.09	0.194	51.5	79
sunrise 5:42	8	4	68.88	21.81	0.404	24.8	68
sunset 6:06	9	3	57.81	31.70	0.625	16.0	58
September 22	10	2	40.79	40.06	0.839	11.9	50
sunrise 5:39	11	1	21.82	45.88	1.036	9.7	41
sunset 6:10	12		0	48.00	1.111	9.0	40
December 22	8	4	52.82	4.28	0.070	142.9	86
sunrise 7:38	9	3	41.63	12.46	0.213	46.9	78
sunset 4:52	10	2	29.01	18.91	0.344	29.1	71
	11	1	14.96	23.09	0.425	23.5	67
	12		0	24.55	0.466	21.5	65

x' = shadow length cast by ten foot high object: 10'/tan a = x'
a = altitude of sun in degrees
γ = shading device angle facing sun: 90° - a = γ

*B (bearing angle) and a (altitude) are found in Graphic Standards
**shadow lengths are derived from the tangent of the altitude

low sun to penetrate through windows into the building. Similarly, summertime cooling can be enhanced by blocking the summer sun by roof overhangs. Precise determination of sun angles will thus permit designers to work within a realistic context of environmental control.

Cloud Cover

Cloud cover, expressed as the percentage of sky that is overcast with clouds, plays an important role in determining the amount of sunlight that reaches a building and that thus can be used for warming the interior. Consequently, it is necessary to determine how often cloudy days occur during the winter period. First, "cloudiness" must be defined: if a day, as measured from sunrise to sunset, has 50% overcast skies for a least half the day, then that day will have to be considered generally unsuitable for gaining more than 50% of its heating needs from the sun. Nevertheless, additional heat gain may often be received by indirect radiation that occurs when light is diffused on bright cloudy days, even days that are 80% cloud-covered, with only 20% clear sunny sky, may still receive an additional 10-20% usable solar heat.

A comparison of daily cloud cover will yield an average of yearly cloud cover for which heat supplementary to the sun will have to be provided (see page 31).

Heat Gain Factors for Solar Position and Intensity

An additional factor of solar heat gain can be determined from the intensity of the heat that penetrates window openings. This is

1973 Daily Cloud Cover for Heating Season for Boston and Vicinity[11]

percentage cloud cover expressed in tenths by day of month and by three-hour time intervals per day for days with 50% or greater cloud cover

January, available sun: 7:28 AM to 4:52 PM

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
10 AM	6			10	8				9				6	10	10		9	10		9		10		6			10	10	10		
1 PM		10		10	8				9				9	10	10		9	8		10		10	10	8			10	10	10	9	
4 PM				10									10	9			9	10	10	10		10	7	10	10		10	10	6	9	

February, available sun: 6:56 AM **to** 5:31 PM

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
7 AM	10	10	10				10	10			9	10	10		10	10	8			10	10	10	10			10	9				
10 AM	10	10	6		9		10	10		10	8	10	10		10	10	10			10	10	10	10			10	10				
1 PM	10	10	10	9	10	5	10	10		10	8	10	8	9	10	10			7			10	8			10	10				
4 PM	10	10	7	8	10	10	10	10	6	10	10	10	9	10	10	10					10	10	9		8	10					

March, available sun: 5:42 AM to 6:06 PM

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
7 AM	6	10	10	10	10	10	10	10	10	10	10	10		10	10	10	10	10	7	8	8	10	10		9	10	9		10	10	10
10 AM	9	10	10	10		10	10	10	10	10	10			9	10	10	10	10	5	10	6	10	7		8	10			10	10	10
1 PM		8	10	10	6	10	10	10	10	10	10	8		10	10	10	10	7		10	10	10	8	9	9	10			10	10	10
4 PM	10	9	10	10	8	10	10	10	10	10	10	10		10	10	10	10	10	6	10	10	10	8	10	10	10			10	10	10

April, available sun: 5:21 AM to 6:41 PM

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
7 AM	10	10	10	10	10			10		10							10	10			10	10				10	10	10	10		
10 AM	10	10	10	10	8			10		10	9				9		10	10	8			8			9	10	10	10	10		
1 PM	10	10	10	10	9	6		10	9	10	9				6	10	10	8	10		10	8	9	9	9	10	10	10	10		
4 PM	10	10	10	10	9	5		10	9	8	9					10	10				9	7	10	10	10	10	10		10		

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
October, available sun: 6:12 AM to 5:19 PM																															
7 AM			10		10		9		8				9	6				9	8	10					10	10		9	10	10	10
10 AM			10		10		9			10	5	8	8				9	8		10			8		10	10		10	10	10	10
1 PM	6	10	10		10		9		6	10	5	6	10			5	8	10		10					10	10		10	10	7	
4 PM	9	10	10				9		6	10	10	9	10				6	10		10					10	10		10	10		
November, available sun: 6:48 AM to 4:41 PM																															
7 AM	10							5	9			10	8	8	10	10			10			10	10		10		10	10			
10 AM	10		6		9	5		9				9	10	5	10	10			10	8	5	10	10	8	10		10	10	10		
1 PM	10		6		9	9		10	7			9	10	10	10	10						10	10	6	10		10	10	9	10	
4 PM	7	9				9		10	10			7	10	8	10	9						10	10	10	10	10	10	10		8	
December, available sun: 7:18 AM to 4:33 PM																															
7 AM			9	10	10	10		10	10	10	10	6		10		7	10			10	10	5	10		6	10	10	8	10	10	10
10 AM			10	10	10	7	7	10	10	10	10			10		10	10			10	10		10		8	10	10				10
1 PM			10	10	10		7	10	10	5	10		7	10	7	10	10			10	10				10	10	10		9		10
4 PM		7	8	10	10			10	10	8	5		10	10	7	10	10		10	10	10				10	10	10		10		10

measured in British Thermal Units; one Btu is the amount of heat needed to raise one pound of water 1°F.

Data are available to enable the designer to calculate solar heat gain for each month for each square foot of single glass in a building that faces the sun at any given time during the day.[12] The data indicate that even in December, when the least amount of sun reaches the earth during the shortest days of the year, significant quantities of energy will still enter the building.

HEAT GAIN FOR DECEMBER 21 FOR LATITUDE 40°

FULL DAY TOTALS OF SOLAR HEAT GAIN BY DIRECTION
PER SQUARE FOOT OF SINGLE GLASS:

Direction	Morning	+	Afternoon	=	Total Btu
North	49		49		98
Northwest	49		54		103
West	50		380		430
Southwest	273		831		1104
South	781		781		1562
Southeast	831		273		1104
East	380		50		430
Northeast	54		49		103
				Total:	4934 Btu

Even if a 50% cloudy day factor is figured into this total, it will still result in 4934/2 , or 2467 total Btu for a building with 1 square foot of glass facing each of the directions listed. January, which is even a colder month for air temperatures, actually has more light reaching each square foot of surface.

When this energy passes through the glass, much of it is retained

ASHRAE Chart for Solar Heat Gain Factors for Latitude 40°N[12]

Date	Solar Time A.M.	Solar Position		Direct Normal Irradiation, Btuh/sq ft	Solar Heat Gain Factors, Btuh/sq ft									Solar Time P.M.
		Alt.	Azimuth		N	NE	E	SE	S	SW	W	NW	Hor.	
Jan 21	8	8.1	55.3	141	5	17	111	133	75	5	5	5	13	4
	9	16.8	44.0	238	11	12	154	224	160	13	11	11	54	3
	10	23.8	30.9	274	16	16	123	241	213	51	16	16	96	2
	11	28.4	16.0	289	18	18	61	222	244	118	18	18	123	1
	12	30.0	0.0	293	19	19	20	179	254	179	20	19	133	12
			Half Day Totals		59	68	449	903	815	271	59	59	353	
Feb 21	7	4.3	72.1	55	1	22	50	47	13	1	1	1	3	5
	8	14.8	61.6	219	10	50	183	199	94	10	10	10	43	4
	9	24.3	49.7	271	16	22	186	245	157	17	16	16	98	3
	10	32.1	35.4	293	20	21	142	247	203	38	20	20	143	2
	11	37.3	18.6	303	23	23	71	219	231	103	23	23	171	1
	12	39.2	0.0	306	24	24	25	170	241	170	25	24	180	12
			Half Day Totals		81	144	634	1035	813	250	81	81	546	
Mar 21	7	11.4	80.2	171	8	93	163	135	21	8	8	8	26	5
	8	22.5	69.6	250	15	91	218	211	73	15	15	15	85	4
	9	32.8	57.3	281	21	46	203	236	128	21	21	21	143	3
	10	41.6	41.9	297	25	26	153	229	171	28	25	25	186	2
	11	47.7	22.6	304	28	28	78	198	197	77	28	28	213	1
	12	50.0	0.0	306	28	28	30	145	206	145	30	28	223	12
			Half Day Totals		112	310	849	1100	692	218	112	112	764	
Apr 21	6	7.4	98.9	89	11	72	88	52	5	4	4	4	11	6
	7	18.9	89.5	207	16	141	201	143	16	14	14	14	61	5
	8	30.3	79.3	253	22	128	225	189	41	21	21	21	124	4
	9	41.3	67.2	275	26	80	203	204	83	26	26	26	177	3
	10	51.2	51.4	286	30	37	153	194	121	32	30	30	218	2
	11	58.7	29.2	292	33	34	81	161	146	52	33	33	244	1
	12	61.6	0.0	294	33	33	36	108	155	108	36	33	253	12
			Half Day Totals		153	509	969	1003	489	196	146	145	962	
May 21	5	1.9	114.7	1	0	0	0	0	0	0	0	0	0	7
	6	12.7	105.6	143	35	128	141	71	10	10	10	10	30	6
	7	24.0	96.6	216	28	165	209	131	20	18	18	18	87	5
	8	35.4	87.2	249	27	149	220	164	29	25	25	25	146	4
	9	46.8	76.0	267	31	105	197	175	53	30	30	30	196	3
	10	57.5	60.9	277	34	54	148	163	83	35	34	34	234	2
	11	66.2	37.1	282	36	38	81	130	105	42	36	36	258	1
	12	70.0	0.0	284	37	37	40	82	112	82	40	37	265	12
			Half Day Totals		203	643	1002	874	356	194	171	170	1083	
June 21	5	4.2	117.3	21	10	21	20	6	1	1	1	1	2	7
	6	14.8	108.4	154	47	142	151	70	12	12	12	12	39	6
	7	26.0	99.7	215	37	172	207	122	21	20	20	20	97	5
	8	37.4	90.7	246	29	156	215	152	29	26	26	26	153	4
	9	48.8	80.2	262	33	113	192	161	45	31	31	31	201	3
	10	59.8	65.8	272	35	62	145	148	69	36	35	35	237	2
	11	69.2	41.9	276	37	40	80	116	88	41	37	37	260	1
	12	73.5	0.0	278	38	38	41	71	95	71	41	38	267	12
			Half Day Totals		242	714	1019	810	311	197	181	180	1121	
July 21	5	2.3	115.2	2	0	2	1	0	0	0	0	0	0	7
	6	13.1	106.1	137	37	125	137	68	10	10	10	10	31	6
	7	24.3	97.2	208	30	163	204	127	20	19	19	19	88	5
	8	35.8	87.8	241	28	148	216	160	29	26	26	26	145	4
	9	47.2	76.7	259	32	106	194	170	52	31	31	31	194	3
	10	57.9	61.7	269	35	56	146	159	80	36	35	35	231	2
	11	66.7	37.9	274	37	39	81	127	102	42	37	37	255	1
	12	70.6	0.0	276	38	38	41	80	109	80	41	38	262	12
			Half Day Totals		211	645	986	850	347	197	177	176	1074	
Aug 21	6	7.9	99.5	80	12	67	82	48	5	5	5	5	11	6
	7	19.3	90.0	191	17	135	191	135	17	15	15	15	62	5
	8	30.7	79.9	236	23	126	216	180	40	22	22	22	122	4
	9	41.8	67.9	259	28	82	197	196	79	28	28	28	174	3
	10	51.7	52.1	271	32	40	149	187	116	34	32	32	213	2
	11	59.3	29.7	277	34	35	81	156	140	52	34	34	238	1
	12	62.3	0.0	279	35	35	38	105	149	105	38	35	247	12
			Half Day Totals		161	503	936	961	471	202	154	153	945	
Sep 21	7	11.4	80.2	149	8	84	146	121	21	8	8	8	25	5
	8	22.5	69.6	230	16	87	205	199	71	16	16	16	82	4
	9	32.8	57.3	263	22	47	195	226	124	23	22	22	138	3
	10	41.6	41.9	279	26	28	148	221	165	30	26	26	180	2
	11	47.7	22.6	287	29	29	77	192	191	77	29	29	206	1
	12	50.0	0.0	290	30	30	32	141	200	141	32	30	215	12
			Half Day Totals		116	300	803	1045	672	221	117	116	738	
Oct 21	7	4.5	72.3	48	1	20	45	41	12	1	1	1	3	5
	8	15.0	61.9	203	10	49	173	187	88	10	10	10	43	4
	9	24.5	49.8	257	17	23	180	235	151	18	17	17	96	3
	10	32.4	35.6	280	21	22	139	238	196	38	21	21	140	2
	11	37.6	18.7	290	23	23	70	212	224	100	23	23	167	1
	12	39.5	0.0	293	24	24	26	165	234	165	26	24	177	12
			Half Day Totals		83	143	610	989	783	245	84	83	535	
Nov 21	8	8.2	55.4	136	5	17	107	128	72	5	5	5	14	4
	9	17.0	44.1	232	12	13	151	219	156	13	12	12	54	3
	10	24.0	31.0	267	16	16	122	237	209	50	16	16	96	2
	11	28.6	16.1	283	19	19	61	218	240	116	19	19	123	1
	12	30.2	0.0	287	19	19	21	176	250	176	21	19	132	12
			Half Day Totals		61	71	442	884	798	267	62	61	353	
Dec 21	8	5.5	53.0	88	2	7	67	83	49	3	2	2	6	4
	9	14.0	41.9	217	9	10	135	205	151	12	9	9	39	3
	10	20.7	29.4	261	14	14	113	232	210	55	14	14	77	2
	11	25.0	15.2	279	16	16	56	217	242	120	16	16	103	1
	12	26.6	0.0	284	17	17	18	177	253	177	18	17	113	12
			Half Day Totals		49	54	380	831	781	273	50	49	282	↑
					N	NW	W	SW	S	SE	E	NE	HOR.	←P.M

Total solar heat gains for DS (⅛ in.) sheet glass. Based on a ground reflectance of 0.20 and values in Tables 1 and 9.

inside the volume of the building as a trapped bubble of heat which is available to act as a source of warmth to the inhabitants. This heat is identical in quality and warmth to an equivalent Btu-capacity fossil-fuel burning furnance, and can simply be thought of as an alternative source of heat. Design characteristics suggested by this phenomenon include providing ample transparent, but well insulated, surfaces to receive the maximum amount of light possible, so that, in effect, heat from the sun will provide the major source of heat for an average heating season, while conventional sources will provide supplementary heat.

The chart on page 34 gives the solar heat gain factors necessary for calculating the number of Btu received each hour for each square foot of glass.

Windflow

Wind flow also changes seasonally for Boston and vicinity. Prevalent winter winds come predominantly from the northwest, although rare winter storms come from the northeast. Summer breezes are generally from the southwest. Flow patterns that are interrupted by buildings are changed according to the way the wind encounters solid volumes or openings.

Trees also affect wind flow according to their type. Coniferous, or "softwood" trees such as many pines, present a rather solid barrier to the wind, whereas deciduous, or "hardwood" trees such as maples or oaks, present a more penetrable surface. The resulting actions can be used fortuitously for planning wind barriers or for light wind screens.

In addition, correct planting of these trees can also aid heat gain and heat loss balancing. Since deciduous trees have a leaf canopy in the summertime, southwest and west plantings can shield unwanted solar heat gain and yet direct the prevailing southwest breezes through the building. These trees lose their leaves during the winter so that necessary heat gain is utilized from the maximum available sunlight. Planting of coniferous trees, on the other hand, around the north and northwest sides of a building will present a more solid barrier to the prevailing winter winds as well as to late afternoon unwanted summer solar heat.

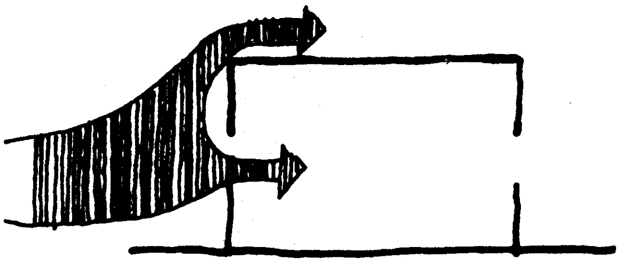
Tree barriers can also redirect and control the wind. The use of vegetation in this manner includes clues for designing windbreaks as shelter belts:[13]

- The height of a barrier will cause the wind to flow over the barrier to produce a protected wake for ten to fifteen times the height of the barrier. In addition, the windward side of the barrier will be protected for a forward distance of two to five times the height of the barrier.
- Barriers should rise gradually on the windward side and drop on the leeward side; some air must be able to penetrate through the barrier to minimize leeward turbulence.

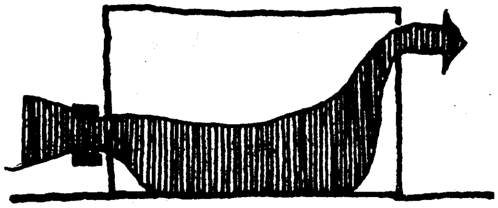
Various wind tunnel experiments have established wind flow patterns through buildings and vegetation which can be used advantageously by the designer.

Wind Flow Effects[14]

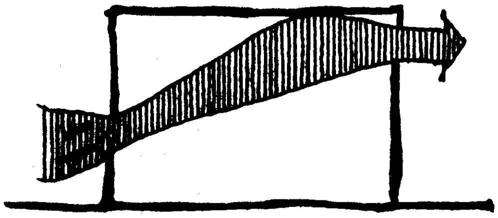
The location and the type of window presented to the wind at the entry to the room or building affect air flow movements.



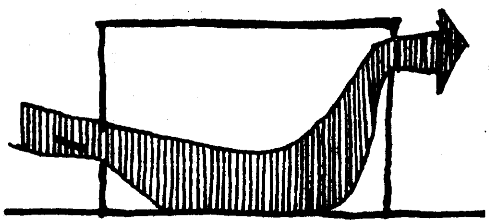
(A)
maximum air flow occurs when large openings or windows of the same size are placed opposite each other



(B)
effect of casement windows on windward side with high double-hung window on opposite side



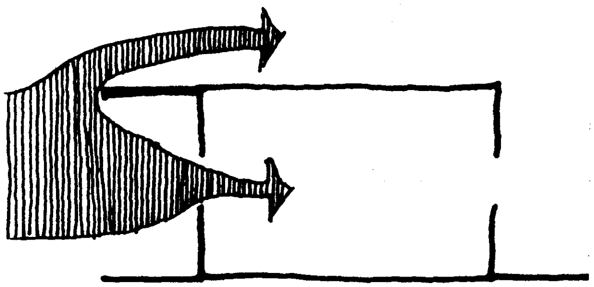
(C)
effect of awning on windward side with high double-hung window on opposite side



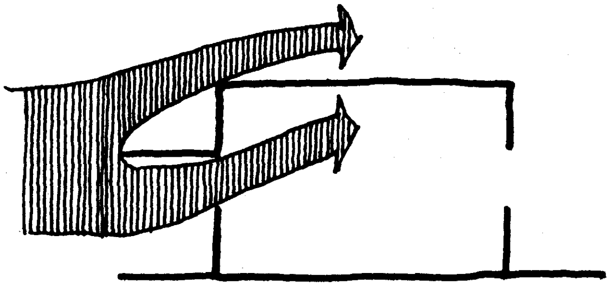
(D)
effect of downward pivoted window with high double-hung window on opposite side

Different types of overhangs affect wind flow movement.

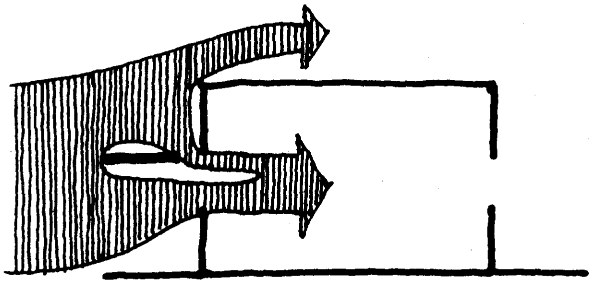
(E)
an overhang projecting from the top of the building collects air flow which would otherwise escape



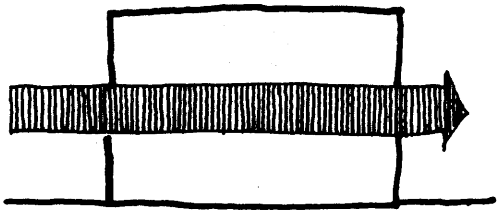
(F)
a solid overhang above a window directs air flow upward and above the living zone (compare D, downward pivoted window)



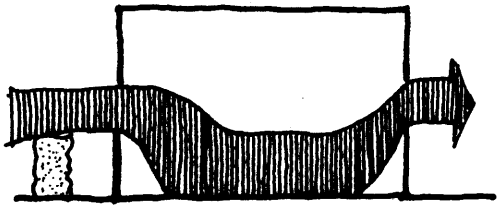
(G)
slotted overhang forces air flow downward into the living zone



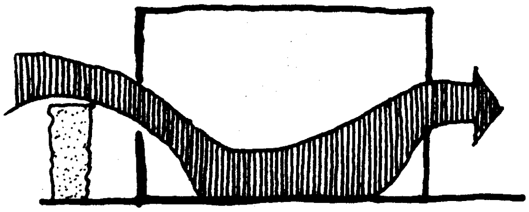
The use of broadleafed evergreen hedges of vigorous compact growth will also affect wind flow through the building depending on the height of the hedges.



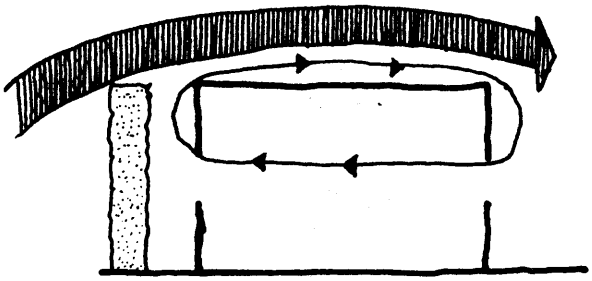
(H)
effect of wind flow without hedge planting



(I)
effect of low hedge planted five feet from the building



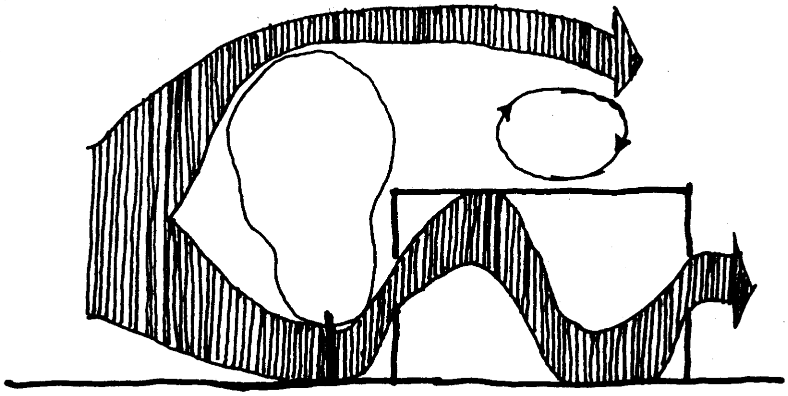
(J)
effect of medium-height hedge planted five feet from the building



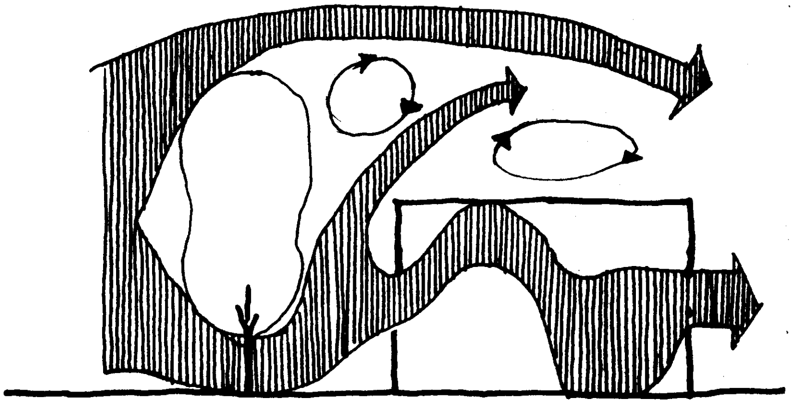
(K)
effect of high hedge planted five feet from the building; this will cause some eddying effects but not enough for comfort

Trees can act as wind barriers or wind guides. The tree used in these diagrams is assumed to be thirty feet high with a twenty-five foot spread and branching at approximately five feet high.

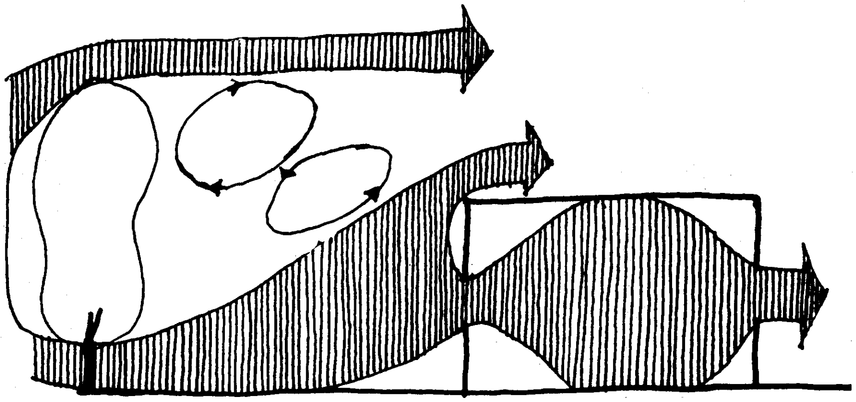
(L)
effect on wind
if tree is
planted 5 feet
from the building



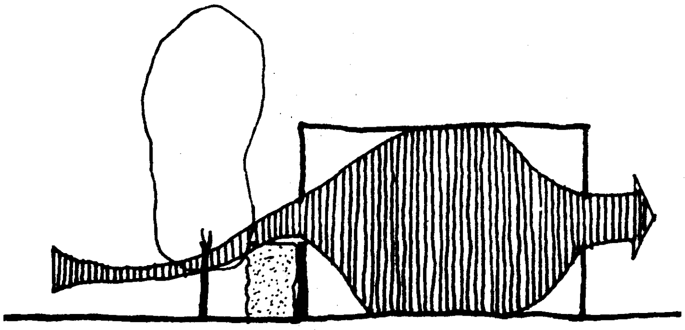
(M)
effect on wind
if tree is
planted 10 feet
from the
building



(N)
effect on wind
if tree is
planted 30
feet from
the building

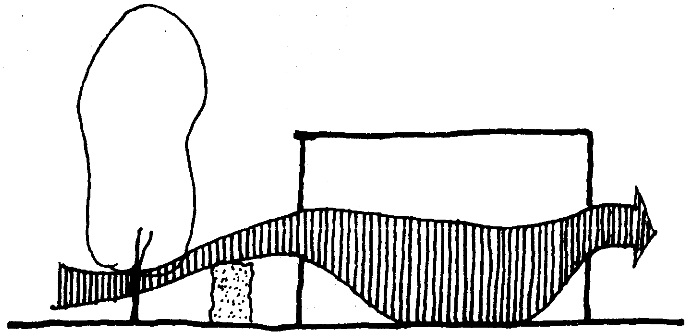


Combined barriers will also produce wind flow modification.



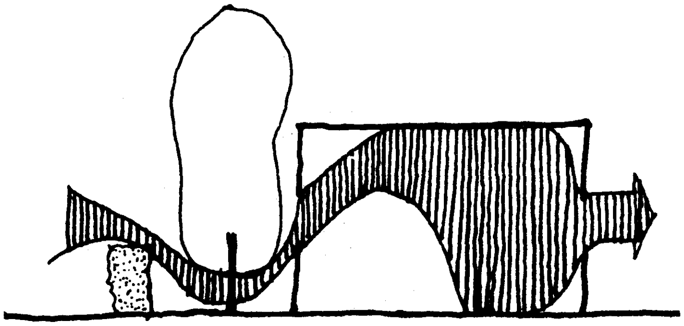
(O)

effect on wind flow of planting an evergreen hedge next to the building with a 30 foot high tree with a 25 foot spread and branching at 5 feet high planted 5 feet from the building



(P)

effect on wind flow with hedge 5 feet from building and tree 10 feet from building



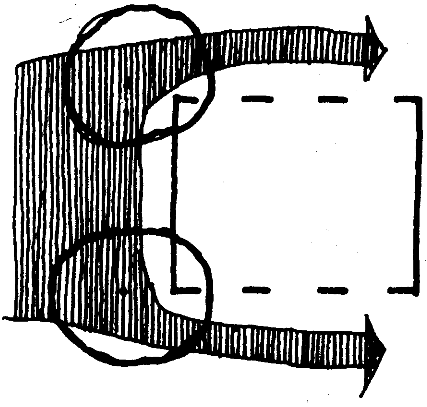
(Q)

effect on wind flow with tree 5 feet from building and hedge 10 feet from building

Depending on their location, vegetation barriers show distinct differences in wind flow modification in plans of buildings with no windows on the windward side.

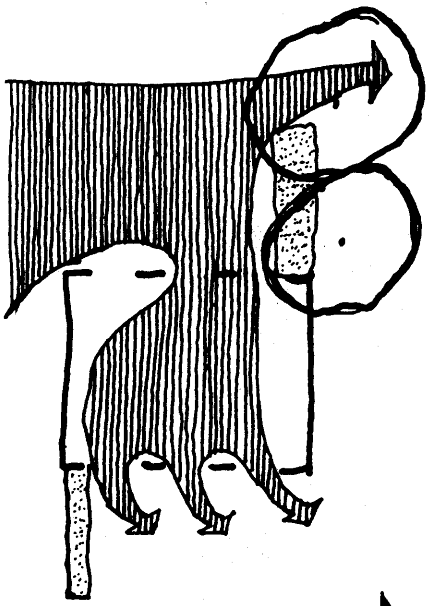
(R)

trees planted 5 feet from the building's corners on the windward side do not produce cooling effcts inside the building



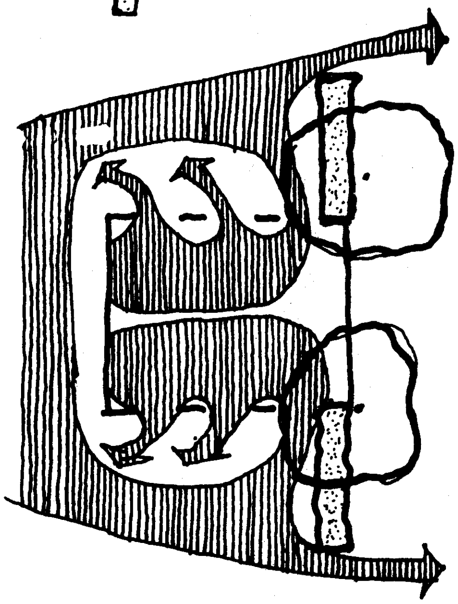
(S)

hedges planted at edges of the building perpendicularly to the wind with trees planted at the rear of one corner of the building act as a wind flow barricade to force wind into the building



(T)

hedges and trees planted at the rear edges of the building force air backwards through both sides of the building



USE OF HEAT FLOW MECHANISMS FOR COMFORT CONTROL

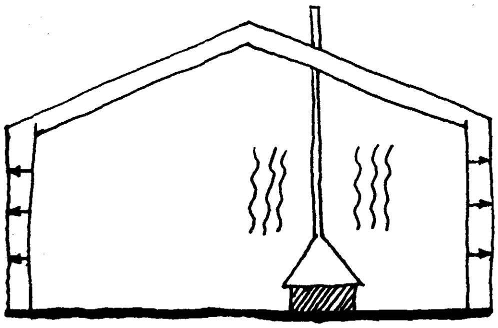
> The use of properly designed insulation can frequently so reduce the heating and cooling load that the consequent smaller sized heating and cooling equipment reduces the overall cost more than the cost of the insulation; thus, a thermally efficient building is obtained for a lesser initial capital outlay cost than a poorly insulated one, while reduced heating and cooling loads will provide continuous savings.[15]

Principles of Heat Flow

Understanding basic tenets of heat flow enables the designer to determine for himself or herself various principles that will facilitate the design process. The first axiom of heat flow is that heat flows from heat sources to heat sinks. That is, a hot surface will lose heat to a colder surface, a room with warm temperature will lose heat to an adjoining cooler alcove, a warm room will lose heat to a cold exterior wall, and a source of heat, such as a "radiator" or stone fireplace, will lose heat to a cold room. Thus, it can be seen that surfaces as well as spaces can lose heat to either surfaces or spaces. Three specific mechanisms can cause this heat flow: conduction, radiation, and convection.

Conduction

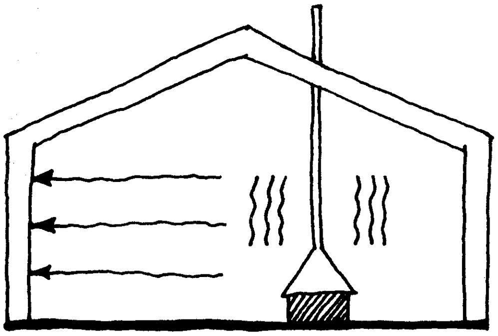
A material that is bounded by a cold volume, or heat sink, on one side and a warm volume, or heat source, on the other will lose heat through the material by a process called conduction. The side of the material that is next to the heat source will be warmer than the side of the material that is next to the heat sink. Heat will be "conducted" through the material, causing an overall lowering of the temperature at the warmer side of the material and an overall raising of the temperature on the previously colder side of the material.



A common example of this mechanism takes place in the exterior wall of a living space. If the wall is uninsulated, lower temperature differentials will exist across the wall, which in turn lower the temperature of the inside surface of the wall. The warmth produced by the interior heating element will literally be constantly "sucked" toward the exterior wall of the room and from there to the cold outdoors. The heating bills of the house will then reflect not only the needs for warmth of the family living in the house, but also the demands imposed by the heat sink of the winter air temperature. A design clue offered by the mechanism of conduction will thus suggest insulation of the two extreme temperature differences from each other in order to use the available heat to warm only the interior of the living space.

Radiation

When a warm surface gives up its heat <u>through a volume of air</u> to colder surfaces, the same principle of heat flow from source to sink is taking place, but it is occurring by the heat transfer mechanism of radiation.

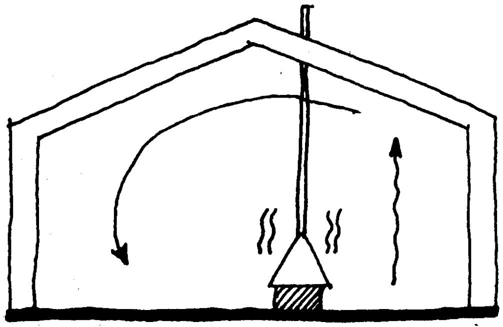


Radiation of heat is not subject to gravitation, or upward flow of warm, lighter molecules. Consequently, if the warm surface is on the ceiling of the room, warming effects of the area at sitting height will be felt due to radiation from the warm surface downward through the cooler air.

Heat losses due to radiation can compound the losses due to conduction. A poorly insulated room may have a fireplace on one interior wall that will lose heat (radiate) across the room toward the progressively colder walls. When the radiation meets the wall, conduction losses will take place as the heated molecules lose heat to each consecutive layer of cooler molecules through the solid exterior wall. The lack of insulation causes the heat that is needed to warm the wall to be drawn toward the outside because of the temperature difference existing within the solid wall from the warmer side to the cooler side.

Convection

A third mechanism of heat flow is called convection, by which gravitational air flow moves warm air to areas of cooler air.



As the air is warmed, the air particles become lighter and less dense and rise, while cooler air particles fall to take the place vacated by the warmed particles. This gravitational change causes heat losses when air movement "carries off" heat from a warmed surface upward and away from the living level or level at which the inhabitants' need for warmth is felt. Convection losses can also compound radiation and conduction losses when heat that has already been lost from the original source is conveyed further by the action of this continuous air movement.

Comfort Control Using Principles of Heat Flow

Proper control of heat flow can, however, be used to reinforce correct heating situations to give a balanced thermal environment. One of the most important corrective measures is an adequate insulation barrier between areas of great temperature differences. Sufficient insulation establishes an effective barrier such that the heat sources in the room are interrupted from the cold outdoor air and thus cannot "see", or lose heat to, the heat sink.

This immediately causes a raised temperature differential across the barrier. Radiation losses are noticeably lessened due to warmer interior wall temperatures and conduction losses through the elements of the exterior wall are decreased. Convection currents are also lessened; they may be controlled to balance the feeling of comfort in the living space. Placing the heating sources next to coldest areas of the room will enable naturally occurring convection currents to carry heat from the heat source upwards, over, and back down through the room. The currents will now have become cooler, having left heat at each previous space in the room along the path they travelled, and thus, will be susceptible to be warmed by the heat source again. The heat source near the coldest room surface will also provide radiation effects to balance the localized cooling conditions of that cold spot.

Another alternative for using heat flow mechanisms for positive comfort control is to combine a glass wall (shaded from higher summer sun angles) on the southern side of the house with walls and roof of high insulation values and exterior insulated concrete slab floor. This will cause a winter condition of solar heat gain penetrating deeply into the houses with daytime back losses shielded by the insulated barriers that act to reduce re-radiation and re-conduction through the walls. The well-insulated slab acts at first as a medium to reduce conduction losses downward and then as a source of storage for the sun's heat that is not immediately utilized by the interior of the living space. It then releases the stored heat by conduction through the slab, by radiation from the slab to the air and surrounding surfaces, and finally, by convection around the entire living space that is open onto the area covered by the exposed slab. Supplementary heating elements for non-sunny periods can be "plugged" into the existing system so that the same mechanism can be used to advantage. Thus, the supplementary heat would have to be located near the cold window area in order to force convection currents to work backwards into the living area rather than, if placed on a warmer side of the space, to carry warm air toward the glass, and from there, through the glass by conduction and then to the outside. This alternative involves no expenses that are not already commonly allocated in conventional housing: glass, concrete slabs, and heating elements. Insulation costs are usually higher, but the better constructed wall and roof will lead to longer building life, lessened fuel bills, and possible financing advantages. The value of the insulation in reducing heat loss will not only be useful for life-cycle heat bill control, but will enable the house to "feel" more comfortable and thus, require a lower maintenance temperature for winter heating needs. This occurs because exterior surfaces will not act as heat sinks to the warm human body sitting or standing near an outside wall. It gives a picture of a family comfortably using their entire living space during winter months rather than that of a family huddling near a central heat source seeking warm hands while their backs freeze.

Thermal Resistance

In order to arrive at an advantageous insulation package to minimize the effects of heat flow losses, while maximizing heat gain benefits, materials must be appropriately chosen. Each material can be measured and compared to every other material available so that the designer can construct a correct package. Thick material does not necessarily provide better insulation than thinner alternatives; for example, one inch of plywood is equal in value to five inches of asbestos cement board, and one inch of glass fiber is twenty-one times as effective as each inch in a common brick!

Every material is compared by a single standard: the number of hours it takes for one Btu to pass through a given thickness of material measuring one square foot on a side, with a 1°F temperature drop across the thickness. Most materials are judged by Btu per hour through *one inch* by one square foot of material; for example, it will generally take almost six hours for one Btu to pass through each inch of expanded polyurethane in a wall, while it will usually take only four hours for the same amount of heat to be conducted through one inch of expanded polystyrene. The number of hours the insulation can *resist* each Btu of heat loss is measured as the reciprocal of the conductivity, and is given a value of 1/k. Thus, the Resistance (R) of expanded polyurethane will be almost six, while the R, or 1/k, of expanded polystyrene will be four.

Often, certain materials are commercially available in thicknesses other than one inch. Gypsum board is usually required by builders in thicknesses of 3/8 inch or 1/2 inch, while face brick is usually found in 4 inch thicknesses. To facilitate design requiring these materials of non-standard thicknesses, the Resistance of the materials to heat loss is calculated to accommodate the sizes in common usage and is known as the reciprocal of the Conductance of the given material, or the number of hours of resistance to heat loss for the thickness used. Gypsum board with a 3/8 inch thickness has a Resistance, or reciprocal of Conductance, of 1/C = 0.32 of an hour, while 1/C for 1/2 inch gypsum board = 0.45 of an hour. Four inch brick can be found by determining the reciprocal of Conductivity of one inch of face brick which equals 0.11, and multiplying by four inches, which would yield a total Resistance to heat loss of 0.44 of an hour.

Conductivity = k = number of Btu per hour that flow through one square foot of a material one inch thick when the temperature drop through the material under conditions of steady heat flow is one degree Fahrenheit.[16]

Conductance = C = the same as for Conductivity, except that the thickness measured is for other than one inch.

Resistance = R = 1/k = 1/C = the ability of a material to withstand heat loss; measured for one square foot of material by a given thickness per hour per degree Fahrenheit.

Coefficient of Transmission = U = 1/R overall coefficient of heat transmission for a structure including surface air films and the combination of materials used.

The thermal resistance of various materials can now be compared.

Selected Materials for Prefabrication:

Resistance to Heat Loss of Common Building Materials*

Material	Density lb / ft^3	Conductivity k	Conductance C	Resistance R 1/k	 1/C
Insulation					
blanket and batt					
cotton fiber	0.8-2.0	0.26		3.85	
mineral wool	0.5	0.32		3.12	
wood fiber	3.2-3.6	0.25		4.00	
boards and slabs (values will vary according to commercial brand, blowing or pressing methods, and densities)					
glass fiber 1"	4.0-9.0	0.24		4.17	
2"				8.34	
3"				12.51	
4"				16.68	
5"				20.85	
6"				25.02	
corkboard 1"	6.5-8.0	0.27		3.70	
6"				22.20	
expanded rubber, rigid	4.5	0.22		4.55	
expanded polyurethane 1"	1.5-2.5	0.16		6.25	
4"				25.00	
6"				37.50	
expanded polystyrene, extruded 1"	1.9	0.25		4.00	
4"				16.00	
6"				24.00	
expanded polystyrene, molded beads 1"		0.26		3.85	

Material	Density	Conductivity	Conductance	Resistance R	
	lb / ft^3	k	C	1/k	1/C
4"				15.40	
6"				23.10	
wood or cane fiberboard: acoustical					
1/2"			0.84		1.19
3/4"			0.56		1.78
1"		0.42		2.38	
loose fill:					
sawdust	0.8-15	0.45		2.22	
vermiculite	4.0-6.0	0.43		2.33	
Building Paper					
vapor barrier:					
permeable felt			16.70		0.06
2 layers of mopped 15# felt			8.35		0.12
seal, plastic film			negligible		negl.
Siding Materials					
shingles:					
asbestos-cement			4.76		0.21
wood, 16", 7½" exposure			1.15		0.87
wood, double, 16", 12" exposure			0.84		1.19
siding:					
asbestos-cement, ¼" lapped			4.76		0.21
asphalt, ½" bd.			0.69		1.46

Material	Density	Conductivity	Conductance	Resistance R	
	lb / ft^3	k	C	1/k	1/C
wood:					
drop, 1x8			1.27		
bevel, ½x8, lapped			1.23		0.81
plywood, 3/8", lapped			1.59		0.59
Woods					
hardwoods:					
maple,	45				
across grain		1.26		0.79	
along grain		3.02		0.33	
oak,	51				
across grain		1.46		0.68	
along grain		2.42		0.41	
hardwoods:	34				
elm		0.88		1.13	
fir		0.67		1.49	
pine, white, across grain		0.80		1.25	
Building Board					
asbestos-cement, 1"	120	4.00		0.25	
1/8"	120		33.00		0.033
gypsum or plaster					
3/8"	50		3.10		0.32
1/2"	50		2.25		0.45
plywood	34	0.80		1.25	

* these values are selected or derived from several sources: McGuiness and Stein, Malloy, Sweet's Catalogue, and are generally based upon work done by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) in the Society's Handbook of Fundamentals.

Effects of Air on Insulation Values

Air Spaces and Emissivities

Heat loss can be greatly minimized by introducing a dead air space into a composite wall because motionless air is an excellent insulator. Radiation exchange could reduce this potential unless faced on one side by a shiny reflective surface. This is due to the principle that reflective material will accept, or emit, only a small amount of heat relative to that emitted by common building materials. If a shiny, reflective material is simply sandwiched between two solids within a composite wall without an air space, no radiated heat loss reduction will take place, since radiation depends upon an air space for heat transfer. It is only the combination of air space plus reflective material that results in lowered transmission of heat through the wall. In addition, conduction losses will be low across such a space, since motionless air has a low conductivity.

The term emissivity has two uses: it can indicate the average emissivity, or ϵ , for a single material, or it can relate the effects of emissivity, or E, on an air space faced by two separate building materials of emissivity ϵ_1, and ϵ_2.

Comparative Emissivities:[18]

Surface	% Reflectivity	ϵ_1,	Effective E	
			using ϵ_1 with ϵ_2 = 0.9	using ϵ_1 on both sides
Aluminum foil, bright	92 to 97	0.05	0.05	0.03
Aluminum sheet	80 to 95	0.12	0.12	0.06
Aluminum coated paper, polished	75 to 84	0.20	0.20	0.11

Surface	% Reflectivity	ϵ_1,	Effective E using ϵ_1 with ϵ_2 = 0.9	Effective E using ϵ_1 on both sides
Steel, bright galvanized	70 to 80	0.20	0.20	0.11
Aluminum paint	30 to 70	0.50	0.47	0.35
Common building materials: wood, paper, glass, masonry, non-metallic paints	5 to 15	0.90	0.82	0.82

Heat loss resistance for walls, roofs, and floors can thus be compared for structures using an air space-plus-bright aluminum foil and for structures with an air space, but with no reflective surface:

<u>Resistance and Conductance of 3/4" Air Space</u>[19]

Position of air space	Direction of heat flow	Conductance = C			Resistance = R		
		E=0.05	E=0.20	E=0.82	E=0.05	E=0.20	E=0.82
Horizontal	Up	0.06	0.73	1.24	1.67	1.37	0.78
45° slope	Up	0.51	0.65	1.20	1.95	1.54	0.83
Vertical	Horizontal	0.36	0.49	1.04	2.80	2.04	0.96

The values of E are derived from the preceding chart on Comparative Emissivities:

0.05 = an air space that is faced on one side by bright aluminum foil and on the other, by common building materials.

0.20 = an air space that is faced on one side by polished aluminum coated paper and on the other, by common building materials.

0.82 = an air space that is faced on both sides by common building materials.

It can be seen from this chart that with the minimal effort and cost involved in inserting a reflective barrier between common building materials and the air space, resulting in a composite wall of common building material + reflective surface + air space + common building material, effective thermal resistance to heat loss across the air space is nearly doubled.

Air Films

Air films represent a small area of motionless air that clings to surfaces of walls, floors, or roofs. This motionless air resists heat loss mechanisms of conduction and convection. However, as cool air moves past a warm surface, it carries away heat from the material by convection. This must be taken into account when determining the amount of insulation that will adequately resist discomfort conditions. Indoor conditions, of course, will be less drastic than outdoor conditions, but they also contribute to heat loss and must be calculated.

Indoor conditions actually reflect a combination of convection and conduction: warm room air flows, or is conveyed, towards the cooler surface of the walls and loses heat through the solid wall by conduction. This surface conductance is different for walls, floors, and roofs; the slope of walls and roofs will also play a role.

Surface Conductance and Resistance for Still Air[20]

Position of Surface	Direction of Heat Flow	ε = 0.90		ε = 0.20		ε = 0.05	
		C	R	C	R	C	R
Horizontal (ceilings)	Upward	1.63	0.61	0.91	1.10	0.76	1.32

Sloping 45° (ceilings)	Upward	1.60	0.62	0.88	1.14	0.73	1.37
Vertical (walls)	Horizontal	1.46	0.68	0.74	1.35	0.59	1.70
Horizontal (floors)	Downward	1.08	0.92	0.37	2.70	0.22	4.55

Again, as is seen in the chart for comparative air space resistance, reflective materials are shown to have much higher resistance to heat loss:

ϵ = 0.05 = one surface with bright aluminum foil

ϵ = 0.20 = one surface with polished aluminum coated paper

ϵ = 0.90 = one surface with common building materials

Exterior conditions reflect more clearly the effects of convection alone as the colder exterior air acts as a heat sink for the warmer outside wall of the building. The wind affects the heat loss through the wall, since it rips away the insulating air film that normally clings to the wall surface.

Surface Conductance for Moving Air[21]

Any Position (f_o)	Direction of Heat Flow	Surface Emissivity = 0.90	
		C	R
15 mph wind (usual average for winter)	Any	6.00	0.17
7½ mph wind (usual average for summer)	Any	4.00	0.25

This wind factor is known as the "f_o", or outdoor factor; it only is given for ϵ = 0.90, since most materials that are used on the outside of a house are non-reflective.

Temperature Determination

Temperature Determination

Most calculations involving comfort conditions require knowledge of the temperature differences between the cold outdoors and the desired warmth of the indoors for the heating season and the exact opposite for the summer cooling season when outdoor temperatures may rise to a higher degree than indoor comfort conditions require.[22]

Cooling Season

Summer season conditions for Boston and vicinity, and for the Northeast in general, are not as extreme as the wintertime differential: 99% of the summer, the temperature is below 85°. Ventilation provided by good control of prevailing summer breezes combined with devices to shade direct sunlight will usually yield adequate regulation for comfort conditions. In addition, glare protection, adequate insulation, and judicious placement of plants, trees, trellises, and overhangs will further enable the inhabitants of a living space to avoid mechanical equipment. This passive "low-tech" approach favors large cost savings for huge air conditioning elements that are not required: small supplementary fans should be able to balance the comfort requirements for the 1% of the summer that cannot be accommodated by design measures.

Heating Season

Heating season conditions for Boston and vicinity are calculated by the difference between the average outdoor temperature and the desired indoor temperature determined from actual winter temperatures:

92% of the year, the temperature is above 25°.

Only three days are likely to be at or below 0°.

The average temperature for December = 32°
January = 30°
February = 31°

Average "low" temperature for December = 25°
January = 20°
February = 21°

From this, the outdoor design temperature can be assumed to be 28°, which is determined by averaging the proportion of time above and below 25° for these cold months. Thus, the temperature difference, or delta t, can be determined by subtracting the outdoor design temperature, t_o, from the indoor design temperature, or indoor desired maintenance temperature, t_i:

delta t = $(t_i - t_o)$

delta t = $(68^\circ - 28^\circ) = 40^\circ$

Thus, the total temperature difference for use in all winter heat loss calculations will be 40°.

As in the summer, large mechanical plan equipment can be avoided by designing for major winter requirements rather than by designing for an arbitrary and unnecessary general outdoor design temperature of 0°. Small local heating elements can be used to supplement a system designed to accommodate 28° usual needs. Solar heat gain, good insulation, and careful construction techniques can further minimize reliance on expensive, but not optimal, equipment.

This suggests an approach to design known as "peak chopping", or design for mean conditions rather than design for the rare and extreme condition. Traditionally, mechanically systems are "over-designed", or designed for the worst conditions that the building will ever undergo. Large and expensive equipment is installed that, during the entire lifetime of the building, will operate at only 40% to 50% of capacity in order to accommodate the exceptional condition that occurs only a few times during a season. The "peak chopping" attitude for sizing mechanical equipment advocates designing for mean conditions, or conditions that are true for <u>most</u> of the year or given season, with supplementary elements that can be plugged in or turned on when needed to meet the difference between the regular equipment and the unusual outdoor weather condition. Each piece of equipment will then be operating at its optimum capacity. This approach thus encourages planning for actual daily needs with actual reasonable associated costs.

Infiltration

Often, people notice that houses, in which thermostats are set for extraordinarily high temperatures, nevertheless are "drafty". Sometimes, it seems as if there are actually "cold spots" in the house or as if there is a general feeling of overheatedness concurrent with "cold chills". This is usually due to the phenomenon of infiltration losses which can account for nearly 50% of the heat loss that occupants of a living space will feel. These losses may even occur in well insulated houses. Infiltration may be understood as the action of wind or cold exterior air in seeping through crack in walls, cracks around poorly framed doors and windows, leaks in roofs, cracks around plumbing pipes, etc. This cold air finds its way into the warm interior of the house and displaces the heat generated by heating elements or maintained by generally good insulation in the walls and roof. Thus, the thermostat can be set at temperatures that will enervate the inhabitants, but the heat will still be continuously drained as if an attempt were actually being made to heat the outdoors.

Of course, some fresh air is needed to carry off foul odors, kitchen smells, and excess humidity as well as to provide necessary clean air for respiration. But design and construction should provide only <u>needed</u> air; they should not ignore heat losses and greatly reduced comfort conditions due to infiltration. The necessary air supply can be calculated to provide the infiltration required for health conditions:

1. Determine necessary air supply in cubic feet per minute per person:

Reasonable cubic feet per minute =
10 cfm (below 5 cfm, odors accumulate)
number of people for "standard" family =
4 persons

10 cfm x 4 people = 40 cfm per family required

2. Determine hourly cubic feet of air: 40 cfm for 4 people x 60 minutes = 2400 cubic feet of air per hour

3. Determine Btu per hour heat loss due to Infiltration:

Infiltration = (specific heat for air) x (density of air) x (change in temperature) x (desired cubic feet per hour)

0.24 Btu = specific heat for air, or the heat required to raise one pound of air $1^{o}F$

0.075 pound per cubic foot = density of air

$40^{o}F$ = temperature difference, or average temperature difference between interior and exterior winter temperatures = delta t

2400 cubic feet per hour = desired cubic feet per hour for 4 people

A constant can be used for facilitating frequent multiplication of the specific heat of air x density of air = K = 0.24 x 0.075 = 0.018 Btu per hour

Thus I = (K) x (delta t) x (ft^3/hr)
Infiltration = 0.018 x 40^{o} x 2400 ft^3/hr
= 1728 Btu per hour

This calculation assumes that the fresh air requirements for 90% of the year or more will be met for the four inhabitants. When guests arrive during the remainder of the year, more fresh air is required to meet their needs. Rather than underdesigning the comfort system for the entire heating season for this occasional situation, the air supply can be freshened by simply opening a window. The additional heat generated by the movements of the additional people will compensate for heat loss and the fresh air supply can be monitored by closing the window or opening it to a height that will yield comfort.

This method of determining infiltration can be called "the desired air supply" method, as opposed to the traditional method of calculating losses by determining "probable" infiltration which is known as "the air change" method, which assumed poor inspection supervision over cracks occurring during construction. New materials, such as poured foam, and methods of building, such as the use of calking guns and complete building sheathing, are now available to enable the designer to control unwanted infiltration and to provide only the amount of air necessary for comfort (see also the discussion of infiltration under "doors").

BASIS OF MATERIALS SELECTION

Materials chosen for a "prototypical living space" must fulfill many criteria if optimal building packages or homes are to be constructed. Therefore, materials selection to be incorporated into a prefabrication system will be based on criteria determined from the principles derived in this thesis.

Most importantly, of course, is the "acceptability" factor. Future residents must be able to see themselves enjoying life surrounded by materials that are warm and "home-y"; cheapness and efficiency may be useful factors, but if materials are not satisfying, then the entire building will not have value as a living space that is used day after day for forty, sixty, or eighty years.

Aluminum siding, for example, has become popular as a method of suggesting the "look of wood" without associated continual repainting costs. But the actual appearance of aluminum can never approximate the qualities of wood: aluminum does not "age gracefully" -- it becomes dented; it has none of the thermal properties of wood that reduce heat transmission -- instead, it is cold in the winter and hot in the summer. Even wood can disrupt a neighborhood's contextural response by using vertical board and batten siding amidst narrow-width horizontal siding in order to make a "bold design statement". Corner moldings, window treatment, and sizes of shutters when used all indicate a sensitivity to an existing framework. This does not require slavish imitation of previous centuries' pattern books, but rather suggests an allusion to detailing that can provide a sense of harmony from house to house and from old to new.[23]

Nevertheless, desirable materials must be chosen within a framework of <u>financing acceptability</u>. That is, if the costs of financing special materials are more than construction costing and mortgage availability can sustain, then the building simply will not be built. However, an advantage to the bank of requiring materials acceptable to families is that the bank's investment in the house will have a better chance of withstanding fluctuations in national economics since it will be better able to retain its basic desirability.

Another determinant of planning that is advantageous to the bank and to future occupants is correct insulation to <u>reduce heat transmission</u> throughout the year, with heat loss minimized in the winter and heat gain minimized in the summer. Heat transmission control affects not only monthly utility bills, it also influences long-term maintenance of the building for decreasing effects of <u>weathering</u>, <u>condensation</u>, and <u>rot</u>. Consequently, with these variables taken into consideration during the planning stage, the homeowner has lower associated costs and the banker has lower associated worrries throughout the life cycle of the living space.

Further reductions in overall costs will be found in innovating in materials use during the design period rather than making after-the-fact corrections. Prefabrication as a cost-accountable method of building, will require materials selection based on ease of application at the prefabrication plant and ease of on-site assembly, rapid handling time, accurate forecasting of transportation-associated costs of heavy or unwieldy materials, etc.

Fire-resistance is an important safety criterion. The loss from fires in the United States to property alone in 1973 was $3.1 billion, while 12,000 people lost their lives in fires, and another 300,000 sustained serious burn injuries; additional factors such as loss of productivity and the cost of operating fire departments, providing insurance, and treating burns, brought the total cost to society to $11.4 billion, or more than 1% of the gross national product.[24] Materials will thus have to compare favorably with standards on flame spread, fuel contribution, and smoke development; when possible, information on noxious fumes development should also be compared. These factors will be judged in comparison with asbestos board; red oak is also given to present a comparative picture of wood and asbestos:

	Asbestos Board	Red Oak
Flame spread	0	100
Fuel contributed	0	100
Smoke developed	0	100

Consequently, although it may actually cost more to choose materials that have excellent fire ratings, again in terms of true costs, both banker and homeseeker will benefit from a total package that has a chance of remaining standing for the expected life of the building!

In summary, then, the general process of choosing materials should include a selection method whereby these criteria can be examined, compared, and acted upon.

Materials Use

Sweet's Catalogue of architectural and builders' materials, which is the most complete compilation of available materials, will also be used as a guide for materials selection since the criterion of current, or "off-the-shelf", availability is necessary.

Wall Panels

The basic panels must fulfill two requirements: structural stability and weather protection. Each prefabricated panel must have its own sheathing and anti-racking ability as an integral part of its own package. In this way, assemblers will have only to join together various panels without the worry of insufficient structural protection. The panel must also provide a weather seal from excessive heat loss as well as from condensation and infiltration. Poorly installed vapor barriers will encourage the condensing of moisture inside the sealed panel package, making it virtually impossible for the homeowner to take any measures in the future to correct the problem. Infiltration of cold air through poorly sealed cracks occurring anywhere along the surface of the panel can negate most of the positive effects on heat loss reduction of the insulation package within the panel.

Interior panels may serve three purposes: room partitioning, acoustic separation, and often, structural stability. For these requirements, the panel that will be designated "interior" may be constructed according to a module more useful to the circumstances. Structural stability can be provided without the need for exploring deep wall sections since a minimal four-inch by four-inch post will satisfy most interior support needs. Acoustic separation is extremely important: one of the greatest sources of dissatisfaction in inexpensive houses is the complete disregard for acoustical privacy. Sound insulation between rooms, especially between sleeping and living areas, will help encourage the feeling that there is at least some place in the house where family members can fulfill needs for complete privacy. A side benefit of sound insulation is that it causes interior walls to seem more "substantial", that is, the sound-deadening properties enable an otherwise thin wall to have the acoustical properties of a very thick wall. The privacy and "established" feeling afforded by this type of interior wall may enhance feelings of "home-iness".

A further comparison of specific appropriate insulation materials, plastics costs, and panel sections, using Sweet's Catalogue's manufacturers' descriptions, can now be undertaken.

RAPCOFOAM INSULATION

- non-combustible urea formaldehyde resin
- foamed-in-place thermal and acoustical insulation
- contains no polyurethane nor polystyrene
- non-flammable and non-combustible

- thermal conductivity = k = 0.2, R = 5.0
- sound absorption: provides 83 - 92% sound absorption at 2" thicknesses

- temperature and humidity variations do not cause volume changes or exert pressure
- water vapor transmission: 32 - 38 perms; will not hydrolyse; moisture absorption in wet cavity wall over 24 hour period: 2% by weight

fire rating:

non-combustible per ASTM test number E136-65

will not ignite up to 1208°F.

with foam exposed (per ASTM test number E84-70):

flame spread = 25

smoke density = 0 - 5

fuel contributed = 10

gas evolution: when subjected to flame or radiant heat of 1208°F., the material decomposes, releasing water vapors and chemicals (from a

(RapcoFoam, continued)

2 gram sample in a 5 ft^3 cavity):

117 ppm CO

52 ppm HCHO

7 ppm HCN

8 ppm NO_2

- toxicity: "non-toxic" according to Federal Hazardous Substance Act; complies with New York City building law
- pest and mold resistant
- installation:

  no preparation needed;

  can be applied through small opening one inch in diameter;

  applied by patented gun with working pressure of 65 pounds per square inch;

  after application, no further expansion takes place;

  may be applied at any temperature, but components must be brought to gun at temperatures between 55°F - 85°F;

  typical void between studs filled after two minutes;

  setting time: initial setting time is 10 - 60 seconds out of gun, additional curing occurs within 2 - 4 hours, and drying occurs within

(RapcoFoam, continued)

1 - 2 days (longer in cold weather or in enclosed cavity);
can be smoothed and trowelled;
stability guarantee: 10 years;
normal shrinkage during drying: 1.8% - 3%

Rapco is an attractive material for thermal insulation, fire resistance, and sound absorption; its application method and curing time may, however, pose problems for prefabrication.

STYROPOR INSULATION

- exterior insulation finish system
- expanded beaded polystyrene: beads are composed of a styrene polymer containing an expanding agent which will, when subjected to heat, expand up to 40 times its original volume; then beads are molded into blocks by further heat processing; after aging or curing time, the blocks are cut into slabs, sheets, or other specified shapes
- water vapor transmission in perm inches:

  density: 1 pcf = 1.2 - 3.0
  1.5 pcf = 0.8 - 1.7
  2 pcf = 0.6 - 1.2
- non-structural: requires corner bracing
- low material and installation costs
- will not twist or warp
- unaffected by vibration
- does not support bacterial growth
- non-irritating to skin; clean; odorless
- size availability: thickness, ½" increments to 20"
  length, 4' - 16'
  width, 12" - 48"
- fire rating: flammability for 1.1 pcf density per ASTM test number E84 and tested by Underwriters Laboratories:

(Styropor, continued)

	for 3" thickness	for 4" thickness
flame spread	0	5
fuel contributed	0	0
smoke developed	40-100	250-350

toxicity on inhalation is less than for wood fumes

- thermal conductivity varies with density and reporting agency: the Styropor manufacturer, BASF Wyandotte, reports for 1 pound per cubic foot, k = 0.25, (R = 4.00)

  1.5 pounds per cubic foot, k = 0.23, (R = 4.34)

  2 pounds per cubic foot, k = 0.22, (R = 4.54)

  ASHRAE (in McGuiness and Stein): 1 pcf, k = 0.27, R = 3.7

STYROFOAM:

- plastic foam molded into board form
- can be used as a nail base for any siding except wood shakes if nailed through to studs
- good moisture control
- thermal conductivity: k = 0.2, R = 5.0
- fire rating: as a plastic foam, it is susceptible to flame spread; once ignited, it will burn rapidly, releasing dense smoke; company specifications state: "when wood or other combustible finish is specified, styrofoam shall be covered with ½" taped gypsum wallboard."

Styrofoam's good thermal resistance and ease in application to exterior of stud wall system make it a desirable product for the exterior prefabricated wall panel, but its susceptibility to fire may make it unacceptable.

C.I.S. INSULATION

- mineral wool fiber non-dusting spray
- can be applied directly onto gypsum board, lath, or plaster, but not onto unsealed wood
- thermal conductivity: $k = 0.26$, $R = 3.85$
- good sound control according to manufacturer
- odor-free
- fire rating: fire-resistant and non-combustible due to inorganic, lava base; mineral fibers are not dependent on water soluble fire retardant chemicals as in cellulose fibers according to manufacturer; rated non-combustible by Underwriters Laboratories

C.I.S. has a better fire resisting mechanism inherent in its material than RapcoFoam, but its lower thermal resistance may make it less desirable.

FIBER GLASS INSULATION

- long, fine glass fibers
- great resiliency: reduces bulk and consequent costs of shipping, storing, and handling
- sound control: in conjunction with various stud wall

(Fiber Glass, continued)

systems, provides excellent sound absorption; Sound Transmission Control ratings:

above 53 STC = excellent
47 - 52 STC = good
42 - 46 STC = marginal
below 42 STC = poor

using these ratings developed at sound testing laboratories of Owens-Corning Fiberglas, appropriate interior wall panels can be developed:

STC of 45 = single wood studs, 16" on center + double layer of ½" type x gypsum board on each side + 3½" Fiberglas insulation between studs (R = 11)

STC of 49 = staggered wood studs, 16" on center (this requires a 2" x 6" plate for 2" x 4" staggered studs which will cause the interior wall to be thicker) + single layer of ½" gypsum board on each side + 3½" Fiberglas (R = 11)

STC of 51 = single wood studs with resilient channel (this will require a ½" x 3" filler stop of gypsum board to fill the gap caused by the channel) + a single layer of ½" gypsum board on

(Fiber Glass, continued)

either side + 3½" Fiberglas

STC of 53 = staggered wood studs, 24" on center + double layer of ½" gypsum board on one side of panel + single layer of ½" gypsum board on other side + 3½" Fiberglas

STC of 56 = single wood studs with resilient channel + double layer of ½" gypsum board on each side + 3½" Fiberglas

additional reduction of sound transmission will be possible if all cracks and surfaces are sealed and if any potentially connecting airways, such as back-to-back electrical outlets, are blocked

- thermal resistance for glass fiber insulation varies with density, type (batt, blanket, or board), and with reporting agency, such as Johns Manville Co., Owens-Corning Fiberglas, or texts such as Malloy or McGuinnes & Stein (taken from ASHRAE); for this paper, the ASHRAE figures will be used: density of 4 - 9 pounds per cubic foot is greater than that of most other reporting agencies; for mean temperature of 60°F., R = 4.17, U = 0.24
- availability appropriate to prefabrication: blankets that fit between studs - "friction fit" has no

(Fiber Glass, continued)

inherent vapor barrier, should be used with polyethylene film or foil-backed gypsum; also available with integral vapor resisting foil facing

- fire rating for "friction fit" fiberglas without facing listed by Underwriters Laboratories:

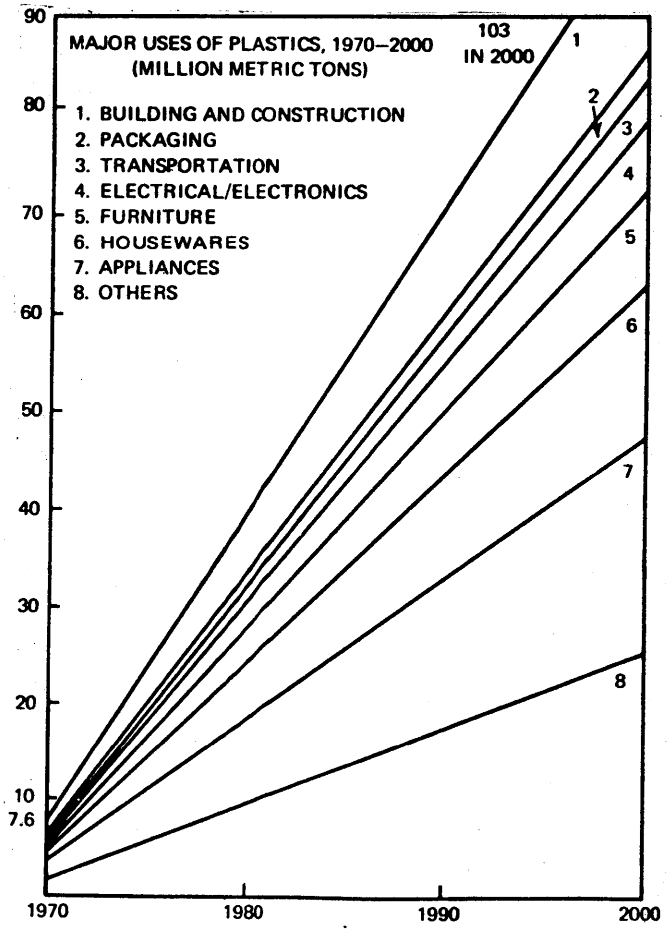
  flame spread = 20
  smoke developed = 20
  fuel contributed = 15

  this rating, by Underwriters Laboratories, is for Friction-Fit Fiberglas and equals 20% of the fire-contributing factors of untreated red oak
- water vapor transmission: Foil-Faced Fiberglas has a permeance (vapor transmission) of 0.5, while Kraft paper-faced Fiberglas has a permeance rating of one perm or less; Friction-Fit has almost no vapor transmission control; Noise Barrier Fiberglas, similar to Friction-Fit, has no facing, fits by friction into place in interior stud walls, and similarly has no vapor transmission control

Fiber glass is an attractive material for prefabrication due to its ease in handling and application, its low cost, and its good fire-resistance. It has lower thermal resistance than seems optimal; a comparison with other materials in an actual wall package is necessary to determine its appropriateness.

Questions of Increased Plastics Use

In most of the insulating materials, the use of plastics plays an important role. Since most plastics are petrochemical-dependent for production, this increased use raises the question of the validity of intensive plastics use for heat bill reduction and fossil fuel independence versus the increased potential energy costs of plastics production. In fact, even without future innovations in additional applications for plastics, the rapid rise of plastics use since 1950 has been phenomenal. In 1950, one million tons were produced as compared with 1972, when approximately eleven million tons were used.[25] When major domestic outlets for plastic materials are broken down into uses, it becomes clear that applications centering around the home play the major part today as well as for estimated uses until the year 2000.[26]



In addition, a comparison of energy required for variou materials' production in kilowatt hours per ton further intensifies the feeling that the panel sections that use plastics as insulation are costing more than they save:[27]

Material	kwh per ton	$ per ton
Steel	3,600	184
Aluminum	64,000	560
Glass	3,500	140
Plastics	25,000	3,000
Cement	1,300	17
Lumber	940	100

Fortunately, however, plastics requirements are not as energy-voracious as it would appear. Plastic is such a light material that a comparison of actual density reveals that typical insulating plastic weighs only 1.1 pounds per cubic foot while plywood weighs at least 34 pounds per cubic foot. Consequently, the energy price of plastics is among the lowest of all common building materials:[28]

Material	kwh per $ of material = kwh per ton/$ per ton	Energy Price % = the percentage of the purchase price devoted to fuel required to produce the material
Steel	20	4
Aluminum	114	23
Glass	25	5
Plastics	8	2
Cement	76	15
Lumber	9	2

the energy price % was obtained by multiplying kwh per $ by 2 mills: equivalent to 60 cents per million Btu and expressed as %

Consequently, panel choices can be made with optimum insulation possibilities using optimal criteria as goals: increased plastics use will not alter the validity of using plastics as a method of fuel cost reduction.

Wall panel packages that use the advantages of the insulating materials of the previous pages can now be compared.

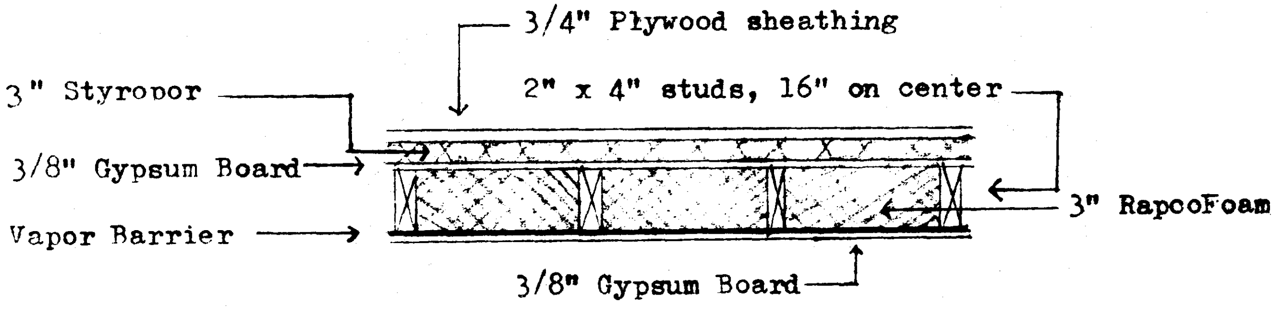
Exterior Wall Panel

Gypsum Board + Vapor Barrier + Rapcofoam + Gypsum + Styropor + Plywood

Material	Thermal Resistance (R)
Gypsum Board, 3/8"	0.32
Vapor Barrier	0.06
Rapcofoam, 3"	15.00
Gypsum Board, 3/8"	0.32
Styropor, 3"	11.63
Plywood, 3/4", sheathing and siding	1.07
	28.40

R= 28.40

U= 0.035



If air resistance is added to materials, the total resistance will change:

indoor air resistance = f_i = 1.46, R = 0.68

outdoor air resistance = f_o = 6.00 R = 0.17

R = 0.85 = air film

$$\begin{array}{ll} R_{\text{materials}} & 28.40 \\ R_{\text{air film}} & \underline{+\ 0.85} \\ & 29.25 = R_{\text{total}} \qquad (U_{\text{total}} = 0.034) \end{array}$$

Compare "Styropor + RapcoFoam" Wall Panel with "RapcoFoam" Wall Panel

Use actual possible conditions:

Assume 1 exterior wall, 8' x 8' = 64 square feet area

Expected glazing = 20% of wall area

20% glazing = 64 ft^2 x (0.20) = 12.8 ft^2

80% solid = 64 ft^2 x (0.80) = 51.2 ft^2

Glazing:

Assume double glazed, ½" air space, U = 0.58

80% glass with wood sash, % multiplication factor = 0.95

Total U-value = (0.58) x (0.95) = 0.55

R = 1/(0.55) = 1.82

Find heat loss for exterior wall with "Stropor + RapcoFoam"

(12.8 ft^2) x (0.55) x 40° change in temperature = 281.60

(51.2 ft^2) x (0.034) x 40° change in temperature = 69.60

Btuh heat loss = 351.20

Change wall section: retain RapcoFoam
leave out Styropor

$$\begin{array}{rll} & 29.25 = R_{total} & \text{for non-glazed panel} \\ - & \underline{11.63 = R} & \text{for Styropor} \\ & 17.56 = R_{new\ total} & (U = 1/17.56 = 0.057) \end{array}$$

Find heat loss for exterior wall with RapcoFoam and glazing

(12.8 ft^2) x (0.55) x 40° change in temperature = 281.60

(51.2 ft^2) x (0.057) x 40° change in temperature = 116.80

398.40

Compare heat loss: 398.40 for RapcoFoam wall package

− 351.20 for Styropor + RapcoFoam

47.20 Btuh difference

This difference may not be worth the additional costs of Styropor.

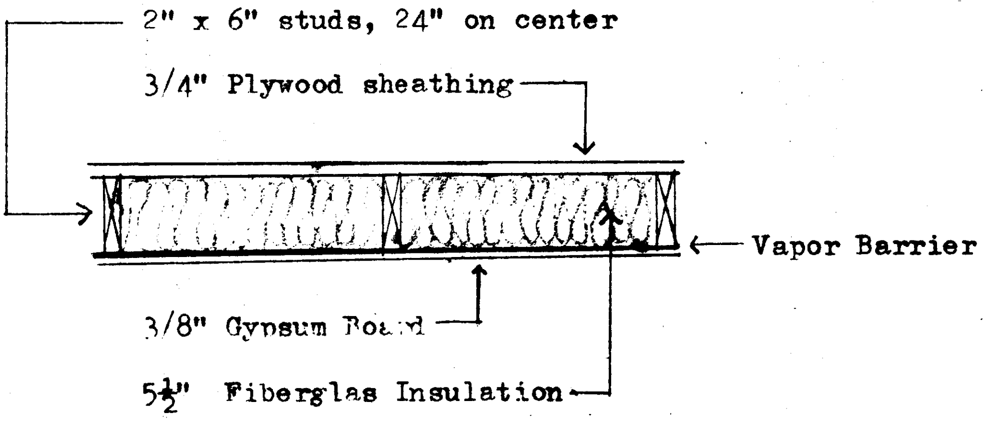
Exterior Wall Panel

Plywood + Glass Fiber Insulation + Vapor Barrier + Gypsum Board

Material	Thermal Resistance (R)
Gypsum Board, 3/8"	0.32
Fiberglass Insulation, 6" nominal thichness	22.94
Vapor Barrier	0.06
Plywood, Texture 111 sheathing, 3/4" siding	1.07
	24.39

R = 24.39

U = 1/R = 0.041



Roof Panel

same material as wall panel

for greater thermal resistance and structural requirements, add:

2" x 10"s with 9½" Fiberglas Insulation

R = 41.07

U = 0.024

Fiber glass appears to be a useful choice for the panel package since it has favorable thermal resistance, is easily incorporated into the prefabrication system, and is low in cost.

Doors

Doors, as additional "pieces" for prefabrication, will depend for heat loss transmission on their thickness as well as on their material composition and storm door usage. Transmission can be determined similarly to other building materials using known U-values:[29]

Nominal Thickness	Btu per hour per square foot per degree F. no storm door	wood storm door	metal storm door
1 inch	0.64	0.30	0.39
1¼ inches	0.55	0.28	0.34
1½ inches	0.49	0.27	0.33
2 inches	0.43	0.24	0.29

(values for wood storm doors are for 50% glass; values for metal storm doors are for any percentage glass)

These standard thicknesses and values can be improved by the use of special doors, wood storm doors without glass, tight connections between the storm door, the house door, and the door jamb in order to further reduce infiltration, and by using available magnetic strips that form a sealed joint between a magnet on the door and a magnet on the door frame whenever the door is closed causing the strips to come into contact with each other along the entire crack around the door opening. Rubber and cloth strips have often been used for this purpose in old drafty houses. Rubber has the advantage of being a poor conductor of building heat to the outdoors, but unless it is a synthetic rubber, it is subject to deterioration and cracking after constant use and repeated exposure to extreme temperature fluctuations.

Glazing

Glazing is often the single largest contributor to both heat gain and heat loss. It provides natural light that gathers all the colors of the landscape and brings them into the house subtly to enhance the tones of the furnishings and materials inside. It enables a person to see all the variations in the seasons while feeling safe and cozy indoors. Glazing can provide accoustical privacy and inhabitants can "guard" their street scene while being physically separated from strangers.

Wintertime needs, of course, demand a tight weather barrier from the extreme temperature differential existing between the sides of the sheet of glazing. If glass is used the number of sheets becomes critical. Single panes of glass encourage constant condensation throughout the winter. This phenomenon occurs whenever very low exterior temperatures come into close contact with a minimal barrier to very high interior temperatures. Moisture that is always present in the air condenses along this cold sheet, because low temperatures cannot sustain the high moisture content that warm air can contain. Consequently, the single sheet of glass acts not as a barrier, but as a plane upon which the moisture conveniently is able to condense. This causes "fogging" and even water dripping as well as costly associated problems of eventual rotting of the materials around the pane of glass.

Double glass correctly installed immediately forestalls these problems: the adequate air space between the two panes of glass prevents the two extreme temperature conditions from coming into contact with each other. Heat loss is substantially reduced. Triple glass with two air spaces is even more remarkably successful in reducing heat loss. A comparison of coefficients of transmission, or U-values, for single glass, insulating glass, and storm windows, which act similarly to double glass, offers proof of these effects:[30]

Glazing	Winter U-Values
Single glass	1.13
Double glass: two panes with ½" air space	0.58
Triple glass: three panes with	
¼" air space	0.47
½" air space	0.36
Storm windows: 1" - 4" air space	0.56

Since glazing is figured into heat loss calculations by its square footage, the cladding or mullion treatment must be factored in because it reduces the net square footage of the glass. This mullion factor or percentage should be multiplied by the U-values used in order to arrive at a total figure for the window type:[31]

	single	double or triple	storm windows
all glass	1.00	1.00	1.00
wood sash: 80% glass	0.90	0.95	0.90
wood sash: 60% glass	0.80	0.85	0.80
metal sash: 80% glass	1.00	1.20	1.20

These figures indicate that a single pane of glass transmits heat three times as fast as three panes, and that three panes are nearly half as susceptible to heat loss as double glazing.

Why Double Glazing is Better Than Triple Glazing

Nevertheless, to determine accurately whether triple or double glass is actually more efficient, it is necessary to compare winter heat loss to potential winter solar heat gain. Summertime heat gain can be discounted from this determination since all glass must be shaded from the sun.

For a given house with given glass square footages:

Glass	Area	U-value	delta t	Btuh heat loss
triple panes with two ½" air spaces and wood sash with 80% glass	296 ft^2	0.34	40°	4025 Btuh
double panes with one ½" air space and wood sash with 80% glass	296 ft^2	0.55	40°	6512 Btuh

6512 Btuh - 4025 Btuh = 1487 Btuh per hour difference

1487 Btuh x 24 hours = 35,688 Btu per day difference between triple glass and double glass

This makes it appear as if double glazing has a net loss of 35,688Btu per day more than triple glazing.

BUT each additional pane of glass cuts down on heat transmission through the glass.[32] Any heat gain that can be realized for the living space by means of solar radiation will be consequently reduced by a percentage for each sheet of glass beyond single pane glass:

> Single pane glass receives a maximum of 1630 Btu per square foot for the south wall of the building. Greater quantities of heat will, of course, be received if there is glazing on other sides of the building that receive sunlight.

In comparison with the same square footage as for double and triple glazing, single glass on the south wall will thus receive 1630 Btu/day x 296 ft^2 = 482,480 Btu:

Number of glass panes	maximum gain	x	percentage reduction in transmission over single pane	= net Btu
two	482,480		91%	439,057 Btu
three	482,480		82%	395,634 Btu

439,057 Btu for double glass
− 395,634 Btu for triple glass
43,423 net additional Btu if double glass is used instead of triple glass

No comparison is made between single and double glass since aforementioned problems of condensation and extreme temperature differentials that are modified by double glass cannot be handled in any way by single glass.

Other savings are possible in addition to Btu solar heat gain. The initial cost for triple glass is higher than for double glass. Framing costs are less for double glass since thinner stock wood pieces can be ordered for the frames. Labor also will be slightly less because less work is involved in setting in a double window than a triple. The additional weight of triple glass may also play a role in transportation cost savings from the window manufacturer to the prefabrication plant and then to the site, as well as in the number of trucks or other transportation units that will be needed to deliver the volume of material that is again greater for triple than for double glass.

These calculations indicate that tremendous heat gain can be received from the sun, more than will be lost by the windows. But what happens on cloudy days on which the temperature is at a winter extreme low? Again, this is the time to use supplementary heat which will be able to operate efficiently since overall infiltration losses of the house will be minimized by careful construction techniques.

Shades and curtains can further modify heat loss by window spaces. A person standing near a window in the winter will inevitably notice a difference between his perception of warmth there as compared to any other place in the room. His body acts as a heat source toward the slightly colder sheet of glass which, unlike the wooden walls of the rest of the room, is an excellent conductor; the window will "feel" cooler to the touch than the wall next to it. The shade acts as a cloth "barrier" to radiant heat loss from the person's body. Conduction losses will also be less if the person touches the shade lightly; he will perceive a cloth that is similar in temperature "feel" to other materials in the room. Only convection losses will still occur. Air spaces between the window and the window shade will still allow air to circulate. Warm air currents in the room will flow to replace cooler air behind the shade, and the person may feel a "draft". This can be corrected in part by having the window shade slide up and down within its own frame. This will only work well to reduce heat transmission during the winter, since summertime heat flow, which is the reverse of the winter situation, will cause increased discomfort once the heat is allowed to be trapped within the building.

In summertime, various screening mechanisms can play an integral role in the building's design. They can be movable to allow the family to operate them to permit varying amounts of sun into the building throughout the day. They can be demountable, or assembled in the summer to screen the building from the sun and dismounted in the winter to allow maximum solar heat gain to enter the building. They can be permanent, such as roof overhangs that have been carefully calculated to shield high summer sun angles while yielding to the low winter sun. Hot summer afternoon sun hits the house at a western as well as a high angle to the building; screens on that side must take this into account, resisting both directional rays from the sun. And, of course, deciduous landscaping, as mentioned earlier, can play a successful role similar to demountable screens.

New materials are being developed which have inherent in their physical constitution the ability to permit sun to penetrate similarly to two panes of glass and yet do not allow heat buildup within the house to escape as rapidly during the critical heating season as glass does. "Transparent insulation", developed by Day Chahroudi, Sean Wellesley-Miller and others at M.I.T., has a U-value identical to eight inches of lightweight aggregate with filled cores of mineral wool or to one inch of expanded polyurethane insulation. Its U-value is 0.2 and its heat loss resistance = R = 5.00. It is a plastic-like material that can be used for skylights or window walls above a height that is likely to sustain damage should someone lean against it. This material is available for design use now, and other innovative materials are constantly being studied.

Thermal Mass

Concrete slab-on-grade construction has traditionally been a source of heat loss as well as a cause of cold and "clammy" feet. This has been due to poor insulation from losses due to exposed edges of the slab. Slabs have often been heated by means of imbedded tubes carrying heated water or heated air to provide radiantly heated spaces. Heated water tubes have not been completely satisfactory due to occasional cracking and difficulty in effecting any repairs. Heated air has often been inadequate in providing enough heat to offset the losses sustained. New insulation is available, however, that resists heat loss. A system comprised of five inches of concrete slab set on polyurethane insulation completely surrounding the edges will prevent transmission of heat from the house through the slab and from there to the outdoors. The heat that has been conducted through the slab from the heat source of the house to the cooler heat sink in the slab will re-conduct through the material and re-radiate into the room which will have become cooler, having lost its heat to the slab. Thus the slab, in conjunction with a heat source, such as solar radiation shining through windows directly onto the slab, will begin to act similarly to a giant "radiator" throughout the house. In addition, the polyurethane is insulated from fire by means of the slab and the surrounding dirt. It will not deteriorate, as previous insulation has, when in contact with the moist dirt because the polyurethane will not rot, become mildewed, moldy, or otherwise respond to organic deterioration. The concrete slab will also be able to support great weights. In sum, this composite concrete slab can effectively be considered to resist net heat loss, and thus does not have to be factored into heat loss calculations.

The "delaying" effect on heat loss (via the conduction/re-conduction pattern) of concrete exhibits positive features of employing thermal mass to spread out the results of heat loss control. Bricks, decorative tiling, moist soil for indoor gardens, brick floors, rock sculptures, and indoor pools of water can advantageously use these principles. Collection of heat from the sun can, of course, only take place during the sunrise-to-sunset period, but storage in decorative, utilitarian, or exotic materials with great thermal mass, or long "lag" times for releasing heat gained, can effectively lengthen the heating period for up to twenty-four hours or even slightly longer. This means that design elements can respond to heating needs and can supply a living space with heat for a day or more.

If more solar Btu are entering the living space than can be used up right away by the concurrent heat losses of the house, then these design elements of thermal mass become not just an interesting or ornamental idea, they become absolutely essential for storing the extra heat. If these storage elements were not available, the living space would become drastically overheated and unbearably uncomfortable. In that case, it becomes necessary to depend on their properties of thermal mass. Rocks are able to store about 30 Btus of heat per cubic foot provided per degree increase in temperature, while water can store nearly twice as much heat.[33]

Water also compares favorably with concrete for heat storage:

Q/hour = $(v_p) \times (C_p\ \text{Btu}/\#^{o}\text{F}) \times (\text{delta } t)$
Q = heat flow
V_p = Volume for a given size x weight
C_p = specific heat (for water, concrete, etc.) measured in Btu per pound and per degree Fahrenheit
delta t = change in temperature, here, it is 20°F for a maximum swing of 20°F in temperature
WATER = $(1000\ \text{ft}^3 \times 64\ \text{pounds}/\text{ft}^3) \times (1.0\ \text{Btu/pound}\ ^{o}\text{F}) \times 20^{o}\text{F}$
= 1,280,000 Btu
divide this by 8 hours for hourly heat rate
CONCRETE = $(1000\ \text{ft}^3 \times 144\ \text{pounds}/\text{ft}^3) \times (0.2\ \text{Btu/pound}\ ^{o}\text{F}) \times 20^{o}\text{F}$
= 576,000 Btu

Thus it can be seen that water contained within the same cubic footage as concrete will be able to store more than twice as much heat. In addition, the temperature of the water is maintained consistently because of convection currents whereas the equation for concrete represents an average across the solid, reflecting local deformities or other conditions that serve to produce slight variations in concrete. Nevertheless, it may sometimes be convenient to use concrete in conjunction with water storage when a large floor slab is already designed and available.

PROCEDURE FOR HEAT LOSS, HEAT GAIN, AND HEAT STORAGE CALCULATIONS

The technical principles discussed now enable the designer to understand a building in terms of overall comfort. Calculations will prove whether this intuitive lucidity is defensible.

A. Determine <u>total heat loss</u> in Btu

1. list each material, item, wall, etc. in the house in a column
2. list each item's square footage
3. list the U-value for each item
4. list the change in temperature between the surfaces or spaces on either side of each item
5. find the hourly Btu loss by multiplying each variable on a line

   Example:

Material, wall, or item	square footage	U-value	delta t	hourly heat loss, in Btu
Wall	100ft^2	0.05	40°	200 Btu
Window: double glass, ½" air space, wood sash with 80% glass	10ft^2	0.55	40°	220 Btu
Wood door, 2" thick with wood storm door	20ft^2	0.24	40°	192 Btu

6. add the values in the heat loss column to find total hourly heat loss for the house; if only the items in the Example existed, it would mean that this house had an hourly heat loss of 612 Btuh

7. find the daily heat loss for the house by multplying the hourly heat loss rate by 24 hours; if the items in the Example were a real house, then the daily heat loss rate would = 612 Btuh x 24 hours = 14,688 Btu

This equals the total heat loss in Btu sustained by the living space.

B. Now determine the total solar heat gain in Btu

1. list the sides of the house that receive sun during the day in a column
2. list the square footages of glazing on each of these sides that allow the sun to enter the house
3. list the percent light transmission through the glazing used
4. list the daily Btu of solar radiation available to be collected for each square foot of glazed surface
5. multiply each variable on a line to find the daily heat gain for that side of the house
6. add the directional heat gain column to find the total daily heat gain

Example:

Direction	ft^2	% transmission	Btu	solar heat gain
East	100	100%	508	50,800
South	100	100%	1630	163,000
	10	91%	1630	14,833
Total daily heat gain =				228,633

7. multiply the total heat gain by 50% to find out what heat gain will be if the "50% cloudy day" factor is included: 228,633 Btu x .50 = 114,316 Btu

If it is assumed that a given house, for the purposes of the example, loses 100,000 Btu per day, it can easily be seen that, if the house is gaining at least 114,316 Btu in solar heat gain and can be stored and used then the system as a whole can confidently be expected to work to keep the inhabitants comfortable during the winter.

Storage of Excess Btu

Whenever more Btu enter the house than are required to balance immediate heat loss, it will be necessary to prepare a storage medium if the house is not to become temporarily overheated:

1. first find the heat loss that takes place during eight hours, or the maximum heat gain period for that day, in order to find out how much heat loss must be compensated for immediately by sunlight
2. then substract this daytime heat loss from the total Btu gained; this will represent the number of Btu that will have to be stored
3. to find out what is left over after that day's collection, multiply the hourly heat loss rate by sixteen hours; then subtract this figure from the total heat gain - this will yield heat that can be stored through the night to provide heat for the next cloudy day

Water as Storage Medium

If water will be the storage medium, simple calculations will indicate the size of storage tank or storage wall necessary:

1. use the number of Btu for storage as determined in the previous calculation
2. divide this number by 20°F in order to provide a maximum swing in the water temperature of 20°F and to indicate the number of pounds of water to be stored
3. divide the number of pounds of water by 8.4 pounds per gallon; this will yield the number of gallons of water to be stored
4. divide the number of gallons of water by 7.48 gallons per cubic foot to find the total cubic footage of water to be stored; for example, if this number equals 300 cubic feet, a tank or storage wall ten feet high by ten feet long by three feet wide will suffice for storage

RESIDENTIAL DOMESTIC WATER USE

Hot Water Requirements

Since the requirements for hot water use are different from those of the space heating system, the two systems can be separated from each other. The collection point is an example of a very different need: heat received from the sun for winter passive energy collection is optimally trapped by a vertical shaded screen or glass. This allows maximum winter sun to penetrate the building while shading summer heat gain. Hot water for domestic usage, on the other hand, must be collected throughout the entire year; even though it does not require the same quantity of heat, it cannot be shaded at any time. A different kind of collector will therefore be more appropriate. This may be a solar collector placed at an angle of 45^o to allow optimal solar collection, or it may be a supplementary conventional hot water heating system. In addition, unlike space heating requirements which are nearly continuous for the entire heating season, domestic hot water usage undergoes periods ranging from no use to sudden peak demand, such as occurs in a comparison of 6 A.M. to 7 A.M. usage. Since hot water can be collected or heated and stored during non-peak hours, smaller, less expensive heating elements can be used in conjunction with correctly-sized storage tanks.

Hot water usage per 24 hour demand period may vary from person to person by as much as 50%, depending on appliances such as dishwashers and clothes washing machines. Variations may also occur weekly for the same family. A family may wash its clothes once each week and thus have tremendous demand rate for that one day while having restrained hot water requirements for the other six days. In general, though, provision should be made for approximately twenty to forty gallons of hot water per day per person; this usually represents one-third to one-fourth of total daily water needs.[34]

These requirements can be met by using a small "active" element: a hot water solar collector that can be supplemented by a conventional system. The solar collector is sized according to a "rule of thumb" that requires one square foot of collector for each gallon of hot water required each day; this is not to be confused with the requirement for space heating that a solar collector equal in size 50% of the total square footage to be heated. Thus, for the four person family that is projected to live in a prototypical living space, the collector will have to equal approximately 30 gallons x 1 square foot x 4 people or 120 square feet in size. This small collector, which could be about ten feet by twelve feet or eight feet by fifteen feet, could easily fit on one side of a south-facing roof and should be integrated with the design of the house: it can emphasize a space underneath the roof or be extended to form a porch shelter. As long as the roof is a dark color, the collector can be painted the same color; it does not have to be black. Since the slope of most northeast homes approximates a good collection angle, the collector does not have to represent an extraordinarily steep roof in design. There are many commercially available collectors that can be "plugged into" the roof space. As years pass, and they become naturally outdated by advances in active and high technology systems, the small collector can be replaced in the same way that the supplementary hot water heater will also eventually be replaced. Storage and continuous temperature maintenance for domestic hot water can also share the same hot water system as the space heating elements use.

Cold Water Requirements

Cold water usage can also be subjected to conserving measures, although, at present, most legal codes do not yet permit water recycling or "composting" toilets which use waste material in a safe and sanitary fashion to produce a clear waste plus a useful fertilizer material. Ways in which a contemporary living space can accomodate recycling techniques include providing mechanisms for future changes, such as bathrooms located near exterior walls or over basements so that innovative toilets can be added in the future as well as purchasing toilets that require less water than the standard seven gallons in order to flush out waste. This may also require more frequent cleaning of toilet bowls, but the savings over a year in totally wasted clean water can be tremendous. This introduces the idea of classifying water for appropriate use rather than using drinking water for all purposes. Clean, drinking water is known as potable water, water that has been used for washing dishes or bathing is known as grey water, and toilet waste water is known as black water.

Appropriate use of water may require that potable water arrive through normal water faucets that may be supplemented with foot pedals so that hands that are busy "soaping up" or are otherwise engaged would not be relied on to turn off water during moments that flowing water in not required. This faucet water becomes "grey" through use and would then flow through the drains. The grey water could then pass through a filter that would remove soap and heavy particles and allow the clear liquid to be used to flush the toilets. This liquid could be stored with rainwater for use not only in the toilet system, but also for "watering the lawn" which would be a positive advantage over present systems of collecting all water that reaches the earth and removing it from the local water tables by means of storm sewers that carry off clean and used water to rivers and oceans. This system is not a present commercially available, but again, planning the plumbing system accordingly can allow future innovation to become a part of present design without adding new costs. Thus, this would require "wet walls", or walls with plumbing pipes, to be shared: the kitchen sink and bathroom appliances would have to be "back-to-back" for a future plug-in filter trap. This would also save costs of extra plumbing trees and plumbers' work in a building as well as cutting down costs in the future on a community's regional water filtration system.

"Composting" toilets, of course, even as developed until now, place no burden on a regional system: all waste is disposed of on the property upon which it is made. For people who do not favor using their fertilizer for gardening, surely small businesses will arise, as in other centuries when large scale solutions were not possible, which will make their living by removing city fertilizer from any given toilet every few years as required, and taking it to the country for organic re-use or for regional methane generation. In other words, future possibilities that cannot realistically be acted upon now can be planned for by being foreseen.

SECTION III

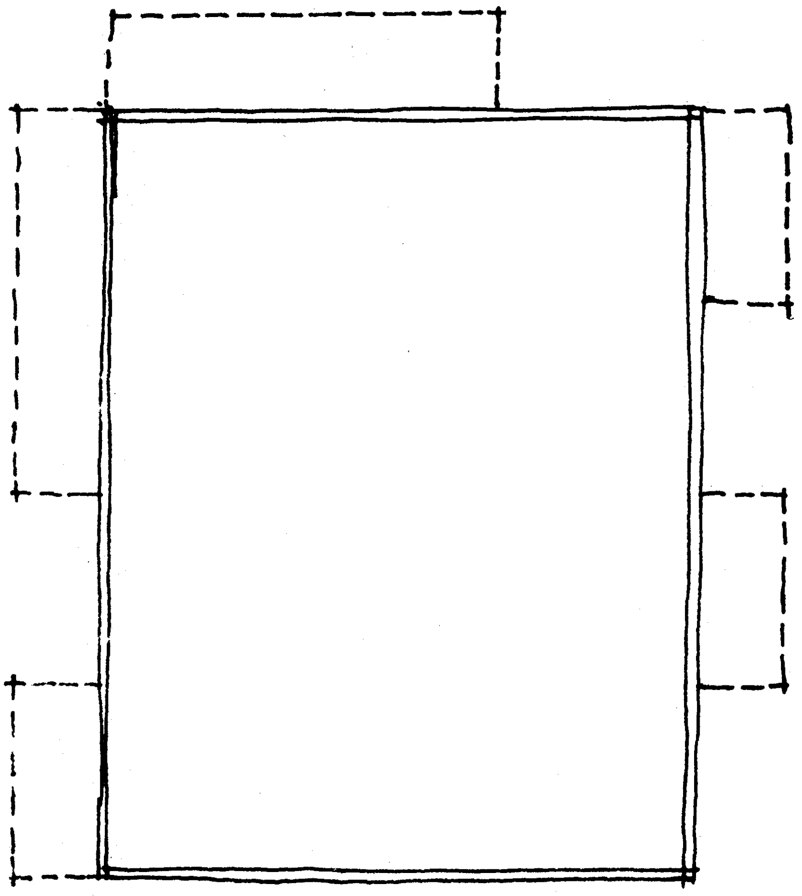
PROPOSALS FOR THE DESIGN OF PROTOTYPES BASED ON THE DETERMINANTS OF SECTIONS I AND II

This section seeks to show design proposals that prove that the assumptions made from the principles and issues set forth in the first two sections are feasible and realistic for further development. Necessary calculations and explanatory discussions as well as pragmatic evaluations accompany each proposal so that the process of development will be clear.

This section consists of three parts. The first part shows a first proposal including process, sketches, calculations, and an evaluation of why the proposal acts as a form and idea generator, and yet why it does not fulfill the requirements of this thesis. The second part shows another proposal that includes the same process as in the first part. It also includes "nooks", floor materials, "add-ons", calculations, a cost/benefit analysis, and an evaluation of this more useful proposal or prototype. The third part includes discussions of clustering possibilities, of problems of orienting prototypes in other directions, and of various design "pieces" or elements that can be prefabricated and that can add to the sense of "home".

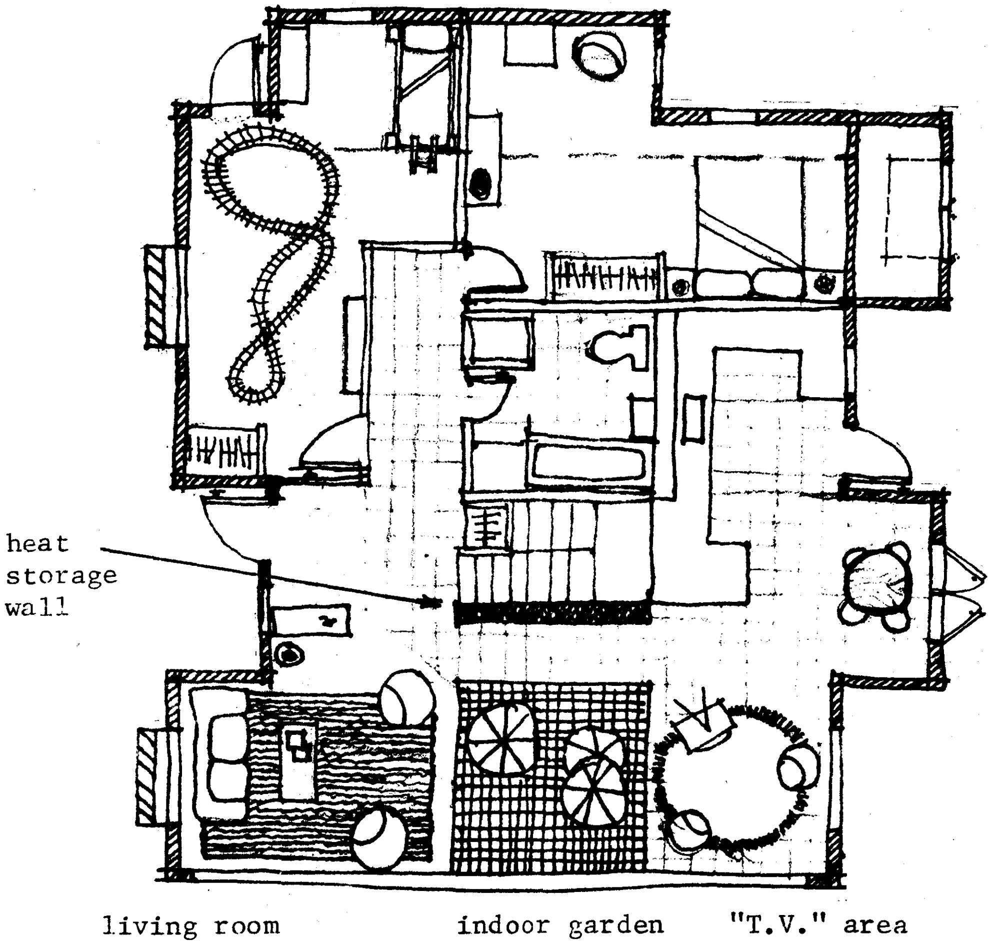
All drawings in this section are oriented with south at the bottom of the page and are drawn at a scale of 1/8" = 1' - 0" unless otherwise noted.

The first proposal attempts to include "nooks" as part of the basic layout by using a simple rectangular foundation with cantilevered prefabricated "add-on" pieces which should reduce usual additional construction costs associated with bay windows, alcoves, or other additional spaces. The basic foundation, following the Geocom modular system, is 24' x 32' or 768 square feet, with six heated add-ons, 4' x 8' each, or 192 square feet, with one non-heated storage add-on at 4' x 8', for a total area of 992 square feet.



The basic plan includes:

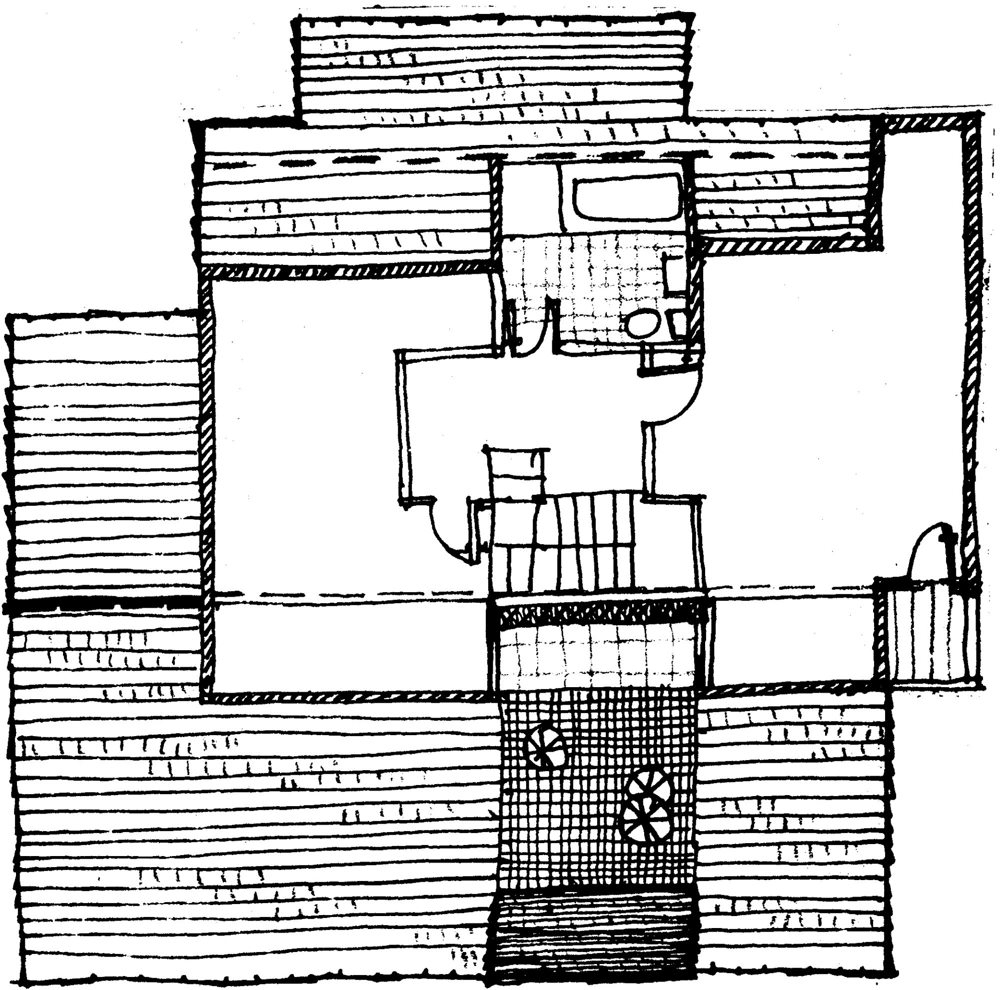
- kitchen + eating area; with another "add-on" the eating area could become a dining room
- storage
- living area
- "den" - this provides a "common area" that family members can use together or to "get away from each other"
- bedroom for parents
- bedroom for children with "play area"; with wall removed, this could become a "library" or work area; with dividing walls added, this could become two small bedrooms



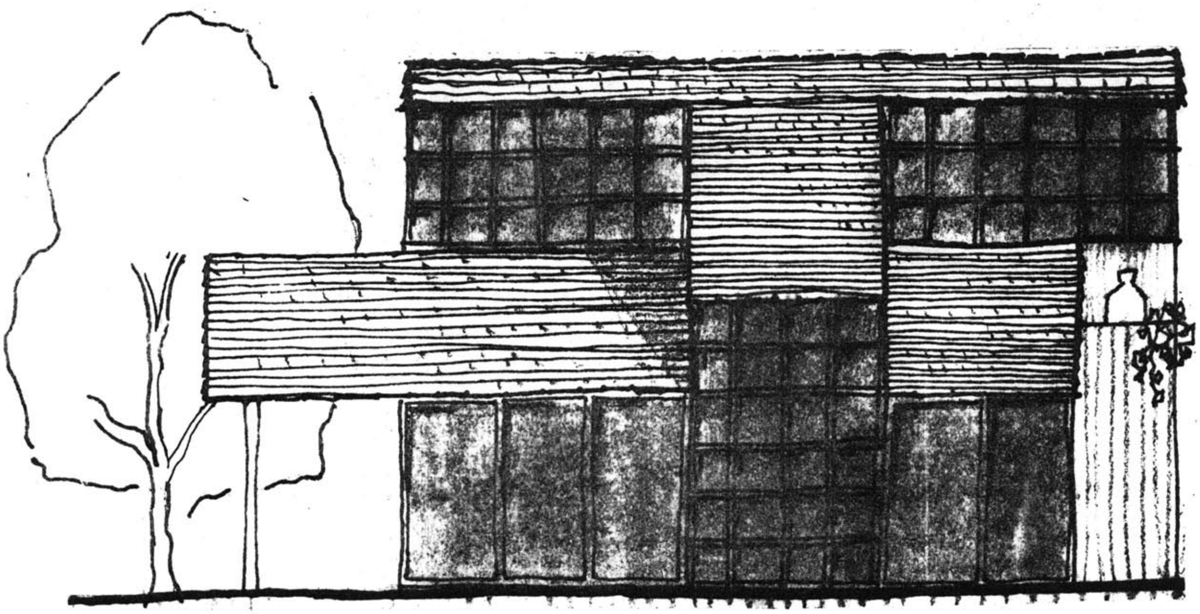
The heat storage wall and tile, brick, or concrete floor act as storage for excess Btu of solar heat gain received by the south-facing glazed wall. The location of the storage wall next to the stairway space allows convection currents to flow upward and around the interior space after being heated by direct heat from the sun, by stored heat in the wall, or by a supplementary heating element.

A potential development of the "unfinished attic" could include:

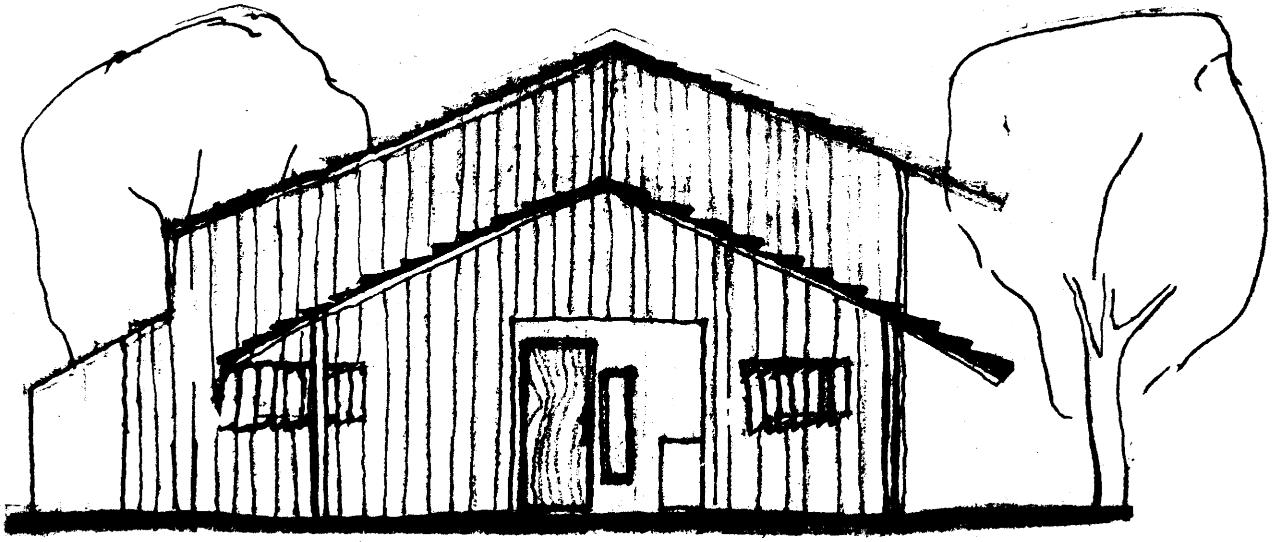
2 bedrooms with storage under the eaves
1 bathroom that shares the existing plumbing wall
stairway that overlooks the "atrium" or indoor garden



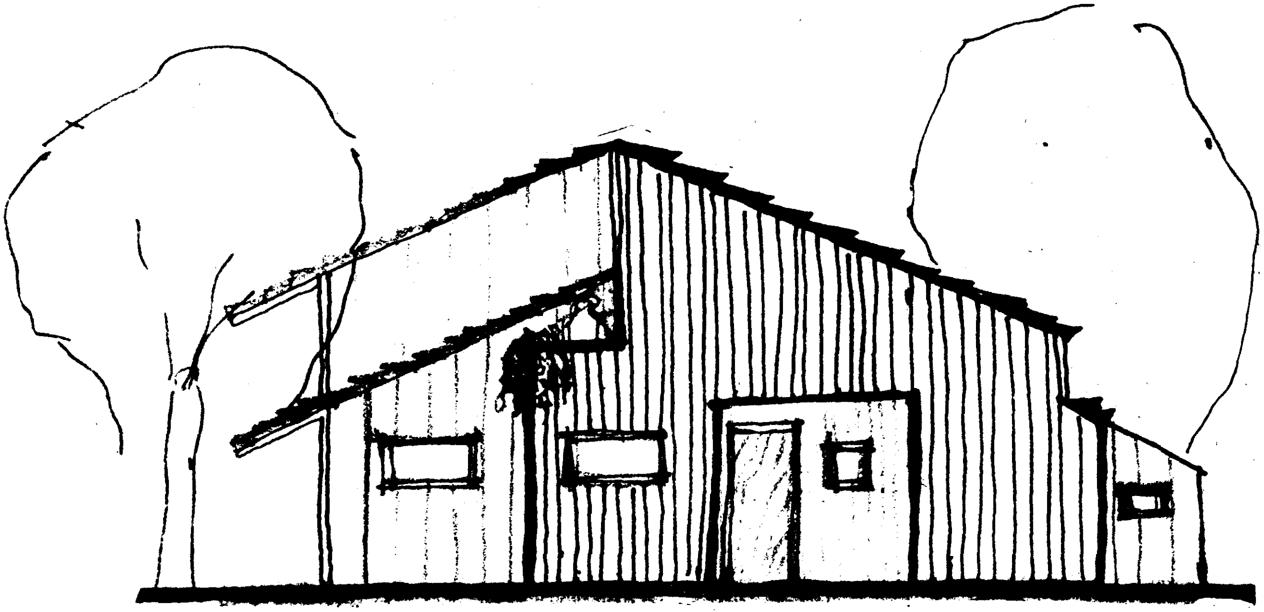
This plan is oriented towards the south for maximum possible solar heat gain. It utilizes large expanses of glazing, including transparent insulation in all areas that will not be subject to accidental damage by being bumped, such as above eight feet in height in the living room, along the length of the "indoor garden" since that area would more frequently be "looked at" rather than bumped against or used, and in skylights. The glazed areas will have to be shielded from summer solar heat gain. The plan indicates roof overhangs for this purpose; deciduous trees would also help cool the warm summer ambient air temperatures. The south elevation shows the glazing used as well as the "atrium" area:



The roof plan and other elevations of the first proposal are also suggested so that calculations of heat loss and heat gain can be determined;

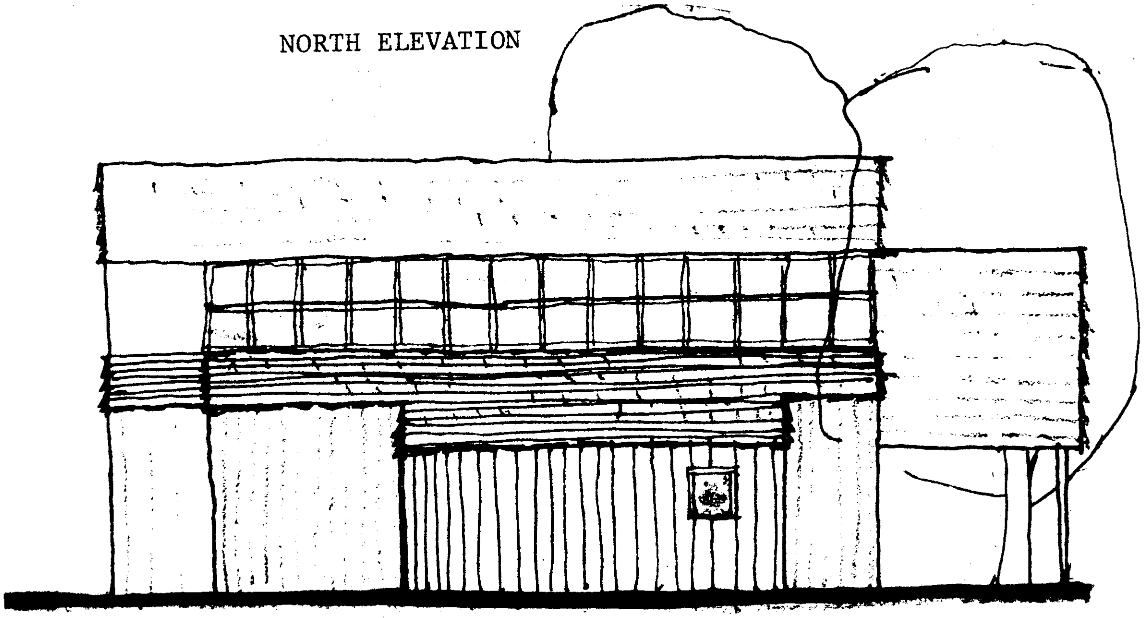


WEST ELEVATION

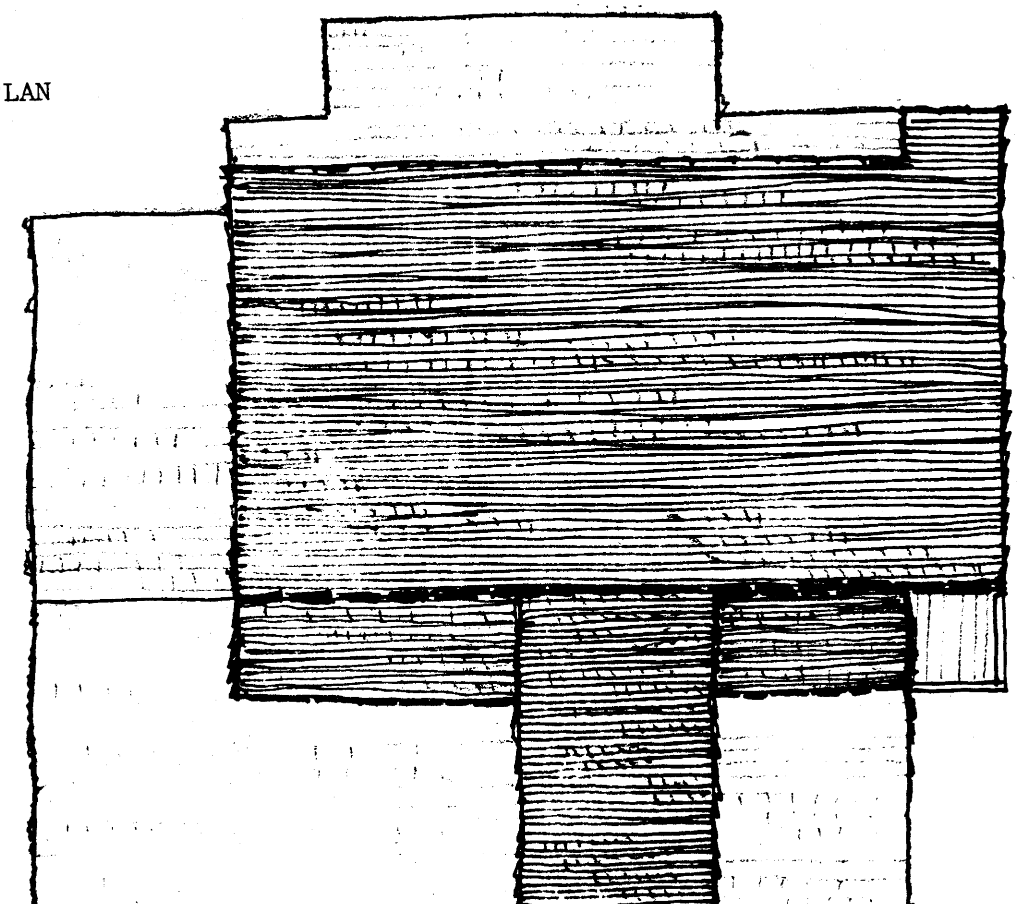


EAST ELEVATION

NORTH ELEVATION



ROOF PLAN



HEAT LOSS CALCULATIONS FOR THE FIRST PROPOSAL

Design Temperature = delta t = 40°F

Item	Area in ft^2	U-value	delta t	Btuh Heat Loss
Walls	624	0.034	40°	848.64
Wall next to storage	64	0.034	20°	43.52
Glass, double ½" air space	194	0.55	40°	4268.00
Transparent Insulation	360	0.20	40°	2880.00
Attic space walls	388	0.034	40°	527.68
Doors, three	63	0.240	40°	604.80
Roof	960	0.019	40°	729.60
Infiltration	2400 ft^3/hour x 0.018 x 40° =			1728.00

Heat Loss in Btu per hour = 11,630.24

Heat Loss per day = 24 x 11,630.24 = 279,125.76

HEAT GAIN CALCULATIONS

For January 21

Full Day Totals of Solar Heat Gain for Direction

Direction	Morning	+	Afternoon	=	Btu per ft^2	Area	Btu
East	449	+	59	=	508	24	12,192
South	815	+	815	=	1630	336	593,320
West	59	+	449	=	508	24	12,192
							617,704

Transparency Factor = 617,704 x 91% = Total Btu = 562,110

(50% Cloudy Day Factor = 562,110/2 = 281,055 Btu Gain

281,055Btu Gain - 279,125.76 Btu Loss

= 1,929.24 Btu Difference)

HEAT STORAGE CALCULATIONS

Total Btu received = 562,110 Btu
Total Btu lost = 279,125 Btu

1. heat loss for 8 hours, or time during which sunlight must immediately compensate for heat loss = 8 x 11,630 Btuh heat loss = 93,040
2. total Btu gained, 562,110
   8 hour loss, - 93,040
   469,070 total Btu to be stored
3. 469,070 Btu to be stored/20°F for 20°F temperature swing control = 23,454 = number of pounds of water needed for storage
4. 23,454 pounds of water/8.4 pounds per gallon = 2,792 = number of gallons of water to be stored
5. 2,792 gallons of water/7.48 gallons per cubic foot = 373 cubic feet
6. 373 cubic feet will yield a tank that can be of various sizes:
   10' x 10' x 3.73'
   10' x 12' x 3.10'
   12' x 12' x 1.50'
   This first proposal uses a storage tank that is 12' x 12' x 1.5'

Since there is more room between the proposed first and second floors, additional space could be allocated to the heat storage wall. This additional space could be used for storing and warming water for domestic hot water usage. It could also be used for "decorative" or "home-y" uses: "holes" can be left in the wall for "look-out" points or for places to set vases or other bric-a-brac important to the family; at low points in the wall, these "holes" could also be warm sitting nooks or "hideouts" that lead under the stairway for the kids or young-at-heart.

This first proposal shows interesting directions for the prototype to explore: the use of the storage wall as "heating tank" as well as ornament or "territorializer" for each family; the use of large south-facing glazing areas as heat collection point; the use of nooks to give a flavor to a tiny house that a simple rectangular box can only do with great difficulty; the use of roof changes for an alternative to the usual simple shed or gable roof; the use of a common space in addition to the living room to add to the feeling of spaciousness in a small house; the use of a large overhang to present a sheltering entryway and covered patio.

Nevertheless, there are strong reasons against the use of this first proposal as a valid alternative for a "back-to-basics" prototype. The nooks add unreasonable additional costs to the basic plan although they would be acceptable as add-ons chosen by a given family. Since costs absolutely must be minimized, these nooks must be redesigned so that they appear within the limits of a simple foundation. Each turn in the building's surface and each level change in the roof represent additional materials costs and additional labor costs. They also indicate the need for additional flashing against rain leakage that would otherwise be unnecessary. The geometric configuration also reduces maximum heat gain utilization throughout the house. It is longer on the north-south axis than on the east-west axis which means that the northern part of the house will be only minimally heated by the solar heat gain that would be more readily available throughout the entire house were it on a longer ease-west axis.

These considerations indicate new directions for the prototype:

-simple, rectangular foundation and exterior for strict cost controls that lead inevitably to designing within a "box" framework; Jan Wampler has discussed the idea of this "box" as a "barn" in which the same exterior layout is present, but in which the "flavor" of the building is immeasurably more acceptable, as large tract builders have found; this may lead to a sense of harmony within a small grouping of these prototypes since an overall unity of design will prevail, while detailing as well as individual choice of add-ons according to each family's desire or financial ability will encourage a smaller scale level of personalized articulation;[35]

-concrete slab construction should be further explored for further reduction in the size of the storage wall; this will enable the storage wall to be developed even further for use as decorative display, children's "hideouts", etc.;

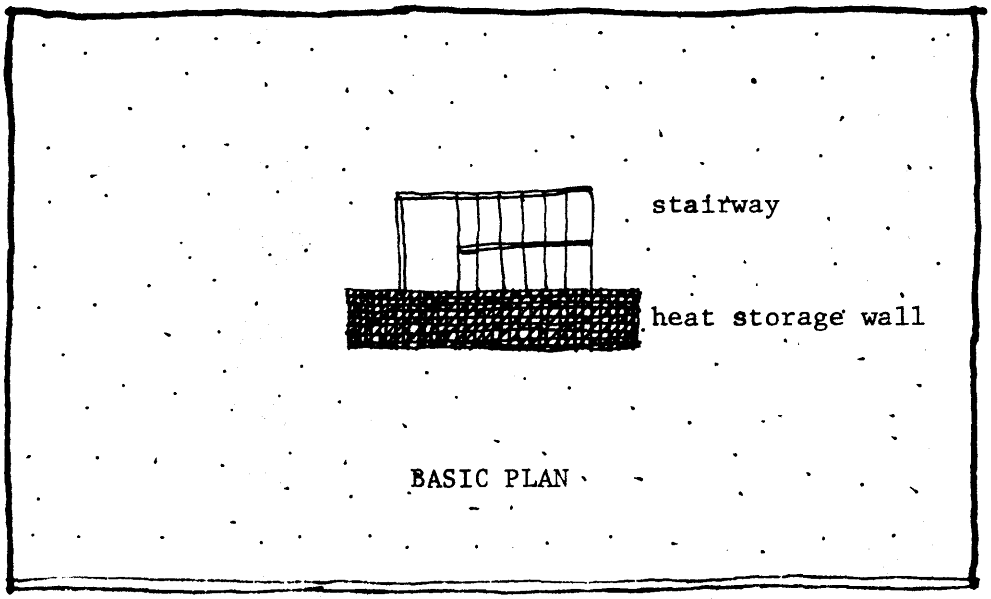
-a combination of concrete slab along the south wall with raised wooden floor on the north side should be explored; this would open the possibility of having a small basement under the north side of the house;

-explore design proposals for interior layouts that will permit "nooks" to occur within the confines of the "box/barn";

-explore locations for future room or exterior "nook" add-ons that do not disrupt present energy-conserving features.

By using the information derived from the evaluation of the first proposal, new specifications for prototypes can be established.

1. There should be a simple foundation, planned according to the four-foot module of the Geocom prefabrication system.
2. There should not be any exterior jogs, bay windows, or nooks.
3. There should be an insulated concrete slab floor.
4. The heat storage wall should be located in a central place within the house; also there should not be any obstructions between the wall and the sun.

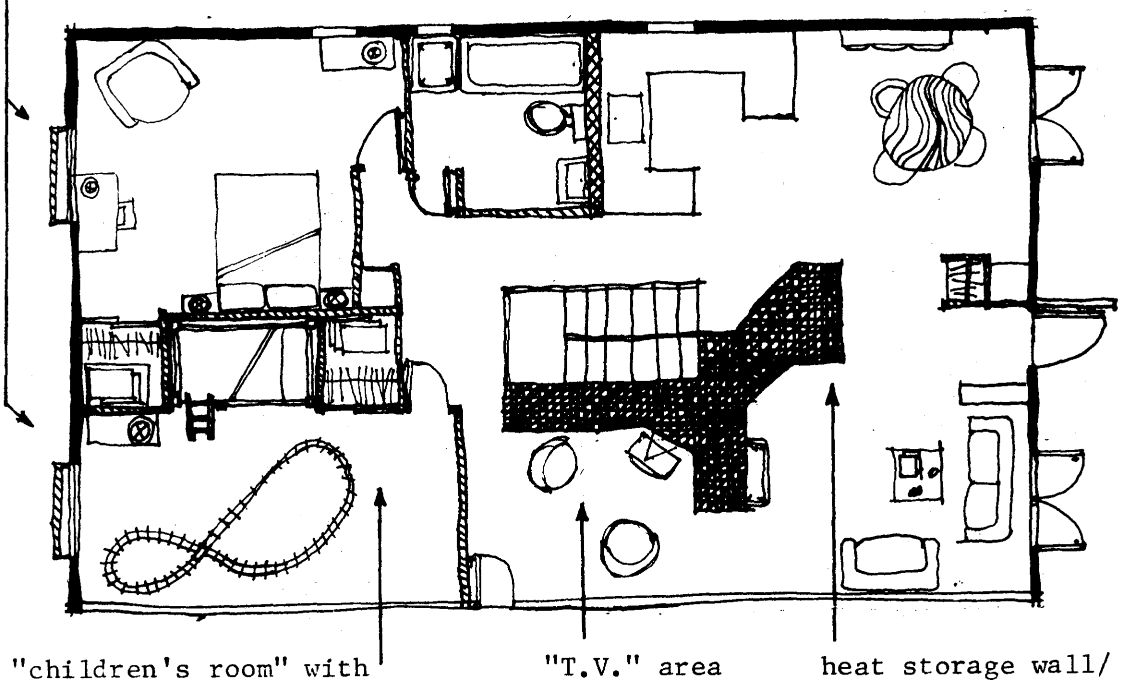


5. The heat storage wall should be used in conjunction with a stairwell or other 2-storey space to guarantee space for continuous air circulation.
6. The storage wall can be concrete, water-filled barrels of galvanized steel, water-filled concrete containers appropriately sealed, etc. If water is used, it should be stored in several containers that may be stacked. Water should not be stored in one large, high, single-space container in order to minimize the tremendous outward pressure that would build up, possibly forcing the walls of the container to burst.
7. Auxiliary heating should "plug-in" to the heat storage system.
8. The south-facing wall, or the walls that receive the most sun, should have maximum glazing for winter heat gain with appropriate shading for summer heat reduction.
9. The east and west walls should have fewer windows than the south wall; the north wall should have only the minimum number of windows necessary for natural light, views, or ventilation.

This new 24' x 40' prototype attempts to fulfill the specifications.

west window
protection from sun

bathroom with window seat



"children's room" with
interior nook

"T.V." area

heat storage wall/
fireplace hearth
in living room

1. The "children's room" is the warmer of the two bedrooms; the "nook" formed by the two closets can be a space for bunkbeds, for "hideouts", for "built-ins", for a desk, or for a plump chair; in the future, when the unfinished attic is developed, this area can be used for a workshop, a "library",

a large downstairs playroom, etc.

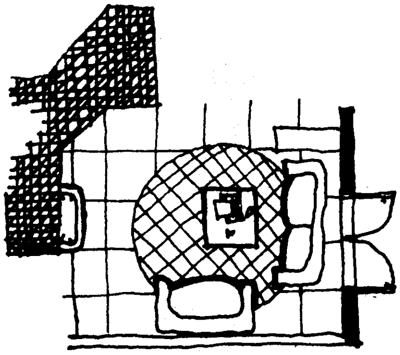
2. The tiny "T.V." area preserves the possibility of a common space that some members of the family can be using while other family members are in the living or dining areas; this should help relieve the feeling of being "in each other's hair" without having to mope in one's bedroom. This seems to be especially important in a small house. This "T.V." area could also be used as an indoor garden or atrium in a way similar to the garden of the first proposal.
3. The mechanism in front fo the west windows allows north light as well as cooling breezes to enter the rooms in the summertime while completely shading unwanted southwestern, western, and northwestern sun. In the wintertime, the operable louvers can be turned toward the southwest in order to trap all available sunlight.
4. The open stairway (with storage underneath) next to the storage wall guarantees space for air currents to flow freely; this is advantageous for heating and cooling.
5. The storage wall can have a fireplace built into it. If this is too costly for a given family, the wall can be shaped like a fireplace, and in the future, a prefabricated metal fireplace could be placed in

the center. It will have the hugh massive backdrop of old cozy hearths and will work by similar principles. Heat given off by the "short thermal lag" metal fireplace will partly be used immediately to warm the living space and will partly be used to heat up the "long thermal lag" storage wall. The fireplace would only have to be operating a few hours and then the living space would be able to benefit from the thermal lag of the storage wall. The fireplace could be wood-burning, or it could be electric or gas-fired and become a part of the house's auxiliary heating system.

6. The eating area or "dining room" is largein proportion to the rest of the house in order to give the family a feeling of spaciousness and comfort while eating. Mealtimes may be the only times that family member come together; it is important in such a small house that they not feel cramped.
7. Since the living areas may become uncomfortably warm if "wall-to-wall" carpeting is installed on top of the concrete slab that would otherwise be available for heat storage, it will be an assumption of this proposal that <u>large</u> floor areas not be covered with rugs although "scatter rugs" may be used. However, since the concrete slab must be

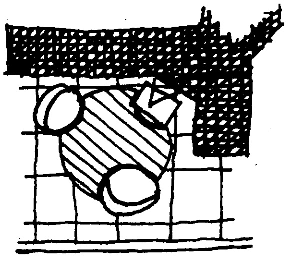
covered with some finish, various materials can be provided for the family to select. These can include simple dark concrete-paint, brick, tile, or resilient heat-conducting cork currently available. One possibility for use of tiles or bricks would be to lay them out in even course works through the house, but then to turn the tiles in a different direction in a given area to provide people sitting in that area with the intimate feeling that a rug usually gives.

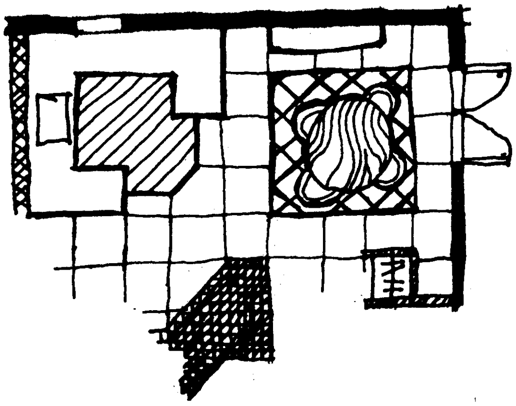
Examples of a few possibilities for "tile turning" or "brick turning":



in the living room, the materials could take the place of a large round rug

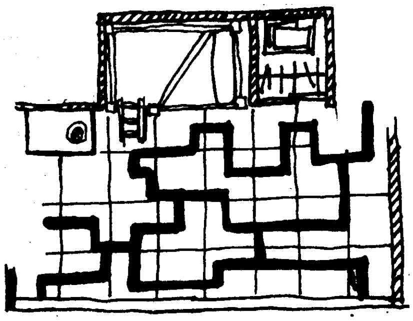
in the "T.V." area, the materials could suggest a small "scatter rug"





in the kitchen and in the dining area, the materials will be able to be kept clean more easily than a rug, and yet can still suggest the separateness of an area defined by a rug

Another possibility for turning decorative materials in a direction different from the general floor covering could include using materials in an "educational" or an "artistic" way:



In the "children's room", smaller pieces of tile or brick or other material could be used to form a suggestive pattern. It could be a "make-believe"

-railroad system

-highway or bike paths

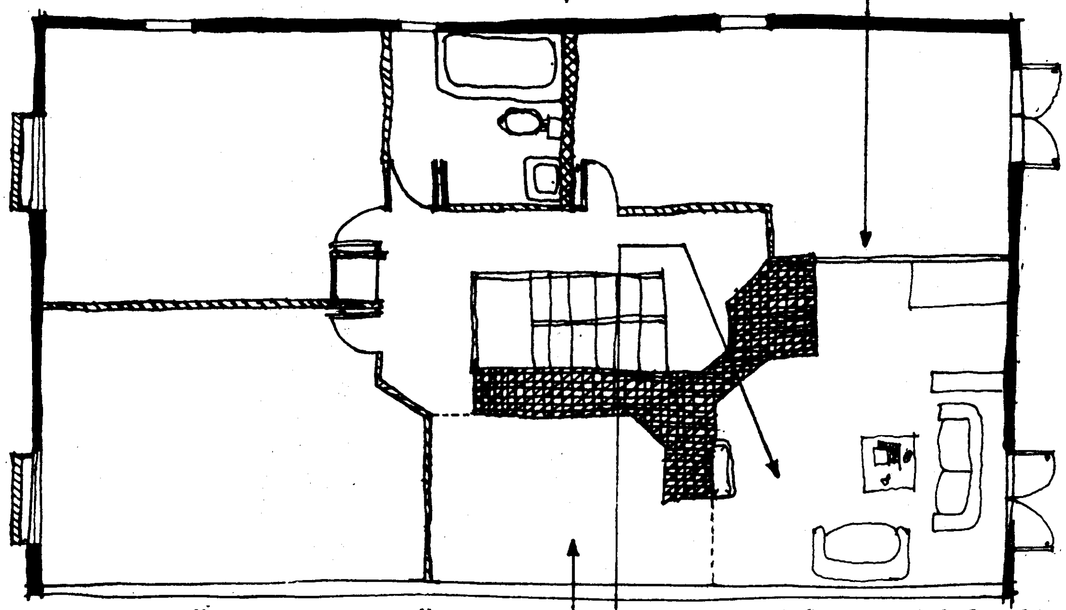
-games setting, such as "you-can't-get-out-of-the-box-til-I-say-go" or "every-3-seconds-you-have-to-move-3-paces" or any other of a number of games made up on the spot by children

-walking path; kids could time how long it takes to walk around the path; they could use the path as a way to find their bed or personal corner if they happened to be pretending they couldn't see

- if the path were well planned and beautiful to the family as well as interesting for the kids, it could become a built-in work of family art after the room is no longer used by little children

-although the material would probably have to be smooth or even with the floor in order not to present any dangerous or unsuspected obstacle, the material would easily be differentiated from the floor covering around it since it would be in smaller or larger pieces; but there may be a way to enable the family to add on to the design through the years, perhaps by having some of the floor tiles more easily removable.

The development of the unfinished attic can take place when it becomes possible for the family to finance it. One potential layout could start with the shared plumbing wall from the first floor as a given;



shared plumbing wall

open balcony overlooking living area

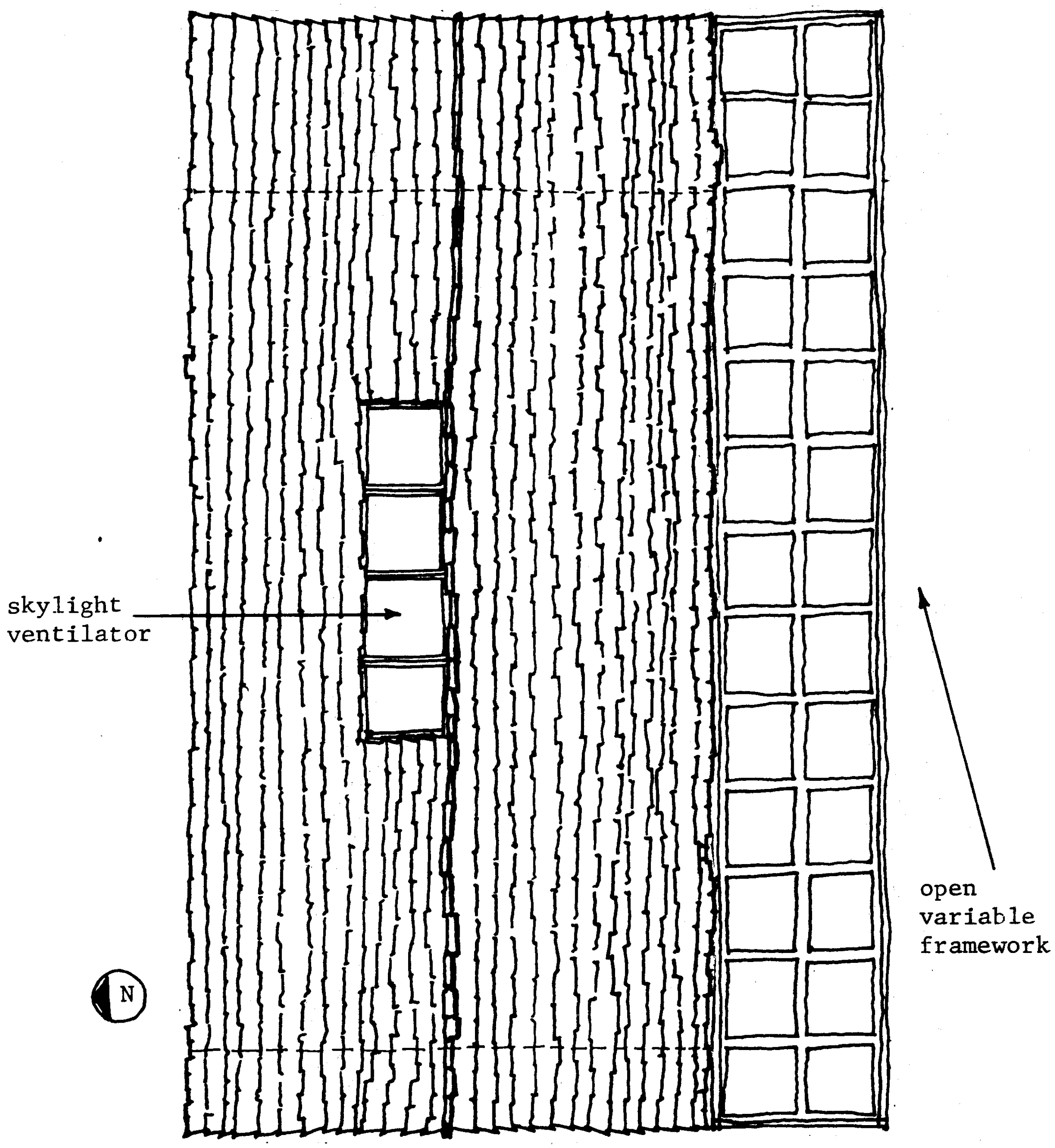
"sleeping loft", four feet above second floor

stairway and landing overlooking storage wall/ fireplace and living area

1. The room in the upper left corner has a northwest exposure and thus will be cooler than the other rooms; this could suggest that this be used for storage or for a guest room so that the use of auxiliary heating can be minimized.

2. The room on the upper right, even though it has a northeast exposure, will be warmer since it has one wall that is partially exposed to the warm downstairs. This area could be used as an upstairs work room or playroom with its southern wall left half open.. This will serve as a balcony and will allow warm air to enter easily.
3. The space above the "T.V." area should probably be at least twelve feet high so that sun can penetrate to the storage wall; this will leave a small space under the roof that can be used as a sleeping loft, for "hideouts", or for storage.
4. Since the storage wall ends four feet above the floor of the second storey, this provides the possibility of an interesting "overlook" from the landing and the top of the stairway. This also permits air to flow freely.

The roof plan also must be simple. However, a simple gable roof could offer possibilities for future growth if it is designed with large overhangs or deep overhanging eaves. Future additions to the house would thus be able to fit under the existing roof and would require only walls and floors for completion.

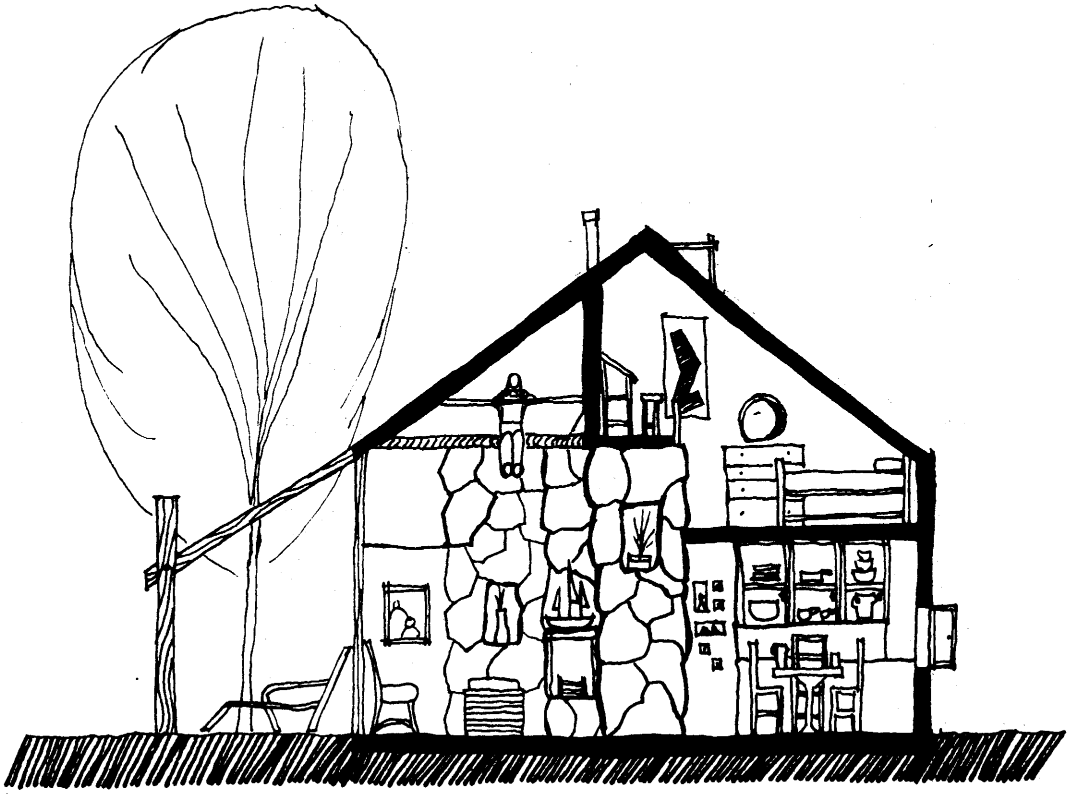


This roof shows a four-foot overhang on the west side and an eight foot overhang on the east side. This deeper overhang shelters the entry area and suggests a location for future add-ons. The roof for this proposed prototype includes a necessary overhang or projection over the south-facing wall that permits maximum winter sunlight to enter the house while it blocks summer sun. It consists of a framework that would remain completely open during the winter and that would be closed during the summer. The framework can support various mechanisms. Standard, "off-the-shelf" rolling wood or metal shutters would fit within the frame and be rolled down during the summer or rolled up during the winter. Canvas awnings could also be used since the framework would be able to reduce flapping caused by the wind which can tear or shed awnings. The major drawback to canvas is that it is not able to reflect as much unwanted summer sun.as more impermeable materials, such as wood or metal, can reflect. Ivy or other vine-like plants may also be used to reflect sun. Since ivy presents a growth pattern similar to deciduous vegetation, it will have a thick summer leaf cover and it will "die" each winter. This overhang can become a porch cover or shelter for summer activities and an open arbor for winter sunshine.

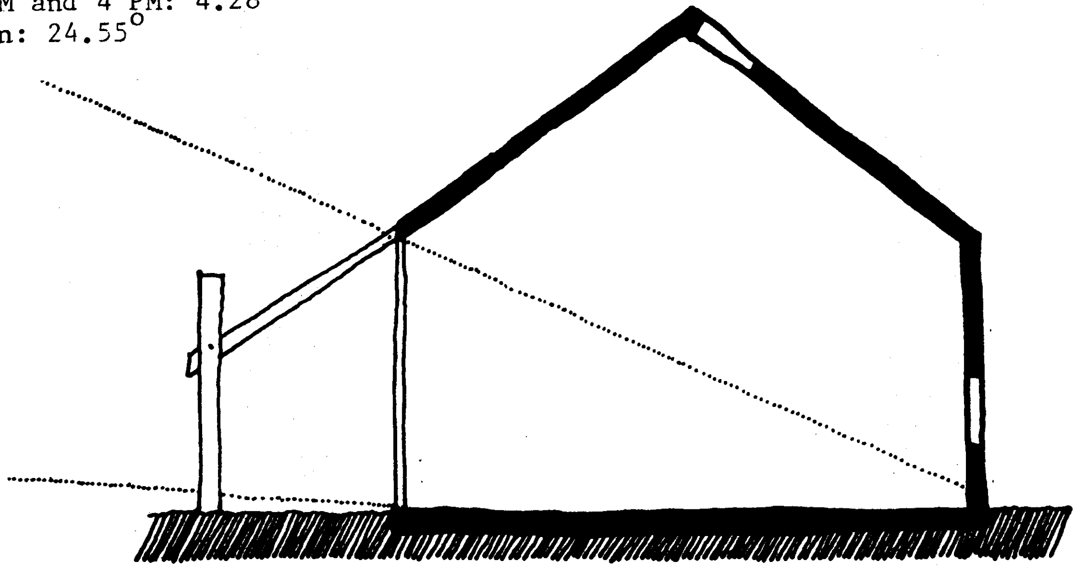
The skylight on the north side of the roof has two functions. It acts as a ventilator for the house during the summer. Warm air that collects in the house during the summer will rise through the house until it reaches the highest point in the building. If there were no ventilator, this heat would remain and the building would soon become overheated. The ventilator windows allow the heat to escape;

the air flow through the house will thus cause a pleasant breeze. The ventilator skylight also allows non-glaring north light to backlight the stairwell, the landing, and parts of the living room and "T.V." area. This will help reduce the contrast that could be caused by the large expanse of southern glazing. In addition, since the skylight is made of transparent insulation, winter heat loss will be minimized.

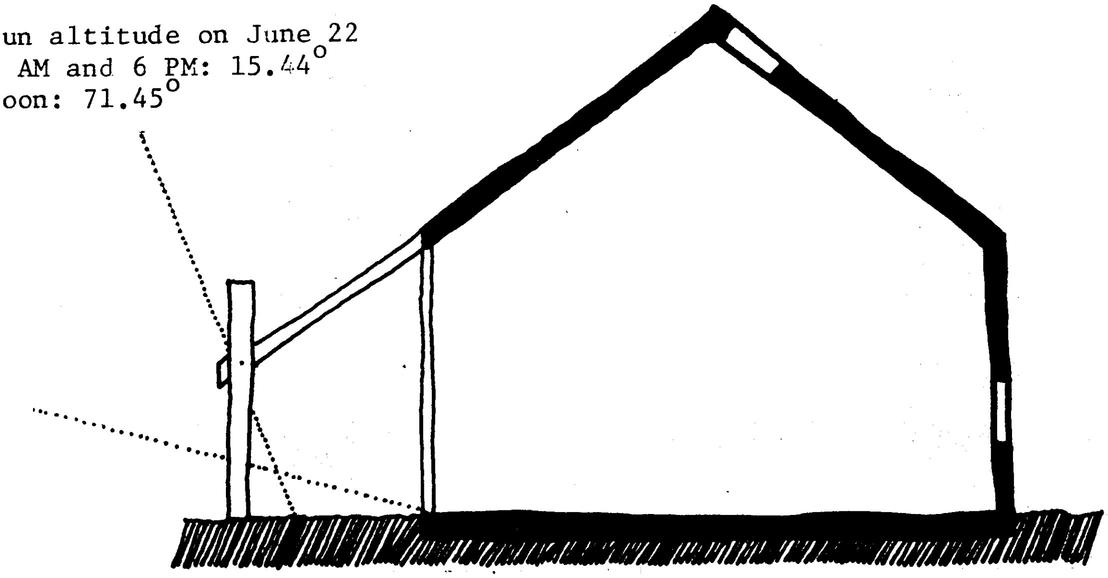
A section taken at the entry area to the little house would show the guest or the family that the living space has a massive hearth, with nooks and level changes also visible from the front door. The "porch", or area covered by the open variable framework on the south side, allows the roof framework to continue past the edges of the house.



Diagrams of sun angles show solar penetration into the building. The low winter sun angles will allow sun to warm the interior of the building throughout the sunrise-to-sunset, whereas the high summer sun angles will be blocked by closing the variable framework across the southern side of the building.

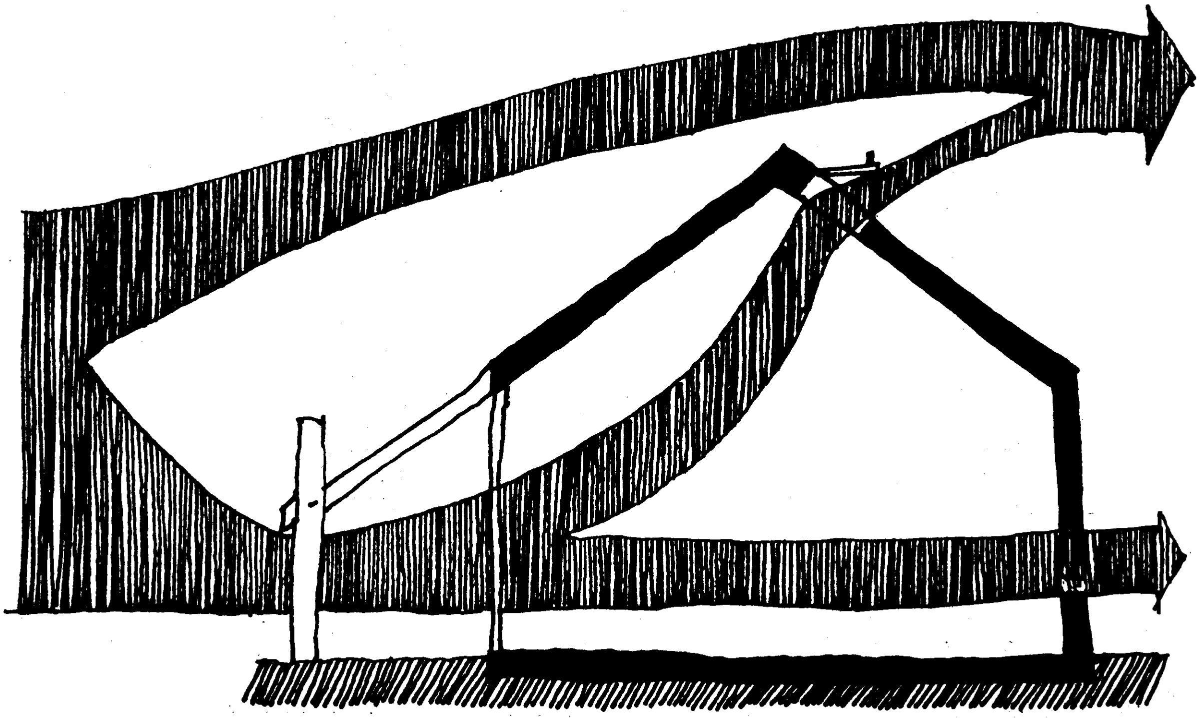


sun altitude on December 22
8 AM and 4 PM: 4.28°
Noon: 24.55°



sun altitude on June 22
6 AM and 6 PM: 15.44°
Noon: 71.45°

Effect on summer air flow of closed variable framework and opened skylight ventilator:



Cooling breezes are "sucked" through the house and carry out the heat bubble that would otherwise build up under the ridge of the roof.

HEAT LOSS CALCULATIONS FOR THIS PROPOSAL

Design Temperature = delta t = 40°F

Item	Area in ft^2	U-value	delta t	Btuh Heat Loss
Walls	1272	0.041	40°	2086.08
Glass:				
double, ½" air space, wood sash with 80% glass	328	0.55	40°	7216.00
triple, ½" air space, wood sash with 80% glass, north side only	12	0.34	40°	163.20
Transparent Insulation	352	0.20	40°	2816.00
Doors	42	0.24	40°	403.20
Roof	992	0.024	40°	952.32
Infiltration	2400 ft^3 per hour	x 0.018	x 40°	1728.00
		Total hourly heat loss =		15,364.80
	Heat Loss per day = 24 x 15,364.80 =			368,755.20

HEAT GAIN CALCULATIONS

For January 21

Full Day Totals of Solar Heat Gain for Direction

Direction	Morning	+	Afternoon	=	Btu per ft^2	Area	Btu
East	449	+	59	=	508	40	20,320
South	815	+	815	=	1630	544	886,720
West	59	+	449	=	508	32	16,256
							923,296

Transparency Factor = 923,296 x 91% = Total Btu = 840,199

(50% Cloudy Day Factor = 840,199/2 = 420,099

420,199 Btu Gain - 368,755 Btu Loss

= 51,344 Btu Difference)

HEAT STORAGE CALCULATIONS

Total Btu received = 840,199 Btu
Total Btu lost = 368,755 Btu
Total Btuh lost = 15,364 Btu

1. heat loss fo 8 hours, or time during which sunlight must immediately be used to compensate for heat loss = 8 x 15,364 = 122,912 Btu

2. total Btu gained, 840,199
   8 hour loss, -122,912
   717,287 total Btu to be stored

3. 717,287 Btu to be stored/20°F for 20°F temperature swing control = 35,864 = number of pounds of water needed for storage

4. 35,864 pounds of water/8.4 pounds per gallon = 4,127 = number of gallons of water to be stored

5. 4,127 gallons of water/7.48 gallons per cubic foot = 553 cubic feet

6. 553 cubic feet will yield a tank that can be of various sizes:
   10' x 10' x 5.3'
   12' x 14' x 3.2'
   12' x 23' x 2.0'
   The size of the tank in this proposal is 560 cubic feet

It is not necessary, however, to store all the heat in the storage wall; the concrete floor slab can store about 40% of the Btu received The wall can also thus be used to keep domestic hot water warm or it can be used decoratively until future house expansion would require additional heat storage.

LIFE COSTING ANALYSIS

This is a method for determining net savings by using energy-conserving principles instead of standard construction methods and includes additional capital costs and long-term interest rates.

1. Find heat loss for standard 1000 sq. ft. house from Hittman report:
   standard house = 1650 sq. ft.[36]
   prorated 1000 sq. ft. house = 72% of heat needs for 1650 sq. ft. house
   for January: 1650 sq. ft. uses 14,710,000 Btu
   1000 sq. ft. uses 14,710,000 x 72% = 10,591,200 Btu
   for whole heating season:
   January 14,710,000 x 72% = 10,591,200
   February 10,070,000 x 72% = 7,250,400
   March 10,320,000 x 72% = 7,430,400
   April 4,330,000 x 72% = 3,117,600
   October 3,860,000 x 72% = 2,779,200
   November 9,540,000 x 72% = 6,868,800
   December 14,140,000 x 72% = 10,180,800
   48,218,400
   48,218,400 Btu are needed per heating season for a standard 1000 sq. ft. house

2. Find heat loss for prototype:
   A. the prototype requires 335,219 Btu for January, 1973
      this is for daily heat loss and daily heat gain calculated for consecutive days
   B. for the total heating season's figure, it would be necessary to calculate heat loss + heat gain for 30 days x 7 months x 20 years minimum, a total of 8400 calculations

C. it is possible to estimate heat loss and gain by proportioning the figures for heat loss according to the Hittman report and including in this number the proportionate heat gain for January for the other months

according to Hittman, losses are proportionately less than January and December for the other months:

	% of Jan. heat loss	x Btu for Jan.	
January	100%	335,219	= 335,219
February	66%	335,219	= 221,245
March	66%	335,219	= 221,245
April	25%	335,219	= 83,805
October	25%	335,219	= 83,805
November	66%	335,219	= 221,245
December	100%	335,219	= 335,219
			1,501,783

1,501,783 Btu are needed per heating season for prototype

3. Annual savings in first year of operation:

$$\text{savings} = \frac{\text{item 1} - \text{item 2}}{110{,}000 \text{ Btu/gal} \times 75\%} \times 40¢/\text{gallon}$$

$$= \frac{48{,}218{,}400 - 1{,}501{,}783}{110{,}000 \times .75} \times .40$$

$$= \frac{46{,}716{,}617}{82{,}500} \times .40$$

$$= 566.26 \times .40$$

$$= \$226.50$$

4. Estimated additional capital costs = $3000

5. Additional principal and interest charges

= \$3000 x discount factor

$$\text{discount factor} = \frac{r\ (1 + r)^N}{(1 + r)^N - 1}$$

where r = 8% and N = 30 years

$$d = \frac{.08\ (1 + .08)^{30}}{(1 + .08)^{30} - 1}$$

$$d = \frac{.08 \times 10.0627}{10.0627 - 1}$$

$$d = \frac{.805}{9.063}$$

$$d = 0.089$$

= \$3000 x 0.089

= \$267

6. $$\frac{\text{Benefit}}{\text{Cost}} = \frac{\text{item 3}}{\text{item 4} \times d} = \frac{\text{item 3}}{\text{item 4}} \times \frac{1}{d} = \frac{\text{item 3}}{\text{item 4}} \times \frac{a\ (a^N - 1)}{a - 1}$$

$$\text{where } a = \frac{1 + g}{1 + r}$$

g = annual % inflation for oil = 12% (relative to the overall inflation rate)

r = interest rate = 8%

$$= \frac{1 + .12}{1 + .08} = \frac{1.12}{1.08}$$

$$= 1.037$$

$$\frac{\text{Benefit}}{\text{Cost}} = \frac{\$226.50}{\$3000} \times \frac{1.037\ (1.037^{30} - 1)}{1.037 - 1}$$

$$= \frac{\$226.50}{\$3000} \times \frac{1.037\ (2.974 - 1)}{0.037}$$

$$= 0.0755 \times \frac{1.037\ (1.974)}{0.037}$$

$$= 0.0755 \times \frac{2.047}{0.037} = 0.0755 \times 55.325$$

$$= 4.177$$

7. Years to repay $= \frac{30\text{ years}}{\text{Benefit/Cost}}$

$= \frac{30}{4.177}$

$= 7.18$ years

Net life-cost savings = (30 years - 7.18 years) x $226.50

= $5168.73

This depends on a high overall inflation rate; lower national inflation rates will cause the repayment period for energy-related materials to be longer.

This proposal seems to offer many possibilities for development as a prototype. Its simple basic plan can accommodate differing living styles. The downstairs "children's room" can be a bedroom and play area for a family with young children; it could be a workroom for a young professional couple; it could be a library for a couple that loves books; or it could be a guest room for the "grandchildren" in a home for a "seasoned-citizen" or retired couple. The unfinished attic could become separate bedrooms for older children; it could become a large open studio for an artist; or it could include a little "sewing room", a "map collection" room, or a hugh and mysterious attic playroom for children of all ages.

The plan also presents possibilities for growth that would become important and financially feasible during succeeding stages of a family's life. When the family matures and only the older parents remain, the expanded house may have become too large for them. At that point, they might convert their house into a smaller home for themselves plus a small rental apartment: the older couple could retain the first floor for themselves and add a kitchen to the second floor. The upstairs would probably have completed rooms which could be used by the rental couple as bedroom + living room +eating area + loft or storage + bathroom. If the first and second floors are completely separated from each other, they will still have the same mechanism for solar collection in each separate apartment, but the space as a whole will not be able to use convection currents of warm or cool air as advantageously as before. Slightly more auxiliary heat might be needed. Entry to the second floor could be arranged by an added exterior staircase, or it could be through the present "children's room" which would become a "foyer" or downstairs sitting room with an interior staircase leading from there to the upstairs. It is possible, however, that the older couple may want to keep this as a "children's room" for the new generation of children that may visit them.

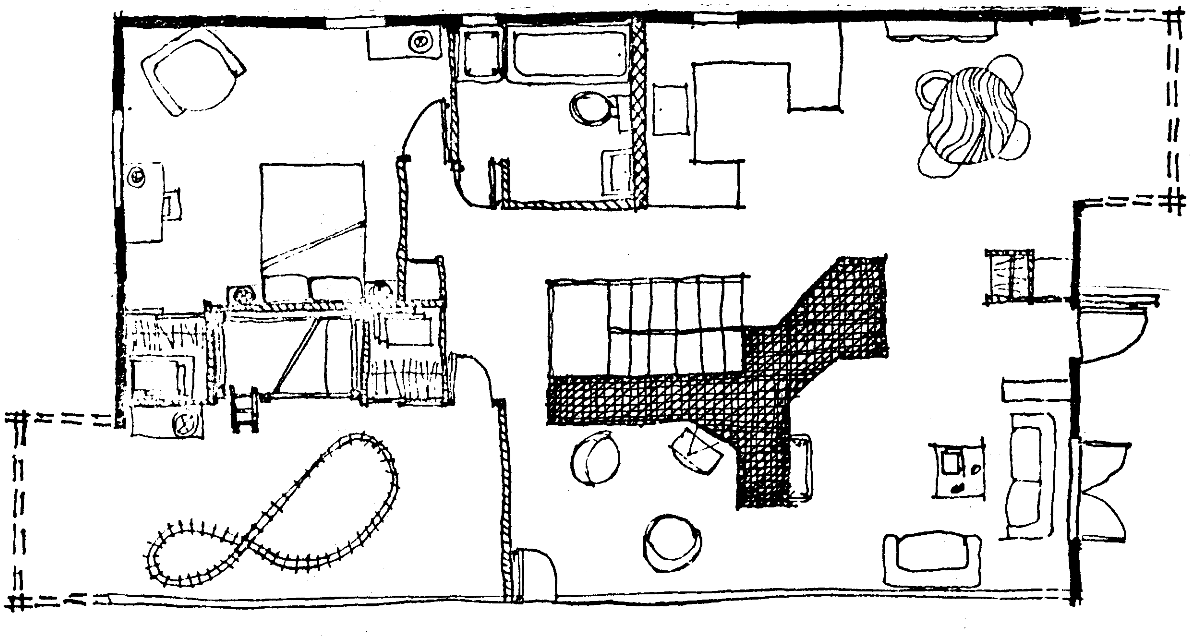
The heating system of this prototype depends upon natural convection from the heat storage unit and, when necessary, upon supplementary heating elements. These elements, which could probably be electric, would have a low initial cost and would be used infrequently. They could derive their energy from many sources: regional electric generating stations, local windmills, or alternative electricity-producing mechanisms of the future. The heat storage wall could also be separated into separate "pieces of heat storage" so that they would act similarly to individual room radiators. This would suggest locating the smaller storage walls between the northern and southern sides of the building in ways that would allow somewhat isolated bedrooms or other rooms on the north side of the house to utilize the storage system. The same air flow patterns that are advantageous for heating also enable ventilating principles to be used beneficially.

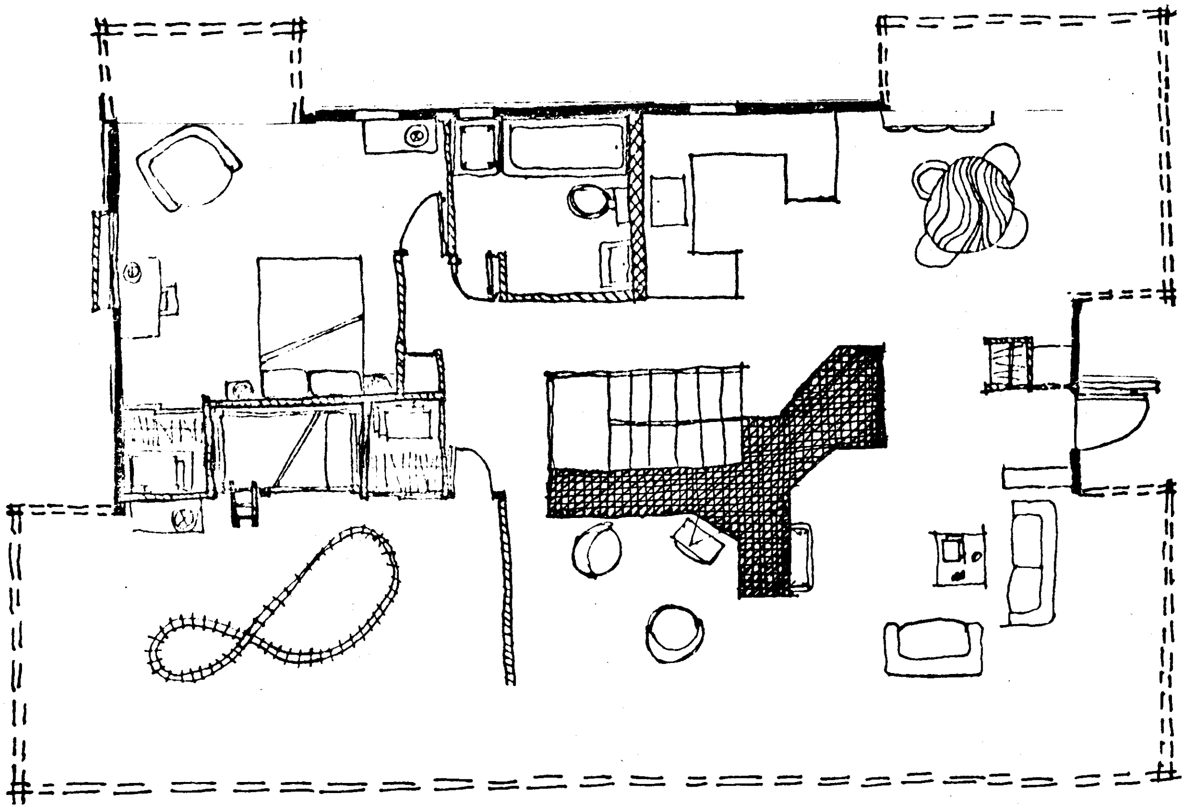
The large storage wall presents many possibilities for individual families to "territorialize" in a way that would be individual and thus personally interesting for each defferent family. Different exterior shapes due to different add-ons, and porch or patio and entrance detailing will also help develop variations that would enable each family to say, "That house, and no other, is <u>our</u> home."

This proposal will be used as one basic prototype for all locations that have appropriate street-and-sidewalk access for the house; that is, with the living room + "T.V. area + "children's room" facing due south.

The simple geometry of this prototype and the location of all rooms on exterior walls facilitate exterior additions wherever a family would want them. In addition, small prefabricated add-ons could be constructed without having to make decisions about future add-ons, that is, a small dining room add-on would not require determining whether or not future dining room add-ons would also someday be required to further enlarge the eating area. A residential block of little houses of this prototype would, at any given time, not be filled with "identical boxes". Each house would be different in its own way: some families would be able to afford one or two different add-ons at the time of original construction, others would be able to afford several add-ons that would turn the little house into a substantial building, and some families would only be able to afford the basic prototype. Thus there could easily be a sense of harmony from building to building and from an overall view of the area, and yet personalized variations would enable each family to identify its own living place.

Two examples of possible add-ons using the proposed prototype:



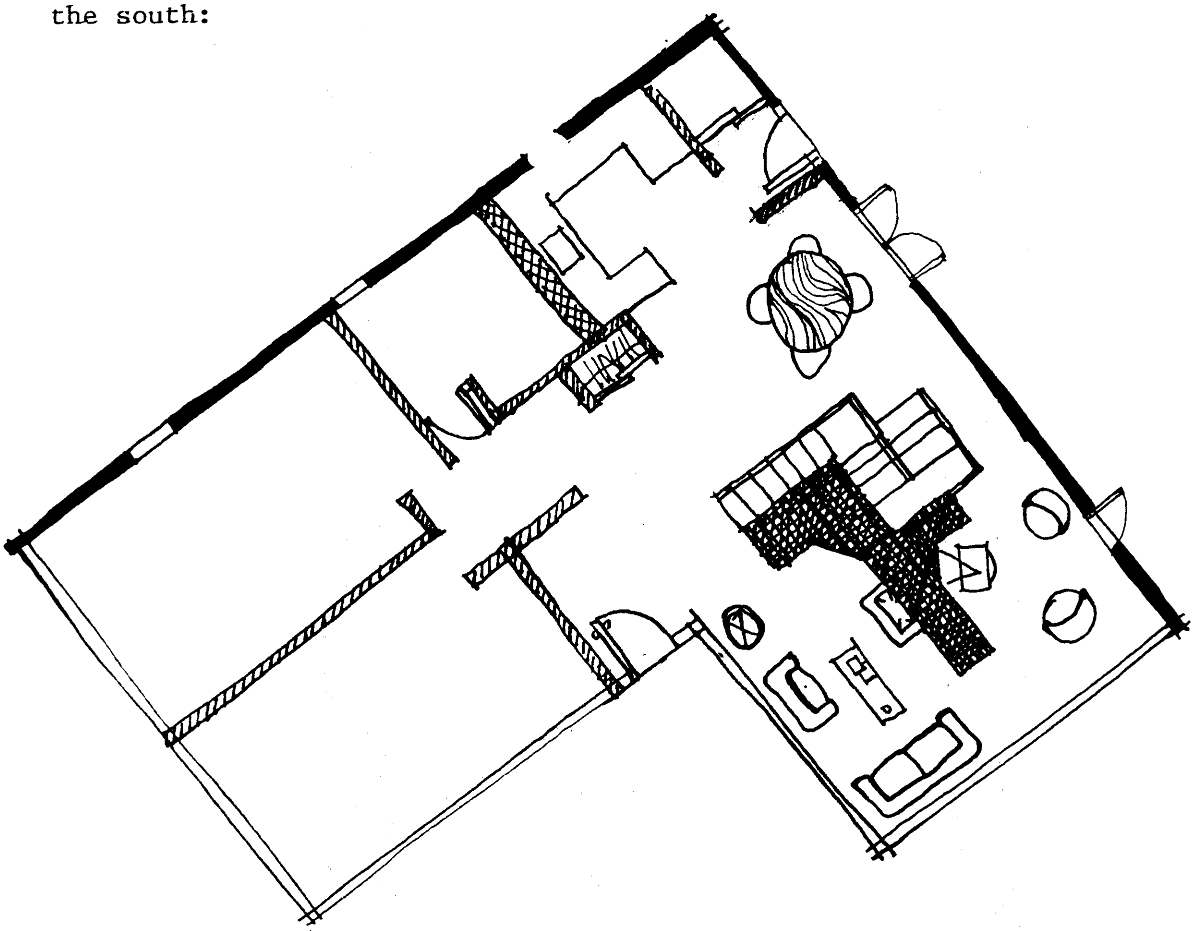


The second floor or unfinished attic could be added onto in the same way. Second storey porches, dormers, roof cutouts, turrets, and other additions could develop more space for the areas above the living and "T.V." rooms, so that loft areas could become additional rooms. Small first floor additions could become balconies for second floor bedrooms. The simplicity of the plan could even encourage fantasies to be indulged, for example, a tiny circular staircase could be installed to connect the upstairs front room with the downstairs children's room, thus providing a little "world of their own" for the children with a downstairs bedroom and a "secret" upstairs playroom.

One rule, however, that would probably have to be followed in all changes in construction, would be that south wall additions would have to be carefully organized so that shadows are not cast on south-facing, sunlight-collecting glazing.

There will be occasions when the orientation of this prototype to the street-and-sidewalk will be unsuitable. Thought must thus be given to proposals that may be oriented towards other directions while still retaining the basic necessity of optimal relationship to sunlight and wind.

An alternative design possibility might involve an access from the south:

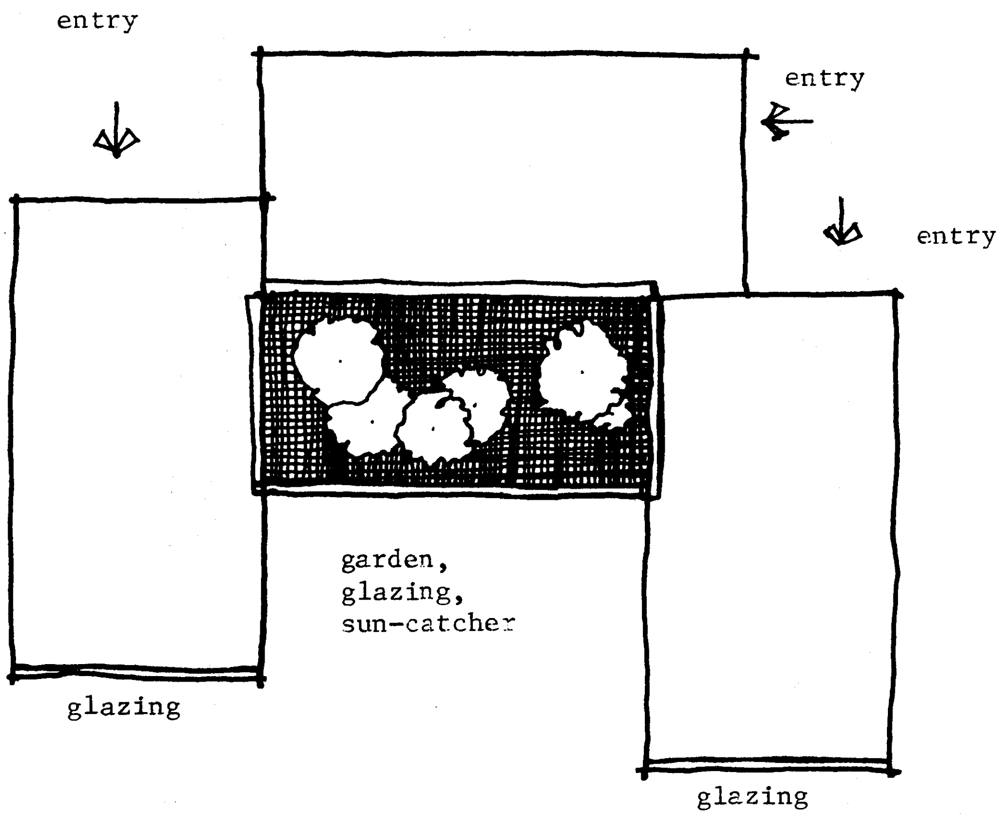


This is for a south entry from a street oriented northeast to southwest or northwest to southeast; this variation uses a "reverse bow" effect, that is, there is an inverted bow facing the sun so that southeastern and southwestern sunlight can be collected along each south-facing edge of the building.

Although a study in depth of clustering and apartment design is not the main focus of this thesis, a discussion of the possibilities of aggregating groups of the proposed prototype is appropriate.

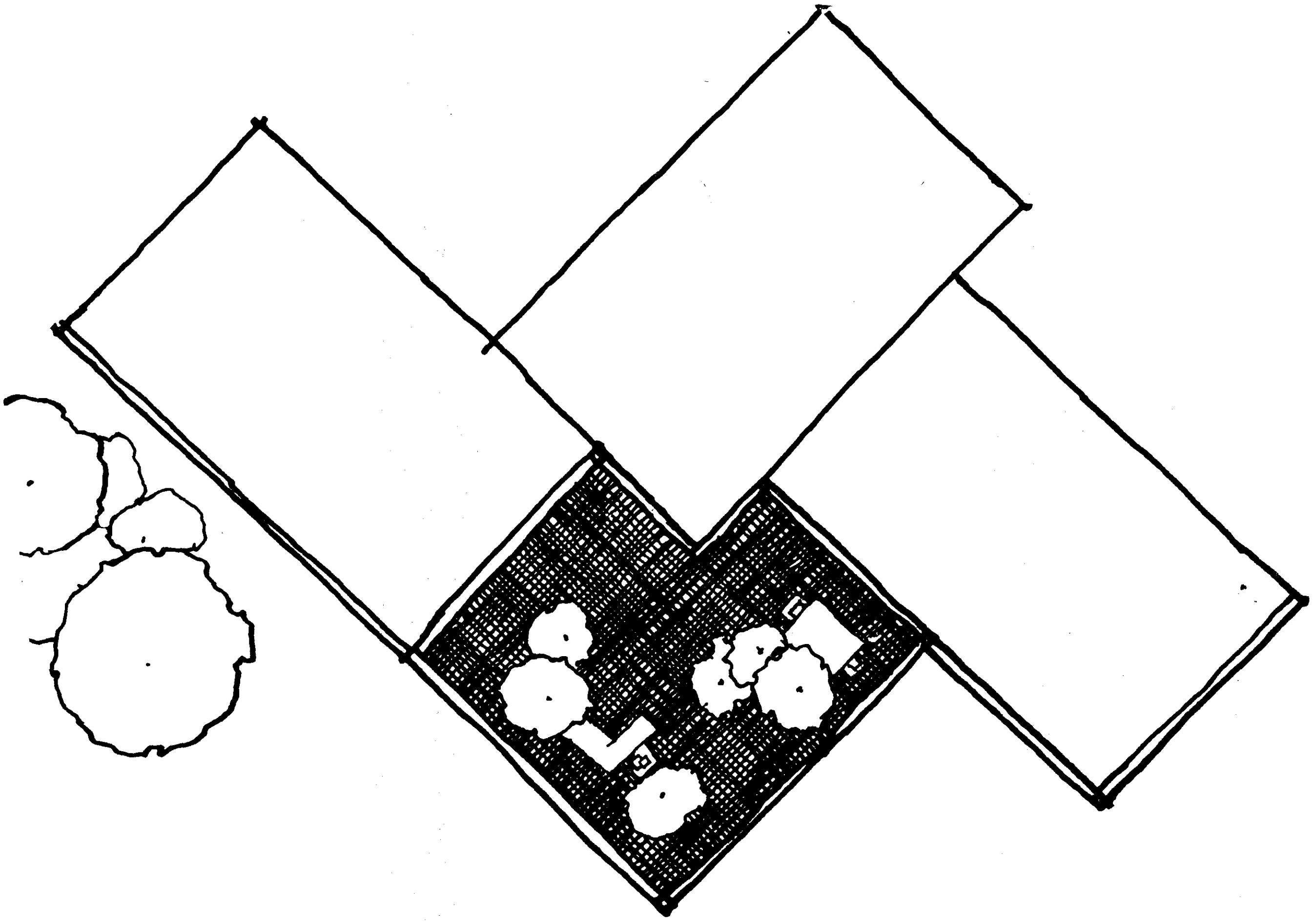
It is important to remember that groups of buildings will behave similarly to one large building. Thus attached prototypes would no longer require the same orientations as a single prototype, rather the attached group as a whole would act as if it were a single building. Each piece of the larger building could have its own separate orientation if the larger building is oriented for optimal heat gain. For example, three units of the prototype could be attached on two sides with a "common living room" in the center that would be on the south side of the complex and thus be the main area to collect and store the solar heat. This common area could become an indoor garden or atrium which would radiate heat to the surrounding living spaces. In addition, the shared walls would reduce the total exterior perimeter wall area exposed which would immediately reduce heat loss.

A few diagrammatic representations of clusters follow:



This configuration of three units would suggest a living style for people who would be more comfortable in apartments then in typical single-family houses. The areas in each unit that abut the common area must be constructed of light materials so that heat may flow freely. Shutters that lock and that have built-in possibilities for acoustic separation may be more appropriate than glass-with curtains. The center unit, which has the least privacy, but perhaps the most pleasant "view" of the garden, would probably be more suitable for a couple that prefers "being in the center of things". The shared common space with its concommittant lessened privacy may, in general, be more consistent with life styles in which activities are sometimes shared with neighbors. This may be found in dormitories or where groups of students live or possibly in rental situations in which the owners are an older couple who may be searching for the bustle of a lively household long forgotten. Since this cofiguration may include six living spaces within the three units (two floors or small "homes" per unit), it may indeed be appropriate for people who will rent from a resident, gregarious "landlord" or "housemother".

The next example of the use of a shared living area or garden for heat loss reduction may be advantageous as an alternative to retired citizen housing projects. The common garden may become a common living room. Since senior citizen housing projects in general allocate only about five hundred square feet for a single senior citizen's living space allotment, this prototype may be bisected so that four apartments of five hundred square feet will be formed. The cluster of three units would house twelve single people or a corresponding number of singles and couples so that at least twelve people will be living there. The common living room will then become necessary as a place for additional living needs to be fulfilled. It can contain a garden, a "coffee klatsch" area, a card game area, a reading area of shared magazine subscriptions and books, a mail area, and of course, a hugh massive fireplace wall for "coziness" and heat storage. The open area may also become a place to put treasured pieces of furniture that could not possibly fit into the tiny apartment areas usually allowed.

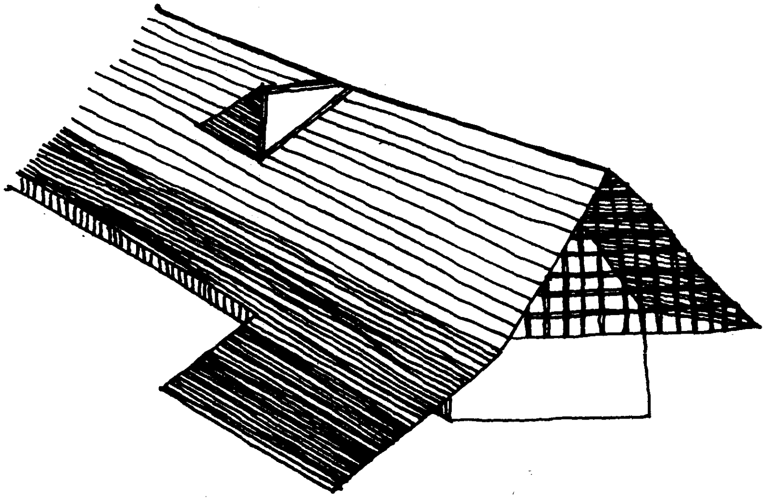


The "bow" of the entire front part of the cluster acts similarly to the previous cluster's "reverse bow" to receive maximum sunshine.

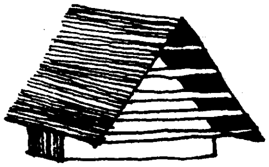
In this way it can be seen that the requirements of heat collection, heat storage, and heat disbursement for residents of a cluster of apartments can encourage, or allow to develop, a living arrangement that will be much richer than standard apartment lobbies which are totally separated from the lives of the people who live there.

The openness of, and the uncomplicated access to, the common area will hopefully reinforce the feeling that the cluster as a whole is a "home". An important factor that must be included in this concept is that each living unit must have a separate private entrance in addition to entries through the common space.

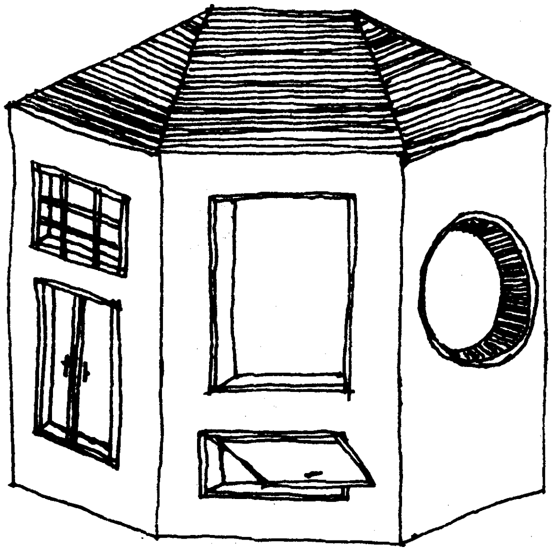
Various design "pieces" can be incorporated into the Geocom prefabrication system, ranging from skylights to bay windows. These elements can be choosen by each family to help it individualize its living space.

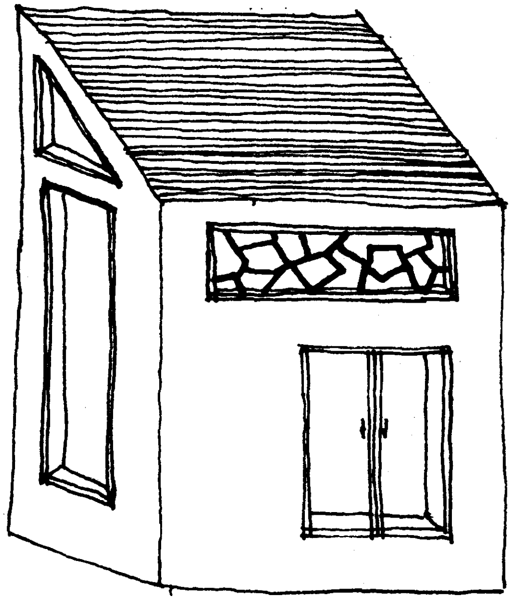


external sun blinds

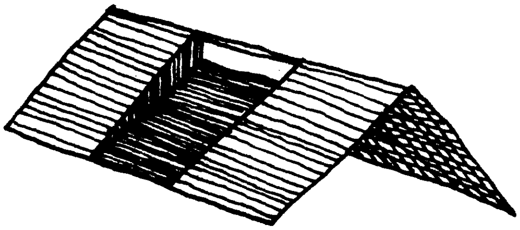


"Bay windows" or nooks can be rectangular or bow-shaped. They can have a variety of windows such as double-hung, non-operable, or vertical or horizontal casement windows. The bay can even be planned to include old stained glass windows that may have been found by a family in an old mansion slated for destruction.

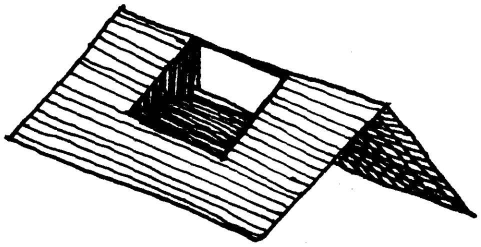


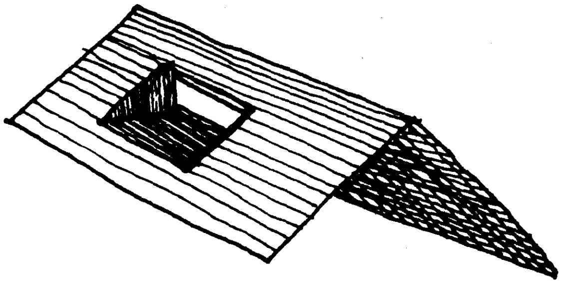


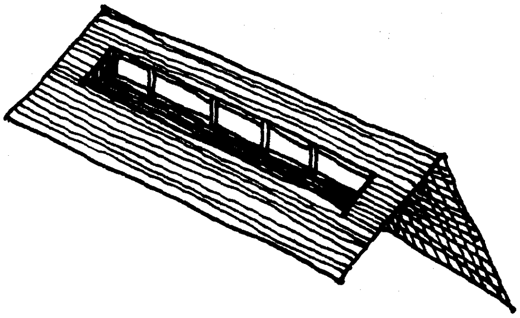
Many different skylights or other roof "pieces" can be incorporated intc the system if the Geocom four-foot module is respected.



skylights for the east side of the building can be recessed in the roof; this shields the building from oblique rays of the summer sun after 10 A.M., when the sun enters the "discomfort zone" (see Olgyay's chart of Bioclimatic Comfort Zones, p.   )

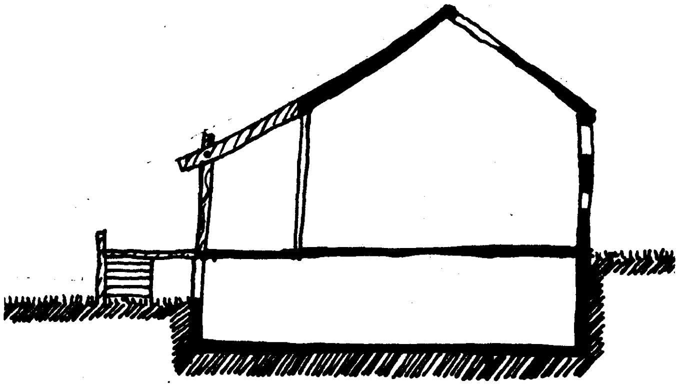


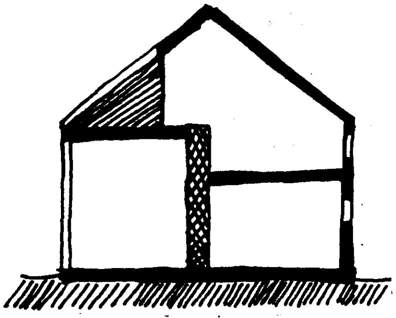




Variations can also take place within the shell of the prototype. Basements, porches, roof overhangs, and roof staggering enable the basic principles to function with modified forms.

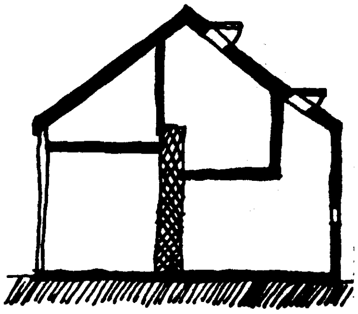
the porch works within the prototypical system because the whole house is raised four feet and a basement is added four feet below grade; the first storey floor cannot be concrete, thus requiring the storage wall to have adequate depth



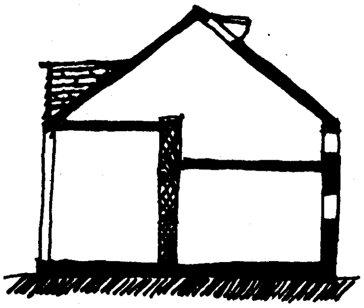


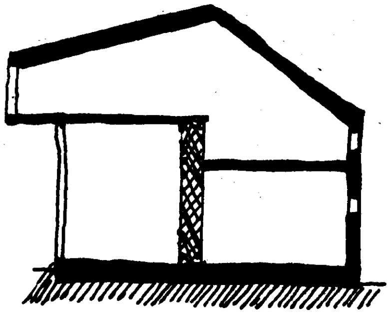
the area above the living room could also be used for collection of heat for domestic hot water usage

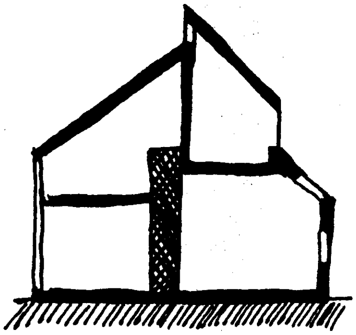
the simple gable roof and rectangular plan can include a varied development of upper storey spaces



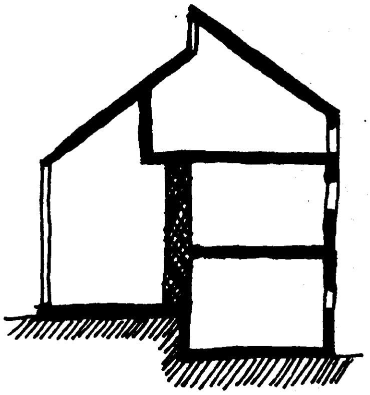
additional space can be found by building dormers or by changing the roof line and building outwards



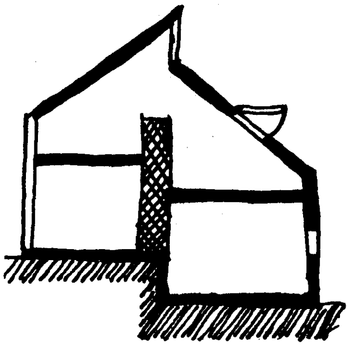




with a staggered roof, skylights can let sunlight into the upper parts of the back of the house; the storage wall would connect to the upper rooms to allow continuity of air flow



staggering the roof and the ground floor on the north or south side of the house will permit new variations



Certain problems have developed in this section which should be mentioned as worthwhile for future research directions. First of all, such a large quantity of heat is potentially gained by solar radiation in comparison with heat loss for the prototype and with heat loss for a "standard" house, that many changes in design can be made without a great sacrifice to heat balancing. Consequently, some families may need or want less south-wall glazing, others may want more north-wall windows, and others may need a much larger roof area devoted to skylights for backlighting the living space to control glare. Some families may decide that north windows can be double glazed rather than triple glazed, since the difference in total heat loss between the two is minimal. Other families may "put together" or design a different prefabricated geometric configuration, others may choose a larger heat storage wall in exchange for a wooden floor or, on the contrary, may choose to utilize the masonry floor for more storage and minimize the size of the storage wall. These variations can be made even if they result in reduced solar heat gain and more increased reliance on supplementary heat if the family is willing to pay slightly more for fuel bills.

Other unit and clustering variations could also be explored that cast fewer shadows on component parts of prototypes. Further work could also be done to orient the prototypes in different directions, for different street and road accesses, and for various terrains. Shading and privacy must also be further examined: built-in shades or window curtains offer possibilities for privacy and also act to reduce re-radiation of trapped heat from the living space to the outdoors.

The single largest area for further research would be into the development of the heat storage wall. This thesis assumes a simple "thermostatic" action in the way the heat storage wall will lose heat to the living space as the house cools and becomes a heat sink for the wall. However, the possibility exists that the wall (or other storage media) will not be so predictable. There can be a lag between the time the living space begins to cool down and the time it will take for the storage medium to release heat. This is known as the "fly-wheel" effect. New ways to control the heat transfer mechanisms of the storage wall would be an interesting and useful direction to explore.

APPENDIX

PROJECTED DAILY HEAT LOSS FOR PROPOSED PROTOTYPE

BASED ON NATIONAL WEATHER SERVICE DATA FOR BOSTON FOR JANUARY, 1973

Day of Month	Heat Loss in Btu
1	184,377
2	304,222
3	331,879
4	304,222
5	304,222
6	433,287
7	507,038
8	543,913
9	516,257
10	405,630
11	387,192
12	414,849
13	442,506
14	359,536
15	295,004
16	276,566
17	193,596
18	147,502
19	184,377
20	276,566
21	350,317
22	258,128
23	175,158
24	276,566
25	322,660
26	248,909
27	276,566
28	295,004
29	377,973
30	479,381
31	507,038

Total January Heat Loss
for Prototype = 10,380,440 Btu

Total January Heat Loss
for "Standard 1000 square
foot House" based on
Hittman report = 10,591,200 Btu

The large amount of heat loss for the prototype reflects the increased glazing used to maximize solar heat gain in order to minimize reliance on supplementary heating elements. It is, however, erroneous to look only at the total monthly heat loss for the prototype since the heating system for the prototype works by gaining and storing heat each day to balance the heat loss of that day. Since heat can be stored for up to two days in the storage wall, heat loss on any given day may be balanced by retaining stored heat from the previous day. In actuality, it often occurs that days with large heat losses also are days with minimal cloudiness, and that days with small heat losses occur simultaneously with heavily overcast skies. This usually effectively balances heat losses and explains why each day's heat loss must be consecutively compared to each day's heat gain. The "Daily Consecutive Heat Gain and Heat Storage Table" on the next page easily demonstrates this principle. It indicates that supplementary heat would have to be provided on only four days, Days 14, 15, 29, and 30. While this may be optimistic and concerned with ideal possibilities, it nevertheless still demonstrates a useful methodology for computing true consecutive conditions.

PROJECTED DAILY CONSECUTIVE HEAT GAIN AND HEAT STORAGE FOR PROTOTYPE BASED ON NATIONAL WEATHER SERVICE DATA FOR BOSTON FOR JANUARY, 1973

Day of Month	Maximum Heat Gain Possible		% Clear Sky		Btu Gain	-	Btu Loss	Consecutive Btu in storage
1	840,199	x	.50	=	420,099	-	184,377	235,722
2	840,199	x	.50	=	420,099	-	304,222	351,599
3	840,199	x	1.00	=	840,199	-	331,879	717,287
4	840,199	x	.00	=	0	-	304,222	413,065
5	840,199	x	.50	=	420,099	-	304,222	528,942
6	840,199	x	.90	=	756,179	-	433,287	717,287
7	840,199	x	1.00	=	840,199	-	507,038	717,287
8	840,199	x	.80	=	662,159	-	543,913	717,287
9	840,199	x	.60	=	504,199	-	516,257	705,149
10	840,199	x	1.00	=	840,199	-	405,630	717,287
11	840,199	x	1.00	=	840,199	-	387,192	717,287
12	840,199	x	1.00	=	840,199	-	414,849	717,287
13	840,199	x	.20	=	168,039	-	442,506	442,820
14	840,199	x	.10	=	84,019	-	359,536	736
15	840,199	x	.30	=	252,059	-	295,004	49,945
16	840,199	x	.80	=	672,159	-	276,566	395,593
17	840,199	x	.10	=	84,019	-	193,596	286,016
18	840,199	x	.10	=	84,019	-	147,502	222,533
19	840,199	x	.50	=	420,099	-	184,377	458,255
20	840,199	x	.00	=	0	-	276,566	181,689
21	840,199	x	1.00	=	840,199	-	350,317	671,571
22	840,199	x	.00	=	0	-	258,128	413,443
23	840,199	x	.40	=	336,079	-	175,158	583,364
24	840,199	x	.10	=	84,019	-	276,566	390,817
25	840,199	x	.50	=	420,099	-	322,660	488,256
26	840,199	x	1.00	=	840,199	-	248,909	717,287
27	840,199	x	.00	=	0	-	276,566	440,721
28	840,199	x	.00	=	0	-	295,004	145,717
29	840,199	x	.00	=	0	-	377,973	-232,256
30	840,199	x	.50	=	420,099	-	479.381	- 59,282
31	840,199	x	.90	=	756,179	-	507,038	249.141

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A UNITED STATES
DEPARTMENT OF
COMMERCE
PUBLICATION

LOCAL CLIMATOLOGICAL DATA
ANNUAL SUMMARY WITH COMPARATIVE DATA

BOSTON, MASSACHUSETTS

1973

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ENVIRONMENTAL DATA SERVICE

NARRATIVE CLIMATOLOGICAL SUMMARY

Climate is the composite of numerous weather elements. Three important influences are responsible for the main features of Boston's climate. First, the latitude (42° N) places the city in the zone of prevailing west to east atmospheric flow in which are encompassed the northward and southward movements of large bodies of air from tropical and polar regions. This results in variety and changeability of the weather elements. Secondly, Boston is situated on or near several tracks frequently followed by systems of low air pressure. The consequent fluctuations from fair to cloudy or stormy conditions reinforce the influence of the first factor, while also assuring a rather dependable precipitation supply. The third factor, Boston's east-coast location, is a moderating factor effecting temperature extremes of winter and summer.

Hot summer afternoons are frequently relieved by the locally celebrated "sea-breeze", as air flows inland from the cool water surface to displace the warm westerly current. This refreshing east wind is more commonly experienced along the shore than in the interior of the city or the western suburbs. In winter, under appropriate conditions, the severity of cold waves is reduced by the nearness of the then relatively warm water. The average date of the last occurrence of freezing temperature in spring is April 8; the latest is May 3, 1874 and 1882. The average date of the first occurrence of freezing temperature in autumn is November 7; the earliest on record is October 5, 1881. In suburban areas, especially away from the coast, these dates are later in spring and earlier in autumn by up to one month in the more susceptible localities.

Boston has no dry season. For most years the longest run of days with no measurable precipitation does not extend much more than two weeks. This may occur at any time of year. Most growing seasons have several shorter dry spells during which irrigation for high-value crops may be useful.

Much of the rainfall from June to September comes from showers and thunderstorms. During the rest of the year, low pressure systems pass more or less regularly and produce precipitation on an average of roughly one day in three. Coastal storms, or "northeasters", are prolific producers of rain and snow. The main snow season extends from December through March. The average number of days with four inches or more of snowfall is four per season, and days with seven inches or more come about twice per season. Periods when the ground is bare or nearly bare of snow may occur at any time in the winter.

Relative humidity has been known to fall as low as 5% (May 10, 1962), but such desert dryness is very rare. Heavy fog occurs on an average of about two days per month with its prevalence increasing eastward from the interior of Boston Bay to the open waters beyond.

The greatest number of hours of sunshine recorded in any month was 390, or 86% of possible, in June 1912, while the least was 60 hours, or 21%, in December 1972.

Although winds of 32 m.p.h. or higher may be expected on at least one day in every month of the year, gales are both more common and more severe in winter.

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METEOROLOGICAL DATA FOR THE CURRENT YEAR

Station: BOSTON, MASSACHUSETTS GEN LOGAN INTERNATIONAL AP Standard time used: EASTERN Latitude: 42° 22' N Longitude: 71° 02' W Elevation (ground): 15 feet Year: 1973

Month	Temperature							Degree days (Base 65°)		Precipitation						Relative humidity				Wind &						Percent of possible sunshine	Average sky cover sunrise to sunset	Number of days											Average daily solar radiation - langleys
	Averages			Extremes									Snow, Ice pellets							Resultant			Fastest mile					Sunrise to sunset							Temperatures				
																																			Maximum		Minimum		
	Daily maximum	Daily minimum	Monthly	Highest	Date	Lowest	Date	Heating	Cooling	Total	Greatest in 24 hrs.	Date	Total	Greatest in 24 hrs.	Date	Hour 01 (Local time)	Hour 07	Hour 13	Hour 19	Direction	Speed	Average speed	Speed	Direction #	Date			Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	90° and above $	32° and below	32° and below	0° and below	
JAN	39.1	23.7	31.4	61	18+	1	8	1032	0	3.12	1.55	28-29	3.6	1.7	4	60	63	49	53	28	9.8	14.9	34	NW	20	62	5.1	11	9	11	7	2	1	0	0	10	23	0	
FEB	37.2	22.9	30.1	54	3+	3	1	971	0	2.13	1.16	2-3	2.5	1.1	26	58	63	53	56	32	7.5	13.7	44	S	2	44	7.0	5	7	16	10	1	0	1	0	9	23	0	
MAR	50.2	36.4	43.3	67	12	26	1	660	0	2.20	0.69	17	0.3	0.3	22	70	69	59	67	03	3.1	10.0	37	SW	18	47	8.2	3	4	24	9	0	1	6	0	0	6	0	
APR	57.8	41.9	49.9	84	22	31	14+	450	7	5.65	2.31	1-2	T	T	11+	66	67	54	61	29	3.1	13.0	40	W	6	39	6.5	7	7	16	12	0	0	1	0	0	3	0	
MAY	64.3	49.6	57.0	87	29	42	1	250	18	3.70	0.99	20-21	0.0	0.0		78	78	62	68	21	1.3	9.7	30	NE	21+	54	7.7	2	11	18	13	0	3	1	0	0	0	0	
JUN	78.5	61.4	70.0	97	11	50	3	24	180	4.60	1.29	30	0.0	0.0		76	75	60	68	23	1.9	7.7	34	NW	12	54	7.3	4	8	18	13	0	3	5	3	0	0	0	
JUL	82.3	66.2	74.3	98	8	59	31+	0	296	4.83	1.73	29	0.0	0.0		76	72	59	68	23	3.0	6.8	26	W	29+	63	6.2	9	6	16	11	0	4	4	4	0	0	0	
AUG	82.7	66.9	74.8	99	30	57	23	3	316	2.78	1.22	15	0.0	0.0		80	77	59	73	25	2.0	7.4	34	NW	31	64	5.9	7	14	10	11	0	2	1	10	0	0	0	
SEP	72.3	56.4	64.4	94	4+	43	21	94	84	1.95	1.03	18	0.0	0.0		75	74	55	67	28	3.2	10.7	49	SW	6	72	5.2	9	14	7	9	0	3	3	2	0	0	0	
OCT	62.9	48.2	55.6	77	13+	37	28	289	3	2.71	1.76	29-30	0.0	0.0		72	72	55	65	29	2.4	11.6	30	SE	30+	63	5.2	11	10	10	8	0	0	3	0	0	0	0	
NOV	52.0	39.5	45.8	71	14	30	11+	570	0	1.74	0.55	28	0.0	0.0		63	65	49	58	27	8.1	12.7	44	W	1	50	5.8	9	9	12	9	0	0	2	0	0	5	0	
DEC	46.7	32.4	39.6	63	8+	11	19	782	0	7.20	2.76	16-17	T	T	31+	66	69	61	65	28	5.0	12.7	43	S	21	40	6.6	9	4	18	13	0	0	3	0	2	16	0	
YEAR	60.5	43.5	53.0	99	AUG. 30	1	JAN. 8	5139	904	42.75	2.76	DEC. 16-17	6.4	1.7	JAN. 4	70	70	56	64	28	3.5	10.9	49	SW	SEP. 6	57	6.4	86	103	176	125	3	17	29	19	21	76	0	

NORMALS, MEANS, AND EXTREMES

Month	Temperature							Normal heating degree days (Base 65°)	Precipitation												Relative humidity				Wind &					Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days												Average daily solar radiation - langleys
	Normal			Extremes #												Snow, Ice pellets											Fastest mile					Sunrise to sunset							Temperatures				
																																							Max.		Min		
	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year		Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Hour 01 (Local time)	Hour 07	Hour 13	Hour 19	Mean speed	Prevailing direction	Speed	Direction ##	Year			Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	90° and above $	32° and below	32° and below	0° and below	
(a)	(b)	(b)	(b)	9		9		(b)	(b)	22		22		22		38	38		38		9	9	9	9	16	13	16	16		38	38	38	38	38	22	38	38	38	9	9	9	9	
J	35.9	22.5	29.2	62	1967	-4	1968+	1110	3.69	9.54	1958	0.89	1970	2.07	1958	12.0	32.5	1948	12.8	1943	65	66	57	60	14.4	NW	52	SW	1960	54	6.2	9	7	15	12	3	*	2	0	11	26	*	
F	37.5	23.3	30.4	58	1970+	-3	1967	969	3.54	7.08	1969	1.15	1968	2.68	1969	11.9	41.3	1969	19.4	1958	65	68	58	62	14.6	WNW	57	S	1970	56	6.2	8	7	13	11	3	*	2	0	8	25	*	
M	44.6	31.5	38.1	67	1973	6	1967	834	4.01	11.00	1953	1.48	1962	4.13	1960	8.3	31.2	1956	17.7	1960	68	69	59	63	14.1	NW	55	SW	1971	57	6.3	8	8	15	12	2	*	2	0	2	18	0	
A	56.3	40.8	48.6	84	1973	22	1965	492	3.49	7.82	1958	1.24	1966	2.31	1973	0.7	3.3	1967	3.1	1956	68	67	54	61	13.5	WNW	52	NW	1963	56	6.4	7	9	14	12	*	1	2	0	0	3	0	
M	67.1	50.1	58.6	93	1964	37	1967	218	3.47	13.38	1954	0.53	1964	8.74	1954	T	T	1967+	T	1967+	73	71	56	64	12.3	SW	50	NE	1967	58	6.5	6	11	14	12	0	2	3	*	0	0	0	
J	76.6	59.3	68.0	97	1973	46	1965	27	3.19	8.63	1959	0.48	1953	2.46	1960	0.0	0.0		0.0		77	73	59	67	11.4	SW	44	NNW	1958	63	6.2	7	10	13	11	0	4	2	2	0	0	0	
J	81.4	65.1	73.3	98	1960	54	1965	0	2.74	8.12	1959	0.52	1952	2.42	1959	0.0	0.0		0.0		76	73	56	66	10.9	SW	45	N	1964	65	6.2	7	12	12	9	0	5	2	5	0	0	0	
A	79.3	63.3	71.3	99	1973	47	1965	8	3.46	17.09	1955	0.83	1972	8.40	1955	0.0	0.0		0.0		77	74	56	67	10.9	SW	65	NNW	1958	66	5.6	9	11	11	10	0	4	2	3	0	0	0	
S	72.3	56.7	64.5	95	1969	38	1965	76	3.16	8.31	1954	0.35	1957	5.64	1954	0.0	0.0		0.0		79	78	61	72	11.5	SW	57	S	1960	64	5.5	11	8	11	9	0	2	2	1	0	0	0	
O	63.2	47.5	55.4	86	1971	30	1969	301	3.02	8.68	1962	0.96	1967	4.26	1962	T	T	1972+	T	1972+	75	76	57	67	12.3	SW	45	NW	1963	61	5.5	11	8	12	9	0	1	2	0	0	1	0	
N	51.7	38.7	45.2	78	1971	17	1972	594	4.51	8.10	1969	1.72	1952	3.33	1955	1.2	10.0	1938	8.0	1940	73	75	62	69	13.2	SW	58	SW	1958	51	6.4	8	7	15	12	*	*	2	0	*	7	0	
D	39.3	26.6	33.0	70	1966	-3	1968	992	4.24	9.74	1969	1.03	1955	4.17	1969	7.7	27.9	1970	13.0	1960	69	72	62	66	14.0	WNW	49	NW	1962	52	6.2	9	7	15	12	2	*	1	0	6	21	*	
YR	58.7	43.8	51.3	99	AUG. 1973	-4	JAN. 1968+	5621	42.52	17.09	AUG. 1955	0.35	SEP. 1957	8.40	AUG. 1955	41.8	41.3	FEB. 1969	19.4	FEB. 1958	72	72	58	65	12.7	SW	65	NNW	AUG. 1958	59	6.1	100	105	160	128	11	19	23	11	27	100	1	

For period April 1964 through current year.
Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows:
Highest temperature 104 in July 1911; lowest temperature -18 in February 1934; minimum monthly precipitation T in March 1915; fastest mile wind 87 S in September 1938.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological normals (1941-1970).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
\- Below zero temperatures are preceded by a minus sign.
$ ≥ 70° at Alaskan stations.

The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

\## Data for the year 1958 are fastest observed 1-minute speeds with directions to 16 compass points; otherwise data are fastest mile with directions to 8 compass points.

\# To 8 compass points only.

AVERAGE TEMPERATURE

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1934	29.6	17.9	39.1	48.0	60.6	66.9	73.2	67.3	64.6	49.0	45.6	28.4	49.9
#1935	23.2	27.8	38.6	45.2	55.5	65.5	72.6	70.7	61.4	53.8	45.4	27.1	48.9
1936	28.2	22.8	41.8	45.2	60.6	66.2	71.1	69.7	62.6	54.4	39.5	35.0	49.8
1937	37.4	33.2	34.1	45.2	59.1	66.4	73.2	74.6	63.0	52.6	44.0	31.2	51.2
1938	28.0	30.6	39.1	48.7	55.8	67.2	71.8	73.6	62.2	56.0	46.4	34.0	51.1
1939	27.8	32.2	35.2	43.6	56.4	65.0	72.3	73.8	64.5	54.2	40.8	33.4	49.8
1940	23.0	29.6	33.1	43.6	56.2	65.1	71.6	68.4	63.3	50.8	42.9	34.3	48.5
1941	25.2	29.4	33.4	51.6	59.8	68.2	71.4	70.6	66.0	55.9	48.0	35.2	51.2
1942	28.6	27.0	40.8	49.7	60.8	67.4	71.1	70.7	64.6	55.8	43.5	28.6	50.7
1943	25.5	30.6	36.0	43.4	57.6	71.2	74.1	71.0	63.0	53.8	43.3	29.6	49.9
1944	31.0	29.6	36.1	44.6	63.2	67.0	73.8	74.7	65.0	53.8	43.2	30.8	50.9
1945	25.8	30.5	46.3	52.5	55.2	66.6	71.9	70.8	67.1	53.1	45.5	28.5	51.0
1946	28.4	27.6	47.2	46.2	58.0	67.5	70.8	67.8	65.8	58.4	47.8	34.8	51.7
1947	32.6	29.6	37.7	47.2	56.9	68.4	76.4	73.2	64.8	61.0	41.2	30.4	51.2
1948	25.4	26.6	38.0	48.0	55.0	63.6	74.5	73.7	65.7	56.2	49.0	36.3	50.7
1949	34.6	34.6	38.2	50.8	60.4	71.6	76.2	74.6	63.2	58.4	43.5	36.8	53.6
1950	34.2	28.0	33.7	46.8	55.8	69.1	73.5	70.8	61.5	56.3	47.8	35.5	51.3
#1951	34.0	34.7	38.1	51.0	58.1	66.0	74.0	70.7	65.6	54.8	42.6	35.0	52.2
1952	32.6	32.5	37.2	50.5	57.2	70.7	77.5	72.3	66.3	53.0	44.9	35.7	52.6
1953	34.7	35.0	38.1	48.8	58.4	70.5	73.2	72.0	66.3	56.2	46.6	40.2	53.6
1954	26.0	36.4	38.8	50.1	56.3	66.6	72.2	70.1	63.2	58.6	44.4	34.6	51.4
1955	28.5	32.0	37.6	49.2	62.8	66.8	77.2	74.5	64.5	55.1	41.9	26.6	51.4
1956	30.6	32.5	33.6	45.6	55.6	68.9	71.7	71.9	61.1	54.4	46.1	38.0	50.7
1957	23.4	34.7	39.1	49.4	59.9	71.3	76.1	69.3	67.3	56.0	47.2	40.0	52.5
1958	31.0	25.5	39.1	48.0	56.6	63.9	72.4	72.4	64.6	52.8	46.6	26.4	50.0
1959	28.7	26.7	37.0	48.0	62.0	64.6	74.7	74.1	68.1	55.1	44.4	36.3	51.8
1960	30.9	35.3	32.7	48.3	59.7	69.6	73.1	72.1	63.7	53.9	48.0	29.5	51.4
1961	25.0	31.6	36.8	45.3	56.3	68.9	72.1	72.5	69.0	57.3	44.6	32.8	51.0
1962	28.7	26.7	38.5	49.4	57.2	68.4	70.4	70.0	62.9	54.1	41.7	30.0	49.8
#1963	29.5	25.9	39.1	48.9	59.4	69.5	74.7	70.4	60.8	60.0	48.3	25.9	51.0
#1964	31.7	29.1	38.7	46.1	60.3	67.1	71.5	66.4	62.0	52.5	44.1	32.4	50.2
1965	25.4	28.0	35.8	44.2	59.5	67.4	71.0	70.5	62.5	52.8	42.1	36.1	49.6
1966	28.8	31.5	39.8	45.9	57.3	69.4	74.9	71.3	63.5	54.5	46.9	34.2	51.5
1967	35.1	26.4	33.2	44.9	51.7	67.2	73.0	70.9	62.7	53.8	40.1	35.0	49.5
1968	25.6	26.1	39.1	49.6	56.1	64.9	75.2	70.7	65.0	57.9	43.8	30.9	50.4
1969	29.3	29.5	35.4	50.4	58.5	69.3	71.0	74.3	63.7	54.3	46.9	33.4	51.2
1970	23.0	32.5	37.4	48.0	59.6	67.0	74.3	73.8	65.4	54.9	46.8	28.9	50.9
1971	23.8	30.5	36.7	45.1	55.7	69.1	73.4	73.4	68.0	59.8	45.1	30.3	51.2
1972	33.0	29.6	36.2	44.9	57.6	65.4	73.8	71.5	65.7	51.8	42.3	33.0	50.4
1973	31.4	30.1	45.3	48.9	57.0	70.4	74.3	74.8	66.4	55.6	45.8	39.6	53.0
RECORD MEAN	28.8	29.1	36.8	46.9	57.7	67.0	72.5	70.7	64.0	54.2	43.4	32.6	50.3
MAX	36.3	36.8	44.3	54.9	66.3	75.7	80.9	78.7	72.0	62.1	50.3	39.6	58.2
MIN	21.2	21.5	29.3	38.8	49.0	58.2	64.1	62.6	56.0	46.2	36.2	25.5	42.4

HEATING DEGREE DAYS

BOSTON, MASSACHUSETTS

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1934-35	0	47	53	476	583	1135	1295	1040	823	601	318	96	6467
#1935-36	6	16	126	348	586	1176	1142	1224	711	598	183	41	6157
1936-37	2	28	122	330	769	932	854	891	954	595	210	35	5730
1937-38	2	8	128	387	631	1046	1150	964	802	496	291	51	5956
1938-39	7	4	114	295	564	959	1147	920	987	640	296	62	5995
1939-40	0	2	89	358	727	981	1302	1029	990	642	269	75	6464
1940-41	13	31	111	450	684	953	1228	998	981	409	199	61	6098
1941-42	6	9	89	299	511	923	1132	1063	749	486	164	61	5472
1942-43	3	23	103	288	646	1132	1226	967	902	649	243	18	6200
1943-44	4	7	120	355	648	1097	1091	1030	986	608	121	78	6073
1944-45	0	10	90	363	657	1062	1200	965	585	388	313	94	5807
1945-46	0	17	71	368	504	1133	1139	1050	561	565	237	74	5799
1946-47	18	37	57	234	515	940	1001	992	847	537	286	86	5590
1947-48	0	4	137	164	718	1073	1294	1118	837	511	313	113	6279
1948-49	3	1	76	341	461	892	940	858	798	423	192	20	5003
1949-50	0	1	108	230	644	872	886	1029	961	539	280	12	5599
1950-51	0	4	149	281	512	905	953	861	797	410	215	63	5136
#1951-52	0	3	65	309	665	923	997	935	856	432	258	6	5427
1952-53	0	2	62	308	595	901	930	834	799	475	215	32	5213
1953-54	2	2	71	277	487	761	1201	792	806	442	287	61	5189
1954-55	0	11	107	248	612	941	1127	917	841	469	133	73	5479
1955-56	0	5	85	307	685	1181	1057	930	966	575	304	54	6155
1956-57	15	6	174	330	560	893	1284	842	798	466	201	21	5590
1957-58	0	7	57	317	529	766	1046	1102	796	481	202	85	5468
1958-59	6	2	84	386	547	1190	1118	1065	862	476	142	92	5968
1959-60	1	7	79	319	611	885	1048	855	992	493	166	33	5409
1960-61	0	5	102	335	503	1094	1231	928	885	587	287	22	5960
1961-62	6	3	51	246	604	901	1118	1068	814	467	271	35	5672
1962-63	6	13	105	330	691	1078	1094	1087	798	477	196	38	5913
#1963-64	1	3	160	198	495	1207	1026	1033	808	559	187	57	5734
1964-65	14	28	140	380	620	1004	1220	1032	900	617	195	80	6228
1965-66	2	37	136	371	680	888	1115	930	776	566	258	40	5811
1966-67	0	1	88	322	535	950	921	1075	977	596	403	58	5926
1967-68	0	4	110	347	739	923	1214	1122	797	454	270	76	6056
1968-69	1	9	46	247	630	1050	1099	987	911	430	208	21	5659
1969-70	2	3	107	326	595	973	1295	909	846	473	184	52	5765
1970-71	0	0	68	314	598	1113	1269	962	868	586	287	29	6090
1971-72	0	2	37	189	651	882	965	1021	883	598	250	54	5532
1972-73	3	4	51	409	673	985	1033	971	666	450	258	24	5523
1973-74	0	2	94	289	570	782							

TOTAL PRECIPITATION

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1934	2.67	4.49	4.04	3.23	1.56	3.11	1.25	1.83	5.67	2.94	1.78	1.66	34.19
#1935	6.13	3.28	1.52	4.77	1.35	5.07	1.10	2.14	2.69	0.34	3.91	0.66	32.96
1936	6.46	3.66	6.40	3.56	1.70	2.37	1.04	5.13	3.79	2.67	1.33	8.19	46.30
1937	3.92	1.31	3.57	5.36	2.52	3.47	1.17	4.97	3.69	3.95	4.66	5.09	43.67
1938	4.91	2.36	2.42	3.22	4.42	6.30	9.46	3.31	6.00	2.43	2.89	2.80	50.54
1939	2.18	3.79	5.23	4.54	1.29	2.70	0.75	2.14	1.01	4.77	1.14	2.91	32.45
1940	1.88	4.78	3.83	4.28	3.28	1.88	3.17	0.85	2.32	0.78	6.24	2.76	36.05
1941	4.21	1.70	3.40	1.70	2.43	4.29	2.90	1.55	1.18	1.92	2.40	3.19	30.87
1942	3.69	3.65	7.01	1.59	2.11	4.24	4.14	2.09	1.96	2.78	4.69	4.72	42.47
1943	3.74	1.23	4.02	2.64	4.56	1.69	3.91	1.28	1.61	4.82	2.16	0.99	32.25
1944	2.03	2.19	3.92	3.52	0.25	5.35	1.61	1.79	5.36	2.58	5.88	2.83	37.07
1945	3.67	4.09	1.90	2.02	4.47	6.44	2.12	4.27	1.81	2.23	6.86	7.42	47.30
1946	4.18	3.00	1.50	2.62	4.91	2.76	2.22	9.92	2.04	0.36	0.98	3.60	38.07
1947	2.65	1.44	2.30	4.15	4.36	2.88	3.98	2.19	3.95	1.13	5.13	3.95	37.91
1948	5.11	2.08	3.14	2.62	5.37	4.50	4.53	1.24	0.67	4.84	5.16	1.25	40.51
1949	3.21	3.29	1.66	3.29	2.53	0.93	1.10	2.12	6.47	1.60	3.71	1.66	31.45
1950	3.86	3.81	2.99	2.38	1.55	1.10	1.65	3.14	0.89	1.99	6.17	3.37	32.70
#1951	4.04	3.71	4.41	3.06	4.81	4.31	2.13	3.23	2.00	3.88	6.60	4.69	46.97
1952	4.31	4.71	4.41	6.61	3.57	3.26	0.52	6.86	1.13	1.61	1.72	4.09	40.60
1953	6.28	4.14	11.00	6.04	5.06	0.48	2.76	1.81	2.50	4.91	7.66	5.09	57.73
1954	3.26	3.37	3.32	5.29	13.38	2.78	2.30	3.64	8.31	3.58	5.52	5.40	62.32
1955	0.92	4.11	5.48	4.12	0.99	3.52	4.28	17.09	2.40	6.94	5.68	1.03	56.50
1956	6.99	4.36	5.30	2.96	1.85	2.03	3.32	1.46	5.07	4.39	3.46	6.13	47.39
1957	2.47	1.34	3.38	3.79	3.63	1.62	0.64	1.71	0.35	2.67	5.75	6.58	33.92
1958	9.54	5.87	6.48	7.82	4.45	2.96	3.91	5.37	7.50	4.62	3.35	1.78	61.05
1959	2.72	3.49	5.81	4.64	1.24	8.63	8.12	2.93	0.63	4.60	4.20	4.06	51.41
1960	3.04	4.84	3.23	3.51	3.80	3.40	5.18	1.64	5.97	2.48	2.49	4.82	44.46
1961	2.92	4.96	4.71	6.39	4.51	1.67	3.29	3.17	7.04	2.40	3.18	3.36	47.86
1962	3.11	4.16	1.48	3.65	1.86	2.33	1.61	3.72	4.10	8.68	3.80	4.33	43.23
1963	3.13	2.60	4.39	1.68	2.86	1.92	1.72	1.67	3.05	1.25	7.74	3.03	34.84
1964	4.56	4.67	3.48	3.64	0.53	1.91	3.12	1.78	2.65	2.82	2.18	5.08	36.47
1965	2.84	3.17	2.22	2.25	0.93	2.99	0.55	1.48	2.01	1.59	2.08	1.73	23.71
1966	3.29	3.48	1.08	1.26	2.66	3.40	3.21	1.25	3.42	2.62	4.43	3.09	36.01
1967	2.28	4.09	4.67	4.85	7.32	3.48	2.47	5.74	2.00	0.98	3.38	6.42	47.00
1968	3.65	1.15	7.06	1.72	3.26	5.65	0.55	1.03	1.70	1.63	6.74	6.23	42.28
1969	2.26	7.08	2.03	4.27	1.96	0.63	2.98	1.88	4.42	1.64	8.18	9.74	47.78
1970	0.89	4.65	4.32	2.79	3.01	4.62	1.27	4.12	2.60	2.63	4.09	6.92	41.91
1971	1.88	5.00	3.00	2.92	3.72	1.74	2.86	1.59	1.35	2.16	6.76	2.63	35.67
1972	2.05	5.29	5.37	3.34	5.26	6.76	2.19	0.83	5.96	2.98	7.02	6.08	55.11
1973	3.12	2.13	2.20	5.25	3.76	4.68	4.83	2.70	1.95	2.71	1.74	7.20	42.75
RECORD MEAN	3.54	3.40	3.88	3.58	3.27	3.18	3.17	3.55	3.19	3.21	3.90	3.66	41.52

TOTAL SNOWFALL

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1934-35	0.0	0.0	0.0	T	T	1.6	20.7	13.1	2.1	1.9	0.0	0.0	45.6
#1935-36	0.0	0.0	0.0	0.0	1.0	0.3	12.7	12.6	2.9	T	0.0	0.0	29.5
1936-37	0.0	0.0	0.0	0.0	4.4	0.7	2.0	T	1.9	T	0.0	0.0	9.0
1937-38	0.0	0.0	0.0	0.0	0.3	4.6	29.6	10.0	0.3	0.9	0.0	0.0	45.7
1938-39	0.0	0.0	0.0	0.0	10.0	1.3	7.3	4.7	18.5	0.2	0.0	0.0	40.2
1939-40	0.0	0.0	0.0	0.0	1.0	6.5	4.6	23.0	0.3	1.5	0.0	0.0	37.7
1940-41	0.0	0.0	0.0	T	8.5	4.5	20.4	1.3	13.1	0.3	T	0.0	47.8
1941-42	0.0	0.0	0.0	T	T	0.2	8.2	6.2	7.9	1.5	0.0	0.0	24.0
1942-43	0.0	0.0	0.0	0.0	T	6.8	20.4	4.5	8.0	T	0.0	0.0	45.7
1943-44	0.0	0.0	0.0	0.0	T	0.3	5.1	9.0	12.7	T	0.0	0.0	27.7
1944-45	0.0	0.0	0.0	0.0	1.2	6.9	24.3	20.3	0.5	0.0	T	0.0	59.2
1945-46	0.0	0.0	0.0	0.0	4.9	24.6	9.8	9.8	0.2	1.5	0.0	0.0	50.8
1946-47	0.0	0.0	0.0	0.0	T	4.9	4.0	9.0	0.9	0.6	0.0	0.0	19.4
1947-48	0.0	0.0	0.0	0.0	1.1	20.8	32.5	17.0	11.8	0.0	0.0	0.0	89.2
1948-49	0.0	0.0	0.0	0.0	1.1	5.5	13.7	6.9	9.9	0.0	0.0	0.0	37.1
1949-50	0.0	0.0	0.0	0.0	1.4	2.3	7.9	15.2	5.1	T	0.0	0.0	31.9
1950-51	0.0	0.0	0.0	0.0	T	2.7	13.9	9.2	3.9	0.0	0.0	0.0	29.7
#1951-52	0.0	0.0	0.0	0.0	T	8.4	10.7	19.1	1.4	0.0	0.0	0.0	39.6
1952-53	0.0	0.0	0.0	T	T	2.4	13.6	11.6	0.2	2.2	T	0.0	29.8
1953-54	0.0	0.0	0.0	0.0	T	T	19.2	1.7	0.4	2.1	0.0	0.0	23.6
1954-55	0.0	0.0	0.0	0.0	T	10.3	0.9	6.5	7.0	0.4	0.0	0.0	25.1
1955-56	0.0	0.0	0.0	0.0	2.5	1.8	7.7	14.5	31.2	3.2	0.0	0.0	60.9
1956-57	0.0	0.0	0.0	0.0	0.6	15.4	20.6	2.8	11.5	1.1	0.0	0.0	32.0
1957-58	0.0	0.0	0.0	T	0.1	T	6.6	23.9	12.0	2.1	T	0.0	44.7
1958-59	0.0	0.0	0.0	0.0	0.1	4.6	4.1	10.7	14.6	T	0.0	0.0	34.1
1959-60	0.0	0.0	0.0	0.0	0.6	5.5	10.2	7.3	22.3	T	0.0	0.0	40.9
1960-61	0.0	0.0	0.0	T	T	16.9	18.7	14.9	9.0	2.0	0.0	0.0	61.5
1961-62	0.0	0.0	0.0	T	0.9	11.4	2.5	20.7	1.1	0.1	0.0	0.0	44.7
1962-63	0.0	0.0	0.0	T	0.9	5.3	6.5	4.6	13.6	T	0.0	0.0	30.9
1963-64	0.0	0.0	0.0	T	0.0	17.7	14.4	23.2	7.7	T	0.0	0.0	63.0
1964-65	0.0	0.0	0.0	T	T	12.2	22.2	4.7	9.7	1.6	0.0	0.0	50.4
1965-66	0.0	0.0	0.0	0.0	T	2.3	20.4	12.1	3.3	T	T	0.0	44.1
1966-67	0.0	0.0	0.0	0.0	0.8	9.9	0.5	23.5	22.9	3.3	T	0.0	60.1
1967-68	0.0	0.0	0.0	0.0	2.2	14.7	17.7	3.4	6.8	0.0	0.0	0.0	44.8
1968-69	0.0	0.0	0.0	0.0	0.4	5.1	0.9	41.3	6.1	T	0.0	0.0	53.8
1969-70	0.0	0.0	0.0	T	T	12.6	7.4	10.5	18.2	0.1	0.0	0.0	48.8
1970-71	0.0	0.0	0.0	T	T	27.9	12.0	8.1	7.4	1.9	0.0	0.0	57.3
1971-72	0.0	0.0	0.0	0.0	2.8	7.9	7.8	10.5	12.1	0.4	0.0	0.0	47.5
1972-73	0.0	0.0	0.0	T	0.6	3.3	3.6	2.8	0.3	T	0.0	0.0	10.3
1973-74	0.0	0.0	0.0	0.0	0.0	T							

Record mean values above (not adjusted for instrument location changes listed in the Station Location table) are means for the period beginning in 1872 for temperature and 1871 for precipitation.

# Indicates a break in the data sequence during the year, or season, due to a station move or relocation of instruments. See Station Location table. Data are from City Office locations through 1935 and from Airport locations thereafter.

D255 273-B

Lindgren

LOCAL CLIMATOLOGICAL DATA

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ENVIRONMENTAL DATA SERVICE

BOSTON, MASSACHUSETTS
NAT WEATHER SERVICE FCST OFC
GEN LOGAN INTERNATIONAL AP
JANUARY 1973

Latitude 42° 22' N Longitude 71° 02' W Elevation (ground) 15 ft. Standard time used: EASTERN WBAN #14739

Date	Temperature °F Maximum	Minimum	Average	Departure from normal	Average dew point	Degree days Base 65° Heating	Cooling	Weather types on dates of occurrence 1 Fog 2 Heavy fog X 3 Thunderstorm 4 Ice pellets 5 Hail 6 Glaze 7 Duststorm 8 Smoke, Haze 9 Blowing snow	Snow, ice pellets or ice on ground at 07AM In.	Precipitation Water equivalent In.	Snow, ice pellets In.	Avg. station pressure In. Elev. 29 feet m.s.l.	Wind Resultant direction	Resultant speed m.p.h.	Average speed m.p.h.	Fastest mile Speed m.p.h.	Fastest mile Direction	Sunshine Hours and tenths	Percent of possible	Sky cover Tenths Sunrise to sunset	Midnight to midnight	Date
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	61	34	48	18	43	17	0	1	0	.35	0	29.90	25	10.6	13.7	22	W	5.7	62	5	5	1
2	41	28	35	5	20	30	0		0	0	0	30.04	30	15.2	15.7	26	NW	5.8	64	5	2	2
3	36	27	32	2	15	33	0		0	0	0	30.40	31	7.5	11.8	21	NW	9.2	100	0	1	3
4	41	29	35	5	30	30	0	1	2	.25	1.7	29.90	21	4.0	12.7	24	W	0.0	0	10	9	4
5	40	29	35	5	23	30	0		T	0	0	29.73	28	17.8	18.3	28	NW	6.1	66	9	3	5
6	30	11	21	-9	4	44	0		0	0	0	29.82	30	21.3	21.7	30	NW	8.8	95	1	1	6
7	19	7	13	-17	-9	52	0		0	0	0	30.05	30	22.9	23.2	30	NW	9.3	100	0	0	7
8	16	1•	9•	-21	-18	56	0		0	0	0	30.28	31	16.8	17.0	24	NW	9.3	100	2	1	8
9	20	4	12	-18	-12	53	0		0	0	0	30.10	30	12.1	13.4	17	W	6.4	69	4	4	9
10	30	18	24	-6	4	41	0		0	0	0	30.04	26	13.2	14.0	20	SW	9.2	100	0	1	10
11	32	19	26	-4	4	39	0		0	0	0	29.88	27	13.9	14.1	21	NW	9.3	100	0	2	11
12	27	18	23	-7	0	42	0		0	0	0	29.99	28	15.5	16.4	24	W	9.4	100	0	0	12
13	26	13	20	-10	3	45	0		0	0	0	30.34	31	3.8	8.2	14	N	8.1	87	8	6	13
14	39	19	29	-1	15	36	0		0	0	0	30.07	22	14.6	15.0	18	SW	5.9	62	9	7	14
15	40	32	36	6	22	29	0		0	0	0	29.90	28	8.4	9.5	14	SW	1.9	20	7	6	15
16	45	31	38	8	24	27	0		0	0	0	30.02	25	12.2	12.9	23	SW	9.2	98	2	3	16
17	54	40	47	17	27	18	0		0	0	0	30.00	25	11.6	12.2	19	SW	8.2	87	9	8	17
18	61•	42	52•	22	34	13	0		0	0	0	30.09	24	8.9	9.1	16	SW	3.4	35	9	10	18
19	60	36	48	18	37	17	0		0	T	0	29.77	22	10.9	12.9	23	SW	6.1	64	5	6	19
20	50	25	38	8	29	27	0	1	0	.39	.3	29.33	30	17.0	20.6	34	NW	0.1	1	10	10	20
21	39	21	30	0	10	35	0		T	0	0	30.11	31	10.0	12.2	31	NW	9.6	100	0	1	21
22	51	29	40	10	28	25	0	1	0	.25	0	30.10	17	6.3	9.6	23	S	0.0	0	10	8	22
23	56	41	49	19	39	16	0	1	0	.30	0	29.53	25	14.4	17.8	28	SW	2.8	29	6	5	23
24	43	33	38	8	25	27	0		0	0	0	29.67	28	15.1	15.8	25	W	1.7	17	9	8	24
25	40	25	33	3	9	32	0		0	0	0	29.87	29	13.4	14.0	20	NW	6.8	69	5	3	25
26	48	34	41	11	23	24	0		0	0	0	30.02	29	6.7	8.1	12	NW	9.8	100	0	2	26
27	42	33	38	8	30	27	0	1 8	0	T	0	29.97	04	3.0	11.8	20	NE	2.3	23	10	8	27
28	40	32	36	6	29	29	0	1	0	.31	T	29.87	05	17.2	19.4	23	NE	0.0	0	10	10	28
29	38	15	27	-3	23	38	0	1 3 4 6	T	1.27	1.6	29.35	35	14.9	23.4	33	NW	0.0	0	10	7	29
30	24	7	16	-14	3	49	0		T	0	0	29.95	27	18.3	20.3	28	SW	7.1	71	5	3	30
31	23	3	13	-17	-8	52	0		T	T	T	30.39	31	13.5	17.0	28	SW	9.8	98	1	1	31

Sum	Sum				Total	Total
1212	736				1033	0
Avg.	Avg.	Avg.	Dep.	Avg.	Dep.	Dep.
39.1	23.7	31.4	1.5	16	-55	
					Season to date Total	Total
					3196	0
					Dep.	Dep.
					95	

Number of days			
Maximum Temp. ≥ 90° ‡	Maximum Temp. ≤ 32°	Minimum Temp. ≤ 32°	Minimum Temp. ≤ 0°
0	10	23	0

Number of days	
Precipitation ≥ .01 inch	7
Snow, ice pellets ≥ 1.0 inch	2
Thunderstorms	1
Heavy fog X	0

Clear 11 Partly cloudy 9 Cloudy 11

	Precipitation Water equivalent	Snow, ice pellets	For the month: Avg. station pressure	Resultant direction	Resultant speed	Average speed	Fastest mile Speed	Fastest mile Direction	Sunshine Total	% for month	Sky cover Sum	Sum
Total	3.12	3.6	29.95	28	9.8	14.9	34	NW	181.6		157	141
Dep.	-0.82						Date:	20	Possible		Avg.	Avg.
									296.2	62	5.1	[illegible]

Greatest in 24 hours and dates				Greatest depth on ground of snow, ice pellets or ice and date	
Precipitation		Snow, ice pellets			
1.58	28-29	1.7	4	2	4

HOURLY PRECIPITATION (Water equivalent in inches)

Date	A.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	P.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	Date
1	.06	T	.09	.03	.08	.06	.01		.01	.01															1
2																									2
3																									3
4					.06	.07	.04	T	T	.01	.02	.01	.02	.02	T										4
5																									5
6																									6
7																									7
8																									8
9																									9
10																									10
11																									11
12																									12
13																									13
14																									14
15																									15
16																									16
17																									17
18																									18
19																	T								19
20	T	.02	.06	.06	.04	.06	.02	T	T		T	.01	.03	.03	.04	.02	T	T	T		T	T	T		20
21																									21
22																		T	.01	.01	.01	.02	.08	[illegible]	22
23	.26	.04	T																						23
24																									24
25																									25
26																									26
27																						T	T		27
28	T	T	.01	.02	T	T	T	T		T	T	T	T	T		T	T	T	.01	.01	.03	.05	.09	.09	28
29	.06	.07	.12	.11	.19	.23	.16	.10	.11	.04	.05	.02	.01	T	T										29
30																									30
31					T	T	T																		31

- • Extreme temperatures for the month. May be the last of more than one occurrence.
- \- Below zero temperature or negative departure from normal.
- ‡ ≤ 70° at Alaskan stations.
- \+ Also on an earlier date, or dates.
- X Heavy fog restricts visibility to ¼ mile or less.
- T In the Hourly Precipitation table and in columns 9, 10, and 11 indicates an amount too small to measure.

The season for degree days begins with July for heating and with January for cooling.

Data in columns 6, 12, 13, 14, and 15 are based on 8 observations per day at 3-hour intervals.

Wind directions are those from which the wind blows. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. Figures for directions are tens of degrees from true North: i.e., 09 = East, 18 = South, 27 = West, 36 = North, and 00 = Calm. When directions are in tens of degrees in Col. 17, entries in Col. 16 are fastest observed 1-minute speeds. If the / appears in Col. 17, speeds are gusts.

Any errors detected will be corrected and changes in summary data will be annotated in the annual summary.

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

William H. Haggard
Director, National Climatic Center

SUMMARY BY HOURS

Hour Local time	Averages Sky cover Tenths	Station pressure In.	Temperature Air °F	Wet bulb °F	Dew Pt. °F	Relative humidity %	Wind speed m.p.h.	Resultant wind Direction	Speed m.p.h.
01	4	29.94	30	26	17	60	14.4	27	9.8
04	4	29.94	29	26	17	62	14.6	28	9.1
07	4	29.95	28	25	17	63	14.2	28	9.1
10	5	29.98	32	28	17	55	15.6	29	10.3
13	5	29.92	35	29	16	49	16.4	29	11.8
16	5	29.94	35	29	16	49	14.3	29	11.2
19	4	29.96	32	27	15	53	14.5	28	9.5
22	4	29.97	30	26	15	56	[illegible]	28	8.6

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LOCAL CLIMATOLOGICAL DATA

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ENVIRONMENTAL DATA SERVICE

BOSTON, MASSACHUSETTS
NAT WEATHER SERVICE FCST OFC
GEN LOGAN INTERNATIONAL AP
FEBRUARY 1973

Latitude 42° 22' N Longitude 71° 02' W Elevation (ground) 15 ft. Standard time used: EASTERN WBAN #14739

Weather types on dates of occurrence: 1 Fog; 2 Heavy fog X; 3 Thunderstorm; 4 Ice pellets; 5 Hail; 6 Glaze; 7 Duststorm; 8 Smoke, Haze; 9 Blowing snow

Date	Temperature °F Maximum	Minimum	Average	Departure from normal	Average dew point	Degree days Base 65° Heating	Cooling	Weather types on dates of occurrence	Snow, ice pellets or ice on ground at 07AM In.	Precipitation Water equivalent In.	Snow, ice pellets In.	Avg. station pressure In. Elev. 29 feet m.s.l.	Wind Resultant direction	Resultant speed m.p.h.	Average speed m.p.h.	Fastest mile Speed m.p.h.	Direction	Sunshine Hours and tenths	Percent of possible	Sky cover Tenths Sunrise to sunset	Midnight to midnight	Date
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	25	3•	14•	-16	- 1	51	0	6 8	T	T	0	30.73	34	5.2	6.2	11	N	0.0	0	10	9	1
2	54	25	40	10	37	25	0	2 6	T	1.11	0	30.01	18	10.2	14.6	44	S	0.0	0	10	10	2
3	54•	35	45•	15	38	20	0		0	.07	0	29.31	26	16.4	17.7	29	NW	3.8	37	7	7	3
4	42	32	37	7	20	28	0		0	0	0	29.79	28	16.6	17.1	27	NW	5.4	53	5	3	4
5	42	29	36	6	21	29	0		0	0	0	30.18	31	8.4	12.9	18	SW	8.7	86	8	5	5
6	33	27	30	0	18	35	0		0	0	0	30.40	05	12.1	13.5	18	NE	6.2	60	6	6	6
7	36	30	33	3	26	32	0	4	0	T	T	30.25	04	11.2	12.5	16	E	0.0	0	10	10	7
8	40	32	36	6	33	29	0	1	0	.07	T	29.66	32	2.8	8.6	18	SW	0.0	0	10	10	8
9	39	15	27	-3	9	38	0	1	0	.04	T	29.92	32	17.3	17.4	28	NW	10.1	97	3	4	9
10	24	10	17	-13	6	48	0		0	0	0	30.26	36	10.5	11.4	18	N	1.0	1	9	7	10
11	22	13	18	-12	4	47	0		T	T	T	30.30	01	24.5	24.7	33	NE	0.0	0	9	10	11
12	24	13	19	-11	6	46	0		0	T	T	30.22	36	13.1	14.0	24	N	0.0	0	10	10	12
13	32	15	24	-6	10	41	0		1	.03	.6	30.09	31	13.7	14.0	20	NW	1.9	18	9	8	13
14	48	26	37	7	8	28	0		T	0	0	30.17	28	5.4	10.2	19	W	10.1	96	5	6	14
15	44	37	41	11	33	24	0	1 4	T	.58	T	29.69	31	2.5	12.7	22	E	0.0	0	10	8	15
16	39	16	28	-2	24	37	0	1 9	0	.09	.6	29.62	33	13.1	13.7	24	NW	0.0	0	10	9	16
17	21	8	15	-15	- 5	50	0	9	1	.01	.2	29.98	33	16.9	17.3	25	NW	7.7	72	5	4	17
18	31	8	20	-10	- 6	45	0		T	0	0	30.13	30	14.1	14.7	21	NW	10.7	100	2	1	18
19	42	23	33	3	13	32	0		T	0	0	30.11	26	11.9	12.9	20	SW	10.4	97	4	4	19
20	50	36	43	13	26	22	0	8	T	0	0	30.14	21	9.1	10.2	14	S	5.6	51	5	8	20
21	50	37	44	13	32	21	0	1 8	0	0	0	29.99	13	8.2	11.1	13	SE	1.9	17	8	9	21
22	44	34	39	8	31	26	0	1 8	0	.03	T	29.51	35	12.5	13.5	17	NW	0.0	0	10	10	22
23	40	31	36	5	21	29	0		0	T	T	29.54	31	15.9	16.7	24	NW	2.5	23	9	8	23
24	40	28	34	3	9	31	0		0	0	0	29.88	30	17.6	18.1	27	NW	11.0	100	0	1	24
25	36	25	31	0	3	34	0		0	0	0	30.33	30	16.1	14.8	22	NW	11.1	100	2	4	25
26	34	24	29	-3	18	36	0	1 8	T	.10	1.1	30.36	02	3.8	6.2	24	N	3.1	28	10	8	26
27	24	15	20	-12	5	45	0		T	T	T	30.45	01	15.6	16.5	20	NE	8.6	78	9	6	27
28	32	14	23	-9	6	42	0		T	0	0	30.33	01	2.4	9.6	17	N	10.8	97	0	0	28
	Sum 1042	Sum 641				Total 971	Total 0			Total 2.13	Total 2.5	For the month: 30.06	32	7.5	13.7	44	S	Total 130.6	% for month 44	Sum 199	Sum 185	
	Avg. 37.2	Avg. 22.9	Avg. 30.1	Dep. -0.2	Avg. 16	Dep. -1	Dep.			Dep. -1.19						Date:	02	Possible 296.0		Avg. 7.0	Avg. 6.6	

Number of days:

Maximum Temp. ≥ 90° ‡	Maximum Temp. ≤ 32°	Minimum Temp. ≤ 32°	Minimum Temp. ≤ 0°
0	9	23	0

Season to date:

	Heating	Cooling
Total	4125	0
Dep.	94	

Number of days:

Precipitation ≥ .01 inch	10
Snow, ice pellets ≥ 1.0 inch	1
Thunderstorms	0
Heavy fog X	1
Clear	5
Partly cloudy	7
Cloudy	16

Greatest in 24 hours and dates:

Precipitation	Date	Snow, ice pellets	Date
1.16	2- 3	1.1	26

Greatest depth on ground of snow, ice pellets or ice and date:

Depth	Date
1	26

HOURLY PRECIPITATION (Water equivalent in inches)

Date	A.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	P.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	Date
1																							T	T	1
2	T	.01	.02	.02	.06	.06	.01	T		T	T	.06	.08	.01	.02	.01	.05	.05	.10	.15	.19	.17	.02	.02	2
3	.05	T	.02																						3
4																									4
5																									5
6																									6
7											T	T	T	T											7
8				T	T	T		T	T	T	T	T	T					T	T	.02	.03	.01	.01	T	8
9	.03	.01	T																						9
10																									10
11	T		T	T	T	T	T	T	T	T				T	T	T	T	T	T	T	T	T	T		11
12													T	T	T	T	T	T	T	T	T	T	T	T	12
13	T	T	T	.01	.01	.01	T																		13
14																									14
15		T	T	T	.05	.30	.22	.01	T	T	T														15
16									T	T	.01	.01	.01	.01	.01	.01	.01	.01	.01	T	T	T	T	T	16
17	T	T	T	T	T	T	.01	T																	17
18																									18
19																									19
20																									20
21																									21
22																	T	T	.01	.01	.01	T	T	T	22
23	T	T	T					T	T	T									T	T					23
24																									24
25																									25
26				T	T	T	.01	.02	.02	.02	.02	.01	T												26
27									T	T	T	T	T	T	T										27
28																									28

- • Extreme temperatures for the month. May be the last of more than one occurrence.
- – Below zero temperature or negative departure from normal.
- ‡ ≥ 70° at Alaskan stations.
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- X Heavy fog restricts visibility to ¼ mile or less.
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William H. Haggard
Director, National Climatic Center

SUMMARY BY HOURS

Hour Local time	Averages Sky cover Tenths	Station pressure In.	Temperature Air °F	Wet bulb °F	Dew Pt. °F	Relative humidity %	Wind speed m.p.h.	Resultant wind Direction	Speed m.p.h.
01	6	30.06	28	25	19	58	13.6	32	8.9
04	6	30.06	27	24	14	61	14.5	32	9.0
07	6	30.08	26	23	14	63	13.6	32	9.0
10	7	30.08	30	26	15	57	13.1	33	8.7
13	7	30.04	34	29	17	53	13.9	32	6.8
16	7	30.03	35	30	19	54	13.5	32	4.8
19	7	30.05	32	28	18	58	13.1	31	5.0
22	6	30.05	31	27	16	58	14.0	32	7.9

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BOSTON, MASSACHUSETTS
NAT WEATHER SERVICE FCST OFC
GEN LOGAN INTERNATIONAL AP
MARCH 1973

Lindgren

Latitude 42 ° 22 ' N Longitude 71 ° 02 ' W Elevation (ground) 15 ft. Standard time used: EASTERN WBAN #14739

Date	Temperature °F: Maximum	Minimum	Average	Departure from normal	Average dew point	Degree days Base 65°: Heating	Cooling	Weather types on dates of occurrence (1 Fog, 2 Heavy fog x, 3 Thunderstorm, 4 Ice pellets, 5 Hail, 6 Glaze, 7 Duststorm, 8 Smoke, Haze, 9 Blowing snow)	Snow, ice pellets or ice on ground at 07AM In.	Precipitation: Water equivalent In.	Snow, ice pellets In.	Avg. station pressure In. Elev. 29 feet m.s.l.	Wind: Resultant direction	Resultant speed m.p.h.	Average speed m.p.h.	Fastest mile: Speed m.p.h.	Direction	Sunshine: Hours and tenths	Percent of possible	Sky cover Tenths: Sunrise to sunset	Midnight to midnight	Date
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	51	26*	39	6	20	26	0		0	0	0	30.34	20	8.0	8.2	25	SW	10.4	93	5	5	1
2	60	38	49	15	31	16	0	1 8	0	0	0	30.35	23	.5	10.5	18	E	7.4	65	9	9	2
3	40	36	38	4	34	27	0	2	0	T	0	30.52	06	9.0	9.5	17	NE	0.0	0	10	10	3
4	50	40	45	11	39	20	0	2	0	.45	0	30.15	33	3.3	6.3	12	W	1.6	14	10	8	4
5	48	38	43	8	34	22	0		0	0	0	30.37	04	6.8	10.4	16	E	9.2	80	7	6	5
6	45	37	41	6	32	24	0		0	0	0	30.58	06	9.8	9.9	17	E	2.5	22	10	10	6
7	43	37	40	5	37	25	0	1	0	.08	0	30.43	04	8.1	8.3	14	NE	0.0	0	10	10	7
8	65	41	53	18	48	12	0	2	0	.39	0	30.16	21	2.9	4.3	26	SW	2.6	22	10	8	8
9	54	37	46	10	37	19	0		0	0	0	30.36	03	2.9	6.0	15	E	10.9	94	10	5	9
10	44	35	40	4	32	25	0		0	0	0	30.50	08	9.5	10.4	17	E	7.9	68	10	8	10
11	44	37	41	5	35	24	0	2	0	T	0	30.26	08	5.7	5.9	12	E	0.0	0	10	10	11
12	67*	43	55*	18	46	10	0	2	0	.06	0	29.64	27	9.6	10.9	22	NW	4.4	37	8	8	12
13	60	41	51	14	29	14	0		0	0	0	29.91	31	9.5	10.9	30	NW	11.8	100	1	1	13
14	47	38	43	6	26	22	0		0	0	0	30.01	06	3.9	6.6	10	E	5.2	44	10	8	14
15	49	38	44	7	34	21	0	1 3	0	.08	0	29.93	11	4.4	5.8	17	SE	3.3	28	10	10	15
16	64	44	54	16	41	11	0	1	0	T	0	29.74	26	5.1	7.8	17	W	8.5	71	10	10	16
17	63	44	54	16	46	11	0	2	0	.69	0	29.31	15	7.7	11.7	36	SW	0.0	0	10	8	17
18	47	33	40	1	24	25	0		0	T	T	29.04	26	16.3	18.6	37	SW	5.9	49	9	7	18
19	51	34	43	4	23	22	0		0	0	0	29.36	30	14.7	16.0	29	NW	9.4	77	4	4	19
20	41	31	36	-3	22	29	0		0	T	T	29.72	31	10.0	10.6	17	NW	0.5	4	9	8	20
21	39	28	34	-5	22	31	0		0	T	T	30.05	04	9.3	12.1	28	E	7.0	58	8	7	21
22	35	30	33*	-6	25	32	0	9	0	.05	.3	30.00	04	22.4	23.0	35	NE	0.0	0	10	10	22
23	54	32	43	3	14	22	0		T	0	0	30.00	02	18.1	18.8	32	NE	9.9	81	8	6	23
24	60	35	48	8	17	17	0		0	0	0	30.06	33	4.0	5.9	15	NW	10.8	88	5	4	24
25	61	39	50	10	24	15	0		0	0	0	29.92	21	2.9	6.3	16	SE	10.1	81	9	8	25
26	52	42	47	7	37	18	0	1	0	.35	0	29.64	04	7.7	11.5	25	NE	0.0	0	10	10	26
27	45	34	40	-1	22	25	0		0	T	0	29.88	04	19.0	19.6	34	NE	10.9	87	2	3	27
28	41	32	37	-4	24	28	0		0	0	0	30.34	08	6.3	7.5	14	E	12.5	100	1	1	28
29	42	33	38	-3	29	27	0	8	0	0	0	30.30	12	6.2	6.6	12	E	8.4	66	10	7	29
30	44	34	39	-3	35	26	0	1 8	0	T	0	30.21	14	2.6	7.3	13	E	4.2	33	10	10	30
31	50	40	45	3	42	20	0	1 8	0	.05	0	30.18	15	2.0	3.6	7	SE	0.0	0	10	10	31

Sum	Sum				Total	Total
1556	1127				666	0
Avg.	Avg.	Avg.	Dep.	Avg.	Dep.	Dep.
50.2	36.4	43.3	5.6	31	-180	
					Season to date	
Number of days					Total	Total
Maximum Temp.		Minimum Temp.			4791	0
≥ 90° ‡	≤ 32°	≤ 32°	≤ 0°		Dep.	Dep.
0	0	6	0		-86	

Number of days	
Precipitation ≥ .01 inch	9
Snow, ice pellets ≥ 1.0 inch	0
Thunderstorms	1
Heavy fog X	6
Clear 3 Partly cloudy 4 Cloudy 24	

Precipitation Total	Snow Total	For the month:						Sunshine Total	% for month	Sky cover Sum	Sum
2.20	.3	30.04	03	3.1	10.0	37	SW	175.3		255	229
Dep.						Date:	18	Possible month		Avg.	Avg.
-2.02								370.3	47	8.2	7.4

Greatest in 24 hours and dates: Precipitation		Snow, ice pellets		Greatest depth on ground of snow, ice pellets or ice and date	
.69	17	.3	22	T	23+

HOURLY PRECIPITATION (Water equivalent in inches)

Date	A.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	P.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	Date
1																									1
2																									2
3										T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	3
4	T	.03	.04	.09	.06	.05	.04	T	T	.04	.06	.04	T												4
5																									5
6																									6
7		T	T	T	T	T	.01	T	T	T	.01	T	T	T	T	.01	.01	.01	T	T	T	.01	.01	.01	7
8	.01	T	T	T	T	.01	.01	.01		T	.03	.04	.20	.04	.01	T	.01	T	.01	.01					8
9																									9
10																									10
11																		T			T	T	T		11
12	T	.01	.01	.01	T	T	T								T	.03	T						T	T	12
13																									13
14																									14
15								T	T						.04	.02	.02		T	T	T	T	T		15
16																							T	T	16
17	.01	.06	.09	.08	.07	.03	.02	.01	T	.03	.03	.09	.08	.01	T	.03	.02	.06	.01						17
18								T	T	T	T	T	T												18
19																									19
20									T																20
21																					T	T	T	T	21
22	T	T	T	T	T	T	T	T	T	T	T	T	T	.02	.02	.01	T	T	T	T	T	T	T	T	22
23																									23
24																									24
25																									25
26	T	T	.01	T	T	.04	.01	.06	.08	.01	.07	.02	.02	.01	.01	T	T	T	T	T	T	T	T	.01	26
27	T	T																							27
28																									28
29																									29
30																						T	T		30
31						T	.01	.01	.02	.01	T	T	T												31

- * Extreme temperatures for the month. May be the last of more than one occurrence.
- – Below zero temperature or negative departure from normal.
- ‡ ≥ 70° at Alaskan stations.
- + Also on an earlier date, or dates.
- X Heavy fog restricts visibility to ¼ mile or less.
- T In the Hourly Precipitation table and in columns 9, 10, and 11 indicates an amount too small to measure.

The season for degree days begins with July for heating and with January for cooling.

Data in columns 6, 12, 13, 14, and 15 are based on 8 observations per day at 3-hour intervals.

Wind directions are those from which the wind blows. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. Figures for directions are tens of degrees from true North; i.e., 09 = East, 18 = South, 27 = West, 36 = North, and 00 = Calm. When directions are in tens of degrees in Col. 17, entries in Col. 16 are fastest observed 1-minute speeds. If the / appears in Col. 17, speeds are gusts.

Any errors detected will be corrected and changes in summary data will be annotated in the annual summary.

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

William H. Haggard
Director, National Climatic Center

SUMMARY BY HOURS

Hour Local time	Averages: Sky cover Tenths	Station pressure In.	Temperature: Air °F	Wet bulb °F	Dew Pt. °F	Relative humidity %	Wind speed m.p.h.	Resultant wind: Direction	Speed m.p.h.
01	6	30.04	40	36	30	70	9.4	36	3.2
04	6	30.04	39	35	30	72	8.7	36	3.4
07	9	30.06	39	36	29	69	10.1	01	3.5
10	8	30.07	44	39	31	62	10.9	03	4.1
13	8	30.03	47	41	31	59	11.6	06	4.3
16	9	30.02	46	40	32	63	11.0	05	3.8
19	8	30.03	44	39	32	67	9.5	07	2.7
22	7	30.03	42	38	32	71	8.9	36	2.3

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LOCAL CLIMATOLOGICAL DATA

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ENVIRONMENTAL DATA SERVICE

BOSTON, MASSACHUSETTS
NAT WEATHER SERVICE FCST OFC
GEN LOGAN INTERNATIONAL AP
APRIL 1973

Latitude 42 ° 22 ' N Longitude 71 ° 02 ' W Elevation (ground) 15 ft. Standard time used: EASTERN . WBAN #14739

Weather types on dates of occurrence: 1 Fog; 2 Heavy fog X; 3 Thunderstorm; 4 Ice pellets; 5 Hail; 6 Glaze; 7 Duststorm; 8 Smoke, Haze; 9 Blowing snow

Date	Temperature °F Maximum	Minimum	Average	Departure from normal	Average dew point	Degree days Base 65° Heating	Cooling	Weather types on dates of occurrence	Snow, ice pellets or ice on ground at 07AM In.	Precipitation Water equivalent In.	Snow, ice pellets In.	Avg. station pressure In. Elev. 29 feet m.s.l.	Wind Resultant direction	Resultant speed m.p.h.	Average speed m.p.h.	Fastest mile Speed m.p.h.	Direction	Sunshine Hours and tenths	Percent of possible	Sky cover Tenths Sunrise to sunset	Midnight to midnight	Date
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	46	41	44	2	38	21	0	1	0	1.36	0	29.95	09	9.7	10.4	32	E	4.5	36	10	10	1
2	48	43	46	3	42	19	0	2	0	1.05	0	29.38	06	5.1	12.4	36	E	0.0	0	10	10	2
3	43	37	40	-3	35	25	0	1	0	.05	0	29.61	35	7.2	8.2	17	N	0.0	0	10	10	3
4	43	36	40	-4	34	25	0	1 4	0	.63	T	29.68	08	13.0	13.5	31	E	4.5	35	10	10	4
5	49	36	43	-1	33	22	0	1	0	.05	T	29.30	30	15.9	17.3	32	NW	7.6	50	9	8	5
6	56	39	48	3	28	17	0		0	0	0	29.62	28	20.4	20.7	40	W	12.9	100	2	2	6
7	65	42	53	8	21	12	0		0	0	0	29.75	30	11.6	13.1	21	NW	12.3	95	2	4	7
8	48	37	43	-2	26	22	0		0	0	0	29.76	05	8.3	10.9	18	NE	0.2	1	10	8	8
9	53	35	44	-2	16	21	0		0	0	0	30.02	30	2.2	10.2	17	NW	13.1	100	4	3	9
10	58	37	48	2	35	17	0	1	0	.62	0	29.53	20	5.2	16.5	28	W	3.8	29	9	8	10
11	41	34	38*	-9	21	27	0		0	T	T	29.49	28	20.6	21.7	33	W	10.7	81	7	5	11
12	47	32	40	-7	15	25	0		0	0	0	29.74	28	16.9	18.1	28	W	13.2	99	2	2	12
13	47	31	39	-8	17	26	0		0	0	0	29.95	32	9.9	10.5	19	N	13.3	100	1	1	13
14	46	31*	39	-9	20	26	0		0	0	0	30.25	13	.8	9.8	17	SE	13.3	100	0	0	14
15	59	38	49	1	26	16	0		0	0	0	30.35	22	4.0	9.2	17	SW	13.4	100	4	2	15
16	79	44	62	14	31	3	0		0	0	0	30.22	24	11.5	12.2	25	SW	12.2	91	5	4	16
17	71	54	63	14	44	2	0	8	0	T	0	30.09	24	15.7	15.8	24	SW	5.1	38	10	10	17
18	73	56	65	16	53	0	0	8	0	.03	0	30.15	23	5.3	7.9	16	SW	7.0	52	8	8	18
19	73	50	62	13	50	3	0		0	0	0	30.18	09	3.1	6.6	27	NE	12.4	91	5	3	19
20	50	42	46	-4	30	19	0		0	0	0	30.46	09	8.2	11.4	21	NE	13.6	100	0	0	20
21	66	41	54	4	33	11	0		0	0	0	30.33	22	11.9	12.5	19	SW	7.2	52	8	6	21
22	84*	50	67	16	51	0	2		0	.02	0	29.86	22	10.8	12.4	19	SW	7.1	52	9	8	22
23	83	56	70*	19	49	0	5	1	0	.44	0	29.67	29	14.3	15.0	24	NW	9.6	70	7	8	23
24	71	50	61	10	47	4	0		0	T	0	29.73	25	2.5	8.8	17	SW	9.3	68	4	5	24
25	62	46	54	2	43	11	0		0	0	0	29.89	08	1.9	9.4	20	E	10.2	74	8	7	25
26	51	43	47	-5	43	18	0	1	0	.60	0	29.98	05	16.0	16.3	24	NE	0.0	0	10	10	26
27	50	41	46	-6	43	19	0	1	0	.74	0	29.76	05	21.5	21.7	31	NE	0.0	0	10	10	27
28	67	50	59	6	50	6	0	1	0	.06	0	29.43	17	6.7	9.5	25	S	6.5	47	8	8	28
29	51	44	48	-5	35	17	0		0	T	0	29.72	27	15.0	15.8	25	W	0.0	0	10	10	29
30	55	42	49	-5	36	16	0		0	0	0	30.09	10	2.0	11.7	17	SE	12.1	86	3	3	30

Maximum Sum	Minimum Sum				Heating Total	Cooling Total
1733	1258				450	7
Avg.	Avg.	Avg.	Dep.	Avg.	Dep.	Dep.
57.8	41.9	49.9	2.0	35	-63	
					Season to date	
					Total	Total
					5241	7
					Dep.	Dep.
					-169	

Number of days			
Maximum Temp. ≥ 90° ‡	Maximum Temp. ≤ 32°	Minimum Temp. ≤ 32°	Minimum Temp. ≤ 0°
0	0	3	0

Number of days	
Precipitation ≥ .01 inch	12
Snow, ice pellets ≥ 1.0 inch	0
Thunderstorms	0
Heavy fog X	1

Clear 7 Partly cloudy 7 Cloudy 16

Precipitation Water equivalent	Snow, ice pellets	For the month: Avg. station pressure	Resultant direction	Resultant speed	Average speed	Fastest mile Speed	Direction	Sunshine Total	% for month	Sky cover Sum	Sum
Total 5.65	Total T	29.86	29	3.1	13.0	40	W	235.1		195	183
Dep. 1.88						Date:	06	Possible 401.6	59	Avg. 6.5	Avg. 6.1

Greatest in 24 hours and dates Precipitation		Snow, ice pellets		Greatest depth on ground of snow, ice pellets or ice and date	
2.31	1-2	T	11+	0	

HOURLY PRECIPITATION (Water equivalent in inches)

Date	A.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	P.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	Date
1											T	T	.01	T	.01	.13	.17	.22	.15	.16	.14	.18	.09	.10	1
2	.09	.02	.20	.17	.17	.11	.05	.09	.02	T	T	T	.03	.01	T	.01	.01	.04	.01	T	T	.01	.01	T	2
3	.01	.01	.01	.01	.01											T	T								3
4															.02	.03	.08	.14	.06	.17	.10	.02	.01	T	4
5	.01	.01	T	T	T	T	.02	.01	T				T												5
6																									6
7																									7
8																									8
9																									9
10				T	T		T	.03	.09	.17	.19	.14	T	T		T									10
11								T																	11
12																									12
13																									13
14																									14
15																									15
16																									16
17					T	T				T				T	T										17
18													.03												18
19																									19
20																									20
21																									21
22						.01	.01			T													T	T	22
23	T																	T	T	.04	.12	.22	.06	T	23
24																			T	T	T	T			24
25																									25
26									.01	.01	.03	.02	.04	.13	.06	.05	.05	.07	.03	.02	.03	T	.02	.03	26
27	.06	.04	.02	.04	.01	.05	.03	.02	.01	.02	T	.01	.02	.02	.04	.04	.03	.06	.13	.05	T	.01	.01	.02	27
28										T	.04	.02													28
29	T														T	T	T	T							29
30																									30

- * Extreme temperatures for the month. May be the last of more than one occurrence.
- \- Below zero temperature or negative departure from normal.
- ‡ ≥ 70° at Alaskan stations.
- \+ Also on an earlier date, or dates.
- X Heavy fog restricts visibility to ¼ mile or less.
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William H. Haggard
Director, National Climatic Center

SUMMARY BY HOURS

Hour Local time	Averages: Sky cover (tenths)	Station pressure In.	Temperature Air °F	Wet bulb °F	Dew Pt. °F	Relative humidity %	Wind speed m.p.h.	Resultant wind Direction	Speed m.p.h.
01	6	29.86	46	41	35	66	12.7	28	6.0
04	5	29.87	44	40	34	68	11.1	30	3.6
07	6	29.90	46	41	35	67	11.7	29	3.4
10	6	29.89	51	44	34	50	13.0	30	3.0
13	8	29.85	54	45	35	54	13.9	30	1.3
16	6	29.83	54	45	35	53	14.8	28	2.0
19	6	29.85	50	44	36	61	13.8	27	2.1
22	6	29.86	48	43	35	64	12.8	28	4.7

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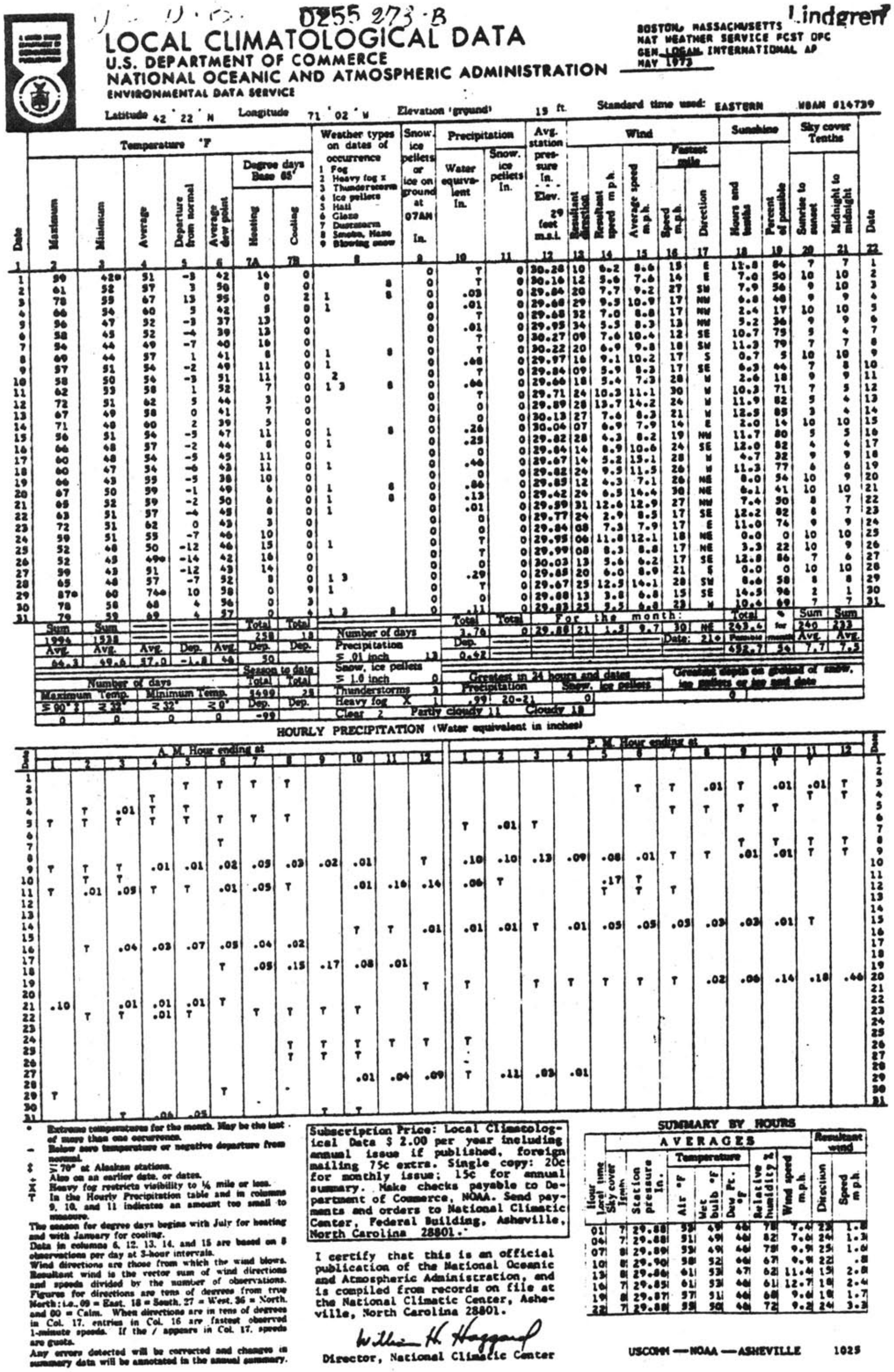

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LOCAL CLIMATOLOGICAL DATA

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ENVIRONMENTAL DATA SERVICE

BOSTON, MASSACHUSETTS
NAT WEATHER SERVICE FCST OFC
GEN. LOGAN INTERNATIONAL AP
MAY 1973

Latitude 42° 22' N Longitude 71° 02' W Elevation (ground) 19 ft. Standard time used: EASTERN WBAN 014739

Date	Temperature °F: Maximum	Minimum	Average	Departure from normal	Average dew point	Degree days Base 65°: Heating	Cooling	Weather types on dates of occurrence (1 Fog; 2 Heavy fog X; 3 Thunderstorm; 4 Ice pellets; 5 Hail; 6 Glaze; 7 Duststorm; 8 Smoke, Haze; 9 Blowing snow)	Snow, ice pellets or ice on ground at 07AM In.	Precipitation: Water equivalent In.	Snow, ice pellets In.	Avg. station pressure In. Elev. 29 feet m.s.l.	Wind: Resultant direction	Resultant speed m.p.h.	Average speed m.p.h.	Fastest mile: Speed m.p.h.	Direction	Sunshine: Hours and tenths	Percent of possible	Sky cover Tenths: Sunrise to sunset	Midnight to midnight	Date
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	59	42*	51	-3	42	14	0		0	T	0	30.28	10	6.2	8.6	15	E	11.8	84	7	7	1
2	61	52	57	3	50	8	0	8	0	T	0	30.16	12	5.6	7.6	14	E	7.0	50	10	10	2
3	78	59	67	13	55	0	2	1 8	0	.03	0	29.84	20	7.7	9.2	27	SW	7.9	56	9	10	3
4	66	54	60	5	42	5	0	1	0	.01	0	29.68	29	9.5	10.9	17	NW	6.8	48	9	9	4
5	56	47	52	-3	37	13	0		0	T	0	29.68	32	7.0	8.8	17	NW	2.4	17	10	10	5
6	58	45	52	-4	39	13	0		0	.01	0	29.95	34	5.5	8.3	13	NW	5.2	36	9	9	6
7	54	44	49	-7	40	16	0		0	T	0	30.27	09	7.6	10.4	12	SE	10.7	75	5	4	7
8	69	44	57	1	41	8	0	1 8	0	T	0	30.22	20	6.9	9.8	18	SW	11.3	79	7	7	8
9	57	51	54	-2	49	11	0	1	0	.68	0	29.97	16	9.1	10.2	17	S	0.7	5	10	10	9
10	58	50	54	-3	51	11	0	2	0	T	0	29.84	09	5.9	8.3	17	SE	6.3	44	7	8	10
11	62	53	58	1	52	7	0	1 3 8	0	.66	0	29.60	18	5.4	7.3	28	W	2.6	18	9	9	11
12	72	51	62	5	44	3	0		0	T	0	29.71	24	10.3	11.1	30	W	10.3	71	7	5	12
13	67	49	58	0	41	7	0		0	0	0	29.89	28	13.7	14.2	24	W	11.9	82	5	4	13
14	71	48	60	2	39	5	0		0	0	0	30.13	27	7.6	8.3	21	W	12.5	85	3	4	14
15	56	51	54	-5	47	11	0	1 8	0	.26	0	30.04	07	6.9	7.9	14	E	2.0	14	10	10	15
16	66	48	57	-2	44	8	0	1	0	.25	0	29.82	28	4.3	8.2	19	NW	11.7	80	5	5	16
17	60	48	54	-5	45	11	0		0	0	0	29.84	14	8.9	10.6	24	SE	12.0	82	4	4	17
18	60	47	54	-6	43	11	0	1	0	.40	0	29.67	14	5.2	13.1	28	W	4.7	32	9	9	18
19	66	43	55	-5	38	10	0		0	0	0	29.82	24	9.5	11.5	26	W	11.3	77	6	6	19
20	67	50	59	-1	49	6	0	1 8	0	.86	0	29.85	12	4.3	7.1	26	NE	8.0	54	10	9	20
21	68	52	59	-2	50	6	0	1 8	0	.13	0	29.42	24	6.5	14.4	30	NE	6.1	41	10	10	21
22	63	51	57	-4	45	8	0	1	0	.01	0	29.59	31	12.6	12.9	27	NW	7.4	50	8	7	22
23	72	51	62	0	43	3	0		0	0	0	29.77	24	2.9	8.5	17	SE	12.2	82	8	7	23
24	59	51	55	-7	46	10	0		0	0	0	29.84	08	7.3	7.9	17	E	11.0	74	9	9	24
25	52	48	50	-12	46	15	0	1	0	T	0	29.95	06	11.8	12.1	18	NE	0.0	0	10	10	25
26	52	43	49*	-14	42	16	0		0	T	0	29.99	08	8.3	8.8	17	NE	3.3	22	10	9	26
27	59	43	51	-12	43	14	0		0	0	0	30.03	13	5.6	6.2	17	SE	12.8	86	7	6	27
28	65	48	57	-7	52	8	0	1 3	0	.29	0	29.85	20	6.0	8.9	21	S	0.0	0	10	10	28
29	87*	60	74*	10	58	0	9	1	0	T	0	29.67	25	12.5	14.1	28	SW	8.6	58	8	8	29
30	78	58	68	4	56	0	3		0	0	0	29.88	13	3.8	6.8	15	SE	14.5	96	2	1	30
31	79	59	69	4	57	0	4	1 2 8	0	.11	0	29.83	25	9.5	6.8	23	W	10.4	69	7	7	31

Sum	Sum				Total	Total	
1994	1538				258	18	
Avg.	Avg.	Avg.	Dep.	Avg.	Dep.	Dep.	
64.3	49.6	57.0	-1.8	46	50		
					Season to date		
Number of days					Total	Total	
Maximum Temp.		Minimum Temp.			5499	28	
≥ 90° ‡	≤ 32°	≤ 32°	≤ 0°		Dep.	Dep.	
0	0	0	0		-99		

Number of days		Precipitation Total	Snow, ice pellets Total	For the month:						
Precipitation ≥ .01 inch	13	3.76	0	29.88	21	1.5	9.7	30	NE	
Snow, ice pellets ≥ 1.0 inch	0	Dep.						Date:	21+	
Thunderstorms	3	0.42								
Heavy fog X	1									
Clear 2	Partly cloudy 11	Cloudy 18								

Sunshine Total	% for month	Sky cover Sum	Sum
243.4		240	233
Possible		Avg.	Avg.
452.7	54	7.7	7.5

Greatest in 24 hours and dates: Precipitation		Snow, ice pellets	Greatest depth on ground of snow, ice pellets or ice and date
.99	20-21	0	0

HOURLY PRECIPITATION (Water equivalent in inches)

Date	A.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	P.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	Date
1																									1
2																						T	T		2
3					T	T	T	T										T	T	.01	T	.01	.01	T	3
4				T																			T	T	4
5		T	.01	T	T														T	T	T	T			5
6	T	T	T	T	T	T	T	T					T	.01	T										6
7																									7
8						T															T	T	T	T	8
9	T	T	T	.01	.01	.02	.05	.03	.02	.01		T	.10	.10	.13	.09	.08	.01	T	T	.01	.01	T	T	9
10		T	T															T							10
11	T	.01	.05	T	T	.01	.05	T		.01	.16	.14	.06	T			.17								11
12																	T	T	T						12
13																									13
14																									14
15										T	T	.01	.01	.01	T	.01	.05	.05	.03	.03	.03	.01	T		15
16		T	.04	.03	.07	.05	.04	.02																	16
17																									17
18						T	.05	.15	.17	.08	.01														18
19																									19
20												T	T		T	T	T	T	T	.02	.06	.14	.18	.46	20
21	.10		.01	.01	.01	T																			21
22		T	T	.01	T		T	T	T	T															22
23																									23
24																									24
25								T	T	T	T	T	T												25
26								T	T	T															26
27																									27
28										.01	.04	.09	T	.11	.03	.01									28
29	T					T																			29
30																									30
31			T	.06	.05				T	T															31

- * Extreme temperatures for the month. May be the last of more than one occurrence.
- \- Below zero temperature or negative departure from normal.
- ‡ ≥ 70° at Alaskan stations.
- \+ Also on an earlier date, or dates.
- X Heavy fog restricts visibility to ¼ mile or less.
- T In the Hourly Precipitation table and in columns 9, 10, and 11 indicates an amount too small to measure.

The season for degree days begins with July for heating and with January for cooling.

Data in columns 6, 12, 13, 14, and 15 are based on 8 observations per day at 3-hour intervals.

Wind directions are those from which the wind blows. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. Figures for directions are tens of degrees from true North: i.e., 09 = East, 18 = South, 27 = West, 36 = North, and 00 = Calm. When directions are in tens of degrees in Col. 17, entries in Col. 16 are fastest observed 1-minute speeds. If the / appears in Col. 17, speeds are gusts.

Any errors detected will be corrected and changes in summary data will be annotated in the annual summary.

Subscription Price: Local Climatological Data $ 2.00 per year including annual issue if published, foreign mailing 75¢ extra. Single copy: 20¢ for monthly issue; 15¢ for annual summary. Make checks payable to Department of Commerce, NOAA. Send payments and orders to National Climatic Center, Federal Building, Asheville, North Carolina 28801.

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

William H. Haggard
Director, National Climatic Center

SUMMARY BY HOURS

Hour Local time	Averages: Sky cover Tenths	Station pressure In.	Temperature: Air °F	Wet bulb °F	Dew Pt. °F	Relative humidity %	Wind speed m.p.h.	Resultant wind: Direction	Speed m.p.h.
01	7	29.88	55	49	46	78	7.4	22	1.8
04	7	29.88	51	49	46	82	7.6	24	1.3
07	8	29.89	53	49	46	78	9.9	25	1.6
10	8	29.90	58	52	46	67	9.9	22	.8
13	8	29.86	61	53	47	62	11.4	15	2.8
16	7	29.85	61	53	46	61	12.7	18	2.4
19	8	29.87	57	51	46	68	9.6	18	1.7
22	7	29.88	55	50	46	72	9.2	24	3.3

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LOCAL CLIMATOLOGICAL DATA

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ENVIRONMENTAL DATA SERVICE

BOSTON, MASSACHUSETTS
NAT WEATHER SERVICE FCST OFC
GEN LOGAN INTERNATIONAL AP
JUNE 1973

Latitude 42 ° 22 ' N   Longitude 71 ° 02 ' W   Elevation (ground) 15 ft.   Standard time used: EASTERN   WBAN #14739

Date	Temperature °F: Maximum	Minimum	Average	Departure from normal	Average dew point	Degree days Base 65°: Heating	Cooling	Weather types on dates of occurrence (1 Fog, 2 Heavy fog X, 3 Thunderstorm, 4 Ice pellets, 5 Hail, 6 Glaze, 7 Duststorm, 8 Smoke, Haze, 9 Blowing snow)	Snow, ice pellets or ice on ground at 07AM In.	Precipitation: Water equivalent In.	Snow, ice pellets In.	Avg. station pressure In. Elev. 29 feet m.s.l.	Wind: Resultant direction	Resultant speed m.p.h.	Average speed m.p.h.	Fastest mile: Speed m.p.h.	Direction	Sunshine: Hours and tenths	Percent of possible	Sky cover Tenths: Sunrise to sunset	Midnight to midnight	Date
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	82	60	71	6	50	0	6		0	T	0	29.88	26	11.2	11.4	22	SW	12.3	82	4	4	1
2	72	55	64	-1	41	1	0		0	.01	0	29.97	31	8.4	10.6	30	N	13.6	90	1	2	2
3	68	50*	59*	-7	41	6	0		0	0	0	30.14	13	4.8	7.5	18	SE	14.5	96	1	2	3
4	70	55	67	1	58	0	2	1 8	0	T	0	30.00	24	5.4	6.8	13	SW	8.6	57	10	8	4
5	74	54	64	-2	58	1	0	2 8	0	.06	0	30.11	06	6.0	6.9	15	NE	7.4	49	9	9	5
6	68	54	61	-5	56	4	0	2 8	0	T	0	30.15	08	4.0	5.3	12	E	7.3	48	8	9	6
7	85	65	75	8	64	0	10	1 8	0	0	0	30.05	20	10.5	10.8	20	SW	10.0	66	9	8	7
8	89	63	76	9	59	0	11	1 8	0	0	0	30.08	20	4.0	6.5	17	SW	14.5	96	3	2	8
9	92	68	80	13	64	0	15	3 8	0	.26	0	29.88	25	9.6	10.6	32	W	11.0	72	8	6	9
10	86	69	78	11	52	0	13		0	0	0	29.87	29	9.9	10.6	21	NW	14.5	95	6	6	10
11	97*	71	84*	17	61	0	19		0	0	0	29.80	26	9.3	9.6	20	W	13.3	88	4	4	11
12	96	70	83	15	65	0	18	3 8	0	.11	0	29.78	27	8.3	10.1	34	NW	10.4	68	5	6	12
13	72	63	68	0	64	0	3	1 3 8	0	.73	0	29.79	31	1.2	5.9	13	W	2.1	14	10	8	13
14	81	62	72	4	54	0	7	8	0	T	0	29.83	30	7.7	7.8	17	NW	14.0	92	3	2	14
15	77	59	68	0	38	0	3		0	.02	0	29.93	32	7.9	8.2	18	NW	11.9	78	7	6	15
16	69	53	61	-7	52	4	0	1	0	.05	0	29.77	05	6.3	8.1	20	N	4.1	27	10	10	16
17	68	52	60	-9	46	5	0		0	0	0	29.85	02	3.6	10.2	21	N	9.5	62	5	5	17
18	68	55	62	-7	48	3	0		0	T	0	30.05	23	7.9	8.3	16	SW	3.9	25	10	8	18
19	76	58	67	-2	56	0	2		0	T	0	30.15	16	3.7	5.6	12	SE	6.8	45	9	8	19
20	82	60	71	2	61	0	6		0	0	0	30.17	12	3.4	4.5	12	E	12.1	79	5	4	20
21	87	68	78	9	66	0	13	1 8	0	0	0	30.05	20	7.0	7.5	17	SW	9.7	63	8	8	21
22	83	69	76	7	66	0	11	1 8	0	.59	0	29.95	21	3.0	5.6	16	NW	3.6	23	10	9	22
23	81	66	74	4	64	0	9	1 8	0	0	0	29.99	22	4.3	5.8	13	SW	2.7	17	10	9	23
24	75	62	69	-1	62	0	4	2 8	0	0	0	30.01	11	5.0	6.9	17	E	11.1	72	7	7	24
25	68	61	65	-5	61	0	0	2	0	0	0	30.02	09	5.3	5.5	12	E	2.5	16	10	10	25
26	71	62	67	-3	62	0	2	2	0	.62	0	30.05	08	3.6	4.2	12	E	1.4	9	9	10	26
27	71	62	67	-3	63	0	2	1	0	.34	0	30.01	12	4.4	5.5	13	E	0.0	0	10	10	27
28	82	66	74	4	67	0	9	1	0	.06	0	29.91	19	6.9	7.6	18	S	8.2	54	9	9	28
29	80	65	73	3	67	0	8	1 8	0	.54	0	29.91	15	8.1	8.6	25	S	4.6	30	9	10	29
30	77	66	72	1	66	0	7	1	0	1.29	0	29.94	14	7.2	7.6	20	S	0.9	6	10	10	30

Sum	Sum				Total	Total		Total	Total	For the month:						Total	% for month	Sum	Sum
2356	1843				24	180	Number of days	4.68	0	29.97	23	1.9	7.7	34	NW	246.5		219	209
Avg.	Avg.	Avg.	Dep.	Avg.	Dep.	Dep.	Precipitation	Dep.						Date: 12		Possible		Avg.	Avg.
78.5	61.4	70.0	2.2	58	-12		≥ .01 inch 13	1.20								456.8	54	7.3	7.0
					Season to date		Snow, ice pellets												
Number of days					Total	Total	≥ 1.0 inch 0	Greatest in 24 hours and dates				Greatest depth on ground of snow, ice pellets or ice and date							
Maximum Temp.		Minimum Temp.			5523	205	Thunderstorms 3	Precipitation		Snow, ice pellets									
≥ 90° ‡	≤ 32°	≤ 32°	≤ 0°		Dep.	Dep.	Heavy fog X 5	1.29	30	0		0							
3	0	0	0		-111		Clear 4 Partly cloudy 8 Cloudy 18												

HOURLY PRECIPITATION (Water equivalent in inches)

Date	A.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	P.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	Date
1																		T							1
2		T	T	T	.01																				2
3																									3
4								T	T	T	T														4
5															.01	.02	.03	T	T	T				T	5
6	T	T	T	T	T																				6
7																									7
8																									8
9																.25		.01							9
10																									10
11																									11
12																		T	.04	.05	.02				12
13					T		.05	.18	.09	.07	.03	.01	.01	.01	.14	.13	.01			T	T				13
14																				T					14
15																							.01	.01	15
16	.01	T	T	.01															T	T	T	T	T	.03	16
17																									17
18										T	T	T	T	T											18
19				T	T																				19
20																									20
21																									21
22				T	T											.01	.51	.03	.02	.01	.01				22
23																									23
24																									24
25																									25
26						T				.05	.18	.22	.15	.02											26
27									T	.03	.06	.09	.07	.03	.06	T	T	T	T	T	T	T			27
28																.05			T					.01	28
29			.06	T	T	T					T	T	T		T				T	.41	.07				29
30	.01	.01	.02	.03	.06	.45	.04				T	.01	.04	.02	.01		T	.01	.01	.07	.12	.20	.17	.01	30

- * Extreme temperatures for the month. May be the last of more than one occurrence.
- \- Below zero temperature or negative departure from normal.
- ‡ ≥ 70° at Alaskan stations.
- \+ Also on an earlier date, or dates.
- X Heavy fog restricts visibility to ¼ mile or less.
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William H. Haggard
Director, National Climatic Center

SUMMARY BY HOURS

Hour Local time	AVERAGES: Sky cover tenths	Station pressure In.	Temperature: Air °F	Wet bulb °F	Dew Pt. °F	Relative humidity %	Wind speed m.p.h.	Resultant wind: Direction	Speed m.p.h.
01	6	29.97	66	61	57	76	6.3	25	2.9
04	7	29.97	63	60	57	82	5.8	26	2.3
07	7	30.00	66	61	58	75	6.3	26	2.3
10	7	29.99	71	63	57	64	8.7	24	1.7
13	7	29.97	74	64	58	60	9.7	16	1.5
16	8	29.94	74	65	58	62	9.2	18	1.7
19	7	29.95	70	63	58	68	7.8	21	2.4
22	6	29.97	67	62	59	76	7.5	21	2.9

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LOCAL CLIMATOLOGICAL DATA

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ENVIRONMENTAL DATA SERVICE

BOSTON, MASSACHUSETTS
NAT WEATHER SERVICE FCST OFC
GEN LOGAN INTERNATIONAL AP
JULY 1973

Latitude 42° 22' N Longitude 71° 02' W Elevation (ground) 15 ft. Standard time used: EASTERN WBAN #14739

Date	Temperature °F: Maximum	Minimum	Average	Departure from normal	Average dew point	Degree days Base 65°: Heating	Cooling	Weather types on dates of occurrence (1 Fog; 2 Heavy fog X; 3 Thunderstorm; 4 Ice pellets; 5 Hail; 6 Glaze; 7 Duststorm; 8 Smoke, Haze; 9 Blowing snow)	Snow, ice pellets or ice on ground at 07AM In.	Precipitation: Water equivalent In.	Snow, ice pellets In.	Avg. station pressure In. Elev. 29 feet m.s.l.	Wind: Resultant direction	Resultant speed m.p.h.	Average speed m.p.h.	Fastest mile: Speed m.p.h.	Direction	Sunshine: Hours and tenths	Percent of possible	Sky cover Tenths: Sunrise to sunset	Midnight to midnight	Date
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	78	67	73	2	67	0	8	1 3 8	0	.09	0	30.02	14	3.2	4.5	12	S	9.3	61	6	6	1
2	88	67	78	7	66	0	13	1 8	0	0	0	30.10	20	6.7	7.1	15	S	10.6	70	5	6	2
3	87	66	77	5	65	0	12	8	0	0	0	30.05	20	7.8	8.1	18	SW	12.9	85	8	8	3
4	83	71	77	5	68	0	12	1	0	.24	0	29.87	19	7.0	7.2	20	S	3.7	24	10	10	4
5	75	68	72	0	67	0	7	1	0	.56	0	29.71	20	3.5	4.9	16	SW	4.5	30	9	7	5
6	86	65	76	4	57	0	11		0	0	0	29.82	29	9.1	9.4	15	W	14.4	95	1	1	6
7	90	68	79	7	60	0	14		0	0	0	29.94	26	5.7	7.2	22	SW	14.3	94	1	2	7
8	96*	74	85	12	66	0	20	8	0	0	0	29.89	25	10.0	10.1	19	W	13.8	91	9	7	8
9	95	75	85*	12	67	0	20	8	0	0	0	29.83	26	1.8	4.6	11	W	14.1	93	2	2	9
10	78	65	72	-1	64	0	7	2 8	0	0	0	29.78	08	4.7	5.2	16	E	13.2	87	8	7	10
11	83	63	73	0	66	0	8	1 8	0	.42	0	29.66	20	1.5	3.9	17	NW	3.2	21	10	10	11
12	73	59	66	-8	49	0	1		0	.04	0	29.74	31	8.8	9.1	22	NW	10.4	69	6	6	12
13	82	59	71	-3	53	0	6		0	0	0	29.79	23	10.1	11.5	26	SW	12.4	82	4	4	13
14	93	70	82	8	64	0	17	8	0	T	0	29.71	25	8.7	9.5	22	SW	9.7	64	9	9	14
15	78	61	70	-4	61	0	5		0	.22	0	29.85	24	1.2	2.6	13	W	0.0	0	10	9	15
16	75	62	69	-5	59	0	4		0	0	0	29.98	09	1.9	3.6	13	SE	12.1	81	2	2	16
17	79	62	71	-4	55	0	6		0	0	0	30.11	03	5.1	5.3	14	NE	14.3	95	5	4	17
18	76	64	70	-5	56	0	5		0	0	0	30.12	01	2.1	5.8	13	NW	4.3	29	9	8	18
19	89	64	77	2	58	0	12		0	0	0	30.05	26	8.5	8.8	16	W	14.1	95	1	3	19
20	88	69	79	4	65	0	14	3 8	0	.17	0	29.95	23	8.0	9.8	17	SW	9.4	63	8	8	20
21	74	64	69	-6	66	0	4	2 8	0	.47	0	29.85	16	2.3	3.5	14	SW	0.0	0	10	10	21
22	77	64	71	-4	59	0	6	2	0	0	0	30.02	11	2.2	3.6	12	SE	14.3	97	3	4	22
23	77	64	71	-4	54	0	6		0	0	0	30.25	05	4.1	8.5	14	N	14.8	100	0	1	23
24	85	66	76	1	57	0	11		0	0	0	30.20	24	3.5	6.8	15	W	14.7	100	2	1	24
25	89	69	79	4	61	0	14		0	0	0	30.04	22	3.1	5.9	16	SW	13.4	91	7	5	25
26	75	70	73	-2	64	0	8		0	.01	0	29.94	22	9.3	9.9	18	SW	0.0	0	10	10	26
27	83	70	77	1	69	0	12	3 8	0	.88	0	29.82	22	9.8	11.9	21	W	4.4	30	9	7	27
28	89	74	82	6	69	0	17	8	0	0	0	29.85	22	9.8	10.4	20	S	10.9	75	8	8	28
29	81	69	75	-1	68	0	10	3 8	0	1.73	0	29.85	19	4.7	5.2	26	W	2.7	19	10	8	29
30	77	63	70	-5	64	0	5		0	0	0	30.01	07	2.9	4.5	14	E	14.4	99	1	1	30
31	72	59*	66*	-9	63	0	1	2 8	0	0	0	30.05	09	3.4	3.6	11	E	3.5	31	10	10	31

Maximum	Minimum	Average	Departure	Dew point	Heating	Cooling
Sum	Sum				Total	Total
2551	2051				0	296
Avg.	Avg.	Avg.	Dep.	Avg.	Dep.	Dep.
82.3	66.2	74.3	0.6	62	0	

Number of days				Season to date	
Maximum Temp.		Minimum Temp.		Total	Total
				0	501
≥ 90° ‡	≤ 32°	≤ 32°	≤ 0°	Dep.	Dep.
4	0	0	0	0	

Number of days	
Precipitation ≥ .01 inch	11
Snow, ice pellets ≥ 1.0 inch	0
Thunderstorms	4
Heavy fog X	4
Clear 9	Partly cloudy 6 Cloudy 16

Precipitation: Water equivalent	Snow, ice pellets	For the month: Avg. station pressure	Resultant direction	Resultant speed	Average speed	Fastest mile: Speed	Direction	Sunshine: Total	%	Sky cover: Sum	Sum
Total	Total							Total	for month	Sum	Sum
4.83	0	29.93	23	3.0	6.8	26	W	293.8		193	184
Dep.						Date: 29+		Possible		Avg.	Avg.
1.95								462.7	63	6.2	5.9

Greatest in 24 hours and dates: Precipitation		Snow, ice pellets		Greatest depth on ground of snow, ice pellets or ice and date	
1.73	29	0		0	

HOURLY PRECIPITATION (Water equivalent in inches)

Date	A.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	P.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	Date
1	.02	.05	.02																						1
2																									2
3																									3
4								T				T	T	T	T	T	.24	T	T	T	T	T			4
5							T	.06	.02	.05	.13	.26	.03	.01											5
6																									6
7																									7
8																									8
9																									9
10																									10
11				.03	T		.03	.04	.06	.02					.08	.01	T			.01	.02	.01	.02	.09	11
12	.03	T	.01	T	T																				12
13																									13
14													T	T								T	T		14
15							.05	.01	.01	T	T	T	.01	.01	.05	.02	.01	.04	.01						15
16																									16
17																									17
18																									18
19																									19
20																	.05	.11	.01						20
21		.03	.05	.05	.03	.03	.09	.09	.07	.01	T		T	T	.01	.01	T								21
22																									22
23																									23
24																									24
25																									25
26										T			.01		T	T	T								26
27										T	T	T	.50	.38											27
28																									28
29												T	T	.60		.97	.05	.08	.03						29
30																									30
31																									31

MASS. INST. TECH.
5 SEP 1973
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* Extreme temperatures for the month. May be the last of more than one occurrence.
\- Below zero temperature or negative departure from normal.
‡ ≥ 70° at Alaskan stations.
\+ Also on an earlier date, or dates.
X Heavy fog restricts visibility to ¼ mile or less.
T In the Hourly Precipitation table and in columns 9, 10, and 11 indicates an amount too small to measure.

The season for degree days begins with July for heating and with January for cooling.

Data in columns 6, 12, 13, 14, and 15 are based on 8 observations per day at 3-hour intervals.

Wind directions are those from which the wind blows. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. Figures for directions are tens of degrees from true North; i.e., 09 = East, 18 = South, 27 = West, 36 = North, and 00 = Calm. When directions are in tens of degrees in Col. 17, entries in Col. 16 are fastest observed 1-minute speeds. If the / appears in Col. 17, speeds are gusts.

Any errors detected will be corrected and changes in summary data will be annotated in the annual summary.

Subscription Price: Local Climatological Data $ 2.00 per year including annual issue if published, foreign mailing 75¢ extra. Single copy: 20¢ for monthly issue; 15¢ for annual summary. Make checks payable to Department of Commerce, NOAA. Send payments and orders to National Climatic Center, Federal Building, Asheville, North Carolina 28801.

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

William H. Haggard
Director, National Climatic Center

SUMMARY BY HOURS

Hour Local time	Averages: Sky cover tenths	Station pressure In.	Temperature: Air °F	Wet bulb °F	Dew Pt. °F	Relative humidity %	Wind speed m.p.h.	Resultant wind: Direction	Speed m.p.h.
01	5	29.92	70	65	62	76	6.4	24	4.5
04	6	29.93	68	64	62	79	5.8	20	3.6
07	7	29.95	72	65	62	72	5.8	20	3.1
10	6	29.95	77	68	62	62	7.2	25	1.9
13	6	29.93	79	68	62	59	8.1	20	3.0
16	7	29.91	78	68	62	62	9.0	19	3.6
19	6	29.91	75	67	62	68	6.0	20	3.2
22	4	29.93	72	66	62	74	5.8	22	4.1

USCOMM — NOAA — ASHEVILLE 1025

NOTICE: CLIMATOLOGICAL NORMALS BASED ON THE PERIOD 1941-1970 ARE EFFECTIVE AS FOLLOWS
HEATING DEGREE DAYS - JULY 1, 1973
COOLING DEGREE, DAYS, TEMPERATURE, AND PRECIPITATION - JANUARY 1, 1974

[illegible] D25

273-B

Lindgren

LOCAL CLIMATOLOGICAL DATA

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ENVIRONMENTAL DATA SERVICE

BOSTON, MASSACHUSETTS
NAT WEATHER SERVICE FCST OFC
GEN LOGAN INTERNATIONAL AP
AUGUST 1973

Latitude 42 ° 22 ' N Longitude 71 ° 02 ' W Elevation (ground) 15 ft. Standard time used: EASTERN WBAN #14739

Weather types on dates of occurrence: 1 Fog; 2 Heavy fog X; 3 Thunderstorm; 4 Ice pellets; 5 Hail; 6 Glaze; 7 Duststorm; 8 Smoke, Haze; 9 Blowing snow

Date	Temperature °F Maximum	Minimum	Average	Departure from normal	Average dew point	Degree days Base 65° Heating	Cooling	Weather types on dates of occurrence	Snow, ice pellets or ice on ground at 07AM In.	Precipitation Water equivalent In.	Snow, ice pellets In.	Avg. station pressure In. Elev. 29 feet m.s.l.	Wind Resultant direction	Resultant speed m.p.h.	Average speed m.p.h.	Fastest mile Speed m.p.h.	Fastest mile Direction	Sunshine Hours and tenths	Percent of possible	Sky cover Tenths Sunrise to sunset	Midnight to midnight	Date
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	76	63	70	-5	66	0	5	1 8	0	.35	0	29.93	02	4.2	7.5	18	N	3.7	25	9	9	1
2	78	65	72	-3	68	0	7	1 8	0	.45	0	29.88	18	7.0	7.9	19	SW	0.7	5	10	10	2
3	83	65	74	-1	70	0	9	1 8	0	.04	0	29.88	19	2.4	4.3	13	SE	4.2	29	10	10	3
4	90	68	79	4	66	0	14	1 8	0	.01	0	29.95	30	4.3	5.5	15	NW	8.9	62	5	5	4
5	89	70	80	5	59	0	15		0	0	0	30.01	30	8.6	8.8	17	NW	14.0	98	1	1	5
6	84	67	76	1	60	0	11		0	0	0	30.04	07	1.9	5.8	16	E	12.2	86	1	1	6
7	92	65	79	4	63	0	14	8	0	0	0	30.07	24	6.3	7.3	17	SW	13.1	92	4	4	7
8	91	71	81	7	67	0	16	8	0	0	0	30.04	22	9.9	10.4	18	SW	9.6	66	7	6	8
9	94	76	84	10	68	0	19	8	0	0	0	29.98	24	9.6	9.9	17	SW	10.5	74	7	7	9
10	96	76	86	12	69	0	21	8	0	T	0	29.83	24	7.3	7.8	20	SW	9.6	68	6	6	10
11	91	72	82	9	70	0	17	1 3 8	0	.19	0	29.85	22	6.6	7.3	21	W	5.0	35	9	8	11
12	89	72	81	8	66	0	16	8	0	0	0	29.82	26	8.0	8.6	19	W	9.1	65	7	6	12
13	85	69	77	4	59	0	12		0	0	0	29.82	31	8.3	8.5	17	N	13.3	95	2	1	13
14	73	65	69	-4	63	0	4	1	0	0	0	29.95	06	4.8	7.3	15	NE	8.9	64	9	8	14
15	65	62	64	-9	63	1	0	2 8	0	1.22	0	29.94	07	6.9	7.5	17	E	0.0	0	10	10	15
16	68	62	65	-7	62	0	0	1	0	T	0	30.07	07	2.5	5.5	13	SE	6.7	48	6	6	16
17	79	64	72	0	64	0	7	1 8	0	0	0	30.15	20	2.8	4.3	12	SE	13.8	100	5	4	17
18	80	65	73	2	64	0	8	8	0	0	0	30.11	20	3.7	5.3	15	SW	9.5	69	8	8	18
19	72	63	68	-3	62	0	3		0	0	0	30.05	08	4.6	4.9	16	E	9.7	70	6	5	19
20	74	63	69	-2	61	0	4	8	0	0	0	29.99	05	4.4	6.0	16	E	11.1	81	8	6	20
21	72	62	67	-4	60	0	2	1 8	0	0	0	30.03	12	5.1	6.2	14	E	10.6	77	6	6	21
22	67	60	64*	-6	59	1	0		0	.01	0	30.00	09	3.7	5.6	12	E	0.5	4	10	8	22
23	76	57*	67	-3	52	0	2		0	0	0	30.03	27	3.6	7.3	15	NW	13.0	96	2	3	23
24	76	63	70	0	55	0	5		0	0	0	30.12	19	1.3	5.3	14	SE	8.8	65	6	5	24
25	81	62	72	2	58	0	7	8	0	0	0	30.12	21	5.5	8.2	18	SW	8.4	62	5	4	25
26	88	67	78	9	62	0	13	8	0	0	0	30.03	24	2.8	7.2	15	SW	6.7	65	6	5	26
27	80	68	74	5	67	0	9	8	0	.01	0	29.99	13	2.3	6.3	12	E	5.8	43	9	8	27
28	94	75	85	16	69	0	20	1 8	0	.01	0	29.83	29	10.0	12.7	23	W	9.2	69	7	6	28
29	93	72	83	15	62	0	18		0	0	0	29.97	29	7.2	10.6	13	NW	13.3	100	1	2	29
30	99*	78	89*	21	68	0	24	8	0	.06	0	29.99	29	6.5	9.6	24	W	11.1	84	3	3	30
31	90	68	79	11	67	0	14	3 8	0	.43	0	30.11	30	4.5	11.2	34	NW	10.5	80	2	3	31

Sum	Sum				Total	Total		Total	Total	For the month:						Total	% for month	Sum	Sum
2565	2073				2	316	Number of days	2.78	0	29.98	25	2.0	7.4	34	NW	273.3		183	174
Avg.	Avg.	Avg.	Dep.	Avg.	Dep.	Dep.	Precipitation	Dep.						Date: 31		Possible		Avg.	Avg.
82.7	66.9	74.8	3.1	63	-6		≥ .01 inch 11	-0.88								429.6	64	5.9	5.6

				Season to date		Snow, ice pellets ≥ 1.0 inch 0
Number of days				Total	Total	
Maximum Temp.		Minimum Temp.		2	817	Thunderstorms 2
≥ 90° ‡	≤ 32°	≤ 32°	≤ 0°	Dep.	Dep.	Heavy fog X 1
10	0	0	0	-6		Clear 7 Partly cloudy 14 Cloudy 10

Greatest in 24 hours and dates Precipitation		Snow, ice pellets		Greatest depth on ground of snow, ice pellets or ice and date	
1.22	15	0		0	

HOURLY PRECIPITATION (Water equivalent in inches)

Date	A.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	P.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	Date
1				T	.19	.01	.10	.01	T	T	T	T							.04						1
2								T	.03	.05	.04		T	.01	.01	.02	.02	T	.02	.01			.23	.01	2
3	.02																	T	T	T	.02	T			3
4					.01	T																			4
5																									5
6																									6
7																									7
8																									8
9																									9
10																	T	T							10
11														.07	.07	.04	.01	T							11
12																									12
13																									13
14																									14
15				T	.05	.10	.12	.05	.08	.10	.10	.13	.14	.22	.10	.03	T	T	T						15
16		T	T	T																					16
17																									17
18																									18
19																									19
20																									20
21																									21
22							T	T	T	.01	T														22
23																									23
24																									24
25																									25
26																									26
27	T	T	T												.01	T									27
28					.01	T																			28
29																									29
30																			.06	T					30
31																			.22	.09	.11	.01	T	T	31

- * Extreme temperatures for the month. May be the last of more than one occurrence.
- − Below zero temperature or negative departure from normal.
- ‡ ≥ 70° at Alaskan stations.
- + Also on an earlier date, or dates.
- X Heavy fog restricts visibility to ¼ mile or less.
- T In the Hourly Precipitation table and in columns 9, 10, and 11 indicates an amount too small to measure.

The season for degree days begins with July for heating and with January for cooling.
Data in columns 6, 12, 13, 14, and 15 are based on 8 observations per day at 3-hour intervals.
Wind directions are those from which the wind blows. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. Figures for directions are tens of degrees from true North; i.e., 09 = East, 18 = South, 27 = West, 36 = North, and 00 = Calm. When directions are in tens of degrees in Col. 17, entries in Col. 16 are fastest observed 1-minute speeds. If the / appears in Col. 17, speeds are gusts.
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William H. Haggard
Director, National Climatic Center

SUMMARY BY HOURS

Hour Local time	Averages Sky cover Tenths	Station pressure In.	Temperature Air °F	Wet bulb °F	Dew Pt. °F	Relative humidity %	Wind speed m.p.h.	Resultant wind Direction	Speed m.p.h.
01	5	29.98	70	66	63	80	6.6	27	4.0
04	5	29.98	69	65	63	82	6.3	29	3.8
07	6	30.00	71	66	63	77	6.2	29	3.4
10	6	30.00	78	69	64	65	7.0	29	1.7
13	6	29.98	81	70	64	59	9.0	18	.6
16	5	29.96	78	69	64	63	8.7	15	2.5
19	5	29.97	74	67	64	73	8.1	20	2.0
22	5	29.99	72	67	64	77	7.5	24	4.4

USCOMM — NOAA — ASHEVILLE 1029

NOTICE: CLIMATOLOGICAL NORMALS BASED ON THE PERIOD 1941-1970 ARE EFFECTIVE AS FOLLOWS
HEATING DEGREE DAYS - JULY 1, 1973
COOLING DEGREE DAYS, TEMPERATURE, AND PRECIPITATION - JANUARY 1, 1974

MASS. INST. TECH.
OCT 2 197

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LOCAL CLIMATOLOGICAL DATA

U.S. DEPARTMENT OF COMMERCE
U.S. NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
~~ENVIRONMENTAL DATA SERVICE~~

BOSTON, MASSACHUSETTS
NAT WEATHER SERVICE FCST OFC
GEN LOGAN INTERNATIONAL AP
SEPTEMBER 1973

Latitude 42° 22' N Longitude 71° 02' W Elevation (ground) 15 ft. Standard time used: EASTERN WBAN #14739

Weather types on dates of occurrence: 1 Fog; 2 Heavy fog X; 3 Thunderstorm; 4 Ice pellets; 5 Hail; 6 Glaze; 7 Duststorm; 8 Smoke, Haze; 9 Blowing snow

Date	Temperature °F: Maximum	Minimum	Average	Departure from normal	Average dew point	Degree days Base 65°: Heating	Cooling	Weather types	Snow, ice pellets or ice on ground at 07AM In.	Precipitation: Water equivalent In.	Snow, ice pellets In.	Avg. station pressure In. Elev. 29 feet m.s.l.	Wind: Resultant direction	Resultant speed m.p.h.	Average speed m.p.h.	Fastest mile: Speed m.p.h.	Direction	Sunshine: Hours and tenths	Percent of possible	Sky cover Tenths: Sunrise to sunset	Midnight to midnight	Date
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	88	68	78	10	67	0	13	8	0	0	0	30.14	19	.9	7.3	10	SE	13.2	100	3	3	1
2	78	60	74	6	68	0	9	1 8	0	.01	0	30.14	11	4.8	7.3	12	E	11.8	70	6	5	2
3	94	72	83*	15	70	0	18	1 8	0	.02	0	30.02	22	5.5	7.9	11	SW	9.0	69	4	3	3
4	94*	67	81	14	69	0	16	23 8	0	T	0	29.99	03	2.7	8.6	15	NE	10.5	81	3	4	4
5	70	65	68	1	64	0	3	1	0	T	0	30.08	11	7.3	9.1	13	SE	0.0	0	10	10	5
6	82	66	74	7	67	0	9	1 3 8	0	.44	0	29.86	20	8.7	9.9	49	SW	1.4	9	10	9	6
7	77	63	70	3	51	0	5		0	0	0	29.84	27	14.6	14.8	22	W	11.3	87	3	1	7
8	71	57	64	-3	46	1	0		0	0	0	29.93	30	12.2	13.2	21	NW	11.4	89	5	5	8
9	68	55	62	-5	42	3	0		0	0	0	29.95	31	12.9	14.0	22	NW	12.2	95	6	5	9
10	70	51	61	-5	41	4	0		0	0	0	29.87	28	8.4	10.5	20	SW	12.7	100	1	0	10
11	81	56	69	3	54	0	4		0	T	0	29.57	25	15.5	15.7	24	SW	11.5	91	2	3	11
12	74	61	68	2	47	0	3		0	0	0	29.74	31	10.0	10.5	16	W	10.9	86	3	5	12
13	75	54	65	-1	47	0	0		0	0	0	30.09	29	5.7	8.8	16	W	12.6	100	5	5	13
14	64	57	61	-5	55	4	0		0	.18	0	30.06	06	3.5	5.3	10	S	0.8	6	10	10	14
15	68	57	63	-3	54	2	0		0	.16	0	29.84	06	7.4	10.6	17	NE	5.0	40	8	8	15
16	74	57	66	1	54	0	1	8	0	0	0	29.93	27	10.6	12.2	20	NW	9.9	79	6	4	16
17	61	50	56	-9	43	9	0		0	0	0	30.19	09	3.7	11.8	14	NW	12.4	100	4	5	17
18	68	56	62	-3	56	3	0	1	0	1.03	0	29.90	17	4.2	11.7	23	NW	2.9	23	9	7	18
19	61	50	56	-9	43	9	0		0	0	0	29.99	36	.5	11.4	20	NW	12.3	100	0	0	19
20	69	51	60	-5	49	5	0		0	0	0	29.98	24	9.8	11.4	22	NW	8.5	69	7	5	20
21	61	43*	52*	-13	34	13	0		0	0	0	30.28	35	5.3	9.2	22	NW	10.7	88	4	3	21
22	68	45	57	-7	46	8	0	8	0	.01	0	30.24	21	6.9	11.1	26	W	4.1	33	9	8	22
23	77	57	67	3	62	0	2	23 8	0	.07	0	29.99	19	2.5	10.8	20	W	5.1	42	7	7	23
24	58	54	56	-8	53	9	0	1	0	.03	0	30.27	05	14.0	14.2	19	NE	0.0	0	10	10	24
25	60	47	54	-10	46	11	0		0	0	0	30.43	07	5.8	9.1	15	NE	12.1	100	1	0	25
26	66	49	58	-5	49	7	0		0	0	0	30.44	18	4.7	8.3	17	SE	12.0	100	6	4	26
27	75	54	65	2	54	0	0		0	0	0	30.20	25	11.6	12.1	18	SW	11.9	100	6	6	27
28	73	58	66	3	48	0	1		0	0	0	29.98	33	9.8	10.9	19	N	11.9	100	4	4	28
29	76	53	65	3	46	0	0		0	0	0	29.79	28	10.4	13.5	22	NW	9.3	79	5	4	29
30	68	50	59	-3	35	6	0		0	0	0	30.10	32	10.1	10.8	17	NW	11.8	100	0	0	30
	Sum 2168	Sum 1692				Total 94	Total 84	Number of days		Total 1.95	Total 0	For the month: 30.03	28	3.2	10.7	49	SW	Total 249.2	% for month 72	Sum 157	Sum 143	
	Avg. 72.3	Avg. 56.4	Avg. 64.4	Dep. -0.9	Avg. 52	Dep. 18	Dep.			Dep. -1.51							Date: 06	Possible 374.6		Avg. 5.2	Avg. 4.8	

Number of days
- Precipitation ≥ .01 inch 9
- Snow, ice pellets ≥ 1.0 inch 0
- Thunderstorms 3
- Heavy fog X 2
- Clear 9 Partly cloudy 14 Cloudy 7

Degree days, Season to date: Heating Total 94, Dep. 12; Cooling Total 901, Dep.

Number of days

Maximum Temp. ≥ 90° ‡	Maximum Temp. ≤ 32°	Minimum Temp. ≤ 32°	Minimum Temp. ≤ 0°
2	0	0	0

Greatest in 24 hours and dates: Precipitation 1.03, 18; Snow, ice pellets 0

Greatest depth on ground of snow, ice pellets or ice and date: 0

HOURLY PRECIPITATION (Water equivalent in inches)

Date	A.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	P.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	Date
1																									1
2																					.01				2
3																	.02								3
4																	T	T							4
5																					T		T	T	5
6				T									.08	.03				.33	T						6
7																									7
8																									8
9																									9
10																									10
11																				T	T				11
12																									12
13																									13
14														T	T	T	T	T	.01	.01	.03	.04	.04	.05	14
15	.03	.04	.04	.02	.02	.01																			15
16																									16
17																									17
18											.07	.44	.13	.39	T										18
19																									19
20																									20
21																									21
22												T	T											.01	22
23	.02	.01	T	T	.01	.01											.02						T	T	23
24	T	T			T	.01	.01	.01			T	T	T	T	T					T	T				24
25																									25
26																									26
27																									27
28																									28
29																									29
30																									30

* Extreme temperatures for the month. May be the last of more than one occurrence.
\- Below zero temperature or negative departure from normal.
‡ ≥ 70° at Alaskan stations.
† Also on an earlier date, or dates.
X Heavy fog restricts visibility to ¼ mile or less.
T In the Hourly Precipitation table and in columns 9, 10, and 11 indicates an amount too small to measure.

The season for degree days begins with July for heating and with January for cooling.
Data in columns 6, 12, 13, 14, and 15 are based on 8 observations per day at 3-hour intervals.
Wind directions are those from which the wind blows. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. Figures for directions are tens of degrees from true North; i.e., 09 = East, 18 = South, 27 = West, 36 = North, and 00 = Calm. When directions are in tens of degrees in Col. 17, entries in Col. 16 are fastest observed 1-minute speeds. If the / appears in Col. 17, speeds are gusts.
Any errors detected will be corrected and changes in summary data will be annotated in the annual summary.

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

William H. Haggard
Director, National Climatic Center

SUMMARY BY HOURS

Hour Local time	Averages: Sky cover tenths	Station pressure In.	Temperature: Air °F	Wet bulb °F	Dew Pt. °F	Relative humidity %	Wind speed m.p.h.	Resultant wind: Direction	Speed m.p.h.
01	4	30.03	61	56	52	75	10.4	29	4.8
04	3	30.03	59	55	52	77	9.8	29	4.9
07	5	30.05	60	55	51	74	10.1	29	5.4
10	5	30.05	67	59	52	60	11.7	30	3.2
13	6	30.01	70	60	52	55	12.3	24	2.4
16	5	29.99	69	59	52	58	12.0	24	1.4
19	5	30.01	65	58	52	67	9.6	22	1.8
22	5	30.04	62	57	52	71	10.0	28	3.4

USCOMM — NOAA — ASHEVILLE 1025

NOV [illegible] 1973

NOTICE: CLIMATOLOGICAL NORMALS BASED ON THE PERIOD 1941-1970 ARE EFFECTIVE AS FOLLOWS
HEATING DEGREE DAYS - JULY 1, 1973
COOLING DEGREE DAYS, TEMPERATURE, AND PRECIPITATION - JANUARY 1, 1974

~~U.S. Weather~~

Lindgren

LOCAL CLIMATOLOGICAL DATA

U.S. DEPARTMENT OF COMMERCE
U S NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ENVIRONMENTAL DATA SERVICE

BOSTON, MASSACHUSETTS
NAT WEATHER SERVICE FCST OFC
GEN LOGAN INTERNATIONAL AP
OCTOBER 1973

Latitude 42° 22' N Longitude 71° 02' W Elevation (ground) 15 ft. Standard time used: EASTERN WBAN 814739

Date	Temperature °F: Maximum	Minimum	Average	Departure from normal	Average dew point	Degree days Base 65°: Heating	Cooling	Weather types on dates of occurrence (1 Fog, 2 Heavy fog X, 3 Thunderstorm, 4 Ice pellets, 5 Hail, 6 Glaze, 7 Duststorm, 8 Smoke, Haze, 9 Blowing snow)	Snow, ice pellets or ice on ground at 07AM In.	Precipitation: Water equivalent In.	Snow, ice pellets In.	Avg. station pressure In. Elev. 29 feet m.s.l.	Wind: Resultant direction	Resultant speed m.p.h.	Average speed m.p.h.	Fastest mile: Speed m.p.h.	Direction	Sunshine: Hours and tenths	Percent of possible	Sky cover Tenths: Sunrise to sunset	Midnight to midnight	Date
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	63	49	56	-6	43	9	0	8	0	0	0	30.39	10	3.0	7.5	12	E	11.7	99	4	4	1
2	70	50	60	-1	53	5	0	8	0	T	0	30.33	10	3.8	6.8	12	SW	7.8	66	6	5	2
3	65	58	62	7	60	3	0	2	0	.26	0	29.99	08	5.2	6.2	11	E	0.2	2	10	10	3
4	77	58	68*	8	58	0	3	2 8	0	0	0	29.96	06	2.4	7.5	15	E	8.0	69	3	5	4
5	71	57	64	4	54	1	0	2 8	0	.10	0	29.93	27	6.0	15.0	28	NW	2.8	24	6	6	5
6	70	52	61	2	34	4	0		0	0	0	30.14	30	13.5	14.0	25	NW	11.5	100	0	1	6
7	67	50	59	0	32	6	0		0	0	0	30.16	29	9.6	9.9	14	NW	7.8	68	8	6	7
8	61	46	54	-5	39	11	0		0	0	0	30.19	10	.8	6.8	12	SE	11.2	98	0	0	8
9	64	46	55	-3	47	10	0	1	0	0	0	30.20	00	2.1	6.9	12	E	11.1	98	6	3	9
10	57	47	52	-6	46	13	0	1 8	0	T	0	30.22	03	8.6	12.7	28	NE	3.4	30	7	7	10
11	55	44	50	-7	38	15	0		0	0	0	30.31	08	3.8	8.8	11	SE	10.5	93	5	6	11
12	73	46	60	3	43	5	0		0	0	0	30.18	24	5.2	7.2	12	SW	10.8	96	6	4	12
13	77*	52	65	8	52	0	0	8	0	0	0	30.02	22	12.0	12.4	20	SW	8.1	72	9	8	13
14	69	55	62	6	40	3	0	1 8	0	.01	0	29.73	27	21.0	22.3	36	W	10.1	90	1	3	14
15	70	52	61	5	30	4	0		0	0	0	29.65	26	14.9	15.7	30	W	11.1	100	0	0	15
16	61	48	55	0	30	10	0		0	T	0	29.62	28	18.7	19.0	30	W	9.3	84	3	2	16
17	57	43	50	-4	32	15	0		0	0	0	29.86	28	13.0	13.5	17	W	7.2	65	5	5	17
18	55	45	50	-4	36	15	0	8	0	.06	0	29.96	26	8.8	9.5	28	SW	2.6	24	9	8	18
19	55	43	49	-5	34	16	0		0	0	0	30.10	29	.3	10.1	17	NW	6.7	62	4	4	19
20	56	47	52	-1	41	13	0		0	.07	0	30.00	21	6.5	11.1	16	NW	0.0	0	10	8	20
21	58	44	51	-2	38	14	0		0	0	0	30.18	33	2.6	8.2	16	N	10.8	100	0	0	21
22	58	42	50	-3	39	15	0		0	0	0	30.25	17	2.0	8.1	13	E	10.8	100	0	0	22
23	73	46	60	8	43	5	0	8	0	0	0	30.10	23	10.4	10.6	17	SW	10.7	100	3	1	23
24	67	49	58	6	45	7	0	1 8	0	0	0	30.15	07	4.0	8.2	15	NE	10.7	100	0	3	24
25	56	52	54	3	48	11	0	1 8	0	T	0	30.17	06	13.6	14.0	17	NE	0.1	1	10	10	25
26	54	51	53	2	47	12	0	1 8	0	T	0	29.85	02	10.3	12.7	17	NE	0.0	0	10	8	26
27	63	43	53	2	39	12	0		0	0	0	29.86	32	13.1	13.4	23	NW	10.6	100	1	0	27
28	50	37*	44*	-6	31	21	0		0	0	0	30.31	05	9.9	12.9	17	NE	0.5	5	10	7	28
29	54	44	49	-1	42	16	0	1	0	.79	0	30.17	07	18.8	19.0	34	NE	0.0	0	10	10	29
30	62	50	56	6	50	9	0	1	0	.99	0	29.57	14	9.8	16.3	36	SE	4.4	42	7	7	30
31	62	49	56	6	45	9	0	1	0	.43	0	29.47	28	5.1	12.7	22	SW	6.7	64	5	6	31

Sum	Sum				Total	Total
1950	1495				289	3
Avg.	Avg.	Avg.	Dep.	Avg.	Dep.	Dep.
62.9	48.2	55.6	0.6	42	-12	
					Season to date	
					Total	Total
					385	906
					Dep.	Dep.
					0	

Number of days: Maximum Temp. ≥ 90° ‡	Maximum Temp. ≤ 32°	Minimum Temp. ≤ 32°	Minimum Temp. ≤ 0°
0	0	0	0

Number of days	
Precipitation ≥ .01 inch	8
Snow, ice pellets ≥ 1.0 inch	0
Thunderstorms	0
Heavy fog X	3
Clear 11	Partly cloudy 10
Cloudy 10	

Precipitation: Total 2.71; Dep. -0.43. Snow, ice pellets: Total 0.

Greatest in 24 hours and dates: Precipitation 1.74 29-30; Snow, ice pellets 0.

Greatest depth on ground of snow, ice pellets or ice and date: 0

For the month: Avg. station pressure 30.03; Resultant direction 29; Resultant speed 2.4; Average speed 11.6; Fastest mile 36 SE, Date: 30+.

Sunshine: Total 217.2; Possible 342.9; % for month 63. Sky cover: Sum 160, 147; Avg. 5.2, 4.7.

HOURLY PRECIPITATION (Water equivalent in inches)

Date	A.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	P.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	Date
1																									1
2															T	T									2
3		T	.03	.02	.05	.04	.05	T	.03	.01	.01	.01	.01		T	T	T								3
4																									4
5	T	T	T	T		.04	.02	.02				T	T	.02	T										5
6																									6
7																									7
8																									8
9																									9
10											T	T				T	T			T					10
11																									11
12																									12
13																									13
14		T	.01																						14
15																									15
16													T	T											16
17																									17
18												T	T	T	T	.03	.03						T	T	18
19																									19
20							T	T	.01	.02	.02	.02	T			T	T								20
21																									21
22																									22
23																									23
24																									24
25									T	T							T	T	T						25
26					T	T	T	T	T	T	T	T	T	T											26
27																									27
28																									28
29								T					.04	.09	T	.13	.10	.20	.06	.02	.01	T	.14	T	29
30	T	.01	.02	.01	.35	.28	.17	.10	.02	.01	T											T	T	.02	30
31	.01	.02	.03	.09	.08	.15	.04	.01	T	T															31

* Extreme temperatures for the month. May be the last of more than one occurrence.
\- Below zero temperature or negative departure from normal.
‡ ≤ 70° at Alaskan stations.
\+ Also on an earlier date, or dates.
X Heavy fog restricts visibility to ¼ mile or less.
T In the Hourly Precipitation table and in columns 9, 10, and 11 indicates an amount too small to measure.

The season for degree days begins with July for heating and with January for cooling.
Data in columns 6, 12, 13, 14, and 15 are based on 8 observations per day at 3-hour intervals.
Wind directions are those from which the wind blows. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. Figures for directions are tens of degrees from true North; i.e., 09 = East, 18 = South, 27 = West, 36 = North, and 00 = Calm. When directions are in tens of degrees in Col. 17, entries in Col. 16 are fastest observed 1-minute speeds. If the / appears in Col. 17, speeds are gusts.
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H. Haggard
Director, National Climatic Center

SUMMARY BY HOURS

Hour Local time	AVERAGES: Sky cover Tenths	Station pressure In.	Temperature: Air °F	Wet bulb °F	Dew Pt. °F	Relative humidity %	Wind speed m.p.h.	Resultant wind: Direction	Speed m.p.h.
01	4	30.04	52	47	42	72	10.9	28	2.0
04	4	30.03	51	47	42	75	9.8	30	2.3
07	5	30.05	51	47	42	73	10.2	29	4.5
10	5	30.05	58	50	42	59	11.6	32	3.4
13	5	30.01	61	52	42	55	14.2	29	1.2
16	5	30.00	60	51	42	56	13.5	28	1.2
19	5	30.02	55	49	42	65	11.3	27	2.4
22	5	30.03	53	48	42	69	10.8	27	2.4

USCOMM — NOAA — ASHEVILLE 1025

NOTICE: CLIMATOLOGICAL NORMALS BASED ON THE PERIOD 1941-1970 ARE EFFECTIVE AS FOLLOWS
HEATING DEGREE DAYS - JULY 1, 1973
COOLING DEGREE DAYS, TEMPERATURE, AND PRECIPITATION - JANUARY [illegible]

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LOCAL CLIMATOLOGICAL DATA

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. ENVIRONMENTAL DATA SERVICE

BOSTON, MASSACHUSETTS
NAT WEATHER SERVICE FCST OFC
GEN LOGAN INTERNATIONAL AP
NOVEMBER 1973

Latitude 42° 22' N Longitude 71° 02' W Elevation (ground) 15 ft. Standard time used: EASTERN WBAN #14739

Date 1	Temperature °F: Maximum 2	Minimum 3	Average 4	Departure from normal 5	Average dew point 6	Degree days Base 65°: Heating 7A	Cooling 7B	Weather types on dates of occurrence 8	Snow, ice pellets or ice on ground at 07AM In. 9	Precipitation: Water equivalent In. 10	Snow, ice pellets In. 11	Avg. station pressure In. Elev. 29 feet m.s.l. 12	Wind: Resultant direction 13	Resultant speed m.p.h. 14	Average speed m.p.h. 15	Fastest mile: Speed m.p.h. 16	Direction 17	Sunshine: Hours and tenths 18	Percent of possible 19	Sky cover Tenths: Sunrise to sunset 20	Midnight to midnight 21	Date 22
1	59	51	55	6	44	10	0	1	0	.26	0	29.29	25	14.5	19.1	44	W	1.1	10	9	8	1
2	63	49	56	7	34	9	0		0	0	0	29.70	27	17.2	19.4	37	W	8.3	81	3	2	2
3	62	40	56	5	34	11	0		0	T	0	29.69	28	21.3	22.4	42	W	7.6	74	5	3	3
4	52	41	47	-2	20	18	0		0	0	0	29.87	29	17.2	17.3	28	NW	10.2	100	0	0	4
5	49	38	44	-4	21	21	0		0	0	0	29.89	28	14.0	14.1	20	W	5.5	54	7	5	5
6	45	34	39	-9	20	24	0		0	0	0	29.78	28	17.3	18.3	30	W	4.1	40	6	5	6
7	49	37	43	-5	23	22	0		0	0	0	29.98	30	13.4	13.7	21	NW	10.1	100	1	1	7
8	50	35	43	-4	28	22	0		0	0	0	29.99	23	12.5	14.0	20	SW	3.6	39	8	6	8
9	48	34	41	-6	18	24	0		0	0	0	29.80	29	13.3	14.1	21	NW	4.8	48	6	8	9
10	41	30	36*	-11	14	29	0		0	0	0	30.10	31	15.6	15.7	23	NW	10.0	100	0	1	10
11	44	30*	37	-9	15	28	0		0	0	0	30.37	31	6.4	7.5	13	NW	9.9	100	0	2	11
12	46	35	41	-5	23	24	0		0	0	0	30.28	20	4.0	6.9	14	SW	1.2	12	9	9	12
13	55	44	50	4	32	15	0		0	0	0	30.03	23	12.5	12.9	19	SW	0.3	3	10	9	13
14	71*	54	63*	17	39	2	0		0	0	0	29.77	26	14.0	15.1	23	W	4.6	47	9	8	14
15	68	45	57	12	41	8	0	1 8	0	0	0	29.69	19	6.0	9.5	22	SW	0.6	6	10	8	15
16	57	35	46	1	38	19	0	1 8	0	.04	0	29.49	31	9.5	12.7	24	NW	0.3	3	10	9	16
17	42	32	37	-8	18	28	0		0	0	0	29.95	29	17.7	18.3	23	W	9.5	98	0	1	17
18	51	39	45	1	25	20	0		0	T	0	29.93	27	13.8	14.7	22	SW	9.1	94	2	5	18
19	48	34	41	-3	31	24	0		0	.07	0	29.96	34	6.6	8.9	17	NW	6.0	63	4	4	19
20	42	31	37	-7	23	28	0		0	0	0	30.33	31	3.2	9.2	13	NW	5.9	61	3	1	20
21	50	31	41	-3	29	24	0	8	0	.01	0	30.41	20	5.9	7.6	13	SW	8.7	91	4	5	21
22	54	45	50	7	44	15	0	1	0	.24	0	30.15	07	2.4	6.2	12	NW	1.0	10	9	9	22
23	47	43	45	2	41	20	0	2	0	0	0	30.13	09	.6	6.5	10	SW	0.0	0	10	8	23
24	51	41	46	3	39	19	0	1 8	0	.15	0	30.04	14	2.7	7.2	12	S	7.4	78	6	6	24
25	59	43	51	9	45	14	0	1 8	0	.32	0	29.62	27	4.8	13.1	17	N	0.0	0	10	10	25
26	45	36	41	-1	29	24	0		0	0	0	30.14	03	1.5	8.3	16	N	9.1	97	2	4	26
27	48	42	45	3	36	20	0	1	0	.10	0	30.13	15	8.7	9.5	14	SE	0.0	0	10	10	27
28	62	48	55	14	47	10	0	2	0	.55	0	29.57	11	2.1	6.6	22	SW	0.0	0	10	10	28
29	57	42	50	9	34	15	0		0	0	0	29.54	27	16.9	17.7	28	W	4.7	50	4	4	29
30	48	40	44	4	28	21	0		0	0	0	29.89	25	14.0	14.8	23	SW	4.9	52	6	6	30

Weather types: 1 Fog; 2 Heavy fog X; 3 Thunderstorm; 4 Ice pellets; 5 Hail; 6 Glaze; 7 Duststorm; 8 Smoke, Haze; 9 Blowing snow

Maximum	Minimum	Average	Departure	Avg. dew point	Heating	Cooling
Sum	Sum				Total	Total
1561	1189				570	0
Avg.	Avg.	Avg.	Dep.	Avg.	Dep.	Dep.
52.0	39.5	45.8	0.9	30	-24	
					Season to date	
					Total	Total
					955	906
					Dep.	Dep.
					-24	

Number of days: Maximum Temp. ≥ 90° ‡	≤ 32°	Minimum Temp. ≤ 32°	≤ 0°
0	0	5	0

Number of days	
Precipitation ≥ .01 inch	9
Snow, ice pellets ≥ 1.0 inch	0
Thunderstorms	0
Heavy fog X	2
Clear 9	Partly cloudy 9 Cloudy 12

Precipitation Total	Snow Total	For the month: Station pressure	Resultant direction	Resultant speed	Average speed	Fastest mile speed	Direction	Sunshine Total	% for month	Sky cover Sum	Sum
1.74	0	29.92	27	8.1	12.7	44	W	148.5		173	167
Dep.						Date: 01		Possible		Avg.	Avg.
-2.19								296.1	50	5.8	5.6

Greatest in 24 hours and dates: Precipitation	Date	Snow, ice pellets	Date	Greatest depth on ground of snow, ice pellets or ice and date
.55	28	0		0

HOURLY PRECIPITATION (Water equivalent in inches)

Date	A.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	P.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	Date
1			T	T	T	T	.01	T	T	.18	.06	T	T	.01	T		T								1
2																									2
3				T																					3
4																									4
5																									5
6																									6
7																									7
8																									8
9																									9
10																									10
11																									11
12																									12
13																									13
14																									14
15																									15
16							T	.01	T	.01	.01	T	.01	T	T										16
17																									17
18																					T	T	T		18
19	.02	.02	.01	T	.01	.01	T	T	T	T															19
20																									20
21																						.01	T		21
22	.03	.04	.01		.04	.04	.06	T																	22
23																									23
24																			T	T	.03	.04	.02	.06	24
25	.05	.01	T	T	T							T	T	.01	T	.03	.08	.07	.06	.01	T				25
26																									26
27		T	T	T			T	T			T	T	.02	T	T	.02	T	.03	.01	T	T	T	.01	.01	27
28	.02	.05	.16	.07	.01	.01	.04		T	T	T	T	T	T	T		.01	T		.01	.08	.04	.02	.03	28
29																									29
30																									30

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- * Extreme temperatures for the month. May be the last of more than one occurrence.
- − Below zero temperature or negative departure from normal.
- ‡ ≥ 70° at Alaskan stations.
- \+ Also on an earlier date, or dates.
- X Heavy fog restricts visibility to ¼ mile or less.
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I certify that this is an official publication of the National Oceanic and Atmospheric Administration, and is compiled from records on file at the National Climatic Center, Asheville, North Carolina 28801.

William H. Haggard
Director, National Climatic Center

SUMMARY BY HOURS

Hour Local time	AVERAGES: Sky cover Tenths	Station pressure In.	Temperature: Air °F	Wet bulb °F	Dew Pt. °F	Relative humidity %	Wind speed m.p.h.	Resultant wind: Direction	Speed m.p.h.
01	6	29.91	44	39	31	63	11.3	27	6.4
04	5	29.91	43	38	31	64	11.3	28	8.0
07	5	29.94	42	37	30	65	11.1	27	8.0
10	6	29.94	46	40	30	57	14.9	28	10.4
13	6	29.89	49	41	30	49	14.4	28	9.5
16	6	29.90	48	41	30	52	14.3	27	8.2
19	5	29.92	45	39	30	58	12.5	27	7.1
22	7	29.93	44	39	31	61	11.8	27	7.2

USCOMM — NOAA — ASHEVILLE 1029

NOTICE: CLIMATOLOGICAL NORMALS BASED ON THE PERIOD 1941-1970 ARE EFFECTIVE AS FOLLOWS
HEATING DEGREE DAYS - JULY 1, 1973
COOLING DEGREE DAYS, TEMPERATURE, AND PRECIPITATION - JANUARY 1, 1974

D255
273-B

LOCAL CLIMATOLOGICAL DATA

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ENVIRONMENTAL DATA SERVICE

BOSTON, MASSACHUSETTS
NAT WEATHER SERVICE FCST OFC
GEN LOGAN INTERNATIONAL AP
DECEMBER 1973

Latitude 42° 22' N Longitude 71° 02' W Elevation (ground) 15 ft. Standard time used: EASTERN WBAN #14739

	Temperature °F					Degree days Base 65°		Weather types on dates of occurrence	Snow, ice pellets or ice on ground at 07AM	Precipitation		Avg. station pressure	Wind					Sunshine		Sky cover Tenths		
Date	Maximum	Minimum	Average	Departure from normal	Average dew point	Heating	Cooling	1 Fog 2 Heavy fog X 3 Thunderstorm 4 Ice pellets 5 Hail 6 Glaze 7 Duststorm 8 Smoke, Haze 9 Blowing snow	In.	Water equivalent In.	Snow, ice pellets In.	In. Elev. 29 feet m.s.l.	Resultant direction	Resultant speed m.p.h.	Average speed m.p.h.	Fastest mile Speed m.p.h.	Fastest mile Direction	Hours and tenths	Percent of possible	Sunrise to sunset	Midnight to midnight	Date
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	41	31	36	-4	20	29	0		0	0	0	30.22	31	15.4	15.7	24	NW	8.4	90	2	2	1
2	39	28	34	-5	15	31	0		0	0	0	30.49	31	4.8	9.6	16	NW	9.2	99	2	1	2
3	46	31	39	1	28	26	0		0	0	0	30.24	18	10.9	11.1	20	S	1.3	14	9	6	3
4	58	41	50	12	40	15	0	8	0	T	0	29.99	21	5.4	6.6	13	SW	0.8	9	10	7	4
5	63	45	54*	17	50	11	0	1 8	0	.40	0	29.01	18	17.0	12.1	36	SW	0.0	0	10	10	5
6	63*	42	53	16	43	12	0	1	0	.10	0	29.88	27	11.6	15.0	36	SW	5.2	56	6	6	6
7	46	34	40	4	25	25	0		0	0	0	30.31	31	11.3	11.8	17	W	3.3	36	6	3	7
8	41	32	37	1	27	28	0		0	0	0	30.56	01	9.6	11.5	16	E	0.0	0	10	9	8
9	58	41	50	14	43	15	0	1	0	.86	0	30.08	11	14.0	20.6	29	SE	0.0	0	10	10	9
10	51	42	47	12	39	18	0		0	0	0	29.86	23	12.3	14.2	21	SW	1.6	17	8	8	10
11	42	36	39	4	31	26	0	1 8	0	.14	0	29.81	33	9.5	9.8	22	NW	0.0	0	9	7	11
12	41	32	37	3	20	28	0		0	0	0	29.93	31	10.4	10.6	21	NW	8.1	89	2	1	12
13	44	28	36	2	23	29	0		0	0	0	29.97	17	4.3	7.8	20	SE	7.4	81	5	5	13
14	54	44	49	15	44	16	0	1	0	.74	0	29.61	17	6.8	15.4	26	SE	0.0	0	10	8	14
15	44	33	39	6	28	26	0		0	0	0	29.88	30	12.4	12.8	22	NW	6.0	66	5	5	15
16	34	29	32	-1	22	33	0	1 4 6	0	.31	T	30.04	34	9.5	10.8	17	N	0.0	0	10	10	16
17	59	33	46	13	36	19	0	1 6	T	2.04	T	29.47	30	3.0	11.1	30	SW	0.0	0	10	10	17
18	38	18	28	-4	10	37	0		0	T	T	29.91	28	19.2	22.0	30	SW	9.1	100	1	2	18
19	25	11*	18*	-14	0	47	0		0	0	0	30.57	31	6.1	8.5	16	NW	7.6	84	1	4	19
20	54	25	40	8	23	25	0	1	0	T	0	30.33	36	1.7	8.3	26	S	0.0	0	10	10	20
21	61	31	46	15	50	19	0	1	0	.70	0	29.39	18	22.2	23.3	43	S	0.0	0	10	9	21
22	33	25	29	-2	9	36	0		0	0	0	29.70	28	18.5	19.1	29	W	8.8	96	0	3	22
23	39	27	33	2	17	32	0		0	T	T	29.92	27	11.4	13.2	22	NW	2.6	29	8	7	23
24	32	20	26	-4	9	39	0		0	0	0	30.45	32	13.5	13.8	24	NW	9.1	100	1	0	24
25	44	19	32	2	17	33	0	1	0	T	0	30.53	26	1.2	6.6	13	S	3.6	40	9	7	25
26	60	44	52	22	49	13	0	2	0	.57	0	30.03	22	11.1	12.5	25	SW	0.8	9	10	10	26
27	50	42	46	16	42	19	0	2	0	.30	0	29.92	01	9.4	10.6	19	NE	0.0	0	10	10	27
28	49	39	44	14	33	21	0	2	0	.08	0	29.93	30	11.1	12.1	29	NW	9.0	99	1	5	28
29	52	36	44	14	34	21	0		0	T	0	29.89	20	8.7	9.4	25	SW	4.7	52	8	6	29
30	51	34	43	13	22	22	0	1	0	.21	0	29.80	27	15.6	18.4	32	NW	7.3	80	3	5	30
31	35	32	34	4	22	31	0	1 6	0	.15	T	30.15	01	5.5	9.2	15	NW	0.0	0	10	10	31

Sum	Sum				Total	Total
1447	1005				782	0
Avg.	Avg.	Avg.	Dep.	Avg.	Dep.	Dep.
46.7	32.4	39.6	6.3	28	-210	
					Season to date	
					Total	Total
Number of days					1737	904
Maximum Temp.		Minimum Temp.			Dep.	Dep.
≥ 90° ‡	≤ 32°	≤ 32°	≤ 0°		-234	
0	2	16	0			

Number of days		Precipitation Total	Snow, ice pellets Total
		7.20	T
Precipitation ≥ .01 inch	13	Dep.	
Snow, ice pellets ≥ 1.0 inch	0	3.57	
Thunderstorms	0		
Heavy fog X	3		

Clear 9 Partly cloudy 4 Cloudy 18

For the month:	Avg. station pressure	Resultant direction	Resultant speed	Average speed	Fastest mile speed	Fastest mile direction
	30.02	28	5.0	12.7	43	S
					Date:	21

Greatest in 24 hours and dates				Greatest depth on ground of snow, ice pellets or ice and date	
Precipitation		Snow, ice pellets			
2.76	16-17	T	31+	T	17

Sunshine Total	% for month	Sky cover Sunrise to sunset Sum	Midnight to midnight Sum
112.9		206	198
Possible		Avg.	Avg.
283.4	40	6.6	6.4

HOURLY PRECIPITATION (Water equivalent in inches)

	A.M. Hour ending at												P.M. Hour ending at												
Date	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	Date
1																									1
2																									2
3																									3
4						T	T																		4
5						T	T	.03	.05	.03	.08	.01	T			T	T	.06	.02			.01	.06	.03	5
6	.07	T		T	.01	.01	.01	T																	6
7																									7
8																									8
9				T	.04	.05	.04	.01	T	.02	.16	.07	T	T	T	.02	.15	.18	.10	T	.02	T			9
10																									10
11								T	T	.04	.05	.04	T	.01											11
12																									12
13																									13
14	T	T			.01	.08	.06	.08	.07	.08	.10	.12	.10	.01	.03	T									14
15																									15
16													T	.03	.03	.05	.03	.02	.05	.09	.04	.01	T	T	16
17	.02	.02	.02	.01	.08	.03	.30	.35	.39	.28	.40	.30	.18	.08	T	.09	.02	.04	.03			T	T	T	17
18	T			T	T	T																			18
19																									19
20																T									20
21				T	T	T	.01	.07	.01	.02		.02	.31	.19	.04	.03									21
22																									22
23																						T	T	T	23
24																									24
25																								T	25
26		T	T									T	.06	.01		T	.03	.06	.04	.03	.03	.12	.08	.11	26
27	.09	.01	.09	.05	T		.01	.02	T		.01	T	T	.01	.01	T	T	T	T	T	T	T	T		27
28						.05	.03																		28
29																				T	T				29
30			T	.07	.10	.04	T																		30
31									T	T	.04	.05	.02	T	T	.01	.01	.01	T	T	T	T	T	.01	31

- * Extreme temperatures for the month. May be the last of more than one occurrence.
- \- Below zero temperature or negative departure from normal.
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William H. Haggard
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SUMMARY BY HOURS

	AVERAGES							Resultant wind	
			Temperature						
Hour Local time	Sky cover Tenths	Station pressure In.	Air °F	Wet bulb °F	Dew Pt. °F	Relative humidity %	Wind speed m.p.h.	Direction	Speed m.p.h.
01	6	30.02	38	34	27	68	12.6	28	5.4
04	7	30.02	37	34	27	69	11.8	27	4.6
07	7	30.03	37	33	27	69	12.1	28	5.0
10	6	30.05	39	35	27	62	14.4	29	6.5
13	6	30.00	42	37	28	61	13.7	29	5.0
16	6	30.01	42	37	29	62	12.3	28	4.6
19	6	30.03	40	36	29	65	12.5	27	4.6
22	6	30.03	39	35	28	67	12.2	26	5.2

USCOMM — NOAA — ASHEVILLE, 1025

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HEATING DEGREE DAYS - JULY 1, 1973
COOLING DEGREE DAYS, TEMPERATURE, AND PRECIPITATION - JANUARY 1, 1974

FEB

NOTES

1. David Rose, "Energy Policy in the United States," Scientific American, January, 1974, Volume 230, #1, p. 20.

2. ibid., p. 28.

3. ibid., p. 27.

4. Budget allocation diagram derived from Rose, p. 28.

5. Victor Olgyay, Design with Climate, (Princeton, New Jersey: Princeton University Press), 1963, p. 94.

6. Rose, p. 23.

7. Information from the Department of Commerce and Housing and Urban Development quoted in U.S. News and World Report, November 3, 1975, p. 67.

8. All numbers for percentages and interest rates can be determined by using the "Expanded Payment Table for Monthly Mortgage Loans," Financial Publishing Company, Publication Number 193 (Boston: Financial Publishing Company), 1969.

9. Olgyay, see the discussion on experiments in comfort zone requirements, p. 17 ff.

10. Olgyay, p. 22.

11. Data selected from Local Climatological Data for Boston and Vicinity, 1973, United States Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service.

12. ASHRAE Handbook of Fundamentals, (New York: American Society of Heating, Refrigeration, and Air-Conditioning Engineers), 1967, p. 390.

13. Vivian Loftness, "Natural Forces and the Craft of Building: Site Reconnaissance," M. Arch. Thesis, Massachusetts Institute of Technology, May, 1975, see the chapter on windbreak design.

14. Information on wind flow effects was gathered and selected from various sources and compared using a common format:

    A. Loftness, section on wind flow

    B, C, D. William Caudill and Bob Reed, "Geometry of Classrooms as related to Natural Lighting and Natural Ventilation, Research Report Number 36, (College Station, Texas: Texas Engineering Experimenting Station), 1952, reprinted in "Architects and Energy: Issues and Proposals," by Wei-i Chiu, M.Arch. Thesis, Massachusetts Institute of Technology, February, 1975.

    E, F, G. Olgyay, p. 101 ff.

    H - T. Robert F. White, "Effects of Landscape Development on the Natural Ventilation of Buildings and their Adjacent Areas," Research Report Number 45, (College Station, Texas: Texas Engineering Experimenting Station), 1954, reprinted in Wei-i Chiu.

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15. John Malloy, Thermal Insulation (New York: Van Nostrand Reinhold Company), 1969, p. 91.

16. William J. McGuinness and Benjamin Stein, Mechanical and Electrical Equipment for Buildings (New York: John Wiley and Sons), 1971, p. 140.

17. McGuinness, p. 141

18. McGuinness, p. 159, Section B, discussion of emissivity.

19. McGuinness, p. 160.

20. McGuinness, p. 159, chart of still air conductivity.

21. McGuinness, p. 159, chart of moving air conductivity.

22. "Regional Climate Analysis and Design Data," House Beautiful Climate Control Project for Boston Area, Bulletin of the American Institute of Architects, September, 1949 - January, 1952, comparative heating and cooling season figures for this thesis are derived from the data presented.

23. George Stephen, Revitalizing Older Houses in Charlestown, Boston Redevelopment Authority manual, Boston, 1973; includes many suggestions for sensitive development of houses.

24. Howard Emmons, "Fire and Fire Protection," Scientific American, Volume 231, Number 1, July, 1974, p. 21; includes interesting experiments on material and flashover problems.

25. "Material Needs and the Environment: Today and Tomorrow," Jerome Klaff, chairman, Final Report of the National Commission

on Materials Policy, (Washington, D.C: United States Government Printing Office), June, 1973, p. 2-12.

26. National Commision on Materials Policy, p. 2-14, source: "The Plastic Industry in the Year 2000," prepared by the Stanford Research Institute, April, 1973.

27. National Commission on Materials Policy, p. 4c-9, sources: figures for steel, aluminum, and glass were taken from "Energy Expenditures Associated with the Production and Recycle of Materials," J.C. Brevard and C. Portal, Oak Ridge National Laboratory, CRNL-MIT-132, May 26, 1971; for cement they are based on estimates by C.J. Whittemore, University of Washington; for plastics; on a report to this Commission by the Society of Plastics Industries; for lumber on a Forest Service Staff Paper, "Energy Requirements for Wood and Wood Substitutes and the 'Energy Crisis'," 1972.

28. ibid.

29. McGuinness, p. 170.

30. McGuinness, p. 169, glazing charts.

31. McGuinness, p. 170, glazing charts.

32. H.C. Hottel and B.B. Woertz, "The Performance of Flat-Plate Solar-Heat Collectors," paper presented at the Spring Meeting of the American Society of Mechanical Engineers; this paper was Publication Number 3 of the Solar Energy Conversion Research Project, Massachusetts Institute of Technology, 1940.

33. Bruce Anderson, "Solar Energy and Shelter Design," M.Arch. Thesis, Massachusetts Institute of Technology, February, 1973, p. 77.

34. McGuinness, p. 35.

35. Professor Jan Wampler of the Department of Architecture of the Massachusetts Institute of Technology, suggestions from various studios and from discussions at the mid-term review of this thesis.

36. Hittman Asociates, Inc., "Residential Energy Consumption, Single Family Housing, Final Report," Contract No. H-1654 for the Office of the Assistant Secretary for Policy Development and Research, Department of Housing and Urban Development, March, 1973.

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