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COMPREHENSIVE PLANNING FOR PASSIVE SOLAR ARCHITECTURAL RETROFIT

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MASTER of ARCHITECTURE THESIS
MIAMI UNIVERSITY · OXFORD, OHIO

STANLEY H. SCOFIELD
CAPTAIN, USAF.

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AUTHOR: STANLEY H. SCOFIELD, CAPT., USAF

TITLE: COMPREHENSIDE PLANNING FOR PASSIVE SOLAR ARCHITECTURAL RETROFIT.

ABSTRACT:

This Thesis proposes a new method for developing Passive Solar Architectural Retrofit Concepts to be used in Air Force Project Booklets. This method can be used for "in-house" design projects, A&E design projects, and major projects administered by Army or Navy Engineering.

This Thesis has three parts:

1. A series of 35 "Patterns" to be used by the Architectural Programmer and user. The recommendations contained in each "pattern" are specific enough for the programmer and user to identify, for them, the decisions they need to make early in the programming process, and yet the recommendations are not overly restrictive to the designer.
2. A sample Passive Solar Architectural Retrofit Program using selected "patterns" from part one of this Thesis.
3. A sample Conceptual Design using the Architectural Program of part two of this Thesis.

The Thesis also contains expanded Appendicies. Copies of the Appendicies are located at:

1. Air Force Engineering & Services Center-Energy Group (AFESC/DEB), Tyndall AFB, Fl.
2. Air Force Institute of Technology Library (AFIT/LD-School of Civil Engineering) WPAFB, OHIO.
3. Miami University-Department of Architecture, Oxford, Ohio.

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COMPREHENSIVE PLANNING FOR PASSIVE SOLAR ARCHITECTURAL RETROFIT

PART 1

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DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE OF TECHNOLOGY (ATC)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

REPLY TO ATTN OF: Stanley H. Scofield, Capt., USAF 9 May 1980

SUBJECT: Final submission of my thesis / DRAFT PROGRAMMING PAMPHLET forPASSIVE SOLAR ARCHITECTURAL RETROFIT

TO: AFESC/DEB (Mr. Bruce Mc Donald)
Prof. Fuller Moore - Miami University
Prof.Daniel Miskie - Miami University
Prof. John Hoffman - Miami University

Part One of my Thesis is designed to be used as an Air Force Programming Pamphlet with "rules of thumb" for starting the Passive Solar Architectural Retrofit Process. This process is Architectural in nature because passive heating and cooling systems are integral to the architecture of a building, or to put it another way, the building or some element of it is the system. Passive design is an integrated design process requiring the integration of user needs (functional, comfort, etc.), technology, and the natural environment (site, sun, wind, rain etc) into a synergistic architecture.

The Passive Solar Architectural Retrofit process begins with Architectural Programming. For that reason I have developed a programming tool to be used with the using agency to develop program concepts for integrating user needs, technical information, and the natural environment.

Since the Air Force Energy plan stresses Passive Solar (Architecture) before using Active Solar (Equipment), it is necessary for the programmer to integrate natural heating and cooling systems into the conceptual organization of interior spaces. The integrating of the passive systems and interior spaces require the expertise of an Architect to define the architectural problem.

Unfortunately, not all bases have an architect. Thus it seems logical to adopt a system of architectural programming developed by Architects.

William Pena, FAIA, of Caudill, Rowlett Scott (CRS) is probably the leading expert about Architectural Programming. His book Problem Seeking - Architectural Programming Primer presents the method of programming he and his firm have developed in over 30 years of programming. It is a five step process: 1) Establish User Goals; 2) Collect and Analyze Facts; 3) Uncover Concepts; 4) Establish Needs; 5) State the Architectural Problem.

His programming method is used in the Architectural Programming section of National Council of Architectural Registration Boards, Professional Registration Examination and this programming method is being presented to the AFIT students in ENG 480 (Building Systems) by Major Marvin Kissinger.

I HAVE BEEN USING PENA'S METHOD OF PROGRAMMING TO ESTABLISH THE USER GOALS, COLLECT AND ANALYZE THE FACTS, DETERMINE NEEDS AND STATE THE ARCHITECTURAL PROBLEM IN PROGRAMMING THE DESIGN PHASE OF MY THESIS.

This method serves the following functions:

1) It serves as a starting point for dialog and interviews with the user, and the programming team;
2) It is a checklist of missing information;
3) It is a means of documenting the programming process.

I HAVE NOT USED PEÑA'S METHOD OF UNCOVERING CONCEPTS BECAUSE IT DOES NOT LEND ITSELF DIRECTLY TO THE PASSIVE SOLAR RETROFIT PROBLEM. THIS DOCUMENT IS MY PROPOSAL FOR THE METHOD TO BE USED, IN AIR FORCE PROGRAMMING, TO UNCOVER PROGRAMMING AND DESIGN CONCEPTS OR RULES OF THUMB TO BE USED FOR PASSIVE SOLAR ARCHITECTURAL RETROFIT. All buildings, no matter how large or small, are based on rules of thumb. The rules of thumb are called "patterns" and together they are called a "Pattern Language".[1]

The following information - General Instruction for using the Pattern Language-is an introduction for the programmer, to work with the user to develop passive system concepts, which integrate user needs, technical information, and the natural environment.

GENERAL INSTRUCTIONS FOR USING THE PATTERN LANGUAGE

TO BE USEFUL IN THE PROGRAMMING PROCESS, YOU, THE PROGRAMMER, MUST CAREFULLY STUDY THE ENTIRE LANGUAGE, AND HAVE A THOROUGH UNDERSTANDING OF THE PATTERNS BEFORE ATTEMPTING TO USE THEM IN THE PROGRAMMING PROCESS WITH THE USER. THE PATTERN RECOMMENDATIONS ARE SPECIFIC ENOUGH TO WORK WITH THE USER, TO IDENTIFY FOR THEM, THE DECISIONS

1. Christopher Alexander. The Timeless Way to Build, Oxford University Press, New York, NY 1979.p203.

THEY NEED TO MAKE EARLY IN THE PROGRAMMING PROCESS, AND YET NOT BE OVERLY RESTRICTIVE TO THE DESIGNER. For example, SOLAR WINDOWS(11) recommends an approximate south-facing glass area needed for each square foot of building floor area. Then you can work with user to decide how to divide the glass area: 1) all the area as SOLAR WINDOWS (11); 2) a combination of SOLAR WINDOWS (11) and CLERESTORIES AND SKYLIGHTS(12); 3) all CLERESTORIES AND SKYLIGHTS(12). The designer will incorporate the users system concept selection into the design and make adjustments in size based on heat calculations.

THE PURPOSE OF THE THIRTY-FIVE PATTERNS,OUTLINED IN THIS THESIS, IS TO PROVIDE YOU (THE PROGRAMMER) WITH A PROGRAMMING TOOL TO WORK WITH THE USING AGENCY, TO DEVELOP PROGRAM CONCEPTS FOR INTEGRATING USER NEEDS, TECHNICAL INFORMATION, AND THE NATURAL ENVIRONMENT. This allows the user to choose a passive heating and cooling system concept suited to their particular set of functional requirements and climatic conditions.

The patterns are ordered in a rough sequence, from large-scale concerns - Geographic Determinism (1), Building Location (2), Building Shape and Orientation (3)- to smaller ones - Movable Insulation (23), Reflectors(24); from applications with the most influence on the building's retrofit design to ones which deal with specific details of the passive heating and cooling systems. When used in this sequence, the patterns form a step-by-step process for the programming of a passive solar heated and cooled building, and in a sense, act as a check-list. Each pattern contains a rule of thumb, based on all the available information at this time, for that particular aspect of the building's design.

PASSIVE SOLAR ARCHITECTURAL SYSTEMS DEMAND A SKILLFUL AND TOTAL INTEGRATION OF ALL THE ARCHITECTURAL ELEMENTS WITHIN EACH SPACE- GLAZING, WALLS, FLOOR, ROOF AND IN SOME CASES, EVEN INTERIOR AND EXTERIOR COLORS. Every pattern is independent, but it needs other patterns to make it more complete. Large-scale patterns set the context for the ones that follow, and each succeeding pattern helps refine the one that came before it. For example,a window will be more effective as a solar energy collector if the pattern, MOVABLE INSULATION (23), which recommends using insulating shutters over windows at night, is used with the pattern, SOLAR WINDOWS (11). Also, the patterns, CHOOSING THE SYSTEM(9) and SUMMER COOLING (27) have a close relationship and must be considered together because, with both, the Architecture and Landscape Architec-

ture are the climatic-control mechanism.

EACH PATTERN HAS THE SAME FORMAT AND TOGETHER THE PATTERNS FORM A COHERENT PICTURE OF A STEP-BY-STEP PROCESS FOR PROGRAMMING OF A PASSIVE SOLAR ARCHITECTURAL RETROFIT. Each pattern is written so the headlines (Bold-ALL CAPITALS) summarize and describe THE PROBLEM and THE RECOMMENDATION. TO UNDERSTAND THE ENTIRE PROCESS FOR PROGRAMMING CONCEPTS, FIRST READ ONLY THE HEADLINES (PROBLEM STATEMENT AND RECOMMENDATION) ON THE FIRST PAGE OF EACH PATTERN. Once the whole process is understood, it easy to go back and read the related LARGE SCALE PATTERNS, SMALL SCALE PATTERNS, and INFORMATION in each pattern, when more detail is needed. The format used is similar to the format used by Christopher Alexander in A Pattern Language, and Edward Mazria in The Passive Solar Energy Book - Expanded Professional Edition. Each pattern has the following sequence of format

HEADING - description of the content of the pattern.

PHOTOGRAPH - visual representation of the pattern (most patterns)

LARGE SCALE PATTERNS- patterns which help set the context of the pattern.

THE PROBLEM - description of the essence of the problem.

THE RECOMMENDATION - the rule of thumb that gives physical relationships necessary to solve the problem.

SMALL SCALE PATTERNS - patterns which embellish this pattern, and help implement it and fill in the details.

ILLUSTRATIONS - a visual representation of the rule of thumb.

INFORMATION - provides all available information about the pattern, evidence for its validity and the range of ways the pattern can be applied to a building.

REFERENCES - Bibliographic information for further reference.

SOURCE OF ILLUSTRATIONS - information to be used for copyright usage.

NOT ALL THE PATTERNS APPLY TO EACH PROJECT. For example, the patterns, CHOOSING THE SYSTEM(9) and SUMMER COOLING(27), give criteria to help the user, with your (the programmers) assistance, to select the most appropriate passive system for the project. After the user makes

this choice, patterns defining other passive systems are not relevent. Also, a pattern presented here may not apply to a special situation. If this happens; then it is important for you and the user to understand the spirit of the pattern - open-ended, adaptable, general, and "each solution (The Recommendation) is stated in such a way that it gives the essential relationship needed to solve the architectural problem, but in a very general abstract way, so the designer can solve the problem in their own (creative) way, by adapting it to local conditions and user preferences"[2] - and modify it, so it fits the user's situation.

SELECT THE PATTERNS MOST USEFUL TO YOUR PROJECT, MORE OR LESS IN THE SEQUENCE PRESENTED HERE. You may want to add some of your own patterns, or update a pattern. If so, use the format described earlier. The following list of patterns is divided into three major groups.

First are the patterns to be used for evaluating the overall location, shape and position of the existing building on the site according to the sun, wind and vegetation:

1. GEOGRAPHIC DETERMINISM
2. BUILDING LOCATION
3. BUILDING SHAPE AND ORIENTATION
4. HISTORICAL BUILDING TYPE SOLUTION
5. NORTH SIDE
6. LOCATION OF INDOOR SPACES
7. PROTECTED ENTRANCE
8. WINDOW LOCATION

Second are patterns with criteria for passive system selection and specific details for retrofit design:

9. CHOOSING THE SYSTEM
10. APPROPRIATE MATERIALS

DIRECT GAIN SYSTEMS

11. SOLAR WINDOWS
12. CLERESTORIES AND SKYLIGHTS
13. MASONRY HEAT STORAGE
14. INTERIOR WATER WALL

THERMAL STORAGE WALL SYSTEMS

15. SIZING THE WALL
16. WALL DETAILS

2. Christopher Alexander. The Timeless Way to Build, Oxford University Press, New York, N.Y., 1979. xiii.

ATTACHED GREENHOUSE SYSTEMS
17.SIZING THE GREENHOUSE
18.GREENHOUSE CONNECTION

ROOF POND SYSTEMS
19.SIZING THE ROOF POND
20.ROOF POND DETAILS

21.COMBINING SYSTEMS
22.CLOUDY DAY STORAGE

And third are patterns with specific instructions to make the building more efficient as a passive system.

23.MOVABLE INSULATION
24.REFLECTORS
25.SHADING DEVICES
26.INSULATION ON THE OUTSIDE
27.SUMMER COOLING
28.EARTH TUBES
29.KING VENTILATION SYSTEM
30.BREATHING WALL
31.SOLAR CHIMNEY
32.SOLAR DEHUMIDIFICATION
33.INDUCED EVAPORATION
34.ZONING
35.DIURNAL AIR FLUSHING

IT IS IMPORTANT TO REMEMBER, THESE PATTERNS ARE EVOLVING AND WILL CHANGE OVER TIME. Each pattern presents current recommendation on how to solve a particular problem. As new information becomes available, especially in the area of SUMMER COOLING (27), new problems will be defined, and new patterns will be generated and added to the process. Since research into passive systems is relatively new, there is a need to question and refine the patterns.

THE USE OF THE "PATTERN LANGUAGE" IS MEANT TO BE FLEXIBLE AND ACCOMODATE CHANGE AND REFINEMENT. AND MORE IMPORTANTLY, IT ALSO ALLOWS THE YOU TO WRITE AN EXPLICIT STATEMENT ABOUT ESSENTIAL RELATIONSHIPS NEEDED TO SOLVE THE ARCHITECTURAL PROBLEM, BUT IN A GENERAL ABSTRACT WAY, SO THE DESIGNER CAN SOLVE THE PROBLEM IN A CREATIVE MANNER. THUS, THE PATTERNS SHOULD BECOME PART OF THE HAND-OFF PACKAGE (DD FORM'S 1391) FROM THE PROGRAMMER TO THE DESIGNER (In-House Design or A&E Contract).

CONCLUSIONS & RECOMMENDATIONS

The following conclusions and recommendations are based on my observations and experiences in the programming and design phases of my thesis work.

1. I feel the "pattern language" presented in this thesis is valid and usable as an Air Force Programming Pamphlet. The use of the "patterns" as part of an Air Force Regulation or Manual would defeat their original intent of being of being open-ended, adaptable and general in nature as cited earlier from Christopher Alexander's The Timeless Way to Build. The "Pattern" structure is adaptable to change, and development of new products, etc. For example, in my design (Part 3 of the thesis) I used two new products (eutectic salts - Thermal 81 ^{R} and the Transparent Heat Mirror) that were not basic patterns. These two new products could be designated patterns 9F (EUTECTIC SALTS) and 9G (HEAT MIRROR) and added to the Programming Pamphlet. Other patterns can also be added as required.

2. Part 2 of the thesis (Program for WPAFB Central Technical Library) is a sample Programming Booklet, and has copies of selected "patterns" included in the Architectural Program (see Attachments 3 & 4 of the Program). Their inclusion in the Architectural Program will make them an effective communication tool for an A & E Firm that is not familiar with Passive Design, and for the 35% design review.

3. Part 3 of the thesis (Conceptual Design for WPAFB Central Technical Library) is an example of the application of the "patterns". The drawings have numerous notes to demonstrate the use of the "patterns".

RECOMMENDATION: Drawings for 35% design reviews should be annotated similarly to the drawings in Part 3. This requirement will serve as a spring board for designer/user discussions during the conceptual design review.

4. In the general information section of CHOOSING THE PATTERN (9), I mentioned that tables 9B, 9C and 9D show the retrofit potential for eight typical Air Force facilities. I have only completed two - 1) Family Housing, Airman's Dorm and Officer Quarters; 2) Base Library, because of time limitations, but they should illustrate how the forms can be used to compare advantages and disadvantages of various basic passive systems.

I found these tables useful several times during design. However, I feel I need to use them more to completely evaluate their usefulness.

RECOMMENDATION: AFESC/DEB and I should decide future action/development after my arrival at HQ MAC/DEEAT.

5. EDUCATION ABOUT PASSIVE SOLAR IS ESSENTIAL AND IS A MUST KNOW ITEM FOR ALL AIR FORCE PERSONNEL AND CIVIL SERVANTS. It is not just for Civil Engineering. Passive Systems requires occupant (housing, offices, etc) participation in one form or another.

The U.S. Department of Energy has produced a new movie - "Sunbuilders", and the New Mexico Solar Energy Association has developed copyrighted material for educational purposes.

RECOMMENDATIONS:

1. One or both of the above movie/slide shows should be manditory training films for anyone occupying government housing quarters. This will allow existing windows to be used as "Passive Solar Collectors", and reduce the need for supplemental heat and cooling.

2. Technical Training at Sheppard AFB.Tx should include curriculum about energy conscious construction techniques. This is essential because good design is only as good as the actual construction techniques. If the construction techniques are poor, then a good design is doomed to failure. For AFESC/DEB - I will send you a construction training curriculum used by USDOE and USDOL in the Project SUEDE Program.

6. Historical research, about ventilation and cooling systems has been a major area of my independent research and was presented in my paper at the 4th National Passive Solar Conference. The two historical systems are in the KING VENTILATION (29) and BREATHING WALL (30) "patterns" of this thesis. The King Ventilation System is a major Architectural feature of my design. The diagram on page 15 of the April 1943 (Appendix S) BRICK AND CLAY RECORD was the historical resource for the following recommendation.

RECOMMENDATION: A "Passive Solar-Building Concept Diagram" should be a required drawing for the 35% design review. In most cases it should be an isometric or axonometric drawing. (see Part 3 of the thesis for an example of this requirement). This diagram should be photo reducible so it can be inserted in the "FACILITY JACKET" in Work Authorization. This will allow rapid evaluation of the impact of a work request (AF FORM 332) upon the passive operation of the building.

7. I personally feel this methodology is good and is workable. The next step for me is to start using this method in my next assignment at HQ.MAC/DEEAT (Autovon 638-5107) on projects that are closer to actual accomplishment than the WPAFB CENTRAL TECHNICAL LIBRARY.

8. I have not considered economics and life cycle cost issues as part of my thesis, because of my requirement to do a building design as part of my Master of Architecture Thesis. My economic design assumption is that passive solar is likely to be cost effective since much of the construction is already

required and is therefore not chargeable to the solar portion of the design; then the critical issue for me, as an Air Force Architect, is to provide Air Force Engineers with a method or rules of thumb for starting the Passive Solar Architectural Programming Process.

Stanley Holcofield

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1. GEOGRAPHIC DETERMINISM

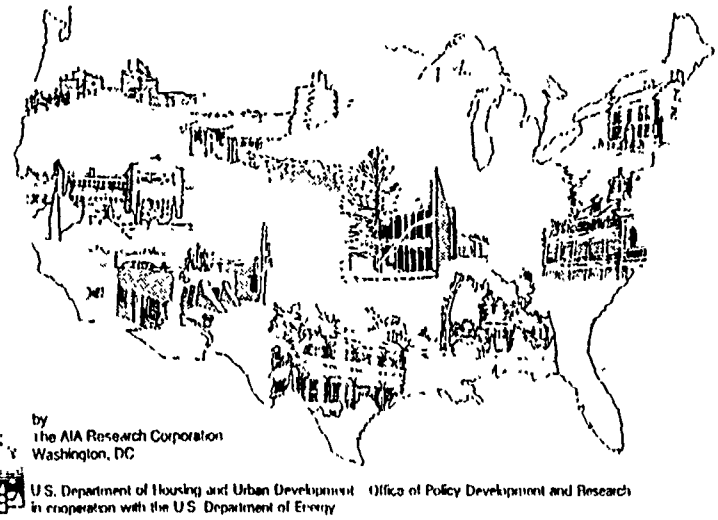


Figure 1-1

LARGE SCALE PATTERNS

This pattern is the starting point for evaluating your building's overall location, shape and orientation, and its relationship to the sun, wind and vegetation.

THE PROBLEM

DEPENDING ON THE GEOGRAPHIC LOCATION OF YOUR BUILDING, DIFFERENT CLIMATIC CONDITIONS CAN BE A LIABILITY OR AN ASSET TO YOUR BUILDING'S ENERGY CONSUMPTION. TO BE MORE SPECIFIC, TEMPERATURE, HUMIDITY LEVELS, WIND VELOCITIES AND SUNSHINE DEFINE THE CLIMATIC ENVIRONMENT YOUR BUILDING MUST OPERATE IN.[1]

THE RECOMMENDATION

USE THE REGIONAL GUIDELINES FOR BUILDING PASSIVE ENERGY CONSERVING HOMES, BY THE AIA RESEARCH CORPORATION (Appendix B), AS A SOURCE OF REGIONAL (INDIGENOUS) ARCHITECTURAL RESPONSES TO CLIMATIC CONDITIONS. THE BOOK DIVIDES THE UNITED STATES INTO 13 CLIMATIC REGIONS, AND CONTAINS RECOMMENDED REGIONAL ENERGY CONSERVING DESIGN PRIORITIES FOR EACH REGION. YOU SHOULD USE THE REGIONAL DESIGN PRIORITIES LISTED FOR YOUR REGION AS A BUILDING AND SITE EVALUATION TOOL.[2,3]

SMALL SCALE PATTERNS

Use BUILDING LOCATION (2) and BUILDING SHAPE AND ORIENTATION (3) in conjunction with this pattern to evaluate your building's response to climatic conditions. You should also refer to the morphologic solutions contained in REGIONAL GUIDELINES FOR BUILDING PASSIVE ENERGY CONSERVING HOMES (Appendix B) to form your own small scale patterns.

ILLUSTRATION

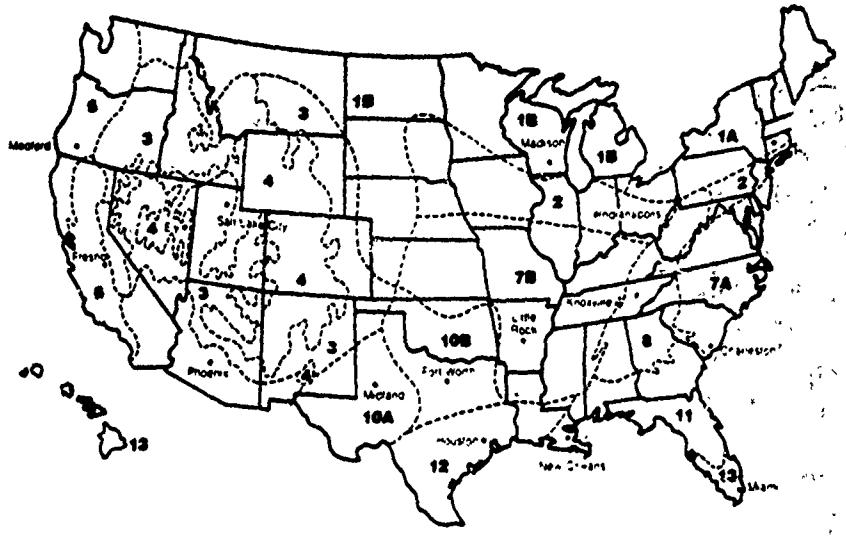


Figure 1-2

INFORMATION

Regional Guidelines for Building Passive Energy Conserving Homes is a new Government Printing Office publication prepared by the AIA Research Corporation for U.S. Department of Housing and Urban Development. This book divides the country into 13 climatic regions, (Fig 1-2) and is a source of regional (indigenous) architectural responses to climatic conditions.

The major feature (for universal use) of this book is the prioritizing of the architectural responses to the regional climatic conditions. These prioritized responses have application to all buildings, not just housing. For example, Wright-Patterson AFB, Ohio and Grissom AFB, Indiana are in Region #2. Their architectural design priorities should be the following:

1. Keep the heat in and the cold temperatures out during winter, and minimize heat loss through material selection, reducing exterior surfaces and through openings.

2. Protect from the wind when it's too cold for comfort - NORTH SIDES (5).

3. Let the sunlight in when it's too cold for comfort and consider passive solar systems - CHOOSING THE SYSTEM (9) for maximum solar heating.

4. Keep hot temperatures out during the summer in the same way you keep cold temperatures out during winter.

5. Protect from the sun when it's too hot for comfort - SHADING DEVICES (25).

6. Open up to cooling breezes when it is too hot for comfort - SUMMER COOLING (27).[3]

You may find your regional description to be inaccurate for your micro-climate. If so, find the regional description most resembling your site micro-climate. Use its regional design priorities for simple application to energy conservation for building retrofit.[2,3]

REFERENCES

1. AIA Research Corporation, Regional Guidelines for Building Passive Energy Conserving Homes, HUD-PDR 355, November 1978, GPO Stock No. S/N 023-000-00481-0. p.3

2. IBID. p.2

3. IBID. p.56-60 (See Appendix B)

4. Victor Olgyay. Design with Climate-Bioclimatic Approach to Architectural Regionalism, Princeton University Press, 1963.

SOURCES OF ILLUSTRATIONS

Figure 1-1, Reference 1.Cover
Figure 1-2, Reference 1.p12

2. BUILDING LOCATION

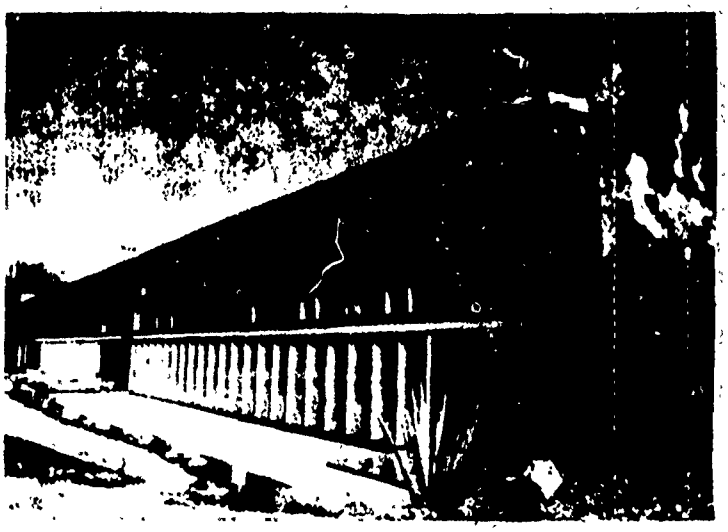


Figure 2-1

LARGE SCALE PATTERNS

Using the idea of Geographic Determinism (1), you should evaluate the location of the existing building and its relationship to open space and the sun. This evaluation is probably the most important evaluation of natural resources at the site you will make for passive solar retrofit.

THE PROBLEM

A BUILDING BLOCKED FROM EXPOSURE TO THE LOW WINTER SUN BETWEEN THE HOURS OF 9:00 am AND 3:00 pm CANNOT MAKE DIRECT USE OF THE SUN'S ENERGY FOR HEATING. DURING THE WINTER MONTHS, APPROXIMATELY 90% OF THE SUN'S ENERGY OUTPUT OCCURS BETWEEN THE HOURS OF 9:00am AND 3:00pm SUN TIME (See Chapter 6 of Ref 2 for an explanation of sun time). FOR EXAMPLE, IN NEW YORK CITY (40 degrees NL) ON A SQUARE FOOT OF SOUTH-FACING SURFACE ON A CLEAR DAY IN THE MONTH OF DECEMBER, 1,610 BTU'S OUT OF A DAILY TOTAL OF 1,724 BTU'S (or 93% of the total) ARE INTERCEPTED BETWEEN THE HOURS OF 9:00am AND 3:00pm. BETWEEN THE HOURS OF 9:30am AND 2:30pm 1,272 BTU'S (or 74% of the total) ARE INTERCEPTED.[1]

THE RECOMMENDATION

TO TAKE ADVANTAGE OF THE SUN IN CLIMATES WHERE HEATING IS NEEDED DURING THE WINTER, USE THE AREAS ON THE SITE THAT RECEIVE THE MOST SUN DURING THE HOURS OF MAXIMUM SOLAR RADIATION - 9:00am TO 3:00pm (SUN TIME). BUILDING IN THE NORTHERN PORTION OF A SUNNY AREA WILL (1) INSURE THAT THE OUTDOOR AREAS PLACED TO THE SOUTH WILL HAVE ADEQUATE WINTER SUN AND (2) HELP MINIMIZE THE POSSIBILITY OF SHADING THE BUILDING IN THE FUTURE BY OFF-SITE DEVELOPMENTS.[1]

SMALL SCALE PATTERNS

Evaluate your building's location within a sunny area and its existing BUILDING SHAPE AND ORIENTATION (3). This evaluation is essential for determining potential for passive solar retrofit. Rearrange the entrance of your building so it receives the greatest protection from the cold winter winds - PROTECTED ENTRANCE (7). You should also consider using the patterns in Appendix C from A Pattern Language by Christopher Alexander.

ILLUSTRATION

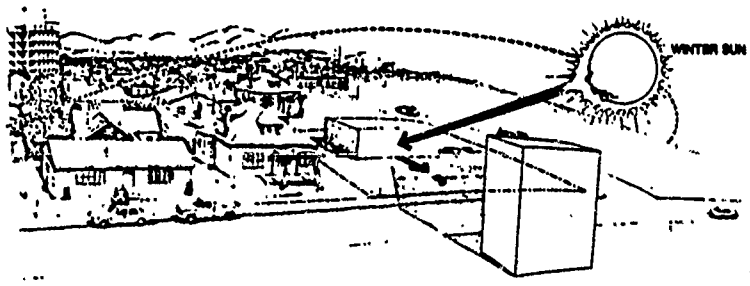


Figure 2-2

INFORMATION

To use the sun for winter heating, you should evaluate how your building relates to other buildings, conifer trees, hills or anything else blocking the low winter sun. To do this, you can use a Solar Pathfinder™ (See Appendix C) or the sun charts ("Plotting the Skyline") in chapter six of the Passive Solar Energy Book-Expanded Professional Edition by Edward Mazria.

If you use the Solar Pathfinder you can photograph solar obstructions, and use the photograph as a design tool.

You will not have to use either method (Solar Pathfinder or Plotting the Skyline) if the southern skyline is low and has no obstructions: abruptly rising hills, conifer trees, or deciduous trees with large branches.

To bring life to your site and building you should refer to the patterns of Christopher Alexander's in Appendix C. After reading them, you will see the south side of your building as a valuable outdoor space on a sunny day, in addition to collecting solar radiation.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, PA, 1979. pp73-75.

2. Christopher Alexander, A Pattern Language, Oxford University Press, New York, N.Y., 1977 (See Appendix C); and Christopher Alexander.. The Oregon Experiment, Oxford University Press, New York, N.Y., 1975.

SOURCES OF ILLUSTRATIONS

Figure 2-1. Passive Solar Buildings. Sandia Laboratories, Albuquerque, N.M., and Livermore, Ca. For the USDOE under Contract DE-AC04-76DP00789. July 1979. p.91.

Figure 2-2. Reference 2. p. 74.

3. BUILDING SHAPE AND ORIENTATION



Figure 3-1

LARGE SCALE PATTERNS

Using the ideas of GEOGRAPHIC DETERMINISM (1), BUILDING LOCATION (2) and the patterns in Appendix C, you should evaluate the buildings shape and orientation for potential to admit natural light and inducing natural ventilation before laying out interior spaces.

THE PROBLEM

BUILDINGS SHAPED WITHOUT REGARD FOR THE SUN'S IMPACT, AND NATURAL LIGHT AND VENTILATION, REQUIRE LARGE AMOUNTS OF ENERGY TO HEAT AND COOL.

THE RECOMMENDATION

FOR PASSIVE SOLAR RETROFIT, YOU SHOULD EVALUATE THE SHAPE OF YOUR BUILDING FOR ADMITTING SUNLIGHT AND INDUCING VENTILATION. AN ELONGATED BUILDING ALONG THE EAST-WEST AXIS, IN ALL CLIMATES, MINIMIZES HEATING AND COOLING REQUIREMENTS. A SLOPED ROOF WILL HELP INDUCE VENTILATION BY INCREASING WIND GENERATED SUCTION AND "STACK EFFECT".

SMALL SCALE PATTERNS

Evaluate your building shape and orientation with the following small scale patterns: HISTORICAL BUILDING TYPE SOLUTIONS (4), Christopher Alexander's patterns contained in Appendix D, LOCATION OF INTERIOR SPACES (6), PROTECTED ENTRANCE (7) and, LOCATION OF WINDOWS (8). Using the roof to admit sunlight allows flexibility to distribute heat and light to various parts of a space - CLERESTORIES AND SKYLIGHTS (12). This allows flxibility to locate thermal mass within a space - MASONRY HEAT STORAGE (13) and INTERIOR WATER WALLS (14). Building shape and orientation also can induce ventilation - SUMMER COOLING (27) and KING VENTILATION SYSTEM (29).

ILLUSTRATION

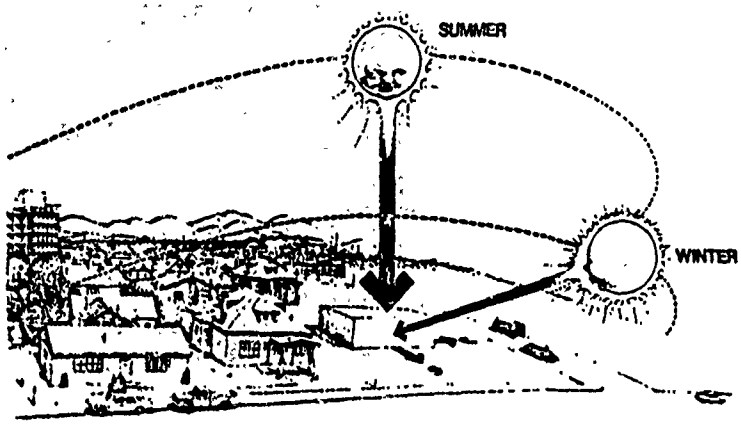


Figure 3-2

INFORMATION

Victor Olgyay in his book Design with Climate, investigated the effect of thermal impacts (sun and temperature) on building shapes in the United States. He drew the following conclusions:

1. The square is not the optimum shape in any location.

2. Buildings elongated on the north-south axis are less efficient (summer and winter) than a square.

3. The optimum shape in all climates is elongated along the east-west axis.[1]

You should refer to Appendix D for expanded information.

Elongating the east-west axis gives the southern wall good sun exposure for maximum winter heat gain, and reduces the east and west wall surface area, thereby minimizing summer heat gain in the morning and afternoon. During the winter, in the northern hemisphere (32 degrees to 56 degrees), the southern side of the building receives nearly 3 times as much solar radiation as the east and west sides of the building. The situation is reversed in the summer, with the roof and the east and west walls receiving the majority of the solar radiation.

Studies by the Illuminating Engineering Society show the space depth range should be 2 to 2½ times the window height (from the floor to the top fo the window) if the primary source of natural light is from south-facing windows. This means a maximum space depth of 14 to 18 feet for an average window height of 7 feet.

If the major spaces of your building are placed along the south wall (for sunlight requirements) and the buffer spaces placed along the north wall, then the maximum depth of the building will be roughly 25 to 30 feet.[2]

If your building is over 30 feet deep, or if you do not want large south-facing windows with direct light shining through the space, then the use of operable south-facing CLERESTORIES AND SKYLIGHTS (12) gives you flexibility to distribute light and heat to different parts of the interior. Also, they help induce ventilation and NATURAL SUMMER COOLING (27).[2]

NOTE: Many Air Force building projects (including additions) handled by the Corp of Engineers will probably use Pre-Engineered Buildings (PEB). The use of the Pattern - BUILDING SHAPE AND ORIENTATION - is essential for accomodating the natural radiation, convection, and conduction processes. You should read Reference #7 (in Appendix D) to see what is currently being done in the area of Passive Solar PEB's.

REFERENCES

1. Victor Olgyay. Design with Climate, Princeton University Press, Princeton, NJ, 1963. pp86-90 (See Appendix D).

2. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, PA, 1979 pp79-84.

3. Christopher Alexander. A Pattern Language, Oxford University Press, New York, NY, 1977 (See Appendix D); and Christopher Alexander. The Oregon Experiment, Oxford University Press, New York, NY, 1975.

4. Professor F.H. King. Ventilation for Dwellings, Rural Schools and Stables. Published by Author, 1908. p.50.

5. "Passive Design Handbook". New Mexico Solar Energy Association.

6. Doug Balcomb and Bruce Anderson. "Passive Heating and Cooling Handbook". February 1980 (being developed on USDOE contract).

7. Bruce Baccei. "Mass Produced Lowcost Passive Buildings," Solar Age, December 1979. pp 25-27.
NOTE: Bruce Baccei is a former Army Corp of Engineers Major, and is the author of Energy Conscious Design, U.S. Army Corp of Engineers, Norfolk District, Norfolk, Va.

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SOURCE OF ILLUSTRATIONS

Figure 3-1. Passive Solar Buildings. Sandia Laboratories, Albuquerque, NM, and Livermore, CA. For the USDOE under Contract DEAC04-76DP00789. July 1979. p.79.

Figure 3-2 Reference #2. p 80.

4. HISTORICAL BUILDING TYPE SOLUTIONS

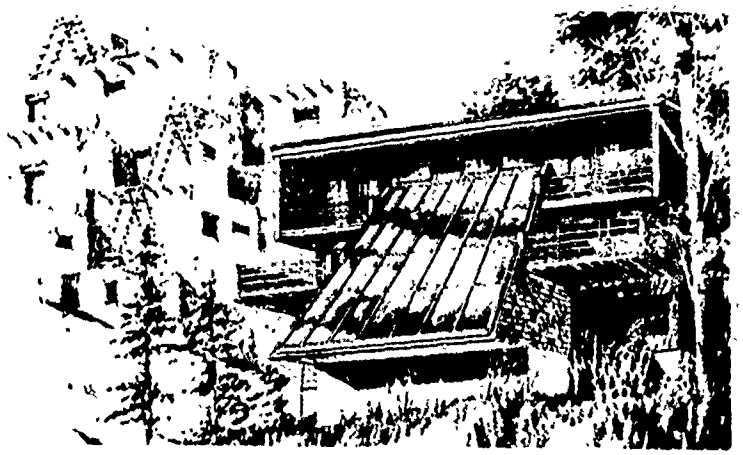


Figure 4-1

LARGE SCALE PATTERNS

Using the idea "There's nothing new under the sun", Architectural History has many answers to our present day energy problems, if you will only apply them. One of our founding fathers- Thomas Jefferson- was an avid student of Architectural History, and applied that knowledge in Monticello. It serves as an example of the application of historical environmental controls, which we can all learn from. This pattern describes how you can do historical research about your building type's use of natural heating, ventilation and lighting.

THE PROBLEM

PRIOR TO THE EMERGENCE OF THE "MODERN ARCHITECTURE" MOVEMENT, AROUND 1920, BUILDINGS WERE SHAPED AND ORIENTED SO THEY RESPONDED TO THEIR NATURAL ENVIRONMENT. BUILDINGS WERE PATTERNS BASED ON INTUITIVE OBSERVATIONS OF HOW TO CONTROL THE ENVIRONMENT, AND WERE AN APPLICATION OF THE CONCEPT OF GEOGRAPHIC DETERMINISM (1) AND APPROPRIATE MATERIALS (10). THE OLD BUILDING TYPE PATTERNS WERE DISCARDED BY "MODERN ARCHITECTURE", AND HAVE BEEN LOST TO SEVERAL GENERATIONS OF ARCHITECTS AND ENGINEERS. YOUR TASK IS TO KNOW HOW THE ENVIRONMENT WAS CONTROLLED NATURALLY BY YOUR BUILDING TYPE, SO YOU CAN APPLY IT TO YOUR BUILDING IF AT ALL POSSIBLE.[2,3]

THE RECOMMENDATION

AS PART OF YOUR BACKGROUND INFORMATION FOR PROGRAMMING YOUR BUILDING TYPE, YOU SHOULD DO A QUICK REVIEW OF THE HISTORICAL BUILDING TYPE SOLUTIONS FOR YOUR BUILDING TYPE. THE RESEARCH CAN BE USEFUL IF APPLIED PROPERLY TO YOUR RETROFIT PROGRAMMING AND DESIGN.[2,3]

SMALL SCALE PATTERNS

The application of this pattern could be useful to you with LOCATION OF INDOOR SPACES (6), WINDOW LOCATION (8), SOLAR WINDOWS (11), CLERESTORIES AND SKYLIGHTS (12), MOVABLE INSULATION (23) and SHADING DEVICES (25).

INFORMATION

Prior to 1920, every building type got its structure from its patterns.

> "A barn gets its structure from its patterns....And an expensive restaurant gets its structure and character from its particular patterns, too.[1]"

Some architectural history knowledge of your building type is necessary if you are going to effectively deal with energy conservation, in the programming of your retrofit project. A quick historical review of your building type should be part of your programming process. Hopefully, the historical research can be useful, if applied properly to the retrofit.

Ideally, you have an architect in your programming office. If you do, he or she will be familiar with procedures to do historical research, (architects are required to take one year of architectural history).

If you do not have an architect, then the following list of bibliographic resources might be useful to guide your research.

1. General card catalog.
2. Art index.
3. Applied Science and Technology Index.
4. Avery Architectural Index.
5. Harvard Graduate School of Design Index.

Another excellent resource is the United States Military Academy Archives at West Point, New York. The Archives has extensive documentation of their buildings, and should not be overlooked in your retrofit programming of your building.

Two patterns dealing with passive cooling and ventilation systems-KING VENTILATION SYSTEM (29) and BREATHING WALL (30) - were re-discovered by a non-standard process described in Reference 2 (See Appendix E).

Once you have your material, write your own Historical Building Type Solution(s) pattern using the format described in the introduction. Refer to Appendix E for an example - Historical Library Solution.

REFERENCES

1. Christopher Alexander. A Pattern Language, Oxford University Press, New York, NY, 1977.p.96.

2. Stanley H. Scofield, Captain, USAF. "A Historical Review of Natural Ventilation in a Humid Climate," 4th National Passive Solar Conference Proceedings, Kansas City, Mo, October 3-5, 1979. pp. 504-506 (See Appendix E.)

3. Kevin W. Green. "Passive Cooling", Research and Design-The Quarterly of the AIA Research Corp. Vol II, No.3, Fall 1979 pp5-9.

SOURCE OF ILLUSTRATIONS

Figure 4-1 Sunset Homeowner's Guide to Solar Heating, Lane Publishing Company, Menlo Park, Ca, 1978 p.4.

5. NORTH SIDE

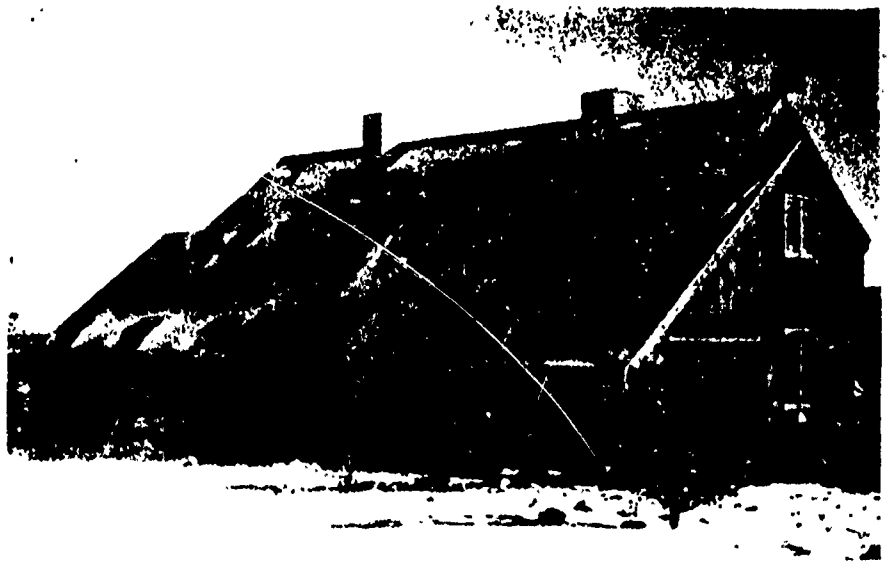


Figure 5-1

LARGE SCALE PATTERNS

Even though your building might already be located in the northern portion of a sunny site - BUILDING LOCATION (2) the northern outdoor space needs sunlight to make it alive. When evaluating the BUILDING SHAPE AND ORIENTATION (3) you should consider the building's impact on outdoor spaces to the north.

THE PROBLEM

THE NORTH SIDE OF A BUILDING IS THE COLDEST, DARKEST AND USUALLY THE LEAST USED SIDE BECAUSE IT RECEIVES NO DIRECT SUNLIGHT ALL WINTER.

THE RECOMMENDATION

IF POSSIBLE, RE-SHAPE THE NORTH SIDE OF YOUR BUILDING BY EARTH BERMING AGAINST THE NORTH FACE OF YOUR BUILDING OR BY SLOPING THE ROOF TOWARD THE NORTH. THE GOAL IS TO REDUCE THE AMOUNT OF EXPOSED NORTHERN WALL. BERMING WILL REDUCE THE NORTHERN WALL HEIGHT. USE A LIGHT-COLORED WALL (OR NEARBY STRUCTURE) TO THE NORTH TO REFLECT LIGHT INTO NORTH-FACING ROOMS AND OUTDOOR SPACES.

SMALL SCALE PATTERNS

Locate spaces with small lighting and heating requirements on the north. These spaces act as a buffer between the occupied spaces and the cold north wall of the building - LOCATION OF INDOOR SPACES (6). You should provide INSULATION ON THE OUTSIDE (26) of the structure so the thermal mass will retain heat, and not loose it to the berming. However berming (soil) can be used for reducing heat loss to wind - APPROPRIATE MATERIAL (10).

ILLUSTRATION

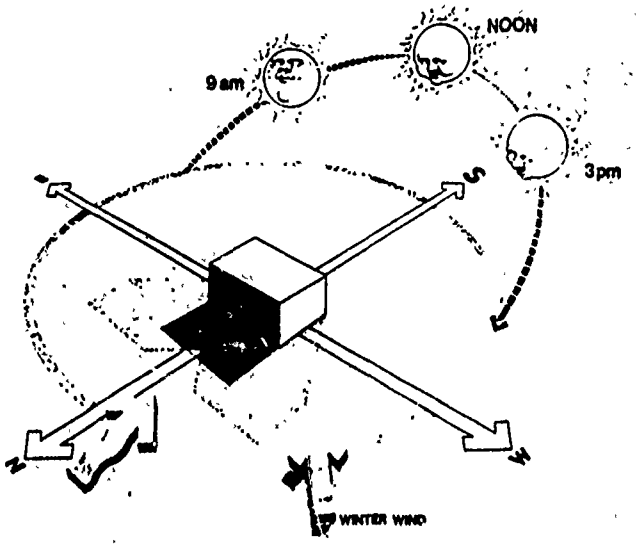


Figure 5-2

INFORMATION

People do not use spaces in continual shade for most of the winter.

There are ways for you to retrofit and make these places alive and useful. For example, you can use earth berming against the north wall to reduce or eliminate the shadow cast by your building. Berming on the north will do the following: provide sunlight on the north side of the building, reduces heat loss through the wall in the winter, and prevents heat gain in the summer. Berming of the north wall also protects your building from prevailing winds from the north and/or west in the Continental United States.

When you provide earth berming, you must also provide INSULATION ON THE OUTSIDE (26). "This is done to enable the structural mass to store some of the building's heat, thus lowering the building's peak heating (and cooling) loads."[1]

REFERENCES

1. Malcolm Wells. Malcolm Wells Underground Designs, printed by Malcolm Wells, Box 1149, Brewster, MA 02631, 1977.

2. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition Rodale Press, Emmaus, PA, 1979.p86-89.

3. Christopher Alexander. A Pattern Language, Oxford University Press, New York, NY, 1977. pp761-763.

SOURCES OF ILLUSTRATIONS

Figure 5-1. Passive Solar Buildings. Sandia Laboratories, Albuquerque, NM, and Livermore, Ca. For the USDOE under contract DE-AC04-76DP00789. July 1979. p.80.

Figure 5-2. Reference #2. p.88.

6. LOCATION OF INDOOR SPACES



Figure 6-1

LARGE SCALE PATTERNS

Using the ideas of BUILDING LOCATION (2), BUILDING SHAPE AND ORIENTATION (3), and HISTORICAL BUILDING TYPE SOLUTIONS (4) you need to place interior spaces within the shape according to their requirements for heat and sunlight. This placement of interior spaces might indicate some possible changes of BUILDING SHAPE AND ORIENTATION (3).

THE PROBLEM

CONVENTIONAL ENERGY CONSUMPTION IS PROPORTIONALLY HIGHER IN SPACES NOT USING SUNLIGHT DIRECTLY OR PASSIVELY FOR HEATING DURING THE WINTER MONTHS. THE MORE DIRECT SUNLIGHT USED TO HEAT A SPACE, THE LESS CONVENTIONAL ENERGY IS REQUIRED FOR SPACE HEATING. THIS ALSO APPLIES TO ACTIVE SOLAR-HEATING SYSTEMS. IF THE DESIGN OF A SPACE DOES NOT DIRECTLY OR PASSIVELY TAKE ADVANTAGE OF THE WINTER SUN TO SUPPLY SOME OF ITS HEATING REQUIREMENTS, AN ACTIVE SOLAR-HEATING SYSTEM WILL BE PROPORTIONALLY MORE EXPENSIVE, AND LARGER.

THE RECOMMENDATION

INTERIOR SPACES CAN BE SUPPLIED WITH MUCH OF THEIR HEATING AND LIGHTING REQUIREMENTS BY PLACING THEM ALONG THE SOUTH FACE OF THE BUILDING, THUS CAPTURING THE SUN'S ENERGY DURING DIFFERENT TIMES OF THE DAY. PLACE ROOMS TO THE SOUTHEAST, SOUTH AND SOUTHWEST, ACCORDING TO THEIR REQUIREMENTS FOR SUNLIGHT. THOSE SPACES HAVING MINIMAL HEATING AND LIGHTING REQUIREMENTS SUCH AS CORRIDORS AND CLOSETS, WHEN PLACED ALONG THE NORTH FACE OF THE BUILDING, WILL SERVE AS A BUFFER BETWEEN THE HEATED SPACES AND THE COLDER NORTH FACE.[1]

SMALL SCALE PATTERNS

Evaluate your building's openings (in walls and roof) to admit sunlight and provide ventilation - WINDOW LOCATION (8), PROTECTED ENTRANCE (7) and CLERESTORIES AND SKYLIGHTS (12), and at the same time choose the most appropriate passive solar heating system for each space - CHOOSING THE SYSTEM (9). If an attached greenhouse is to be integrated into your building - SIZING THE GREENHOUSE (17), place it along the south face of the building for maximum exposure to the winter sun. You should also consider using the patterns in Appendix F (from A Pattern Language by Christopher Alexander). EXISTING SHADING DEVICES (25) should also be evaluated.

ILLUSTRATION

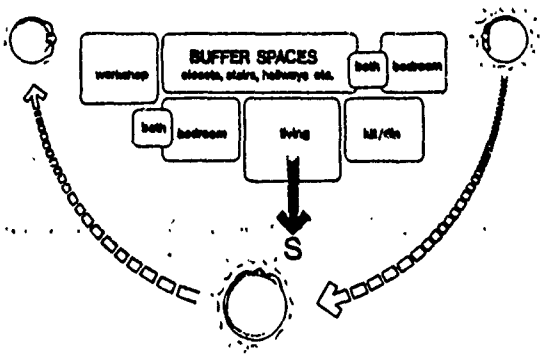


Figure 6-2

INFORMATION

During the winter, the microclimatic conditions along the sides of a building (outside walls) are the key to the location of indoor spaces. The north side of a building remains the coolest during the winter because it receives no direct sunlight. The east and west sides of a building receive equal amounts of direct sunlight for half-a-day since the sun's path across the sky is symmetrical along the southern axis. But over the period of a day, the west side will be slightly warmer than the east side because of the combination of solar radiation and higher afternoon air temperatures. The south side of a building will be the warmest and sunniest during the winter because it receives sunlight throughout the day. Common sense tells us to place spaces with specific heating and lighting requirements along the side of the building which has microclimatic conditions that can easily satisfy those requirements.

The south side of a building is a good location for spaces that are continually occupied during the day. These spaces usually have large heating and lighting requirements. Since the south face of

a building receives nearly 3 times as much sunlight in the winter as the east and west sides, spaces placed along the south face can make direct use of the sun's energy to fill these requirements. Also, the extent to which as continually used space is felt as bright, sunny and cheerful will depend upon the amount of direct sunlight it receives.

Arrange these spaces to the south, southeast and southwest according to your own special requirements for sunlight. For example, in a residence, orient a breakfast area to the southeast for good morning sunlight, a common area (living room) which is used throughout the day to the south, and a workshop that is used only late in the day to the southwest. Placing the frequently inhabited spaces to the south means the building will be elongated along the east-west axis. Spaces needing sunlight that are not located along the south face of a building can receive direct sunlight through south-facing CLERESTORIES AND SKYLIGHTS (12).

To bring life to the interior of your building, you should also consider using the patterns in Appendix F from A Pattern Language by Christopher Alexander.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, PA, 1979. p.90-92.

2. Christopher Alexander. A Pattern Language, Oxford University Press, New York, NY, 1977, (See Appendix F).

SOURCES OF ILLUSTRATIONS

Figure 6-1. Passive Solar Buildings. Sandia Laboratories, Albuquerque, NM, and Livermore, CA, for the USDOE under Contract DE-AC04-76DP00789. July 1979. p.20.

Figure 6-2. Reference #1. p 91.

7. PROTECTED ENTRANCE

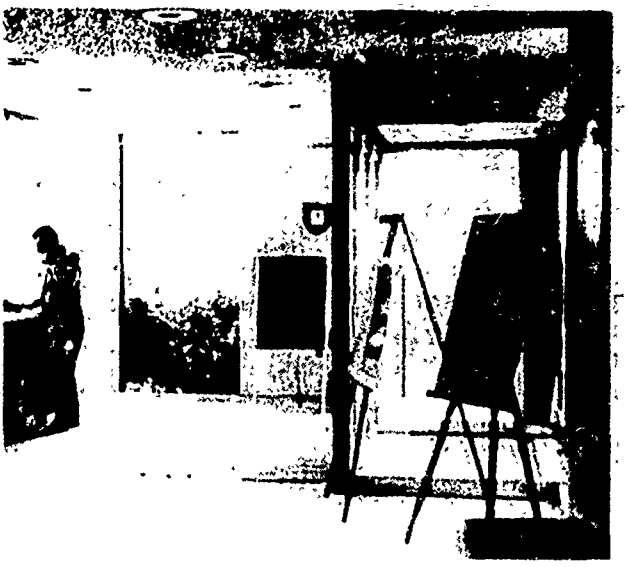


Figure 7-1.

LARGE SCALE PATTERNS

Using the ideas of BUILDING LOCATION (2), BUILDING SHAPE AND ORIENTATION (3) and LOCATION OF INDOOR SPACES (6) you can evaluate your building's entry. This pattern describes the thermal criteria for locating the entrance and provides information for its design.

THE PROBLEM

IN WINTER, A GREAT QUANTITY OF COLD OUTDOOR AIR ENTERS A BUILDING THROUGH CRACKS AROUND THE ENTRANCE DOOR AND FRAME AS WELL AS EACH TIME THE DOOR IS OPENED. ALL EDGES AROUND ENTRANCES LEAK AIR. THROUGH THESE CRACKS WARM INDOOR AIR IS EXCHANGED WITH COLD OUTDOOR AIR. WHEN AN ENTRANCE DOOR IS OPENED, A LARGE QUANTITY OF OUTDOOR AIR ENTERS THE ADJOINING SPACE. FOR SMALL COMMERCIAL BUILDINGS, SUCH AS SHOPS AND OFFICES, THE HEAT LOSS THROUGH ENTRANCE DOORS WILL BE GREATER THAN 10% BECAUSE OF INCREASED TRAFFIC INTO AND OUT OF THE BUILDING.[1]

THE RECOMMENDATION

MAKE THE MAIN ENTRANCE TO THE BUILDING A SMALL ENCLOSED SPACE (VESTIBULE OR FOYER) THAT PROVIDES A DOUBLE ENTRY OR AIR LOCK BETWEEN THE BUILDING AND EXTERIOR. THIS WILL PREVENT A LARGE QUANTITY OF WARMED (OR COOLED) AIR FROM LEAVING THE BUILDING EACH TIME A DOOR IS OPENED. THE INFILTRATION OF COLD AIR THAT OCCURS AROUND EXTERIOR DOORS WILL BE VIRTUALLY ELIMINATED BECAUSE THE ENTRY CREATES A STILL-AIR SPACE BETWEEN THE INTERIOR AND EXTERIOR DOORS. ORIENT THE ENTRANCE AWAY FROM THE PREVAILING WINTER WINDS OR PROVIDE A WINDBREAK TO REDUCE THE WIND'S VELOCITY AGAINST THE ENTRANCE. MAKE USE OF THE ENTRY SPACE FOR THE STORAGE OF UNHEATED ITEMS, AS A PLACE TO REMOVE WINTER CLOTHING OR FOR ACTIVITIES THAT REQUIRE LITTLE SPACE HEATING.[1]

SMALL SCALE PATTERNS

If the entry is large and supports other activities, provide a way to passively heat the space in winter - CHOOSING THE SYSTEM (9) and to passively cool the space in the summer - SUMMER COOLING (27). You should also use ANSI Standard A-117.1 - Specifications for Making Buildings and Facilities Accessible to and Usable by the Physically Handicapped - and consider using the patterns in Appendix G from A Pattern Language by Christopher Alexander.

ILLUSTRATION

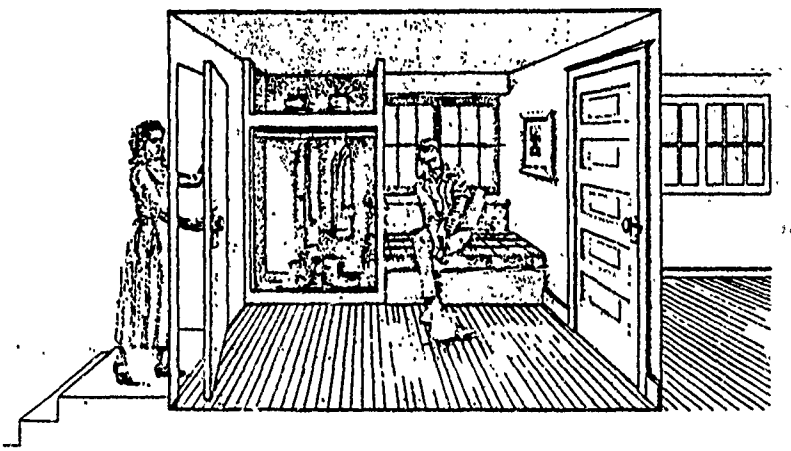


Figure 7-2

INFORMATION

Providing an air lock or double entry will decrease the heat loss due to both infiltration and conduction. A double entry has two doors, one that opens to the exterior and one to the interior of the building, trapping a still-air space between them. Since the interior entrance to the building faces a still-air space, infiltration is minimized. Also, when the exterior door is opened, only the small quantity of unheated air in the entry is exchanged with cold outdoor air, thus the spaces near entrance doors are protected from becoming cold and drafty each time a person enters the building. During the summer, the double entry works in reverse, keeping cooled indoor air from being replaced by hot outdoor air. A double entry or entry space, when properly designed, can serve other functions besides the reduction of heat loss. It can also be a place to leave frequently used items, and a protected place to wait for transportation. When arriving and leaving a building, people need a transition space to accommodate a number of activities, such as removing and storing outer garmets.

Protecting the building's entrance from winter winds and sealing edges around the door frame as tightly as possible will minimize heat transfer. The rate of infiltration of cold air through an

entrance increases as the velocity of the wind against the entrance increases. In the Northern Hemisphere the prevailing winter winds are usually from the north and/or west (check with your base Weather Detachment for the direction of the prevailing winter winds). Entrances placed on the east and south sides of a building will be protected from the wind's impact. If an entrance is placed on the north or west side of the building, careful siting of a windbreak (dense evergreen planting or solid fence), recessing the entrance into the building or the addition of wing walls will reduce the wind's velocity and impact.

Weather stripping, when properly applied, prevents air leakage by making a weathertight seal between the exterior door and door frame. Caulking should be applied around the door frame and the wall to prevent air leakage through these joints. By providing an effective seal around the edges of the door and frame, infiltration at the entry can be reduced by as much as 50%.[1]

Place the main entrance of the building at a point where it can be seen immediately from the main avenues of approach and give it a bold, visible shape which stands out in front of the building.[2]

You should evaluate your building's entry for meeting the requirements of ANSI STANDARD A-117.1.[3]

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, PA, 1979. pp 94 & 97

2. Christopher Alexander. A Pattern Language, Oxford University Press, New York, NY, 1977 (See Appendix G). p 544.

3. AFM 88-15(C6), paragraph 1-31.

4. Ashrae Fundamentals, 1977, Chapter 21. (Infiltration)

SOURCES OF ILLUSTRATIONS

Figure 7-1. AFIT Engineering Building WPAFB, OH. Photo by Stanley H. Scofield, Capt., USAF.

Figure 7-2. Reference 1.p.95.

8. WINDOW LOCATION



Figure 8-1

LARGE SCALE PATTERNS

Using the ideas of BUILDING SHAPE AND ORIENTATION (3), HISTORICAL BUILDING TYPE SOLUTIONS (4) and LOCATION OF INDOOR SPACES(6) you can evaluate the existing window openings.

THE PROBLEM

ONE OF THE LARGEST SINGLE FACTORS AFFECTING BUILDING ENERGY CONSUMPTION IS THE LOCATION AND SIZE OF WINDOWS. WINDOWS PLACED WITHOUT CONSIDERING THE AMOUNT OF SUNLIGHT THEY ADMIT WILL USUALLY BE AN ENERGY DRAIN ON THE BUILDING. IN WINTER THE HEAT LOSS THROUGH A WINDOW IS LARGE COMPARED TO THE HEAT LOSS THROUGH A WELL-INSULATED WALL. THE HEAT LOSS THROUGH A WINDOW IS BASICALLY THE SAME REGARDLESS OF THE DIRECTION IT FACES. THEREFORE, WINDOW PLACEMENT IS IMPORTANT SO THE HEAT GAIN (FROM SUNLIGHT) IS GREATER THAN THE HEAT LOSS. DURING THE SUMMER, WINDOWS NEED EXTERIOR SHADING FROM THE SUN TO REDUCE HEAT GAINS BY THE "GREENHOUSE EFFECT" OF GLASS.

THE RECOMMENDATION

LOCATE MAJOR WINDOW OPENINGS TO THE SOUTHEAST, SOUTH AND SOUTHWEST ACCORDING TO THE INTERNAL REQUIREMENTS OF EACH SPACE. ON THE EAST, WEST AND ESPECIALLY THE NORTH SIDE OF THE BUILDING, KEEP WINDOW AREAS SMALL AND USE DOUBLE GLASS. WHEN POSSIBLE, RECESS WINDOWS TO REDUCE HEAT LOSS.

SMALL SCALE PATTERNS

You can also admit light through south-facing CLERESTORIES AND SKYLIGHTS(12) and store the heat in MASONRY HEAT STORAGE(13) of INTERIOR WATER WALLS(14). Use MOVABLE INSULATION(23) over

large glass areas at night to prevent the heat gained during the day from escaping at night. Locate trees, vegetation and SHADING DEVICES (25) to keep out direct summer sun light. You might consider using the patterns in Appendix H. Also you should identify the position for operable windows, clerestories and skylights to provide adequate ventilation for SUMMER COOLING(27).

ILLUSTRATIONS

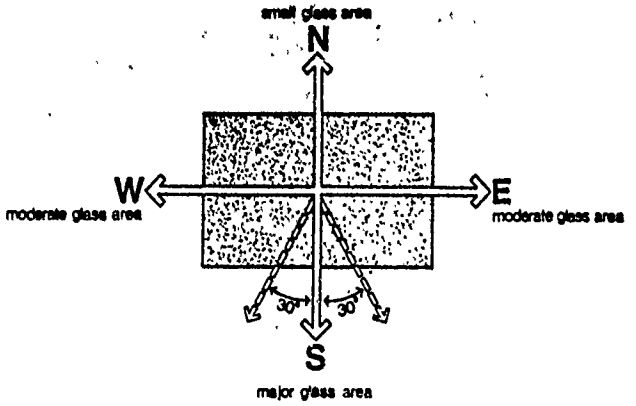
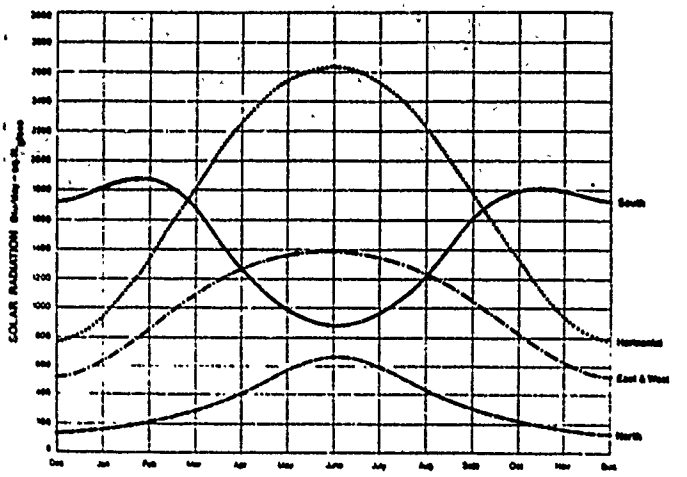


Figure 8-2



Note: This graph represents clear day solar radiation values, on the surfaces indicated, for 40°NL.

Figure 8-3

INFORMATION

The best orientation for major glass areas of a building provides the maximum amount of solar radiation (heat gain) in the winter and the minimum amount in the summer. According to BUILDING SHAPE AND ORIENTATION(2), the south side of a building receives nearly 3 times more solar radiation in winter than any other side. During the summer the situation is reversed and the south side receives much less radiation in comparison to the roof and east and west sides of the building. There are two reasons for this. First, there are more hours of incident sunlight striking the south face of a building in winter than in summer, even though summer days are longer and have more hours of daylight (refer to fig. 8-3). And second, since the sun is lower in the sky during the winter, the sun's rays striking the south face of the building are closer to perpendicular than in the summer when the sun is higher in the sky. Because of this, a square foot of vertical south-facing surface will receive a greater amount of solar radiation during the same hour in winter than in summer. Since the sun's rays striking the surface of a window are closer to perpendicular in winter, the percentage of solar radiation transmitted through the window is greater than in summer. These seasonal characteristics of south glazing insure a degree of automatic control for solar collection.

The optimum window orientation for solar gain is due south. However, variations to the east or west of south, up to 30 degrees,

will reduce performance only slightly. (Fig.8-2). Larger variations, though, will reduce window performance substantially. The heat gained from sunlight during the winter through south-facing glass will exceed the heat loss, in most climates.

Openings should be carefully placed according to the light and heating requirements of each space. For example, a sleeping area may require some southeast or east openings to admit early morning sunlight and heat into the space. It is important to note that east- and west-facing single or double pane windows either come out even or lose heat during the winter in most climates. Since there is no direct sunlight in winter on the north side of a building, north-facing windows are a continuous heat drain.[1]

You should simultaneously evaluate the natural lighting, heat/ventilation requirement for each space, while evaluating the potential of existing windows to provide natural heating and ventilation.

The patterns in Appendix H can be used as additional patterns to give you a variety of window types and give life to your building, while solving functional requirements.

The solar radiation calculator in the separate pocket (of the Passive Solar Energy Book - Expanded Professional Edition) is a quick graphic method for determining the amount of hourly or daily radiation intercepted by a surface facing in different directions. Of course the location and size of windows will be influenced by other considerations as well, such as views, privacy and natural lighting. The Libbey Owens Ford "Sun Angle Calculator" can also be used as a design tool.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Ammaus, PA, 1979.

2. Christopher Alexander. A Pattern Language, Oxford University Press, New York, NY, 1977 (See Appendix H).

SOURCES OF ILLUSTRATIONS

Figure 8-1. Dr. Wm. T. Bolton House, 1906, by Greene and Greene. Photograph courtesy of Document Collection, College of Environmental Design, U. of California-Berkeley.

Figure 8-2. Reference 1. p.102

Figure 8-3. Reference 1. p.103

9. CHOOSING THE SYSTEM

LARGE SCALE PATTERNS

This pattern starts a series of patterns to provide criteria for passive system selection and detailing of retrofit design. After you have roughly arranged the indoor spaces - LOCATION OF INDOOR SPACES (6), you should select a passive heating system for each space before proceeding with your building retrofit. Since a passive system is architectural in nature, you must include it at the beginning of the design process. This pattern describes each of the five basic passive systems in general terms.

THE PROBLEM

WHICH IS THE BEST PASSIVE SYSTEM TO USE? THIS QUESTION IS ONE OF THE MOST LOADED QUESTIONS YOU CAN ASK ABOUT PASSIVE SOLAR HEATING. IT WILL GENERATE HEATED DISCUSSIONS AND MUCH DISAGREEMENT. TO PROVE A POINT, PEOPLE WILL DEFEND THEIR SYSTEM TO THE LAST BTU. WHICH IS THE BEST SYSTEM? WHEN PROPERLY ANALYZED, EACH SPACE OR BUILDING WILL REQUIRE A PARTICULAR SYSTEM BEST SUITED TO ITS ARCHITECTURAL AND THERMAL NEEDS.

THE RECOMMENDATION

EACH SYSTEM HAS SPECIFIC DESIGN OPPORTUNITIES AND DESIGN LIMITATIONS. CHOOSE A PARTICULAR SYSTEM THAT SATISFIES MOST OF THE DESIGN REQUIREMENTS YOU GENERATE FOR EACH SPACE. REMEMBER THAT DIFFERENT SYSTEMS CAN BE USED FOR DIFFERENT SPACES AND/OR SYSTEMS CAN BE COMBINED TO HEAT ONE SPACE. THE INFORMATION SECTION OF THIS PATTERN GIVES AN ASSESSMENT OF EACH SYSTEM'S RETROFIT POTENTIAL FOR USE IN TYPICAL U.S. AIR FORCE FACILITIES.

SMALL SCALE PATTERNS

Recommended sizing procedures for each system are given in SOLAR WINDOWS (11), CLERESTORIES AND SKYLIGHTS (12), SIZING THE WALL (15), SIZING THE GREENHOUSE (17), and SIZING THE ROOF POND (19). When desirable, a combination of systems can be used to heat a space - COMBINING SYSTEMS (21). To prevent overheating, use SHADING DEVICES (25) - reduce solar heat gain. If your building has a year around ventilation requirement, you should consider the following: EARTH TUBES (28), KING VENTILATION SYSTEM (29), SOLAR CHIMNEY (31) and SOLAR DEHUMIDIFIER (32) as passive methods of inducing ventilation. You should also assess the climatic effects of mold growth, animal entry, etc., when considering ventilation systems.

GENERAL INFORMATION

The THERMAL STORAGE WALL (9B) and ATTACHED GREENHOUSE (9C) have universal retrofit application for the Air Force. The ROOF POND SYSTEM (9D) has good retrofit potential, but does not have universal application because of varying roof configurations, structural limitations for supporting water, and climatic variations.

Tables 9B, 9C, and 9D show the retrofit application potential of the THERMAL STORAGE WALL SYSTEM, ATTACHED GREENHOUSE, and ROOF POND SYSTEM to the following typical Air Force facilities: 1) Family Housing/Airman's Dorms/Officer's Quarters; 2) Base Library; 3) Offices/Administration; 4) Air Force Educational Classrooms; 5) Food Services/NCO & Officers Clubs; 6) Police/Fire Stations; 7) Air Passenger Terminals; 8) Shops and Warehouses.

The other two passive solar systems - DIRECT GAIN (9A) and CONVECTIVE LOOP (9E) - have limited retrofit potential in the Air Force and will be explained in their respective sections of this pattern.

Since the Arab oil embargo of 1973-74, passive solar system development, and retrofit have been centered in housing, because of its small size and immediate application potential.

Public Law 95-619 requires all federal buildings over 1000 square feet to be retrofitted by 1990, and the Air Force Energy Plan stresses Passive Solar Applications. Because of this requirement, you must consider the following retrofit issues that apply to the Air Force but usually do not apply to housing:

1. Type of occupancy use, and special heating and cooling requirements.

2. Time of day occupancy, and the duration of heating/cooling requirements, and the number of electrical lights required.

3. For industrial and commercial facilities it is difficult to position activities relative to passive conditions and elements. Size of floor space (required) forces the floor area to southern wall exposure to be large. However, passive (architectural) considerations during floor planning with the user may overcome many problems. For example, use of NORTH SIDE (5) and ZONING (34) could eliminate all north windows by placing utilities, storage, toilets, and a "back door" - PROTECTED ENTRANCE (7) on the north wall. This could provide the opportunity to develop the south side of the building as a "people space". You could use the patterns in Appendix C and Appendix H from A Pattern Language by Christopher Alexander. The use of LIGHT ON TWO SIDES OF OF EVERY ROOM in Appendix H will help to reduce electric lighting requirements during the day.

4. Time of day usage in many cases should be considered relative to passive heat gain. Possibly work hours could be changed for winter, (start at 0900 hours), and summer (start at 0700 hours) to reduce heating and cooling requirements. This should be considered as a design opportunity.

5. Most facilities other than family housing will require ventilation. You should use EARTH TUBES (28), KING VENTILATION SYSTEM (29), SOLAR CHIMNEY (31) and SOLAR DEHUMIDIFICATION (32) as methods of providing passive tempered ventilation.

6. Activities need to be evaluated in terms of the following requirements:

   a. natural light
   b. sensitivity to thermal function
   c. latent heat requirements
   d. moisture requirements

After considering these issues you might need to collect heat from both active and passive collection systems, and store the heat at a central location with mechanical systems to re-distribute the heat.

GENERAL REFERENCES FOR (9A), (9B), (9C), (9D), (9E)

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, PA, 1979.

2. Edward Mazria. "A Design and Sizing Procedure for Passive Solar Heated Buildings", 3rd National Passive Solar Conference Proceedings, San Jose, CA, January 11-13, 1979, pp 249 - 253.

3. Captain Bruce C. Baccei, Corp of Engineers, Energy Conscious Design, U.S. Army Corp of Engineers, Norfolk District, Norfolk, VA.

4. Fred Dubin. "Air Conditioning For Books and People", Architectural Record v. 121, June 1957, p 231 - 234.

9A. DIRECT GAIN

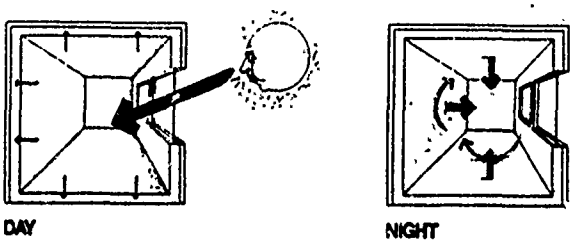
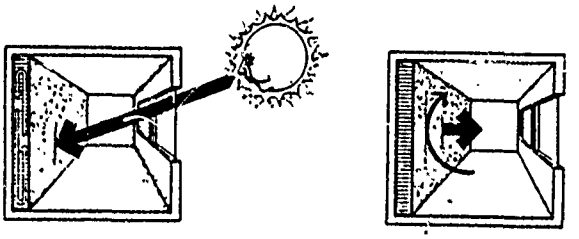


Figure 9a MASONRY HEAT STORAGE



INTERIOR WATER WALL

INFORMATION

The direct Gain System is the simplest passive solar system, and is represented by figure 9a. It uses an expanse of south-facing glass - SOLAR WINDOWS (11) - and enough thermal mass, strategically located in the space for heat absorption and storage. This system usually creates glare problems, and causes fading of material - see APPROPRIATE MATERIALS (10) for references.

The two most common materials used for heat storage are masonry and water - MASONRY HEAT STORAGE (13), and INTERIOR WATER WALL (14). Heat gain is reduced by using SHADING DEVICES (25). Note: Wall to wall carpet cannot be used if you intend to use the floor mass as heat storage.

Another application of the Direct Gain System is the use of a south-facing clerestory - CLERESTORIES AND SKYLIGHTS (12). Clerestories and skylights give good light, privacy and do not put direct sunlight on people and furniture.

Clerestories provide good lighting to large areas, however they are difficult and expensive to retrofit. Skylights will overheat a space if a shading device (25) is not provided for summer use.

Summer cooling is accomplished by keeping the sun out during the day and ventilating the space at night.[1]

RETROFIT OPPORTUNITIES:

If you already have a direct gain system, or because of the Architectural Program you need it, then you should maximize the system operation by using WINDOW LOCATION (8), SOLAR WINDOWS(11), CLERESTORIES AND SKYLIGHTS (12), MASONRY HEAT STORAGE (13), INTERIOR WATER WALL (14), and MOVABLE INSULATION (23).

RETROFITTING LIMITATIONS OF THE DIRECT GAIN SYSTEM:

Retrofitting an existing building with a Direct Gain System can be relatively easy or very difficult depending on your building's construction materials. A prefabricated metal structure, such as a flight line maintenance building, would be relatively easy and cost effective. However, an existing masonry structure is very difficult to retrofit for Direct Gain since THE BUILDING IS THE SYSTEM. Only when a space is constructed with masonry walls and floors exposed on the interior, and has clear southern exposure, is it possible to add SOLAR WINDOWS (11) or CLERESTORIES AND SKYLIGHTS (12) and modify interior surface finishes to solar heat the space.[2]

REFERENCES

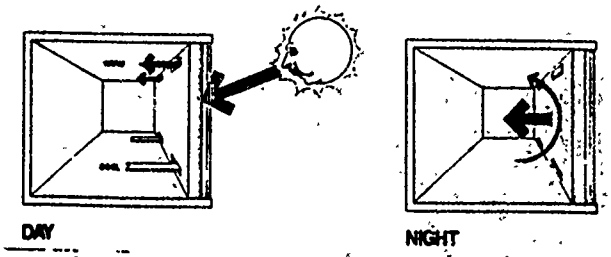
1. General References 1 and 2.

2. General References 1. p.109.

SOURCES OF ILLUSTRATIONS

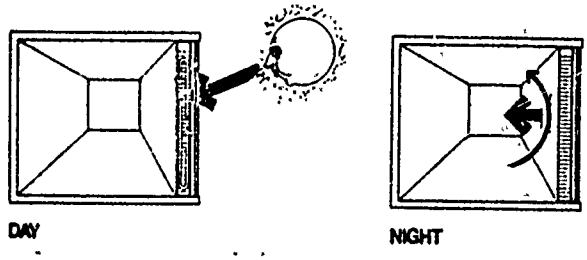
1. General Reference 1. p.30.

9B. THERMAL STORAGE WALL



MASONRY HEAT STORAGE

Figure 9b



INTERIOR WATER WALL

INFORMATION

The Thermal Storage Wall is characterized by the storage media being directly behind the south-facing glazing. There are a wide range of appropriate thermal storage wall materials; however, most fall into two catagories: either masonry - MASSONRY HEAT STORAGE (13) - or water - INTERIOR WATER WALL (14). Both types of storage walls are limited to 20 feet for effective radiant heating. The requirement for southern exposure dictates a linear arrangement unless modified by stacking and or staggering spaces.

MASONRY WALL

The masonry wall transfers heat from the surface to the interior at a slow rate by conduction. If direct sunlight hits the surface of a dark colored masonry material it will become uncomfortably hot, giving much of its heat to the air instead of storing it by conduction. To reduce heat fluctuation, direct sunlight must be spread over a large surface area of masonry so roughly 60% of the solar energy admitted into the space is stored as heat in the walls and/or floor and/or ceiling at sunset. The masonry wall can be used as a SOLAR CHIMNEY (31) for summer ventilation, but needs MOVABLE INSULATION (23) on the inside to prevent radiation to the interior space.

See tables 9B-1 through 9B-8 for retrofit application potential to various Air Force building types, and see MASONRY HEAT STORAGE (13) for sizing details.

WATER WALL

Water is more efficient as a heat storage medium than masonry. It has the potential to store more than twice as many

BTU's for each 1 degree F temperature rise for the same volume of material. The volume of water in direct sunlight and the surface color of the container (thin metal or plastic) will determine the temperature fluctuation in the space over the day.[2]

See tables 9B-1 through 9B-8 for retrofit application potential to various Air Force building types, and see INTERIOR WATER WALL (14) for sizing details.

In most cases the thermal storage wall is able to achieve a higher solar fraction than a direct gain system, if the thermal storage mass does not exceed about 175 lbs/square foot of glazing.[3]

Retrofitting this system is easily done to the south wall of a space with a clear exposure.[4]

REFERENCES

1. General Reference 2. p 251.

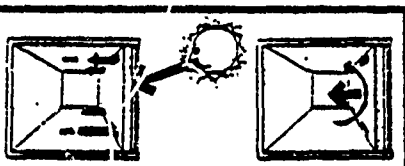
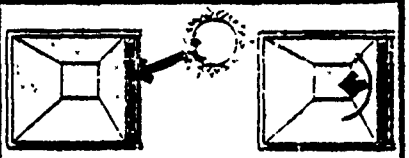
2. IBID

3. J. Douglas Balcomb. "Trombe Wall vs. Direct Gain: A Comparative Analysis of Passive Solar Heating Systems", Third National Passive Solar Conference Proceedings, San Jose, CA, Jan 11-13, 1979. p 45.

4. General Reference 1. p 110.

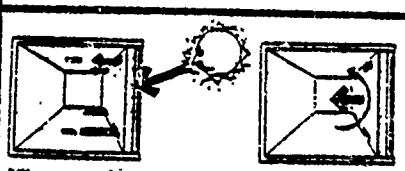
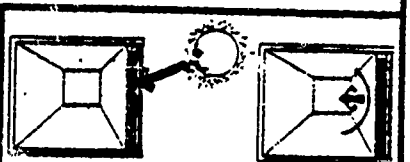
SOURCES OF ILLUSTRATIONS

1. General Reference 1. pp 44 and 51.

● EXCELLENT ◒ GOOD ⊖ FAIR ○ POOR ◍ UNKNOWN ◍ VARIABLE	BUILDING TYPE(S): FAMILY HOUSING, AIRMAN'S DORM OFFICER'S QUARTERS	TABLE 98-1
	TIME OF USE AND OCCUPANCY: 24 hour occupancy is expected with standard 65 F (winter) and 78 F (summer) heating and cooling maximums.	
DESIGN CONSIDERATIONS	 Masonry Thermal Storage Wall	 Water Thermal Storage Wall
HEAT STORAGE POTENTIAL	◒ GOOD	● EXCELLENT
WINTER VENTILATION	Not required. Infiltration should supply sufficient ventilation	Not required. Infiltration should supply sufficient ventilation.
SUMMER VENTILATION	● Dark masonry creates a thermal chimney for induced ventilation. Use in conjunction with EARTH TUBES (28), KING VENTILATION SYSTEM(29) & SOLAR CHIMNEY(3) to secure night ventilation.	○ An Interior Water Wall will absorb heat and will not allow it to function as a Solar Chimney (31).
NATURAL LIGHT POTENTIAL/ CONTROL	● Excellent control of light to reduce glare and fading of furniture.	◍ Varies with container. Opaque-excellent Translucent-good
SENSITIVITY TO THERMAL FUNCTION	◒ Good	● Excellent
LATENT HEAT	Kitchens, Bathrooms and laundry rooms are sources of latent heat Winter asset -Summer liability.	Kitchens, Bathrooms and Laundry rooms are sources of latent heat. Winter asset - Summer liability.
MOISTURE	● Masonry will not collect condensation. Use EARTH TUBES(28) & SOLAR DEHUMIDIFIER (32) with this wall as a SOLAR CHIMNEY (31) to dehumidify the air.	◒ High humidity causes condensation on containers.
WALL / FLOOR (RATIO)	◒ The ratio varies with local climate, latitude and space heating requirements. Range0.22 to 0.72-1.0. See table 15-1 for details.	● The ratio varies with local climate, latitude and space heating requirements. Range 0.16 to 0.55-1.0. See table 15-1 for details.
DEPTH OF SPACE LIMITATIONS	◒ Limited to 20 feet for effective radiant heating. The requirement for southern exposure dictates linear arrangement unless modified by stacking or staggering	◒ Limited to 20 feet for effective radiant heating. The requirement for southern exposure dictates linear arrangement unless modified by stacking or staggering

● EXCELLENT
◒ GOOD
⊖ FAIR
○ POOR
Q UNKNOWN
V VARIABLE

BUILDING TYPE(S): BASE LIBRARY	TYPE 96-2
TIME OF USE AND OCCUPANCY: This building type has a 24 hour heat control requirement to preserve books. The heating and cooling requirements are similar to living/working spaces (72 degrees F - 78 degrees F with optimum of 76 degrees F). The books also contribute to the thermal mass of the building with a specific heat of .32 BTU/LB/degree F for paper. Books should not be exposed to direct sunlight.	

DESIGN CONSIDERATIONS	 Masonry Thermal Storage Wall	 Water Thermal Storage Wall
HEAT STORAGE POTENTIAL	◒ GOOD	● EXCELLENT
WINTER VENTILATION	◒ A library requires winter ventilation. Use EARTH TUBES(28) and KING VENTILATION SYSTEM(29) for earth tempered ventilating air.	◒ A library requires winter ventilation. Use EARTH TUBES(28) and KING VENTILATION SYSTEM (29) for earth tempered ventilating air.
SUMMER VENTILATION	● Dark masonry creates a thermal chimney for induced ventilation. Use in conjunction with EARTH TUBES(28), KING VENTILATION SYSTEM(29) and SOLAR CHIMNEY (31) for secure night ventilation.	○ An interior water wall will absorb heat and not allow it to function as a Solar Chimney (31) to drive EARTH TUBES (28).
NATURAL LIGHT POTENTIAL/ CONTROL	● Excellent way to control direct sunlight on books and provide natural heat.	V Varies with container Opaque - good Translucent - poor
SENSITIVITY TO THERMAL FUNCTION	◒ GOOD	● EXCELLENT
LATENT HEAT	◒ Libraries do not have latent heat problems unless there are many people.	◒ Libraries do not have latent heat problems unless there are many people.
MOISTURE	● A library needs humidity control. Masonry will not collect condensation. Use EARTH TUBES(28) and SOLAR DEHUMIDIFIER(32), with this wall as a SOLAR CHIMNEY (31) to dehumidify the air.	⊖ High humidity causes condensation on containers.
WALL / FLOOR (RATIO)	◒ The ratio varies with local climate, latitude and space heating requirements. Range 0.22 to 0.72 - 1.0. See table 15.1 for details.	◒ The ratio varies with local climate, latitude and space heating requirements. Range 0.16 to 0.55 - 1.0. See table 15.1 for details.
DEPTH OF SPACE LIMITATIONS	◒ Limited to 20 feet for effective radiant heating. The requirement for southern exposure dictates linear arrangement unless modified by stacking or staggering.	◒ Limited to 20 feet for effective radiant heating. The requirement for southern exposure dictates linear arrangement unless modified by stacking or staggering.

9C. ATTACHED GREENHOUSE

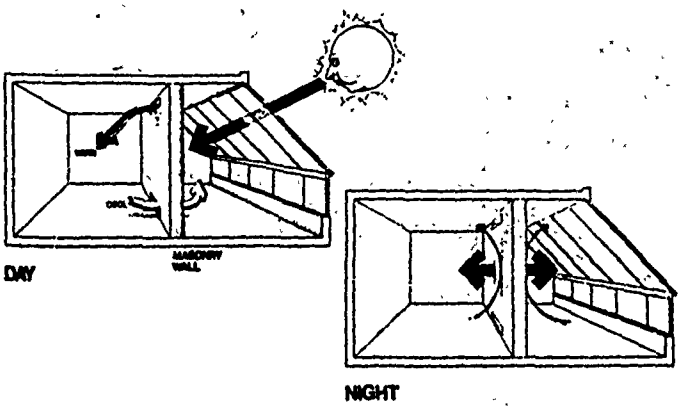
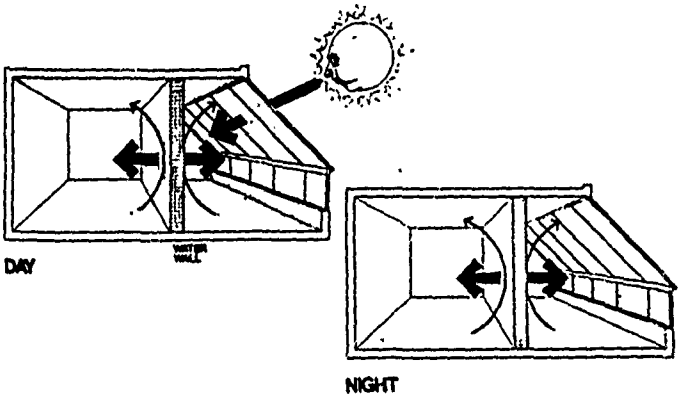


Figure 9C



INFORMATION

An Attached Greenhouse essentially is a combination of the DIRECT GAIN SYSTEM (9A) and the THERMAL STORAGE WALL (9B). The back wall of the greenhouse converts sunlight into heat, and a portion is then transferred into the building. To be effective as a heating source for the building, the common wall usually is constructed of either masonry or water for heat storage.

There are many possible variations that allow for design flexibility in attached greenhouse applications. For example, active systems such as fans can be used to get a better percentage of heat extracted from the greenhouse to heat adjoining spaces.

Retrofitting this system is easily done to the south wall of a space with a clear exposure.[1]

MOVABLE INSULATION (23) should be considered when necessary to avoid night heat loss from the main building space.

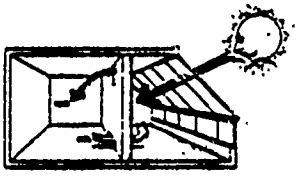
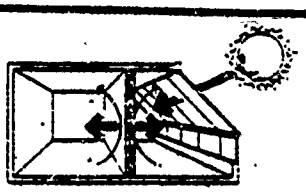
See tables 9C-1 through 9C-8 for retrofit application potential to various Air Force building types, and see SIZING THE GREENHOUSE (17) and GREENHOUSE CONNECTION (18).

REFERENCES

1. General References 1.pp52-54.

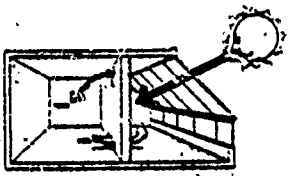
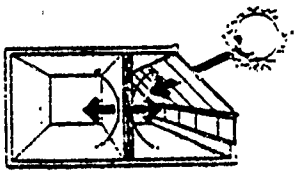
SOURCES OF ILLUSTRATIONS

1. General Reference 1. p 54.

● EXCELLENT ◒ GOOD ⊖ FAIR ○ POOR ◍ UNKNOWN ◉ VARIABLE	BUILDING TYPE(S): FAMILY HOUSING, AIRMAN'S DORMS, OFFICER'S QUARTERS	TABLE 9C-1
	TIME OF USE AND OCCUPANCY: 24 hour occupancy is expected with standard 65°F (winter) and 78°F (summer) heating and cooling maximums.	
DESIGN CONSIDERATIONS	 Attached Greenhouse - Masonry Wall	 Attached Greenhouse - Water Wall
HEAT STORAGE POTENTIAL	◒ Good. Fan should be incorporated to extract a better percentage of heat than by natural convection.	● Excellent. Fan should be incorporated to extract a better percentage of heat than by natural convection.
WINTER VENTILATION	◒ Not Required. Infiltration should be sufficient.	◒ Not required. Infiltration should be sufficient.
SUMMER VENTILATION	● Dark Masonry in the Attached Greenhouse will create a SOLAR CHIMNEY(31) to induce ventilation. Use EARTH TUBES(28), KING VENTILATION SYSTEM(29) for earth tempered ventilating air.	○ An interior water wall will absorb heat and not allow it to function as a SOLAR CHIMNEY(31).
NATURAL LIGHT POTENTIAL/ CONTROL	● Excellent-same as standard construction if a window or sliding door is in the common wall.	◉ Varies with container. Opaque-Excellent. Translucent-Good.
SENSITIVITY TO THERMAL FUNCTION	◉ Excellent in winter as a protected SOUTH FACING INDOOR SPACE & a SUNNY PLACE to study. Poor in summer unless protected by SHADING DEVICES(25), Tree Places and Climbing plants -Appendix P	◉ Excellent in winter as a protected SOUTH FACING INDOOR SPACE & and a SUNNY PLACE to study. Poor in summer unless protected by SHADING DEVICES(25), Tree Places & Climbing plants-Appendix P.
LATENT HEAT	◒ Kitchens, Bathrooms and Laundry rooms are sources of latent heat Winter asset-Summer liability.	◒ Kitchens, Bathrooms and Laundry rooms are sources of latent heat. Winter asset - Summer liability.
MOISTURE	● Masonry will not collect condensation. Use EARTH TUBES(28) & SOLAR DEHUMIDIFIER(32) with this wall as a SOLAR CHIMNEY(31) to dehumidify the air.	⊖ High humidity causes condensation on containers.
WALL / FLOOR (RATIO)	◉ The ratio varies with local latitude, climate and space heating requirements. Range 0.33-1.5. See table 17-1 for details.	◉ The ratio varies with local climate, latitude and space heating requirements. Range 0.24-1.27. See table 17-1 for details.
DEPTH OF SPACE LIMITATIONS	◒ Not applicable because the heat should be removed by mechanical means when it primarily for heating.	◒ Not applicable because the heat should be removed by mechanical means when it primarily for heating.

● EXCELLENT
◒ GOOD
⊖ FAIR
○ POOR
◔ UNKNOWN
◒ VARIABLE

BUILDING TYPE(S): BASE LIBRARY	TABLE 9C-2
TIME OF USE AND OCCUPANCY: This building type has a 24 hour heat control requirement to preserve books. The heating and cooling requirements are similar to living/working spaces (72°F-78°F with optimum of 76°F). The books also contribute to the thermal mass of the building with a specific heat of .32 BTU/Lb/°F for paper. Books should not be exposed to direct sunlight.	

DESIGN CONSIDERATIONS	 Attached Greenhouse - Masonry Wall	 Attached Greenhouse - Water Wall
HEAT STORAGE POTENTIAL	◒ Good heat storage. Fan should be incorporated to extract a better percentage of heat than by natural convection	● Excellent heat storage. Fan should be incorporated to extract a better percentage of heat than by natural convection.
WINTER VENTILATION	A library requires winter ventilation. Use EARTH TUBES (28) and KING VENTILATION SYSTEM(29) for earth tempered ventilating air.	A library requires winter ventilation. Use EARTH TUBES (28) and KING VENTILATION SYSTEM (29) for earth tempered ventilating air.
SUMMER VENTILATION	● Dark masonry in the Attached Greenhouse will create a SOLAR CHIMNEY(31) to induce ventilation. Use with EARTH TUBES(28) and KING VENTILATION SYSTEM(29)for earth tempered ventilating air.	○ An interior water wall will absorb heat and not allow it to function as a Solar Chimney (31) to drive EARTH TUBES (28).
NATURAL LIGHT POTENTIAL/ CONTROL	● Excellent way to control direct sunlight on books, provide natural heat, and can provide a protected SOUTH FACING OUTDOOR SPACE and a SUNNY PLACE to study.(App C)	◒ Varies by container: Opaque-excellent; translucent-poor. Attached Greenhouse provides a protected SOUTH FACING OUTDOOR SPACE to study(See Appendix C.)
SENSITIVITY TO THERMAL FUNCTION	◒ Excellent in winter as a protected SOUTH FACING INDOOR SPACE & a SUNNY PLACE to study. Poor in summer unless protected by SHADING DEVICES(25),Tree Places&Climbing Plants - Appendix B	◒ Excellent in winter as a protected SOUTH FACING INDOOR SPACE & a SUNNY PLACE to study. Poor in summer unless protected by SHADING DEVICES(25),Tree Places & Climbing Plants - Appendix B
LATENT HEAT	Libraries do not have latent heat problems unless there are many people in the space.	Libraries do not have latent heat problems unless there are many people in the space.
MOISTURE	● A library needs humidity control. Masonry will not collect condensation. Use EARTH TUBES(28) and SOLAR DEHUMIDIFIER (32) with this wall as SOLAR CHIMNEY(31) to dehumidify the air.	⊖ High humidity causes condensation on containers. Low thermal chimney action to drive a SOLAR DEHUMIDIFIER (32).
WALL/FLOOR (RATIO)	◒ The ratio varies with local latitude, climate and space heating requirements. Range 0.33-1.5. See Table 17-1 for details.	◒ The ratio varies with local climate, latitude and space heating requirements. Range 0.24-1.27. See Table 17-1 for details.
DEPTH OF SPACE LIMITATIONS	Not applicable because the heat should be removed be mechanical means when it primarily for heating.	Not applicable because the heat should be removed be mechanical means when it primarily for heating.

9D. ROOF POND SYSTEM

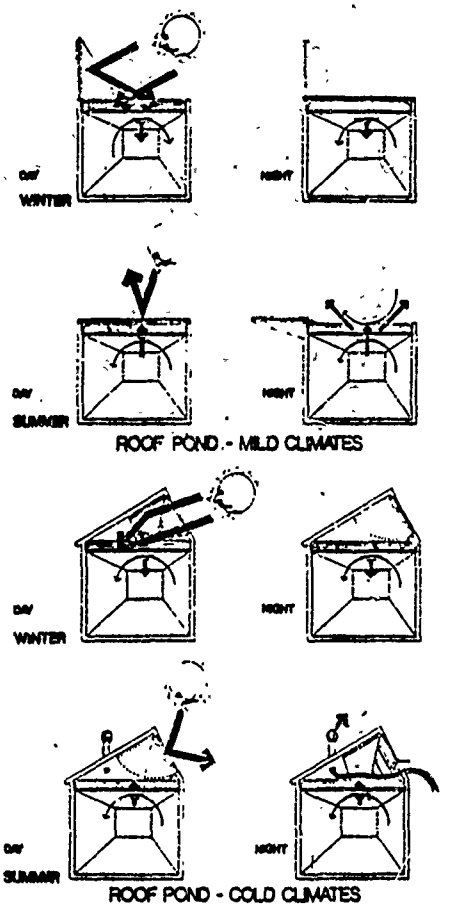


Figure 9d

INFORMATION

The Roof Pond System generally acts as a combined solar collector, heat dissipator (for summer cooling), storage medium, and radiator. It operates independantly of building axis orientation.

The sizing and configuration depend on the emphasis: heating, cooling, or a balance of both.

This system does not have universal (Air Force) application because of varying roof configurations and possible structural limitations. In every part of the nation, natural processes can supply sufficient sensible cooling to produce comfortable temperatures in well designed residential and commercial buildings.[1]

However, if you have a large flat (metal deck) roof on your building, and if structural calculations indicates the roof will support water bags, and MOVABLE INSULATION (23), then you should consider the use of roof ponds. And if your building's axis is north-south, this system would allow your

roof to work for you to heat and cool your building, where DIRECT GAIN (9A), THERMAL STORAGE WALL (9B) and ATTACHED GREENHOUSE (9C) would have limited potential application.

If you should decide to use this system for retrofit, you should know the Department of Defense roof slope criteria; i.e. "avoidance of roof ponding problems, can be met by sloping the roof deck and orienting water bags 3 or 4 feet wide, perpendicular to the slope."[2]

See tables 9D-1 through 9D-8 for retrofit application potential of various Air Force building types, and see SIZING THE ROOF POND (19) and ROOF POND DETAILS (20).

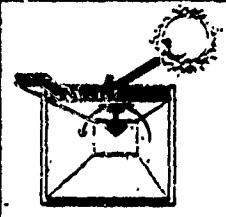
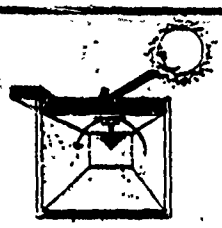
REFERENCES

1. F.M. Loxsom et.al. "A National Assessment of Passive Nocturnal Cooling from Horizontal Surfaces," 4th National Passive Solar Conference Proceedings, Kansas City, MO, October 3-5, 1979. pp 466-470. (See Appendix M).

2. General Reference 3. p A-33

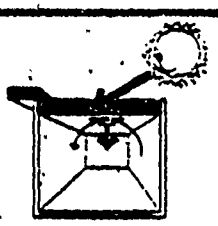
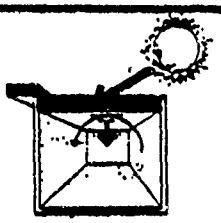
SOURCES OF ILLUSTRATIONS

1. General Reference 1. p 190.

● EXCELLENT ◒ GOOD ⊖ FAIR ○ POOR ◔ UNKNOWN ◔ VARIABLE	BUILDING TYPE(S): Family Housing, Airmans Dorms, and Officers Quarters	TABLE 90- 1
	TIME OF USE AND OCCUPANCY: 24 hour occupancy is expected with standard 65 F (winter) and 78 F (summer) heating and cooling maximums. NOTE: This system is not applicable for Air Force Housing Units because they do not have flat roofs.	
DESIGN CONSIDERATIONS	 Roof Pond on Metal Deck	 Roof Pond on Concrete Deck
HEAT STORAGE POTENTIAL		
WINTER VENTILATION		
SUMMER VENTILATION		
NATURAL LIGHT POTENTIAL/ CONTROL		
SENSITIVITY TO THERMAL FUNCTION		
LATENT HEAT		
MOISTURE		
WALL / FLOOR (RATIO)		
DEPTH OF SPACE LIMITATIONS		

● EXCELLENT
◒ GOOD
⊖ FAIR
○ POOR
Ⓤ UNKNOWN
Ⓥ VARIABLE

BUILDING TYPE(S): BASE LIBRARY	TABLE 9D-2
TIME OF USE AND OCCUPANCY: This building type has a 24 hour heat control requirement to preserve books. The heating and cooling requirements are similar to living/working spaces (72°F-73°F with optimum of 76°F).. The books also contribute to the thermal mass of the building with a specific heat of .32 BTU/Lb/°F for paper. Books should not be exposed to direct sunlight.	

DESIGN CONSIDERATIONS	 Roof Pond on Metal Deck	 Roof Pond on Concrete Deck
HEAT STORAGE POTENTIAL	● Excellent radiant heating and cooling potential. Structural system may not support. Building orientation does not affect its operation	Ⓥ Variable by latitude and climate, and depth of concrete deck. Concrete reduces the efficiency of the system as a radiant heating and cooling system. There are no rules of thumb for deck thickness.
WINTER VENTILATION	However, a library requires ventilation. Use EARTH TUBES (28) and KING VENTILATION SYSTEM (29) for earth tempered ventilating air.	However, a library requires ventilation. Use EARTH TUBES(28) and KING VENTILATION SYSTEM(29) for earth tempered ventilating air.
SUMMER VENTILATION	However, a library requires ventilation all day and night for cooling and fresh air. Use EARTH TUBES (28),KING VENTILATION SYSTEM (29) for secure night ventilation.	However, a library requires ventilation all day and night for cooling and fresh air.Use EARTH TUBES (28),KING VENTILATION SYSTEM (29) for secure night ventilation.
NATURAL LIGHT POTENTIAL/ CONTROL	⊖ This system would require use of windows for natural light because clerestories would not be possible	⊖ This system would require use of windows for natural light because clerestories would not be possible
SENSITIVITY TO THERMAL FUNCTION	● Excellent as a radiant heat and cool surface for thermal comfort	Ⓥ Variable by depth of concrete.
LATENT HEAT	Libraries do not have latent heat problems unless there are many people in the space.	Libraries do not have latent heat problems unless there are many people in the space.
MOISTURE	○ High humidity causes condensation on metal deck. Use the south wall as a SOLAR CHIMNEY (31) along with EARTH TUBES (28) and SOLAR DEHUMIDIFIER(32) to reduce moisture.	Ⓤ Unknown at present time.
~~WALL~~ FLOOR (RATIO)	Ⓥ Varies by local climate, latitude and space heating/cooling requirements. Heating 0.25-1.0 Cooling 0.33-1.0. See Table 19.1	Ⓤ Unknown at present time.
DEPTH OF SPACE LIMITATIONS	Ⓥ Limited to 20 feet for effective radiant heating or cooling.	Ⓤ Unknown

9E. CONVECTIVE LOOP

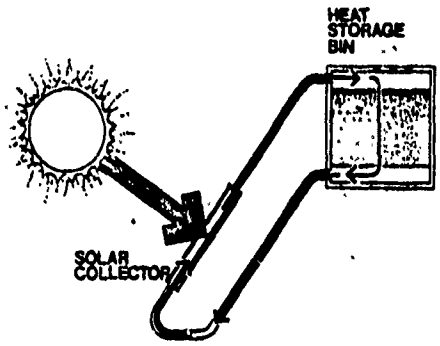


Figure 9E-1

INFORMATION

The Convective Loop System uses natural convection as the motive force for this passive solar system. The major component of this system is a flat plate collector located below the heat storage unit and occupied space. The geometry of the system makes it difficult or improbable that you will use it.

However, if your building is on the edge of a south-facing hill then you could use this system.

Water, and air with rock storage are the usual heat transfer media.

REPTROFIT OPPORTUNITIES

Buildings on bases with rolling terrain, such as Andrews AFB, Wright-Patterson AFB and Little Rock AFB have possible potential use of this system.

The spandrels of a multistory building can also be used as a passive heating and/or ventilation system.

The following rules of thumb for design are taken from Sunspots by Steve Baer: for sizing an air with rock storage convective loop system.

DESIGN TIPS (See Figure 9E-2)

1. Make d = at least 1/15 L.
2. Make rocks (h) 2 feet deep if small gravel (1") and up to 4 feet deep if large rock (6").
3. Make collector slant at least 45 degrees.
4. Insulate storage box with at least 6 inch batt.
5. Make collector at least 6 feet long.
6. Keep all flow channels at least 1/15 of collector area.
7. Avoid corners in flow channels.
8. Make storage cross section at least 1/3 of collector area.
9. Insulate divide between down flow and up flow with at least 1 inch duct board.
10. Double glaze collectors if 7000 degree day climate or more.
11. Hand place rock if possible to avoid layers of dirt in bin.
12. Place all of storage rocks above collector, or use damper.
13. Build house above storage bin.
14. Build vent flap at top of collector to open during summer to prevent overheating.
15. Heat house with trap door to rock bin and duct to cold under for return air.

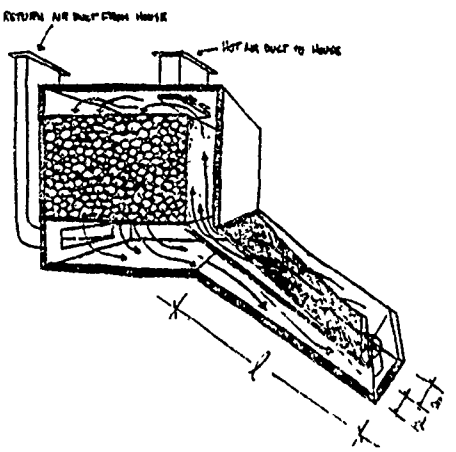


Figure 9E-2

The method of analysis of this system is the same as an active-solar system flat plate collector.[2]

RETROFITTING LIMITATIONS OF THE CONVECTIVE LOOP SYSTEM.

This system generally has limited potential for retrofit because it relies on geometry with the collector being lower than storage, and storage below the occupied space, as shown in Figure 9E-1.

The Convective Loop System will not be discussed further because of its limited retrofit potential.

REFERENCES

1. General Reference 1. pp 59-62.

2. Steve Baer. Sunspots, Zomeworks Corporation, Albuquerque, N.M. 1977. pp 63, 71-72.

SOURCES OF ILLUSTRATIONS

1. General Reference 1. p 60.

2. Reference 2 (above). p 72.

10. APPROPRIATE MATERIALS

LARGE SCALE PATTERNS

The construction materials in your building and its structural system will influence the choice of a passive solar system - CHOOSING THE SYSTEM (9) - used for retrofitting your building. Also using the idea of earth berming - NORTH SIDE (5) - will affect your selection of materials.

THE PROBLEM

MORE ENERGY WAS CONSUMED IN CONSTRUCTING YOUR BUILDING THAN WAS USED IN MANY YEARS OF OPERATION. THUS THE ARCHITECTURAL PROBLEM IS TO EFFECTIVELY RE-USE YOUR STRUCTURE AND THERMAL MASS (which should be considered as site provided natural resource) AS A RESOURCE FOR COLLECTING, STORING AND DISTRIBUTING HEAT THROUGHOUT THE STRUCTURE IN A NATURAL MANNER.

THE RECOMMENDATION

DESIGN YOUR RETROFIT SO THE BUILDING'S THERMAL MASS FUNCTIONS AS A NATURAL HEAT COLLECTOR, HEAT STORAGE MATERIAL AND HEAT DISTRIBUTING SYSTEM THROUGHOUT THE BUILDING. YOU SHOULD USE LOCALLY PRODUCED BIODEGRADABLE AND LOW ENERGY-CONSUMING MATERIAL WHENEVER POSSIBLE. IF ADDITIONAL THERMAL MASS IS REQUIRED, USE ADOBE, SOIL-CEMENT, BRICK, STONE, CONCRETE AND WATER IN CONTAINERS. FOR FINISH MATERIALS USE WOOD, PLYWOOD, PARTICLE BOARD AND GYPSUM BOARD. USE THE FOLLOWING MATERIALS ONLY IN SMALL QUANTITIES OR WHEN THEY HAVE BEEN RE-CYCLED: STEEL PANELS AND CONTAINERS, ROLLED STEEL SECTIONS, ALUMINUM AND PLASTICS.

SMALL SCALE PATTERNS

Distribute and size bulk materials so they work effectively for heat storage. For Direct Gain Systems see MASONRY HEAT STORAGE(13) and INTERIOR WATER WALL (14); for Thermal Storage Wall Systems see WALL DETAILS (16); for Attached Greenhouse Systems see GREENHOUSE CONNECTION (18); for Roof Pond Systems see ROOF POND DETAILS (20); for reducing heat loss or heat gain see MOVABLE INSULATION (23), SHADING DEVICES (25) and INSULATION ON THE OUTSIDE (26).

INFORMATION

This pattern should help you select materials which use a minimum amount of energy to manufacture and have good potential for heat storage (thermal mass-specific heat) or resistance to heat flow (insulation).

Energy conscious design requires selection of appropriate materials. Table 10-1 shows that thermal mass materials require relatively little energy to manufacture when compared to energy-

intensive materials such as aluminum and high grade steel alloys.

In some cases, thermal mass materials will be as much as 80 to 90% of the total volume of materials used in your building. With some consideration given to energy consciousness in selecting and detailing of secondary/finishing materials - MOVABLE INSULATION (23), REFLECTORS (24), SHADING DEVICES (25) and INSULATION ON THE OUTSIDE (26) - you can modify your building so your thermal mass is insulated from the elements, and becomes a heat sink or "thermal flywheel." Your selection of good secondary/finishing materials will, by its nature, be energy conservative.

Wood is an excellent secondary material. Other finish and secondary materials include plywood, particle board, gypsum board, plaster and vinyl. Your use of energy-intensive materials is appropriate when applied in moderation or when the materials are recycled.

Soil is not insulation but can be used as a buffer for strong north winds - NORTH SIDE (5) and on roofs.

The selection of materials and furnishings for interior design is developing as an Interior Architectural Design specialty, and is beyond the scope of this set of patterns. However, if you apply the recommendation of this pattern to your interior design, the thermal performance of your building will improve in your retrofitting process. A good resource for Interior Solar Design is Solar Interiors: Energy, A New Element in Design by Denise Guerin[6].

REFERENCES

1. A.B. Makhijani and A.J. Lichtemberg, "Energy and Well-Being," p 14.

2. Robert A. Kegel, "The Energy Intensity of Building Materials," p 39.

3. Andrew MacKilleys, "Low Energy Housing," p 8.

4. ASHRAE Handbook of Fundamentals, 1977.

5. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition. Rodale Press, Emmaus, PA 1979. pp115-117.

6. Denise Guerin. Solar Interiors: A New Element in Design (Miami University Home Economics Department - unpublished).

7. Denise Guerin. "Energy and Interior Design, " Master's Thesis, Michigan State University, May 1977.

8. Denise Guerin. "Textiles in an Ecological Framework," unpublished graduate paper, Michigan State University, June 1976.

9. "Window Treatments for Thermal Comfort, "Energy Facts, Cooperative Extension Service, Michigan State University, October 1977.

ITEM	REFERENCES			SPECIFIC HEAT	
		Btu/lb	Btu per unit	Reference	Btu/lb/°F
Water				4	.999
Steel (rolled)	1	19,974		4	.12
Aluminum	1	112,676		4	.214
Copper	1	34,144		4	.092
Concrete	2	413		4	.156
Cement	1	3,755		4	.16
Sand and gravel	1	30		4	.191
Lead	1	20,486		4	.0309
Concrete block	2		15,200/block	4	.156
Silicone, metal and high-grade steel allows	1	99,018			
Glass	1	11,438		4	.15-.20
Titanium (rolled)	1	239,010			
Plastics	1	4,097			
Drywall	2	2,160		4	.259
Insulation (board)	2		2,040/sq ft		
Paint	2	4,134			
Lumber	1		5,019/board ft	4	.325
Paper	1	10,072		4	.32
Roofing	2		6,945/sq ft		
Vinyl tile	2	8,000			
Brick	3	138	682/block	4	.2
10% soil-cement block	3	34	170/block		
Soil					

SOURCES:
1. A.B. Makhijani and A. J. Lichtenberg, "Energy and Well-Being," p.14.
2. Robert A. Kegel, "The Energy Intensity of Building MAterials," p.39.
3. Andrew MacKillop, "Low Energy Housing," p.8.
4. Ashrae Handbook of Fundamentals, 1977.

TABLE 10-1

11. SOLAR WINDOWS



Figure 11-1

LARGE SCALE PATTERNS

Using the ideas of existing or proposed windows from WINDOW LOCATION (8) and CHOOSING THE SYSTEM/DIRECT GAIN (9A), this pattern defines the area of south-facing glazing needed for solar heating each space.

THE PROBLEM

DIRECT GAIN SYSTEMS ARE CURRENTLY CHARACTERIZED BY LARGE AMOUNTS OF SOUTH FACING GLASS. MOST OF OUR PRESENT INFORMATION ABOUT DIRECT GAIN SYSTEMS HAS BEEN LEARNED THROUGH THE PERFORMANCE OF VARIOUS EXISTING PROJECTS WHICH UTILIZE LARGE SOUTH-FACING GLASS AREAS FOR WINTER SOLAR GAIN. THESE BUILDINGS ARE OFTEN THOUGHT OF AS OVERHEATING ON SUNNY WINTER DAYS. THIS HAPPENS BECAUSE SOLAR WINDOWS ARE FREQUENTLY OVERSIZED DUE TO LACK OF ANY ACCURATE METHODS FOR PREDICTING A SYSTEM'S PERFORMANCE. THESE DRAWBACKS HAVE LED TO A VERY LIMITED APPLICATION OF DIRECT GAIN SYSTEMS IN BUILDING DESIGN AND CONSTRUCTION.

THE RECOMMENDATION

IN COLD CLIMATES (average winter temperatures 20° to 30°F), PROVIDE BETWEEN 0.19 AND 0.31 SQUARE FEET OF SOUTH-FACING GLASS FOR EACH ONE SQUARE FOOT OF SPACE FLOOR AREA. THIS AMOUNT OF GLAZING WILL ADMIT ENOUGH SUNLIGHT TO KEEP THE SPACE AT AN AVERAGE TEMPERATURE OF 65° to 70° DURING MUCH OF THE WINTER.[1,2]

SMALL SCALE PATTERNS

The glazing area recommendations in this pattern can be divided between south-facing window space and/or south-facing

CLERESTORIES AND SKYLIGHTS (12) as shown in figure 11-1. To prevent daytime overheating and large space temperature fluctuations, store a portion of the heat gained during the daytime for use at night by locating a thermal mass within each space - MASONRY HEAT STORAGE (13) and INTERIOR WATER WALL (14). Use MOVABLE INSULATION (23) over the solar windows at night to reduce heat loss and protect the windows from the hot summer sun by applying SHADING DEVICES(25). The area of window needed to heat a space can be substantially reduced by using exterior RELECTORS(24). A Direct Gain System with undersized solar windows can be combined with other passive systems to achieve the same recommended performance - COMBINING SYSTEMS (21).

Finally, your windows should function as breeze catchers for SUMMER COOLING (27).

ILLUSTRATION

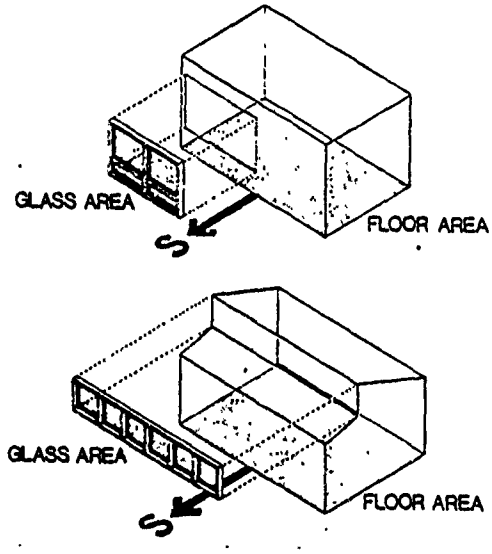


Figure 11-2

INFORMATION

A window, skylight or clerestory that faces south and opens directly into a space is a very efficient solar collector - WINDOW LOCATION (8). Light entering the space is unlikely to be reflected back out regardless of the color or shape of the space. This means that virtually all the sunlight is absorbed by the walls, floor, ceiling and other objects in the space and is converted into heat. Openings that are designed primarily to admit solar energy into a space are referred to as "solar windows." You can orient a solar window as much as 25° to the east or west of true south and still intercept over 90% of the solar radiation incident on a south-facing surface.

The size of a solar window determines the average temperature in a space over the day. During a typical sunny winter day, if a space becomes uncomfortably hot from too much sunlight, then

the solar windows are either oversized or there is not enough thermal mass distributed within the space to properly absorb the incoming radiation. As a space becomes too warm, heated air is vented by opening windows or activating an exhaust fan to maintain comfort. This reduces the system's efficiency since valuable heat is allowed to escape. For this reason, our criterion for a well-designed space is that it gain enough solar energy, on an average sunny day in December or January, to maintain an average space temperature of 70°F for that 24-hour period. Mazria used this criteria to develop size ratios for preliminary sizing of solar windows, skylights and clerestories (table 11-1.)

Sizing Solar Windows for Different Climatic Conditions[1]

Average Winter Outdoor Temperature (°F) (degree-days/mo.)[2]	Square Feet of Window[3] Needed for Each One Square Foot of Floor Area
Cold Climates	
15° (1,500)	0.27–0.42 (w/night insulation over glass)
20° (1,350)	0.24–0.38 (w/night insulation over glass)
25° (1,200)	0.21–0.33
30° (1,050)	0.19–0.29
Temperate Climates	
35° (900)	0.16–0.25
40° (750)	0.13–0.21
45° (600)	0.11–0.17

NOTES: 1. These ratios apply to a residence with a space heat loss of 8 to 10 Btu/day-sq ft$_g$-°F. If space heat loss is less, lower values can be used. These ratios can also be used for other building types having similar heating requirements. Adjustments should be made for additional heat gains from lights, people and appliances.

2. Temperatures and degree-days are listed for December and January, usually the coldest months. Consult the Base Weather Detachment for Daily Temperature for your base.

3. Within each range, choose a ratio according to your latitude. For southern latitudes, i.e., 30°NL, use the lower window-to-floor-area ratios; for northern latitudes, i.e., 48°NL, use the higher ratios.

Table 11-1

The exact size for retrofitting of your windows will depend on Architectural considerations as well as thermal performance requirements.

If you need additional internal mass to prevent overheating and large temperature swings, then you should consider the concepts presented in INTERIOR WATER WALL(14) as an application of APPROPRIATE MATERIALS(10).

You should also replace metal sash windows with wooden sash windows to reduce heat loss.

You can also use this pattern to add Solar Windows, which meet the criteria outlined in CHOOSING THE SYSTEM/DIRECT GAIN (9A).

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa 1979. 119-121.

2. Edward Mazria. "A Design and Sizing Proceedure for Passive Solar Heated Buildings", 3rd Nation Passive Solar Conference Proceedings, San Jose, Ca, January 11-13 1979. p.250.

SOURCES OF ILLUSTRATIONS & TABLES

Figure 11-1 Passive Solar Buildings. Sandia Laboratories, Albuquerque, NM, and Livermore, Ca. For USDOE under Contract DE-AC04-76DP00789. July 1979. p 53.

Figure 11-2 Reference 1 p. 120.

Table 11-1 Reference 1 p. 122.

12. CLERESTORIES AND SKYLIGHTS



Figure 12-1

LARGE SCALE PATTERNS

Using the ideas of existing or proposed clerestories and skylights from WINDOW LOCATION (8) and CHOOSING THE SYSTEM/DIRECT GAIN (9A), plus the recommended areas of south-facing glass needed to admit direct sunlight to solar heat a space-SOLAR WINDOWS (11), then this pattern describes architectural methods other than windows for collecting the sun's energy.

THE PROBLEM

THERE ARE MANY SITUATIONS WHEN ADMITTING DIRECT SUNLIGHT THROUGH SOUTH-FACING WINDOWS IS NOT FEASIBLE OR DESIRABLE. SOLAR BLOCKAGE OF THE SOUTH WALL BY NEARBY OBSTRUCTIONS, OR SPACES WITHOUT A CLEAR SOUTHERN EXPOSURE, MAKE IT IMPOSSIBLE TO USE WINODWS FOR SOLAR GAIN. ALSO, THE DISTANCE FROM A SOLAR WINDOW TO A THERMAL STORAGE MASS IS LIMITED BY THE HEIGHT OF THE WINDOW. A MASS LOCATED TOO FAR FROM THE WINDOW WILL NOT RECEIVE AND ABSORB DIRECT SUNLIGHT. LARGE SOLAR WINDOWS, WHICH ARE THE PRIMARY SOURCE OF DIRECT SUNLIGHT IN A SPACE, MAY RESULT IN TROUBLESOME GLARE, CREATE UNCOMFORTABLY WARM AND BRIGHT CONDITIONS FOR PEOPLE OCCUPYING THE SPACE AND DISCOLOR CERTAIN FABRICS. FOR THESE AND OTHER REASONS (privacy and aesthetics) IT IS NECESSARY TO EXPLORE ALTERNATIVE METHODS FOR COLLECTING THE SUN'S ENERGY IN A DIRECT GAIN BUILDING.[1]

THE RECOMMENDATION

ANOTHER METHOD FOR ADMITTING SUNLIGHT INTO A SPACE IS THROUGH THE ROOF. USE EITHER SOUTH-FACING CLERESTORIES OR SKYLIGHTS TO DISTRIBUTE SUNLIGHT OVER A SPACE OR TO DIRECT IT TO A

PARTICULAR INTERIOR SURFACE. MAKE THE CEILING OF THE CLERESTORY A LIGHT COLOR AND APPLY SHADING DEVICES TO BOTH CLERESTORIES AND SKYLIGHTS FOR SUMMER SUN CONTROL.[1]

SMALL SCALE PATTERNS

Apply MOVABLE INSULATION (23) and REFLECTORS (24) to make clerestories and skylights more efficient as solar collectors. Shade all glass areas, especially horizontal and south-facing glass, to protect them from the hot summer sun - SHADING DEVICES (25).

Another important consideration in the selection and location of a particular configuration is whether sunlight is to be diffused throughout a space - MASONRY HEAT STORAGE (13), or directed to a particular surface - INTERIOR WATER WALL (14), and that your clerestories and skylights be operable for "stack effect" SUMMER COOLING (27).

ILLUSTRATION

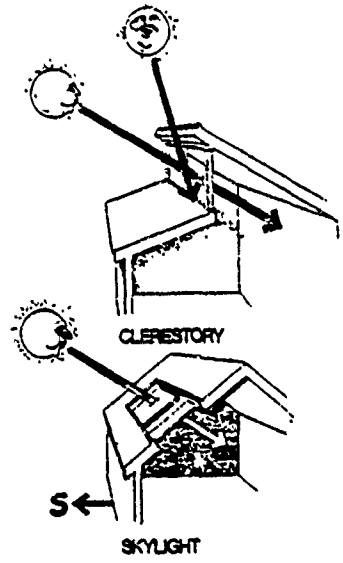


Figure 12-2

INFORMATION

CHOOSING THE SYSTEM /DIRECT GAIN (9A) described the advantage of Clerestories and Skylights, plus their retrofit opportunities and limitations.

If you are going to use south-facing Clerestories and Skylights in your architectural plan, then you should use the following guidelines:

Clerestory - locate the clerestory at a distance in front of an interior thermal storage wall of roughly 1 to 1.5 times the height of the thermal wall. Make the ceiling of the clerestory a light color to reflect and diffuse sunlight down into the space.

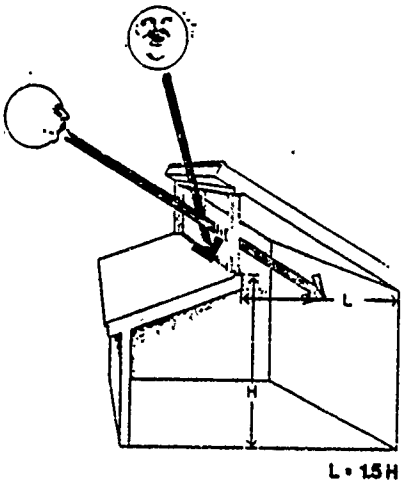


Figure 12-3

Sawtooth Clerestories - make the angle of each clerestory roof (as measured from horizontal) equal to, or less than the altitude of the sun at noon, on December 21, the winter solstice. Make the underside of the clerestories a light color.

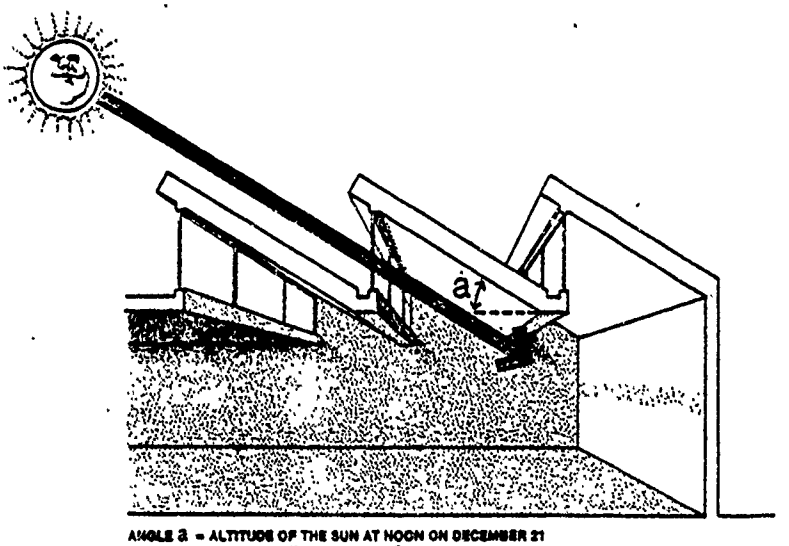


Figure 12-4

Skylight - use a reflector with horizontal skylights to increase solar gain in winter and shade both horizontal and south-facing skylights in summer to prevent excessive solar gain.[2]

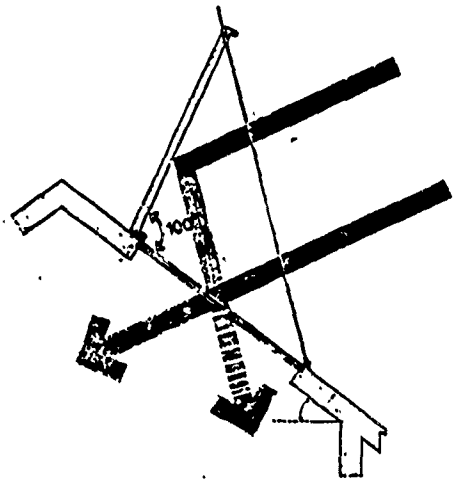


Figure 12-5

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa, 1979. p125.

2. Edward Mazria. "A Design and Sizing Proceedure for Passive Solar Heated Buildings", 3rd National Passive Solar Conference Proceedings, San Jose, Ca, January 11-13 1979. pp250-251.

SOURCES OF ILLUSTRATIONS

Figure 12-1 Patoka Nature Center by Fuller Moore

Figure 12-2 Reference 1 p 126

Figure 12-3 Reference 1 p 128

Figure 12-4 Reference 1 p 130

Figure 12-5 Reference 1 p 242

13. MASONRY HEAT STORAGE

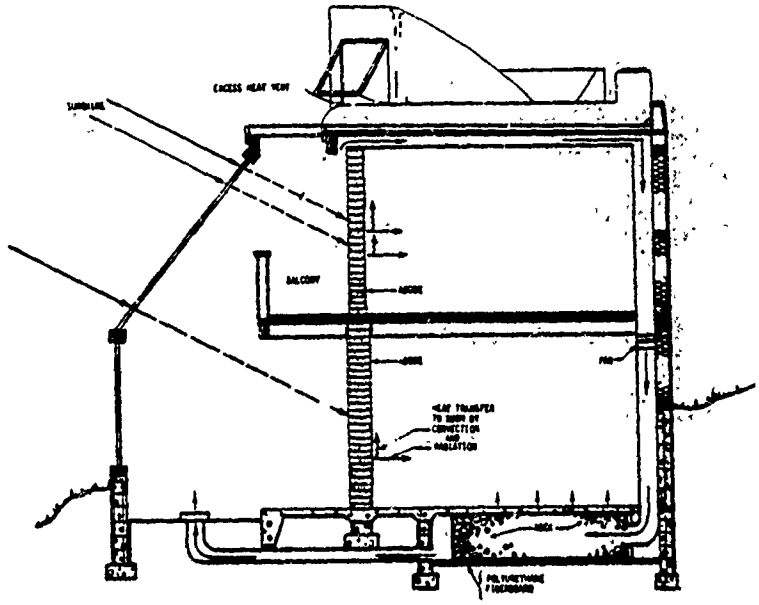


Figure 13-1

LARGE SCALE PATTERNS

After sizing your SOLAR WINDOWS (11) and/or CLERESTORIES AND SKYLIGHTS (12) a portion of the sunlight (heat) admitted into each space must be stored to prevent daytime overheating and for use during evening hours.

THE PROBLEM

THE STORAGE AND CONTROL OF HEAT IN A MASONRY BUILDING IS THE MAJOR PROBLEM CONFRONTING THE DESIGNER OF A DIRECT GAIN SYSTEM. In a Direct Gain System, the amount of solar energy admitted into a space through windows, skylights or clerestories determines the average temperature in the space over the day. A large portion of this energy must be stored in the masonry walls and/or floor of the space for use during the evening. In the process of storing and releasing heat, the masonry fluctuates in temperature, yet the object of the heating system is to maintain a relatively constant interior temperature. The location, quantity, distribution and surface color of the masonry in a space will determine the indoor temperature fluctuation over the day.[1]

THE RECOMMENDATION

TO MINIMIZE INDOOR TEMPERATURE FLUCTUATIONS, CONSTRUCT INTERIOR WALLS AND FLOORS OF MASONRY WITH A MINIMUM OF 4 INCHES IN THICKNESS. DIFFUSE DIRECT SUNLIGHT OVER THE SURFACE AREA OF THE MASONRY BY USING A TRANSLUCENT GLAZING MATERIAL, BY PLACING A NUMBER OF SMALL WINDOWS SO THAT THEY ADMIT SUNLIGHT IN PATCHES, OR BY REFLECTING DIRECT SUNLIGHT OFF A LIGHT-COLORED INTERIOR SURFACE FIRST, THUS DIFFUSING IT THROUGHOUT THE SPACE. USE

THE FOLLOWING GUIDELINES FOR SELECTING INTERIOR SURFACE COLORS AND FINISHES.

1. Choose a dark color for masonry floors.

2. Masonry walls can be any color.

3. Paint all lightweight construction (little thermal mass) a light color.

4. Avoid direct sunlight on dark-colored masonry surfaces for long periods of time.

5. Do not use wall-to-wall carpeting over masonry floors.[1]

SMALL SCALE PATTERNS

If your building is masonry then you should consider it as a site provided natural resource, and it is essential to insulate its exterior face to facilitate heat storage in the space - INSULATION ON THE OUTSIDE (26). You should also oversize solar windows and thermal mass to collect and store heat for cloudy days - CLOUDY DAY STORAGE (22). If you design your retrofit to allow ventilation of your masonry building during summer evenings, then the masonry will absorb heat and provide cool interior surfaces on hot days - SUMMER COOLING (27), EARTH TUBES (28), KING VENTILATION SYSTEM (29), and SOLAR CHIMNEY (31). If your building's DIRECT GAIN SYSTEM (9A) overheats on sunny winter days, then you should use INTERIOR WATER WALL (12) as an efficient and compact retrofit method.

ILLUSTRATION

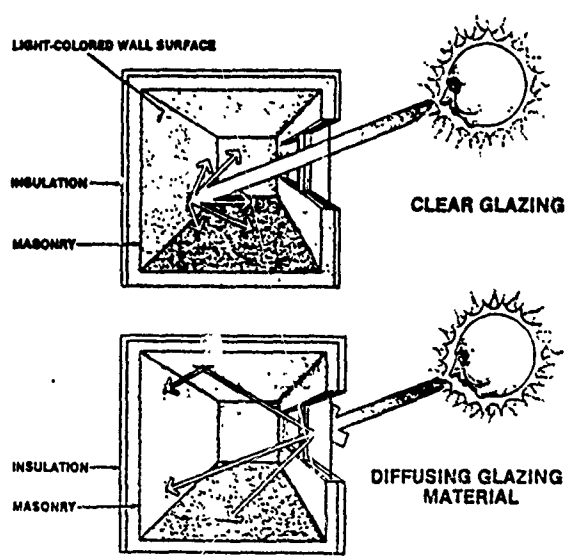


Figure 13-2

INFORMATION

Reference 1 presents information about three case studies performed by M.S. Baker, E. Mazria and F.S. Wessling at the University of Oregon. The following were their findings.

1. Use masonry products with a higher conductivity to reduce air temperature fluctuations within the space. This allows rapid heat transfer from the surface to the interior of the material.

Thermal Storage Material Properties

Material	Conductivity (k)	Specific Heat (Cp)	Density (ρ)
	Btu hr/ft²·°F/ft	Btu/lb·°F	lb/ft
Concrete (dense)	1.00	0.20	140.0
Brick (common)	0.42	0.20	120.0
Brick (magnesium additive)	2.20	0.20	120.0
Adobe	0.30	0.24	106.0

Table 13-1

2. Interior Masonry walls must be at least 4 inches thick.

3. To maintain comfort during the days, each square foot of direct sunlight should be spread over at least 9 square feet of masonry surface.

4. The following general rules can be applied to help you select interior surface colors and finishes for spaces of predominantly masonry construction:

   a. Select masonry floors of medium- dark colors. This assures that a portion of the heat will be absorbed and stored in the floor, low in the room, where it can provide for greater human comfort.

   b. Masonry walls can be any color. Sunlight reflected from light-colored masonry walls (20 to 30% solar absorption) will eventually be absorbed by other masonry surfaces in the space.

   c. Make all lightweight construction, such as wood frame partitions (little thermal mass), a light color so it reflects sunlight to the masonry walls or floor. Sunlight striking a dark-colored material of little thermal mass quickly heats that material. Since it has little capacity to store heat, it gives this heat to the space during the daytime when it is not needed, causing the space to overheat.

d. Avoid direct sunlight on dark-colored masonry surfaces for long periods of time since these surfaces will also become uncomfortably warm.

e. Do not cover a masonry floor with wall-to-wall carpet. Carpet insulates the heat storage mass from the room. Scatter or area rugs, covering a small area of the floor, make little difference.

Ref 1,2 &3.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa, 1979 pp 134-143.

2. E. Mazria, M.S. Baker, F.C. Wessling. "Predicting the performance of Passive Solar Heated Buildings," Proceedings of the 1977 Meeting of the AS/ISES. Vol 1, sec 2. 1977.

3. Edward Mazria. "A Design and Sizing Proceedure for Passive Solar Heated Buildings." 3rd National Passive Solar Conference Proceedings, San Jose, Ca, January 11-13 1979. p 251.

SOURCES OF ILLUSTRATIONS

Figure 13-1 Passive Solar Buildings. Sandia Laboratories, Albuquerque, NM, and Livermore, Ca. for USDOE under contract DE-AC04-76DP00789. July 1979. p.22.

Figure 13-2 Reference 1 p.135

Table 13-1 Reference 1 p.141

14. INTERIOR WATER WALL



Figure 14-1

LARGE SCALE PATTERNS

After sizing your SOLAR WINDOWS (11) and/or CLERESTORIES AND SKYLIGHTS (12) a portion of the sunlight (heat) admitted into each space must be stored to prevent daytime overheating and for use during evening hours. This pattern also gives information for applying the ideas from APPROPRIATE MATERIALS (10).

THE PROBLEM

THE SIZE OF A WATER WALL (Volume) AND ITS SURFACE COLOR DETERMINE THE TEMPERATURE FLUCTUATION IN A SPACE OVER THE DAY. Solar windows are sized to admit enough sunlight to keep a space at an average temperature of 65° to 70°F during most of the winter. The volume of water in the space and surface color of the container will influence the indoor temperature fluctuation above and below this average. The size of the water wall needed to maintain a comfortable environment is directly related to the area of the solar windows.[1]

THE RECOMMENDATION

WHEN USING AN INTERIOR WATER WALL (Volume) FOR HEAT STORAGE, LOCATE IT IN THE SPACE SO THAT IT RECEIVES DIRECT SUNLIGHT BETWEEN THE HOURS OF 10:00a.m. and 2:00p.m. Make the surface of the container exposed to direct sunlight a dark color, of at least 60% solar absorption, and use about one cubic foot (7½ gallons) of water for each one square foot of solar window.[1]

SMALL SCALE PATTERNS

Slightly oversize the solar windows and water wall to collect and store heat for cloudy days - CLOUDY DAY STORAGE (22). Insulate the exterior face of the wall when exposed to the outside - INSULATION ON THE OUTSIDE (26). In dry climates a water wall cooled during the summer with cool night air will provide for SUMMER COOLING (27).

ILLUSTRATION

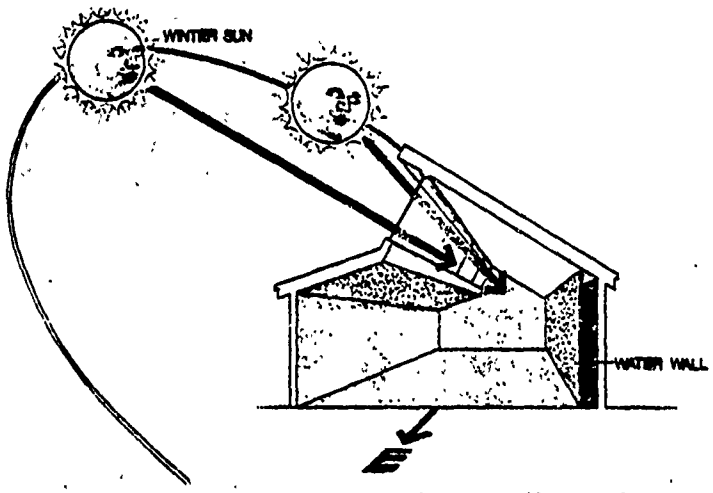


Figure 14-2

INFORMATION

The name Interior Water Wall should probably be called Interior Water Volume. The phrase "water wall" was coined to describe Steve Baer's Thermal Storage Wall system. The name is kept for ease of cross reference with Edward Mazria's book - The Passive Solar Energy Book - The Expanded Professional Edition.

The concept of this pattern is to locate a volume(s) of water in space so it is exposed to direct sunlight (from 10:00 AM to 2:00PM) to reduce heat fluctuations in the space. The amount of surface area exposed to sunlight and its surface color are critical. The more surface exposed to sunlight, the greater amount of heat absorbed. Black, Blue and Red are all good heat absorbing colors

The use of this pattern will also be an application of APPROPRIATE MATERIALS (10) and probably is one of the best retrofit options available.

It is a good retrofit heat storage material for the following reasons:

1. Water is the most effective heat storage medium.
2. Water heats up uniformly by convection currents.
3. The surface temperature of the water container does

not get hot and overheat the space like dark MASONRY HEAT STORAGE (13) media.

4. If the containers are small, they can be put in place easily by hand and filled with water.

You can apply this pattern in three ways:

1. Water in containers against the back wall of a space. (See figure 14-1) using SOLAR WINDOWS (11) and/or CLERESTORIES & SKYLIGHTS (12) as a sunlight source.
2. Water in small containers dispersed throughout the space such as the following using Solar Windows (11) and/or CLERESTORIES AND SKYLIGHTS (13) as a sunlight source.
   a. Water beds could be an optional issue bed for Airmen's Dorms, in place of standard metal frames and mattresses.
   b. Solar furniture (sofas, chairs, etc. made of metal casing with a soft cushion) filled with water.[2]



Figure 14-3

   c. Metal or glass sculptures filled with water.
   d. Metal paint cans (filled with water) to make book shelves.
   e. Limitless other possibilities if imagination is applied to the concept of volumes of water in sunlight (See Appendix J).

Note: The use of water beds and solar furniture locates heat or coolth next to the body for radiant heating or cooling of the body.

3. Water in containers directly behind the south-facing glass - THERMAL STORAGE WALL SYSTEM (9B) (See figure 14-1 and Appendix J.).

Table 14-1 shows room temperature fluctuations for Water Wall (Volume) Systems.

TABLE 14-1

DAILY SPACE AIR TEMPERATURE (°F) Fluctuations FOR WATER STORAGE WALL SYSTEMS

Solar Absorption[2] (surface color)	Volume of Water Wall for Each One Square Foot of South-Facing Glass			
	1cu ft	1.5 cu ft	2 cu ft	3 cu ft
75% (dark color)	17°	15°	13°	12°
90% (black)	15°	12°	10°	9°

NOTES: 1. Temperature fluctuations are for a winter-clear day with approximately 3 square feet of exposed wall area for each one square foot of glass. If less wall area is exposed to the space, temperature fluctuations will be slightly higher. If additional mass is located in the space such as masonry walls and/or floor, then fluctuations will be less than those listed.

2. Assumes 75% of the sunlight entering the space strikes the mass wall.

3. One cubic foot of water = 62.4 pounds or 7.48 gallons.

REFERENCES:

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa. 1979 pp 145-151.

2. David Brainbridge. "Water Wall Passive Systems - For New and Retrofit Construction," Third Nation Passive Solar Conference Proceedings, San Jose, Ca., January 11-13 1979. pp 473-478.

3. J.F. McClelland and R. Fuchs. "A Preliminary Study of A Passive Heating Performance and Visual Clarity for a Trans-wall Structure", Third National Passive Solar Conference Proceedings, San Jose, Ca, January 11-13, 1979. pp 107-112.

4. Fred Hopman. "The Self-Insulating Water Wall - A Passive Solar Module for Heating and Cooling", Third National Passive Solar Conference Proceedings, San Jose, Ca, January 11-13 1979. pp. 481-486.

SOURCES OF ILLUSTRATIONS

Figure 14-1 Reference 1, p 150.

Figure 14-2 Reference 1, p 146.

Figure 14-3 Reference 2, p 474.

Table 14-1 Reference 1, p 149.

15. SIZING THE WALL



Figure 15-1

LARGE SCALE PATTERNS

After locating the major south-facing spaces - LOCATION OF INDOOR SPACES (6) - and choosing your heating system for each space - CHOOSING THE SYSTEM (9) - this pattern describes the sizing procedure for a THERMAL STORAGE WALL SYSTEM (9B).

THE PROBLEM

WHEN A THERMAL STORAGE WALL IS PROPERLY SIZED, THE TEMPERATURE IN A SPACE WILL REMAIN COMFORTABLE THROUGHOUT MUCH OF THE WINTER WITHOUT ANY ADDITIONAL HEATING SOURCE. However, if a thermal wall is oversized, then more heat is transmitted through the wall than is needed, resulting in a space that is uncomfortably warm. Of course, heat will be vented from a warm space to reduce interior temperatures. This also reduces the system's efficiency by disposing of valuable heat in winter. If a wall is undersized, then there is not enough heat transmitted through the wall, and supplementary heating will be needed in the space. The correct size of a Thermal Storage Wall will change as climate, latitude and space heating requirements change.[1]

THE RECOMMENDATION

IN COLD CLIMATES (average winter temperatures 20°to 30°F) use between 0.43 and 1.0 square feet of south-facing, double-glazed, masonry thermal storage wall (0.31 and 0.85 square feet for a water wall) for each one square foot of space floor area. In temperate climates (average winter temperatures 35°to 45°F) use between 0.22 and 0.6 square feet of thermal wall (0.16 and 0.43 square feet for a water wall) for each one square foot of space floor area.[1]

SMALL SCALE PATTERNS

Detail the wall so it performs efficiently - WALL DETAILS(16). The area of thermal wall needed to heat a space can be substantially reduced by using exterior REFLECTORS (24) and/or MOVABLE INSULATION (23). In fact, their use is strongly recommended in cold northern climates. Remember that an under-sized thermal wall can be combined with other passive systems to provide adequate space heating - COMBINING SYSTEMS (21). You should plan the wall for cloudy days- CLOUDY DAY STORAGE (22). By the use of proper WALL DETAILS (16), you can convert a masonry wall into a SOLAR CHIMNEY (31) to drive EARTH TUBES (28) and KING VENTILATION SYSTEM (29) for earth tempered ventilation.[2]

ILLUSTRATION

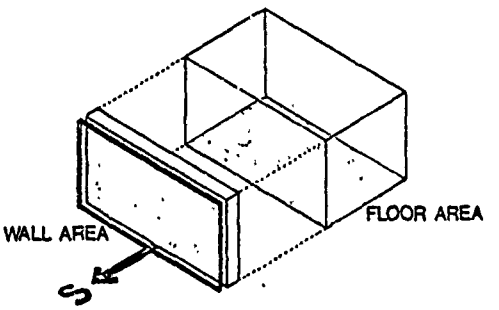


Figure 15-2

INFORMATION

The size of your thermal wall depends on three factors: local climate, latitude, space heat loss. Each factor influences the size of the wall.

Climate: In cold climates, more heat or larger thermal storage is needed to keep the space at ±70°F.

Latitude: The wall will increase in size the further north your building is located.

Space Heating Loss: A well-insulated and tightly sealed space requires less heat to keep it at a specified temperature and, therefore, requires less wall.

SIZING THE SYSTEM

Ed Mazria's criteria for a well-designed thermal storage wall

is that it transmit enough thermal energy (heat), on an average sunny day in January, to supply a space with its heating needs for that day.

That means that the energy transmitted through the wall should be sufficient to maintain an average space temperature of 65°to 75°F over a 24-hour period.

Using this criteria, Ed Mazria developed the sizing ratios shown in table 15-1.[1]

TABLE 15-1

Sizing a Thermal Storage Wall for Different Climatic Conditions

Average Winter Outdoor Temperature (°F) (degree-days/mo.)[1]	Square Feet of Wall[2] Needed for Each One Square Foot of Floor Area	
	Masonry Wall	Water Wall
Cold Climates		
15° (1,500)	0.72–>1.0	0.55–1.0
20° (1,350)	0.60–1.0	0.45–0.85
25° (1,200)	0.51–0.93	0.38–0.70
30° (1,050)	0.43–0.78	0.31–0.55
Temperate Climates		
35° (900)	0.35–0.60	0.25–0.43
40° (750)	0.28–0.46	0.20–0.34
45° (600)	0.22–0.35	0.16–0.25

NOTES: 1. Temperatures and degree-days are listed for December and January, usually the coldest months.

2. Within each range choose a ratio according to your latitude. For southern latitudes, i.e., 35°NL, use the lower wall-to-floor-area ratios; for northern lautudes, i.e., 48°NL, use the higher ratios. For a poorly insulated building always use a higher value. For thermal walls with a horizontal specular reflector equal to the height of the wall in length, use 67% of recommended ratios. For thermal walls with night insulation (R-8), use 85% of recommended ratios. For thermal walls with both reflectors and night insulation, use 57% of recommended ratios.

The exact size of the wall depends on many considerations such as views, natural lighting, solar blockage and cost, and will be decided by the retrofit designer.

Refer to Reference 1 for design details.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa, 1979. pp 153-157.

2. Dr. Donald B. Elmer, Mo Hourmanesh, and Ray Hourmanesch. "Earth Air Heat Exchangers", 2nd National Passive Solar Conference Proceedings, Philadelphia Pa, March 16-18, 1978. Vol I, p146-148.

SOURCES OF ILLUSTRATIONS

Figure 15-1 Reference 1 p 151

Figure 15-2 Reference 1 p 154

Table 15-1 Reference 1 p 156

16. WALL DETAILS



Figure 16-1

LARGE SCALE PATTERNS

Once a rough size for a thermal storage wall is determined - SIZING THE WALL(13) - this pattern helps to detail the wall so the system performs efficiently.

THE PROBLEM

THE EFFICIENCY OF A THERMAL STORAGE WALL SYSTEM IS LARGELY DETERMINED BY THE WALL'S THICKNESS, MATERIAL AND SURFACE COLOR. A space will overheat if more energy is transmitted through a thermal wall than is needed. This happens when a wall is either too large in surface area, or too thin. If a wall is too thick or painted the wrong color, it becomes inefficient as a heating source since little energy is transmitted through it. For each type of wall material there is an optimum thickness.[1]

THE RECOMMENDATION

USE THE FOLLOWING TABLE AS A GUIDE FOR SELECTING A WALL THICKNESS:

Material	Recommended Thickness (in)
Adobe	8-12
Brick (common)	10-14
Concrete (dense)	12-18
Water	6 or more

MAKE THE OUTSIDE FACE OF THE WALL A DARK COLOR. IN COLD CLIMATES

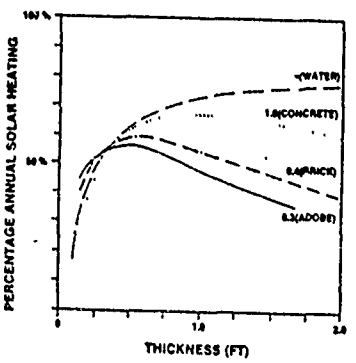
ADD THERMO-CIRCULATION VENTS, OF ROUGHLY EQUAL SIZE, AT THE TOP AND BOTTOM OF A MASONRY WALL TO INCREASE THE SYSTEM'S PERFORMANCE. MAKE THE TOTAL AREA OF EACH ROW OF VENTS EQUAL TO APPROXIMATELY ONE SQUARE FOOT FOR EACH 100 SQUARE FEET OF WALL AREA. PREVENT REVERSE AIR FLOW AT NIGHT BY PLACING AN OPERABLE PANEL (damper), HINGED AT THE TOP, OVER THE INSIDE FACE OF THE UPPER VENTS, OR USE AN AUTOMATIC DAMPER LIKE SHOWN IN FIGURE 16-3.[1,2]

SMALL SCALE PATTERNS

Placing MOVABLE INSULATION (23) over the glazing at night increases the system's performance. If possible, design the movable insulation to be used as REFLECTORS (24) and/or SHADING DEVICES(25). Shading the wall in summer and early fall will prevent the space from overheating.

Or you can locate Movable Insulation on the interior surface of a dark masonry wall to convert the wall into a Solar Chimney (31) to drive EARTH TUBES (28) and KING VENTILATION SYSTEM (29) for earth tempered ventilation.

ILLUSTRATIONS



Yearly performance of a thermal storage wall for various thicknesses and thermal conductivities

Figure 16-2

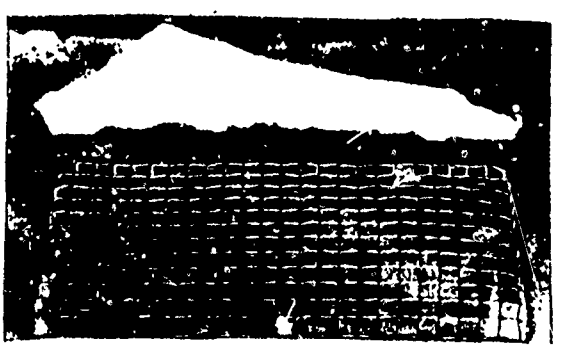


Figure 16-3

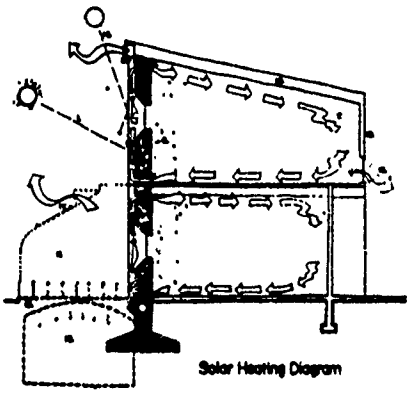


Figure 16-4

INFORMATION

The details of the wall, its thickness, surface color, and addition of thermo-circulation vents, and temperature control devices determine the efficiency of the system and its ability to provide thermal comfort in the winter.

Wall Thickness

From Figure 16-2, the following conclusions have been drawn by Ed Mazria:

1. The optimum thickness of a masonry wall increases as the thermal conductivity of the wall increases.
2. The efficiency of the wall increases as the conductivity of the wall increases.
3. For masonry materials there is a range of optimum thicknesses.
4. The efficiency of a water wall increases as the thickness of the wall increases, although after 6 inches the increase in performance is not very pronounced.

Table 16-1 lists the thermal conductivity and recommended thickness for five commonly used wall materials. Your choice of wall thic ness, within the range given for each material will determine the temperature fluctuation in the space over the day.

TABLE 16-1 Effect of Wall Thickness on Space Air Temperature Fluctuations

Material	Thermal Conductivity (Btu/hr-ft-°F)	Recommended Thickness (in)	Approximate Indoor Temperature (°F) Fluctuation as a Function of Wall Thickness[1]					
			4 in	8 in	12 in	16 in	20 in	24 in
Adobe	0.30	8–12	...	18°	7°	7°	8°	...
Brick (common)	0.42	10–14	...	24°	11°	7°	...	...
Concrete (dense)	1.00	12–18	...	28°	16°	10°	6°	5°
Brick (magnesium additive)[2]	2.20	16–24	...	35°	24°	17°	12°	9°
Water[3]	....	6 or more	31°	18°	13°	11°	10°	9°

NOTES: 1. Assumes a double-glazed thermal wall. If additional mass is located in the space, such as masonry walls and/or floors, then temperature fluctuations will be less than those listed. Values given are for winter-clear days.

2. Magnesium is commonly used as an additive to brick to darken its color. It also greatly increases the thermal conductivity of the material.

3. When using water in tubes, cylinders or other types of circular containers, use at least a 9½-inch-diameter container or ½ cubic foot (31.2 lb or 3.74 gal) of water for each one square foot of glazing.

AS A GENERAL RULE THE GREATER THE WALL THICKNESS THE LESS THE INDOOR TEMPERATURE FLUCTUATIONS.

Wall Surface Color

The greater the absorption of solar energy at the outside surface of a thermal wall, the greater will be the transmission of heat through the wall to the interior space. A black-colored surface, with a solar absorption of 95%, is one of the most efficient absorbers. Performance, though, is only one criterion for the selection of wall color. Other colors such as dark blue (solar absorption 85%) also work well. Reducing the solar absorption for both water and masonry walls from 95% to 85% reduces the system's efficiency proportionally. The inside surface of the wall can be made any color.[1]

You can use Figure V-10 in chapter 5 of Ed Mazria's book (Reference 1) to predict the time of day a space will reach its maximum and minimum temperatures.

Thermocirculation Vents

Locating openings (vents) at the top and bottom of the wall induces a natural (passive) circulation of warmed air into the building. The natural convection of heated air continues for 2 to 3 hours after sunset, when the wall becomes too cool to induce a warm airflow.[1]

At night the air between the glazing and wall cools, and the air movement will reverse. To prevent reverse air flow at night attach an operable panel or automatic damper over the inside face of the upper vents as mentioned in THE RECOMMENDATION.[1,2]

Space Temperature Control

If a space becomes too warm, movable insulation (such as curtains, sliding panels) placed over the inside face of a thermal wall turns off the heating system. This is a very simple and effective way to control indoor temperatures. The system can be adjusted by covering all, part or none of the wall.[1]

A dark masonry wall can be converted into a SOLAR CHIMNEY (31) in the summer by placing MOVABLE INSULATION (23) on the inside surface of the wall, closing the upper interior vent, and venting the wall to the outside with an exhaust fan. This SOLAR CHIMNEY (31) will continue to ventilate the space until late at night. EARTH TUBES (28) and KING VENTILATION SYSTEM (29) can be used as a cool air source for ventilation of the space. This process is illustrated by Figure 16-4.[3,4,5]

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa., 1979. pp 159-171.

2. Doug Kelbaugh, AIA. "Kelbaugh House: Recent Performance," 2nd National Passive Solar Conference Proceedings, Philadelphia, Pa, March 16-18 1978. Vol. I p69-75.

3. Norma Skurka and Jon Naar. Design for a Limited Planet, Ballentine Books, New York, NY, 1976. pp 123-127.

4. Dr. Donald B. Elmer, Mo Hourmanesh and Ray Hourmanesch. "Earth Air Heat Exchangers", 2nd National Passive Solar Conference Proceedings, Philadelphia, Pa., March 16-18, 1978. Vol I. p 146-148.

5. David Wright, AIA. Natural Solar Architecture - A Passive Primer, Van Nostrand Reinhold Company, 1978 pp 194-195 and 210. (Appendix K).

SOURCES OF ILLUSTRATIONS -

Figure 16-1 Reference 1 p.158

Figure 16-2 Reference 1 p.161

Figure 16-3 Reference 2 p.69

Figure 16-4 Reference 2 p.69

Table 16-1 Reference 1 p.163

17. SIZING THE GREENHOUSE

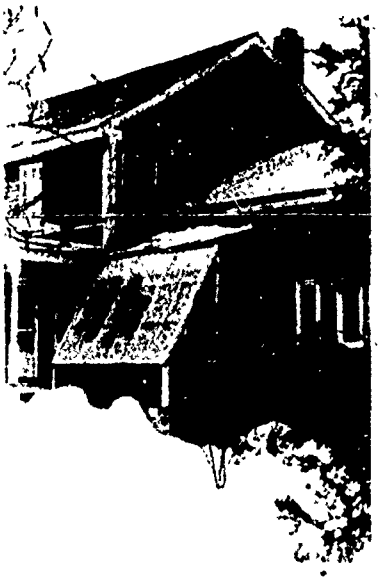


Figure 17-1

LARGE SCALE PATTERNS

A building located in the northern portion of a sunny area - BUILDING LOCATION (2) - insures that any additions or projections along its south wall - BUILDING SHAPE AND ORIENTATION (3)- will receive direct sunlight. The solar greenhouse will supply heat to a building when attached to its south side - CHOOSING THE SYSTEM (9C). This pattern helps size the area of greenhouse glazing necessary for collecting enough solar energy to supply heat for both the greenhouse and the building.

THE PROBLEM

THE COMPLICATED NATURE OF THERMAL ENERGY FLOWS BETWEEN AN ATTACHED GREENHOUSE AND A BUILDING MAKES IT DIFFICULT TO ACCURATELY SIZE A GREENHOUSE AND TO PREDICT ITS PERFORMANCE AS A HEATING SYSTEM. When properly sized, the attached greenhouse not only heats itself but heats the spaces adjacent to it. However, the quantity of heating provided depends upon many variables such as latitude, climate, thermal storage mass, and the size and insulating properties of the greenhouse and spaces being heated.[1]

THE RECOMMENDATION

EXTEND THE GREENHOUSE ALONG THE SOUTH WALL OF THE BUILDING ADJOINING THE SPACES YOU WANT TO HEAT. IN COLD CLIMATES, USE BETWEEN 0.65 and 1.5 SQUARE FEET OF SOUTH-FACING DOUBLE GLASS (greenhouse) FOR EACH ONE SQUARE FOOT OF (adjacent) BUILDING FLOOR AREA. IN TEMPERATE CLIMATES, USE 0.33 TO 0.9 SQUARE FEET OF GLASS FOR EACH ONE SQUARE FOOT OF BUILDING FLOOR AREA. THIS

AREA OF GLAZING WILL COLLECT ENOUGH HEAT DURING A CLEAR WINTER DAY TO KEEP BOTH THE GREENHOUSE AND ADJOINING SPACE AT AN AVERAGE TEMPERATURE OF 60°TO 79°F.[1]

SMALL SCALE PATTERNS

Locate enough thermal mass in the greenhouse so that it absorbs direct sunlight and dampens interior temperature fluctuations. Construct the mass wall between the greenhouse and building so that it allows for the efficient transfer of heat between the two spaces - GREENHOUSE CONNECTION (18). MOVABLE INSULATION (23) should be provided to reduce night heat losses, and summer heat build-up.

ILLUSTRATION

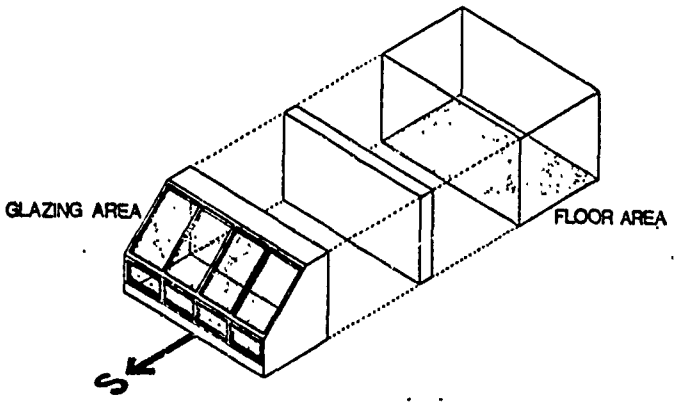


Figure 17-2

INFORMATION

In most climates a well-constructed attached solar greenhouse collects more energy on a clear winter than it needs for heating. A portion of this extra energy can be conducted through the common wall between the greenhouse and the building. In this way the attached greenhouse has the potential to supply a substantial amount of heat to the space(s) adjoining it.

Approximate glass area (double-glazed) for cold and temperate climates are given, in Table 17-1, for incorporating either with common masonry, or water storage wall between the spaces.

When using a thermal wall for heat storage and transfer, attach the greenhouse so it extends along the south wall of a building exposing a large surface area of thermal wall to direct sunlight. A greenhouse elongated along the east-west axis is the most efficient shape for solar collection - BUILDING SHAPE

TABLE 17-1

Sizing the Attached Greenhouse for Different Climatic Conditions

Average Winter Outdoor Temperature (°F) (degree-days/mo.)[1]	Square Feet of Greenhouse Glass[2] Needed[2] for Each One Square Foot of Floor Area	
	Masonry Wall	Water Wall
Cold Climates		
20° (1,350)	0.9 –1.5	0.68–1.27
25° (1,200)	0.78–1.3	0.57–1.05
30° (1,050)	0.65–1.17	0.47–0.82
Temperate Climates		
35° (900)	0.53–0.90	0.38–0.65
40° (750)	0.42–0.69	0.30–0.51
45° (600)	0.33–0.53	0.24–0.38

NOTES: 1. Temperatures and degree-days are listed for December and January, usually the coldest months.

2. Within each range choose a ratio according to your latitude. For southern latitudes, i.e., 35°NL, use the lower glass-to-floor-area ratios; for northern latitudes, i.e., 48°NL, use the higher ratios. For a poorly insulated greenhouse or building, always use slightly more glass.

AND ORIENTATION (3).

Whenever possible recess the greenhouse into the building so that the east and west walls are also common partitions. This not only reduces greenhouse heat loss but increases the amount of heat transferred to the adjacent spaces.

An attached greenhouse with less than the recommended glass area works with the same efficiency. The amount of heat collected through each square foot of glass remains the same, only with less glass, less heat is collected. The area of greenhouse glazing will determine the potential contribution of solar heat supplied to the building over the year.

When the primary function of the greenhouse is to heat the building, taking heat from the greenhouse by mechanical means and storing it for use in the building will increase the efficiency of the system. This approach works best when the greenhouse is allowed to drop in temperature to about 40°to 45°F at night.

To improve the performance of the greenhouse for night operation you should provide MOVABLE INSULATION (23).

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa, 1979.pp pp 173-179.

2. Fuller Moore. Solargreen - A Passive Solar Dwelling for All Seasons - Award Winning Design in recent U.S. Dept of H.U.D. Passive Solar Residential Design Competition. (See Appendix L.)

SOURCES OF ILLUSTRATIONS

Figure 17-1 Reference 1 p.178

Figure 17-2 Reference 1 p.174

Table 17-1 Reference 1 p.175

18. GREENHOUSE CONNECTION



Figure 18-1

LARGE SCALE PATTERNS

This pattern completes SIZING THE GREENHOUSE (17) by specifying the details necessary for a proper connection between the greenhouse and the building.

THE PROBLEM

THE DETAILING OF THE THERMAL CONNECTION BETWEEN THE ATTACHED GREENHOUSE AND THE BUILDING WILL DETERMINE THE EFFECTIVENESS OF THE GREENHOUSE AS A HEATING SOURCE. For systems that rely on heat transfer through the common wall between the greenhouse and adjacent space(s), the efficiency of the system is largely determined by the surface area of the wall, its thickness, material and surface color.[1]

THE RECOMMENDATION

WHEN THE PRINCIPAL METHOD OF HEAT TRANSFER BETWEEN THE GREENHOUSE AND BUILDING IS A THERMAL WALL, USE THE FOLLOWING TABLE AS A GUIDE FOR SELECTING A WALL THICKNESS:

MATERIAL	RECOMMENDED THICKNESS (in)
Adobe	8-12
Brick (common)	10-14
Concrete (dense)	12-18
Water	8 or more (or 0.67 cu ft for each one sq ft of south-facing glass).

MAKE THE SURFACE OF THE WALL A MEDIUM OR DARK COLOR AND BE CAREFUL NOT TO BLOCK DIRECT SUNLIGHT FROM REACHING IT. IN COOL AND COLD CLIMATES, LOCATE SMALL VENTS OR OPERABLE WINDOWS IN THE WALL TO ALLOW HEAT FROM THE GREENHOUSE DIRECTLY INTO THE BUILDING DURING THE DAYTIME.[1]

SMALL SCALE PATTERNS

Provide exterior operable vents and shading devices to prevent a heat buildup in the Greenhouse during the summer - MOVABLE INSULATION (23) and REFLECTORS (24). You can use the "stack effect" within the greenhouse to provide the motive force for EARTH TUBES (28) to give SUMMER COOLING (27).[2,3,4,5]

ILLUSTRATIONS

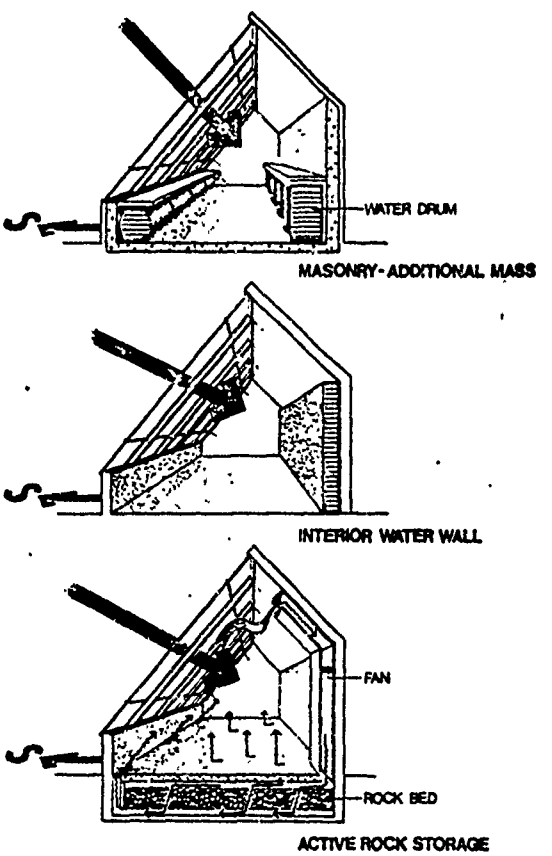


Figure 18-2

INFORMATION

There are three methods of heat transfer from the greenhouse to the building:1) common masonry wall; 2) water wall; 3) active rock storage - passive distribution.

Common Masonry Thermal Wall

If your building has a masonry wall and you retrofit a greenhouse on to it, then you should add some water containers to reduce or dampen heat fluctuations within the Greenhouse. This is necessary because masonry alone cannot store enough heat.

The masonry wall functions very much like a Masonry Thermal Storage Wall System. They are so similar that the optimum wall thickness and surface color are the same as WALL DETAILS (16).[1]

Common Water Thermal Wall

Appendix J gives information about two waterwall systems that could be retrofit to an existing light frame building to provide thermal mass for heat storage. With 0.67 cubic feet of water (or more) for each square foot of south-facing glazing, no additional mass is needed in the greenhouse. The water wall should expose as much surface area as possible in both the greenhouse and adjacent space for adequate heat absorption and transfer.[1]

Active Rock Storage - Passive Heat Distribution

If you desire to use the greenhouse primarily as a heating source, it may be advantageous to actively take heat from the greenhouse and store it in the space for night use.

For a large building with a large floor area to south wall ratio, this method is probably the best, because the night radiant heat is limited to a range of about 20 feet.

Additional Items

Provisions for operable vents and SHADING DEVICES (25) are essential to prevent a heat buildup. You should refer to Ed Mazria's book, Greenhouse Details - pp 209-218 for details.

During the summer, the "stack effect" in the greenhouse can be used as a driving force for EARTH TUBES (28) and SUMMER COOLING (27)[2,3,4,5]

MOVABLE INSULATION (23) should be considered for northern cold climates to reduce winter night time heat losses.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa., 1979. pp 181-185.

2. Dr. Donald B. Elmer, Mo Hourmanesh and Ray Hourmanesh. "Earth Air Heat Exchangers, " 2nd Nation Passive Solar Conference Proceedings, Philadelphia Pa., March 16-18 1978. Vol I p 146-148.

3. Norma Skurka and Jon Naar. "Lee Porter Buttler," Design for a Limited Planet, Ballentine Books, New York, NY, 1976.

4. Fuller Moore. A Passive Solar Dwelling for All Seasons - Award Winning Design in recent U.S. Dept of H.U.D. Passive Solar Residential Design Competition.

5. David Wright, AIA. Natural Solar Architecture - A Passive Primer, Van Nostrand Reinhold Company, 1978. pp 194-195 and 210 (Appendix K).

SOURCES OF ILLUSTRATION

Figure 18-1 Fuller Moore residence - Solargreen

Figure 18-2 Reference 1. p211.

19. SIZING THE ROOF POND

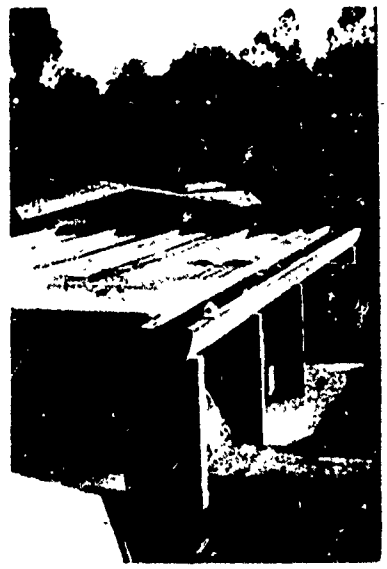


Figure 19-1

LARGE SCALE PATTERNS

After choosing the roof pond as a possible retrofit heating and cooling system - CHOOSING THE SYSTEM/ROOF POND (9A) - this pattern gives you a procedure for sizing the variations of this system.

THE PROBLEM

SINCE ROOF PONDS GENERALLY ACT AS COMBINED SOLAR COLLECTOR, HEAT DISSIPATOR (for summer cooling), STORAGE MEDIUM AND RADIATOR, THE AREA REQUIRED VARIES ACCORDING TO WHETHER THE PONDS ARE USED FOR HEATING OR COOLING, THE TYPE OF MOVABLE INSULATION USED AND THE TYPE OF GLAZING AS WELL AS CLIMATE, LATITUDE AND BUILDING LOAD.[1]

THE RECOMMENDATION

FOR HEATING, THE RECOMMENDED RATIOS OF ROOF POND COLLECTOR AREA FOR EACH ONE SQUARE FOOT OF SPACE FLOOR AREA ARE GIVEN IN THE FOLLOWING TABLE:

Average winter outdoor temperature (°F)	15°-25°	25°-35°	35°-45°
Double-glazed ponds w/night insulation	. . .	0.85-1.0	0.60-0.90
Single-glazed ponds w/night insulation and reflector	. . .	. . .	0.33-0.60

Average winter outdoor temperature (°F)	15°-25°	25°-35°	35°-45°
Double-glazed pond w/night insulation and reflector	. . .	0.50-1.0	0.25-0.45
South-sloping collector cover w/night insulation	0.60-1.0	0.40-0.60	0.20-0.40

WITHIN EACH RANGE, CHOOSE A RATIO ACCORDING TO YOUR LATITUDE. AT LOWER LATITUDES USE THE LOWER RATIO AND AT HIGHER LATITUDES THE HIGHER VALUE. ROOF PONDS REQUIRE AUGMENTATION BY REFLECTORS AT LATITUDES GREATER THAN 36°NL.

RECOMMENDED RATIOS OF ROOF POND AREA TO SPACE FLOOR AREA FOR COOLING ARE GIVEN IN THE FOLLOWING TABLE. THESE AREAS ARE BASED ON THE ASSUMPTION THAT THE PONDS ARE NOT BLOCKED FROM SEEING AT LEAST THREE-FOURTHS OF THE WHOLE SKYDOME.

Type of Pond	Hot-Humid Climate	Hot-Dry Climate
Single-glazed pond	1.0	0.75-1.0
Single-glazed pond augmented by evaporative cooling	0.75-1.0	0.33-0.50

Ref 1

SMALL SCALE PATTERNS

Have your roof pond retrofit project designed by an experienced (roof pond) Architect on an A and E contract - ROOF POND DETAILS (20) so the system is simple to build and functions efficiently.

ILLUSTRATIONS

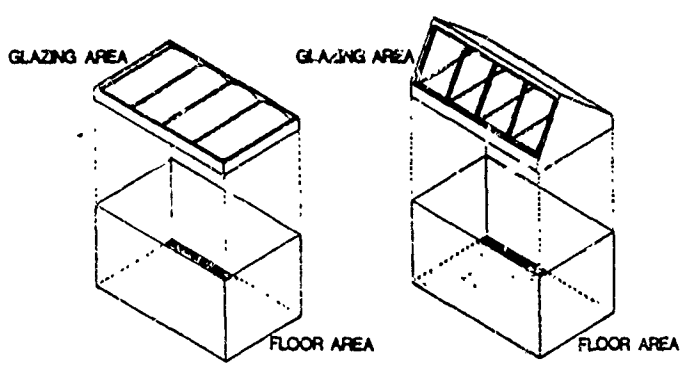


Figure 19-2

INFORMATION

At the present time all the rules of thumb are for metal deck roofs. None have been developed for concrete decks, but in general metal decks will perform better as a radiative surface for heating and cooling.

Trinity University is presently doing the most authoritative research concerning roof pond systems as a cooling system. They are constructing a large experimental station at this time, and should have better sizing rules of thumb available by Spring of 1981.

Another new roof pond system for use in a hot-arrid region is being developed by Karen Crowther. It is an evaporative/thermosiphoning roof pond (See Appendix M).

You should refer to Appendix M for the most recent technical papers on roof pond systems, and to Reference 1 for detailed discussion of function, movable insulation and glazing.

Note: The ROOF POND SYSTEM (9b) is patented under the name "Skytherm" (See Table 23-1) by Harold Hay. You should inform the construction agency of this trademark to avoid sole source procurement.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rowdale Press, Emmaus, Pa. 1979. pp.187-192.

2. "New Research", Research and Design - The Quarterly of the AIA Research Corp. Vol. II, no. 3, Fall 1979. p. 18 (See Appendix M).

3. F.M. Loxson, et.al. "A National Assessment of Passive Nocturnal Cooling From Horizontal Surfaces," 4th National Passive Solar Conference Proceedings, Kansas City, Mo., October 3-5, 1979. pp 466-470 (See Appendix M).

4. Karen Crowther. "Cooling from An Evaporating, Thermosiphoning Roof Pond," 4th National Passive Solar Conference Proceedings, Kansas City, Mo., October 3-5, 1979.pp 499-503.

SOURCES OF ILLUSTRATIONS

Figure 19-1 Reference 1. p 186

Figure 19-2 Reference 1. p 188

20. ROOF POND DETAILS



Figure 20-1

LARGE SCALE PATTERNS

Once a clear idea for the size and shape of the roof pond -SIZING THE ROOF POND (19) - is established, it is necessary to detail the system so that it functions efficiently.

THE PROBLEM

DUE TO THE INTEGRAL NATURE OF ROOF PONDS AND ARCHITECTURE, ESPECIALLY WITH REGARD TO STRUCTURE, ROOF AND CEILING, THERE ARE MANY DETAILS THAT NEED CAREFUL CONSIDERATION. ALTHOUGH ROOF PONDS ARE SIMPLE IN CONCEPT AND POTENTIALLY INEXPENSIVE, MAJOR PROBLEMS HAVE BEEN CAUSED BY FAILURE TO ADEQUATELY WORK OUT THE NUMEROUS SMALL DETAILS THAT MAKE UP THE SYSTEM.[1,2]

THE RECOMMENDATION

HAVE THE PLANS, SPECIFICATIONS AND DETAILS PREPARED BY AN EXPERIENCED (roof pond) ARCHITECT ON AN A and E CONTRACT SO THE SYSTEM IS SIMPLE TO BUILD AND FUNCTIONS EFFICIENTLY.

SMALL SCALE PATTERNS

When the movable insulation panels also double as reflectors, optimize the angle of the reflector according to the information given in Ed Mazria's book (Reference 1)pp241 248. Adjust the depth of the pond to provide heat for CLOUDY DAY STORAGE (22).

INFORMATION

Daniel Aiello in his paper "Architectural Implications of Roof Pond Heating and Cooling Systems," presented at the 4th National Passive Solar Conference discusses the detailing problems that must be solved for roof pond systems. You probably don't have the expertise therefore you should seek design assistance from an experienced Architect, on an A and E contract. Ideally the Architect should have had supervision and past construction evaluation experience with roof ponds in addition to design experience. Then the design and details will be based on experience and feedback.

REFERENCES

1. Daniel P. Aiello. "Architectural Implications of Roof Pond Heating and Cooling Systems," 4th National Passive Solar Conference Proceedings, Kansas City, Mo., October 3-5, 1979. pp329-332 (See Appendix M).

2. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition; Rodale Press, Emmaus, Pa., 1979. pp. 194-199.

SOURCES OF ILLUSTRATIONS

Figure 20-1 Reference 2,p.193.

21. COMBINING SYSTEMS

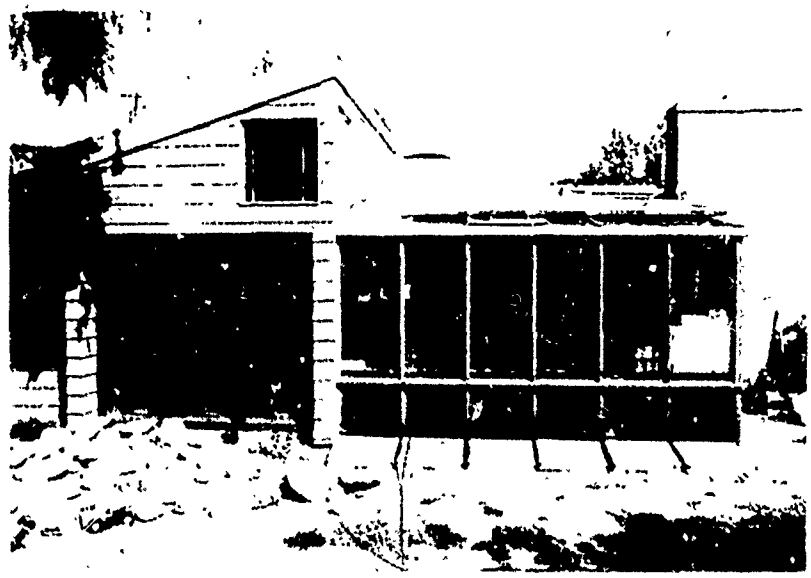


Figure 21-1

LARGE SCALE PATTERNS

If more than one system is chosen to heat a space - CHOOSING THE SYSTEM (9) - this pattern will help determine the relationship between the sizes of the various systems.

THE PROBLEM

IT IS VERY LIKELY THAT A COMBINATION OF PASSIVE SYSTEMS WILL BE USED TO HEAT A SPACE. HOWEVER, SIZING PROCEDURES ARE USUALLY ONLY GIVEN FOR INDIVIDUAL SYSTEMS. For example, many passive solar heated spaces employing a Thermal Storage Wall or Attached Greenhouse System will also include south-facing windows in the space. In some cases, direct gain windows will be part of the thermal wall. In this and other similar situations, the sizing procedures given in previous patterns must be adjusted.

THE RECOMMENDATION

WHEN SIZING A COMBINATION OF SYSTEMS, ADJUST THE PROCEDURES GIVEN IN PREVIOUS PATTERNS ACCORDING TO THE FOLLOWING RATIOS: FOR THE SAME AMOUNT OF HEATING, EACH 1 SQUARE FOOT OF DIRECT GAIN GLAZING EQUALS 2 SQUARE FEET OF THERMAL STORAGE WALL OR EQUALS 3 SQUARE FEET OF GREENHOUSE COMMON WALL AREA.

SMALL SCALE PATTERNS

You should treat the details of each system as if it were the only system, and slightly over-size collector areas and thermal mass when heat storage for cloudy days is needed - CLOUDY DAY STORAGE (22), - and you should not forget to use MOVABLE INSULATION

(23), REFLECTORS (24), SHADING DEVICES (25) INSULATION ON THE OUTSIDE (26) and SUMMER COOLING (27).

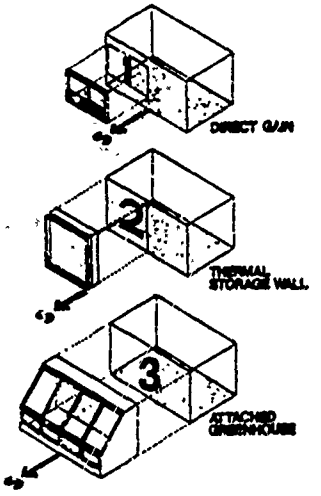


Figure 21-2

INFORMATION

When most of the glazing normally used in a space also doubles as the collector area (south-facing glazing), then a DIRECT GAIN SYSTEM (9A) will utilize approximately 60 to 75% of the energy incident on the collector (south-facing glazing) for space heating. These percentages are largely determined by reflective and absorptive radiation losses through the glazing.

A THERMAL STORAGE WALL SYSTEM (9B) will transfer about 30 to 45% of the energy incident on the collector into a space. This system's efficiency is determined not only by reflective and absorptive losses through glazing, but also by heat lost from the wall's exterior surface because of the high temperatures generated - WALL DETAILS (14).

The ATTACHED GREENHOUSE (9C) is essentially a Thermal Storage Wall System. However, the percentage of incident energy (on the collector) transferred through the common wall between the greenhouse and building is less than a Thermal Storage Wall, or only 15 to 30%. The reason is simply that a greenhouse has more surface area and consequently more heat loss than glass placed only a few inches in front of a wall. This does not imply that this system is inefficient. On the contrary, the energy collected by the greenhouse that is not transferred into the building is used to heat the greenhouse itself.

All of this suggests that a ratio of 1 (Direct Gain) to 2 (Thermal Storage Wall) to 3 (Attached Greenhouse) exists between the systems. (If the collector glazing in a Direct Gain System

is additional to the amount that would normally be used in a space, then double the amount of collector area needed.) This means that each 1 square foot of collector area (glazing) in a Direct Gain System supplies roughly the same quantity of heat to a space as 2 square feet of thermal storage wall, or 3 square feet of attached greenhouse wall area. According to these ratios then, 50 square feet of direct gain glazing will produce roughly the same amount of solar heating as the combination of 25 square feet of direct gain glazing and 75 square feet of attached greenhouse common wall area.[1]

If you actively take heat out of an attached greenhouse and store it in the building - GREENHOUSE CONNECTION (18) - the percentage of incident energy supplied to the space increases. In this case, the ratio of direct gain to attached greenhouse collector area is roughly, 1 to 2.

Because of the many roof pond configurations, it is difficult to give one rule of thumb for combining the pond with other systems. However, for the same amount of heating, the ratio of roof pond collector area to the collector area of other systems can be determined from the sizing procedures given in the patterns SOLAR WINDOWS (11), SIZING THE WALL (15), SIZING THE GREENHOUSE (17) and SIZING THE ROOF POND (19).[1]

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa., 1979. pp. 220-224.

SOURCES OF ILLUSTRATIONS

Figure 21-1 Reference 1 p 219

Figure 21-2 Reference 2 p 221

22. CLOUDY DAY STORAGE



Figure 22-1

LARGE SCALE PATTERNS

This pattern completes all the sizing patterns - SOLAR WINDOWS (9), MASONRY HEAT STORAGE (13) and INTERIOR WATER WALL (14); SIZING THE WALL (15) and WALL DETAILS (16); SIZING THE GREENHOUSE (17) and GREENHOUSE CONNECTION (18); SIZING THE ROOF POND (19) and ROOF POND DETAILS (20). In all of them, the size of the collector area and thermal mass can be adjusted to provide heating during periods of cloudy weather.

THE PROBLEM

IN A PASSIVELY HEATED BUILDING WHERE THERMAL-MASS IS PART OF THE HABITABLE SPACES, ANY ADDITIONAL HEAT COLLECTED WILL AFFECT THE AVERAGE TEMPERATURE IN THE SPACE. The patterns give rules of thumb for sizing a system to maintain an average space temperature of 70°F during clear winter days. To store heat for cloudy days, the collector area and storage mass must be increased. However, as the system becomes larger and the average temperature in the space increases, overheating on sunny days may occur.[1]

THE RECOMMENDATION

DIRECT GAIN SYSTEMS (9A)

AS A GENERAL RULE, TO PROVIDE HEAT STORAGE FOR ONE OR TWO CLOUDY DAYS, INCREASE THE SOUTH GLAZING (COLLECTOR AREA) BY 10-20% and:

-Construct interior walls and floc. of solid masonry 8 inches or more in thickness, or

-Use 2 to 3 cubic feet of interior water wall for each one square foot of south glazing.

THERMAL STORAGE WALL (9B)
ATTACHED GREENHOUSE (9C)
ROOF POND SYSTEM (9D)

TO PROVIDE HEAT STORAGE FOR ONE OR TWO CLOUDY DAYS, INCREASE THE COLLECTOR AREA BY 10 TO 20% AND USE:

- A THICK MASONRY THERMAL STORAGE WALL OF GREATER CONDUCTIVITY,
- ONE CUBIC FOOT OR MORE OF WATER WALL FOR EACH ONE SQUARE FOOT OF COLLECTOR AREA OR
- 6 TO 8 INCHES OF ROOF POND DEPTH; 8 TO 12 INCHES FOR TWO OR THREE DAYS HEAT STORAGE.[1]

NOTE: IF YOUR BUILDING IS WHERE THERE IS EXTENSIVE WINTER CLOUD COVER, YOU SHOULD NOT OVERSIZE YOUR SYSTEM.

SMALL SCALE PATTERNS

Slow the rate of space heat loss on cloudy days by applying MOVABLE INSULATION (23) over the south glazing at night. In climates with hot-dry summers, cool the thermal mass at night to provide for SUMMER COOLING (27) in the daytime.

INFORMATION

The patterns give rules of thumb for programming and designing a space that will maintain an average temperature of approximately 70°F during periods of sunny winter weather conditions. With the arrival of cloudy weather, it can be expected that the average temperature in a space will drop lower than 70°F with each consecutive cloudy day. This, of course, assumes that no auxiliary heat is supplied to the space. The rate at which the average temperature drops is largely dependent upon the quantity of heat stored in the thermal mass at the beginning of the cloudy period. Since this quantity is dependent upon many variables such as climate, latitude, collector area, rate of space heat loss, mass thickness and mass surface color, the following suggestions are general and will change slightly as the situation changes.

By using this pattern to store extra heat you will be able to reduce the amount of supplemental space heating for your building.

Direct Gain (9A)

If your building is in a climate where consecutive sunny

days are common in winter, the storage of heat for cloudy days is accomplished by slightly over-sizing solar windows and thermal mass. With larger south glazing, it can be expected that the average temperature in a space will be warmer than 70°F on sunny winter days.

However, if your building is in a climate where cloudy or foggy winter weather conditions prevail, designing for cloudy day storage is not recommended, since it takes a period of consecutive sunny days to build up temperatures in a large (thick) thermal mass. In cloudy climates use the glazing areas and minimum mass thickness recommended in SOLAR WINDOWS (11), MASONRY HEAT STORAGE (13) and INTERIOR WATER WALL (14).

THERMAL STORAGE WALL (9B)
ATTACHED GREENHOUSE (9C)
ROOF POND SYSTEM (9D)

Depending upon its thermal properties - WALL DETAILS (16), GREENHOUSE CONNECTION (16) - a masonry thermal storage wall or common masonry wall between a greenhouse and building has an optimum range of thicknesses. If the wall is made too thick, then little heat is transferred through the wall and the system is inefficient. Therefore, to store heat for cloudy days, the surface area of the wall (of a given material), and not its thickness, should be increased.

From the recommendations for wall thickness it can be seen that the higher the conductivity of a material the greater its optimum thickness. In general, after a period of sunny days, thicker walls of higher conductivity will be charged with more heat than thinner walls with lower conductivity and therefore, will cool at a slower rate.

Since a water wall is an excellent conductor of heat (because of water thermocirculation) it can be made any thickness (volume). Using a large volume of water per square foot of south glazing causes a space to cool at a very slow rate during cloudy weather. However, increasing the column of water wall also implies that it will take a period of two or more consecutive sunny days to fully charge it with heat. Therefore, in cloudy climates with few sunny winter days, increasing the volume of water above that needed to dampen interior temperature fluctuations is not recommended.[1]

By oversizing the system for cloudy day storage, space overheating will occur during sunny winter weather, possibly causing discomfort. In a direct gain system the temperature can be controlled by opening a window to lower the temperature. With a thermal storage wall, attached greenhouse and roof pond system you can ventilate them also. But the use of MOVABLE

INSULATION (23) over the inside face of the wall will effectively control overheating.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa., 1979. pp 226-229.

SOURCES OF ILLUSTRATIONS

Figure 22-1 Reference 1 p 225

23. MOVABLE INSULATION



Figure 23-1

LARGE SCALE PATTERNS

This pattern is the starting point for a series of patterns with specific instructions to make your building (the passive system) more efficient as a passive system.

Once the solar system for your retrofit has been determined - CHOOSING THE SYSTEM(9) - and the glass areas for each space located - WINDOW LOCATION (8) - the building can be made more efficient as a solar collector by the use of movable insulation. This pattern must be an integral part of your retrofit of windows and the southern wall - WALL DETAILS (16). The application of this pattern will give good return on the investment, if applied properly.

THE PROBLEM

ALTHOUGH GLASS AND CLEAR OR TRANSLUCENT PLASTICS HAVE THE POTENTIAL TO ADMIT LARGE AMOUNTS OF SOLAR RADIATION AND NATURAL LIGHT INTO A SPACE DURING THE DAYTIME, THEIR POOR INSULATING PROPERTIES ALLOW A LARGE PERCENTAGE OF THIS ENERGY TO BE LOST BACK OUT THROUGH THE GLAZING, MOSTLY AT NIGHT. In a well insulated building, glazed openings (windows, skylights and clerestories) can be one of the largest sources of building heat loss. Approximately two-thirds of this heat loss which occurs at night can be greatly reduced by the use of movable insulation.[1]

THE RECOMMENDATION

USE MOVABLE INSULATION OVER ALL GLAZED OPENINGS TO PREVENT THE HEAT GAINED DURING THE DAYTIME FROM ESCAPING RAPIDLY AT NIGHT. EASE OF OPERATION, DURABILITY AND VISUAL APPEARANCE

ARE AS IMPORTANT AS THE INSULATION VALUE. DEVICES THAT ARE TOO LARGE, CUMBERSOME OR DIFFICULT TO OPERATE WILL INHIBIT PROPER USAGE. IF A CHILD CAN OPEN AND CLOSE THE INSULATION, CHANCES ARE THAT THE ROUTINE WILL BECOME HABITUAL AND FUN.[1,2]

SMALL SCALE PATTERNS

Control the amount of sunlight entering a space at different times of the year by detailing movable insulation so it doubles as SHADING DEVICES (25). When using exterior insulating shutters or panels, design them so that they also serve as REFLECTORS (24) to increase the solar gain through each square foot of glazing. For SUMMER COOLING (27) use Movable Insulation on the interior surface of MASONRY HEAT STORAGE(13) so the wall will function as a SOLAR CHIMNEY (31).

ILLUSTRATION

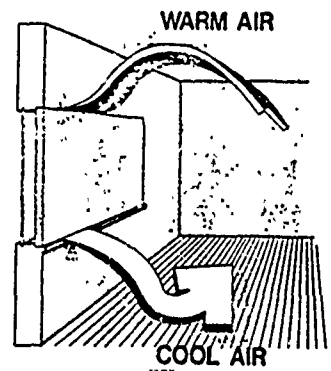


Figure 23-2

INFORMATION

This pattern presents information about using insulation in an Architectural manner. Its use is essential for reducing energy consumption in your building, and improving thermal performance/comfort to the occupants.

Historically this pattern was used in the form of shutters until the emergence of "Modern Architecture". It is now reappearing and being used as a means of protecting glazing and reflecting more light onto a storage media.

Your movable insulation can be located on the outside of the glazing or on the inside. Each has advantages and disadvantages. You and the using organization should select the location of the insulation early in the programming process.

It should be done at the same time you select your solar

system - CHOOSING THE SYSTEM (9), because it will affect the performance of the system.

The location of the insulation also affects the method of moving the insulation: (1) manual, (2) thermally sensitive and (3) motor driven.

Table 23-1 compares the advantages and disadvantages of MOVABLE INSULATION locations and the methods of moving it.

	OUTSIDE	INSIDE
Weather exposure	Must withstand the elements.	N/A
Condensation on Glazing	N/A	Will be a problem.
Location of Critical Seals (Convective Loss)	Top.	Bottom See Figure 23-2
Solar Enhancement	Reflective Surface will enhance solar collection.	N/A
Manual Operation	Must be done by winch and pulleys.	By hand.
Thermal Operation	N/A	SKYLIDS*, heat motor Bimetalic strip - used in difficult areas to reach.
Mechanical Operation	Bead Wall** SKYTHERM*** used in inaccessible location.	N/A

* SKYLIDS are a patented device by Steve Baer, Zomeworks Corp, Albuquerque, N.M.
** Beadwall is a patented device by David Harrison, Zomeworks Corp., Albuquerque, N.M.
*** SKYTHERM is a patented device by Harold Hay.

TABLE 23-1

NOTE: If your building is in an area of extensive winter cloud cover, and you cannot oversize your system -

CLOUDY DAY STORAGE (22) - then you probably should use exterior MOVABLE INSULATION with a reflective surface -REFLECTOR (24). This strategy will allow your building's temperature to respond quickly to solar radiation when the sun does shine. You should also use INSULATION ON THE OUTSIDE (26) to minimize heat losses.

You can use Appendix N and reference 1 as morphologic solution resources:

REFERENCES

1. Edward Mazria. THE PASSIVE SOLAR ENERGY BOOK - Expanded Professional Edition, Rodale Press, Emmaus, Pa., 1979. pp 231-239.

2. David Wright, AIA. Natural Solar Architecture - A Passive Primer, Van Nostrand Reinhold Company, 1978. pp 95-102, 176, 178, 183, 189, 210, 212.

SOURCES OF ILLUSTRATIONS

Figure 23-1 Fuller Moore's roll down reflective insulation shade (See Appendix N).

Figure 23-2 Reference 1. p 233.

24. REFLECTORS

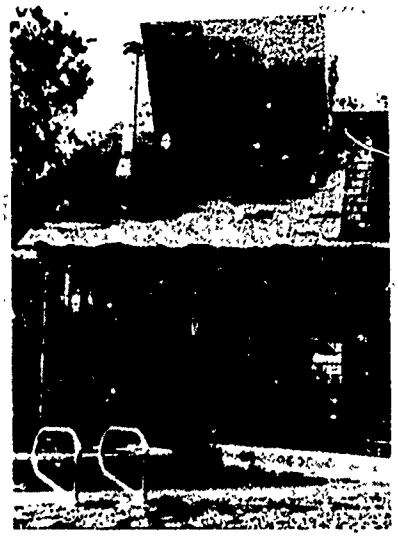


Figure 24-1

LARGE SCALE PATTERNS

After CHOOSING THE SYSTEM (9) and using the ideas about extensive winter cloud cover - CLOUDY DAY STORAGE (22) - and MOVABLE INSULATION (23) the amount of solar energy incident on a collector can be increased with the addition of a reflector. The reflectors must be integrated into the programming of your building's retrofit, because it will affect the sizing and the detailing of the solar system.

THE PROBLEM

A LARGE AMOUNT OF COLLECTOR AREA (south facing glass) MAY NOT BE FEASIBLE OR DESIRABLE IN MANY BUILDING SITUATIONS. In a number of situations, such as partial shading by nearby buildings or vegetation, aesthetic considerations or the limited availability of south wall for solar collection, large south-facing glass areas may not be possible. In addition, since glass is a poor insulator, it makes sense to minimize the area of glazing needed to heat a space. By using exterior reflectors the amount of solar radiation transmitted through each square foot of glass can be dramatically increased.[1]

THE RECOMMENDATION

FOR VERTICAL GLAZING USE A HORIZONTAL REFLECTOR ROUGHLY EQUAL IN WIDTH AND 1 to 2 TIMES THE HEIGHT OF THE GLAZED OPENING IN LENGTH. FOR SOUTH-SLOPING SKYLIGHTS LOCATE THE REFLECTOR ABOVE THE SKYLIGHT AT A TILT ANGLE OF APPROXIMATELY 100^{0}. MAKE THE REFLECTOR ROUGHLY EQUAL TO THE LENGTH AND WIDTH OF THE SKYLIGHT.[1]

SMALL SCALE PATTERNS

When possible, design reflectors to function as SHADING DEVICES (25) and/or insulating shutters - MOVABLE INSULATION (23).

ILLUSTRATION

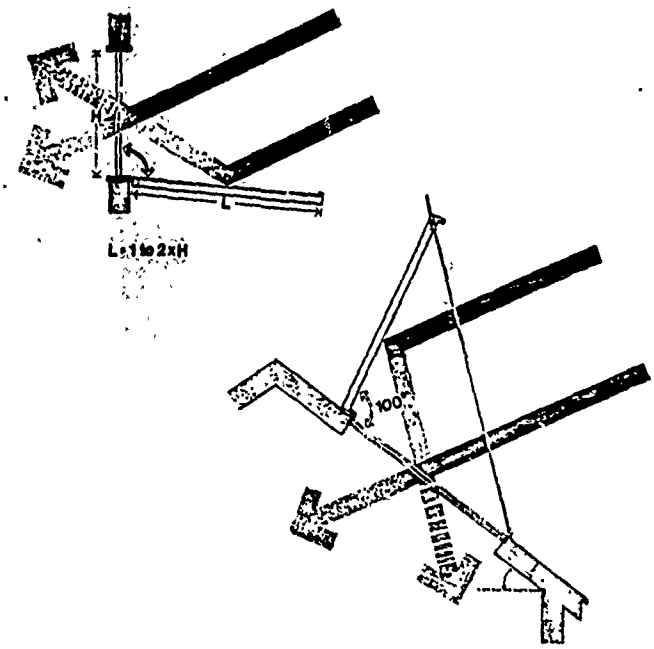


Figure 24-2

INFORMATION

There are two basic types of exterior reflectors/collector configurations: (1) reflectors coupled with vertical or near vertical glazing; (2) reflectors coupled with south-sloping and horizontal skylights (See figure 24-2).

Vertical Glazing:

A horizontal reflector directly in front of the glazing works best. Experiments conducted at the University of Oregon concluded the optimum length of the reflector is 1 to 2 times the height of the glazed opening.

If you use a reflector, the average winter solar radiation incident on the vertical glazing can be increased by roughly 30 to 40% during winter months.[1,2,3]

An intriguing reflector method used by John Reynolds (Eugene, Oregon) is to apply aluminum foil on hot-mopped bituemen in front of clerestory windows.[2,3]

South-Sloping Skylights:

Similar results can be achieved by using a reflector in conjunction with south-sloping skylights (30°to 50°tilt from horizontal) or horizontal skylights.

NOTE: You should not use a skylight reflector if your building is in an area of extensive winter clouding, because the reflector will shade part of the skydome thus reducing the amount of diffuse sky radiation collected by the skylight.

Skylight reflectors can be adjusted for the summer months to serve as SHADING DEVICES (25). In winter the reflector would be raised to increase solar collection. Remember that reflectors which protrude out from the face of a building are usually subject to increased wind loads and must be of sturdy contruction.

Inside the building reflectors can be used to direct sunlight to a particular part of the space. For example, to reflect sunlight onto an INTERIOR WATER WALL (14).

Appropriate materials suitable for reflectors include shiney metals such as polished aluminum, thin metal foils, glass or plastic mirrors and mylar wall coverings. White-colored materials can be used but will not perform as well as polished surfaces. You should be careful using reflectors with windows because of glare.[1]

You should refer to Edward Mazria's book (Reference 1) Appendix J for percent enhancement of vertical south-facing glazing using specular reflectors.



Figure 24-3

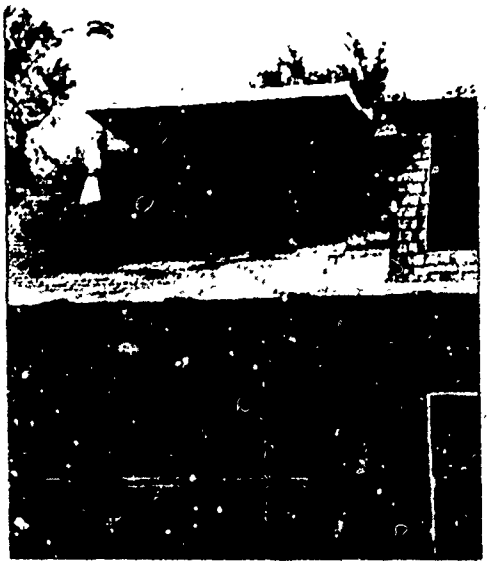


Figure 24-4

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition. Rodale Press, Emmaus, Pa., 1979. pp 248.

2. John Reynolds. Solar Design Symposium at Miami University Oxford,Ohio. 25 April 1978.

3. John Reynolds. "Emerging Architecture" 4th National Passive Solar Conference Proceedings, Kansas City, Mo. October 3-5 1979. p.756.

SOURCES OF ILLUSTRATIONS

Figure 24-1 Reference 1 p.246

Figure 24-2 Reference 1 p.242

Figure 24-3 Reference 1 p.246

Figure 24-4 Reference 1p. 247

25. SHADING DEVICES



Figure 25-1

LARGE SCALE PATTERNS

WINDOW LOCATION (8) calls for the major glass areas in the building to be oriented south. This pattern describes specific methods for shading these glass areas in summer.

THE PROBLEM

LARGE SOUTH-FACING GLASS AREAS, SIZED TO ADMIT MAXIMUM SOLAR GAIN IN WINTER, WILL ALSO ADMIT SOLAR GAIN IN SUMMER WHEN IT IS NOT NEEDED. Although there is less sunlight striking south-facing vertical glass in summer, it is usually enough to cause severe overheating problems. Fortunately, by using an overhang with south glazing, summer sunlight can be effectively controlled. The effectiveness of any shading device, however, depends upon how well it shades the glass in summer without shading it in winter.

THE RECOMMENDATION

SHADE SOUTH GLAZING WITH A HORIZONTAL OVERHANG LOCATED ABOVE THE GLAZING AND EQUAL IN LENGTH TO ROUGHLY ONE-FOURTH THE HEIGHT OF THE OPENING IN SOUTHERN LATITUDES (36°NL) AND ONE-HALF THE HEIGHT OF THE OPENING IN NORTHERN LATITUDES (48°NL).

SMALL SCALE PATTERNS

When possible, design shading devices to act as both REFLECTORS (24) to increase solar gain in winter, and as insulating shutters - MOVABLE INSULATION (23) - to reduce building heat loss.

You can also use the BREATHING WALL (30)[2,3] as a method of shading a large east or west facing wall when vegetation can not be used because of flight and life safety considerations.

ILLUSTRATION

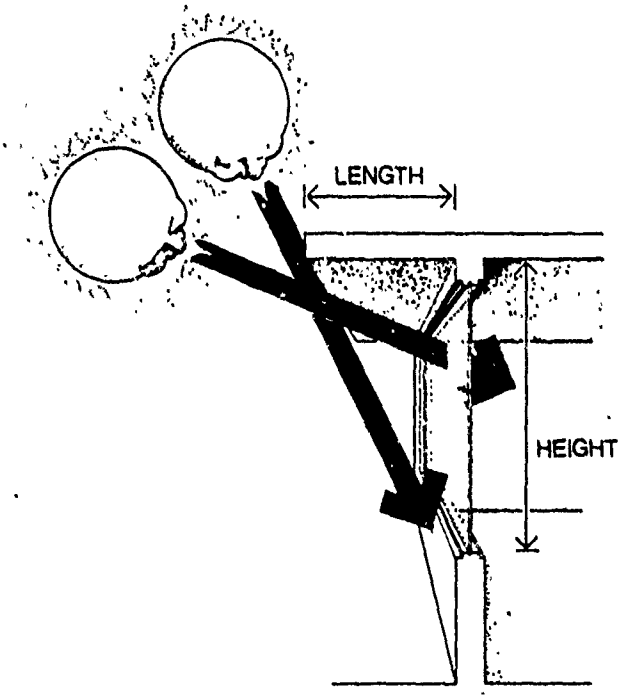


Figure 25-2

INFORMATION

The most effective method for shading south-facing glass in summer is with an overhang. This shading device is simply a solid horizontal projection located at the top exterior of a window. The optimum projection of the overhang from the face of the building is dependent upon window height, latitude and climate. For example, the larger the opening (height) the longer the overhang. At southern latitudes (36°NL) the projection should be slightly smaller than at more northerly latitudes (48°NL), because the sun follows a higher path across the summer skydome. An overhang when tilted up will not only function as a shading device in summer, but also as a reflector in winter.

The following equation provides a quick method for determining the projection of a fixed overhang.

$$\text{Projection} = \frac{\text{Window Opening (Height)}}{F}$$

where

F = Factor from following table

North Latitude	F Factor*
28°	5.6–11.1
32°	4.0– 6.3
36°	3.0– 4.5
40°	2.5– 3.4
44°	2.0– 2.7
48°	1.7– 2.2
52°	1.5– 1.8
56°	1.3– 1.5

NOTE: *Select a factor according to your latitude. The higher values will provide 100% shading at noon on June 21, the lower values until August 1.

A fixed overhang is not necessarily the best solution because the sun's movement does not correspond to climatic seasons. As a general rule the heat cycle is one month behind the solar cycle. A fixed exterior shade will provide the same shading on 21 September when it is hot, and on 21 March when it is cold. An adjustable overhang is a potentially better solution.

There are two options for adjustable overhangs: (1) manual adjust (more expensive to build due to additional hardware); (2) automatic adjust (vine-covered, trellised overhang). This second option follows climatic variations and not solar variations, because a vine will be covered with leaves in summer and early fall, and bare in winter and early spring. Periodic thinning of vines is required so they do not grow too thick and shade the glazing in the winter.

Overhangs do not provide adequate protection for east and west facing glass. Trees, climbing vines and hedges should be used to block the low morning and afternoon sun. Adjustable vertical louvers and awnings or retractable exterior curtains are also effective methods of shading east and west glazing.[1]

Figure 25-1 (United States Military Academy Cadet Library) is a good historical example of the use of this pattern. Note the use of trees, vines and adjustable vertical shading devices above the windows.

If winter gains are of the utmost importance, no tree should intercept the winter sun at all. If trees at the site do intercept the sun, their bare branch effect should be accounted for

in the design.[4]

Interior shading devices such as roller shades, venetian blinds, drapes and panels, are a secondary line of defense against heat gain. However, they do offer ease of maintenance and operation. You should also note that interior shading devices often eliminate or severely limit a view of the outside.[1]

You as the programmer should consult with the using agency concerning their preference of shading device. This is necessary because they will ultimately be responsible for the operation of the system on a daily basis, as seen in Figure 25-1 with the adjustable Shading Devices on the USMA Library.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa., 1979. pp250-257.

2. "Breathing Wall of Brick and Tile - New Masonry Conception," Brick and Clay Record, 1943. pp 14-16 (about building #3001 at Tinker AFB, Oklahoma).

3. Stanley H. Scofield, Capt USAF. "A Historical Review of Natural Ventilation in a Humid Climate", 4th National Passive Solar Conference Proceedings, Kansas City, Mo, October 3-5, 1979.pp 504-506 (See Appendix E).

4. Thomas M Holzberlein. "Don't Let the Trees Make a Monkey of You," 4th National Passive Solar Conference Proceedings Kansas City, Mo., October 3-5, 1979.pp 416-419 (See Appendix P).

SOURCES OF ILLUSTRATIONS

Figure 25-1 East Facade of U.S. Military Academy (USMA) Library Circa 1910, compliments of USMA Archives, West Point, N.Y.

Figure 25-2 Reference 1 p.251.

26. INSULATION ON THE OUTSIDE



Figure 26-1

LARGE SCALE PATTERNS

This pattern completes MASONRY HEAT STORAGE (13) and INTERIOR WATER WALL (14). It describes methods for keeping heat stored in an interior thermal mass from escaping rapidly to the outside.

THE PROBLEM

THE AIR FORCE HAS NUMEROUS MASONRY BUILDINGS WITH INSULATION ON THE INSIDE FACE OF THE WALL. THIS CONDITION DOES NOT ALLOW THE STRUCTURE TO ACT AS A SITE PROVIDED NATURAL RESOURCE FOR STORING HEAT AND COOLTH.

THE RECOMMENDATION

WHEN YOU RETROFIT A MASONRY BUILDING, RELOCATE THE INSULATION ON THE EXTERIOR SURFACE OF THE MASONRY AND PROVIDE A NEW WEATHER - PROOF EXTERIOR SURFACE TO PROTECT THE INSULATION. ALSO AT THE PERIMETER OF THE FOUNDATION WALLS, APPLY APPROXIMATELY 1½ TO 2 FEET OF 2 INCH RIGID WATERPROOF INSULATION BELOW GRADE. THIS WILL PREVENT ANY HEAT STORED IN THE WALLS AND FLOOR FROM BEING CONDUCTED RAPIDLY TO THE OUTSIDE.

SMALL SCALE PATTERNS

If possible, use locally available insulation made of recycled materials, which consumes small amounts of energy to manufacture - APPROPRIATE MATERIALS (10).

If you have a large east or west facing wall, and you can

not grow vines on it or trees near it as a SHADING DEVICE (25) for flight and life safety reasons, then you should consider using the BREATHING WALL (30).[2,3] It will reduce heat transfer to the interior surface of a masonry building.

You must also use SUMMER COOLING (27) to convert your masonry into a summer coolth storage media.

ILLUSTRATION

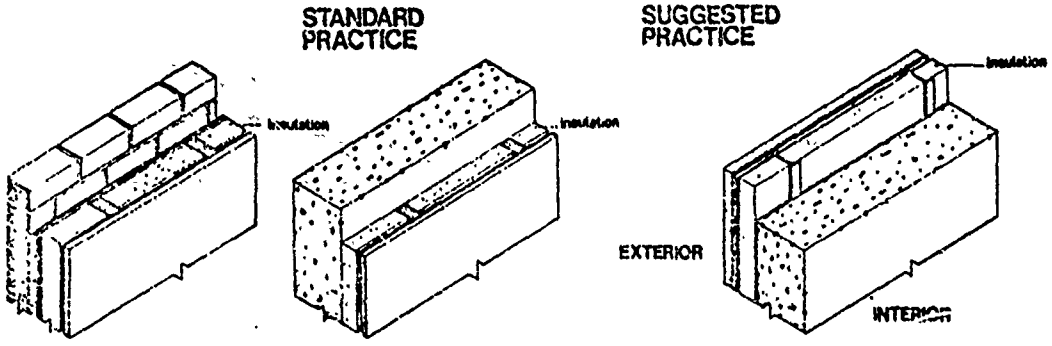


Figure 26-2

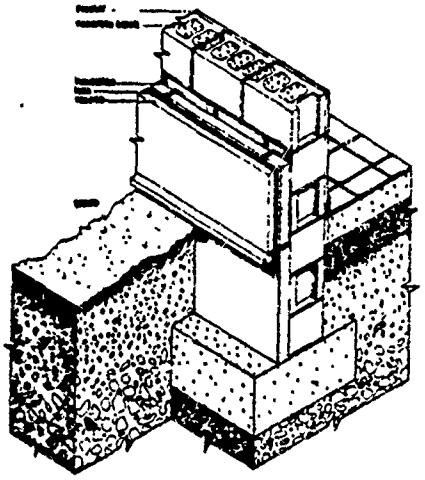


Figure 26-3

INFORMATION

If your building is a masonry building, then the application of this pattern is essential. It probably will be one of

the most cost-effective actions you can take.

THE MASONRY SHOULD BE CONSIDERED AS A SITE PROVIDED NATURAL RESOURCE (energy has been expended to manufacture, transport and construct). YOUR TASK IS TO MAKE IT WORK FOR YOU BY CONVERTING IT INTO A HEAT AND COOLTH STORAGE MEDIA.

The concept is to encapsulate all thermal mass inside of insulation so it can store heat in the day and release it to the space at night. In the winter, the use of MOVABLE INSULATION (23) allows the heat to be retained at night, thus stabilizing heat fluctuations. And during the summer you must use SUMMER COOLING (27) to dissipate the stored heat to the cool night air, and thus store "coolth" in the masonry.

Besides reducing winter night heat losses and summer day heat gains it will reduce the collector area required to heat the space.

After relocating the insulation to the exterior surface of the masonry, you can add water volumes in the interior spaces to increase the thermal mass, as recommended in INTERIOR WATER WALL (14).

NOTE : There is one exception to this rule. In sunny temperate winter climates, south-facing masonry walls with a dark to medium-dark exterior surface color can be left uninsulated, since the south wall absorbs enough sunlight (heat) during the daytime to offset any heat flow out through the wall at night. If your building meets the criteria for this exception to the pattern, then if it is used, it should be identified on the Passive Solar-Building Concept Diagram in the building facilities jacket. This will, hopefully, preclude changing the thermal performance of a building by changing the exterior color of the building to a lighter from a darker color.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa., 1979.pp259-261.

2. "Breathing Wall of Brick and Tile - A New Masonry Conception," Brick and Clay Record, 1943. pp.14-16 (About building #3001 at Tinker AFB, Oklahoma) See Appendix S.

3. Stanley H. Scofield, Capt. USAF. "A Historical Review of Natural Ventilation in a Humid Climate," 4th National Passive Solar Conference Proceedings, Kansas City, Mo., October 3-5, 1979. pp 504-506 (See Appendix E).

SOURCES OF ILLUSTRATIONS

Figure 26-1 Fuller Moore's House for All Seasons - Solargreen- photo by Captain Stanley H. Scofield, May 1979.

Figure 26-2 Reference 1 p.261.

Figure 26-3 Reference 1 p.260

27. SUMMER COOLING

LARGE SCALE PATTERNS

This pattern is the starting point for a series of conceptual patterns that have very few quantifiable rules of thumb. As more experiments are conducted, quantifiable rules of thumb will be developed.

While evaluating your windows for winter solar gain - WINDOW LOCATIONS (8), SOLAR WINDOWS (11) and CLERESTORIES AND SKYLIGHTS (12) and considering possible changes, you must think of windows as summer breeze catchers for cooling.

THE PROBLEM

IF A PASSIVE SOLAR SYSTEM IS DESIGNED PROPERLY, IT WILL GIVE YOU THE POTENTIAL TO PROVIDE BOTH NATURAL HEATING AND NATURAL COOLING, IN CLIMATES WITH COOL OR COLD WINTERS AND WARM SUMMERS. YOU SHOULD NOT OVERLOOK YOUR OPPORTUNITY TO UTILIZE YOUR PASSIVE SOLAR RETROFIT FOR SUMMER COOLING. EVERY PASSIVE SOLAR RETROFIT MUST HAVE TWO ESSENTIAL BUILDING ELEMENTS: 1) SOUTH-FACING GLAZING FOR HEAT GAIN; 2) THERMAL MASS FOR HEAT STORAGE. FOR SUMMER COOLING, THE MASS IS EXPOSED TO THE NIGHT SKY AND NATURAL BREEZE TO LOOSE HEAT - "COOLTH STORAGE" - AND THE MASS ABSORBS AND STORES HEAT AS THE DAY PROGRESSES.[1] WHEN PROPERLY DESIGNED, THE GLAZING AND THERMAL MASS WILL PROVIDE THE POTENTIAL FOR BOTH HEATING AND COOLING. IF SUMMER COOLING CONSIDERATIONS ARE NEGLECTED, THE GLAZING AND THERMAL MASS CAN WORK TO INCREASE HEAT GAIN AND STORAGE AT A TIME WHEN IT IS NOT WANTED, THUS CAUSING UNCOMFORTABLE INTERIOR CONDITIONS.

THE RECOMMENDATION

MAKE THE ROOF A LIGHT COLOR OR REFLECTIVE MATERIAL.

HOT DRY SUMMERS:

1. OPEN THE BUILDING UP AT NIGHT (OPERABLE WINDOWS OR VENTS) TO VENTILATE AND COOL INTERIOR THERMAL MASS.[3]
2. ARRANGE LARGE OPENINGS OF ROUGHLY EQUAL SIZE SO THAT INLETS FACE THE PREVAILING NIGHTTIME SUMMER BREEZES AND OUTLETS ARE LOCATED ON THE SIDE OF THE BUILDING DIRECTLY OPPOSITE THE INLETS OR IN THE LOW PRESSURE AREAS ON THE ROOF AND SIDES OF THE BUILDING.[3]
3. CLOSE THE BUILDING UP DURING THE DAYTIME TO KEEP THE HEAT OUT.[3]
4. USE WIND SCOOPS AND INDOOR WATER FOUNTAINS TO INDUCE EVAPORATIVE COOLING.[4&6]

5. Use EARTH TUBES (28) for INDUCED EVAPORATION (33).[1,2,4,6]

6. Building shape and configuration should make the building act as a flue ("stack effect")[2].

7. USE A BREATHING WALL (30)[5] AS A SHADING DEVICE (25).

HOT HUMID SUMMERS:

1. OPEN THE BUILDING UP TO THE PREVAILING SUMMER BREEZES DURING THE DAY AND EVENING.[3]

2. ARRANGE INLETS AND OUTLETS AS OUTLINED ABOVE, ONLY MAKE THE AREA OF THE OUTLETS SLIGHTLY LARGER THAN THE INLETS.[3]

3. USE EARTH TUBES (28) TO REMOVE MOISTURE.[1,2,6,8]

4. USE A SOLAR CHIMNEY (31) TO INDUCE VENTILATION THROUGH THE SPACE AND THE EARTH TUBES (28).[1,2,6,8]

5. USE A SOLAR DEHUMIDIFIER (32) TO REMOVE MOISTURE.[7]

6. BUILDING SHAPE AND CONFIGURATION SHOULD MAKE THE BUILDING ACT AS A FLUE ("stack effect").[1]

7. USE A BREATHING WALL (30).[5]

SMALL SCALE PATTERNS

All glazed openings must be shaded in the summer - SHADING DEVICES (25) and selectively use vegetation for both wind protection in the winter and summer shading.

You should also consider the use of EARTH TUBES (28), KING VENTILATION SYSTEM (29), BREATHING WALL (30) SOLAR CHIMNEY (31), SOLAR DEHUMIDIFIER (32) INDUCED EVAPORATION (33), ZONING (34) and DIURNAL FLUSHING (35).

You can use Table 27-1 as a rule of thumb for selecting cooling options, and it can be used to conjunction with Tables 9B, 9C, and 9D to choose a system that will be suitable for heat and cooling.

ILLUSTRATION:

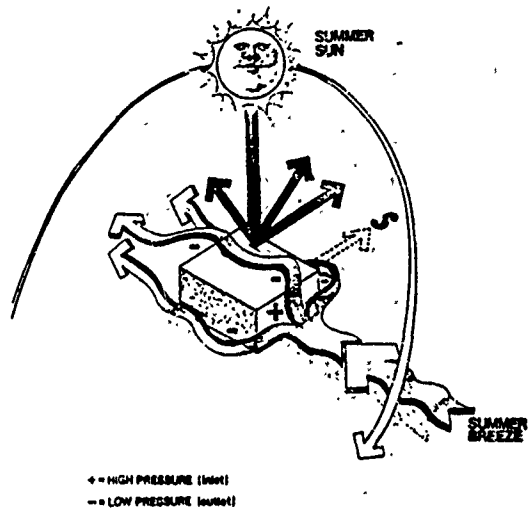


Figure 27-1

INFORMATION

There are nine natural cooling options available for introducing coolness into your building with little or no mechanical assistance: Heat Gain Control, Microclimate, Natural Ventilation, Induced Ventilation, Evaporative Cooling, Desiccant Cooling, Night Sky Radiation, Time Lag Cooling and Earth Cooling.

YOUR TASK IS TO WORK WITH THE USING ORGANIZATION TO SELECT THE APPROPRIATE MIX OF COOLING OPTIONS TO KEEP THE USER COOL, NATURALLY.

This pattern presents information about the basic passive cooling options, and proposes design strategies with a listing of appropriate patterns to accomplish the cooling option (see Table 27-1), while satisfying the four comfort variables (air temperatures, air movement, humidity, and mean radiant temperature).

Heat Gain Control

Controlling the heat your building gains from its environment is what Summer Cooling is all about. Fortunately, passive heating has the same requirement, and allows the user to heat and cool using the sun. The relation between passive heat and cooling is crucial. KEEPING UNWANTED HEAT OUT IN THE SUMMER AND DRAWING IT IN DURING THE WINTER ARE ISSUES THAT SHOULD - IN FACT, MUST- BE ADDRESSED HAND IN HAND, FOR THE SIMPLE REASON THAT IN EITHER CASE THE ARCHITECTURE ITSELF IS THE CLIMATIC-CONTROL MECHANISM.[1,2,8]

The Microclimate

A good passive cooling strategy pays as much attention to the microclimate surrounding the building as the building itself. Landscaping and vegetation can have a tremendous impact on natural comfort inside the building, affecting both summer cooling and winter heating loads. The general effect in an area of massed vegetation is to keep temperatures in the shade a good 10^0-15^0F lower than ambient temperature. This is particularly valuable phenomenon, if the cooler air can be drawn into the building by the thermal chimney action of a vented MASONRY HEAT STORAGE WALL (13) or a vented greenhouse - GREENHOUSE CONNECTION (18).

Massed earth on the North Side (5) makes a good wind break.[1,2,8]

Natural Ventilation

The cooling value of air movement lies in the capacity to evaporate perspiration from the body which allows you to feel cool. The Antebelum architecture of the Southeastern United States was designed to catch the breezes from the ocean. Those breezes are so powerful they have generated an indigenous architectural style - Geographic Determinism(1).

In a dry climate - lower than 20% relative humidity- the same process can dehydrate the body. Evaporative cooling - Induced Evaporation (33) - should be used in a dry climate to prevent dehydration.

If your building is in an area where ventilation is a wise cooling option, you should capitalize on your buildings exposure to the wind. You should also use louvered openings, vents, transomed windows, windowed walls, and planned for through-ventilation.[1,2,8]

Induced Ventilation

You can modify your building so ventilation is induced if there is not enough wind for natural ventilation. By using the sunlight to heat an isolated pocket of interior air to greater than ambient temperatures and controlling its escape, a building can generate air circulation and maximize the influx of cooler air.

The most effective application of this natural law is a SOLAR CHIMNEY (31), a solar-exposed enclosure tall enough to generate maximum air flow and massive enough to retain heat and power the system into the evening hours. The optimum system draws its replacement air from the coolest possible location, a planted, shaded area to the north or an underground

EARTH TUBE (28).

Other solar design elements usually associated with passive heating - THERMAL STORAGE WALL (9B), ATTACHED GREENHOUSE (9C) and CONVECTIVE LOOP (9E) can also be used for the same cooling effect.[1,2,5,6,8]

Evaporative Cooling

Swamp coolers, fountain courts and atrium pools are applications of evaporative cooling. This cooling option is very effective in a hot and relatively dry space, because water evaporates into the air and increases humidity. Sensible heat turns into latent heat, and lowers the air temperature.

The evaporative cooling option - Induced Evaporation (33) - should be joined with ventilation for the most efficient distribution of cool, humidified air - EARTH TUBES (28) and KING VENTILATION SYSTEM (29).[1,2,6,8]

Desiccant Cooling

In regions of high humidity, where moisture in the air actually prevents the body from cooling itself evaporatively, dessicant cooling is a valued traditional strategy. Before energy was harnessed and plentiful, dessicant salts were effective coolers, but needed to be thrown out when they were saturated.

Passive cooling in regions of high humidity remains a problem today, and desiccant solutions remain the focus of research and design experimentation.

More information is presented in SOLAR DEHUMIDIFICATION (32)[1,2,7,8,9,10]

Night Sky Radiation

Radiative cooling involves exposing interior spaces to the heat sink of a thermal mass, and exposing the mass to the planetary heat sink of cool, clear night sky. The mass absorbs heat from the interior during the day and releases it to the sky dome. This cooling option is most effective where the diurnal (day-night) temperature swing is in excess of 20°F and where the night sky is relatively clear.

Historically the puebloes and Spanish Missions of the Southwest are an example of this cooling option. However, since the development of Skytherm$_{TM}$ (roof pond water bags) by Harold Hay, research and performance experiments have focused on water as the radiative mass.

The efficacy of this cooling option is increased by sprinkling water on the roof top water containers to add evaporative cooling to the radiative effect.[8]

Time Lag Cooling

Like radiative cooling, time lag cooling takes advantage of the thermal absorption, reduction, and lag characteristics of mass, and requires the same 20-35°F diurnal temperature swing to be effective. Where the conditions are right, time lag cooling has been around for centuries.

The principle is that the transmission of heat through mass - stone, concrete, adobe - is both delayed and attenuated over time. Depending on the material and the thickness of a massive wall, the delay can stretch from two to 12 hours, and the greater the lag the greater the attenuation of heat transmitted. Thus less heat reaches the interior spaces, and it doesn't arrive until late evening or night, when ambient temperatures have dropped and the exterior wall is radiatively cooling. By night's end the wall is again, a cold barrier to the daytime onslaught of insolation. Exterior sheathing, insulation, or shady vegetation will add to that barrier, further flattening the diurnal curve that ironically is both the nemesis of comfort where time lag strategies are appropriate, and the key to the time lag cooling effect.[8]

Earth Cooling

The earth is where man first sought shelter for a good reason; ground temperatures remained stable at around the average annual air temperature, usually in the range of 50-60°F. The earth attenuates extreme air temperatures, and acts as a maximal time lag device, carrying winter coolness well into late spring, and summer warmth into late fall.

Earth Cooling can be accomplished be earth-integrated construction and/or earth tubes, and/or rock-filled air passages.

The field is undergoing considerable research and experimentation aimed at defining and overcoming difficulties, and quantifying the feasibility of numerous earth-cooling design strategies.[1,2,6,8,11 and 12.]

Summary

Your task as a programmer is to educate and work with the using organization to select the appropriate mix of cooling options to keep the user cool, naturally. This can be done by making the architecture introduce coolness into the building with little or no mechanical assistance.

You can use Table 27-1 in conjunction with Tables 9B, 9C and 9D (Summer Ventilation) to select a system and group of patterns that will meet both heating and cooling requirements for your building type.

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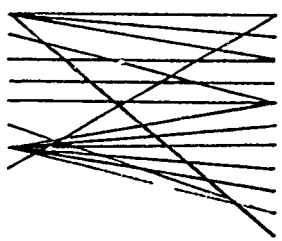
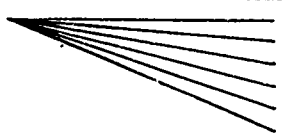
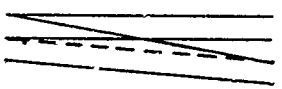
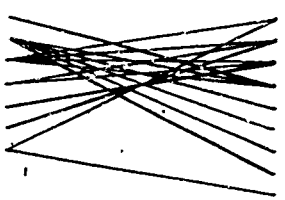
COMFORT VARIABLE	COOLING OPTION		DESIGN STRATEGY	SUGGESTED PATTERNS
Air Temperature	Heat gain control Natural ventilation Time lag/attenuation Radiative loss Conductive loss Humidification Induced ventilation Microclimate		Shading Earth-tempered structure Thermal massing/insulation Night sky radiation Earth-air heat exchange Solar/thermal chimney Solar/trombe wall Solar/direct gain Solar/isolated gain (greenhouse) Evaporative cooling Vegetation/land massing	1,4,25,30 & Appendix P 1,4,5,26 &28 1,4,9,25,26 & 28 4,9B,9C, 19 & 20 4,9B,9C,28,29 & 31 4,9B,9C,28,29 & 31 9B,13,15,16,23,24,28,29 &31 4,9A,11,12,23,24,28,29 & 31 9C,17,18,23,24,28,29 & 31 4,28,29 & 33 1,3,4 &25
Air Movement	Induced ventilation		Solar/thermal chimney Solar/trombe wall Solar/direct gain Solar/isolated gain Earth-air heat exchange Zoning	4,9B,9C,28,29 & 31 9B,13,15,16,23,24,28,29 & 31 4,9A,11,12,23,24,28,29 & 31 9C,17,18,23,24,28,29 & 31 4,9B,9C,23,23 & 31 2,3,4,6 & 34
Humidity	Humidification Dehumidification Microclimate		Evaporative cooling Desiccation Earth-air heat exchange* Vegetation/land massing	4,28,29 & 33 32 4,9B,9C,28,29 & 31 1,3,4 & 5
Mean radiant temperature	Heat gain control Natural ventilation Induced ventilation Time lag/attenuation Radiative loss Conductive loss Microclimate		Shading Earth-tempered structure Thermal massing/insulation Diurnal air flushing Solar/thermal chimney Solar/trombe wall Solar/direct gain Solar/isolated gain Vegetation/land massing	1,4,25,30 & Appendix P 1,4,5,26 & 28 1,4,9,23,26 & 28 11,12,28,29,31 &35 4,9B,9C,28,29 & 31 9B,13,15,16,23,24,28,29 & 31 4,9A,11,12,23,24,28,29 & 31 9C,17,18,23,24,28,29 & 31 1,3,4 & 25

TABLE 27-1 COOLING SYSTEM SELECTION

*Earth-air heat exchange will only dehumidify if the ground temperature is less than the dew point.

28. EARTH TUBES

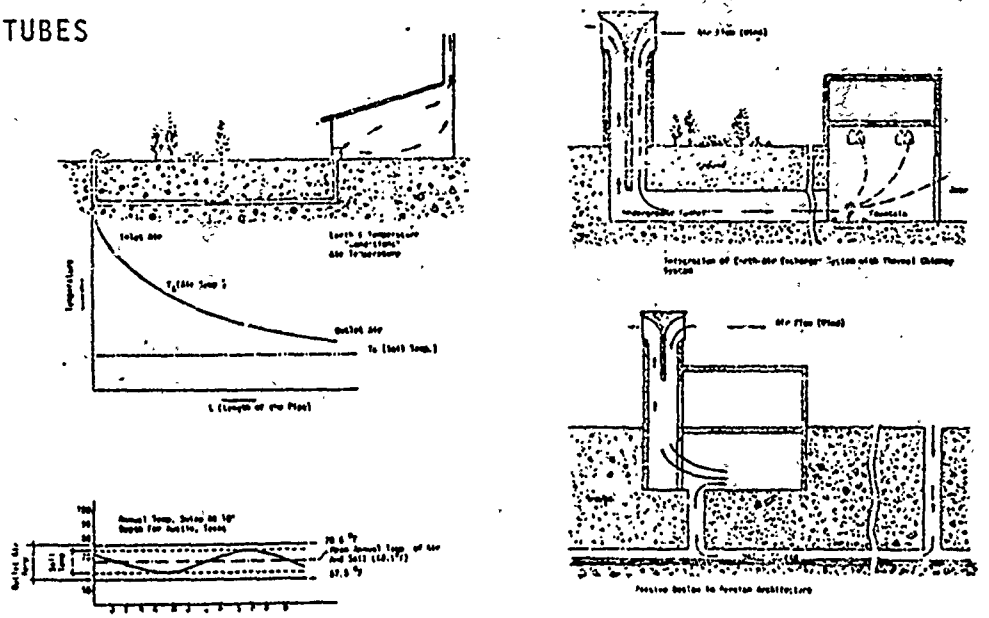


Figure 28-1

LARGE SCALE PATTERNS

Using the ideas of SUMMER COOLING-EARTH COOLING (27) and the requirement for building ventilation - Tables 9B, 9C, and 9D - this pattern is the starting point for providing earth tempered ventilation for your building.

THE PROBLEM

THE EARTH AROUND YOUR BUILDING IS A PASSIVE SOLAR SYSTEM YOU CAN USE AS A HEAT SOURCE/SINK FOR YOUR BUILDING'S RETROFIT.[1,2]

THE RECOMMENDATION

USE EARTH TUBES AS METHOD OF PROVIDING EARTH TEMPERED (WARMED IN WINTER; COOLED AND DEHUMIDIFIED IN SUMMER) VENTILATING AIR FOR YOUR BUILDING. THE DAILY TEMPERATURE FLUCTUATIONS OF EARTH IS MUCH SMALLER THAN AIR, AND AT A DEPTH OF 8 TO 10 FEET BELOW THE SURFACE, THE AVERAGE EARTH TEMPERATURE APPROXIMATES THE YEARLY AVERAGE AMBIENT AIR TEMPERATURE OF A GIVEN LOCATION WITH A SMALL DEVIATION.[1,2]

SMALL SCALE PATTERNS

You can combine this pattern with KING VENTILATION SYSTEM(29), SOLAR CHIMNEY (31) and SOLAR DEHUMIDIFIER (32) to complete the ventilation of your building. This combination of patterns will allow the ventilation of large buildings at night without security problems.

ILLUSTRATION

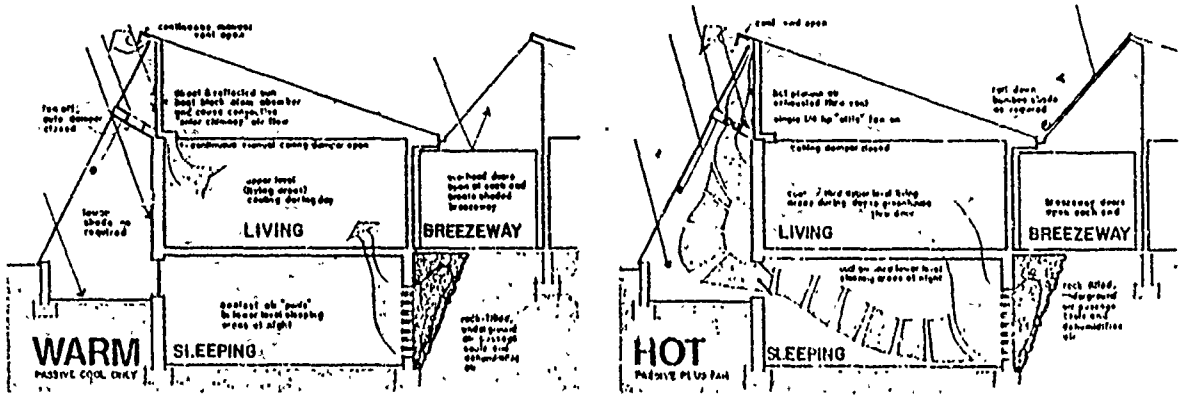


Figure 28-2

INFORMATION

SUMMER COOLING/EARTH COOLING (27) mentioned three methods of Earth Cooling: earth-integrated construction, earth tubes and rock filled air passages.

This pattern will look at the last two methods (earth tubes and rock filled air passages) under the title of EARTH TUBES. This pattern will not look at Earth-integrated architecture because of its limited retrofit potential and probable structural limitations.

The earth tube and rock filled air passages methods are combined in this pattern because their earth-air heat exchange concepts are similar.

An Earth Tube (an Earth-Air Heat Exchange System - names are often used interchangably) is simply a buried pipe through which air is forced. The use of earth as a heat source/sink, with a buried pipe(s) or underground tunnel as a direct heat exchanger, can be traced as far back as 1875 in the United States, and centuries for Persian Architecture - INDUCED EVAPORATION (33).

It is a legitimate solar system, because geothermal temperature gradients do not effect soil above approximently 30 feet. It is chiefly dependent on air temperature, surface soil temperature, thermo-physical properties of soil, ground-water cycles, and depth. The first two variables are solar driven; while the third and fourth variables are mainly dependent on local geology. The fifth variable will be determined by the designer.[2]

This method of cooling, using the stable temperature of the earth's mass to absorb heat from the air passing through the tubes, also has the potential for adding or removing humidity. Gently downward - sloping tubes of proper diameter and length allow cooling air to fall slowly. As the air temperature reaches the dew point of its moisture content, water will condense out. This condensate should be allowed to drain out of the airstream at the point near the bottom end of the tube. A water wick or pan at the same location could add moisture, if humidification is desired INDUCED EVAPORATION (33).

All tubes should be constructed of clay tile or noncorrosive metal. Inlet vents should be screened and placed on the north side or in a well shaded area.[8]

The first documented earth tube research was started in 1963 at Cornell University. Figure 28-3 shows its performance in September 1965. One of the major discoveries was that addition of water to dry soil produces a significant increase in thermal conductivity and may cause the thermal diffusivity to be 2 to 3 times the dry soil.[1,2]

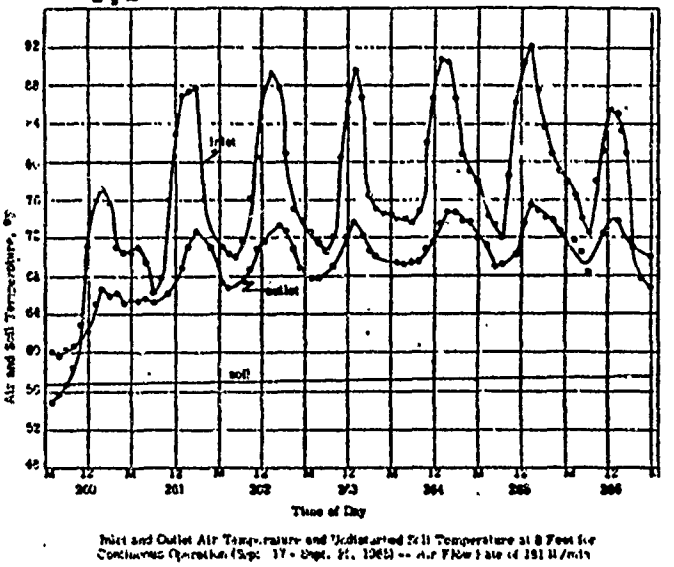


Figure 28-3

At this time there is only one company - LPC (The Lords Power Company, Inc.) that installs earth tubes commercially. Their systems have been designed for agricultural buildings and their system sizing is proprietary.

Other researchers are working on rules of thumb for sizing earth tubes for cooling and ventilating people spaces. When they are available, this pattern must be updated.

The other method - rock filled air passages - was developed independently by George Cristy, and Fuller Moore (see Appendix R). This method uses a rock bed around the foundation of the building.

Fuller Moore's house was completed in September 1979 and has not been put into operation. (see Appendix L).

George Christy's paper (reference 3) presents the following conclusions about the heat transfer process of his system.

> The optimum performance of the rock bed and adjacent soil will be obtained by:
>
> a. Designing and operating the earth fill outside the rock bed at the highest practical value of thermal diffusivity and heat capacity;
>
> b. Maintaining the flow rate at the minimum value necessary to provide adequate ventilation; and
>
> c. Increasing the flow rate during summer backflushing periods.
>
> Under conditions of average values of the heat transfer properties, the rock bed can supply 55% of the heating load required to heat the ventilation air in winter. The resultant cooling of the rock and soil plus utilization of the diurnal cycle will furnish 66% of the cooling needed to dehumidify the ventilation air in summer. The remainder of the heat needed in winter can easily be made up by the passive solar heat received during the day.

Summary

The use of Earth Tubes as a retrofit system has good potential for the following reasons:

1). Earth Tubes use the earth as a heat source/sink for year round use.

2). The earth tempers the ventilating air for the building.

3). Earth Tubes can be used for dehumification or evaporation of the incoming ventilating air.

4). The system is exterior to the building.

5). It has little or no effect on the visual environment.

6). The sun can be used as the motive force for the earth tubes to increase the efficiency of the system (See Table 27-1/Induced Ventilation for design strategies and suggested patterns).

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SOURCES OF ILLUSTRATIONS

Figure 28-1 Reference 2 p 148

Figure 28-2 Reference 6

Figure 28-3 Reference 1 (No page number)

29. KING VENTILATION SYSTEM

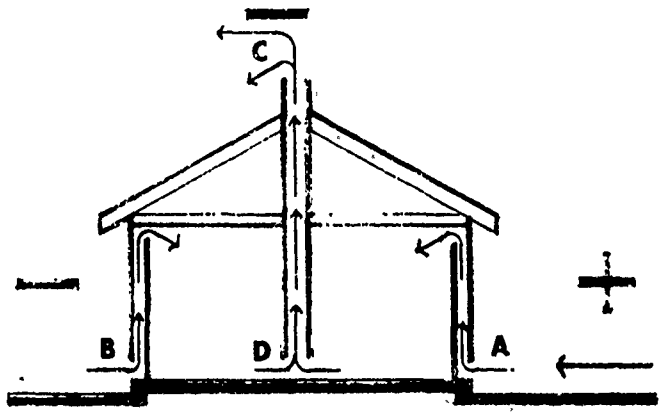


Figure 29-1

LARGE SCALE PATTERNS

With ventilation being a year around building requirement, and especially for SUMMER COOLING (27), the King Ventilation System is a method of providing natural ventilation. This system was developed by Professor F.H. King (Professor of Agricultural Physics - University of Wisconsin). It was first used in a cow barn built in 1889, in Whitewater, Wisconsin. The system allows fresh air to be taken into a building without chilling the interior or creating a draft.

THE PROBLEM

THE VENTILATION PROBLEM THAT MUST BE SOLVED IS HOW TO MAINTAIN THE AIR OF THE BUILDING AT THE NORMAL OUT-OF-DOOR FRESH AIR PURITY WITH PRACTICAL ECONOMY AND WITHOUT DRAFTS AT THE FLOOR.[1]

THE RECOMMENDATION

IF ADDITIONAL VENTILATION IS REQUIRED, NATURAL VENTILATION CAN BE INDUCED BY TAKING AIR OUT AT THE FLOOR LEVEL AND LETTING IT IN AT THE CEILING. THIS MANAGEMENT OF AIR CURRENTS CREATES CIRCULATION NECESSARY FOR VENTILATION BY REMOVING ONLY THE COLD AND CARBON DIOXIDE LADEN AIR, AND FORCES THE WARM AIR TO REMAIN IN THE BUILDING, WHILE AVOIDING DRAFTS AND DANGER OF DISCOMFORT. FOR SUMMER OPERATION, AN ADDITIONAL OPENING HIGH IN THE ROOM SHOULD BE PROVIDED TO REMOVE HOT AIR AND REINFORCE THE DRAFT.[2]

SMALL SCALE PATTERNS

You should combine the King Ventilation System with EARTH TUBES (28), SOLAR CHIMNEY (31), INDUCED EVAPORATION (33) and DIURNAL FLUSHING (35).

ILLUSTRATION

See Figure 29-1.

INFORMATION

As mentioned in SUMMER COOLING (27), there are two natural forces for moving air through a building: 1) wind pressure; 2) temperature difference between indoor and outdoor - "Stack Effect". The King Ventilation System uses both as motive forces.

Ventilating air enters through openings at A & B and leaves at D. This is caused by direct wind pressure exerted at A & B and section effect developed at C.

Drafts are avoided by placing the fresh air intake (outside) at some distance below the fresh air outlet (inside) - see figure 29-1. This arrangement is fundamental because it is the only way to prevent the escape of the warmest air through such an opening on the leeward side of the building. Without this provision it would be like opening a window at the top on the other side of the room.

The flow of air through the building resulting from wind pressure and suction will be most rapid when the wind is permitted to reach the building at A and pass over the roof at C with the least obstruction.[3]

The flat roof (built up), which has been popular in "Modern Architecture", does not provide the physical form to accomodate two building functions: 1) physical form to generate wind suction for ventilation; 2) physical form to create positive water drainage from roof. Therefore, for retrofit of buildings with flat roofs, consideration should be given to providing a new sloped roof, which will generate suction for ventilation, and reduce roof maintenance problems (created by clogged roof drains and pooling of water and ice). This is an important consideration because it is generally true that the suction effect of the wind is stronger than direct wind pressure. The ventilating flue should be above the ridge of the roof, where the wind will sweep. The flue should not be at the eaves.[4]

This system could also be considered for retrofit of above ground fallout shelters, and combined with EARTH TUBES (28), MASONRY HEAT STORAGE (13) and SOLAR CHIMNEY (31) to provide a solar induced ventilation system to remove carbon dioxide and draw in earth tempered oxygen. SOLAR DEHUMIDIFICATION (32) can be added in humid climates.

The King Ventilation System design should be based on "Stack Effect" - temperature differential - because ventilation due to direct wind pressure is not always available. The approximate rate of air exchange when the inlet area is equal to the outlet area can be expressed as:[5]

$$Q = 540A\sqrt{H(t_i - t_o)}$$

where

Q = rate of air flow, cu ft/hr

A = area of inlets, sq ft

H = height between inlets and outlets, ft

t_i = average temperature of indoor air at height H, °F

t_o = temperature of outdoor air, °F

This expression requires adjustment in cases when the area of outlets is appreciably different from the area of inlets according to the following ratios:

Area of outlets / Area of inlets	Value to be substituted for 540 in above expression
5	746
4	740
3	720
2	680
1	540
3/4	455
1/2	350
1/4	185

TABLE 29-1

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TABLE 29-1 Reference 5. p. 212.

30. BREATHING WALL

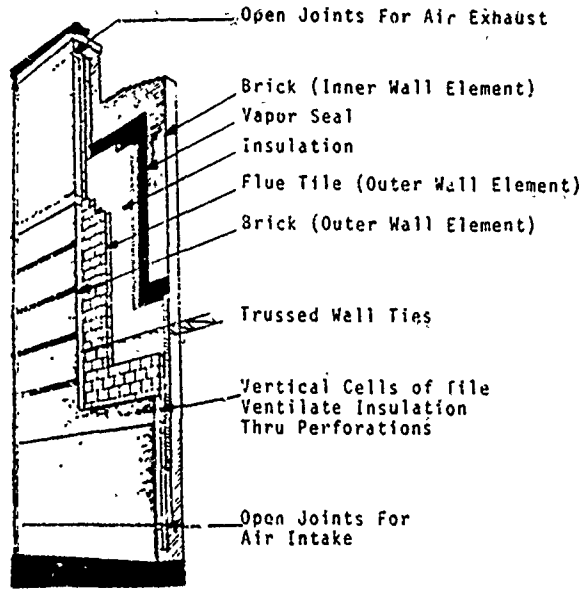


Figure 30-1

LARGE SCALE PATTERNS

This pattern presents information about a passive summer cooling system - SUMMER COOLING (27) - that was developed for a World War II aircraft manufacturing plant at Tinker AFB, Oklahoma City. The "Breathing Wall" - "A Modern Masonry Concept" - was developed in response to an Army Corp of Engineers request to limit the use of vital war materials (steel and fiberglass insulation). The "Breathing Wall" was designed to have a summer insulation value equal to 80 inches of brick.[1]

THE PROBLEM

LARGE VERTICAL WALLS, ESPECIALLY WESTERN AND EASTERN WALLS OF INDUSTRIAL PLANTS, SUCH AS THE ONE AT TINKER AFB, ARE PRONE TO OVERHEATING BECAUSE OF THE DIFFICULTY IN SHADING THE WALLS. THE COOLING PROBLEM IS TO REDUCE TRANSMISSION OF HEAT THROUGH THE WALL, THEREBY REDUCING INTERNAL TEMPERATURES.

THE RECOMMENDATION

USE A "BREATHING WALL" OF BRICK AND HOLLOW VENTILATING TILES ON LARGE WESTERN AND EASTERN WALLS. THE "BREATHING WALL" WILL ACT AS A SOLAR SHADING DEVICE, WHICH WILL REDUCE HEAT TRANSMISSION FROM THE OUTER WALL ELEMENT TO THE INTERIOR WALL ELEMENT. THE HOLLOW VENTILATING TILES SERVE AS A FLUE THROUGH WHICH AIR CIRCULATES VERTICALLY BETWEEN OPEN JOINTS. THE TILE HAS A PERFERATED BACK WHICH ALLOWS A 4 INCH BLANKET OF ROCKWOOL INSULATION TO "BREATH", THEREBY PREVENTING CONDENSATION, AND KEEP IT PERMANENTLY DRY.

SMALL SCALE PATTERNS

This pattern could be used on western and eastern walls in conjunction with the KING VENTILATION SYSTEM (29) and EARTH TUBES (28) to cool the interior spaces.

ILLUSTRATION

See Figure 30-1.

INFORMATION

This system was developed when steel and fiberglass insulation were critical war materials. It functioned as a passive solar shading device to reduce the heat transmission from the outer wall element to the inner wall element. This is accomplished by a convective air flow through the flue tiles of the outer wall element. The "Breathing Wall" is analogous to the Bedowin Black Tents; "which upon heating (outer wall element) in the sun, convection is induced between the fibers and across the inner surface (flue tiles), causing air motion. The low conductivity of the fabric adds little radiative heat to the shaded interior (interior wall element)."[2]

This system was probably developed because of inappropriateness of climbing plants on a building near a flight line. Climbing plants create a sanctuary for nesting birds, and thereby create a flight and life safety hazard, which must be avoided.

This system was re-discovered by the research process described in Appendix E.[3]

Base Civil Engineering personal at Tinker AFB (Oklahoma City) do not have any information about its performance, because they did not know of its existance until July 1979.

The following are theoretical questions that need to be answered about the "Breathing Wall" by instrumentation by the Air Force and/or the Department of Energy:

1) Is the present outside to outside ventilation through the flues the correct scheme? At present, internal heat gain can not exit with the ventilating air in the flues; it can only be absorbed by the inner wall element.

2) What is the optimum mass for the exterior wall element so that it circulates air at the correct time?

3) Is there anything gained with a mass outer wall element, which drives circulation most strongly at night?

4) Does wall height effect efficiency? Does an increase of wall height increase the "Stack Effect" within the wall?

The "Breathing Wall" could be used for retrofit of large western and eastern walls to reduce the heat transmission to the interior wall element. Also, the top air outlet could be closed, by a damper, during the winter to reduce convective heat loss, and trap warm air in the outer wall element. The damper would increase the winter insulation value of the wall.

REFERENCES

1. "Breathing Walls of Brick and Tile - A New Masonry Concept," Brick and Clay Record. April 1943,

2. David Wright, AIA. Natural Solar Architecture - A Passive Primer. VanNostrand Reinhold Company. 1978 p. 209.

3. Stanley H. Scofield, Captain, USAF. "A Historical Review of Natural Ventilation in a Humid Climate," 4th National Passive Solar Conference Proceedings, Kansas City, Mo. 3-5 October 1979. (Appendix E) pp 504-506.

4. 24 July 1979 letter from Dr. Don Elmer (USDOE) to Stanley H. Scofield, Captain, USAF.

31. SOLAR CHIMNEY



Figure 31-1

LARGE SCALE PATTERNS

This pattern is a HISTORICAL BUILDING TYPE SOLUTION (4) for SUMMER COOLING INDUCED VENTILATION (27).[1,2]

THE PROBLEM

VENTILATION MUST BE INDUCED BY THE BUILDING WHEN IT IS HOT AND THERE IS NOT ENOUGH WIND FOR NATURAL VENTILATION.

THE RECOMMENDATION

USE A SOLAR CHIMNEY (plenums, flues or black boxes) PAINTED A "DARK COLOR AND EXPOSE IT TO THE FREE ACTION OF THE SUN'S RAYS".[1,2] THE CHIMNEY IS SELF-BALANCING; THE HOTTER THE CHIMNEY AND THE FASTER THE AIR MOVEMENT.[3]

SMALL SCALE PATTERNS

Combine with EARTH TUBES (28) and KING VENTILATION SYSTEM (29) to provide earth tempered ventilating air. It can also be combined with a SOLAR DEHUMIDIFICATION (32).[5]

DON'T COPY
... PINK MASTER

31. SOLAR CHIMNEY

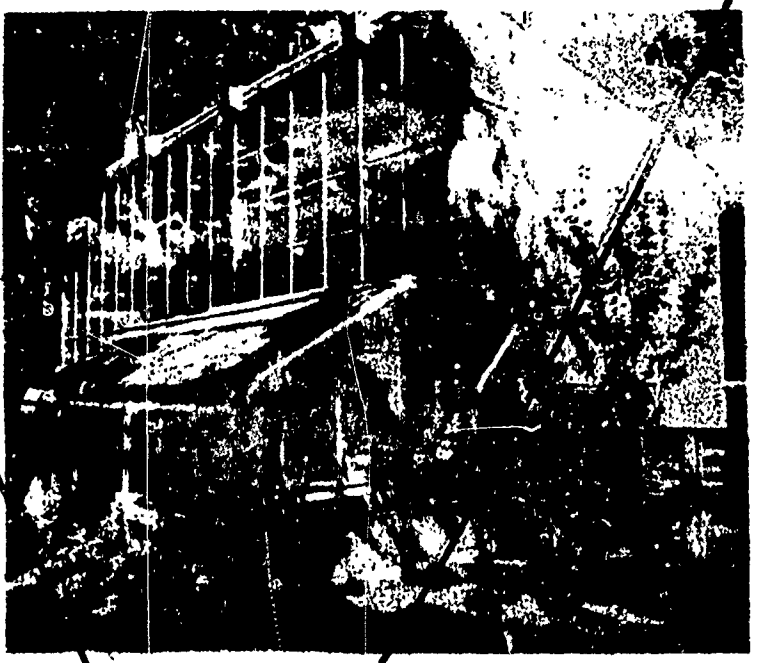


Figure 31-1

LARGE SCALE PATTERNS

This pattern is a HISTORICAL BUILDING TYPE SOLUTION (4) for SUMMER COOLING INDUCED VENTILATION (27).[1,2]

THE PROBLEM

VENTILATION MUST BE INDUCED BY THE BUILDING WHEN IT IS HOT AND THERE IS NOT ENOUGH WIND FOR NATURAL VENTILATION.

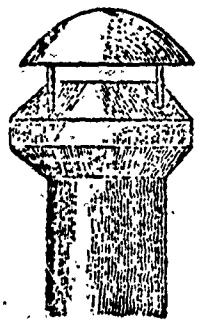
THE RECOMMENDATION

USE A SOLAR CHIMNEY (plenums, flues or black boxes) PAINTED A "DARK COLOR AND EXPOSE IT TO THE FREE ACTION OF THE SUN'S RAYS".[1,2] THE CHIMNEY IS SELF-BALANCING; THE HOTTER THE CHIMNEY AND THE FASTER THE AIR MOVEMENT.[3]

SMALL SCALE PATTERNS

Combine with EARTH TUBES (28) and KING VENTILATION SYSTEM (29) to provide earth tempered ventilating air. It can also be combined with a SOLAR DEHUMIDIFICATION (32).[5]

ILLUSTRATION



The tops may be of thin metal painted a dark colour, and exposed to the free action of the sun's rays. The upper cap prevents down blasts of air, but in a steady horizontal wind the lower cone alone would be sufficient.

Figure 31-2

INFORMATION

The solar chimney shown in figure 31-2 is an example of a Simple Solar Chimney (dark metal flue) used prior to 1850 to induce ventilation in hospitals. As the dark metal chimney gets hot during the day, the air inside heats, expands and rises. In this process it pulls interior air up and out. The advantage of the solar chimney is its ability to self balance; the hotter the day the hotter the chimney and the faster the air movement.[2,3]

You can use table 31-1 to approximate the rate of air exchange when the inlet area is equal to the outlet area.[4]

Variations of the Simple Solar Chimney are the Glazed Chimney, Glazed Chimney with Storage, Summer Solar Vent and the Summer Mass Wall Vent-MASONRY HEAT STORAGE (13).[3] This last variation on the solar chimney has several advantages:

1. The MASONRY HEAT STORAGE WALL (13) functions as a winter heating system.

2. The thermal storage mass behind the glazing will actually store daytime heat, and continue to exhaust air after the sun has set, thus inducing night ventilation.[3]

NOTE: If you elect to retrofit a south-facing masonry wall as a combined MASONRY HEAT STORAGE WALL (13) and SOLAR CHIMNEY, then you must provide MOVABLE INSULATION (23) on the interior side of the wall. This will prevent daytime conductive heat gain and radiation to the interior space, and assures good

night ventilation.

If you have a large west-facing wall surface, and have a large afternoon heating load, then you should consider retrofitting the wall with glazing for increased ventilation during the hot afternoon.[3]

$$Q = 540A\sqrt{H(t_1 - t_o)}$$

where

Q = rate of air flow, cu ft/hr

A = area of inlets, sq ft

H = height between inlets and outlets, ft

t_1 = average temperature of indoor air at height H, °F

t_o = temperature of outdoor air, °F

This expression requires adjustment in cases when the area of outlets is appreciably different from the area of inlets according to the following ratios:

Area of outlets / Area of inlets	Value to be substituted for 540 in above expression
5	745
4	740
3	720
2	680
1	540
3/4	455
1/2	340
1/4	185

TABLE 31-1

REFERENCES

1. Stanley H. Scofield, Capt. USAF. "A Historical Review of Cooling in a Humid Climate," 4th National Passive Solar Conference Proceedings, Kansas City, Mo., October 3-5, 1979. pp 504-506 (See Appendix E).

2. Thomas Young, M.D., FRS. "On Heating and Ventilation." Date unknown circa 1845. pp.91-92---United States Military Academy Archives - BOOK call number (697,T714).

3. David Wright, AIA. Natural Solar Architecture - A Passive Primer, Van Nostrand Reinhold Company, 1978.pp 194-195.

4. Victor Olgyay. Design with Climate-Bioclimatic Approach to Architectural Regionalism. Princeton University Press, 1962. pp110-112.

5. Fuller Moore, et al. Joseph Central, Gene Willeke. "Duel Desiccant-Bed Dehumidifier with Solar-Heated Regeneration," Proceedings of International Solar Energy Society Congress, Atlanta, Ga., May 28-June 1, 1979.

SOURCES OF ILLUSTRATIONS

Figure 31-1 Passive Solar Buildings. Sandia Laboratories, Albuquerque, N.M., and Livermore, Ca. For the USDOE under Contract DE-AC04-76DP00789. July 1979. p. 195.

Figure 31-2 Reference 2.p 92

Table 31-1 Reference 4.p 212

32. SOLAR DEHUMIDIFICATION

LARGE SCALE PATTERNS

Using the ideas of SUMMER COOLING - DESICCANT COOLING AND EARTH COOLING - (27) and EARTH TUBES (28) you can reduce humidity by using a solar regenerated desiccant cooling system.

THE PROBLEM

IF THERE IS TOO MUCH HUMIDITY IN THE AIR, THE BODY CANNOT BE COOLED, NATURALLY, BY EVAPORATION. DESICCANT SALTS HAVE BEEN USED IN THE PAST, BUT NEED TO BE THROWN OUT WHEN SATURATED. THUS, THE PROBLEM IS TO DEVELOP A METHOD OF REMOVING HUMIDITY FROM THE AIR SO EVAPORATIVE COOLING OF THE BODY CAN TAKE PLACE.

THE RECOMMENDATION

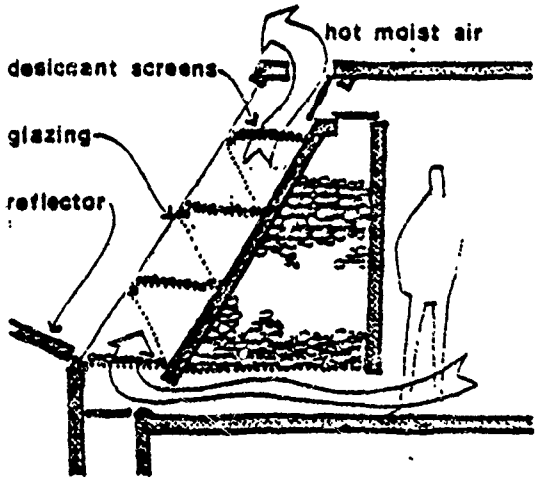
TWO POSSIBLE METHODS OF SOLAR DEHUMIDIFICATION WERE PRESENTED IN A PASSIVE COOLING WORKSHOP AT THE 4th NATIONAL PASSIVE SOLAR CONFERENCE (October 3-5, 1979): PASSIVE SOLAR HEAT PUMP BY H.I. ROBISON AND S.H. HOUSTON OF THE U. OF SOUTH CAROLINA; AND DUAL DESICCANT-BED DEHUMIDIFIER WITH SOLAR-HEATED REGENERATION BY FULLER MOORE, JOSEPH CANTRELL AND GENE WILLEKE OF MIAMI UNIVERSITY, OXFORD OHIO.

BOTH SYSTEMS ARE UNDER DEVELOPMENT AND ARE NOT READY FOR GENERAL APPLICATION.

SMALL SCALE PATTERNS

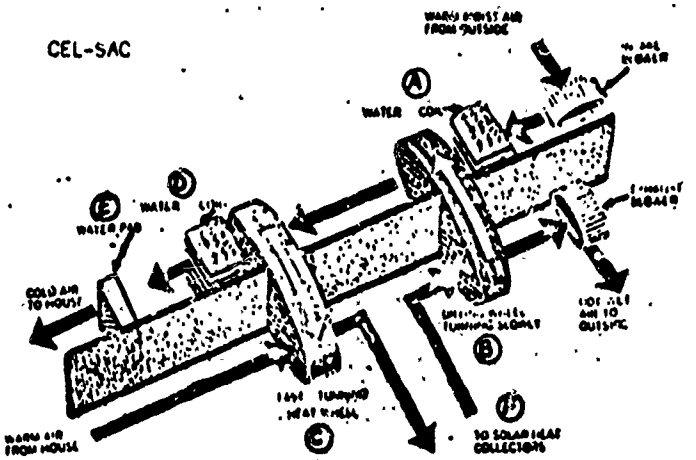
This pattern completes SUMMER COOLING-DESICCANT COOLING AND EARTH COOLING - (27)

ILLUSTRATION



DESICCANT REGENERATION

Figure 32-1



Coastal Energy Laboratory-Solar Air Conditioner

Figure 32-2

INFORMATION

Research in Solar Dehumidification is only beginning. The references about this subject are contained Appendix U. They also contain a more extensive Libliography of references.

REFERENCES

1. Kevin W. Green. "Passive Cooling," Research and Design - The Quarterly of the AIA Research Corporation, Volume II, no. 3, Fall, 1979. p5-9 (See Appendix Q).

2. David Wright, AIA. "Natural Solar Cooling," 3rd National Passive Solar Conference Proceedings, San Jose, Ca., January 11-13,1979.pp512-517.

3. Fuller Moore, et al. "Dual Desiccant - Bed Dehumidifier with Solar-Heated Regeneration," Proceedings of the International Solar Energy Society Congress, Atlanta, Ga., May 28-June 1, 1979. (See Appendix U).

4. H.I. Robison and S.H. Houston. "Thermo-Chemical Energy Storage for Heating and Cooling," Solar Energy Storage Options Workshop, San Antonio,Tx., March 19-20,1979. (See Appendix U.)

5. H.I. Robison, et.al. "Open-Cycle Solar Air Conditioner," Proceedings of the International Solar Energy Society Congress, Atlanta, Ga. May 28-June 1, 1979. (see Appendix U).

6. H.I. Robison, et.al. "Passive Solar Heat Pump"; 4th National Passive Solar Conference Proceedings, Kansas City, Mo., October 3-5, 1979. (See Appendix U).

7. H.I. Robison, et.al. "Absorption/Desorption Solar Cooling System Performance". Proceedings of American Institute of Chemical Engineers 72nd Annual Meeting, San Francisco, Ca., November 25-29, 1979. (See Appendix U).

33. INDUCED EVAPORATION

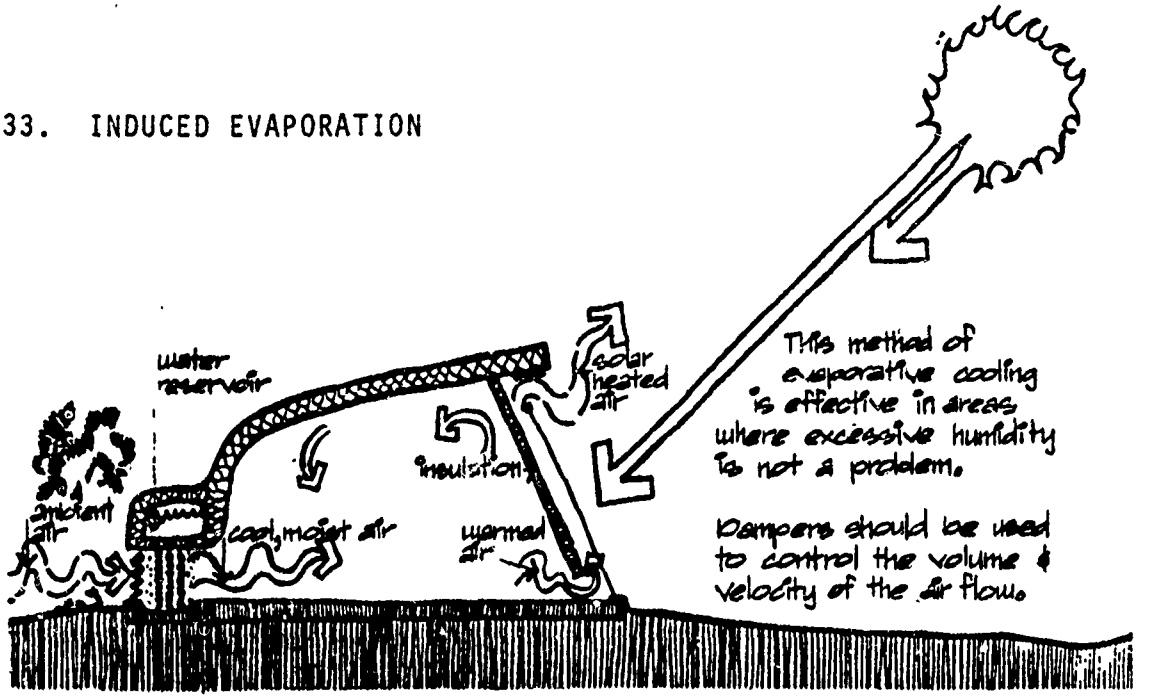


Figure 33-1

LARGE SCALE PATTERNS

Using the ideas of SUMMER COOLING-EVAPORATIVE COOLING (27), EARTH TUBES (28), KING VENTILATION SYSTEM (29) and SOLAR CHIMNEY (31), you can reduce the sensible heat (air temperature) of dry and moderately humid air by inducing evaporation.

THE PROBLEM

THE HEAT-CARRYING CAPACITY OF THE AIR IS INCREASED BY ITS WATER CONTENT. IN A DRY OR MODERATELY HUMID CLIMATE, SENSIBLE HEAT (air temperature) IS REDUCED BY THE EVAPORATION PROCESS. THE RATE OF EVAPORATION IS INCREASED BY INCREASED AIR MOTION.[1]

THE RECOMMENDATION

IF YOU ARE IN AN AREA OF LOW TO MODERATE HUMIDITY, AND HAVE AN ADEQUATE WATER SUPPLY, THEN YOU SHOULD INDUCE EVAPORATION BY INCREASING THE AIR VELOCITY NEAR THE WATER SOURCE. THE WATER SOURCE SHOULD BE PLACED ON THE NORTH SIDE OF THE SPACE SO THE MOIST AIR ENTERING THE SPACE WILL HAVE MAXIMUM OPPORTUNITY TO ABSORB HEAT BEFORE BEING SUCKED OUT BY SOLAR CHIMNEY (31) ACTION.[1]

SMALL SCALE PATTERNS

This pattern concludes a series of patterns to provide SUMMER COOLING-EVAPORATIVE COOLING (27).

ILLUSTRATION

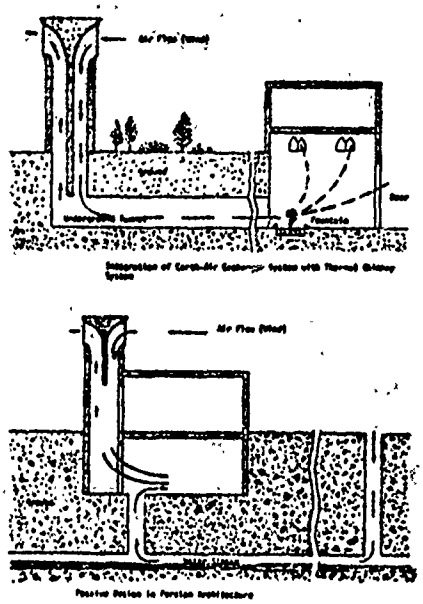


Figure 33-2

INFORMATION

The principle presented in this pattern is the same as used in "swamp" coolers: cooling can be regulated by varying the fan speed and water flow.

This idea can be used for passive cooling of structures, e.g. the Iranian's used it in conjunction with Air Scoops (Figure 33-1) and Earth Tubes (28) to induce evaporation (Figure 33-2).

You can use the SOLAR CHIMNEY (31) as a natural motive force to suck air up and out of the space, and then hot and dry air can be drawn over a water source to replace the removed air. In the process the sensible heat is reduced and latent heat and moisture are increased. As the moist air circulates through the building, it will attract heat from objects before being sucked up and out by the solar-heated convection current of the SOLAR CHIMNEY (31). And the higher the solar intensity, the greater the potential for pulling cool air through the building. You can even use REFLECTORS (24) to increase the solar chimney action.

You should provide dampers to allow the user to control the volume and velocity of the air flow. They should be easy to operate to allow flexibility of operation during Spring and Fall when fluctuating between heating and cooling.

A rule of thumb for evaporative cooling is in the process of evaporation, sensible heat turns into latent heat, and literally lowers the temperature of the air at a rate of 1,000BTU's

lost for every pound of water added to the air.

REFERENCES

1. David Wright, AIA. Natural Solar Architecture - A Passive Primer, Van Nostrand Reinhold Company, 1978. pp 207-211.

2. Kevin W. Green. "Passive Cooling", Research and Design - The Quarterly of the AIA Research Corporation, Vol II no.3 Fall 1979.pp5-9.

3. Mehdi N. Bahadori. "Passive Cooling Systems in Iranian Architecture," Scientific American, February 1978.

4. Dr. Don Elmer, Mo Hourmanesh and Ray Hourmanesh. "Earth Air Heat Exchangers," 2nd National Passive Solar Conference Proceedings, Philadelphia, Pa. March 16-18, 1978. Vol I pp 146-149.

SOURCES OF ILLUSTRATIONS

Figure 33-1

Figure 33-2 Reference 4 p.148.

34. ZONING

LARGE SCALE PATTERNS

Using the ideas of BUILDING LOCATION (2), BUILDING SHAPE AND ORIENTATION (3), HISTORICAL BUILDING TYPE SOLUTIONS (4), and SUMMER COOLING (27) you need to place interior spaces within the shape according to their requirement for SUMMER COOLING (27). This placement of interior spaces might indicate some possible changes of BUILDING SHAPE AND ORIENTATION (3). This pattern is similar to LOCATION OF INDOOR SPACES (6).

THE PROBLEM

CONVENTIONAL ENERGY CONSUMPTION IS PROPORTIONALLY HIGHER IN SPACES NOT USING THE PASSIVE COOLING OPTIONS OUTLINED IN SUMMER COOLING (27). The more you use and control the sun to cool a space, the less conventional energy is required for space cooling. This also applies to active solar - cooling systems. If the design of the interior space and the building's exterior does not passively control heat gain, and use the sun to induce ventilation or evaporation, an active solar-cooling system will be proportionally more expensive and larger.

THE RECOMMENDATION

THIS PATTERN SHOULD BE ACCOMPLISHED IN CONJUNCTION WITH LOCATION OF INDDOR SPACES (6). YOUR INTERIOR SPACES CAN BE SUPPLIED WITH MUCH OF THEIR COOLING REQUIREMENTS BY CONTROLLING HEAT GAIN AND USING THE SUN TO INDUCE VENTILATION OR EVAPORATION. PLACE ROOMS TO THE SOUTHEAST, SOUTH AND SOUTHWEST ACCORDING TO THEIR REQUIREMENTS FOR FILTERED AND SHADED NATURAL SUNLIGHT - SHADING DEVICES (25). THOSE SPACES HAVING MINIMAL COOLING REQUIREMENTS OR SUNLIGHT SUCH AS CORRIDORS AND CLOSETS SHOULD BE ON THE NORTH FACE OF THE BUILDING TO ACT AS A BUFFER AND ALLOW THE GREATEST AIR MOVEMENT AND VENTILATION TO TAKE PLACE NEAR THE INHABITED SPACES.

SMALL SCALE PATTERNS

Evaluate your building's openings (in walk and roof) to admit sunlight and provide ventilation - WINDOW LOCATION (8), PROTECTED ENTRANCE (7) and CLERESTORIES AND SKYLIGHTS (12), and at the same time choose the most appropriate options for providing SUMMER COOLING (27).

ILLUSTRATION

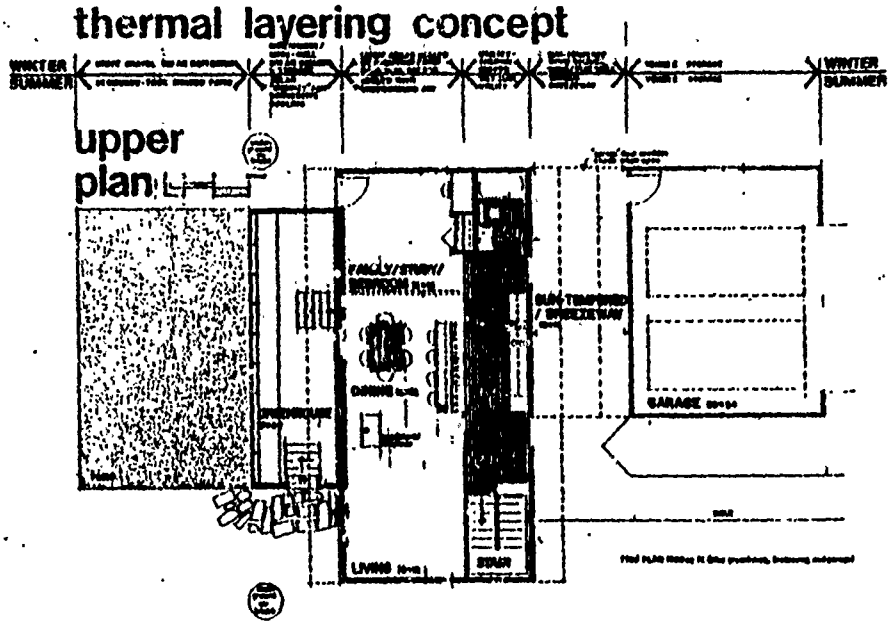


Figure 34-1

INFORMATION

Figure 34-1 (Fuller Moore's Solargreen)is a good example of zoning or thermal layering of indoor spaces for winter and summer.

The summer microclimatic conditions along the sides of your building (outside walls) are the key to locating indoor spaces. The north side remains the coolest because it usually is in shade. The east and west walls receive equal amounts of direct sunlight, but the afternoon temperature is usually warmer and likewise west-facing wall gets hotter than a east-facing wall. The South wall receives very little radiation in the summer if SHADING DEVICES (25) are used, because the sun's altitude i high and exposes the roof to more radiation than the east or west walls.

Your task is to locate spaces with specific cooling requirements based on the microclimatic condition and functional requirements of the using organization (user). And this must be done in conjunction with LOCATION OF INDOOR SPACES (6).

You should also consider using the patterns in Appendix F from A Pattern Language by Christopher Alexander.

REFERENCES

1. Fuller Moore. Solargreen - A Passive Solar Dwelling for All Seasons - Award Winning Design in recent U.S. Dept. H.U.D. Passive Solar Residential Design COmpetition.

2. Edward Mazria. The Passive Solar Energy - Expanded Professional Edition, Rodale Press, Emmaus, Pa., 1979. pp 90-92.

SOURCES OF ILLUSTRATIONS

Figure 34-1 Fuller Moore. Solargreen.

35. DIURNAL AIR FLUSHING

LARGE SCALE PATTERNS

Using the ideas of SUMMER COOLING-HEAT GAIN CONTROL, NATURAL VENTILATION and INDUCED VENTILATION (27) - this pattern gives guidance for night cooling of your building, while maintaining security.

THE PROBLEM

DIURNAL AIR FLUSHING SIMPLY ALLOWS COOLER NIGHT AIR TO CIRCULATE THROUGH YOUR BUILDING, AND STORE COOLTH IN THE STRUCTURE AS A RADIANT COOL SOURCE (with potential to absorb heat the next day). THE PROBLEM IS HOW TO GET STORED HEAT OUT OF THE STRUCTURE DURING THE COOL OF THE NIGHT AND MAINTAIN SECURITY.

THE RECOMMENDATION

IF YOUR BUILDING HAS 24 HOUR OCCUPANCY SUCH AS FAMILY HOUSING AND DORMITORIES, THEN YOU SHOULD USE STRATEGICALLY LOCATED OPERABLE SOLAR WINDOWS (11) AND CLERESTORIES AND SKYLIGHTS (12) TO CIRCULATE COOL AIR AND STORE COOLTH IN THE STRUCTURE.

FOR A STRUCTURE WITHOUT NIGHT OCCUPANTS, YOU SHOULD COMBINE THE FOLLOWING PATTERNS TO PROVIDE A (closed) SOLAR DRIVEN VENTILATION SYSTEM: EARTH TUBES(28), KING VENTILATION SYSTEM (29), SOLAR CHIMNEY (31) - MASONRY HEAT STORAGE WALL (13). THIS COMBINATION WILL PROVIDE SECURE NIGHT TIME VENTILATION OF THE STRUCTURE - DIURNAL AIR FLUSHING. THIS COMBINATION ALSO WILL PROVIDE A PASSIVE WINTER TIME EARTH TEMPERED VENTILATION SYSTEM.FOR WINTER OPERATION THE SOLAR CHIMNEY (31) NEEDS TO BE CONVERTED INTO A HEATING SOURCE MASONRY HEAT STORAGE WALL(13).[1,2]

SMALL SCALE PATTERNS

This pattern concludes the SUMMER COOLING - HEAT GAIN CONTROL, NATURAL VENTILATION and INDUCED VENTILATION (27) cooling options.

ILLUSTRATION

Figure 35-1

INFORMATION

This pattern does not need additional information, because its sole purpose is to synthesize other patterns, into a large pattern, to provide secure night ventilation - Diurnal Flushing - without open windows.

REFERENCES

1. Fuller Moore, Dr. Don Elmer and Mo Hourmanesh. "Comfort Variable/Cooling Option/Design Strategy" (Table) Research and Design-The Quarterly of the AIA Research Corporation Vol II, no.3, Fall 1979.p6.

2. Discussion with Fuller Moore and Stanley H. Scofield, Capt. U.S.A.F., 31 October 1979 about the relationship of induced ventilation and Diurnal Air Flushing - action: add a line connecting induced ventilation and diurnal air flushing. (See table 27-1).

SOURCES OF ILLUSTRATIONS

Figure 35-1



PROGRAM FOR WPAFB, OHIO CENTRAL TECHNICAL LIBRARY

PART 2

DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE OF TECHNOLOGY XXXX (ATC)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

REPLY TO ATTN OF: Stanley H. Scofield, Captain, USAF 7 December 1979

SUBJECT: Master of Architecture Thesis Architectural Programming Development Design Problem Statement

TO: Professor Daniel Miskie
Professor Fuller Moore
Professor John Hoffman

The following Programming Development Design Problem Statement has been prepared by myself and the AFIT Librarian (AFIT/LD) - Virginia Eckel, and is the basis for beginning my schematic design. Space requirements are in Attachments 1 and 2.

This problem statement, the recommended "Passive Solar Architectural Retrofit Patterns," and attachments constitute the Architectural Design Problem Statement. It is purposefully abstract so the designer(s) will know the major design determinants -- those factors which shape the broad composition of the building -- and provide important overall information useful to schematic design.

FUNCTION

Since 40% of the Air Force's Research and Development, and 100% of the Air Force Institute of Technology in-residence graduate research is conducted in Area "B" of Wright-Patterson Air Force Base, THERE IS A NEED FOR A CENTRAL TECHNICAL LIBRARY, which has potential for future expansion, THAT WILL PROVIDE ("The University Library") RESEARCH SERVICE TO THE ENTIRE WRIGHT-PATTERSON AIR FORCE BASE COMMUNITY. This will allow the AFIT (Air Force Institute of Technology) branch libraries to be used primarily for studying, by separating research and classrooms. THE PRIMARY MEANS OF RESEARCH WILL BE WITH O.C.L.C. AND D.D.C. (DEFENSE DOCUMENTATION CENTER) SYSTEM COMPUTER TERMINALS.

Since a major portion of Wright-Patterson AFB's Research and Development deals with classified national security material, THERE IS A NEED FOR CLASSIFIED BIBLIOGRAPHIC RESEARCH CAPABILITY -- USE THE D.D.C. (DEFENSE DOCUMENTATION CENTER) SYSTEM -- AND FOR STORAGE OF CLASSIFIED DOCUMENTS, AND CLASSIFIED WASTE (trash) THAT IS AWAITING DISPOSAL. THIS REQUIREMENT NECESSITATES A CLASSIFIED "VAULT" IN AN AREA OF ACOUSTICAL AND VISUAL PRIVACY, WITH SECURE COMMUNICATIONS LINES. ACCESS TO THIS AREA WILL BE LIMITED BY APPROPRIATE CLEARANCE AND NEED TO USE THE D.D.C. SYSTEM. NOTE: A classified "vault" is in the basement of the building (Bldg #167 - Area B, WPAFB) and should be used for this project requirement.

Since much information is now recorded on microfilm and other similar media, THERE IS A NEED FOR AN AUDIO/VISUAL CAPABILITY IN THE CENTRAL TECHNICAL LIBRARY. IT SHOULD BE VISIBLE WHEN ENTERING THE LIBRARY.

Since the space presently used by the AFIT bookstore is needed for the School of Engineering, and a central technical library is a logical location for it, THERE IS A NEED TO PROVIDE 1100 SQUARE FEET, IN THE CENTRAL TECHNICAL LIBRARY, FOR THE ARMY AND AIR FORCE EXCHANGE SYSTEM (AAFES). IT SHOULD BE NEAR AN ENTRY SO IT CAN BE USED WITHOUT ENTERING THE LIBRARY AREA, AND NEAR A LOADING DOCK FOR DELIVERY OF BOOKS AND SCHOOL SUPPLIES. NOTE: This area is not to be designed in this project, because AAFES will design the interior of the bookstore.

FORM

Since all library users are commuters, THERE IS A NEED FOR A SMOOTH TRAFFIC FLOW, WHICH SEPARATES PEDESTRIANS AND VEHICLES, AND PROVISIONS FOR HANDICAPPED PARKING AND BUILDING ACCESS. ALSO THE LIBRARY ENTRANCE NEEDS TO BE SEEN OR HINTED AT AS SOON AS THE BUILDING IS SEEN. IT SHOULD BE AN AIR LOCK ENTRY TO REDUCE INFILTRATION HEAT LOSSES, AND IT SHOULD BE LARGE ENOUGH TO ACCOMMODATE SOCIALIZING NEAR DOORS.

Since promotion of user confidence ("I will find what I want") is essential to the use and operation of the central technical library, THERE IS A NEED FOR THE FOLLOWING: SMOOTH FLOWING INTERIOR WHERE FUNCTIONALITY SHOULD NOT CREATE OBSTACLES; SELF SERVICE CAPABILITY WHICH IS PROMOTED AND FOSTERED BY A USER INFORMATION SYSTEM BY EACH COMPUTER TERMINAL; PERSONALIZED RESEARCH SERVICE FOR USERS REQUIRING HELP.

The atmosphere created inside and outside of the central technical library are essential to its use and operation, THERE IS A NEED FOR THE DESIGN TO CREATE A PLEASANT, TRANQUIL, AND NATURAL ENVIRONMENT. THIS CAN BE ACCOMPLISHED BY THE FOLLOWING: USING THE VIEW TO THE SOUTH AND WEST; USING TREES AND LANDSCAPE; USE OF NATURAL LIGHT IN THE BUILDING FOR A SENSE OF DIRECTION AND TIME PASSAGE; USE OF SOUTHERN EXPOSURE OF SITE FOR OUTDOOR SEATING WHERE USERS CAN STUDY AND RELAX.

Since the image of a strong library committed to technology is essential to the Air Force Institute of Technology's upcoming reaccreditation process, THERE IS A NEED FOR THE CENTRAL TECHNICAL LIBRARY TO EMPLOY AN ARCHITECTURAL LANGUAGE WHICH EXPRESSES THIS IMAGE, AND AT THE SAME TIME ALLOWS THE STRUCTURE TO ACCOMMODATE AND ACCENTUATE THE NATURAL HEAT TRANSFER PROCESSES (RADIATION, CONVECTION, AND CONDUCTION). THE USE OF NATURAL (PASSIVE) SOLAR

ARCHITECTURAL LANGUAGE WILL PROVIDE THIS IMAGE, WHILE INCREASING THERMAL PERFORMANCE, AND REDUCE OPERATION AND MAINTENANCE COSTS. NOTE: Attachment 3 - Historical Building Type Solution (Library) provides a historical perspective of how libraries were heated and cooled using passive design "patterns."

ECONOMY

Since the National Energy Policy Act (Public Law 95-619) requires retrofit of all existing federal buildings over 1000 square feet by 1990, and since the Air Force energy plan stresses passive solar applications and encourages organizations to actively seek Department of Energy (DOE) grants, and since there have not been any passive solar retrofits of federal buildings in the federal buildings demonstration programs, and since DOE officials are extremely interested in accomplishing a passive solar retrofit in the program, THERE IS AN OPPORTUNITY TO DEVELOP A CONCEPTUAL (PASSIVE SOLAR RETROFIT) DESIGN TO CONVERT BUILDING 167 (OF AREA "A" - WPAFB) INTO A CENTRAL TECHNICAL LIBRARY. ECONOMIC (DOLLAR) CONSTRAINTS ARE NOT TO BE APPLIED FOR PURPOSES OF THIS THESIS DESIGN. THE ECONOMY DESIGN ISSUE IS THAT SINCE THE AIR FORCE ACCEPTS PASSIVE SOLAR AS BEING COST EFFECTIVE, THEN WHAT IS THE METHOD OR WHAT ARE THE "RULES OF THUMB FOR STARTING A PASSIVE SOLAR RETROFIT. NOTE: The "rules of thumb" - Passive Solar Architectural Retrofit Patterns - selected for this project are listed on Attachment 4.

TIME

Since technology and library book collections are constantly growing and changing, THERE IS A NEED FOR VERSATILITY AND EXPANSIBILITY TO ACCOMMODATE GROWING BOOK HOLDINGS AND MEDIA CHANGES. NOTE: Attachment 5 [Xerox copies of site analysis (index) cards] shows the recommended area of expansion based on BUILDING SHAPE AND ORIENTATION (3) and location of utilities.

OTHER

A list of miscellaneous equipment items not listed on the Area Program Requirements forms are listed on Attachment 6. Attachment 7 shows adjacency requirements of spaces within the library.

Stanley H. Scofield

STANLEY H. SCOFIELD, Capt, USAF
AFIT Graduate Architecture Student

7 Atchs
1. Space Requirements
2. Area Program Requirements
3. Historical Bldg Type - Library
4. Passive Solar Arch. Retrofit Patterns
5. Site Analysis (Index) Cards
6. General Equipment Requirements
7. Adjacency Diagram

Cy to: AFIT/CV (Col Adams)
AFIT/DE (Col Strom)
AFIT/LD (Virginia Eckel)

SPACE REQUIREMENTS

Stack Area (Books & Periodicals	29,000
Reading Room	7,000
Staff Offices (etc)	3,100
Audiovisual	1,000
Seminar Room	1,000
Classified Room	1,000
Terminal Room	1,000
Bookstore	1,100
Other (Staff Lounge, Rest Rooms, etc)	1,500
Mechanical	1,000
	46,700

NOTE: The above space allocations are only recommended. They are flexible and can be modified based on the schematic design.

AREA PROGRAM REQUIREMENTS

AREA : READING ROOM & REFERENCE ROOM

USERS : faculty, staff, individual, patrons

GOALS & OBJECTIVES :
users to have a place to read and study. All reference tools - abstracts and ACLC terminals are for public use. Charging for research & some materials

ACTIVITIES : reading, writing, studying, using calculators, waiting for

TIME SCHEDULE : 0730 - 2100 hrs. 600 to 700 people per day with most since 1700 hrs → 80/hr (0730 - 1700 hrs) and 10/hr (1700 - 2100 hrs)

CHARACTER :

PROVIDE FOR : Most special tables to hold large volumes. Some higher tables for standing patrons or checking card files. Tables for ACLC terminals - to be used from seated position. Pleasant atmosphere for research and study.

TECHNOLOGIES :

PROVIDE FOR : HVAC - DIRECT GAIN (OR) CLERESTORIES & SKYLIGHTS (?)
LIGHT LEVEL - Good natural light (indirect)
Sound absorption material required ... space (ceilings, chairs etc)

SURFACE TREATMENTS :

PROVIDE FOR : color : soft, light color for good light ref.
tables : smooth dark surface to reduce glare
flooring : carpet on floor for noise reduction
wall : durable & washable.

EQUIPMENT : tables, chairs + study carrels (60% of 250 seats → 150 seats)
table (40% of 250 seats → 100 seats)
reference desks (2)
open shelving (70% of volumes) — SQUARE FEET
spacesaver shelving (30% of volumes) — SQUARE FEET
ACLC terminals - 4 seated terminals

NOTE: THIS AREA MUST INCORPORATE THE REFERENCE AND READING ROOM REQUIREMENTS.

PLAN :

DIMENSIONS :

TOTAL : APPROX 7,000 SF

HEIGHT :

AREA PROGRAM REQUIREMENTS

AREA : REFERENCE DESK

USERS : staff - short conferences with staff

GOALS & OBJECTIVES :
reference bibliographies (probably 2 desks needed)
one desk for inter-library loans person.

ACTIVITIES : asking & answering questions/information between staff and user; 2 - 5 persons (sometimes one person might be in with a)

TIME SCHEDULE : 0730 - 2100 hrs.
2 - 5 persons at a time

CHARACTER :

PROVIDE FOR :
comfortable desk & chairs
easy access to equipment

TECHNOLOGIES :

PROVIDE FOR : HVAC -
LIGHT LEVEL -

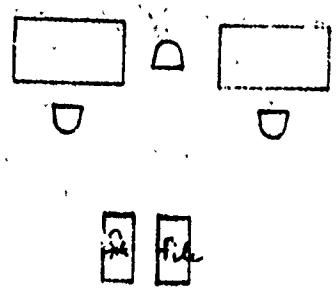
SURFACE TREATMENTS :

PROVIDE FOR :

EQUIPMENT : telephone - 1
terminal - 1
desk & chair - 1&2
file 1

NOTE : THIS AREA IS TO BE PART OF THE REFERENCE AND READING ROOM REQUIREMENTS.

PLAN :



DIMESIONS :

TOTAL : PART OF READING ROOM & REFERENCE ROOM

HEIGHT : SPACE REQUIREMENTS

AREA PROGRAM REQUIREMENTS

AREA : CIRCULATION DESK (CHECK OUT/IN)

USERS : staff, faculty - students - base users

GOALS & OBJECTIVES :
To check library materials out - to know current and know where library materials are at all times.

ACTIVITIES : checking in and out of library materials

TIME SCHEDULE : 0730 - 2100 hrs.

CHARACTER :

PROVIDE FOR :
comfortable conditions for staff members

TECHNOLOGIES :

PROVIDE FOR : HVAC -

LIGHT LEVEL - ~~good~~ natural (indirect) light if possible

SURFACE TREATMENTS :

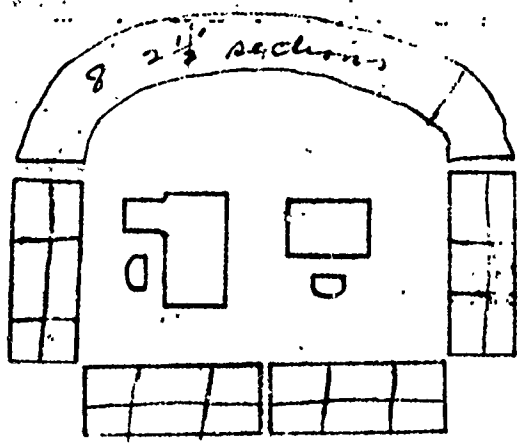
PROVIDE FOR :
color : soft, light color for good light diffusion.
flooring : carpet for noise reduction.
walls : durable & washable

EQUIPMENT :
circulation desk
- staff desk - typewriter - telephone
- terminal / computer equipment (1 terminal
- assistant desk - telephone
- electrical outlet for security system.

security system -

ATCH 2-3

PLAN :



DIMESIONS :

TOTAL :

HEIGHT :

THIS IS PART OF READING ROOM AND REFERENCE ROOM SPACE REQUIREMENTS

193

AREA PROGRAM REQUIREMENTS

AREA : READER SERVICE OFFICE

USERS : director of reader services

GOALS & OBJECTIVES : to provide office space for the director of reader services to perform supervisory functions, review publisher literature & lend selection of new books

ACTIVITIES : writing
reading
communication

TIME SCHEDULE : 0730 - 2100 hrs

CHARACTER :

PROVIDE FOR : pleasant working environment

TECHNOLOGIES :

PROVIDE FOR : HVAC - DIRECT GAIN (9A) / CLERESTORIES & SKYLIGHTS (12' feet not required.
LIGHT LEVEL - natural lighting is desirable
sound absorption material is required.

SURFACE TREATMENTS :

PROVIDE FOR : colors: soft and light
tables: smooth dark surface for work
floors: carpet for noise reduction and reducing glare
walls: durable and washable.

EQUIPMENT :

1 desk and chair
1 typewriter
1 file case
3 book storage sections
1 telephone

ATCH 2-4

PLAN :

DIMESIONS :

TOTAL : APPROX 120 SF

HEIGHT : PART OF STAFF OFFICES SPACE REQUIREMENT.

AREA PROGRAM REQUIREMENTS

AREA : AUDIO VISUAL & MICROFILM READING

USERS : faculty, staff, other libraries, base readers

GOALS & OBJECTIVES :
to store all microforms owned by the library
provide reading & printing equipment
(readers - reader printers - fiche to fiche copiers)

ACTIVITIES : reading of microforms
reproducing of microforms

TIME SCHEDULE : 0730 - 2100 hrs.

CHARACTER :

PROVIDE FOR : properly lighting to use equipment and pleasant atmosphere for study research

TECHNOLOGIES :

PROVIDE FOR : HVAC - EARTH TUBES (28), KING VENTILATION (29) SOLAR
LIGHT LEVEL - variable light level controls

SURFACE TREATMENTS :
PROVIDE FOR :
walls: durable and washable
color: light color
tables: smooth dark surface for writing and reducing glare
floor: carpet to reduce sound transmission

EQUIPMENT (12) microform readers + reader printers
fiche to fiche copier
tables for equipment - properly height for using the equip
chairs
Diebold cabinets to store microfiche - 4
10 vido tape
slide projectors
16 mm film projector

ATCH 2-5

PLAN :

DIMESIONS :

TOTAL : APPROX. 1000 SF

HEIGHT :

AREA PROGRAM REQUIREMENTS

AREA : CLASSIFIED MATERIAL — "VAULT"

USERS : FACULTY, STAFF, STUDENTS, LABORATORY RESEARCHERS.

GOALS & OBJECTIVES : TO PROVIDE FACILITIES FOR CLASSIFIED BIBLIOGRAPHIC RESEARCH CAPABILITY USING THE D.D.C. (DEFENSE DOCUMENTATION CENTER) SYSTEM. THIS NECESSITATES AN AREA OF ACOUSTICAL AND VISUAL PRIVACY FROM THE PUBLIC AREAS.

ACTIVITIES : D.D.C. BIBLIOGRAPHIC RESEARCH, READING AND STORING OF CLASSIFIED MATERIAL

TIME SCHEDULE : 0730 - 2100 HRS. 20 STUDY SPACES
2 LIBRARY STAFF

CHARACTER :
PROVIDE FOR : THE SPACE SHOULD MAKE OCCUPANTS FEEL THEY ARE IN A SPACE REQUIRING CLASSIFIED MATERIAL SECURITY, AND THE OCCUPANTS SHOULD BE ABLE TO OBSERVE OTHER OCCUPANTS OF THE SPACE TO PREVENT PRIVACY. PLEASANT ATMOSPHERE FOR RESEARCH AND STUDY OF CLASSIFIED MATERIAL.

TECHNOLOGIES :
PROVIDE FOR : HVAC — EARTH TUBES (28) KING VENT (29) & SOLAR [illegible]
LIGHT LEVEL — ARTIFICIAL LIGHT (NO NATURAL LIGHT OR WINDOWS IN THIS SPACE)

SURFACE TREATMENTS :
PROVIDE FOR :
- WALLS AND CEILINGS: SHOULD HAVE A STC OF [illegible] (USING MASS AND ACOUSTICAL WALL TREATMENTS)
- COLOR & SOFT AND LIGHT FOR LIGHT DIFFUSION
- FLOOR: CARPET FOR SOUND REDUCTION

EQUIPMENT :
1 - VAULT FOR STORAGE OF CLASSIFIED (SECRET) DOCUMENTS.
10 - SHELF UNITS ALONG WALLS
20 - CHAIRS FOR CLASSIFIED READING AND RESEARCH
- TABLES FOR STUDYING CLASSIFIED DOCUMENTS. (IN CENTER OF ROOM)
- SPACE TO STORE CLASSIFIED (SECRET) TRASH FOR DISPOSAL PICK-UP.

2 - CLASSIFIED (SECRET) D.D.C. TERMINALS

PLAN : THE EXISTING "VAULT" IN THE BASEMENT OF BLDG 167 (± 1005 SF)
IS AN EXCELLENT LOCATION FOR THIS FUNCTION BECAUSE :

1. PHYSICAL SEPARATION FROM OTHER FUNCTIONS.
2. VISUAL SEPARATION FROM OTHER FUNCTIONS
3. ACOUSTICAL SEPARATION BECAUSE OF BUILDING MASS

DIMENSIONS :

TOTAL : APPROX 1000 SF.

HEIGHT :

AREA PROGRAM REQUIREMENTS

AREA : DIRECTORS OFFICE

USERS : director of library - staff - visitors such as faculty, staff

GOALS & OBJECTIVES :
To plan all library activities
Responsible for all library activities

ACTIVITIES : writing
reading
conferences with personnel - private
staff visits

TIME SCHEDULE : 0730 - 2130 hr

CHARACTER :

PROVIDE FOR : pleasant atmosphere for casual conferences

TECHNOLOGIES :

PROVIDE FOR : HVAC - DIRECT GAIN(9A)/CLERESTORIES & SKYLIGHTS (12)
LIGHT LEVEL - natural lighting is desirable but not required
sound absorption material required

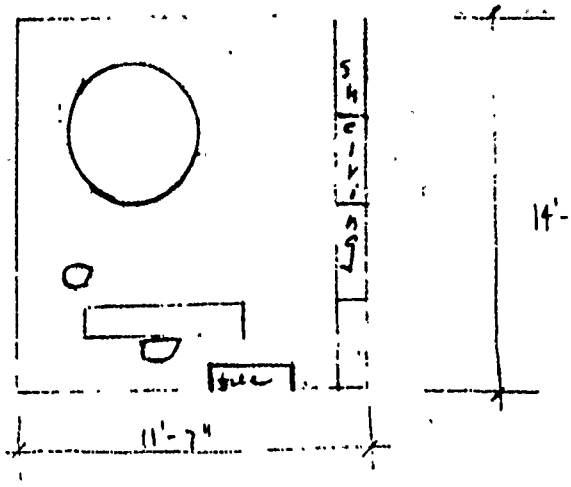
SURFACE TREATMENTS :

PROVIDE FOR : color: soft and light
tables: smooth dark surface for writing and reduced glare
floor: carpet for noise reduction
walls: durable & washable

EQUIPMENT : 1 desk + chair
1 conference table + six chairs
shelving - 12 lineal ft - 6 high
1 coat rack
1 telephone (2)
4 easy chairs for visitors or to use if larger conference

ATCH 2-7

PLAN :



DIMESIONS : same size as present directors office
TOTAL : in bldg 640.
HEIGHT :

PART OF STAFF OFFICE SPACE REQUIREMENTS

201

AREA PROGRAM REQUIREMENTS

AREA : STAFF LOUNGE

USERS : library staff

GOALS & OBJECTIVES :
to provide the staff a place to spend their breaks
and prepare quick food when cafeterias are closed (eve... and weekend

ACTIVITIES : eating
relaxing
[illegible] discussions
staff conferences (15 people)

TIME SCHEDULE : 0730 - 2100 hrs

CHARACTER :

PROVIDE FOR : comfort and relaxation

TECHNOLOGIES :

PROVIDE FOR : HVAC - DIRECT GAIN SA/CLERESTORIES & SKYLIGHTS/12
LIGHT LEVEL - natural lighting is desirable but not required
sound absorption is required

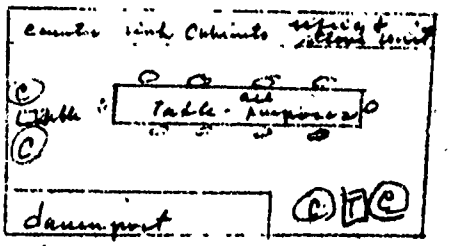
SURFACE TREATMENTS :

PROVIDE FOR : color: soft and light
floor: carpet for noise reduction
walls: durable and washable

EQUIPMENT : one dozen part
chairs
tables
publication [illegible]
[illegible] - if possible

ATCH 2-8

PLAN :



DIMENSIONS :

TOTAL :

HEIGHT :

PART OF "OTHER" SPACE REQUIREMENTS

AREA PROGRAM REQUIREMENTS

AREA : STACK AREA

USERS : faculty, staff, students, base users

GOALS & OBJECTIVES :

to store books & reports
films
records

ACTIVITIES : storing of books
shelving & retrieving books

TIME SCHEDULE : 0730 - 2100

CHARACTER :

PROVIDE FOR :

light
wide enough aisles for handicapped
proper protection for the books.

TECHNOLOGIES :

PROVIDE FOR : HVAC -
LIGHT LEVEL -

SURFACE TREATMENTS :

PROVIDE FOR :

EQUIPMENT :

shelving for 130,000 books and bound volumes
" " 100,000 reports

PLAN :

DIMESIONS :

TOTAL : APPROX. 29,000 SF

HEIGHT :

AREA PROGRAM REQUIREMENTS

AREA : ACQUISITION, CATALOGING & STAFF REF. ROOM

USERS : Library staff members, occasional faculty members

GOALS & OBJECTIVES : to provide work area for acquisition, catalog and process all library materials. Also space requires shelves for temporary storage of materials, and space for "Official Use Only" documents

ACTIVITIES : Ordering, receiving (near loading dock), cataloging and processing of books, periodicals, mail etc.

TIME SCHEDULE : 0730 - 1700 hrs.

CHARACTER :

PROVIDE FOR : Comfortable working conditions for the staff with access, in staff service area, wide enough for book trucks should be near loading dock

TECHNOLOGIES :

PROVIDE FOR : HVAC - DIRECT GAIN (9A) / CLERESTORIES & SKYLIGHTS

LIGHT LEVEL - Must have very good lighting. Natural light is preferable

sound absorption material is required

SURFACE TREATMENTS :

PROVIDE FOR : flat durable carved surfaces for packing and unpacking boxes of books walls durable & washable ; color light flooring : carpet for noise control

EQUIPMENT :

2 OCLC Terminals with printers
1 acquisition terminal with printer
90 lin. ft. of shelving - 6 shelves high
15 lin. ft. of shelving - for "OFFICIAL USE ONLY" and "LIMITED" documents
11 desks
16 chairs
1 reading table
1 work table (packing & unpacking books)
1 index table
11 #564 telephone instruments
6 book trucks
4 type writers
3 file cabinets (official)

ATCH 2-10

PLAN :

DIMESIONS :

TOTAL : PART OF STAFF OFFICE SPACE REQUIREMENT

HEIGHT :

-207

AREA PROGRAM REQUIREMENTS

AREA : ADMINISTRATIVE ASSISTANT

USERS : administrative assistant

GOALS & OBJECTIVES : to assist the Director in Administrative and clerical help

ACTIVITIES : typing - filing - answering phone - meeting visitors of the Director

TIME SCHEDULE : 0730 - 1702 hrs.

CHARACTER :

PROVIDE FOR : pleasant atmosphere

TECHNOLOGIES :

PROVIDE FOR : HVAC - DIRECT GAIN (DA) / CLERESTORIES & SKYLIGHTS
LIGHT LEVEL - natural lighting is desirable but not required.
sound absorption required.

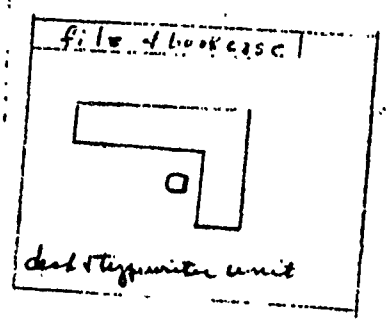
SURFACE TREATMENTS :

PROVIDE FOR : color : soft and light
tables : smooth dark surface for work and reduced glare.
floor : carpet for noise control
walls : durable and washable

EQUIPMENT : / desk + chair
/ typewriter
/ file cabinet
/ bookcase - notebooks for regulations and manuals
/ telephone

ATCH 2-11

PLAN : should be near the Assistant's office.



should be approx. mid. of readers service.

this space can be within Tech Services Work Space and can be open office landscape.

DIMESIONS :

TOTAL : PART OF STAFF OFFICE SPACE REQUIREMENTS

HEIGHT :

AREA PROGRAM REQUIREMENTS

AREA : PARKING

USERS : STAFF, STUDENTS, FACULTY, OTHER VISITORS

GOALS & OBJECTIVES : TO PROVIDE ADEQUATE AND EFFICIENT PARKING — NOTE: ADEQUATE PARKING EXISTS. HOWEVER, CLOSE, BARRIER FREE PARKING DOES NOT EXIST AND MUST BE PROVIDED. IT SHOULD BE ON THE SOUTH SIDE OF BUILDING FOR NATURAL ICE CLEARING OF SIDEWALKS.

ACTIVITIES :

TIME SCHEDULE :

CHARACTER :
PROVIDE FOR :

TECHNOLOGIES :
PROVIDE FOR : HVAC –
LIGHT LEVEL –

SURFACE TREATMENTS :
PROVIDE FOR :

EQUIPMENT :

AREA PROGRAM REQUIREMENTS

AREA : ENTRY / EXIT

USERS : ENTRY: ALL WITH SPECIAL PROVISIONS FOR HANDICAP...

GOALS & OBJECTIVES : TO PROVIDE A WELL DEFINED ENTRY THAT IS "HINTED AT" AS SOON AS THE BUILDING IS SEEN, AND SHOULD ALLOW EASY ENTRY FOR THE HANDICAPPED. THE ENTRY MUST BE AN AIR LOCK-ENTRY -- PROTECTED ENTRY (?)

ACTIVITIES : TRANSITION BETWEEN OUTSIDE AND LIBRARY -- TAKE OFF AND PUT-ON COATS, VISIT WITH OTHER PEOPLE etc..

TIME SCHEDULE : 0730 -- 2130 HRS

CHARACTER :
PROVIDE FOR : PLEASANT ENVIRONMENT FOR TRANSITION FROM OUTSIDE TO LIBRARY ENVIRONMENT, AND CHANCE ENCOUNTERS

TECHNOLOGIES :
PROVIDE FOR : HVAC - NONE
LIGHT LEVEL - NATURAL LIGHT - DAY
LOW LIGHT LEVEL - NIGHT

SURFACE TREATMENTS :
PROVIDE FOR : WALLS: DURABLE & WASHABLE
COLOR: NO PREFERANCE
FLOOR: SKID RESISTANT MASONRY TILE

EQUIPMENT : 1 FLOOR MAT AT EACH DOOR.

NOTES: BLDG 161 PRESENTLY HAS 5 ENTRY DOORS AND NONE ARE WELL DEFINED. THE ENTRIES SHOULD BE MODIFIED WITH ONE SOUTHERN ENTRY, ONE NORTHERN ENTRY, AND OTHER DOORS SHOULD BE MODIFIED TO BE FIRE EXIT DOORS ONLY

PLAN : NONE REQUIRED

DIMESIONS : NONE REQUIRED

TOTAL : PART OF "OTHER" SPACE REQUIREMENTS

HEIGHT :

AREA PROGRAM REQUIREMENTS

AREA : BOOK STORES (ARMY AND AIR FORCE EXCHANGE

USERS : AFIT STUDENTS AND FACULTY

GOALS & OBJECTIVES : TO PROVIDE APPROX. 1100 SQFT. FOR AN AAFES (ARMY & AIR FORCE EXCHANGE SERVICE) OPERATED BOOK STORE FOR PURCHASING OF AFIT GRADUATE COURSES, AND SCHOOL SUPPLIES. IT SHOULD BE NEAR AN ENTRY SO A USER CAN USE IT WITHOUT ENTERING THE LIBRARY.

ACTIVITIES : SALES OF BOOKS AND SCHOOL SUPPLIES.

TIME SCHEDULE : 1000 - 1700 HRS

CHARACTER :

PROVIDE FOR :

NOTE : THIS PROJECT ONLY PROVIDES THE SPACE AND HVAC. AAFES WILL DESIGN THE INTERIOR FOR THEIR NEEDS.

TECHNOLOGIES :

PROVIDE FOR : HVAC -

LIGHT LEVEL -

SURFACE TREATMENTS :

PROVIDE FOR :

EQUIPMENT : SHOULD BE NEAR A LOADING DOCK.

PLAN : NOT REQUIRED

DIMESIONS : 1
TOTAL : 1100 SF
HEIGHT :

215

AREA PROGRAM REQUIREMENTS

AREA : LOADING DOCK

USERS : DELIVERY TRUCK (MERCHANTS & MAIL) WITH BOOKS AND SUPPLIES

GOALS & OBJECTIVES :
TO PROVIDE EASY ACCESS TO THE BUILDING FOR UNLOADING BOOKS AND SUPPLIES.

ACTIVITIES :

TIME SCHEDULE :

CHARACTER :
PROVIDE FOR :

NOTES: A LOADING DOCK ALREADY EXISTS ON THE NORTH SIDE OF THE BUILDING. IT SHOULD HAVE AN NR LOCK [illegible]

TECHNOLOGIES :
PROVIDE FOR : HVAC -
LIGHT LEVEL -

SURFACE TREATMENTS :
PROVIDE FOR :

EQUIPMENT :

HISTORICAL LIBRARY BUILDING TYPE SOLUTION

LARGE SCALE PATTERNS

Using the idea of HISTORICAL BUILDING TYPE SOLUTION (4) it is necessary to know the historical building type pattern for libraries. Hopefully this pattern will give ideas for reducing energy consumption and maintaining thermal conditions conducive to human comfort and book preservation.

THE PROBLEM

NO TWO HISTORICAL LIBRARIES HAD EXACTLY THE SAME BUILDING PROGRAM. HOWEVER, THERE WAS A GENERAL PATTERN TO THEIR CONSTRUCTION:

1. EXTERIOR AND INTERIOR WALLS WERE THICK TO DAMPEN TEMPERATURE FLUCTUATIONS, AND THE BOOKS AND WORKS OF ART ENDURED WITH COMPARATIVELY SMALL DETERIORATION.[1,2] HOWEVER, THIS DESIGN WAS NOT FLEXIBLE TO CHANGE AS LIBRARIES GREW LARGER.[1]

2. THEY HAD HIGH CEILINGS WITH WINDOWS THAT WENT TO THE CEILING, AND THE GLASS WAS USUALLY TO THE SOUTH. THIS PROVIDED GOOD NATURAL LIGHTING AND VENTILATION, AND ALLOWED BOOKS AND PEOPLE TO REMAIN AT A COMFORTABLE TEMPERATURE BECAUSE HEAT ROSE TO THE CEILING, AND OUT THE OPENED WINDOWS (SEE FIGURE E-1).[1]

3. READING ROOMS WERE USUALLY ON AN UPPER LEVEL WITH A SKYLIGHT IN THE CEILING (SEE FIGURE E-2 AND E-3).[1]

4. LIBRARIES HAVE CONSTANTLY GROWN SO THE PROBLEM IS TO PROVIDE MASS FOR TEMPERATURE STABLIZATION, BUT HAVE A FLEXIBLE BUILDING STRUCTURE THAT ACCOMODATES EXPANSION.

THE RECOMMENCATION

1. CONSIDER THE LIBRARY BOOKS AS THERMAL MASS WITH A SPECIFIC HEAT VALUE OF .32 BTU/LB/ F (BETTER THAN MASONRY OR STEEL) AND USE INSULATION ON THE OUTSIDE (26) TO DAMPEN TEMPERATURE FLUCTUATIONS.

2. IF POSSIBLE, RETROFIT YOUR BUILDING WITH AN OPERABLE SOUTH-FACING CLERESTORY - CLERESTORIES AND SKYLIGHTS (12) TO PROVIDE INDIRECT NATURAL SUNLIGHT FOR WINTER HEATING, SUMMER COOLING (27) and DIURNAL AIR FLUSHING. (35)

3. ACCOMODATE GROWTH BY USING MODERN BUILDING AND INSULATION MATERIALS SO INTERIOR SPACES CAN BE FLEXIBLE - APPROPRIATE MATERIALS (10).

SMALL SCALE PATTERNS

You should consider the following patterns for your retrofit to control summer heat and humidity and provide year around ventilation: EARTH TUBES (28), KING VENTILATION SYSTEM (29), SOLAR CHIMNEY (31), SOLAR DEHUMIDIFICATION (32), ZONING (34) and DIURNAL AIR FLUSHING (35).

ILLUSTRATIONS

See the attached photographs of the old West Point Library.

INFORMATION

The oldest and best documented American Library is the Old West Point Library (1840 - 1961). The Superintendants Log show that Isaiah Rogers proposed the library concept and the Elizabethan Gothic Sytle, which started the Collegiate Gothic at West Point and other East Coast Universities (old Yale library).[3,4]

The actual plans for the building were drawn by Cadet Tilden (figure E-5) under the supervision of Major Delafield (the superintendant), and Professor Dennis Hart Mahan as part of the required drawing studio at the academy.

The Old West Point Library fit the Historical Library Building Type Solution as described in THE PROBLEM statement. The southern elevation appeared to be the most important side of the building, prior to 1936, because it was shown in a majority of the archives photographs (see figure E-6). The BUILDING LOCATION (2) was violated in 1936 by the construction of a four story building to the south (figure E-7), which only allowed late afternoon solar gain (figure E-8).

This old library is a good example of the importance of an Architectural Language expressing the importance of a Library at an educational institution, and the projecting of a visual image - it started the Collegiate Gothic style used at several East Coast Universities, as well as the U.S. Military Academy.

REFERENCES

1. Keyes D. Metcalf (Librarian of Harvard College, Emeritus). Planning Academic and Research Library Buildings, McGraw Hill Book Company, 1965.

2. Samuel R. Lewis. "Museum and Library Practice in Heating and Ventilation" Architectural Forum, June 1932. Vol 56, p 635 - 639.

3. Stanley H. Scofield, Captain, USAF, TDY to United States Military Academy Archives - June 5-15, 1979 - To research the old academy library, 1840 - 1961.

4. "The New West Point," Architectural Record Vol 29, pp 86 - 112, January 11, 1911.

SOURCE OF ILLUSTRATIONS - USMA ARCHIVES

Figure E-1 South Elevation - circa 1880

Figure E-2 Interior - Reading Room (Upstairs with Skylight) - circa 1910

Figure E-3 Interior - Main Reading Room - circa 1910

Figure E-4 North/West Elevation - circa 1868

Figure E-5 Original USMA Library . .an (December 1839)

Figure E-6 Library and surrounding Southern exposure - circa 1900

Figure E-7 Library Demolition Looking South From the Air

Figure E-8 Library Demolition Looking North From Bartlett Hall

FIG E-1



FIG. E-2



FIG E-3

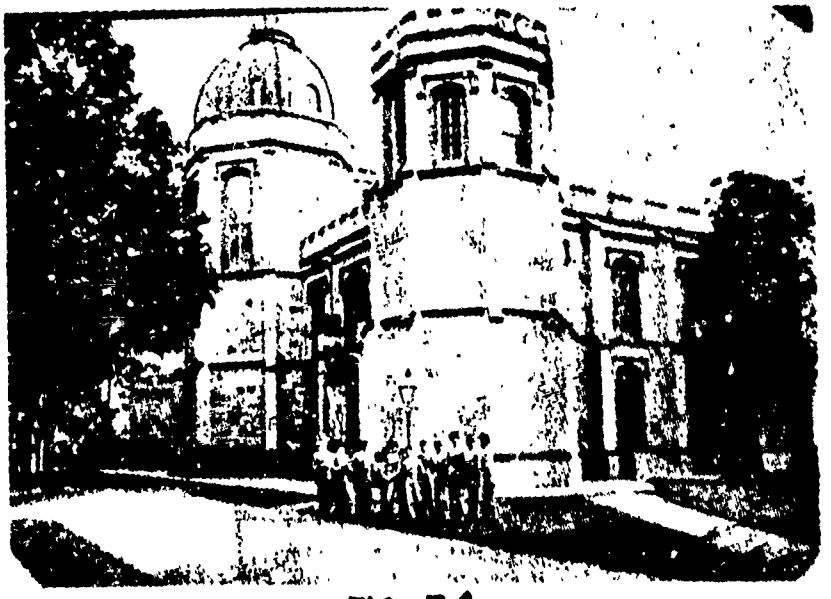
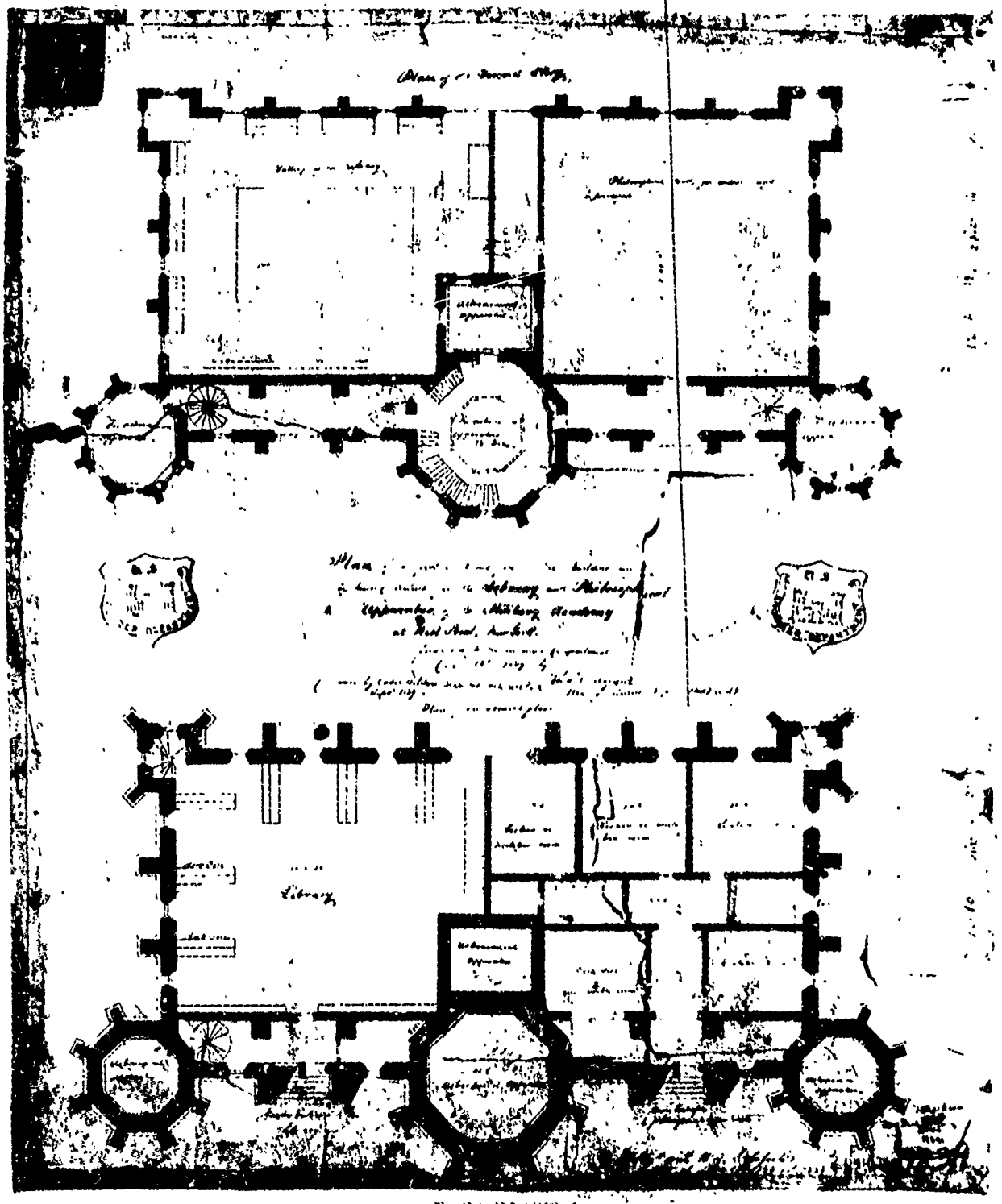


FIG. E-4



FIG E-6



Plan (Date 12 Dec 1839) of the 1841 Library

by

Major Alexander Delafield, 1808-1818
Superintendent 1838-1845 & 1856-1861

FIG E-5

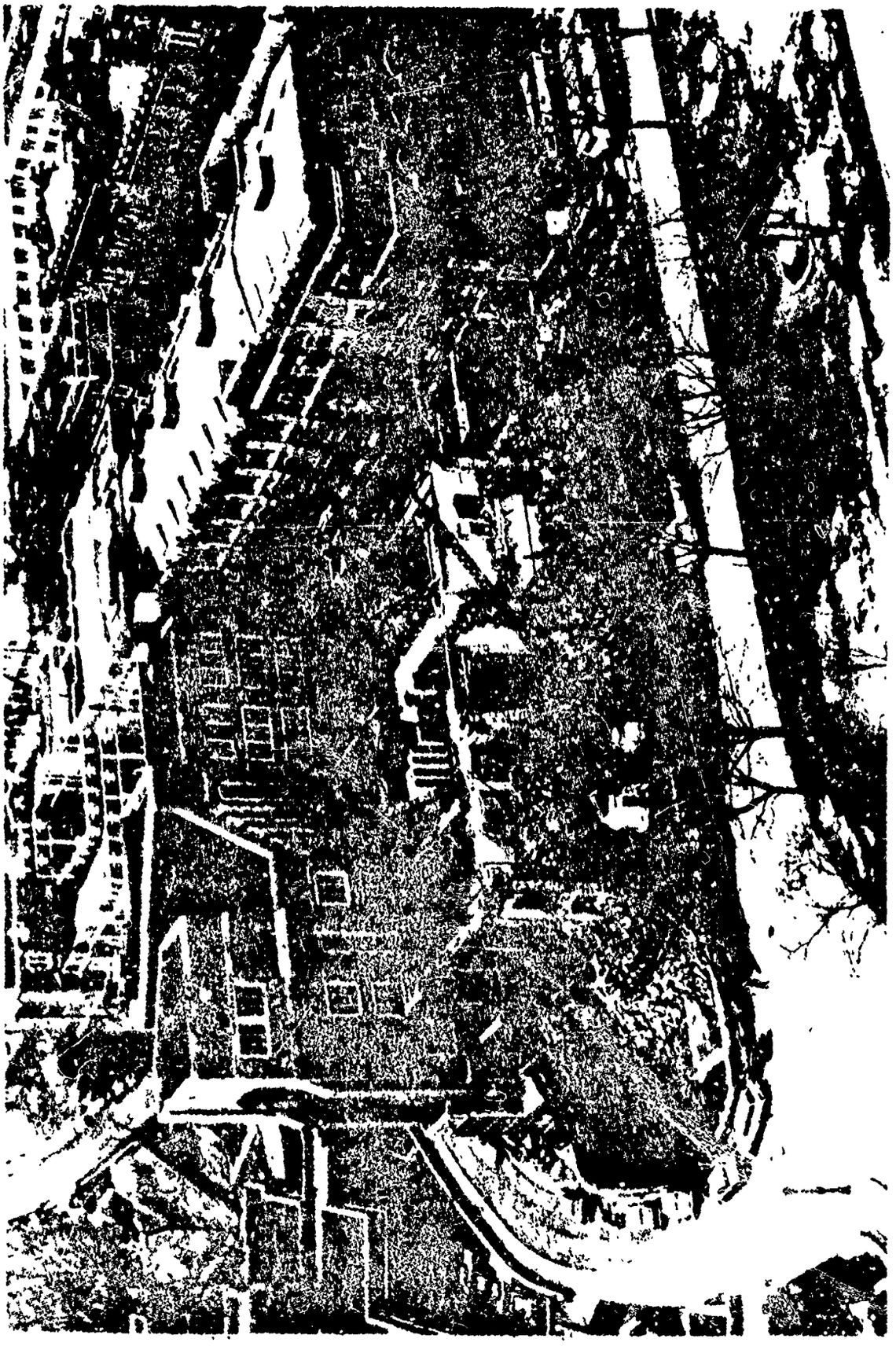


FIG E-7

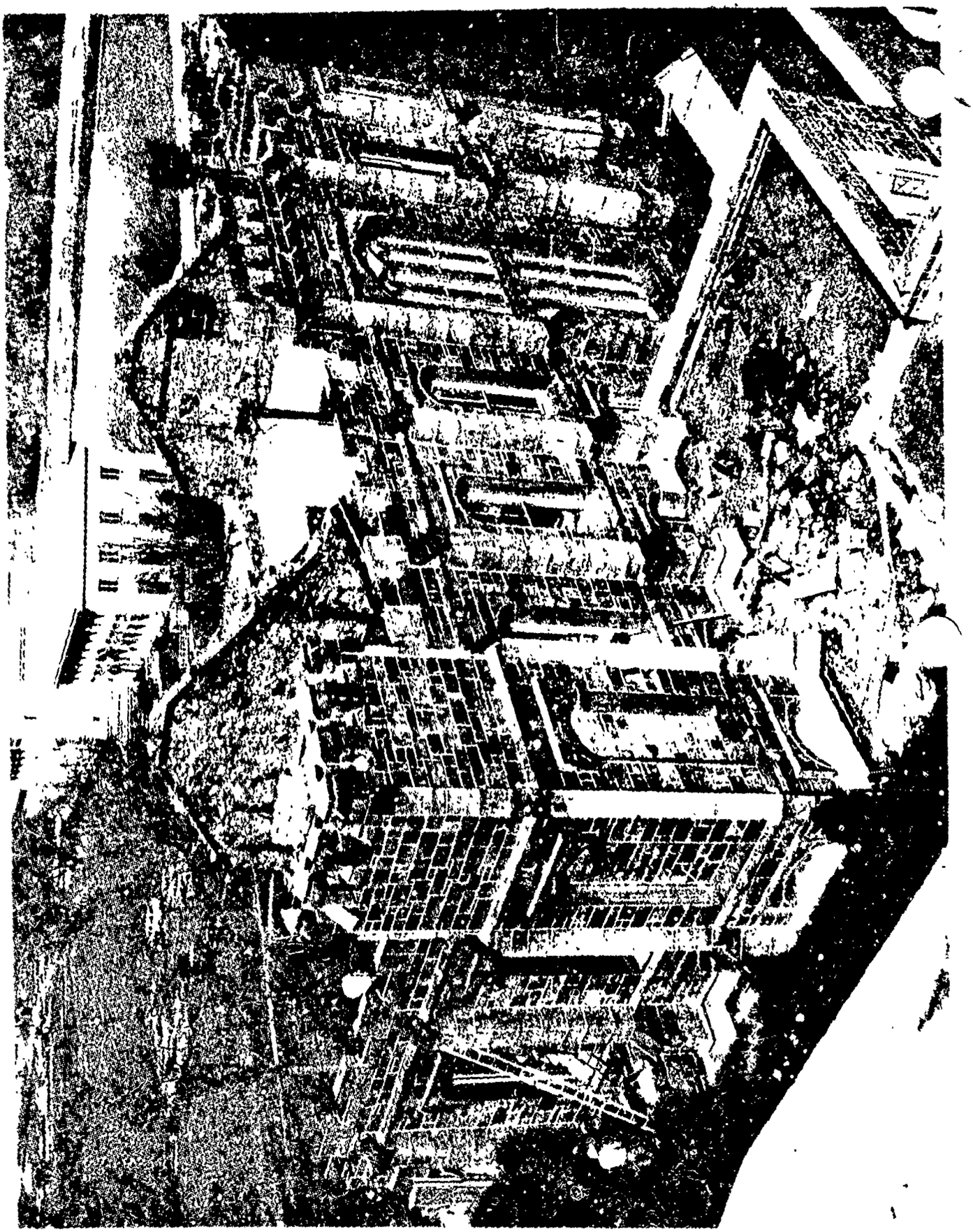


FIG E-6

SELECTION OF PASSIVE SOLAR ARCHITECTURAL RETROFIT "PATTERNS"

The following Passive Solar Architectural Retrofit patterns have been selected by the AFIT Librarian for use in this project:

1. Geographic Determinism
2. Building Location
3. Building Shape and Orientation
4. Historical Library Building Type Solution (See Attachment 3)
5. North Side
6. Location of Indoor Spaces
7. Protected Entrance
8. Window Location
9. Choosing the System
   - 9.A. Direct Gain
   - 9.B. Thermal Storage Wall--Table 9B-2
10. Appropriate Materials

DIRECT GAIN SYSTEMS

11. Solar Windows
12. Clerestories and Skylights
13. Masonry Heat Storage
14. Interior Water Wall

THERMAL STORAGE WALL SYSTEMS

15. Sizing the Wall
16. Wall Details

21. Combining Systems
23. Movable Insulation
24. Reflectors
25. Shading Devices
26. Insulation on the Outside
27. Summer Cooling--Table 27-1
28. Earth Tubes
29. King Ventilation System
31. Solar Chimney
32. Solar Dehumidification
34. Zoning
35. Diurnal Air Flushing

1. GEOGRAPHIC DETERMINISM

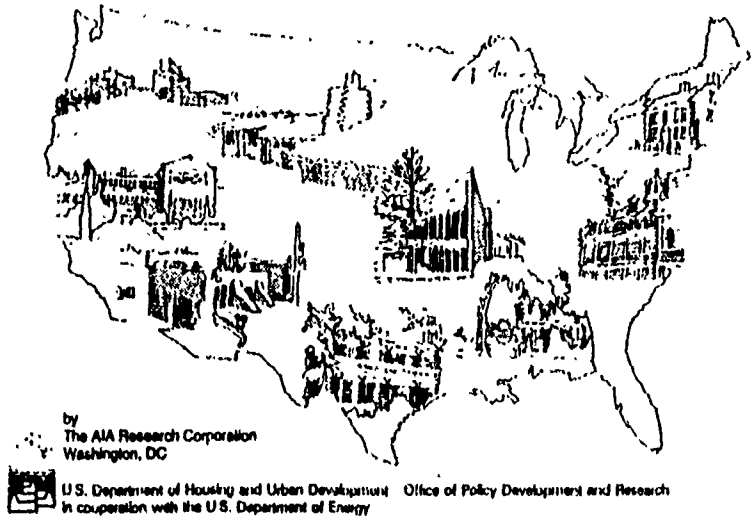


Figure 1-1

LARGE SCALE PATTERNS

This pattern is the starting point for evaluating your building's overall location, shape and orientation, and its relationship to the sun, wind and vegetation.

THE PROBLEM

DEPENDING ON THE GEOGRAPHIC LOCATION OF YOUR BUILDING, DIFFERENT CLIMATIC CONDITIONS CAN BE A LIABILITY OR AN ASSET TO YOUR BUILDING'S ENERGY CONSUMPTION. TO BE MORE SPECIFIC, TEMPERATURE, HUMIDITY LEVELS, WIND VELOCITIES AND SUNSHINE DEFINE THE CLIMATIC ENVIRONMENT YOUR BUILDING MUST OPERATE IN.[1]

THE RECOMMENDATION

USE THE REGIONAL GUIDELINES FOR BUILDING PASSIVE ENERGY CONSERVING HOMES, BY THE AIA RESEARCH CORPORATION (Appendix B), AS A SOURCE OF REGIONAL (INDIGENOUS) ARCHITECTURAL RESPONSES TO CLIMATIC CONDITIONS. THE BOOK DIVIDES THE UNITED STATES INTO 13 CLIMATIC REGIONS, AND CONTAINS RECOMMENDED REGIONAL ENERGY CONSERVING DESIGN PRIORITIES FOR EACH REGION. YOU SHOULD USE THE REGIONAL DESIGN PRIORITIES LISTED FOR YOUR REGION AS A BUILDING AND SITE EVALUATION TOOL.[2,3]

SMALL SCALE PATTERNS

Use BUILDING LOCATION (2) and BUILDING SHAPE AND ORIENTATION (3) in conjunction with this pattern to evaluate your building's response to climatic conditions. You should also refer to the morphologic solutions contained in REGIONAL GUIDELINES FOR BUILDING PASSIVE ENERGY CONSERVING HOMES (Appendix B) to form your own small scale patterns.

ILLUSTRATION

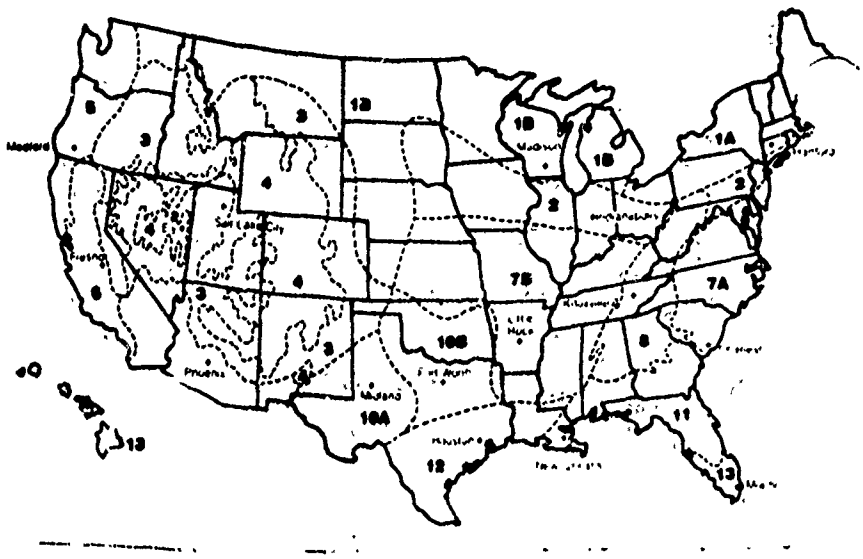


Figure 1-2

INFORMATION

Regional Guidelines for Building Passive Energy Conserving Homes is a new Government Printing Office publication prepared by the AIA Research Corporation for U.S. Department of Housing and Urban Development. This book divides the country into 13 climatic regions, (Fig 1-2) and is a source of regional (indigenous) architectural responses to climatic conditions.

The major feature (for universal use) of this book is the prioritizing of the architectural responses to the regional climatic conditions. These prioritized responses have application to all buildings, not just housing. For example, Wright-Patterson AFB, Ohio and Grissom AFB, Indiana are in Region #2. Their architectural design priorities should be the following:

1. Keep the heat in and the cold temperatures out during winter, and minimize heat loss through material selection, reducing exterior surfaces and through openings.

2. Protect from the wind when it's too cold for comfort - NORTH SIDES (5).

3. Let the sunlight in when it's too cold for comfort and consider passive solar systems - CHOOSING THE SYSTEM (9) for maximum solar heating.

4. Keep hot temperatures out during the summer in the same way you keep cold temperatures out during winter.

5. Protect from the sun when it's too hot for comfort - SHADING DEVICES (25).

6. Open up to cooling breezes when it is too hot for comfort - SUMMER COOLING (27).[3]

You may find your regional description to be inaccurate for your micro-climate. If so, find the regional description most resembling your site micro-climate. Use its regional design priorities for simple application to energy conservation for building retrofit.[2,3]

REFERENCES

1. AIA Research Corporation, Regional Guidelines for Building Passive Energy Conserving Homes, HUD-PDR 355, November 1978, GPO Stock No. S/N 023-000-00481-0. p.3

2. IBID. p.2

3. IBID. p.56-60 (See Appendix B)

4. Victor Olgyay. Design with Climate-Bioclimatic Approach to Architectural Regionalism, Princeton University Press, 1963.

SOURCES OF ILLUSTRATIONS

Figure 1-1, Reference 1.Cover
Figure 1-2, Reference 1.p12

2. BUILDING LOCATION

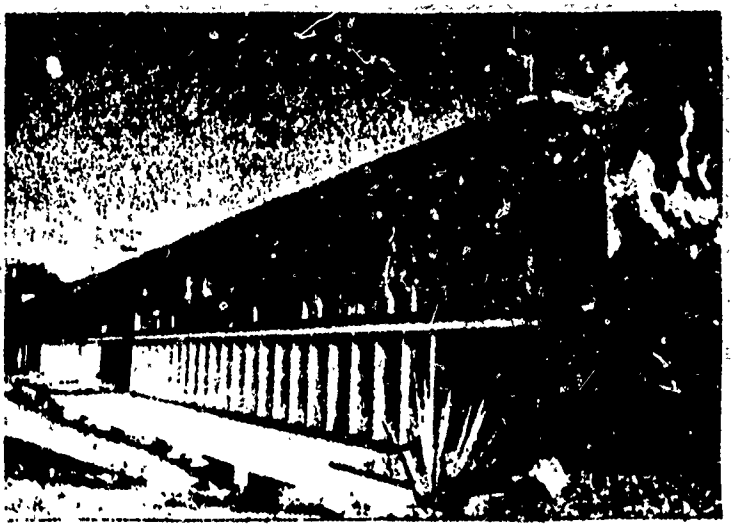


Figure 2-1

LARGE SCALE PATTERNS

Using the idea of Geographic Determinism (1), you should evaluate the location of the existing building and its relationship to open space and the sun. This evaluation is probably the most important evaluation of natural resources at the site you will make for passive solar retrofit.

THE PROBLEM

A BUILDING BLOCKED FROM EXPOSURE TO THE LOW WINTER SUN BETWEEN THE HOURS OF 9:00 am AND 3:00 pm CANNOT MAKE DIRECT USE OF THE SUN'S ENERGY FOR HEATING. DURING THE WINTER MONTHS, APPROXIMATELY 90% OF THE SUN'S ENERGY OUTPUT OCCURS BETWEEN THE HOURS OF 9:00am AND 3:00pm SUN TIME (See Chapter 6 of Ref 2 for an explanation of sun time). FOR EXAMPLE, IN NEW YORK CITY (40 degrees NL) ON A SQUARE FOOT OF SOUTH-FACING SURFACE ON A CLEAR DAY IN THE MONTH OF DECEMBER, 1,610 BTU'S OUT OF A DAILY TOTAL OF 1,724 BTU'S (or 93% of the total) ARE INTERCEPTED BETWEEN THE HOURS OF 9:00am AND 3:00pm. BETWEEN THE HOURS OF 9:30am AND 2:30pm 1,272 BTU'S (or 74% of the total) ARE INTERCEPTED.[1]

THE RECOMMENDATION

TO TAKE ADVANTAGE OF THE SUN IN CLIMATES WHERE HEATING IS NEEDED DURING THE WINTER, USE THE AREAS ON THE SITE THAT RECEIVE THE MOST SUN DURING THE HOURS OF MAXIMUM SOLAR RADIATION - 9:00am TO 3:00pm (SUN TIME). BUILDING IN THE NORTHERN PORTION OF A SUNNY AREA WILL (1) INSURE THAT THE OUTDOOR AREAS PLACED TO THE SOUTH WILL HAVE ADEQUATE WINTER SUN AND (2) HELP MINIMIZE THE POSSIBILITY OF SHADING THE BUILDING IN THE FUTURE BY OFF-SITE DEVELOPMENTS.[1]

SMALL SCALE PATTERNS

Evaluate your building's location within a sunny area and its existing BUILDING SHAPE AND ORIENTATION (3). This evaluation is essential for determining potential for passive solar retrofit. Rearrange the entrance of your building so it receives the greatest protection from the cold winter winds - PROTECTED ENTRANCE (7). You should also consider using the patterns in Appendix C from A Pattern Language by Christopher Alexander.

ILLUSTRATION

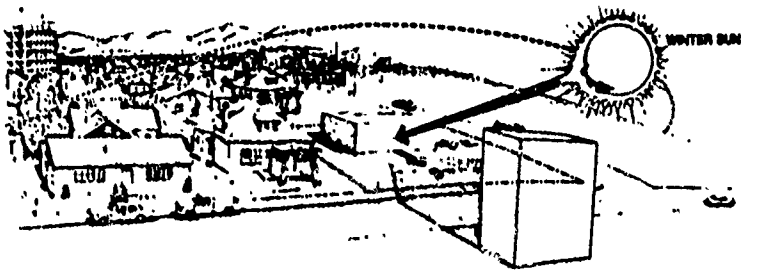


Figure 2-2

INFORMATION

To use the sun for winter heating, you should evaluate how your building relates to other buildings, conifer trees, hills or anything else blocking the low winter sun. To do this, you can use a Solar Pathfinder™ (See Appendix C) or the sun charts ("Plotting the Skyline") in chapter six of the Passive Solar Energy Book-Expanded Professional Edition by Edward Mazria.

If you use the Solar Pathfinder you can photograph solar obstructions, and use the photograph as a design tool.

You will not have to use either method (Solar Pathfinder or Plotting the Skyline) if the southern skyline is low and has no obstructions: abruptly rising hills, conifer trees, or deciduous trees with large branches.

To bring life to your site and building you should refer to the patterns of Christopher Alexander's in Appendix C. After reading them, you will see the south side of your building as a valuable outdoor space on a sunny day, in addition to collecting solar radiation.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, PA, 1979. pp73-75.

2. Christopher Alexander, A Pattern Language, Oxford University Press, New York, N.Y., 1977 (See Appendix C); and Christopher Alexander. The Oregon Experiment, Oxford University Press, New York, N.Y., 1975.

SOURCES OF ILLUSTRATIONS

Figure 2-1. Passive Solar Buildings. Sandia Laboratories, Albuquerque, N.M., and Livermore, Ca. For the USDOE under Contract DE-AC04-76DP00789. July 1979. p.91.

Figure 2-2. Reference 2. p. 74.

3. BUILDING SHAPE AND ORIENTATION



Figure 3-1

LARGE SCALE PATTERNS

Using the ideas of GEOGRAPHIC DETERMINISM (1), BUILDING LOCATION (2) and the patterns in Appendix C, you should evaluate the buildings shape and orientation for potential to admit natural light and inducing natural ventilation before laying out interior spaces.

THE PROB' EM

BUILDINGS SHAPED WITHOUT REGARD FOR THE SUN'S IMPACT, AND NATURAL LIGHT AND VENTILATION, REQUIRE LARGE AMOUNTS OF ENERGY TO HEAT AND COOL.

THE RECOMMENDATION

FOR PASSIVE SOLAR RETROFIT, YOU SHOULD EVALUATE THE SHAPE OF YOUR BUILDING FOR ADMITTING SUNLIGHT AND INDUCING VENTILATION. AN ELONGATED BUILDING ALONG THE EAST-WEST AXIS, IN ALL CLIMATES, MINIMIZES HEATING AND COOLING REQUIREMENTS. A SLOPED ROOF WILL HELP INDUCE VENTILATION BY INCREASING WIND GENERATED SUCTION AND "STACK EFFECT".

SMALL SCALE PATTERNS

Evaluate your building shape and orientation with the following small scale patterns: HISTORICAL BUILDING TYPE SOLUTIONS (4), Christopher Alexander's patterns contained in Appendix D, LOCATION OF INTERIOR SPACES (6), PROTECTED ENTRANCE (7) and, LOCATION OF WINDOWS (8). Using the roof to admit sunlight allows flexibility to distribute heat and light to various parts of a space - CLERESTORIES AND SKYLIGHTS (12). This allows flxibility to locate thermal mass within a space - MASONRY HEAT STORAGE (13) and INTERIOR WATER WALLS (14). Building shape and orientation also can induce ventilation - SUMMER COOLING (27) and KING VENTILATION SYSTEM (29).

ILLUSTRATION

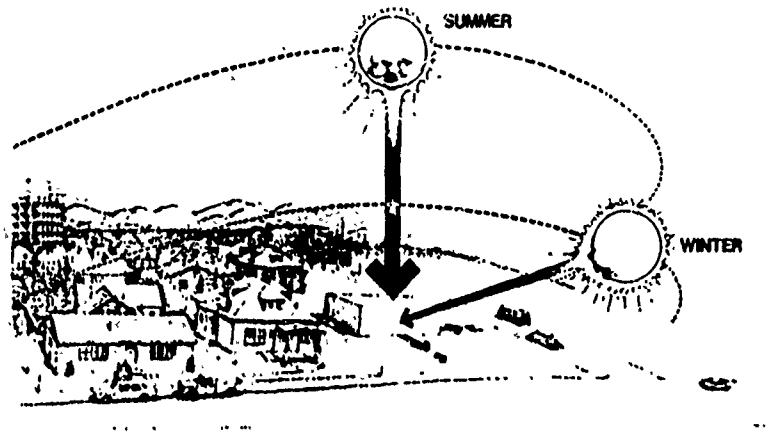


Figure 3-2

INFORMATION

Victor Olgyay in his book Design with Climate, investigated the effect of thermal impacts (sun and temperature) on building shapes in the United States. He drew the following conclusions:

1. The square is not the optimum shape in any location.

2. Buildings elongated on the north-south axis are less efficient (summer and winter) than a square.

3. The optimum shape in all climates is elongated along the east-west axis.[1]

You should refer to Appendix D for expanded information.

Elongating the east-west axis gives the southern wall good sun exposure for maximum winter heat gain, and reduces the east and west wall surface area, thereby minimizing summer heat gain in the morning and afternoon. During the winter, in the northern hemisphere (32 degrees to 56 degrees), the southern side of the building receives nearly 3 times as much solar radiation as the east and west sides of the building. The situation is reversed in the summer, with the roof and the east and west walls receiving the majority of the solar radiation.

Studies by the Illuminating Engineering Society show the space depth range should be 2 to 2½ times the window height (from the floor to the top fo the window) if the primary source of natural light is from south-facing windows. This means a maximum space depth of 14 to 18 feet for an average window height of 7 feet.

If the major spaces of your building are placed along the south wall (for sunlight requirements) and the buffer spaces placed along the north wall, then the maximum depth of the building will be roughly 25 to 30 feet.[2]

If your building is over 30 feet deep, or if you do not want large south-facing windows with direct light shining through the space, then the use of operable south-facing CLERESTORIES AND SKYLIGHTS (12) gives you flexibility to distribute light and heat to different parts of the interior. Also, they help induce ventilation and NATURAL SUMMER COOLING (27).[2]

NOTE: Many Air Force building projects (including additions) handled by the Corp of Engineers will probably use Pre-Engineered Buildings (PEB). The use of the Pattern - BUILDING SHAPE AND ORIENTATION - is essential for accomodating the natural radiation, convection, and conduction processes. You should read Reference #7 (in Appendix D) to see what is currently being done in the area of Passive Solar PEB's.

REFERENCES

1. Victor Olgyay. Design with Climate, Princeton University Press, Princeton, NJ, 1963. pp86-90 (See Appendix D).

2. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, PA, 1979 pp79-84.

3. Christopher Alexander. A Pattern Language, Oxford University Press, New York, NY, 1977 (See Appendix D); and Christopher Alexander. The Oregon Experiment, Oxford University Press, New York, NY, 1975.

4. Professor F.H. King. Ventilation for Dwellings, Rural Schools and Stables. Published by Author, 1908. p.50.

5. "Passive Design Handbook". New Mexico Solar Energy Association.

6. Doug Balcomb and Bruce Anderson. "Passive Heating and Cooling Handbook". February 1980 (being developed on USDOE contract).

7. Bruce Baccei. "Mass Produced Lowcost Passive Buildings," Solar Age, December 1979. pp 25-27.
NOTE: Bruce Baccei is a former Army Corp of Engineers Major, and is the author of Energy Conscious Design, U.S. Army Corp of Engineers, Norfolk District, Norfolk, Va.

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Bruce Baccei
Senior Architect, Program Manager
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1536 Cole Blvd.
Golden Colorado 80401

(303)231-1453
FTS 327-1453

SOURCE OF ILLUSTRATIONS

Figure 3-1. Passive Solar Buildings. Sandia Laboratories, Albuquerque, NM, and Livermore, CA. For the USDOE under Contract DEAC04-76DP00789. July 1979. p.79.

Figure 3-2 Reference #2. p 80.

4. HISTORICAL BUILDING TYPE SOLUTIONS

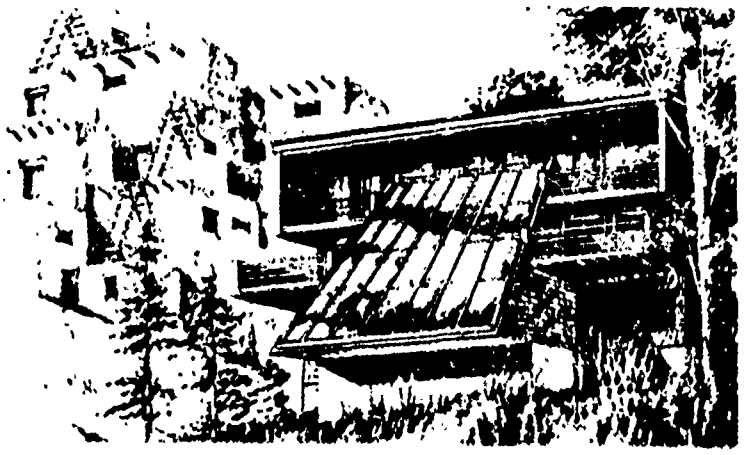


Figure 4-1

LARGE SCALE PATTERNS

Using the idea "There's nothing new under the sun", Architectural History has many answers to our present day energy problems, if you will only apply them. One of our founding fathers- Thomas Jefferson- was an avid student of Architectural History, and applied that knowledge in Monticello. It serves as an example of the application of historical environmental controls, which we can all learn from. This pattern describes how you can do historical research about your building type's use of natural heating, ventilation and lighting.

THE PROBLEM

PRIOR TO THE EMERGENCE OF THE "MODERN ARCHITECTURE" MOVEMENT, AROUND 1920, BUILDINGS WERE SHAPED AND ORIENTED SO THEY RESPONDED TO THEIR NATURAL ENVIRONMENT. BUILDINGS WERE PATTERNS BASED ON INTUITIVE OBSERVATIONS OF HOW TO CONTROL THE ENVIRONMENT, AND WERE AN APPLICATION OF THE CONCEPT OF GEOGRAPHIC DETERMINISM (1) AND APPROPRIATE MATERIALS (10). THE OLD BUILDING TYPE PATTERNS WERE DISCARDED BY "MODERN ARCHITECTURE", AND HAVE BEEN LOST TO SEVERAL GENERATIONS OF ARCHITECTS AND ENGINEERS. YOUR TASK IS TO KNOW HOW THE ENVIRONMENT WAS CONTROLLED NATURALLY BY YOUR BUILDING TYPE, SO YOU CAN APPLY IT TO YOUR BUILDING IF AT ALL POSSIBLE.[2,3]

THE RECOMMENDATION

AS PART OF YOUR BACKGROUND INFORMATION FOR PROGRAMMING YOUR BUILDING TYPE, YOU SHOULD DO A QUICK REVIEW OF THE HISTORICAL BUILDING TYPE SOLUTIONS FOR YOUR BUILDING TYPE. THE RESEARCH CAN BE USEFUL IF APPLIED PROPERLY TO YOUR RETROFIT PROGRAMMING AND DESIGN.[2,3]

SMALL SCALE PATTERNS

The application of this pattern could be useful to you with LOCATION OF INDOOR SPACES (6), WINDOW LOCATION (8), SOLAR WINDOWS (11), CLERESTORIES AND SKYLIGHTS (12), MOVABLE INSULATION (23) and SHADING DEVICES (25).

INFORMATION

Prior to 1920, every building type got its structure from its patterns.

> "A barn gets its structure from its patterns....And an expensive restaurant gets its structure and character from its particular patterns, too.[1]"

Some architectural history knowledge of your building type is necessary if you are going to effectively deal with energy conservation, in the programming of your retrofit project. A quick historical review of your building type should be part of your programming process. Hopefully, the historical research can be useful, if applied properly to the retrofit.

Ideally, you have an architect in your programming office. If you do, he or she will be familiar with procedures to do historical research, (architects are required to take one year of architectural history).

If you do not have an architect, then the following list of bibliographic resources might be useful to guide your research.

1. General card catalog.
2. Art index.
3. Applied Science and Technology Index.
4. Avery Architectural Index.
5. Harvard Graduate School of Design Index.

Another excellent resource is the United States Military Academy Archives at West Point, New York. The Archives has extensive documentation of their buildings, and should not be overlooked in your retrofit programming of your building.

Two patterns dealing with passive cooling and ventilation systems-KING VENTILATION SYSTEM (29) and BREATHING WALL (30) - were re-discovered by a non-standard process described in Reference 2 (See Appendix E).

Once you have your material, write your own Historical Building Type Solution(s) pattern using the format described in the introduction. Refer to Appendix E for an example - Historical Library Solution.

REFERENCES

1. Christopher Alexander. A Pattern Language, Oxford University Press, New York, NY, 1977.p.96.

2. Stanley H. Scofield, Captain, USAF. "A Historical Review of Natural Ventilation in a Humid Climate," 4th National Passive Solar Conference Proceedings, Kansas City, Mo, October 3-5, 1979. pp. 504-506 (See Appendix E.)

3. Kevin W. Green. "Passive Cooling", Research and Design-The Quarterly of the AIA Research Corp. Vol II, No.3, Fall 1979 pp5-9.

SOURCE OF ILLUSTRATIONS

Figure 4-1 Sunset Homeowner's Guide to Solar Heating, Lane Publishing Company, Menlo Park, Ca, 1978 p.4.

5. NORTH SIDE

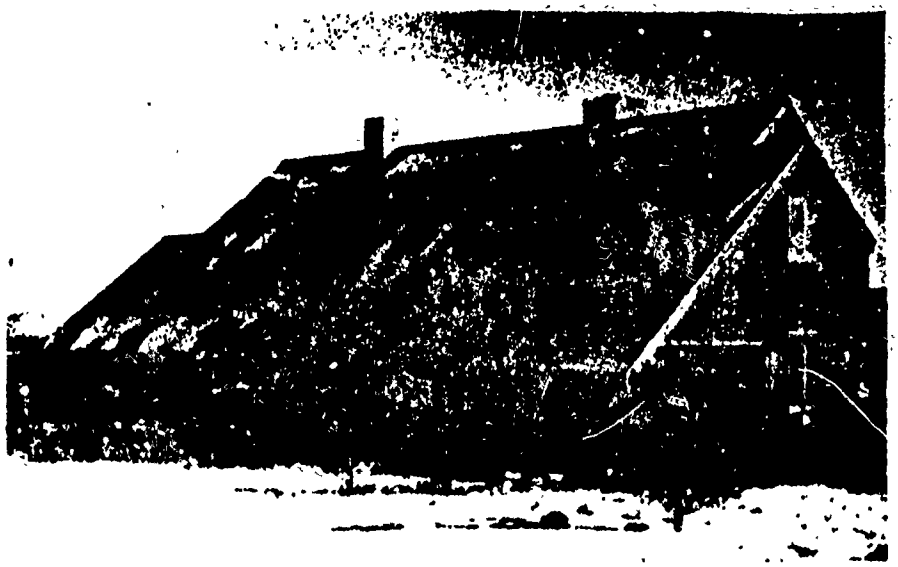


Figure 5-1

LARGE SCALE PATTERNS

Even though your building might already be located in the northern portion of a sunny site - BUILDING LOCATION (2) the northern outdoor space needs sunlight to make it alive. When evaluating the BUILDING SHAPE AND ORIENTATION (3) you should consider the building's impact on outdoor spaces to the north.

THE PROBLEM

THE NORTH SIDE OF A BUILDING IS THE COLDEST, DARKEST AND USUALLY THE LEAST USED SIDE BECAUSE IT RECEIVES NO DIRECT SUNLIGHT ALL WINTER.

THE RECOMMENDATION

IF POSSIBLE, RE-SHAPE THE NORTH SIDE OF YOUR BUILDING BY EARTH BERMING AGAINST THE NORTH FACE OF YOUR BUILDING OR BY SLOPING THE ROOF TOWARD THE NORTH. THE GOAL IS TO REDUCE THE AMOUNT OF EXPOSED NORTHERN WALL. BERMING WILL REDUCE THE NORTHERN WALL HEIGHT. USE A LIGHT-COLORED WALL (OR NEARBY STRUCTURE) TO THE NORTH TO REFLECT LIGHT INTO NORTH-FACING ROOMS AND OUTDOOR SPACES.

SMALL SCALE PATTERNS

Locate spaces with small lighting and heating requirements on the north. These spaces act as a buffer between the occupied spaces and the cold north wall of the building - LOCATION OF INDOOR SPACES (6). You should provide INSULATION ON THE OUTSIDE (26) of the structure so the thermal mass will retain heat, and not loose it to the berming. However berming (soil) can be used for reducing heat loss to wind - APPROPRIATE MATERIAL (10).

ILLUSTRATION

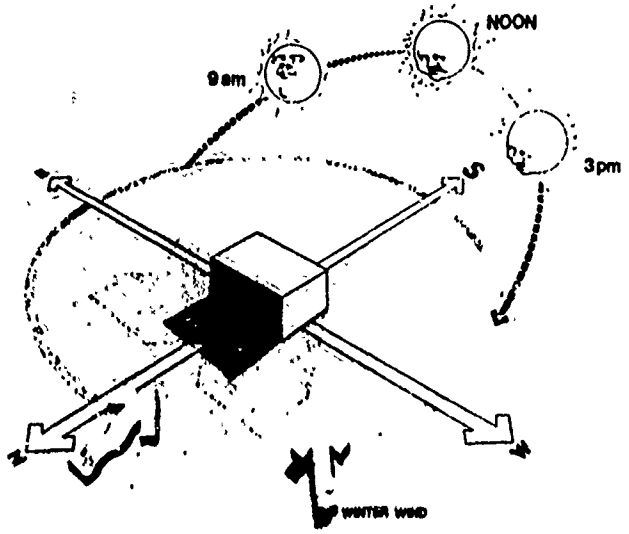


Figure 5-2

INFORMATION

People do not use spaces in continual shade for most of the winter.

There are ways for you to retrofit and make these places alive and useful. For example, you can use earth berming against the north wall to reduce or eliminate the shadow cast by your building. Berming on the north will do the following: provide sunlight on the north side of the building, reduces heat loss through the wall in the winter, and prevents heat gain in the summer. Berming of the north wall also protects your building from prevailing winds from the north and/or west in the Continental United States.

When you provide earth berming, you must also provide INSULATION ON THE CUTSIDE (26). "This is done to enable the structural mass to store some of the building's heat, thus lowering the building's peak heating (and cooling) loads."[1]

REFERENCES

1. Malcolm Wells. Malcolm Wells Underground Designs, printed by Malcolm Wells, Box 1149, Brewster, MA 02631, 1977.

2. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition , Rodale Press, Emmaus, PA, 1979.p86-89.

3. Christopher Alexander. A Pattern Language, Oxford University Press, New York, NY, 1977. pp761-763.

SOURCES OF ILLUSTRATIONS

Figure 5-1. Passive Solar Buildings. Sandia Laboratories, Albuquerque, NM, and Livermore, Ca. For the USDOE under contract DE-AC04-76DP00789. July 1979. p.80.

Figure 5-2. Reference #2. p.88.

6. LOCATION OF INDOOR SPACES

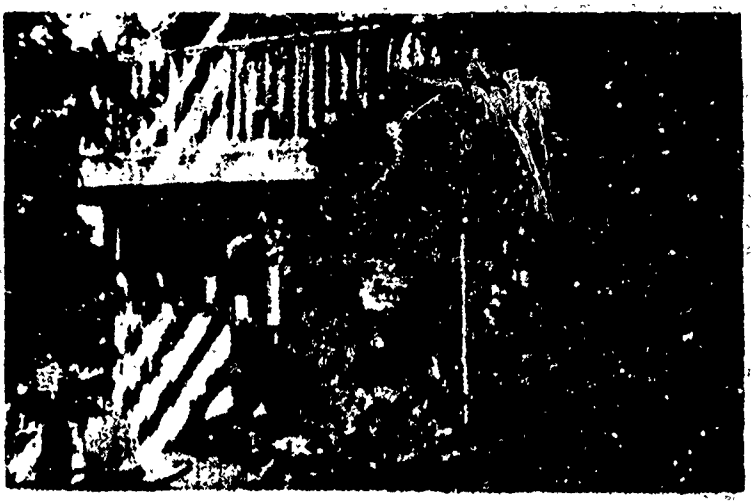


Figure 6-1

LARGE SCALE PATTERNS

Using the ideas of BUILDING LOCATION (2), BUILDING SHAPE AND ORIENTATION (3), and HISTORICAL BUILDING TYPE SOLUTIONS (4) you need to place interior spaces within the shape according to their requirements for heat and sunlight. This placement of interior spaces might indicate some possible changes of BUILDING SHAPE AND ORIENTATION (3).

THE PROBLEM

CONVENTIONAL ENERGY CONSUMPTION IS PROPORTIONALLY HIGHER IN SPACES NOT USING SUNLIGHT DIRECTLY OR PASSIVELY FOR HEATING DURING THE WINTER MONTHS. THE MORE DIRECT SUNLIGHT USED TO HEAT A SPACE, THE LESS CONVENTIONAL ENERGY IS REQUIRED FOR SPACE HEATING. THIS ALSO APPLIES TO ACTIVE SOLAR-HEATING SYSTEMS. IF THE DESIGN OF A SPACE DOES NOT DIRECTLY OR PASSIVELY TAKE ADVANTAGE OF THE WINTER SUN TO SUPPLY SOME OF ITS HEATING REQUIREMENTS, AN ACTIVE SOLAR-HEATING SYSTEM WILL BE PROPORTIONALLY MORE EXPENSIVE, AND LARGER.

THE RECOMMENDATION

INTERIOR SPACES CAN BE SUPPLIED WITH MUCH OF THEIR HEATING AND LIGHTING REQUIREMENTS BY PLACING THEM ALONG THE SOUTH FACE OF THE BUILDING, THUS CAPTURING THE SUN'S ENERGY DURING DIFFERENT TIMES OF THE DAY. PLACE ROOMS TO THE SOUTHEAST, SOUTH AND SOUTHWEST, ACCORDING TO THEIR REQUIREMENTS FOR SUNLIGHT. THOSE SPACES HAVING MINIMAL HEATING AND LIGHTING REQUIREMENTS SUCH AS CORRIDORS AND CLOSETS, WHEN PLACED ALONG THE NORTH FACE OF THE BUILDING, WILL SERVE AS A BUFFER BETWEEN THE HEATED SPACES AND THE COLDER NORTH FACE.

SMALL SCALE PATTERNS

Evaluate your building's openings (in walls and roof) to admit sunlight and provide ventilation - WINDOW LOCATION (8), PROTECTED ENTRANCE (7) and CLERESTORIES AND SKYLIGHTS (12), and at the same time choose the most appropriate passive solar heating system for each space - CHOOSING THE SYSTEM (9). If an attached greenhouse is to be integrated into your building - SIZING THE GREENHOUSE (17), place it along the south face of the building for maximum exposure to the winter sun. You should also consider using the patterns in Appendix F (from A Pattern Language by Christopher Alexander). EXISTING SHADING DEVICES (25) should also be evaluated.

ILLUSTRATION

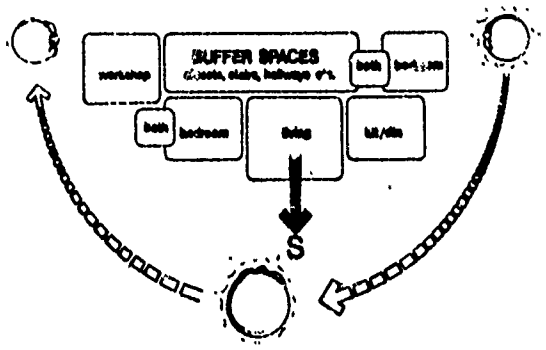


Figure 6-2

INFORMATION

During the winter, the microclimatic conditions along the sides of a building (outside walls) are the key to the location of indoor spaces. The north side of a building remains the coolest during the winter because it receives no direct sunlight. The east and west sides of a building receive equal amounts of direct sunlight for half-a-day since the sun's path across the sky is symmetrical along the southern axis. But over the period of a day, the west side will be slightly warmer than the east side because of the combination of solar radiation and higher afternoon air temperatures. The south side of a building will be the warmest and sunniest during the winter because it receives sunlight throughout the day. Common sense tells us to place spaces with specific heating and lighting requirements along the side of the building which has microclimatic conditions that can easily satisfy those requirements.

The south side of a building is a good location for spaces that are continually occupied during the day. These spaces usually have large heating and lighting requirements. Since the south face of

a building receives nearly 3 times as much sunlight in the winter as the east and west sides, spaces placed along the south face can make direct use of the sun's energy to fill these requirements. Also, the extent to which as continually used space is felt as bright, sunny and cheerful will depend upon the amount of direct sunlight it receives.

Arrange these spaces to the south, southeast and southwest according to your own special requirements for sunlight. For example, in a residence, orient a breakfast area to the southeast for good morning sunlight, a common area (living room) which is used throughout the day to the south, and a workshop that is used only late in the day to the southwest. Placing the frequently inhabited spaces to the south means the building will be elongated along the east-west axis. Spaces needing sunlight that are not located along the south face of a building can receive direct sunlight through south-facing CLERESTORIES AND SKYLIGHTS (12).

To bring life to the interior of your building, you should also consider using the patterns in Appendix F from A Pattern Language by Christopher Alexander.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, PA, 1979. p.90-92.

2. Christopher Alexander. A Pattern Language, Oxford University Press, New York, NY, 1977, (See Appendix F).

SOURCES OF ILLUSTRATIONS

Figure 6-1. Passive Solar Buildings. Sandia Laboratories, Albuquerque, NM, and Livermore, CA, for the USDOE under Contract DE-AC04-76DP00789. July 1979. p.20.

Figure 6-2. Reference #1. p 91.

7. PROTECTED ENTRANCE



Figure 7-1

LARGE SCALE PATTERNS

Using the ideas of BUILDING LOCATION (2), BUILDING SHAPE AND ORIENTATION (3) and LOCATION OF INDOOR SPACES (6) you can evaluate your building's entry. This pattern describes the thermal criteria for locating the entrance and provides information for its design.

THE PROBLEM

IN WINTER, A GREAT QUANTITY OF COLD OUTDOOR AIR ENTERS A BUILDING THROUGH CRACKS AROUND THE ENTRANCE DOOR AND FRAME AS WELL AS EACH TIME THE DOOR IS OPENED. ALL EDGES AROUND ENTRANCES LEAK AIR. THROUGH THESE CRACKS WARM INDOOR AIR IS EXCHANGED WITH COLD OUTDOOR AIR. WHEN AN ENTRANCE DOOR IS OPENED, A LARGE QUANTITY OF OUTDOOR AIR ENTERS THE ADJOINING SPACE. FOR SMALL COMMERCIAL BUILDINGS, SUCH AS SHOPS AND OFFICES, THE HEAT LOSS THROUGH ENTRANCE DOORS WILL BE GREATER THAN 10% BECAUSE OF INCREASED TRAFFIC INTO AND OUT OF THE BUILDING.[1]

THE RECOMMENDATION

MAKE THE MAIN ENTRANCE TO THE BUILDING A SMALL ENCLOSED SPACE (VESTIBULE OR FOYER) THAT PROVIDES A DOUBLE ENTRY OR AIR LOCK BETWEEN THE BUILDING AND EXTERIOR. THIS WILL PREVENT A LARGE QUANTITY OF WARMED (OR COOLED) AIR FROM LEAVING THE BUILDING EACH TIME A DOOR IS OPENED. THE INFILTRATION OF COLD AIR THAT OCCURS AROUND EXTERIOR DOORS WILL BE VIRTUALLY ELIMINATED BECAUSE THE ENTRY CREATES A STILL-AIR SPACE BETWEEN THE INTERIOR AND EXTERIOR DOORS. ORIENT THE ENTRANCE AWAY FROM THE PREVAILING WINTER WINDS OR PROVIDE A WINDBREAK TO REDUCE THE WIND'S VELOCITY AGAINST THE ENTRANCE. MAKE USE OF THE ENTRY SPACE FOR THE STORAGE OF UNHEATED ITEMS, AS A PLACE TO REMOVE WINTER CLOTHING OR FOR ACTIVITIES THAT REQUIRE LITTLE SPACE HEATING.[1]

SMALL SCALE PATTERNS

If the entry is large and supports other activities, provide a way to passively heat the space in winter - CHOOSING THE SYSTEM (9) and to passively cool the space in the summer - SUMMER COOLING (27). You should also use ANSI Standard A-117.1 - Specifications for Making Buildings and Facilities Accessible to and Usable by the Physically Handicapped - and consider using the patterns in Appendix G from A Pattern Language by Christopher Alexander.

ILLUSTRATION

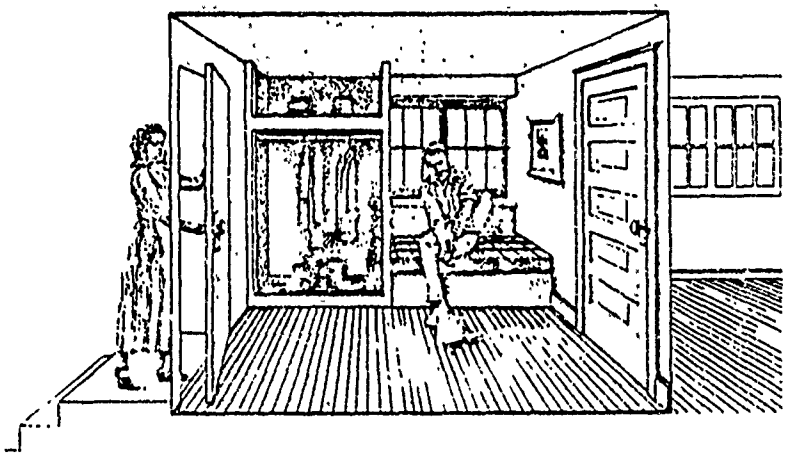


Figure 7-2

INFORMATION

Providing an air lock or double entry will decrease the heat loss due to both infiltration and conduction. A double entry has two doors, one that opens to the exterior and one to the interior of the building, trapping a still-air space between them. Since the interior entrance to the building faces a still-air space, infiltration is minimized. Also, when the exterior door is opened, only the small quantity of unheated air in the entry is exchanged with cold outdoor air, thus the spaces near entrance doors are protected from becoming cold and drafty each time a person enters the building. During the summer, the double entry works in reverse, keeping cooled indoor air from being replaced by hot outdoor air. A double entry or entry space, when properly designed, can serve other functions besides the reduction of heat loss. It can also be a place to leave frequently used items, and a protected place to wait for transportation. When arriving and leaving a building, people need a transition space to accommodate a number of activities, such as removing and storing outer garmets.

Protecting the building's entrance from winter winds and sealing edges around the door frame as tightly as possible will minimize heat transfer. The rate of infiltration of cold air through an

entrance increases as the velocity of the wind against the entrance increases. In the Northern Hemisphere the prevailing winter winds are usually from the north and/or west (check with your base Weather Detachment for the direction of the prevailing winter winds). Entrances placed on the east and south sides of a building will be protected from the wind's impact. If an entrance is placed on the north or west side of the building, careful siting of a windbreak (dense evergreen planting or solid fence), recessing the entrance into the building or the addition of wing walls will reduce the wind's velocity and impact.

Weather stripping, when properly applied, prevents air leakage by making a weathertight seal between the exterior door and door frame. Caulking should be applied around the door frame and the wall to prevent air leakage through these joints. By providing an effective seal around the edges of the door and frame, infiltration at the entry can be reduced by as much as 50%.[1]

Place the main entrance of the building at a point where it can be seen immediately from the main avenues of approach and give it a bold, visible shape which stands out in front of the building.[2]

You should evaluate your building's entry for meeting the requirements of ANSI STANDARD A-117.1.[3]

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, PA, 1979. pp 94 & 97

2. Christopher Alexander. A Pattern Language, Oxford University Press, New York, NY, 1977 (See Appendix G). p 544.

3. AFM 88-15(C6), paragraph 1-31.

4. Ashrae Fundamentals, 1977, Chapter 21. (Infiltration)

SOURCES OF ILLUSTRATIONS

Figure 7-1. AFIT Engineering Building WPAFB, OH. Photo by Stanley H. Scofield, Capt., USAF.

Figure 7-2. Reference 1.p.95.

8. WINDOW LOCATION



Figure 8-1

LARGE SCALE PATTERNS

Using the ideas of BUILDING SHAPE AND ORIENTATION (3), HISTORICAL BUILDING TYPE SOLUTIONS (4) and LOCATION OF INDOOR SPACES(6) you can evaluate the existing window openings.

THE PROBLEM

ONE OF THE LARGEST SINGLE FACTORS AFFECTING BUILDING ENERGY CONSUMPTION IS THE LOCATION AND SIZE OF WINDOWS. WINDOWS PLACED WITHOUT CONSIDERING THE AMOUNT OF SUNLIGHT THEY ADMIT WILL USUALLY BE AN ENERGY DRAIN ON THE BUILDING. IN WINTER THE HEAT LOSS THROUGH A WINDOW IS LARGE COMPARED TO THE HEAT LOSS THROUGH A WELL-INSULATED WALL. THE HEAT LOSS THROUGH A WINDOW IS BASICALLY THE SAME REGARDLESS OF THE DIRECTION IT FACES. THEREFORE, WINDOW PLACEMENT IS IMPORTANT SO THE HEAT GAIN (FROM SUNLIGHT) IS GREATER THAN THE HEAT LOSS. DURING THE SUMMER, WINDOWS NEED EXTERIOR SHADING FROM THE SUN TO REDUCE HEAT GAINS BY THE "GREENHOUSE EFFECT" OF GLASS.

THE RECOMMENDATION

LOCATE MAJOR WINDOW OPENINGS TO THE SOUTHEAST, SOUTH AND SOUTHWEST ACCORDING TO THE INTERNAL REQUIREMENTS OF EACH SPACE. ON THE EAST, WEST AND ESPECIALLY THE NORTH SIDE OF THE BUILDING, KEEP WINDOW AREAS SMALL AND USE DOUBLE GLASS. WHEN POSSIBLE, RECESS WINDOWS TO REDUCE HEAT LOSS.

SMALL SCALE PATTERNS

You can also admit light through south-facing CLERESTORIES AND SKYLIGHTS(12) and store the heat in MASONRY HEAT STORAGE(13) of INTERIOR WATER WALLS(14). Use MOVABLE INSULATION(23) over

large glass areas at night to prevent the heat gained during the day from escaping at night. Locate trees, vegetation and SHADING DEVICES (25) to keep out direct summer sun light. You might consider using the patterns in Appendix H. Also you should identify the position for operable windows, clerestories and skylights to provide adequate ventilation for SUMMER COOLING(27).

ILLUSTRATIONS

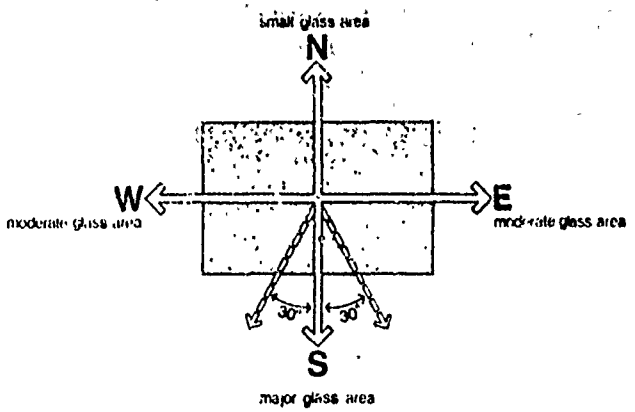
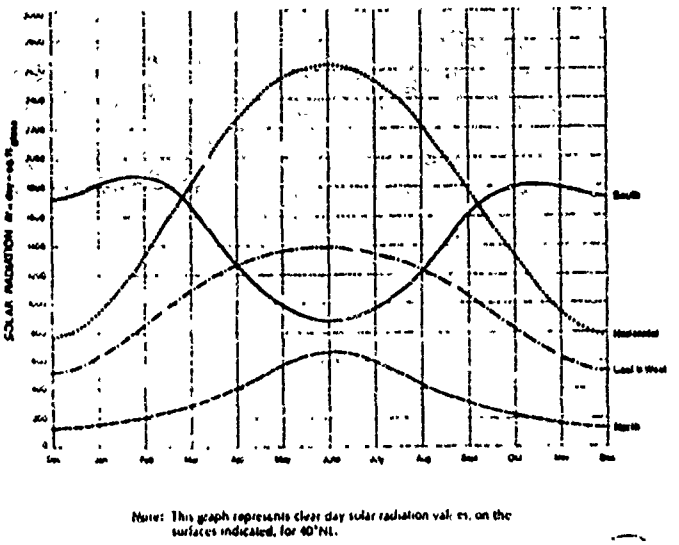


Figure 8-2



Note: This graph represents clear day solar radiation values on the surfaces indicated, for 40°NL.

Figure 8-3

INFORMATION

The best orientation for major glass areas of a building provides the maximum amount of solar radiation (heat gain) in the winter and the minimum amount in the summer. According to BUILDING SHAPE AND ORIENTATION(2), the south side of a building receives nearly 3 times more solar radiation in winter than any other side. During the summer the situation is reversed and the south side receives much less radiation in comparison to the roof and east and west sides of the building. There are two reasons for this. First, there are more hours of incident sunlight striking the south face of a building in winter than in summer, even though summer days are longer and have more hours of daylight (refer to fig. 8-3). And second, since the sun is lower in the sky during the winter, the sun's rays striking the south face of the building are closer to perpendicular than in the summer when the sun is higher in the sky. Because of this, a square foot of vertical south-facing surface will receive a greater amount of solar radiation during the same hour in winter than in summer. Since the sun's rays striking the surface of a window are closer to perpendicular in winter, the percentage of solar radiation transmitted through the window is greater than in summer. These seasonal characteristics of south glazing insure a degree of automatic control for solar collection.

The optimum window orientation for solar gain is due south. However, variations to the east or west of south, up to 30 degrees,

will reduce performance only slightly. (Fig.8-2). Larger variations, though, will reduce window performance substantially. The heat gained from sunlight during the winter through south-facing glass will exceed the heat loss, in most climates.

Openings should be carefully placed according to the light and heating requirements of each space. For example, a sleeping area may require some southeast or east openings to admit early morning sunlight and heat into the space. It is important to note that east- and west-facing single or double pane windows either come out even or lose heat during the winter in most climates. Since there is no direct sunlight in winter on the north side of a building, north-facing windows are a continuous heat drain.[1]

You should simultaneously evaluate the natural lighting, heat/ventilation requirement for each space, while evaluating the potential of existing windows to provide natural heating and ventilation.

The patterns in Appendix H can be used as additional patterns to give you a variety of window types and give life to your building while solving functional requirements.

The solar radiation calculator in the separate pocket (of the Passive Solar Energy Book - Expanded Professional Edition) is a quick graphic method for determining the amount of hourly or daily radiation intercepted by a surface facing in different directions. Of course the location and size of windows will be influenced by other considerations as well, such as views, privacy and natural lighting. The Libbey Owens Ford "Sun Angle Calculator" can also be used as a design tool.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Ammaus, PA, 1979.

2. Christopher Alexander. A Pattern Language, Oxford University Press, New York, NY, 1977 (See Appendix H).

SOURCES OF ILLUSTRATIONS

Figure 8-1. Dr. Wm. T. Bolton House, 1906, by Greene and Greene. Photograph courtesy of Document Collection, College of Environmental Design, U. of California-Berkeley.

Figure 8-2. Reference 1. p.102

Figure 8-3. Reference 1. p.103

9. CHOOSING THE SYSTEM

LARGE SCALE PATTERNS

This pattern starts a series of patterns to provide criteria for passive system selection and detailing of retrofit design. After you have roughly arranged the indoor spaces - LOCATION OF INDOOR SPACES (6), you should select a passive heating system for each space before proceeding with your building retrofit. Since a passive system is architectural in nature, you must include it at the beginning of the design process. This pattern describes each of the five basic passive systems in general terms.

THE PROBLEM

WHICH IS THE BEST PASSIVE SYSTEM TO USE? THIS QUESTION IS ONE OF THE MOST LOADED QUESTIONS YOU CAN ASK ABOUT PASSIVE SOLAR HEATING. IT WILL GENERATE HEATED DISCUSSIONS AND MUCH DISAGREEMENT. TO PROVE A POINT, PEOPLE WILL DEFEND THEIR SYSTEM TO THE LAST BTU. WHICH IS THE BEST SYSTEM? WHEN PROPERLY ANALYZED, EACH SPACE OR BUILDING WILL REQUIRE A PARTICULAR SYSTEM BEST SUITED TO ITS ARCHITECTURAL AND THERMAL NEEDS.

THE RECOMMENDATION

EACH SYSTEM HAS SPECIFIC DESIGN OPPORTUNITIES AND DESIGN LIMITATIONS. CHOOSE A PARTICULAR SYSTEM THAT SATISFIES MOST OF THE DESIGN REQUIREMENTS YOU GENERATE FOR EACH SPACE. REMEMBER THAT DIFFERENT SYSTEMS CAN BE USED FOR DIFFERENT SPACES AND/OR SYSTEMS CAN BE COMBINED TO HEAT ONE SPACE. THE INFORMATION SECTION OF THIS PATTERN GIVES AN ASSESSMENT OF EACH SYSTEM'S RETROFIT POTENTIAL FOR USE IN TYPICAL U.S. AIR FORCE FACILITIES.

SMALL SCALE PATTERNS

Recommended sizing procedures for each system are given in SOLAR WINDOWS (11), CLERESTORIES AND SKYLIGHTS (12), SIZING THE WALL (15), SIZING THE GREENHOUSE (17), and SIZING THE ROOF POND (19). When desirable, a combination of systems can be used to heat a space - COMBINING SYSTEMS (21). To prevent overheating, use SHADING DEVICES (25) - reduce solar heat gain. If your building has a year around ventilation requirement, you should consider the following: EARTH TUBES (28), KING VENTILATION SYSTEM (29), SOLAR CHIMNEY (31) and SOLAR DEHUMIDIFIER (32) as passive methods of inducing ventilation. You should also assess the climatic effects of mold growth, animal entry, etc.. when considering ventilation systems.

GENERAL INFORMATION

The THERMAL STORAGE WALL (9B) and ATTACHED GREENHOUSE (9C) have universal retrofit application for the Air Force. The ROOF POND SYSTEM (9D) has good retrofit potential, but does not have universal application because of varying roof configurations, structural limitations for supporting water, and climatic variations.

Tables 9B, 9C, and 9D show the retrofit application potential of the THERMAL STORAGE WALL SYSTEM, ATTACHED GREENHOUSE, and ROOF POND SYSTEM to the following typical Air Force facilities: 1) Family Housing/Airman's Dorms/Officer's Quarters; 2) Base Library; 3) Offices/Administration; 4) Air Force Educational Classrooms; 5) Food Services/NCO & Officers Clubs; 6) Police/Fire Stations; 7) Air Passenger Terminals; 8) Shops and Warehouses.

The other two passive solar systems - DIRECT GAIN (9A) and CONVECTIVE LOOP (9E) - have limited retrofit potential in the Air Force and will be explained in their respective sections of this pattern.

Since the Arab oil embargo of 1973-74, passive solar system development, and retrofit have been centered in housing, because of its small size and immediate application potential.

Public Law 95-619 requires all federal buildings over 1000 square feet to be retrofitted by 1990, and the Air Force Energy Plan stresses Passive Solar Applications. Because of this requirement, you must consider the following retrofit issues that apply to the Air Force but usually do not apply to housing:

1. Type of occupancy use, and special heating and cooling requirements.

2. Time of day occupancy, and the duration of heating/cooling requirements, and the number of electrical lights required.

3. For industrial and commercial facilities it is difficult to position activities relative to passive conditions and elements. Size of floor space (required) forces the floor area to southern wall exposure to be large. However, passive (architectural) considerations during floor planning with the user may overcome many problems. For example, use of NORTH SIDE (5) and ZONING (34) could eliminate all north windows by placing utilities, storage, toilets, and a "back door" - PROTECTED ENTRANCE (7) on the north wall. This could provide the opportunity to develop the south side of the building as a "people space". You could use the patterns in Appendix C and Appendix H from A Pattern Language by Christopher Alexander. The use of LIGHT ON TWO SIDES OF OF EVERY ROOM in Appendix H will help to reduce electric lighting requirements during the day.

4. Time of day usage in many cases should be considered relative to passive heat gain. Possibly work hours could be changed for winter, (start at 0900 hours), and summer (start at 0700 hours) to reduce heating and cooling requirements. This should be considered as a design opportunity.

5. Most facilities other than family housing will require ventilation. You should use EARTH TUBES (28), KING VENTILATION SYSTEM (29), SOLAR CHIMNEY (31) and SOLAR DEHUMIDIFICATION (32) as methods of providing passive tempered ventilation.

6. Activities need to be evaluated in terms of the following requirements:

   a. natural light
   b. sensitivity to thermal function
   c. latent heat requirements
   d. moisture requirements

After considering these issues you might need to collect heat from both active and passive collection systems, and store the heat at a central location with mechanical systems to re-distribute the heat.

GENERAL REFERENCES FOR (9A), (9B), (9C), (9D), (9E)

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, PA, 1979.

2. Edward Mazria. "A Design and Sizing Procedure for Passive Solar Heated Buildings", 3rd National Passive Solar Conference Proceedings, San Jose, CA, January 11-13, 1979, pp 249 - 253.

3. Captain Bruce C. Baccei, Corp of Engineers, Energy Conscious Design, U.S. Army Corp of Engineers, Norfolk District, Norfolk, VA.

4. Fred Dubin. "Air Conditioning For Books and People", Architectural Record v. 121, June 1957, p 231 - 234.

9A. DIRECT GAIN

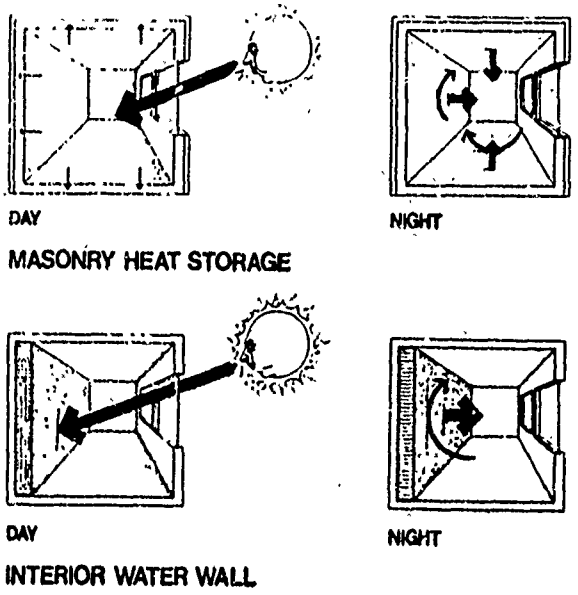


Figure 9a

INFORMATION

The direct Gain System is the simplest passive solar system, and is represented by figure 9a. It uses an expanse of south-facing glass - SOLAR WINDOWS (11) - and enough thermal mass, strategically located in the space for heat absorption and storage. This system usually creates glare problems, and causes fading of material - see APPROPRIATE MATERIALS (10) for references.

The two most common materials used for heat storage are masonry and water - MASONRY HEAT STORAGE (13), and INTERIOR WATER WALL (14). Heat gain is reduced by using SHADING DEVICES (25). Note: Wall to wall carpet cannot be used if you intend to use the floor mass as heat storage.

Another application of the Direct Gain System is the use of a south-facing clerestory - CLERESTORIES AND SKYLIGHTS (12). Clerestories and skylights give good light, privacy and do not put direct sunlight on people and furniture.

Clerestories provide good lighting to large areas, however they are difficult and expensive to retrofit. Skylights will overheat a space if a shading device (25) is not provided for summer use.

Summer cooling is accomplished by keeping the sun out during the day and ventilating the space at night.[1]

RETROFIT OPPORTUNITIES:

If you already have a direct gain system, or because of the Architectural Program you need it, then you should maximize the system operation by using WINDOW LOCATION (8), SOLAR WINDOWS(11), CLERESTORIES AND SKYLIGHTS (12), MASONRY HEAT STORAGE (13), INTERIOR WATER WALL (14), and MOVABLE INSULATION (23).

RETROFITTING LIMITATIONS OF THE DIRECT GAIN SYSTEM:

Retrofitting an existing building with a Direct Gain System can be relatively easy or very difficult depending on your building's construction materials. A prefabricated metal structure, such as a flight line maintenance building, would be relatively easy and cost effective. However, an existing masonry structure is very difficult to retrofit for Direct Gain since THE BUILDING IS THE SYSTEM. Only when a space is constructed with masonry walls and floors exposed on the interior, and has clear southern exposure, is it possible to add SOLAR WINDOWS (11) or CLERESTORIES AND SKYLIGHTS (12) and modify interior surface finishes to solar heat the space.[2]

REFERENCES

1. General References 1 and 2.

2. General References 1. p.109.

SOURCES OF ILLUSTRATIONS

1. General Reference 1. p.30.

9B. THERMAL STORAGE WALL

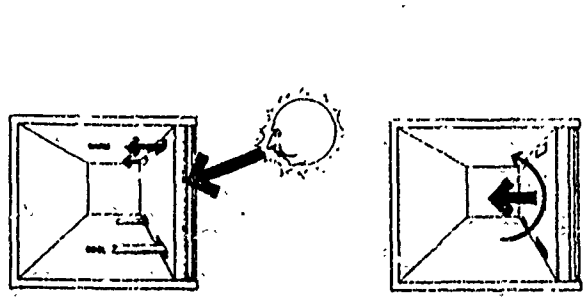
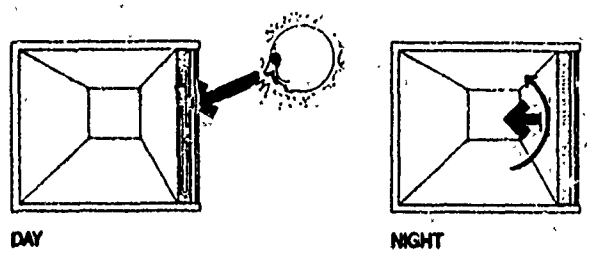


Figure 9b



INFORMATION

The Thermal Storage Wall is characterized by the storage media being directly behind the south-facing glazing. There are a wide range of appropriate thermal storage wall materials; however, most fall into two catagories: either masonry - MASONRY HEAT STORAGE (13) - or water - INTERIOR WATER WALL (14). Both types of storage walls are limited to 20 feet for effective radiant heating. The requirement for southern exposure dictates a linear arrangement unless modified by stacking and or staggering spaces.

MASONRY WALL

The masonry wall transfers heat from the surface to the interior at a slow rate by conduction. If direct sunlight hits the surface of a dark colored masonry material it will become uncomfortably hot, giving much of its heat to the air instead of storing it by conduction. To reduce heat fluctuation, direct sunlight must be spread over a large surface area of masonry so roughly 60% of the solar energy admitted into the space is stored as heat in the walls and/or floor and/or ceiling at sunset. The masonry wall can be used as a SOLAR CHIMNEY (31) for summer ventilation, but needs MOVABLE INSULATION (23) on the inside to prevent radiation to the interior space.

See tables 9B-1 through 9B-8 for retrofit application potential to various Air Force building types, and see MASONRY HEAT STORAGE (13) for sizing details.

WATER WALL

Water is more efficient as a heat storage medium than masonry. It has the potential to store more than twice as many

BTU's for each 1 degree F temperature rise for the same volume of material. The volume of water in direct sunlight and the surface color of the container (thin metal or plastic) will determine the temperature fluctuation in the space over the day.[2]

See tables 9B-1 through 9B-8 for retrofit application potential to various Air Force building types, and see INTERIOR WATER WALL (14) for sizing details.

In most cases the thermal storage wall is able to achieve a higher solar fraction than a direct gain system, if the thermal storage mass does not exceed about 175 lbs/square foot of glazing.[3]

Retrofitting this system is easily done to the south wall of a space with a clear exposure.[4]

REFERENCES

1. General Reference 2. p 251.

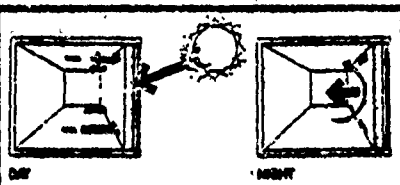
2. IBID

3. J. Douglas Balcomb. "Trombe Wall vs. Direct Gain: A Comparative Analysis of Passive Solar Heating Systems", Third National Passive Solar Conference Proceedings, San Jose, CA, Jan 11-13, 1979. p 45.

4. General Reference 1. p 110.

SOURCES OF ILLUSTRATIONS

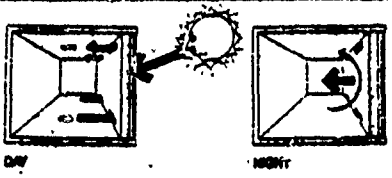
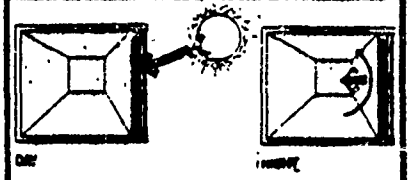
1. General Reference 1. pp 44 and 51.

● EXCELLENT ◒ GOOD ⊖ FAIR ○ POOR Ⓤ UNKNOWN Ⓥ VARIABLE	BUILDING TYPE(S): FAMILY HOUSING, AIRMAN'S DORM OFFICER'S QUARTERS	TABLE 9B-1
	TIME OF USE AND OCCUPANCY: 24 hour occupancy is expected with standard 65 F (winter) and 78 F (summer) heating and cooling maximums.	
DESIGN CONSIDERATIONS	 Masonry Thermal Storage Wall	 Water Thermal Storage Wall
HEAT STORAGE POTENTIAL	◒ GOOD	● EXCELLENT
WINTER VENTILATION	◒ Not required. Infiltration should supply sufficient ventilation	◒ Not required. Infiltration should supply sufficient ventilation.
SUMMER VENTILATION	● Dark masonry creates a thermal chimney for induced ventilation. Use in conjunction with EARTH TUBES (28), KING VENTILATION SYSTEM(29) & SOLAR CHIMNEY(3) to secure night ventilation.	○ An interior Water Wall will absorb heat and will not allow it to function as a Solar Chimney (31).
NATURAL LIGHT POTENTIAL/ CONTROL	● Excellent control of light to reduce glare and fading of furniture.	Ⓥ Varies with container. Opeque-excellent Transiucent-good
SENSITIVITY TO THERMAL FUNCTION	◒ Good	● Excellent
LATENT HEAT	◒ Kitchens, Bathrooms and laundry rooms are sources of latent heat Winter asset -Summer liability.	◒ Kitchens, Bathrooms and Laundry rooms are sources of latent heat. Winter asset - Summer liability.
MOISTURE	◒ Masonry will not collect condensation. Use EARTH TUBES(28) & SOLAR DEHUMIDIFIER (32) with this wall as a SOLAR CHIMNEY (31) to dehumidify the air.	◒ High humidity causes condensation on containers.
~~AL~~ ~~FLOOR~~ (RATIO)	◒ The ratio varies with local climate, latitude and space heating requirements. Range0.22 to 0.72-1.0. See table 15-1 for details.	◒ The ratio varies with local climate, latitude and space heating requirements. Range 0.16 to 0.55-1.0. See table 15-1 for details.
DEPTH OF SPACE LIMITATIONS	◒ Limited to 20 feet for effective radiant heating. The requirement for southern exposure dictates linear arrangement unless modified by stacking or staggering	◒ Limited to 20 feet for effective radiant heating. The requirement for southern exposure dictates linear arrangement unless modified by stacking or staggering

● EXCELLENT
◒ GOOD
⊖ FAIR
○ POOR
◐ UNKNOWN
◒ VARIABLE

BUILDING TYPE(S): BASE LIBRARY — Type 36-2

TIME OF USE AND OCCUPANCY: This building type has a 24 hour heat control requirement to preserve books. The heating and cooling requirements are similar to living/working spaces (72 degrees F - 78 degrees F with optimum of 76 degrees F). The books also contribute to the thermal mass of the building with a specific heat of .32 BTU/LB/degree F for paper. Books should not be exposed to direct sunlight.

DESIGN CONSIDERATIONS	 Masonry Thermal Storage Wall	 Water Thermal Storage Wall
HEAT STORAGE POTENTIAL	◒ GOOD	● EXCELLENT
WINTER VENTILATION	□ A library requires winter ventilation. Use EARTH TUBES(28) and KING VENTILATION SYSTEM(29) for earth tempered ventilating air.	□ A library requires winter ventilation. Use EARTH TUBES(28) and KING VENTILATION SYSTEM (29) for earth tempered ventilating air.
SUMMER VENTILATION	● Dark masonry creates a thermal chimney for induced ventilation. Use in conjunction with EARTH TUBES(28), KING VENTILATION SYSTEM(29) and SOLAR CHIMNEY (31) for secure night ventilation.	○ An interior water wall will absorb heat and not allow it to function as a Solar Chimney (31) to drive EARTH TUBES (28).
NATURAL LIGHT POTENTIAL/ CONTROL	● Excellent way to control direct sunlight on books and provide natural heat.	◐ Varies with container Opaque - good Translucent - poor
SENSITIVITY TO THERMAL FUNCTION	◒ GOOD	● EXCELLENT
LATENT HEAT	□ Libraries do not have latent heat problems unless there are many people.	□ Libraries do not have latent heat problems unless there are many people.
MOISTURE	● A library needs humidity control. Masonry will not collect condensation. Use EARTH TUBES(28) and SOLAR DEHUMIDIFIER(32), with this wall as a SOLAR CHIMNEY (31) to dehumidify the air.	⊖ High humidity causes condensation on containers.
~~WALL~~ / ~~FLOOR~~ (RATIO)	◒ The ratio varies with local climate, latitude and space heating requirements. Range 0.22 to 0.72 - 1.0. See table 15.1 for details.	◒ The ratio varies with local climate, latitude and space heating requirements. Range 0.16 to 0.55 - 1.0. See table 15.1 for details.
DEPTH OF SPACE LIMITATIONS	◒ Limited to 20 feet for effective radiant heating. The requirement for southern exposure dictates linear arrangement unless modified by stacking or staggering.	◒ Limited to 20 feet for effective radiant heating. The requirement for southern exposure dictates linear arrangement unless modified by stacking or staggering.

10. APPROPRIATE MATERIALS

LARGE SCALE PATTERNS

The construction materials in your building and its structural system will influence the choice of a passive solar system - CHOOSING THE SYSTEM (9) - used for retrofitting your building. Also using the idea of earth berming - NORTH SIDE (5) - will affect your selection of materials.

THE PROBLEM

MORE ENERGY WAS CONSUMED IN CONSTRUCTING YOUR BUILDING THAN WAS USED IN MANY YEARS OF OPERATION. THUS THE ARCHITECTURAL PROBLEM IS TO EFFECTIVELY RE-USE YOUR STRUCTURE AND THERMAL MASS (which should be considered as site provided natural resource) AS A RESOURCE FOR COLLECTING, STORING AND DISTRIBUTING HEAT THROUGHOUT THE STRUCTURE IN A NATURAL MANNER.

THE RECOMMENDATION

DESIGN YOUR RETROFIT SO THE BUILDING'S THERMAL MASS FUNCTIONS AS A NATURAL HEAT COLLECTOR, HEAT STORAGE MATERIAL AND HEAT DISTRIBUTING SYSTEM THROUGHOUT THE BUILDING. YOU SHOULD USE LOCALLY PRODUCED BIODEGRADABLE AND LOW ENERGY-CONSUMING MATERIAL WHENEVER POSSIBLE. IF ADDITIONAL THERMAL MASS IS REQUIRED, USE ADOBE, SOIL-CEMENT, BRICK, STONE, CONCRETE AND WATER IN CONTAINERS. FOR FINISH MATERIALS USE WOOD, PLYWOOD, PARTICLE BOARD AND GYPSUM BOARD. USE THE FOLLOWING MATERIALS ONLY IN SMALL QUANTITIES OR WHEN THEY HAVE BEEN RE-CYCLED: STEEL PANELS AND CONTAINERS, ROLLED STEEL SECTIONS, ALUMINUM AND PLASTICS.

SMALL SCALE PATTERNS

Distribute and size bulk materials so they work effectively for heat storage. For Direct Gain Systems see MASONRY HEAT STORAGE(13) and INTERIOR WATER WALL (14); for Thermal Storage Wall Systems see WALL DETAILS (16); for Attached Greenhouse Systems see GREENHOUSE CONNECTION (18); for Roof Pond Systems see ROOF POND DETAILS (20); for reducing heat loss or heat gain see MOVABLE INSULATION (23), SHADING DEVICES (25) and INSULATION ON THE OUTSIDE (26).

INFORMATION

This pattern should help you select materials which use a minimum amount of energy to manufacture and have good potential for heat storage (thermal mass-specific heat) or resistance to heat flow (insulation).

Energy conscious design requires selection of appropriate materials. Table 10-1 shows that thermal mass materials require relatively little energy to manufacture when compared to energy-

intensive materials such as aluminum and high grade steel alloys.

In some cases, thermal mass materials will be as much as 80 to 90% of the total volume of materials used in your building. With some consideration given to energy consciousness in selecting and detailing of secondary/finishing materials - MOVABLE INSULATION (23), REFLECTORS (24), SHADING DEVICES (25) and INSULATION ON THE OUTSIDE (26) - you can modify your building so your thermal mass is insulated from the elements, and becomes a heat sink or "thermal flywheel." Your selection of good secondary/finishing materials will, by its nature, be energy conservative.

Wood is an excellent secondary material. Other finish and secondary materials include plywood, particle board, gypsum board, plaster and vinyl. Your use of energy-intensive materials is appropriate when applied in moderation or when the materials are recycled.

Soil is not insulation but can be used as a buffer for strong north winds - NORTH SIDE (5) and on roofs.

The selection of materials and furnishings for interior design is developing as an Interior Architectural Design specialty, and is beyond the scope of this set of patterns. However, if you apply the recommendation of this pattern to your interior design, the thermal performance of your building will improve in your retrofitting process. A good resource for Interior Solar Design is Solar Interiors: Energy, A New Element in Design by Denise Guerin[6].

REFERENCES

1. A.B. Makhijani and A.J. Lichtemberg, "Energy and Well-Being," p 14.

2. Robert A. Kegel, "The Energy Intensity of Building Materials," p 39.

3. Andrew MacKilleys, "Low Energy Housing," p 8.

4. ASHRAE Handbook of Fundamentals, 1977.

5. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition. Rodale Press, Emmaus, PA 1979. pp115-117.

6. Denise Guerin. Solar Interiors: A New Element in Design (Miami University Home Economics Department - unpublished).

7. Denise Guerin. "Energy and Interior Design, " Master's Thesis, Michigan State University, May 1977.

8. Denise Guerin. "Textiles in an Ecological Framework," unpublished graduate paper, Michigan State University, June 1976.

9. "Window Treatments for Thermal Comfort, "Energy Facts, Cooperative Extension Service, Michigan State University, October 1977.

ITEM	REFERENCES	Btu/lb	Btu per unit	SPECIFIC HEAT Reference	SPECIFIC HEAT Btu/lb/°F
Water				4	.999
Steel (rolled)	1	19,974		4	.12
Aluminum	1	112,676		4	.214
Copper	1	34,144		4	.092
Concrete	2	413		4	.156
Cement	1	3,755		4	.16
Sand and gravel	1	30		4	.191
Lead	1	20,486		4	.0309
Concrete block	2		15,200/block	4	.156
Silicone, metal and high-grade steel allows	1	99,018			
Glass	1	11,438		4	.15-.20
Titanium (rolled)	1	239,010			
Plastics	1	4,097			
Drywall	2	2,160		4	.259
Insulation (board)	2		2,040/sq ft		
Paint	2	4,134			
Lumber	1		5,019/board ft	4	.325
Paper	1	10,072		4	.32
Roofing	2		6,945/sq ft		
Vinyl tile	2	8,000			
Brick	3	138	682/block	4	.2
10% soil-cement block	3	34	170/block		
Soil					

SOURCES:
1. A.B. Makhijani and A. J. Lichtenberg, "Energy and Well-Being," p.14.
2. Robert A. Kegel, "The Energy Intensity of Building MAterials," p.39.
3. Andrew MacKillop, "Low Energy Housing," p.8.
4. Ashrae Handbook of Fundamentals, 1977.

TABLE 10-1

11. SOLAR WINDOWS



Figure 11-1

LARGE SCALE PATTERNS

Using the ideas of existing or proposed windows from WINDOW LOCATION (8) and CHOOSING THE SYSTEM/DIRECT GAIN (9A), this pattern defines the area of south-facing glazing needed for solar heating each space.

THE PROBLEM

DIRECT GAIN SYSTEMS ARE CURRENTLY CHARACTERIZED BY LARGE AMOUNTS OF SOUTH FACING GLASS. MOST OF OUR PRESENT INFORMATION ABOUT DIRECT GAIN SYSTEMS HAS BEEN LEARNED THROUGH THE PERFORMANCE OF VARIOUS EXISTING PROJECTS WHICH UTILIZE LARGE SOUTH-FACING GLASS AREAS FOR WINTER SOLAR GAIN. THESE BUILDINGS ARE OFTEN THOUGHT OF AS OVERHEATING ON SUNNY WINTER DAYS. THIS HAPPENS BECAUSE SOLAR WINDOWS ARE FREQUENTLY OVERSIZED DUE TO LACK OF ANY ACCURATE METHODS FOR PREDICTING A SYSTEM'S PERFORMANCE. THESE DRAWBACKS HAVE LED TO A VERY LIMITED APPLICATION OF DIRECT GAIN SYSTEMS IN BUILDING DESIGN AND CONSTRUCTION.

THE RECOMMENDATION

IN COLD CLIMATES (average winter temperatures 20° to 30°F), PROVIDE BETWEEN 0.19 AND 0.31 SQUARE FEET OF SOUTH-FACING GLASS FOR EACH ONE SQUARE FOOT OF SPACE FLOOR AREA. THIS AMOUNT OF GLAZING WILL ADMIT ENOUGH SUNLIGHT TO KEEP THE SPACE AT AN AVERAGE TEMPERATURE OF 65° to 70° DURING MUCH OF THE WINTER.[1,2]

SMALL SCALE PATTERNS

The glazing area recommendations in this pattern can be divided between south-facing window space and/or south-facing

CLERESTORIES AND SKYLIGHTS (12) as shown in figure 11-1. To prevent daytime overheating and large space temperature fluctuations, store a portion of the heat gained during the daytime for use at night by locating a thermal mass within each space - MASONRY HEAT STORAGE (13) and INTERIOR WATER WALL (14). Use MOVABLE INSULATION (23) over the solar windows at night to reduce heat loss and protect the windows from the hot summer sun by applying SHADING DEVICES(25). The area of window needed to heat a space can be substantially reduced by using exterior REFLECTORS(24). A Direct Gain System with undersized solar windows can be combined with other passive systems to achieve the same recommended performance - COMBINING SYSTEMS (21).

Finally, your windows should function as breeze catchers for SUMMER COOLING (27).

ILLUSTRATION

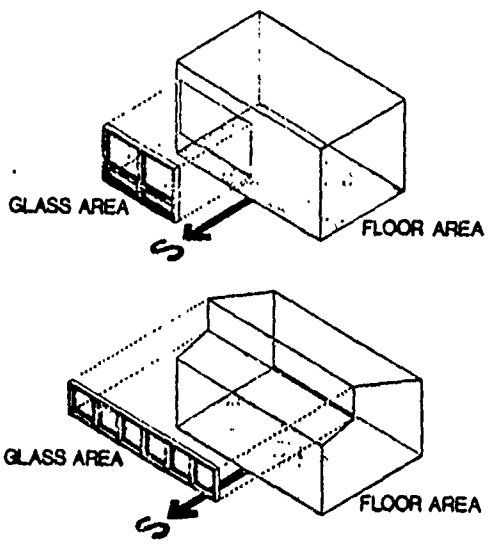


Figure 11-2

INFORMATION

A window, skylight or clerestory that faces south and opens directly into a space is a very efficient solar collector - WINDOW LOCATION (8). Light entering the space is unlikely to be reflected back out regardless of the color or shape of the space. This means that virtually all the sunlight is absorbed by the walls, floor, ceiling and other objects in the space and is converted into heat. Openings that are designed primarily to admit solar energy into a space are referred to as "solar windows." You can orient a solar window as much as 25° to the east or west of true south and still intercept over 90% of the solar radiation incident on a south-facing surface.

The size of a solar window determines the average temperature in a space over the day. During a typical sunny winter day, if a space becomes uncomfortably hot from too much sunlight, then

the solar windows are either oversized or there is not enough thermal mass distributed within the space to properly absorb the incoming radiation. As a space becomes too warm, heated air is vented by opening windows or activating an exhaust fan to maintain comfort. This reduces the system's efficiency since valuable heat is allowed to escape. For this reason, our criterion for a well-designed space is that it gain enough solar energy, on an average sunny day in December or January, to maintain an average space temperature of 70°F for that 24-hour period. Mazria used this criteria to develop size ratios for preliminary sizing of solar windows, skylights and clerestories (table 11-1.)

Sizing Solar Windows for Different Climatic Conditions[1]

Average Winter Outdoor Temperature (°F) (degree-days/mo.)[2]	Square Feet of Window[3] Needed for Each One Square Foot of Floor Area
Cold Climates	
15° (1,500)	0.27–0.42 (w/night insulation over glass)
20° (1,350)	0.24–0.38 (w/night insulation over glass)
25° (1,200)	0.21–0.33
30° (1,050)	0.19–0.29
Temperate Climates	
35° (900)	0.16–0.25
40° (750)	0.13–0.21
45° (600)	0.11–0.17

NOTES: 1. These ratios apply to a residence with a space heat loss of 8 to 10 Btu/day-sq ft.-°F. If space heat loss is less, lower values can be used. These ratios can also be used for other building types having similar heating requirements. Adjustments should be made for additional heat gains from lights, people and appliances.

2. Temperatures and degree-days are listed for December and January, usually the coldest months. Consult the Base Weather Detachment for Daily Temperature for your base.

3. Within each range, choose a ratio according to your latitude. For southern latitudes, i.e., 35°NL, use the lower window-to-floor-area ratios; for northern latitudes, i.e., 48°NL, use the higher ratios.

Table 11-1

The exact size for retrofitting of your windows will depend on Architectural considerations as well as thermal performance requirements.

If you need additional internal mass to prevent overheating and large temperature swings, then you should consider the concepts presented in INTERIOR WATER WALL(14) as an application of APPROPRIATE MATERIALS(10).

You should also replace metal sash windows with wooden sash windows to reduce heat loss.

You can also use this pattern to add Solar Windows, which meet the criteria outlined in CHOOSING THE SYSTEM/DIRECT GAIN (9A).

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa 1979. 119-121.

2. Edward Mazria. "A Design and Sizing Proceedure for Passive Solar Heated Buildings", 3rd Nation Passive Solar Conference Proceedings, San Jose, Ca, January 11-13 1979. p.250.

SOURCES OF ILLUSTRATIONS & TABLES

Figure 11-1 Passive Solar Buildings. Sandia Laboratories, Albuquerque, NM, and Livermore, Ca. For USDOE under Contract DE-AC04-76DP00789. July 1979. p 53.

Figure 11-2 Reference 1 p. 120.

Table 11-1 Reference 1 p. 122.

12. CLERESTORIES AND SKYLIGHTS

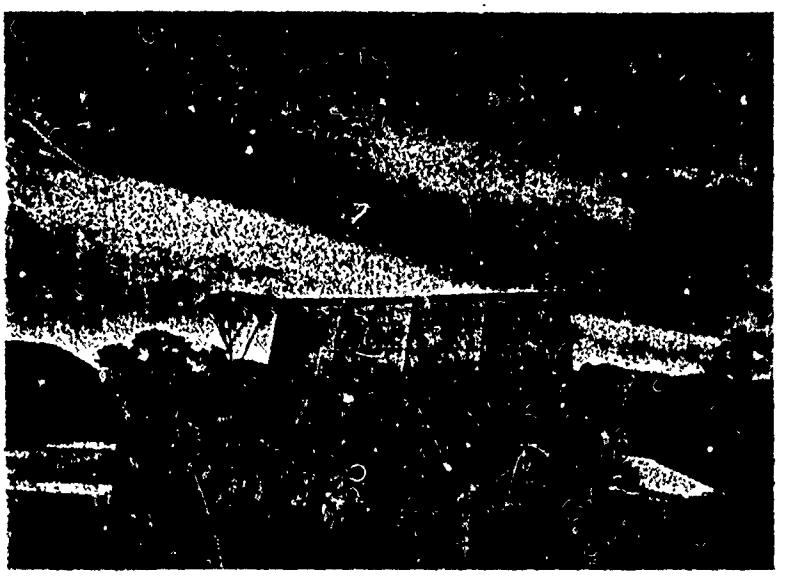


Figure 12-1

LARGE SCALE PATTERNS

Using the ideas of existing or proposed clerestories and skylights from WINDOW LOCATION (8) and CHOOSING THE SYSTEM/DIRECT GAIN (9A), plus the recommended areas of south-facing glass needed to admit direct sunlight to solar heat a space-SOLAR WINDOWS (11), then this pattern describes architectural methods other than windows for collecting the sun's energy.

THE PROBLEM

THERE ARE MANY SITUATIONS WHEN ADMITTING DIRECT SUNLIGHT THROUGH SOUTH-FACING WINDOWS IS NOT FEASIBLE OR DESIRABLE. SOLAR BLOCKAGE OF THE SOUTH WALL BY NEARBY OBSTRUCTIONS, OR SPACES WITHOUT A CLEAR SOUTHERN EXPOSURE, MAKE IT IMPOSSIBLE TO USE WINODWS FOR SOLAR GAIN. ALSO, THE DISTANCE FROM A SOLAR WINDOW TO A THERMAL STORAGE MASS IS LIMITED BY THE HEIGHT OF THE WINDOW. A MASS LOCATED TOO FAR FROM THE WINDOW WILL NOT RECEIVE AND ABSORB DIRECT SUNLIGHT. LARGE SOLAR WINDOWS, WHICH ARE THE PRIMARY SOURCE OF DIRECT SUNLIGHT IN A SPACE, MAY RESULT IN TROUBLESOME GLARE, CREATE UNCOMFORTABLY WARM AND BRIGHT CONDITIONS FOR PEOPLE OCCUPYING THE SPACE AND DISCOLOR CERTAIN FABRICS. FOR THESE AND OTHER REASONS (privacy and aesthetics) IT IS NECESSARY TO EXPLORE ALTERNATIVE METHODS FOR COLLECTING THE SUN'S ENERGY IN A DIRECT GAIN BUILDING.[1]

THE RECOMMENDATION

ANOTHER METHOD FOR ADMITTING SUNLIGHT INTO A SPACE IS THROUGH THE ROOF. USE EITHER SOUTH-FACING CLERESTORIES OR SKYLIGHTS TO DISTRIBUTE SUNLIGHT OVER A SPACE OR TO DIRECT IT TO A

PARTICULAR INTERIOR SURFACE. MAKE THE CEILING OF THE CLERESTORY A LIGHT COLOR AND APPLY SHADING DEVICES TO BOTH CLERESTORIES AND SKYLIGHTS FOR SUMMER SUN CONTROL.[1]

SMALL SCALE PATTERNS

Apply MOVABLE INSULATION (23) and REFLECTORS (24) to make clerestories and skylights more efficient as solar collectors. Shade all glass areas, especially horizontal and south-facing glass, to protect them from the hot summer sun - SHADING DEVICES (25).

Another important consideration in the selection and location of a particular configuration is whether sunlight is to be diffused throughout a space - MASONRY HEAT STORAGE (13), or directed to a particular surface - INTERIOR WATER WALL (14), and that your clerestories and skylights be operable for "stack effect" SUMMER COOLING (27).

ILLUSTRATION

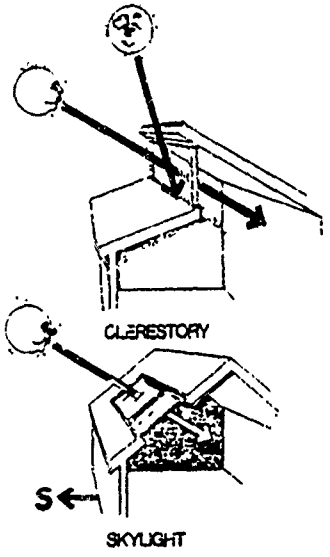


Figure 12-2

INFORMATION

CHOOSING THE SYSTEM /DIRECT GAIN (9A) described the advantage of Clerestories and Skylights, plus their retrofit opportunities and limitations.

If you are going to use south-facing Clerestories and Skylights in your architectural plan, then you should use the following guidelines:

Clerestory - locate the clerestory at a distance in front of an interior thermal storage wall of roughly 1 to 1.5 times the height of the thermal wall. Make the ceiling of the clerestory a light color to reflect and diffuse sunlight down into the space.

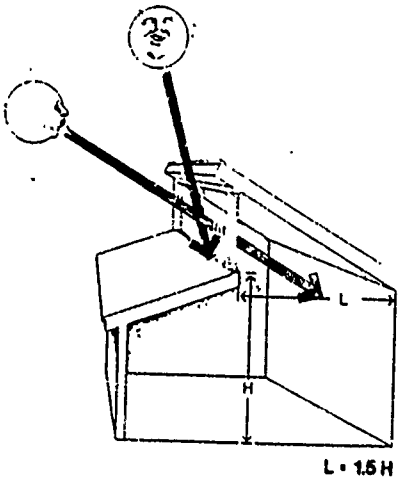


Figure 12-3

Sawtooth Clerestories - make the angle of each clerestory roof (as measured from horizontal) equal to, or less than the altitude of the sun at noon, on December 21, the winter solstice. Make the underside of the clerestories a light color.

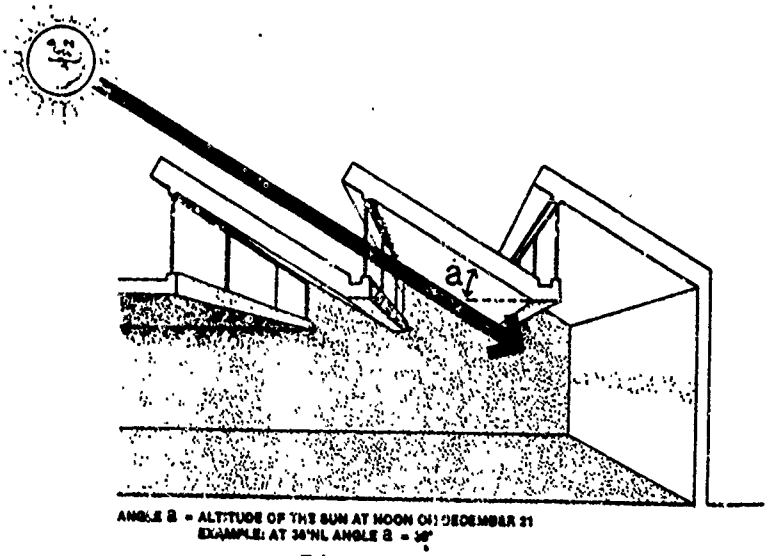


Figure 12-4

Skylight - use a reflector with horizontal skylights to increase solar gain in winter and shade both horizontal and south-facing skylights in summer to prevent excessive solar gain.[2]

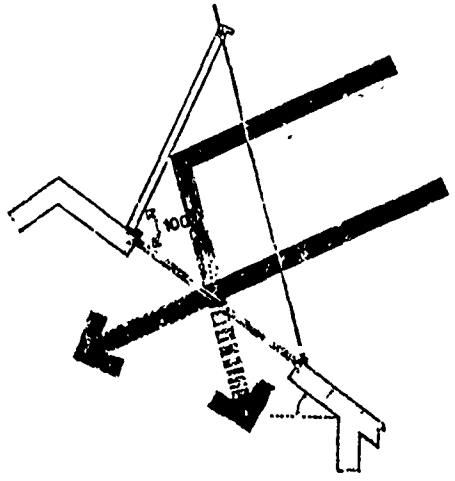


Figure 12-5

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa, 1979. p125.

2. Edward Mazria. "A Design and Sizing Proceedure for Passive Solar Heated Buildings", 3rd National Passive Solar Conference Proceedings, San Jose, Ca, January 11-13 1979. pp250-251.

SOURCES OF ILLUSTRATIONS

Figure 12-1 Patoka Nature Center by Fuller Moore

Figure 12-2 Reference 1 p 126

Figure 12-3 Reference 1 p 128

Figure 12-4 Reference 1 p 130

Figure 12-5 Reference 1 p 242

13. MASONRY HEAT STORAGE

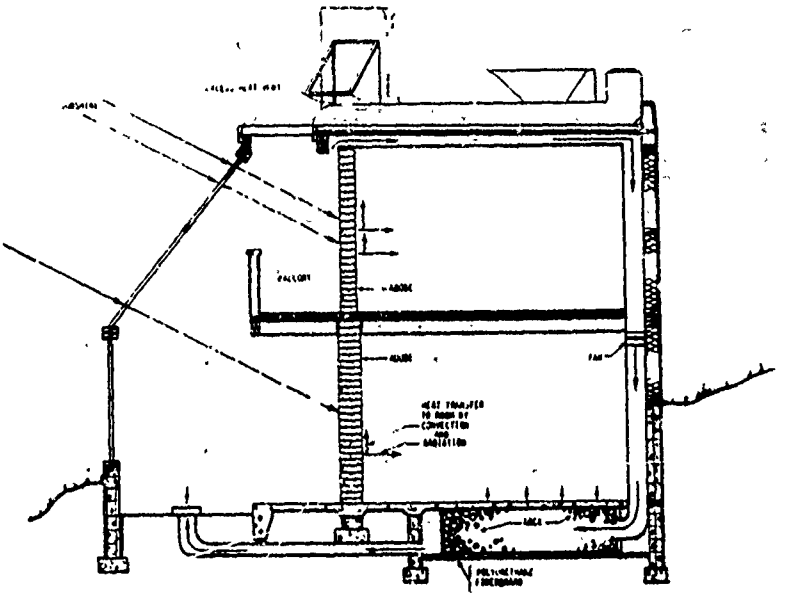


Figure 13-1

LARGE SCALE PATTERNS

After sizing your SOLAR WINDOWS (11) and/or CLERESTORIES AND SKYLIGHTS (12) a portion of the sunlight (heat) admitted into each space must be stored to prevent daytime overheating and for use during evening hours.

THE PROBLEM

THE STORAGE AND CONTROL OF HEAT IN A MASONRY BUILDING IS THE MAJOR PROBLEM CONFRONTING THE DESIGNER OF A DIRECT GAIN SYSTEM. In a Direct Gain System, the amount of solar energy admitted into a space through windows, skylights or clerestories determines the average temperature in the space over the day. A large portion of this energy must be stored in the masonry walls and/or floor of the space for use during the evening. In the process of storing and releasing heat, the masonry fluctuates in temperature, yet the object of the heating system is to maintain a relatively constant interior temperature. The location, quantity, distribution and surface color of the masonry in a space will determine the indoor temperature fluctuation over the day.[1]

THE RECOMMENDATION

TO MINIMIZE INDOOR TEMPERATURE FLUCTUATIONS, CONSTRUCT INTERIOR WALLS AND FLOORS OF MASONRY WITH A MINIMUM OF 4 INCHES IN THICKNESS. DIFFUSE DIRECT SUNLIGHT OVER THE SURFACE AREA OF THE MASONRY BY USING A TRANSLUCENT GLAZING MATERIAL, BY PLACING A NUMBER OF SMALL WINDOWS SO THAT THEY ADMIT SUNLIGHT IN PATCHES, OR BY REFLECTING DIRECT SUNLIGHT OFF A LIGHT-COLORED INTERIOR SURFACE FIRST, THUS DIFFUSING IT THROUGHOUT THE SPACE. USE

THE FOLLOWING GUIDELINES FOR SELECTING INTERIOR SURFACE COLORS AND FINISHES.

1. Choose a dark color for masonry floors.

2. Masonry walls can be any color.

3. Paint all lightweight construction (little thermal mass) a light color.

4. Avoid direct sunlight on dark-colored masonry surfaces for long periods of time.

5. Do not use wall-to-wall carpeting over masonry floors.[1]

SMALL SCALE PATTERNS

If your building is masonry then you should consider it as a site provided natural resource, and it is essential to insulate its exterior face to facilitate heat storage in the space - INSULATION ON THE OUTSIDE (26). You should also oversize solar windows and thermal mass to collect and store heat for cloudy days - CLOUDY DAY STORAGE (22). If you design your retrofit to allow ventilation of your masonry building during summer evenings, then the masonry will absorb heat and provide cool interior surfaces on hot days - SUMMER COOLING (27), EARTH TUBES (28), KING VENTILATION SYSTEM (29), and SOLAR CHIMNEY (31). If your building's DIRECT GAIN SYSTEM (9A) overheats on sunny winter days, then you should use INTERIOR WATER WALL (12) as an efficient and compact retrofit method.

ILLUSTRATION

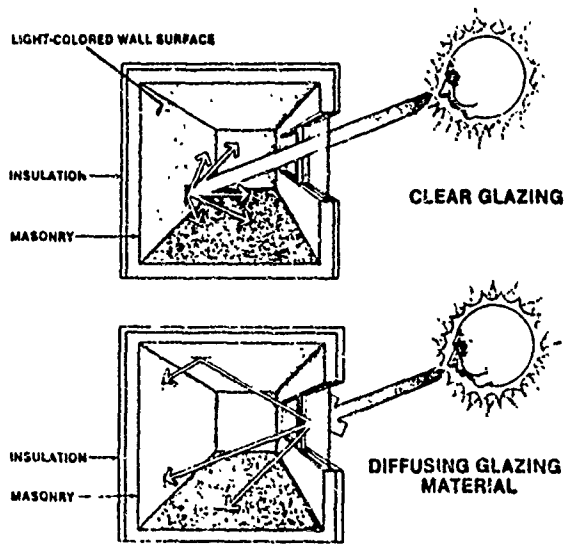


Figure 13-2

INFORMATION

Reference 1 presents information about three case studies performed by M.S. Baker, E. Mazria and F.S. Wessling at the University of Oregon. The following were their findings.

1. Use masonry products with a higher conductivity to reduce air temperature fluctuations within the space. This allows rapid heat transfer from the surface to the interior of the material.

Thermal Storage Material Properties

Material	Conductivity (k)	Specific Heat (Cp)	Density (ρ)
	Btu hr ft²·°F/ft	Btu/lb·°F	lb/ft
Concrete (dense)	1.00	0.20	140.0
Brick (common)	0.42	0.20	120.0
Brick (magnesium additive)	2.20	0.20	120.0
Adobe	0.30	0.24	100.0

Table 13-1

2. Interior masonry walls must be at least 4 inches thick.

3. To maintain comfort during the days, each square foot of direct sunlight should be spread over at least 9 square feet of masonry surface.

4. The following general rules can be applied to help you select interior surface colors and finishes for spaces of predominantly masonry construction:

   a. Select masonry floors of medium- dark colors. This assures that a portion of the heat will be absorbed and stored in the floor, low in the room, where it can provide for greater human comfort.

   b. Masonry walls can be any color. Sunlight reflected from light-colored masonry walls (20 to 30% solar absorption) will eventually be absorbed by other masonry surfaces in the space.

   c. Make all lightweight construction, such as wood frame partitions (little thermal mass), a light color so it reflects sunlight to the masonry walls or floor. Sunlight striking a dark-colored material of little thermal mass quickly heats that material. Since it has little capacity to store heat, it gives this heat to the space during the daytime when it is not needed, causing the space to overheat.

d. Avoid direct sunlight on dark-colored masonry surfaces for long periods of time since these surfaces will also become uncomfortably warm.

e. Do not cover a masonry floor with wall-to-wall carpet. Carpet insulates the heat storage mass from the room. Scatter or area rugs, covering a small area of the floor, make little difference.

Ref 1,2 &3.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa, 1979 pp 134-143.

2. E. Mazria, M.S. Baker, F.C. Wessling. "Predicting the performance of Passive Solar Heated Buildings," Proceedings of the 1977 Meeting of the AS/ISES. Vol 1, sec 2. 1977.

3. Edward Mazria. "A Design and Sizing Proceedure for Passive Solar Heated Buildings." 3rd National Passive Solar Conference Proceedings, San Jose, Ca, January 11-13 1979. p 251.

SOURCES OF ILLUSTRATIONS

Figure 13-1 Passive Solar Buildings. Sandia Laboratories, Albuquerque, NM, and Livermore, Ca. for USDOE under contract DE-AC04-76DP00789. July 1979. p.22.

Figure 13-2 Reference 1 p.135

Table 13-1 Reference 1 p.141

14. INTERIOR WATER WALL



Figure 14-1

LARGE SCALE PATTERNS

After sizing your SOLAR WINDOWS (11) and/or CLERESTORIES AND SKYLIGHTS (12) a portion of the sunlight (heat) admitted into each space must be stored to prevent daytime overheating and for use during evening hours. This pattern also gives information for applying the ideas from APPROPRIATE MATERIALS (10).

THE PROBLEM

THE SIZE OF A WATER WALL (Volume) AND ITS SURFACE COLOR DETERMINE THE TEMPERATURE FLUCTUATION IN A SPACE OVER THE DAY. Solar windows are sized to admit enough sunlight to keep a space at an average temperature of 65° to 70°F during most of the winter. The volume of water in the space and surface color of the container will influence the indoor temperature fluctuation above and below this average. The size of the water wall needed to maintain a comfortable environment is directly related to the area of the solar windows.[1]

THE RECOMMENDATION

WHEN USING AN INTERIOR WATER WALL (Volume) FOR HEAT STORAGE, LOCATE IT IN THE SPACE SO THAT IT RECEIVES DIRECT SUNLIGHT BETWEEN THE HOURS OF 10:00a.m. and 2:00p.m. Make the surface of the container exposed to direct sunlight a dark color, of at least 60% solar absorption, and use about one cubic foot (7½ gallons) of water for each one square foot of solar window.[1]

SMALL SCALE PATTERNS

Slightly oversize the solar windows and water wall to collect and store heat for cloudy days - CLOUDY DAY STORAGE (22). Insulate the exterior face of the wall when exposed to the outside - INSULATION ON THE OUTSIDE (26). In dry climates a water wall cooled during the summer with cool night air will provide for SUMMER COOLING (27).

ILLUSTRATION

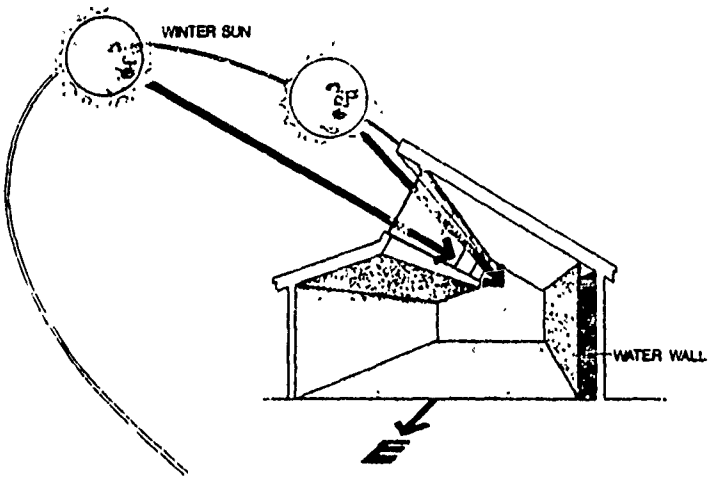


Figure 14-2

INFORMATION

The name Interior Water Wall should probably be called Interior Water Volume. The phrase "water wall" was coined to describe Steve Baer's Thermal Storage Wall system. The name is kept for ease of cross reference with Edward Mazria's book - The Passive Solar Energy Book - The Expanded Professional Edition.

The concept of this pattern is to locate a volume(s) of water in space so it is exposed to direct sunlight (from 10:00 AM to 2:00PM) to reduce heat fluctuations in the space. The amount of surface area exposed to sunlight and its surface color are critical. The more surface exposed to sunlight, the greater amount of heat absorbed. Black, Blue and Red are all good heat absorbing colors

The use of this pattern will also be an application of APPROPRIATE MATERIALS (10) and probably is one of the best retrofit options available.

It is a good retrofit heat storage material for the following reasons:

1. Water is the most effective heat storage medium.
2. Water heats up uniformly by convection currents.
3. The surface temperature of the water container does

not get hot and overheat the space like dark MASONRY HEAT STORAGE (13) media.

4. If the containers are small, they can be put in place easily by hand and filled with water.

You can apply this pattern in three ways:

1. Water in containers against the back wall of a space. (See figure 14-1) using SOLAR WINDOWS (11) and/or CLERESTORIES & SKYLIGHTS (12) as a sunlight source.
2. Water in small containers dispersed throughout the space such as the following using Solar Windows (11) and/or CLERESTORIES AND SKYLIGHTS (13) as a sunlight source.
   a. Water beds could be an optional issue bed for Airmen's Dorms, in place of standard metal frames and mattresses.
   b. Solar furniture (sofas, chairs, etc. made of metal casing with a soft cushion) filled with water.[2]



Figure 14-3

   c. Metal or glass sculptures filled with water.
   d. Metal paint cans (filled with water) to make book shelves.
   e. Limitless other possibilities if imagination is applied to the concept of volumes of water in sunlight (See Appendix J).

Note: The use of water beds and solar furniture locates heat or coolth next to the body for radiant heating or cooling of the body.

3. Water in containers directly behind the south-facing glass - THERMAL STORAGE WALL SYSTEM (9B) (See figure 14-1 and Appendix J.).

Table 14-1 shows room temperature fluctuations for Water Wall (Volume) Systems.

TABLE 14-1

DAILY SPACE AIR TEMPERATURE (^{0}F) Fluctuations FOR WATER STORAGE WALL SYSTEMS

Solar Absorption[2] (surface color)	Volume of Water Wall for Each One Square Foot of South-Facing Glass			
	1cu ft	1.5 cu ft	2 cu ft	3 cu ft
75% (dark color)	17^0	15^0	13^0	12^0
90% (black)	15^0	12^0	10^0	9^0

NOTES: 1. Temperature fluctuations are for a winter-clear day with approximately 3 square feet of exposed wall area for each one square foot of glass. If less wall area is exposed to the space, temperature fluctuations will be slightly higher. If additional mass is located in the space such as masonry walls and/or floor, then fluctuations will be less than those listed.

2. Assumes 75% of the sunlight entering the space strikes the mass wall.

3. One cubic foot of water = 62.4 pounds or 7.48 gallons.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa. 1979 pp 145-151.

2. David Brainbridge. "Water Wall Passive Systems - For New and Retrofit Construction," Third Nation Passive Solar Conference Proceedings, San Jose, Ca., January 11-13 1979. pp 473-478.

3. J.F. McClelland and R. Fuchs. "A Preliminary Study of A Passive Heating Performance and Visual Clarity for a Trans-wall Structure", Third National Passive Solar Conference Proceedings, San Jose, Ca, January 11-13, 1979. pp 107-112.

4. Fred Hopman. "The Self-Insulating Water Wall - A Passive Solar Module for Heating and Cooling", Third National Passive Solar Conference Proceedings, San Jose, Ca, January 11-13 1979. pp. 481-486.

SOURCES OF ILLUSTRATIONS

Figure 14-1 Reference 1, p 150.

Figure 14-2 Reference 1, p 146.

Figure 14-3 Reference 2, p 474.

Table 14-1 Reference 1, p 149.

15. SIZING THE WALL



Figure 15-1

LARGE SCALE PATTERNS

After locating the major south-facing spaces - LOCATION OF INDOOR SPACES (6) - and choosing your heating system for each space - CHOOSING THE SYSTEM (9) - this pattern describes the sizing procedure for a THERMAL STORAGE WALL SYSTEM (9B).

THE PROBLEM

WHEN A THERMAL STORAGE WALL IS PROPERLY SIZED, THE TEMPERATURE IN A SPACE WILL REMAIN COMFORTABLE THROUGHOUT MUCH OF THE WINTER WITHOUT ANY ADDITIONAL HEATING SOURCE. However, if a thermal wall is oversized, then more heat is transmitted through the wall than is needed, resulting in a space that is uncomfortably warm. Of course, heat will be vented from a warm space to reduce interior temperatures. This also reduces the system's efficiency by disposing of valuable heat in winter. If a wall is undersized, then there is not enough heat transmitted through the wall, and supplementary heating will be needed in the space. The correct size of a Thermal Storage Wall will change as climate, latitude and space heating requirements change.[1]

THE RECOMMENDATION

IN COLD CLIMATES (average winter temperatures 20°to 30°F) use between 0.43 and 1.0 square feet of south-facing, double-glazed, masonry thermal storage wall (0.31 and 0.85 square feet for a water wall) for each one square foot of space floor area. In temperate climates (average winter temperatures 35°to 45°F) use between 0.22 and 0.6 square feet of thermal wall (0.16 and 0.43 square feet for a water wall) for each one square foot of space floor area.[1]

SMALL SCALE PATTERNS

Detail the wall so it performs efficiently - WALL DETAILS(16). The area of thermal wall needed to heat a space can be substantially reduced by using exterior REFLECTORS (24) and/or MOVABLE INSULATION (23). In fact, their use is strongly recommended in cold northern climates. Remember that an under-sized thermal wall can be combined with other passive systems to provide adequate space heating - COMBINING SYSTEMS (21). You should plan the wall for cloudy days- CLOUDY DAY STORAGE (22). By the use of proper WALL DETAILS (16), you can convert a masonry wall into a SOLAR CHIMNEY (31) to drive EARTH TUBES (28) and KING VENTILATION SYSTEM (29) for earth tempered ventilation.[2]

ILLUSTRATION

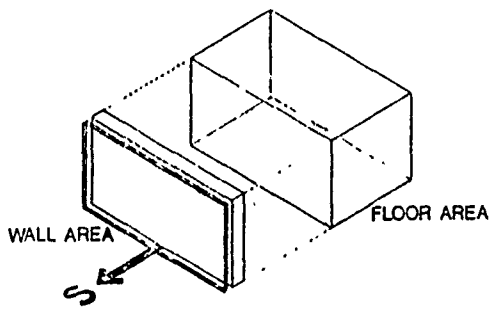


Figure 15-2

INFORMATION

The size of your thermal wall depends on three factors: local climate, latitude, space heat loss. Each factor influences the size of the wall.

Climate: In cold climates, more heat or larger thermal storage is needed to keep the space at ±70°F.

Latitude: The wall will increase in size the further north your building is located.

Space Heating Loss: A well-insulated and tightly sealed space requires less heat to keep it at a specified temperature and, therefore, requires less wall.

SIZING THE SYSTEM

Ed Mazria's criteria for a well-designed thermal storage wall

is that it transmit enough thermal energy (heat), on an average sunny day in January, to supply a space with its heating needs for that day.

That means that the energy transmitted through the wall should be sufficient to maintain an average space temperature of 65°to 75°F over a 24-hour period.

Using this criteria, Ed Mazria developed the sizing ratios shown in table 15-1.[1]

TABLE 15-1

Sizing a Thermal Storage Wall for Different Climatic Conditions

Average Winter Outdoor Temperature (°F) (degree-days mo)[1]	Square Feet of Wall[2] Needed for Each One Square Foot of Floor Area	
	Masonry Wall	Water Wall
Cold Climates		
15° (1,500)	0.72->1.0	0.55-1.0
20° (1,350)	0.60-1.0	0.45-0.85
25° (1,200)	0.51-0.93	0.38-0.70
30° (1,050)	0.43-0.78	0.31-0.55
Temperate Climates		
35° (900)	0.35-0.60	0.25-0.43
40° (750)	0.28-0.46	0.20-0.34
45° (600)	0.22-0.35	0.16-0.25

NOTES: 1. Temperatures and degree days are listed for December and January, usually the coldest months.

2. Within each range choose a ratio according to your latitude. For southern latitudes, i.e., 35°NL, use the lower wall-to-floor area ratios; for northern latitudes, i.e., 48°NL, use the higher ratios. For a poorly insulated building always use a higher value. For thermal walls with a horizontal specular reflector equal to the height of the wall in length, use 67% of recommended ratios. For thermal walls with night insulation (R 6), use 85% of recommended ratios. For thermal walls with both reflectors and night insulation, use 57% of recommended ratios.

The exact size of the wall depends on many considerations such as views, natural lighting, solar blockage and cost, and will be decided by the retrofit designer.

Refer to Reference 1 for design details.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa, 1979. pp 153-157.

2. Dr. Donald B. Elmer, Mo Hourmanesh, and Ray Hourmanesch. "Earth Air Heat Exchangers", 2nd National Passive Solar Conference Proceedings, Philadelphia Pa, March 16-18, 1978. Vol I, p146-148.

SOURCES OF ILLUSTRATIONS

Figure 15-1 Reference 1 p 151

Figure 15-2 Reference 1 p 154

Table 15-1 Reference 1 p 156

16. WALL DETAILS



Figure 16-1

LARGE SCALE PATTERNS

Once a rough size for a thermal storage wall is determined - SIZING THE WALL(13) - this pattern helps to detail the wall so the system performs efficiently.

THE PROBLEM

THE EFFICIENCY OF A THERMAL STORAGE WALL SYSTEM IS LARGELY DETERMINED BY THE WALL'S THICKNESS, MATERIAL AND SURFACE COLOR. A space will overheat if more energy is transmitted through a thermal wall than is needed. This happens when a wall is either too large in surface area, or too thin. If a wall is too thick or painted the wrong color, it becomes inefficient as a heating source since little energy is transmitted through it. For each type of wall material there is an optimum thickness.[1]

THE RECOMMENDATION

USE THE FOLLOWING TABLE AS A GUIDE FOR SELECTING A WALL THICKNESS:

Material	Recommended Thickness (in)
Adobe	8-12
Brick (common)	10-14
Concrete (dense)	12-18
Water	6 or more

MAKE THE OUTSIDE FACE OF THE WALL A DARK COLOR. IN COLD CLIMATES

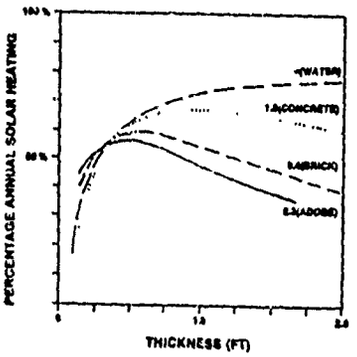
ADD THERMO-CIRCULATION VENTS, OF ROUGHLY EQUAL SIZE, AT THE TOP AND BOTTOM OF A MASONRY WALL TO INCREASE THE SYSTEM'S PERFORMANCE. MAKE THE TOTAL AREA OF EACH ROW OF VENTS EQUAL TO APPROXIMATELY ONE SQUARE FOOT FOR EACH 100 SQUARE FEET OF WALL AREA. PREVENT REVERSE AIR FLOW AT NIGHT BY PLACING AN OPERABLE PANEL (damper), HINGED AT THE TOP, OVER THE INSIDE FACE OF THE UPPER VENTS, OR USE AN AUTOMATIC DAMPER LIKE SHOWN IN FIGURE 16-3.[1,2]

SMALL SCALE PATTERNS

Placing MOVABLE INSULATION (23) over the glazing at night increases the system's performance. If possible, design the movable insulation to be used as REFLECTORS (24) and/or SHADING DEVICES(25). Shading the wall in summer and early fall will prevent the space from overheating.

Or you can locate Movable Insulation on the interior surface of a dark masonry wall to convert the wall into a Solar Chimney (31) to drive EARTH TUBES (28) and KING VENTILATION SYSTEM (29) for earth tempered ventilation.

ILLUSTRATIONS



Yearly performance of a thermal storage wall for various thicknesses and thermal conductivities

Figure 16-2

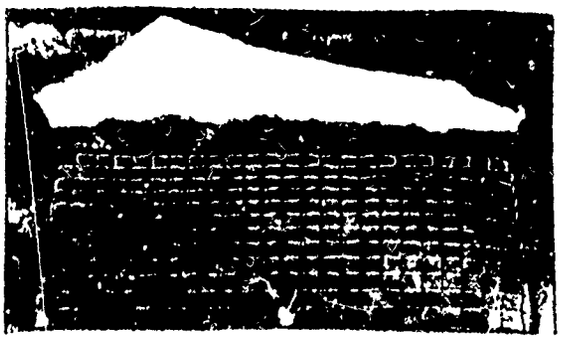


Figure 16-3

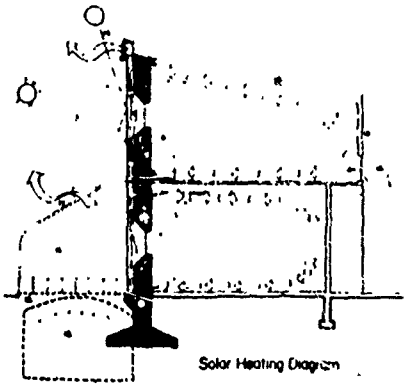


Figure 16-4

INFORMATION

The details of the wall, its thickness, surface color, and addition of thermo-circulation vents, and temperature control devices determine the efficiency of the system and its ability to provide thermal comfort in the winter.

Wall Thickness

From Figure 16-2, the following conclusions have been drawn by Ed Mazria:

1. The optimum thickness of a masonry wall increases as the thermal conductivity of the wall increases.
2. The efficiency of the wall increases as the conductivity of the wall increases.
3. For masonry materials there is a range of optimum thicknesses.
4. The efficiency of a water wall increases as the thickness of the wall increases, although after 6 inches the increase in performance is not very pronounced.

Table 16-1 lists the thermal conductivity and recommended thickness for five commonly used wall materials. Your choice of wall thickness, within the range given for each material will determine the temperature fluctuation in the space over the day.

TABLE 16-1 Effect of Wall Thickness on Space Air Temperature Fluctuations

Material	Thermal Conductivity (Btu hr ft²°F)	Recommended Thickness (in)	Approximate Indoor Temperature (°F) Fluctuation as a Function of Wall Thickness[1]					
			4 in	8 in	12 in	16 in	20 in	24 in
Adobe	0.30	8–12	. .	18°	7°	7°	8°	.
Brick (common)	0.42	10–14	...	24°	11°	7°	.	.
Concrete (dense)	1.00	12–18	...	28°	16°	10°	6°	5°
Brick (magnesium additive)[2]	2.20	18–24	...	35°	24°	17°	12°	9°
Water[3]	...	6 or more	31°	18°	13°	11°	10°	9°

NOTES 1 Assumes a double glazed thermal wall If additional mass is located in the space, such as masonry walls and/or floors then temperature fluctuations will be less than those listed Values given are for winter clear days

2 Magnesium is commonly used as an additive to brick to darken its color It also greatly increases the thermal conductivity of the material

3 When using water in tubes, cylinders or other types of circular containers, use at least a 9½ inch diameter container or 5½ cubic foot (342 lb or 3.74 gals of water for each one square foot of glazing

AS A GENERAL RULE THE GREATER THE WALL THICKNESS THE LESS THE INDOOR TEMPERATURE FLUCTUATIONS.

Wall Surface Color

The greater the absorption of solar energy at the outside surface of a thermal wall, the greater will be the transmission of heat through the wall to the interior space. A black-colored surface, with a solar absorption of 95%, is one of the most efficient absorbers. Performance, though, is only one criterion for the selection of wall color. Other colors such as dark blue (solar absorption 85%) also work well. Reducing the solar absorption for both water and masonry walls from 95% to 85% reduces the system's efficiency proportionally. The inside surface of the wall can be made any color.[1]

You can use Figure V-10 in chapter 5 of Ed Mazria's book (Reference 1) to predict the time of day a space will reach its maximum and minimum temperatures.

Thermocirculation Vents

Locating openings (vents) at the top and bottom of the wall induces a natural (passive) circulation of warmed air into the building. The natural convection of heated air continues for 2 to 3 hours after sunset, when the wall becomes too cool to induce a warm airflow.[1]

At night the air between the glazing and wall cools, and the air movement will reverse. To prevent reverse air flow at night attach an operable panel or automatic damper over the inside face of the upper vents as mentioned in THE RECOMMENDATION.[1,2]

Space Temperature Control

If a space becomes too warm, movable insulation (such as curtains, sliding panels) placed over the inside face of a thermal wall turns off the heating system. This is a very simple and effective way to control indoor temperatures. The system can be adjusted by covering all, part or none of the wall.[1]

A dark masonry wall can be converted into a SOLAR CHIMNEY (31) in the summer by placing MOVABLE INSULATION (23) on the inside surface of the wall, closing the upper interior vent, and venting the wall to the outside with an exhaust fan. This SOLAR CHIMNEY (31) will continue to ventilate the space until late at night. EARTH TUBES (28) and KING VENTILATION SYSTEM (29) can be used as a cool air source for ventilation of the space. This process is illustrated by Figure 16-4.[3,4,5]

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa., 1979. pp 159-171.

2. Doug Kelbaugh, AIA. "Kelbaugh House: Recent Performance," 2nd National Passive Solar Conference Proceedings, Philadelphia, Pa, March 16-18 1978. Vol. I p69-75.

3. Norma Skurka and Jon Naar. Design for a Limited Planet, Ballentine Books, New York, NY, 1976. pp 123-127.

4. Dr. Donald B. Elmer, Mo Hourmanesh and Ray Hourmanesch. "Earth Air Heat Exchangers", 2nd National Passive Solar Conference Proceedings, Philadelphia, Pa., March 16-18, 1978. Vol I. p 146-148.

5. David Wright, AIA. Natural Solar Architecture - A Passive Primer, Van Nostrand Reinhold Company, 1978 pp 194-195 and 210. (Appendix K).

SOURCES OF ILLUSTRATIONS

Figure 16-1 Reference 1 p.158

Figure 16-2 Reference 1 p.161

Figure 16-3 Reference 2 p.69

Figure 16-4 Reference 2 p.69

Table 16-1 Reference 1 p.163

21. COMBINING SYSTEMS

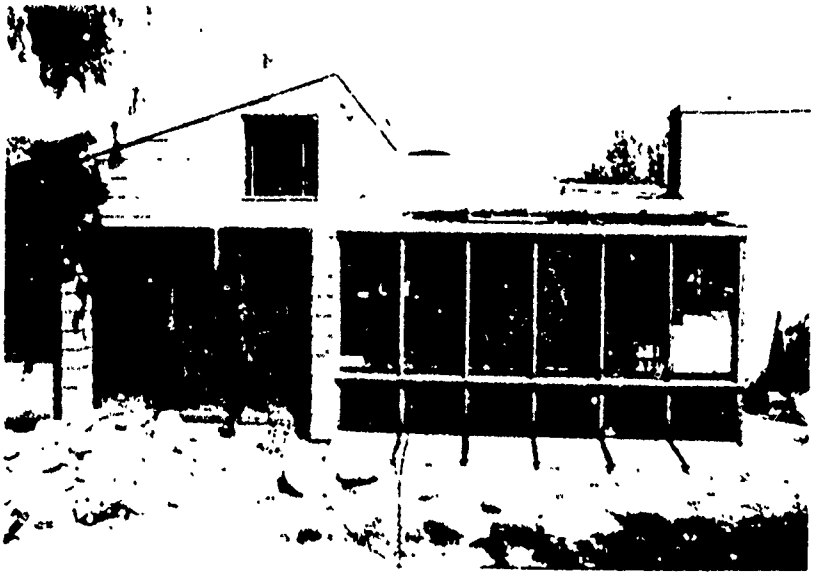


Figure 21-1

LARGE SCALE PATTERNS

If more than one system is chosen to heat a space - CHOOSING THE SYSTEM (9) - this pattern will help determine the relationship between the sizes of the various systems.

THE PROBLEM

IT IS VERY LIKELY THAT A COMBINATION OF PASSIVE SYSTEMS WILL BE USED TO HEAT A SPACE. HOWEVER, SIZING PROCEDURES ARE USUALLY ONLY GIVEN FOR INDIVIDUAL SYSTEMS. For example, many passive solar heated spaces employing a Thermal Storage Wall or Attached Greenhouse System will also include south-facing windows in the space. In some cases, direct gain windows will be part of the thermal wall. In this and other similar situations, the sizing procedures given in previous patterns must be adjusted.

THE RECOMMENDATION

WHEN SIZING A COMBINATION OF SYSTEMS, ADJUST THE PROCEDURES GIVEN IN PREVIOUS PATTERNS ACCORDING TO THE FOLLOWING RATIOS: FOR THE SAME AMOUNT OF HEATING, EACH 1 SQUARE FOOT OF DIRECT GAIN GLAZING EQUALS 2 SQUARE FEET OF THERMAL STORAGE WALL OR EQUALS 3 SQUARE FEET OF GREENHOUSE COMMON WALL AREA.

SMALL SCALE PATTERNS

You should treat the details of each system as if it were the only system, and slightly over-size collector areas and thermal mass when heat storage for cloudy days is needed - CLOUDY DAY STORAGE (22), - and you should not forget to use MOVABLE INSULATION

(23), REFLECTORS (24), SHADING DEVICES (25) INSULATION ON THE OUTSIDE (26) and SUMMER COOLING (27).

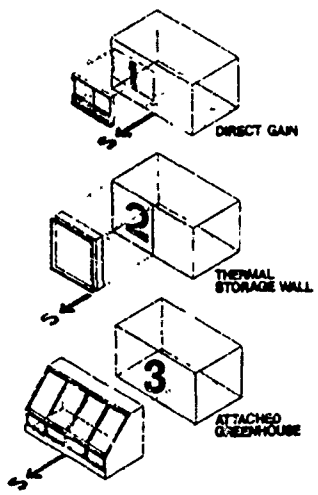


Figure 21-2

INFORMATION

When most of the glazing normally used in a space also doubles as the collector area (south-facing glazing), then a DIRECT GAIN SYSTEM (9A) will utilize approximately 60 to 75% of the energy incident on the collector (south-facing glazing) for space heating. These percentages are largely determined by reflective and absorptive radiation losses through the glazing.

A THERMAL STORAGE WALL SYSTEM (9B) will transfer about 30 to 45% of the energy incident on the collector into a space. This system's efficiency is determined not only by reflective and absorptive losses through glazing, but also by heat lost from the wall's exterior surface because of the high temperatures generated - WALL DETAILS (14).

The ATTACHED GREENHOUSE (9C) is essentially a Thermal Storage Wall System. However, the percentage of incident energy (on the collector) transferred through the common wall between the greenhouse and building is less than a Thermal Storage Wall, or only 15 to 30%. The reason is simply that a greenhouse has more surface area and consequently more heat loss than glass placed only a few inches in front of a wall. This does not imply that this system is inefficient. On the contrary, the energy collected by the greenhouse that is not transferred into the building is used to heat the greenhouse itself.

All of this suggests that a ratio of 1 (Direct Gain) to 2 (Thermal Storage Wall) to 3 (Attached Greenhouse) exists between the systems. (If the collector glazing in a Direct Gain System

is additional to the amount that would normally be used in a space, then double the amount of collector area needed.) This means that each 1 square foot of collector area (glazing) in a Direct Gain System supplies roughly the same quantity of heat to a space as 2 square feet of thermal storage wall, or 3 square feet of attached greenhouse wall area. According to these ratios then, 50 square feet of direct gain glazing will produce roughly the same amount of solar heating as the combination of 25 square feet of direct gain glazing and 75 square feet of attached greenhouse common wall area.[1]

If you actively take heat out of an attached greenhouse and store it in the building - GREENHOUSE CONNECTION (18) - the percentage of incident energy supplied to the space increases. In this case, the ratio of direct gain to attached greenhouse collector area is roughly, 1 to 2.

Because of the many roof pond configurations, it is difficult to give one rule of thumb for combining the pond with other systems. However, for the same amount of heating, the ratio of roof pond collector area to the collector area of other systems can be determined from the sizing procedures given in the patterns SOLAR WINDOWS (11), SIZING THE WALL (15), SIZING THE GREENHOUSE (17) and SIZING THE ROOF POND (19).[1]

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa., 1979. pp. 220-224.

SOURCES OF ILLUSTRATIONS

Figure 21-1 Reference 1 p 219

Figure 21-2 Reference 2 p 221

23. MOVABLE INSULATION

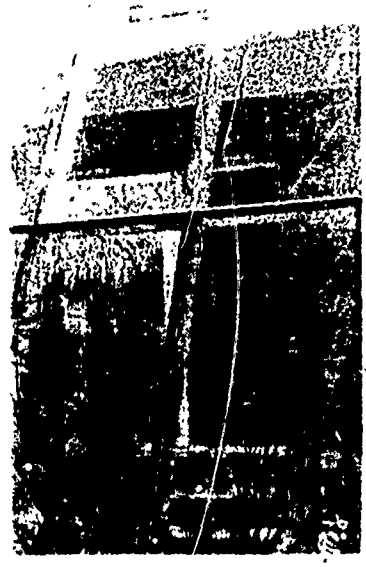


Figure 23-1

LARGE SCALE PATTERNS

This pattern is the starting point for a series of patterns with specific instructions to make your building (the passive system) more efficient as a passive system.

Once the solar system for your retrofit has been determined - CHOOSING THE SYSTEM(9) - and the glass areas for each space located - WINDOW LOCATION (8) - the building can be made more efficient as a solar collector by the use of movable insulation. This pattern must be an integral part of your retrofit of windows and the southern wall - WALL DETAILS (16). The application of this pattern will give good return on the investment, if applied properly.

THE PROBLEM

ALTHOUGH GLASS AND CLEAR OR TRANSLUCENT PLASTICS HAVE THE POTENTIAL TO ADMIT LARGE AMOUNTS OF SOLAR RADIATION AND NATURAL LIGHT INTO A SPACE DURING THE DAYTIME, THEIR POOR INSULATING PROPERTIES ALLOW A LARGE PERCENTAGE OF THIS ENERGY TO BE LOST BACK OUT THROUGH THE GLAZING, MOSTLY AT NIGHT. In a well insulated building, glazed openings (windows, skylights and clerestories) can be one of the largest sources of building heat loss. Approximately two-thirds of this heat loss which occurs at night can be greatly reduced by the use of movable insulation.[1]

THE RECOMMENDATION

USE MOVABLE INSULATION OVER ALL GLAZED OPENINGS TO PREVENT THE HEAT GAINED DURING THE DAYTIME FROM ESCAPING RAPIDLY AT NIGHT. EASE OF OPERATION, DURABILITY AND VISUAL APPEARANCE

ARE AS IMPORTANT AS THE INSULATION VALUE. DEVICES THAT ARE TOO LARGE, CUMBERSOME OR DIFFICULT TO OPERATE WILL INHIBIT PROPER USAGE. IF A CHILD CAN OPEN AND CLOSE THE INSULATION, CHANCES ARE THAT THE ROUTINE WILL BECOME HABITUAL AND FUN.[1,2]

SMALL SCALE PATTERNS

Control the amount of sunlight entering a space at different times of the year by detailing movable insulation so it doubles as SHADING DEVICES (25). When using exterior insulating shutters or panels, design them so that they also serve as REFLECTORS (24) to increase the solar gain through each square foot of glazing. For SUMMER COOLING (27) use Movable Insulation on the interior surface of MASONRY HEAT STORAGE(13) so the wall will function as a SOLAR CHIMNEY (31).

ILLUSTRATION

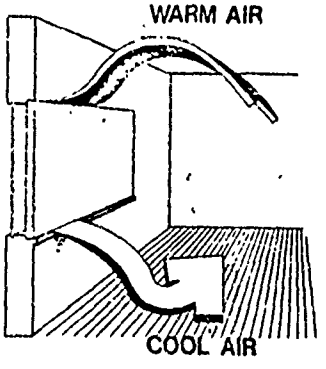


Figure 23-2

INFORMATION

This pattern presents information about using insulation in an Architectural manner. Its use is essential for reducing energy consumption in your building, and improving thermal performance/comfort to the occupants.

Historically this pattern was used in the form of shutters until the emergence of "Modern Architecture". It is now reappearing and being used as a means of protecting glazing and reflecting more light onto a storage media.

Your movable insulation can be located on the outside of the glazing or on the inside. Each has advantages and disadvantages. You and the using organization should select the location of the insulation early in the programming process.

It should be done at the same time you select your solar

system - CHOOSING THE SYSTEM (9), because it will affect the performance of the system.

The location of the insulation also affects the method of moving the insulation: (1) manual, (2) thermally sensitive and (3) motor driven.

Table 23-1 compares the advantages and disadvantages of MOVABLE INSULATION locations and the methods of moving it.

	OUTSIDE	INSIDE
Weather exposure	Must withstand the elements.	N/A
Condensation on Glazing	N/A	Will be a problem.
Location of Critical Seals (Convective Loss)	Top.	Bottom See Figure 23-2
Solar Enhancement	Reflective Surface will enhance solar collection.	N/A
Manual Operation	Must be done by winch and pulleys.	By hand.
Thermal Operation	N/A	SKYLIDS*, heat motor Bimetalic strip - used in difficult areas to reach.
Mechanical Operation	Bead Wall** SKYTHERM*** used in inaccessible location.	N/A

* SKYLIDS are a patented device by Steve Baer, Zomeworks Corp, Albuquerque, N.M.
** Beadwall is a patented device by David Harrison, Zomeworks Corp., Albuquerque, N.M.
*** SKYTHERM is a patented device by Harold Hay.

TABLE 23-1

NOTE: If your building is in an area of extensive winter cloud cover, and you cannot oversize your system -

CLOUDY DAY STORAGE (22) - then you probably should use exterior MOVABLE INSULATION with a reflective surface -REFLECTOR (24). This strategy will allow your building's temperature to respond quickly to solar radiation when the sun does shine. You should also use INSULATION ON THE OUTSIDE (26) to minimize heat losses.

You can use Appendix N and reference 1 as morphologic solution resources.

REFERENCES

1. Edward Mazria. THE PASSIVE SOLAR ENERGY BOOK - Expanded Professional Edition, Rodale Press, Emmaus, Pa., 1979. pp 231-239.

2. David Wright, AIA. Natural Solar Architecture - A Passive Primer, Van Nostrand Reinhold Company, 1978. pp 95-102, 176, 178, 183, 189, 210, 212.

SOURCES OF ILLUSTRATIONS

Figure 23-1 Fuller Moore's roll down reflective insulation shade (See Appendix N).

Figure 23-2 Reference 1. p 233.

24. REFLECTORS

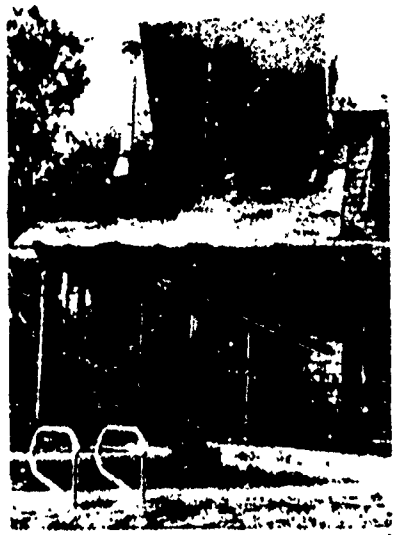


Figure 24-1

LARGE SCALE PATTERNS

After CHOOSING THE SYSTEM (9) and using the ideas about extensive winter cloud cover - CLOUDY DAY STORAGE (22) - and MOVABLE INSULATION (23) the amount of solar energy incident on a collector can be increased with the addition of a reflector. The reflectors must be integrated into the programming of your building's retrofit, because it will affect the sizing and the detailing of the solar system.

THE PROBLEM

A LARGE AMOUNT OF COLLECTOR AREA (south facing glass) MAY NOT BE FEASIBLE OR DESIRABLE IN MANY BUILDING SITUATIONS. In a number of situations, such as partial shading by nearby buildings or vegetation, aesthetic considerations or the limited availability of south wall for solar collection, large south-facing glass areas may not be possible. In addition, since glass is a poor insulator, it makes sense to minimize the area of glazing needed to heat a space. By using exterior reflectors the amount of solar radiation transmitted through each square foot of glass can be dramatically increased.[1]

THE RECOMMENDATION

FOR VERTICAL GLAZING USE A HORIZONTAL REFLECTOR ROUGHLY EQUAL IN WIDTH AND 1 to 2 TIMES THE HEIGHT OF THE GLAZED OPENING IN LENGTH. FOR SOUTH-SLOPING SKYLIGHTS LOCATE THE REFLECTOR ABOVE THE SKYLIGHT AT A TILT ANGLE OF APPROXIMATELY 100°. MAKE THE REFLECTOR ROUGHLY EQUAL TO THE LENGTH AND WIDTH OF THE SKYLIGHT.[1]

SMALL SCALE PATTERNS

When possible, design reflectors to function as SHADING DEVICES (25) and/or insulating shutters - MOVABLE INSULATION (23).

ILLUSTRATION

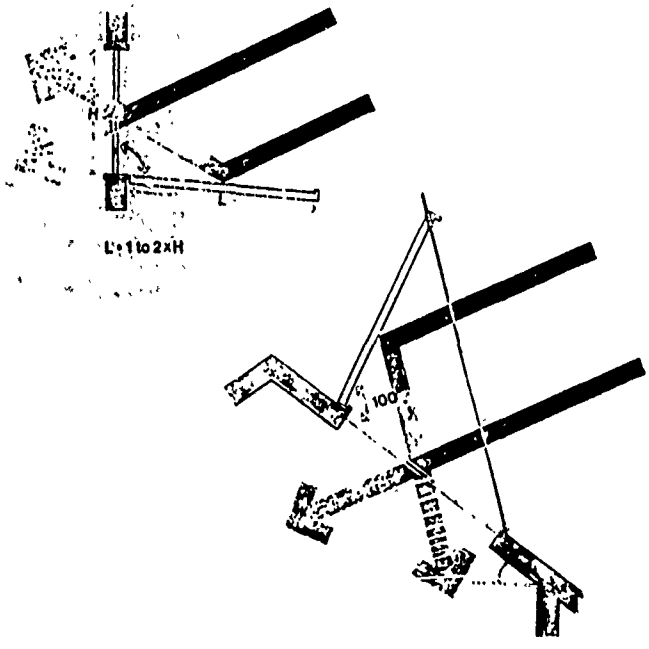


Figure 24-2

INFORMATION

There are two basic types of exterior reflectors/collector configurations: (1) reflectors coupled with vertical or near vertical glazing; (2) reflectors coupled with south-sloping and horizontal skylights (See figure 24-2).

Vertical Glazing:

A horizontal reflector directly in front of the glazing works best. Experiments conducted at the University of Oregon concluded the optimum length of the reflector is 1 to 2 times the height of the glazed opening.

If you use a reflector, the average winter solar radiation incident on the vertical glazing can be increased by roughly 30 to 40% during winter months.[1,2,3]

An intriguing reflector method used by John Reynolds (Eugene, Oregon) is to apply aluminum foil on hot-mopped bituemen in front of clerestory windows.[2,3]

South-Sloping Skylights:

Similar results can be achieved by using a reflector in conjunction with south-sloping skylights (30°to 50°tilt from horizontal) or horizontal skylights.

NOTE: You should not use a skylight reflector if your building is in an area of extensive winter clouding, because the reflector will shade part of the skydome thus reducing the amount of diffuse sky radiation collected by the skylight.

Skylight reflectors can be adjusted for the summer months to serve as SHADING DEVICES (25). In winter the reflector would be raised to increase solar collection. Remember that reflectors which protrude out from the face of a building are usually subject to increased wind loads and must be of sturdy contruction.

Inside the building reflectors can be used to direct sunlight to a particular part of the space. For example, to reflect sunlight onto an INTERIOR WATER WALL (14).

Appropriate materials suitable for reflectors include shiney metals such as polished aluminum, tnin metal foils, glass or plastic mirrors and mylar wall coverings. White-colored materials can be used but will not perform as well as polished surfaces. You should be careful using reflectors with windows because of glare.[1]

You should refer to Edward Mazria's book (Reference 1) Appendix J for percent enhancement of vertical south-facing glazing using specular reflectors.



Figure 24-3



Figure 24-4

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition. Rodale Press, Emmaus, Pa., 1979. pp 248.

2. John Reynolds. Solar Design Symposium at Miami University Oxford,Ohio. 25 April 1978.

3. John Reynolds. "Emerging Architecture" 4th National Passive Solar Conference Proceedings, Kansas City, Mo. October 3-5 1979. p.756.

SOURCES OF ILLUSTRATIONS

Figure 24-1 Reference 1 p.246

Figure 24-2 Reference 1 p.242

Figure 24-3 Reference 1 p.246

Figure 24-4 Reference 1p. 247

25. SHADING DEVICES



Figure 25-1

LARGE SCALE PATTERNS

WINDOW LOCATION (8) calls for the major glass areas in the building to be oriented south. This pattern describes specific methods for shading these glass areas in summer.

THE PROBLEM

LARGE SOUTH-FACING GLASS AREAS, SIZED TO ADMIT MAXIMUM SOLAR GAIN IN WINTER, WILL ALSO ADMIT SOLAR GAIN IN SUMMER WHEN IT IS NOT NEEDED. Although there is less sunlight striking south-facing vertical glass in summer, it is usually enough to cause severe overheating problems. Fortunately, by using an overhang with south glazing, summer sunlight can be effectively controlled. The effectiveness of any shading device, however, depends upon how well it shades the glass in summer without shading it in winter.[1]

THE RECOMMENDATION

SHADE SOUTH GLAZING WITH A HORIZONTAL OVERHANG LOCATED ABOVE THE GLAZING AND EQUAL IN LENGTH TO ROUGHLY ONE-FOURTH THE HEIGHT OF THE OPENING IN SOUTHERN LATITUDES (36°NL) AND ONE-HALF THE HEIGHT OF THE OPENING IN NORTHERN LATITUDES (48°NL).[1]

SMALL SCALE PATTERNS

When possible, design shading devices to act as both REFLECTORS (24) to increase solar gain in winter, and as insulating shutters - MOVABLE INSULATION (23) - to reduce building heat loss.

You can also use the BREATHING WALL (30)$_{2,3}$ as a method of shading a large east or west facing wall when vegetation can not be used because of flight and life safety considerations.

ILLUSTRATION

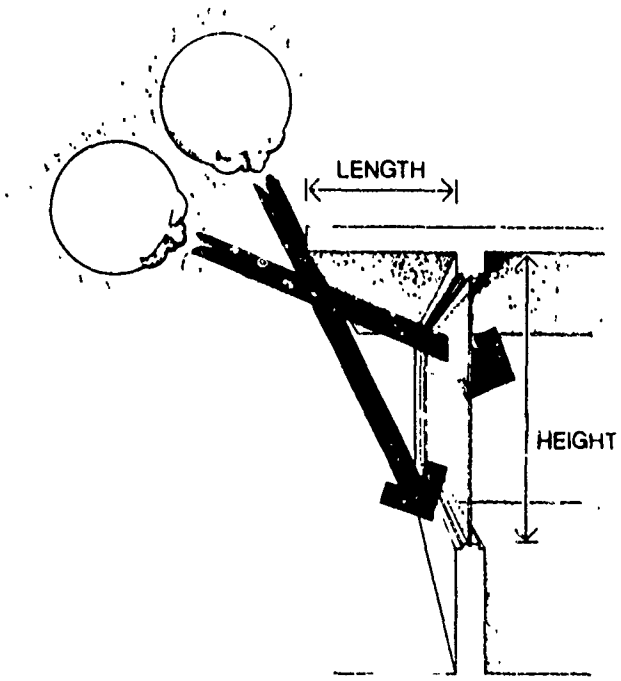


Figure 25-2

INFORMATION

The most effective method for shading south-facing glass in summer is with an overhang. This shading device is simply a solid horizontal projection located at the top exterior of a window. The optimum projection of the overhang from the face of the building is dependent upon window height, latitude and climate. For example, the larger the opening (height) the longer the overhang. At southern latitudes (36°NL) the projection should be slightly smaller than at more northerly latitudes (48°NL), because the sun follows a higher path across the summer skydome. An overhang when tilted up will not only function as a shading device in summer, but also as a reflector in winter.

The following equation provides a quick method for determining the projection of a fixed overhang.

$$\text{Projection} = \frac{\text{Window Opening (Height)}}{F}$$

where

F = Factor from following table

North Latitude	F Factor*
28°	5.6–11.1
32°	4.0– 6.3
36°	3.0– 4.5
40°	2.5– 3.4
44°	2.0– 2.7
48°	1.7– 2.2
52°	1.5– 1.8
56°	1.3– 1.5

NOTE: *Select a factor according to your latitude. The higher values will provide 100% shading at noon on June 21, the lower values until August 1

A fixed overhang is not necessarily the best solution because the sun's movement does not correspond to climatic seasons. As a general rule the heat cycle is one month behind the solar cycle. A fixed exterior shade will provide the same shading on 21 September when it is hot, and on 21 March when it is cold. An adjustable overhang is a potentially better solution.

There are two options for adjustable overhangs: (1) manual adjust (more expensive to build due to additional hardware); (2) automatic adjust (vine-covered, trellised overhang). This second option follows climatic variations and not solar variations, because a vine will be covered with leaves in summer and early fall, and bare in winter and early spring. Periodic thinning of vines is required so they do not grow too thick and shade the glazing in the winter.

Overhangs do not provide adequate protection for east and west facing glass. Trees, climbing vines and hedges should be used to block the low morning and afternoon sun. Adjustable vertical louvers and awnings or retractable exterior curtains are also effective methods of shading east and west glazing.[1]

Figure 25-1 (United States Military Academy Cadet Library) is a good historical example of the use of this pattern. Note the use of trees, vines and adjustable vertical shading devices above the windows.

If winter gains are of the utmost importance, no tree should intercept the winter sun at all. If trees at the site do intercept the sun, their bare branch effect should be accounted for

in the design.[4]

Interior shading devices such as roller shades, venetian blinds, drapes and panels, are a secondary line of defense against heat gain. However, they do offer ease of maintenance and operation. You should also note that interior shading devices often eliminate or severely limit a view of the outside.[1]

You as the programmer should consult with the using agency concerning their preference of shading device. This is necessary because they will ultimately be responsible for the operation of the system on a daily basis, as seen in Figure 25-1 with the adjustable Shading Devices on the USMA Library.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa., 1979. pp250-257.

2. "Breathing Wall of Brick and Tile - New Masonry Conception," Brick and Clay Record, 1943. pp 14-16 (about building #3001 at Tinker AFB, Oklahoma).

3. Stanley H. Scofield, Capt USAF. "A Historical Review of Natural Ventilation in a Humid Climate", 4th National Passive Solar Conference Proceedings, Kansas City, Mo, October 3-5, 1979.pp 504-506 (See Appendix E).

4. Thomas M Holzberlein. "Don't Let the Trees Make a Monkey of You," 4th National Passive Solar Conference Proceedings Kansas City, Mo., October 3-5, 1979.pp 416-419 (See Appendix P).

SOURCES OF ILLUSTRATIONS

Figure 25-1 East Facade of U.S. Military Academy (USMA) Library Circa 1910, compliments of USMA Archives, West Point, N.Y.

Figure 25-2 Reference 1 p.251.

26. INSULATION ON THE OUTSIDE



Figure 26-1

LARGE SCALE PATTERNS

This pattern completes MASONRY HEAT STORAGE (13) and INTERIOR WATER WALL (14). It describes methods for keeping heat stored in an interior thermal mass from escaping rapidly to the outside.

THE PROBLEM

THE AIR FORCE HAS NUMEROUS MASONRY BUILDINGS WITH INSULATION ON THE INSIDE FACE OF THE WALL. THIS CONDITION DOES NOT ALLOW THE STRUCTURE TO ACT AS A SITE PROVIDED NATURAL RESOURCE FOR STORING HEAT AND COOLTH.

THE RECOMMENDATION

WHEN YOU RETROFIT A MASONRY BUILDING, RELOCATE THE INSULATION ON THE EXTERIOR SURFACE OF THE MASONRY AND PROVIDE A NEW WEATHER - PROOF EXTERIOR SURFACE TO PROTECT THE INSULATION. ALSO AT THE PERIMETER OF THE FOUNDATION WALLS, APPLY APPROXIMATELY 1½ TO 2 FEET OF 2 INCH RIGID WATERPROOF INSULATION BELOW GRADE. THIS WILL PREVENT ANY HEAT STORED IN THE WALLS AND FLOOR FROM BEING CONDUCTED RAPIDLY TO THE OUTSIDE.

SMALL SCALE PATTERNS

If possible, use locally available insulation made of recycled materials, which consumes small amounts of energy to manufacture - APPROPRIATE MATERIALS (10).

If you have a large east or west facing wall, and you can

not grow vines on it or trees near it as a SHADING DEVICE (25) for flight and life safety reasons, then you should consider using the BREATHING WALL (30).[2,3] It will reduce heat transfer to the interior surface of a masonry building.

You must also use SUMMER COOLING (27) to convert your masonry into a summer coolth storage media.

ILLUSTRATION

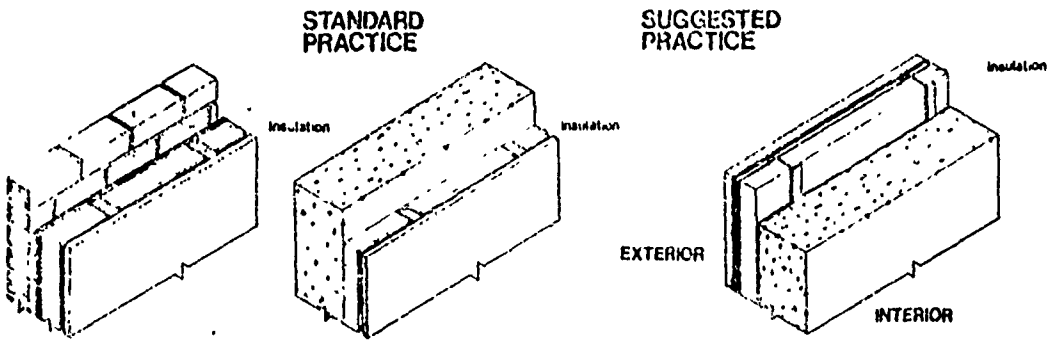


Figure 26-2

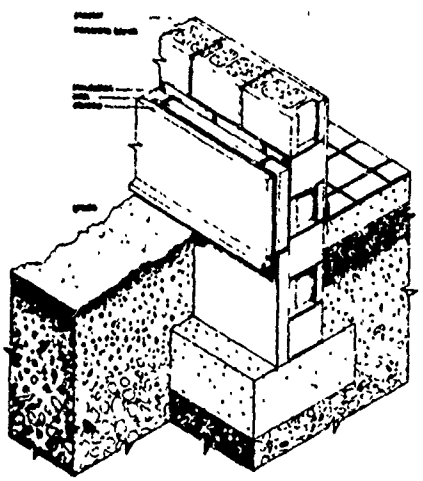


Figure 26-3

INFORMATION

If your building is a masonry building, then the application of this pattern is essential. It probably will be one of

the most cost-effective actions you can take.

THE MASONRY SHOULD BE CONSIDERED AS A SITE PROVIDED NATURAL RESOURCE (energy has been expended to manufacture, transport and construct). YOUR TASK IS TO MAKE IT WORK FOR YOU BY CONVERTING IT INTO A HEAT AND COOLTH STORAGE MEDIA.

The concept is to encapsulate all thermal mass inside of insulation so it can store heat in the day and release it to the space at night. In the winter, the use of MOVABLE INSULATION (23) allows the heat to be retained at night, thus stabilizing heat fluctuations. And during the summer you must use SUMMER COOLING (27) to dissipate the stored heat to the cool night air, and thus store "coolth" in the masonry.

Besides reducing winter night heat losses and summer day heat gains it will reduce the collector area required to heat the space.

After relocating the insulation to the exterior surface of the masonry, you can add water volumes in the interior spaces to increase the thermal mass, as recommended in INTERIOR WATER WALL (14).

NOTE : There is one exception to this rule. In sunny temperate winter climates, south-facing masonry walls with a dark to medium-dark exterior surface color can be left uninsulated, since the south wall absorbs enough sunlight (heat) during the daytime to offset any heat flow out through the wall at night. If your building meets the criteria for this exception to the pattern, then if it is used, it should be identified on the Passive Solar-Building Concept Diagram in the building facilities jacket. This will, hopefully, preclude changing the thermal performance of a building by changing the exterior color of the building to a lighter from a darker color.

REFERENCES

1. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition, Rodale Press, Emmaus, Pa., 1979.pp259-261.

2. "Breathing Wall of Brick and Tile - A New Masonry Conception," Brick and Clay Record, 1943. pp.14-16 (About building #3001 at Tinker AFB, Oklahoma) See Appendix S.

3. Stanley H. Scofield, Capt. USAF, "A Historical Review of Natural Ventilation in a Humid Climate," 4th National Passive Solar Conference Proceedings, Kansas City, Mo., October 3-5, 1979. pp 504-506 (See Appendix E).

SOURCES OF ILLUSTRATIONS

Figure 26-1 Fuller Moore's House for All Seasons - Solargreen-photo by Captain Stanley H. Scofield, May 1979.

Figure 26-2 Reference 1 p.261.

Figure 26-3 Reference 1 p.260

27. SUMMER COOLING

LARGE SCALE PATTERNS

This pattern is the starting point for a series of conceptual patterns that have very few quantifiable rules of thumb. As more experiments are conducted, quantifiable rules of thumb will be developed.

While evaluating your windows for winter solar gain - WINDOW LOCATIONS (8), SOLAR WINDOWS (11) and CLERESTORIES AND SKYLIGHTS (12) and considering possible changes, you must think of windows as summer breeze catchers for cooling.

THE PROBLEM

IF A PASSIVE SOLAR SYSTEM IS DESIGNED PROPERLY, IT WILL GIVE YOU THE POTENTIAL TO PROVIDE BOTH NATURAL HEATING AND NATURAL COOLING, IN CLIMATES WITH COOL OR COLD WINTERS AND WARM SUMMERS. YOU SHOULD NOT OVERLOOK YOUR OPPORTUNITY TO UTILIZE YOUR PASSIVE SOLAR RETROFIT FOR SUMMER COOLING. EVERY PASSIVE SOLAR RETROFIT MUST HAVE TWO ESSENTIAL BUILDING ELEMENTS: 1) SOUTH-FACING GLAZING FOR HEAT GAIN; 2) THERMAL MASS FOR HEAT STORAGE. FOR SUMMER COOLING, THE MASS IS EXPOSED TO THE NIGHT SKY AND NATURAL BREEZE TO LOOSE HEAT - "COOLTH STORAGE"[1] - AND THE MASS ABSORBS AND STORES HEAT AS THE DAY PROGRESSES.[1] WHEN PROPERLY DESIGNED, THE GLAZING AND THERMAL MASS WILL PROVIDE THE POTENTIAL FOR BOTH HEATING AND COOLING. IF SUMMER COOLING CONSIDERATIONS ARE NEGLECTED, THE GLAZING AND THERMAL MASS CAN WORK TO INCREASE HEAT GAIN AND STORAGE AT A TIME WHEN IT IS NOT WANTED, THUS CAUSING UNCOMFORTABLE INTERIOR CONDITIONS.

THE RECOMMENDATION

MAKE THE ROOF A LIGHT COLOR OR REFLECTIVE MATERIAL.

HOT DRY SUMMERS:

1. OPEN THE BUILDING UP AT NIGHT (OPERABLE WINDOWS OR VENTS) TO VENTILATE AND COOL INTERIOR THERMAL MASS.[3]
2. ARRANGE LARGE OPENINGS OF ROUGHLY EQUAL SIZE SO THAT INLETS FACE THE PREVAILING NIGHTTIME SUMMER BREEZES AND OUTLETS ARE LOCATED ON THE SIDE OF THE BUILDING DIRECTLY OPPOSITE THE INLETS OR IN THE LOW PRESSURE AREAS ON THE ROOF AND SIDES OF THE BUILDING.[3]
3. CLOSE THE BUILDING UP DURING THE DAYTIME TO KEEP THE HEAT OUT.[3]
4. USE WIND SCOOPS AND INDOOR WATER FOUNTAINS TO INDUCE EVAPORATIVE COOLING.[4&6]

5. Use EARTH TUBES (28) for INDUCED EVAPORATION (33).[1,2,4,6,]

6. Building shape and configuration should make the building act as a flue ("stack effect")[2].

7. USE A BREATHING WALL (30)[5] AS A SHADING DEVICE (25).

HOT HUMID SUMMERS:

1. OPEN THE BUILDING UP TO THE PREVAILING SUMMER BREEZES DURING THE DAY AND EVENING.[3]

2. ARRANGE INLETS AND OUTLETS AS OUTLINED ABOVE, ONLY MAKE THE AREA OF THE OUTLETS SLIGHTLY LARGER THAN THE INLETS.[3]

3. USE EARTH TUBES (28) TO REMOVE MOISTURE.[1,2,6,8]

4. USE A SOLAR CHIMNEY (31) TO INDUCE VENTILATION THROUGH THE SPACE AND THE EARTH TUBES (28).[1,2,6,8]

5. USE A SOLAR DEHUMIDIFIER (32) TO REMOVE MOISTURE.[7]

6. BUILDING SHAPE AND CONFIGURATION SHOULD MAKE THE BUILDING ACT AS A FLUE ("stack effect").[1]

7. USE A BREATHING WALL (30).[5]

SMALL SCALE PATTERNS

All glazed openings must be shaded in the summer - SHADING DEVICES (25) and selectively use vegetation for both wind protection in the winter and summer shading.

You should also consider the use of EARTH TUBES (28), KING VENTILATION SYSTEM (29), BREATHING WALL (30) SOLAR CHIMNEY (31), SOLAR DEHUMIDIFIER (32) INDUCED EVAPORATION (33), ZONING (34) and DIURNAL FLUSHING (35).

You can use Table 27-1 as a rule of thumb for selecting cooling options, and it can be used to conjunction with Tables 9B, 9C, and 9D to choose a system that will be suitable for heat and cooling.

ILLUSTRATION:

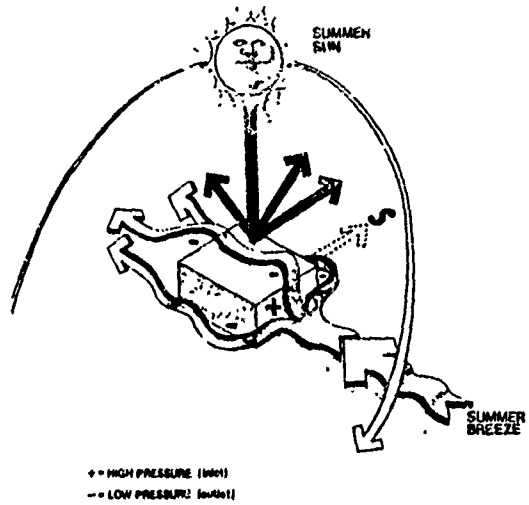


Figure 27-1

INFORMATION

There are nine natural cooling options available for introducing coolness into your building with little or no mechanical assistance: Heat Gain Control, Microclimate, Natural Ventilation, Induced Ventilation, Evaporative Cooling, Desiccant Cooling, Night Sky Radiation, Time Lag Cooling and Earth Cooling.

YOUR TASK IS TO WORK WITH THE USING ORGANIZATION TO SELECT THE APPROPRIATE MIX OF COOLING OPTIONS TO KEEP THE USER COOL, NATURALLY.

This pattern presents information about the basic passive cooling options, and proposes design strategies with a listing of appropriate patterns to accomplish the cooling option (see Table 27-1), while satisfying the four comfort variables (air temperatures, air movement, humidity, and mean radiant temperature).

Heat Gain Control

Controlling the heat your building gains from its environment is what Summer Cooling is all about. Better yet, passive heating has the same requirement, and allows the user to heat and cool using the sun. The relation between passive heat and cooling is crucial. KEEPING UNWANTED HEAT OUT IN THE SUMMER AND DRAWING IT IN DURING THE WINTER ARE ISSUES THAT SHOULD - IN FACT, MUST- BE ADDRESSED HAND IN HAND, FOR THE SIMPLE REASON THAT IN EITHER CASE THE ARCHITECTURE ITSELF IS THE CLIMATIC-CONTROL MECHANISM.[1,2,8]

The Microclimate

A good passive cooling strategy pays as much attention to the microclimate surrounding the building as the building itself. Landscaping and vegetation can have a tremendous impact on natural comfort inside the building, affecting both summer cooling and winter heating loads. The general effect in an area of massed vegetation is to keep temperatures in the shade a good 10^0-15^0F lower than ambient temperature. This is particularly valuable phenomenon, if the cooler air can be drawn into the building by the thermal chimney action of a vented MASONRY HEAT STORAGE WALL (13) or a vented greenhouse - GREENHOUSE CONNECTION (18).

Massed earth on the North Side (5) makes a good wind break.[1,2,8]

Natural Ventilation

The cooling value of air movement lies in the capacity to evaporate perspiration from the body which allows you to feel cool. The Antebelum architecture of the Southeastern United States was designed to catch the breezes from the ocean. Those breezes are so powerful they have generated an indigenous architectural style - Geographic Determinism(1).

In a dry climate - lower than 20% relative humidity- the same process can dehydrate the body. Evaporative cooling - induced Evaporation (33) - should be used in a dry climate to prevent dehydration.

If your building is in an area where ventilation is a wise cooling option, you should capitalize on your buildings exposure to the wind. You should also use louvered openings, vents, transomed windows, windowed walls, and planned for through-ventilation.[1,2,8]

Induced Ventilation

You can modify your building so ventilation is induced if there is not enough wind for natural ventilation. By using the sunlight to heat an isolated pocket of interior air to greater than ambient temperatures and controlling its escape, a building can generate air circulation and maximize the influx of cooler air.

The most effective application of this natural law is a SOLAR CHIMNEY (31), a solar-exposed enclosure tall enough to generate maximum air flow and massive enough to retain heat and power the system into the evening hours. The optimum system draws its replacement air from the coolest possible location, a planted, shaded area to the north or an underground

EARTH TUBE (28).

Other solar design elements usually associated with passive heating - THERMAL STORAGE WALL (9B), ATTACHED GREENHOUSE (9C) and CONVECTIVE LOOP (9E) can also be used for the same cooling effect.[1,2,5,6,8]

Evaporative Cooling

Swamp coolers, fountain courts and atrium pools are applications of evaporative cooling. This cooling option is very effective in a hot and relatively dry space, because water evaporates into the air and increases humidity. Sensible heat turns into latent heat, and lowers the air temperature.

The evaporative cooling option - Induced Evaporation (33) - should be joined with ventilation for the most efficient distribution of cool, humidified air - EARTH TUBES (28) and KING VENTILATION SYSTEM (29).[1,2,6,8]

Desiccant Cooling

In regions of high humidity, where moisture in the air actually prevents the body from cooling itself evaporatively, dessicant cooling is a valued traditional strategy. Before energy was harnessed and plentiful, dessicant salts were effective coolers, but needed to be thrown out when they were saturated.

Passive cooling in regions of high humidity remains a problem today, and desiccant solutions remain the focus of research and design experimentation.

More information is presented in SOLAR DEHUMIDIFICATION (32) [1,2,7,8,9,10]

Night Sky Radiation

Radiative cooling involves exposing interior spaces to the heat sink of a thermal mass, and exposing the mass to the planetary heat sink of cool, clear night sky. The mass absorbs heat from the interior during the day and releases it to the sky dome. This cooling option is most effective where the diurnal (day-night) temperature swing is in excess of 20°F and where the night sky is relatively clear.

Historically the puebloes and Spanish Missions of the Southwest are an example of this cooling option. However, since the development of Skytherm$_{TM}$ (roof pond water bags) by Harold Hay, research and performance experiments have focused on water as the radiative mass.

The efficacy of this cooling option is increased by sprinkling water on the roof top water containers to add evaporative cooling to the radiative effect.[8]

Time Lag Cooling

Like radiative cooling, time lag cooling takes advantage of the thermal absorption, reduction, and lag characteristics of mass, and requires the same 20-35°F diurnal temperature swing to be effective. Where the conditions are right, time lag cooling has been around for centuries.

The principle is that the transmission of heat through mass - stone, concrete, adobe - is both delayed and attenuated over time. Depending on the material and the thickness of a massive wall, the delay can stretch from two to 12 hours, and the greater the lag the greater the attenuation of heat transmitted. Thus less heat reaches the interior spaces, and it doesn't arrive until late evening or night, when ambient temperatures have dropped and the exterior wall is radiatively cooling. By night's end the wall is again, a cold barrier to the daytime onslaught of insolation. Exterior sheathing, insulation, or shady vegetation will add to that barrier, further flattening the diurnal curve that ironically is both the nemesis of comfort where time lag strategies are appropriate, and the key to the time lag cooling effect.[8]

Earth Cooling

The earth is where man first sought shelter for a good reason; ground temperatures remained stable at around the average annual air temperature, usually in the range of 50-60°F. The earth attenuates extreme air temperatures, and acts as a maximal time lag device, carrying winter coolness well into late spring, and summer warmth into late fall.

Earth Cooling can be accomplished be earth-integrated construction and/or earth tubes, and/or rock-filled air passages.

The field is undergoing considerable research and experimentation aimed at defining and overcoming difficulties, and quantifying the feasibility of numerous earth-cooling design strategies.[1,2,6,8,11 and 12.]

Summary

Your task as a programmer is to educate and work with the using organization to select the appropriate mix of cooling options to keep the user cool, naturally. This can be done by making the architecture introduce coolness into the building with little or no mechanical assistance.

You can use Table 27-1 in conjunction with Tables 9B, 9C and 9D (Summer Ventilation) to select a system and group of patterns that will meet both heating and cooling requirements for your building type.

REFERENCES

1. David Wright, AIA. "Natural Solar Cooling" 3rd National Passive Solar Conference Proceedings, San Jose, Ca., January 11-13 1979. p 512-517.

2. David Wright, AIA. Natural Solar Architecture - A Passive Primer, Van Nostrand Reinhold Company, 1978 pp 194-195, 210,232-233, 164, 186-197.

3. Edward Mazria. The Passive Solar Energy Book - Expanded Professional Edition , Rodale Press, Emmaus, Pa. 1979. pp 262-266.

4. Mehdi N. Bahadori. "Passive Cooling Systems in Iranian Architecture," Scientific American, February 1978.

5. Stanley H. Scofield, Capt. USAF. A Historical Review of Natural Ventilation in a Humid CLimate", 4th National Passive Solar Conference Proceedings, Kansas City, Mo. October 3-5 1979. pp 504-506.

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Figure 27-1 Reference 3 p. 263.

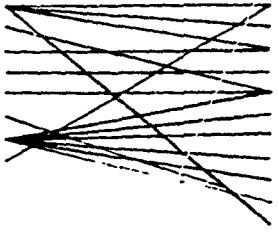
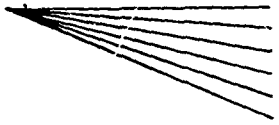
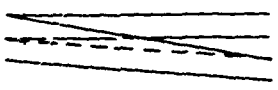
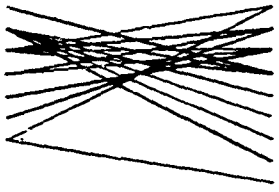
COMFORT VARIABLE	COOLING OPTION		DESIGN STRATEGY	SUGGESTED PATTERNS
Air Temperature	Heat gain control Natural ventilation Time lag/attenuation Radiative loss Conductive loss Humidification Induced ventilation Microclimate		Shading Earth-tempered structure Thermal massing/insulation Night sky radiation Earth-air heat exchange Solar/thermal chimney Solar/trombe wall Solar/direct gain Solar/isolated gain (greenhouse) Evaporative cooling Vegetation/land massing	1,4,25,30 & Appendix P 1,4,5,26 &26 1,4,9,23,26 & 28 4,9B,9D, 19 & 20 4,9B,9C,28,29 & 31 4,9B,9C,28,29 & 31 9B,13,15,16,23,24,28,29 &31 4,9A,11,12,23,24,28,29 & 31 9C,17,18,23,24,28,29 & 31 4,28,29 & 33 1,3,4 &25
Air Movement	Induced ventilation		Solar/thermal chimney Solar/trombe wall Solar/direct gain Solar/isolated gain Earth-air heat exchange Zoning	4,9B,9C,28,29 & 31 9B,13,15,16,23,24,28,29 & 31 4,9A,11,12,23,24,28,29 & 31 9C,17,18,23,24,28,29 & 31 4,9B,9C,28,29 & 31 2,3,4,6 & 34
Humidity	Humidification Dehumidification Microclimate		Evaporative cooling Desiccation Earth-air heat exchange* Vegetation/land massing	4,28,29 & 33 32 4,9B,9C,28,29 & 31 1,3,4 & 5
Mean radiant temperature	Heat gain control Natural ventilation Induced ventilation Time lag/attenuation Radiative loss Conductive loss Microclimate		Shading Earth-tempered structure Thermal massing/insulation Diurnal air flushing Solar/thermal chimney Solar/trombe wall Solar/direct gain Solar/isolated gair Vegetation/land massing	1,4,25,30 & Appendix P 1,4,5,26 & 28 1,4,9,23,26 & 28 11,12,28,29,31 &35 4,9B,9C,28,29 & 31 9B,13,15,16,23,24,28,29 & 31 4,9A,11,12,23,24,28,29 & 31 9C,17,18,23,24,28,29 & 31 1,3,4 & 25

TABLE 27-1 COOLING SYSTEM SELECTION

*Earth-air heat exchange will only dehumidify if the ground temperature is less than the dew point.

28. EARTH TUBES

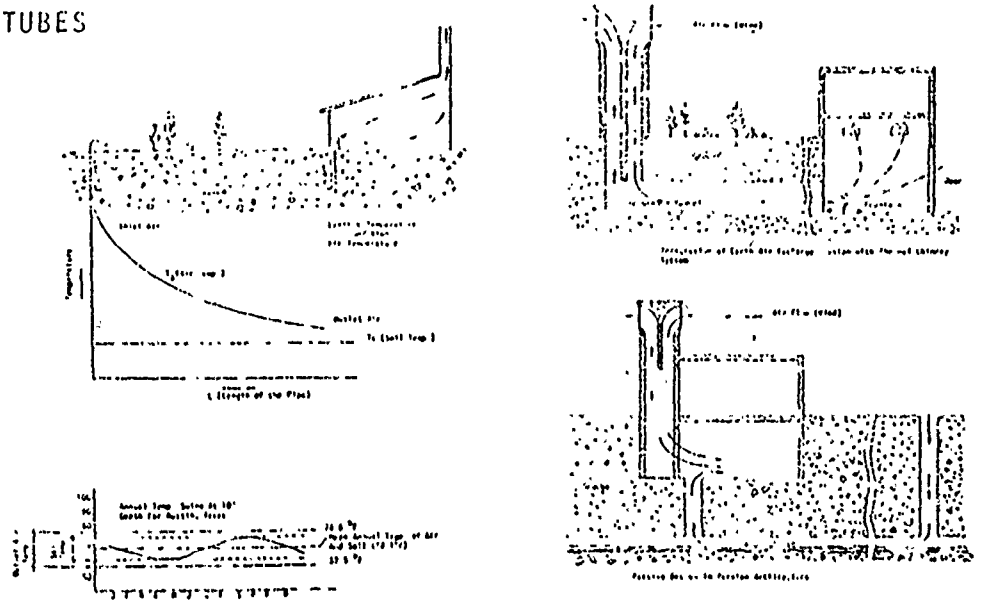


Figure 28-1

LARGE SCALE PATTERNS

Using the ideas of SUMMER COOLING-EARTH COOLING (27) and the requirement for building ventilation - Tables 9B, 9C, and 9D - this pattern is the starting point for providing earth tempered ventilation for your building.

THE PROBLEM

THE EARTH AROUND YOUR BUILDING IS A PASSIVE SOLAR SYSTEM YOU CAN USE AS A HEAT SOURCE/SINK FOR YOUR BUILDING S RETROFIT.[1,2]

THE RECOMMENDATION

USE EARTH TUBES AS METHOD OF PROVIDING EARTH TEMPERED (WARMED IN WINTER; COOLED AND DEHUMIDIFIED IN SUMMER) VENTILATING AIR FOR YOUR BUILDING. THE DAILY TEMPERATURE FLUCTUATIONS OF EARTH IS MUCH SMALLER THAN AIR, AND AT A DEPTH OF 8 TO 10 FEET BELOW THE SURFACE, THE AVERAGE EARTH TEMPERATURE APPROXIMATES THE YEARLY AVERAGE AMBIENT AIR TEMPERATURE OF A GIVEN LOCATION WITH A SMALL DEVIATION.[1,2]

SMALL SCALE PATTERNS

You can combine this pattern with KING VENTILATION SYSTEM(29), SOLAR CHIMNEY (31) and SOLAR DEHUMIDIFIER (32) to complete the ventilation of your building. This combination of patterns will allow the ventilation of large buildings at night without security problems.

ILLUSTRATION

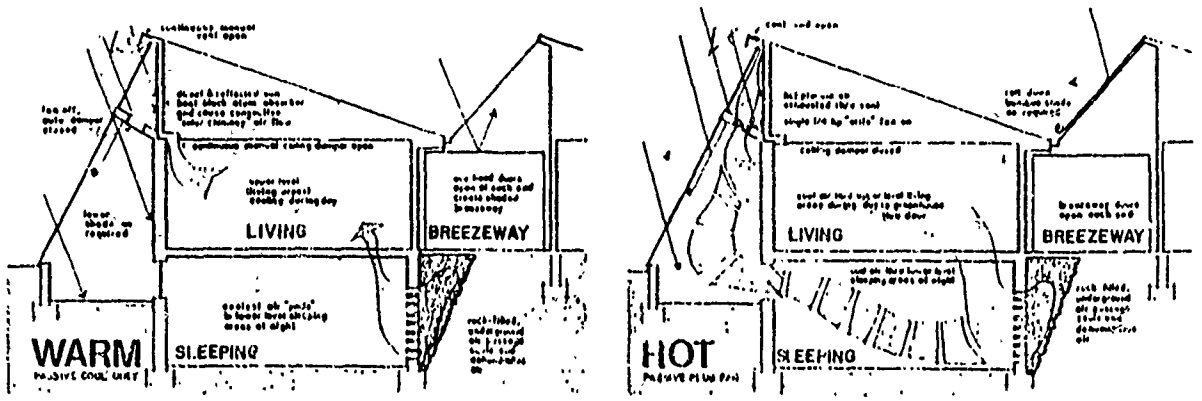


Figure 28-2

INFORMATION

SUMMER COOLING/EARTH COOLING (27) mentioned three methods of Earth Cooling: earth-integrated construction, earth tubes and rock filled air passages.

This pattern will look at the last two methods (earth tubes and rock filled air passages) under the title of EARTH TUBES. This pattern will not look at Earth-integrated architecture because of its limited retrofit potential and probable structural limitations.

The earth tube and rock filled air passages methods are combined in this pattern because their earth-air heat exchange concepts are similar.

An Earth Tube (an Earth-Air Heat Exchange System - names are often used interchangably) is simply a buried pipe through which air is forced. The use of earth as a heat source/sink, with a buried pipe(s) or underground tunnel as a direct heat exchanger, can be traced as far back as 1875 in the United States, and centuries for Persian Architecture - INDUCED EVAPORATION (33).

It is a legitimate solar system, because geothermal temperature gradients do not effect soil above approximently 30 feet. It is chiefly dependent on air temperature, surface soil temperature, thermo-physical properties of soil, ground-water cycles, and depth. The first two variables are solar driven; while the third and fourth variables are mainly dependent on local geology. The fifth variable will be determined by the designer.[2]

This method of cooling, using the stable temperature of the earth's mass to absorb heat from the air passing through the tubes, also has the potential for adding or removing humidity. Gently downward - sloping tubes of proper diameter and length allow cooling air to fall slowly. As the air temperature reaches the dew point of its moisture content, water will condense out. This condensate should be allowed to drain out of the airstream at the point near the bottom end of the tube. A water wick or pan at the same location could add moisture, if humidification is desired INDUCED EVAPORATION (33).

All tubes should be constructed of clay tile or noncorrosive metal. Inlet vents should be screened and placed on the north side or in a well shaded area.[8]

The first documented earth tube research was started in 1963 at Cornell University. Figure 28-3 shows its performance in September 1965. One of the major discoveries was that addition of water to dry soil produces a significant increase in thermal conductivity and may cause the thermal diffusivity to be 2 to 3 times the dry soil.[1,2]

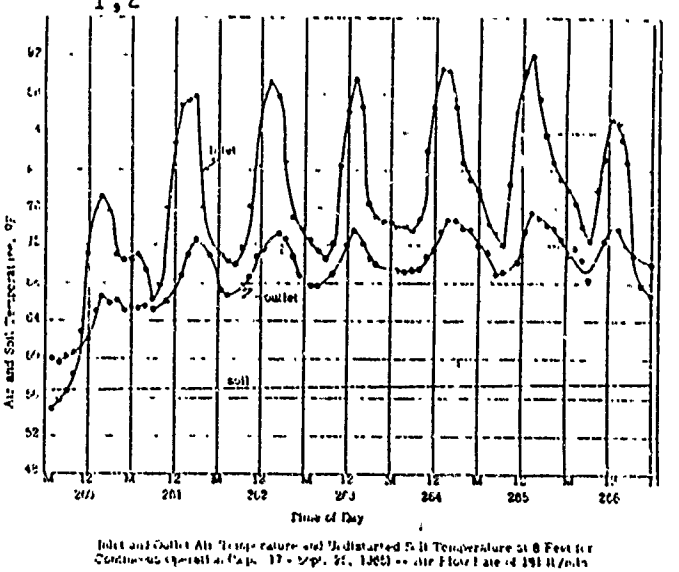


Figure 28-3

At this time there is only one company - LPC (The Lords Power Company, Inc.) that installs earth tubes commercially. Their systems have been designed for agricultural buildings and their system sizing is proprietary.

Other researchers are working on rules of thumb for sizing earth tubes for cooling and ventilating people spaces. When they are available, this pattern must be updated.

The other method - rock filled air passages - was developed independently by George Cristy, and Fuller Moore (see Appendix R). This method uses a rock bed around the foundation of the building.

Fuller Moore's house was completed in September 1979 and has not been put into operation. (see Appendix L).

George Christy's paper (reference 3) presents the following conclusions about the heat transfer process of his system.

> The optimum performance of the rock bed and adjacent soil will be obtained by:
>
> a. Designing and operating the earth fill outside the rock bed at the highest practical value of thermal diffusivity and heat capacity;
>
> b. Maintaining the flow rate at the minimum value necessary to provide adequate ventilation; and
>
> c. Increasing the flow rate during summer backflushing periods.
>
> Under conditions of average values of the heat transfer properties, the rock bed can supply 55% of the heating load required to heat the ventilation air in winter. The resultant cooling of the rock and soil plus utilization of the diurnal cycle will furnish 66% of the cooling needed to dehumidify the ventilation air in summer. The remainder of the heat needed in winter can easily be made up by the passive solar heat received during the day.

Summary

The use of Earth Tubes as a retrofit system has good potential for the following reasons:

1). Earth Tubes use the earth as a heat source/sink for year round use.

2). The earth tempers the ventilating air for the building.

3). Earth Tubes can be used for dehumification or evaporation of the incoming ventilating air.

4). The system is exterior to the building.

5). It has little or no effect on the visual environment.

6). The sun can be used as the motive force for the earth tubes to increase the efficiency of the system (See Table 27-1/Induced Ventilation for design strategies and suggested patterns).

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8. Kevin W. Green. "Passive Cooling". Research and Design - The Quarterly of the AIA Research Corporation, Vol II, no.3 Fall 1979. pp. 5-9. (See Appendix Q).

9. Techniques for Energy Conservation (AFCEC-TR-77-12) p.C-43/53. Distributed through AF/PRE, 1 July 1977.

SOURCES OF ILLUSTRATIONS

Figure 28-1 Reference 2 p 148

Figure 28-2 Reference 6

Figure 28-3 Reference 1 (No page number)

29. KING VENTILATION SYSTEM

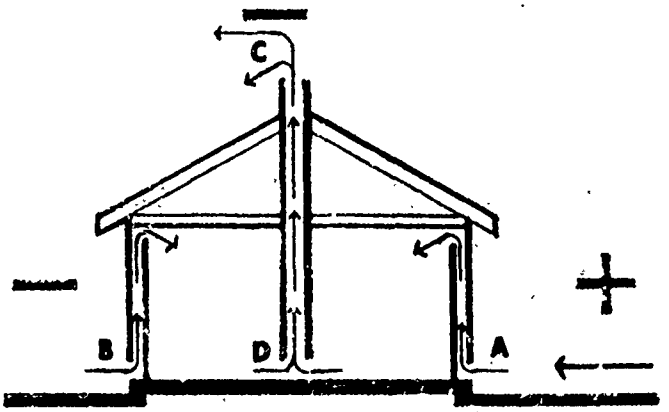


Figure 29-1

LARGE SCALE PATTERNS

With ventilation being a year around building requirement, and especially for SUMMER COOLING (27), the King Ventilation System is a method of providing natural ventilation. This system was developed by Professor F.H. King (Professor of Agricultural Physics - University of Wisconsin). It was first used in a cow barn built in 1889, in Whitewater, Wisconsin. The system allows fresh air to be taken into a building without chilling the interior or creating a draft.

THE PROBLEM

THE VENTILATION PROBLEM THAT MUST BE SOLVED IS HOW TO MAINTAIN THE AIR OF THE BUILDING AT THE NORMAL OUT-OF-DOOR FRESH AIR PURITY WITH PRACTICAL ECONOMY AND WITHOUT DRAFTS AT THE FLOOR.[1]

THE RECOMMENDATION

IF ADDITIONAL VENTILATION IS REQUIRED, NATURAL VENTILATION CAN BE INDUCED BY TAKING AIR OUT AT THE FLOOR LEVEL AND LETTING IT IN AT THE CEILING. THIS MANAGEMENT OF AIR CURRENTS CREATES CIRCULATION NECESSARY FOR VENTILATION BY REMOVING ONLY THE COLD AND CARBON DIOXIDE LADEN AIR, AND FORCES THE WARM AIR TO REMAIN IN THE BUILDING, WHILE AVOIDING DRAFTS AND DANGER OF DISCOMFORT. FOR SUMMER OPERATION, AN ADDITIONAL OPENING HIGH IN THE ROOM SHOULD BE PROVIDED TO REMOVE HOT AIR AND REINFORCE THE DRAFT.[2]

SMALL SCALE PATTERNS

You should combine the King Ventilation System with EARTH TUBES (28), SOLAR CHIMNEY (31), INDUCED EVAPORATION (33) and DIURNAL FLUSHING (35).

ILLUSTRATION

See Figure 29-1.

INFORMATION

As mentioned in SUMMER COOLING (27), there are two natural forces for moving air through a building: 1) wind pressure; 2) temperature difference between indoor and outdoor - "Stack Effect". The King Ventilation System uses both as motive forces.

Ventilating air enters through openings at A & B and leaves at D. This is caused by direct wind pressure exerted at A & B and section effect developed at C.

Drafts are avoided by placing the fresh air intake (outside) at some distance below the fresh air outlet (inside) - see figure 29-1. This arrangement is fundamental because it is the only way to prevent the escape of the warmest air through such an opening on the leeward side of the building. Without this provision it would be like opening a window at the top on the other side of the room.

The flow of air through the building resulting from wind pressure and suction will be most rapid when the wind is permitted to reach the building at A and pass over the roof at C with the least obstruction.[3]

The flat roof (built up), which has been popular in "Modern Architecture", does not provide the physical form to accomodate two building functions: 1) physical form to generate wind suction for ventilation; 2) physical form to create positive water drainage from roof. Therefore, for retrofit of buildings with flat roofs, consideration should be given to providing a new sloped roof, which will generate suction for ventilation, and reduce roof maintenance problems (created by clogged roof drains and pooling of water and ice). This is an important consideration because it is generally true that the suction effect of the wind is stronger than direct wind pressure. The ventilating flue should be above the ridge of the roof, where the wind will sweep. The flue should not be at the eaves.[4]

This system could also be considered for retrofit of above ground fallout shelters, and combined with EARTH TUBES (28), MASONRY HEAT STORAGE (13) and SOLAR CHIMNEY (31) to provide a solar induced ventilation system to remove carbon dioxide and draw in earth tempered oxygen. SOLAR DEHUMIDIFICATION (32) can be added in humid climates.

The King Ventilation System design should be based on "Stack Effect" - temperature differential - because ventilation due to direct wind pressure is not always available. The approximate rate of air exchange when the inlet area is equal to the outlet area can be expressed as:[5]

$$Q = 540A\sqrt{H(t_i - t_o)}$$

where

Q = rate of air flow, cu ft/hr

A = area of inlets, sq ft

H = height between inlets and outlets, ft

t_i = average temperature of indoor air at height H, °F

t_o = temperature of outdoor air, °F

This expression requires adjustment in cases when the area of outlets is appreciably different from the area of inlets according to the following ratios:

Area of outlets / Area of inlets	Value to be substituted for 540 in above expression
5	745
4	740
3	720
2	680
1	540
3/4	455
1/2	340
1/4	185

TABLE 29-1

REFERENCES

1. Professor F.H. King. Ventilation For Dwellings, Rural Schools and Stables. Published by Author, 1908. p. 41.

2. Ibid. p. 73 & 113

3. Ibid. p. 50

4. Ibid. p. 51

5. Victor Olgyay. Design with Climate-Bioclimatic Approach to Architectural Regionalism. Princeton University Press 1962. pp 110-112 (Appendix). and British Building Research Station Data.

SOURCES OF ILLUSTRATIONS

TABLE 29-1 Reference 5. p. 212.

31. SOLAR CHIMNEY



Figure 31-1

LARGE SCALE PATTERNS

This pattern is a HISTORICAL BUILDING TYPE SOLUTION (4) for SUMMER COOLING INDUCED VENTILATION (27).[1,2]

THE PROBLEM

VENTILATION MUST BE INDUCED BY THE BUILDING WHEN IT IS HOT AND THERE IS NOT ENOUGH WIND FOR NATURAL VENTILATION.

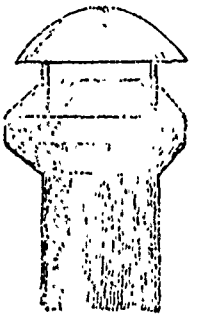
THE RECOMMENDATION

USE A SOLAR CHIMNEY (plenums, flues or black boxes) PAINTED A "DARK COLOR AND EXPOSE IT TO THE FREE ACTION OF THE SUN'S RAYS".[1,2] THE CHIMNEY IS SELF-BALANCING; THE HOTTER THE CHIMNEY AND THE FASTER THE AIR MOVEMENT.[3]

SMALL SCALE PATTERNS

Combine with EARTH TUBES (28) and KING VENTILATION SYSTEM (29) to provide earth tempered ventilating air. It can also be combined with a SOLAR DEHUMIDIFICATION (32).[5]

ILLUSTRATION



The tops may be of thin metal painted a dark colour, and exposed to the free action of the sun's rays. The upper cap prevents down blasts of air, but in a steady horizontal wind the lower cone alone would be sufficient.

Figure 31-2

INFORMATION

The solar chimney shown in figure 31-2 is an example of a Simple Solar Chimney (dark metal flue) used prior to 1850 to induce ventilation in hospitals. As the dark metal chimney gets hot during the day, the air inside heats, expands and rises. In this process it pulls interior air up and out. The advantage of the solar chimney is its ability to self balance; the hotter the day the hotter the chimney and the faster the air movement.[2,3]

You can use table 31-1 to approximate the rate of air exchange when the inlet area is equal to the outlet area.[4]

Variations of the Simple Solar Chimney are the Glazed Chimney, Glazed Chimney with Storage, Summer Solar Vent and the Summer Mass Wall Vent-MASONRY HEAT STORAGE (13).[3] This last variation on the solar chimney has several advantages:

1. The MASONRY HEAT STORAGE WALL (13) functions as a winter heating system.

2. The thermal storage mass behind the glazing will actually store daytime heat, and continue to exhaust air after the sun has set, thus inducing night ventilation.[3]

NOTE: If you elect to retrofit a south-facing masonry wall as a combined MASONRY HEAT STORAGE WALL (13) and SOLAR CHIMNEY, then you must provide MOVABLE INSULATION (23) on the interior side of the wall. This will prevent daytime conductive heat gain and radiation to the interior space, and assures good

night ventilation.

If you have a large west-facing wall surface, and have a large afternoon heating load, then you should consider retrofitting the wall with glazing for increased ventilation during the hot afternoon.[3]

$$Q = 540A\sqrt{H(t_i - t_o)}$$

where

Q = rate of air flow, cu ft/hr

A = area of inlets, sq ft

H = height between inlets and outlets, ft

t_i = average temperature of indoor air at height H, °F

t_o = temperature of outdoor air, °F

This expression requires adjustment in cases when the area of outlets is appreciably different from the area of inlets according to the following ratios:

Area of outlets / Area of inlets	Value to be substituted for 540 in above expression
5	745
4	740
3	720
2	680
1	540
3/4	455
1/2	340
1/4	185

TABLE 31-1

REFERENCES

1. Stanley H. Scofield, Capt. USAF. "A Historical Review of Cooling in a Humid Climate," 4th National Passive Solar Conference Proceedings, Kansas City, Mo., October 3-5, 1979. pp 504-506 (See Appendix E).

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5. Fuller Moore, et al. Joseph Central, Gene Willeke. "Duel Desiccant-Bed Dehumidifier with Solar-Heated Regeneration," Proceedings of International Solar Energy Society Congress, Atlanta, Ga., May 28-June 1, 1979.

SOURCES OF ILLUSTRATIONS

Figure 31-1 Passive Solar Buildings. Sandia Laboratories, Albuquerque, N.M., and Livermore, Ca. For the USDOE under Contract DE-AC04-76DP00789. July 1979. p. 195.

Figure 31-2 Reference 2.p 92

Table 31-1 Reference 4.p 212

32. SOLAR DEHUMIDIFICATION

LARGE SCALE PATTERNS

Using the ideas of SUMMER COOLING - DESICCANT COOLING AND EARTH COOLING - (27) and EARTH TUBES (28) you can reduce humidity by using a solar regenerated desiccant cooling system.

THE PROBLEM

IF THERE IS TOO MUCH HUMIDITY IN THE AIR, THE BODY CANNOT BE COOLED, NATURALLY, BY EVAPORATION. DESICCANT SALTS HAVE BEEN USED IN THE PAST, BUT NEED TO BE THROWN OUT WHEN SATURATED. THUS, THE PROBLEM IS TO DEVELOP A METHOD OF REMOVING HUMIDITY FROM THE AIR SO EVAPORATIVE COOLING OF THE BODY CAN TAKE PLACE.

THE RECOMMENDATION

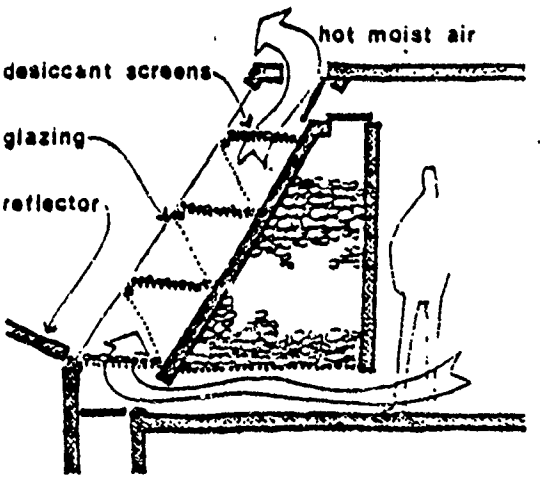
TWO POSSIBLE METHODS OF SOLAR DEHUMIDIFICATION WERE PRESENTED IN A PASSIVE COOLING WORKSHOP AT THE 4th NATIONAL PASSIVE SOLAR CONFERENCE (October 3-5, 1979): PASSIVE SOLAR HEAT PUMP BY H.I. ROBISON AND S.H. HOUSTON OF THE U. OF SOUTH CAROLINA; AND DUAL DESICCANT-BED DEHUMIDIFIER WITH SOLAR-HEATED REGENERATION BY FULLER MOORE, JOSEPH CANTRELL AND GENE WILLEKE OF MIAMI UNIVERSITY, OXFORD OHIO.

BOTH SYSTEMS ARE UNDER DEVELOPMENT AND ARE NOT READY FOR GENERAL APPLICATION.

SMALL SCALE PATTERNS

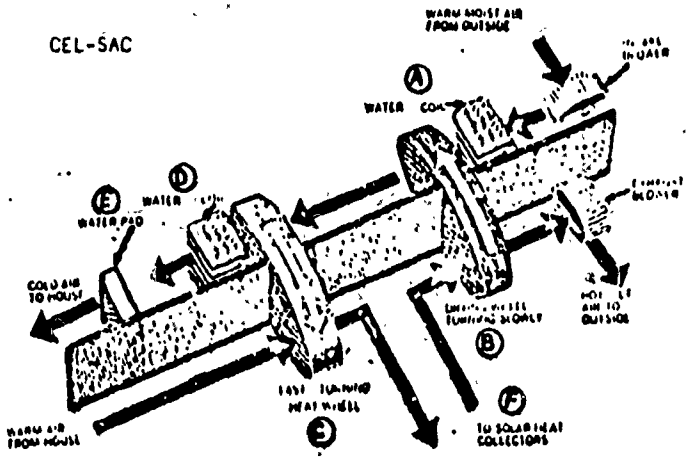
This pattern completes SUMMER COOLING-DESICCANT COOLING AND EARTH COOLING - (27)

ILLUSTRATION



DESICCANT REGENERATION

Figure 32-1



Coastal Energy Laboratory-Solar Air Conditioner

Figure 32-2

INFORMATION

Research in Solar Dehumidification is only beginning. The references about this subject are contained Appendix U. They also contain a more extensive bibliography of references.

REFERENCES

1. Kevin W. Green. "Passive Cooling," Research and Design - The Quarterly of the AIA Research Corporation, Volume II, no. 3, Fall, 1979. p5-9 (See Appendix Q).

2. David Wright, AIA. "Natural Solar Cooling," 3rd National Passive Solar Conference Proceedings, San Jose, Ca., January 11-13,1979.pp512-517.

3. Fuller Moore, e al. "Dual Desiccant - Bed Dehumidifier with Solar-Heated Regeneration," Proceedings of the International Solar Energy Society Congress, Atlanta, Ga., May 28-June 1, 1979. (See Appendix U).

4. H.I. Robison and S.H. Houston. "Thermo-Chemical Energy Storage for Heating and Cooling," Solar Energy Storage Options Workshop, San Antonio,Tx., March 19-20,1979. (See Appendix U.)

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34. ZONING

LARGE SCALE PATTERNS

Using the ideas of BUILDING LOCATION (2), BUILDING SHAPE AND ORIENTATION (3), HISTORICAL BUILDING TYPE SOLUTIONS (4), and SUMMER COOLING (27) you need to place interior spaces within the shape according to their requirement for SUMMER COOLING (27). This placement of interior spaces might indicate some possible changes of BUILDING SHAPE AND ORIENTATION (3). This pattern is similar to LOCATION OF INDOOR SPACES (6).

THE PROBLEM

CONVENTIONAL ENERGY CONSUMPTION IS PROPORTIONALLY HIGHER IN SPACES NOT USING THE PASSIVE COOLING OPTIONS OUTLINED IN SUMMER COOLING (27). The more you use and control the sun to cool a space, the less conventional energy is required for space cooling. This also applies to active solar - cooling systems. If the design of the interior space and the building's exterior does not passively control heat gain, and use the sun to induce ventilation or evaporation, an active solar-cooling system will be proportionally more expensive and larger.

THE RECOMMENDATION

THIS PATTERN SHOULD BE ACCOMPLISHED IN CONJUNCTION WITH LOCATION OF INDDOR SPACES (6).. YOUR INTERIOR SPACES CAN BE SUPPLIED WITH MUCH OF THEIR COOLING REQUIREMENTS BY CONTROLLING HEAT GAIN AND USING THE SUN TO INDUCE VENTILATION OR EVAPORATION. PLACE ROOMS TO THE SOUTHEAST, SOUTH AND SOUTHWEST ACCORDING TO THEIR REQUIREMENTS FOR FILTERED AND SHADED NATURAL SUNLIGHT - SHADING DEVICES (25). THOSE SPACES HAVING MINIMAL COOLING REQUIREMENTS OR SUNLIGHT SUCH AS CORRIDORS AND CLOSETS SHOULD BE ON THE NORTH FACE OF THE BUILDING TO ACT AS A BUFFER AND ALLOW THE GREATEST AIR MOVEMENT AND VENTILATION TO TAKE PLACE NEAR THE INHABITED SPACES.

SMALL SCALE PATTERNS

Evaluate your building's openings (in walk and roof) to admit sunlight and provide ventilation - WINDOW LOCATION (8), PROTECTED ENTRANCE (7) and CLERESTORIES AND SKYLIGHTS (12), and at the same time choose the most appropriate options for providing SUMMER COOLING (27).

ILLUSTRATION

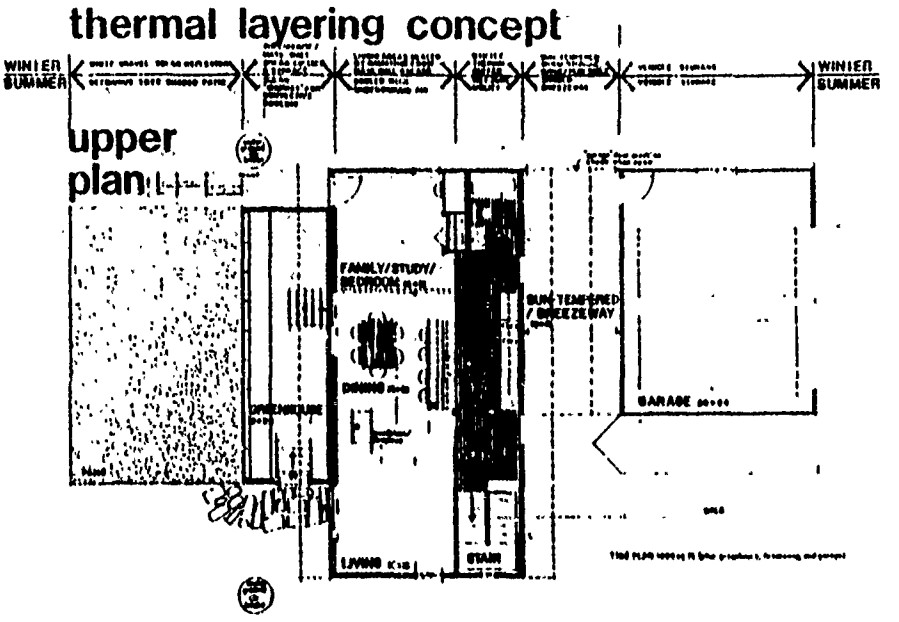


Figure 34-1

INFORMATION

Figure 34-1 (Fuller Moore's Solargreen)is a good example of zoning or thermal layering of indoor spaces for winter and summer.

The summer microclimatic conditions along the sides of your building (outside walls) are the key to locating indoor spaces. The north side remains the coolest because it usually is in shade. The east and west walls receive equal amounts of direct sunlight, but the afternoon temperature is usually warmer and likewise west-facing wall gets hotter than a east-facing wall. The South wall receives very little radiation in the summer if SHADING DEVICES (25) are used, because the sun's altitude is high and exposes the roof to more radiation than the east or west walls.

Your task is to locate spaces with specific cooling requirements based on the microclimatic condition and functional requirements of the using organization (user). And this must be done in conjunction with LOCATION OF INDOOR SPACES (6).

You should also consider using the patterns in Appendix F from A Pattern Language.by Christopher Alexander.

REFERENCES

1. Fuller Moore. Solargreen - A Passive Solar Dwelling for All Seasons - Award Winning Design in recent U.S. Dept. H.U.D. Passive Solar Residential Design COmpetition.

2. Edward Mazria. The Passive Solar Energy - Expanded Professional Edition, Rodale Press, Emmaus, Pa., 1979. pp 90-92.

SOURCES OF ILLUSTRATIONS

Figure 34-1 Fuller Moore. Solargreen.

35. DIURNAL AIR FLUSHING

LARGE SCALE PATTERNS

Using the ideas of SUMMER COOLING-HEAT GAIN CONTROL, NATURAL VENTILATION and INDUCED VENTILATION (27) - this pattern gives guidance for night cooling of your building, while maintaining security.

THE PROBLEM

DIURNAL AIR FLUSHING SIMPLY ALLOWS COOLER NIGHT AIR TO CIRCULATE THROUGH YOUR BUILDING, AND STORE COOLTH IN THE STRUCTURE AS A RADIANT COOL SOURCE (with potential to absorb heat the next day). THE PROBLEM IS HOW TO GET STORED HEAT OUT OF THE STRUCTURE DURING THE COOL OF THE NIGHT AND MAINTAIN SECURITY.

THE RECOMMENDATION

IF YOUR BUILDING HAS 24 HOUR OCCUPANCY SUCH AS FAMILY HOUSING AND DORMITORIES, THEN YOU SHOULD USE STRATEGICALLY LOCATED OPERABLE SOLAR WINDOWS (11) AND CLERESTORIES AND SKYLIGHTS (12) TO CIRCULATE COOL AIR AND STORE COOLTH IN THE STRUCTURE.

FOR A STRUCTURE WITHOUT NIGHT OCCUPANTS, YOU SHOULD COMBINE THE FOLLOWING PATTERNS TO PROVIDE A (closed) SOLAR DRIVEN VENTILATION SYSTEM: EARTH TUBES(28), KING VENTILATION SYSTEM (29), SOLAR CHIMNEY (31) - MASONRY HEAT STORAGE WALL (13). THIS COMBINATION WILL PROVIDE SECURE NIGHT TIME VENTILATION OF THE STRUCTURE - DIURNAL AIR FLUSHING. THIS COMBINATION ALSO WILL PROVIDE A PASSIVE WINTER TIME EARTH TEMPERED VENTILATION SYSTEM.FOR WINTER OPERATION THE SOLAR CHIMNEY (31) NEEDS TO BE CONVERTED INTO A HEATING SOURCE MASONRY HEAT STORAGE WALL(13).[1,2]

SMALL SCALE PATTERNS

This pattern concludes the SUMMER COOLING - HEAT GAIN CONTROL, NATURAL VENTILATION and INDUCED VENTILATION (27) cooling options.

ILLUSTRATION

Figure 35-1

INFORMATION

This pattern does not need additional information, because its sole purpose is to synthesize other patterns, into a large pattern, to provide secure night ventilation - Diurnal Flushing - without open windows.

REFERENCES

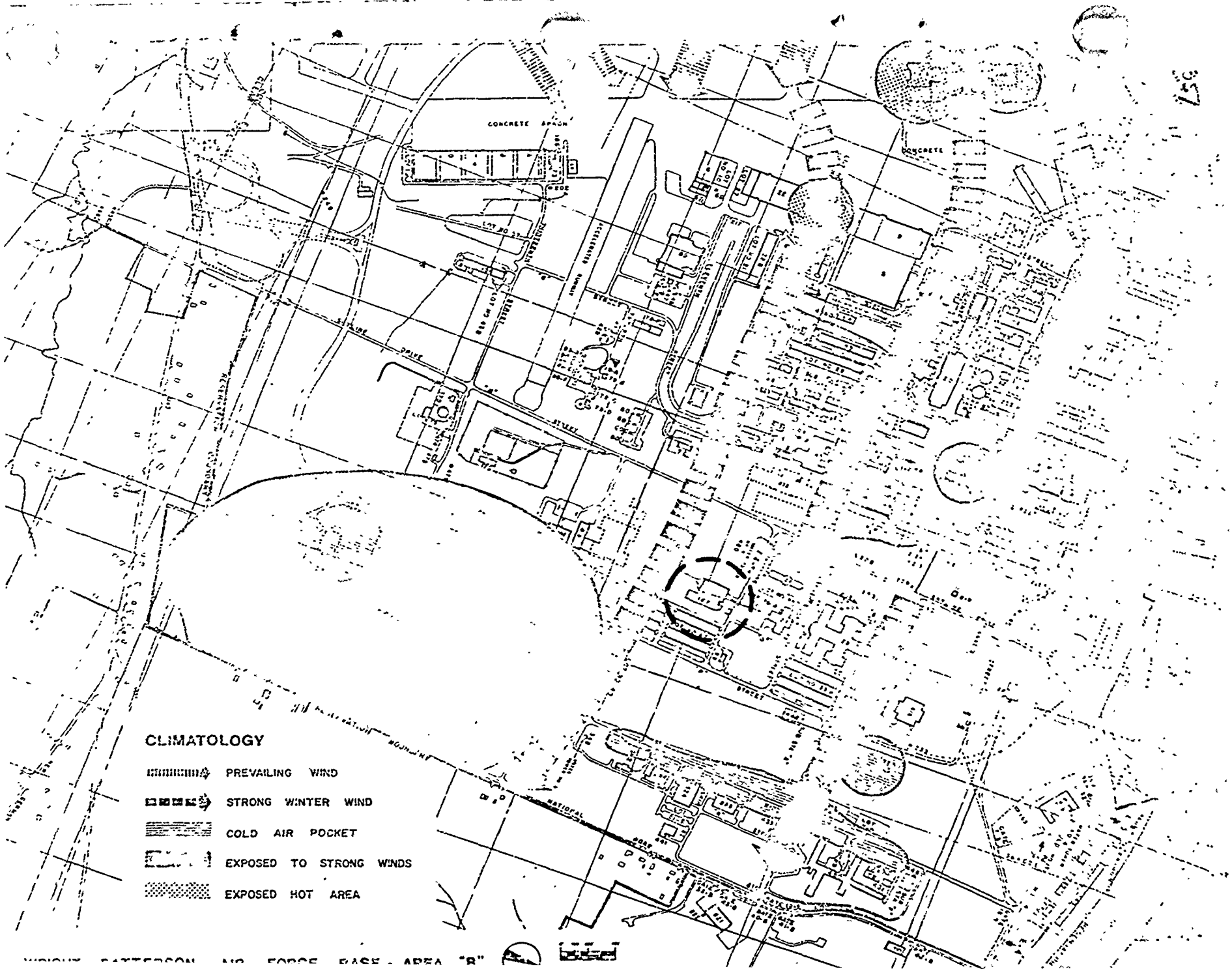
1. Fuller Moore, Dr. Don Elmer and Mo Hourmanesh. "Comfort Variable/Cooling Option/Design Strategy" (Table) Research and Design-The Quarterly of the AIA Research Corporation Vol II, no.3, Fall 1979.p6.

2. Discussion with Fuller Moore and Stanley H. Scofield, Capt. U.S.A.F., 31 October 1979 about the relationship of induced ventilation and Diurnal Air Flushing - action: add a line connecting induced ventilation and diurnal air flushing. (See table 27-1).

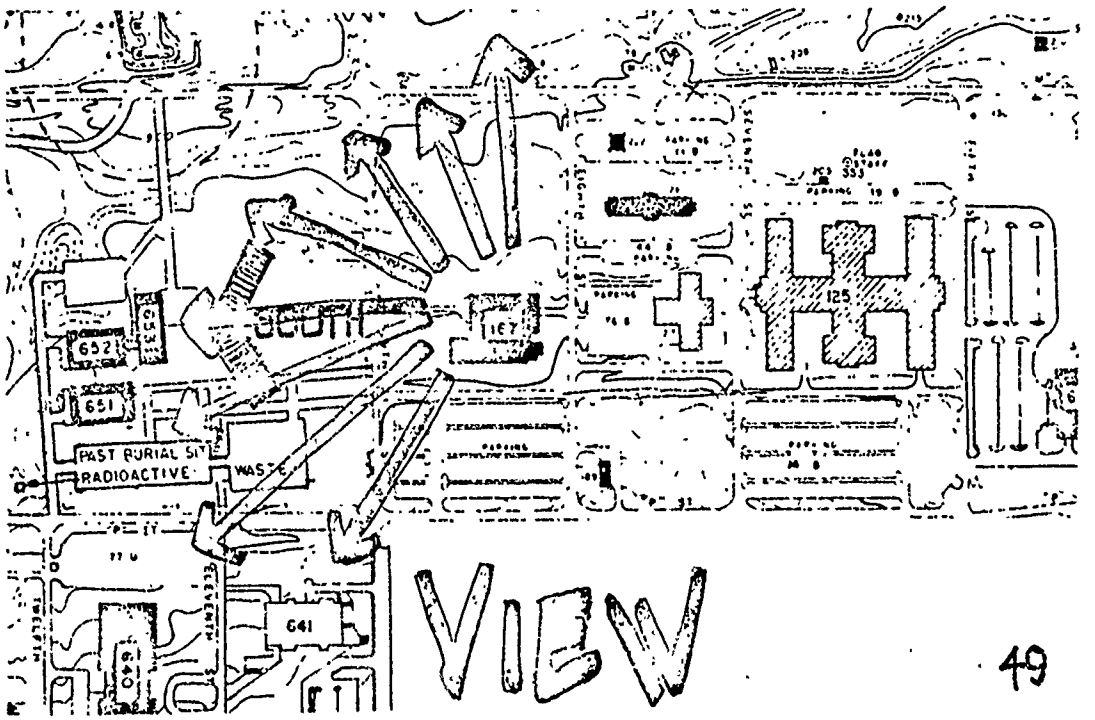
SOURCES OF ILLUSTRATIONS

Figure 35-1

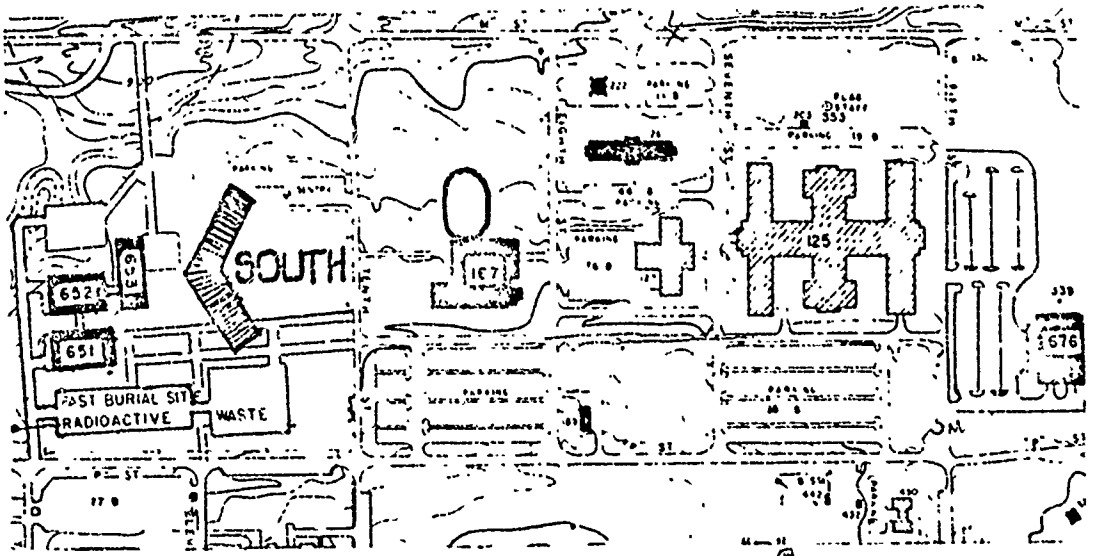
ATCH 5-1



WRIGHT-PATTERSON AIR FORCE BASE - AREA "B"

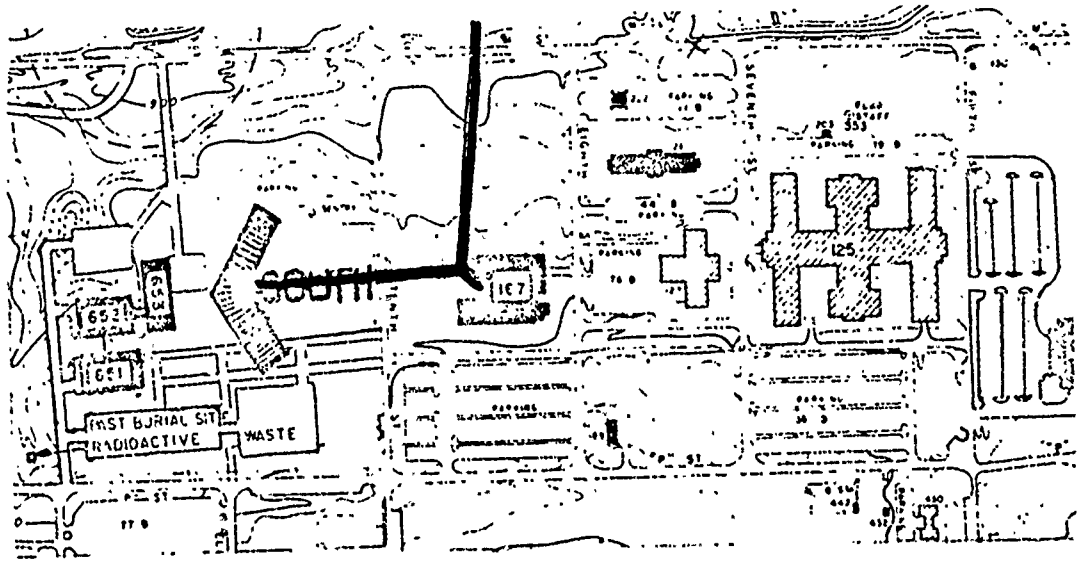


VIEW 49

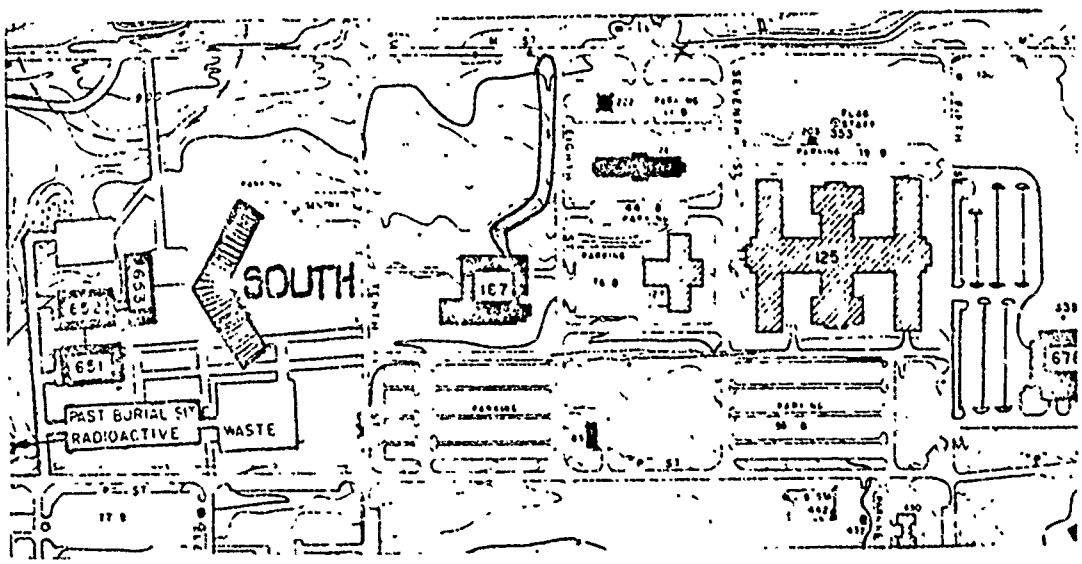


BUILDABLE AREA 49

ATCH 5-2

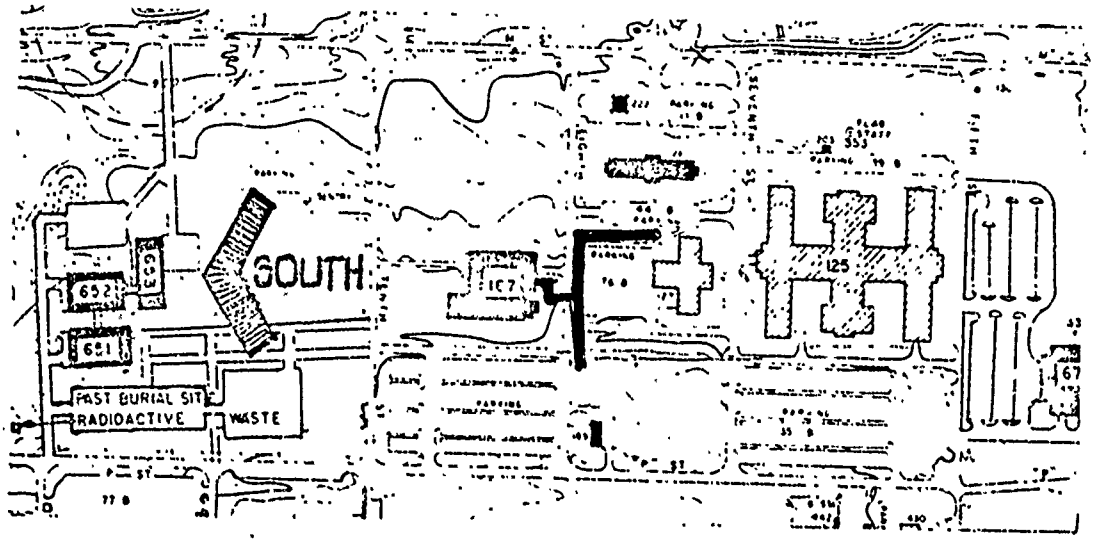


TELEPHONE 49

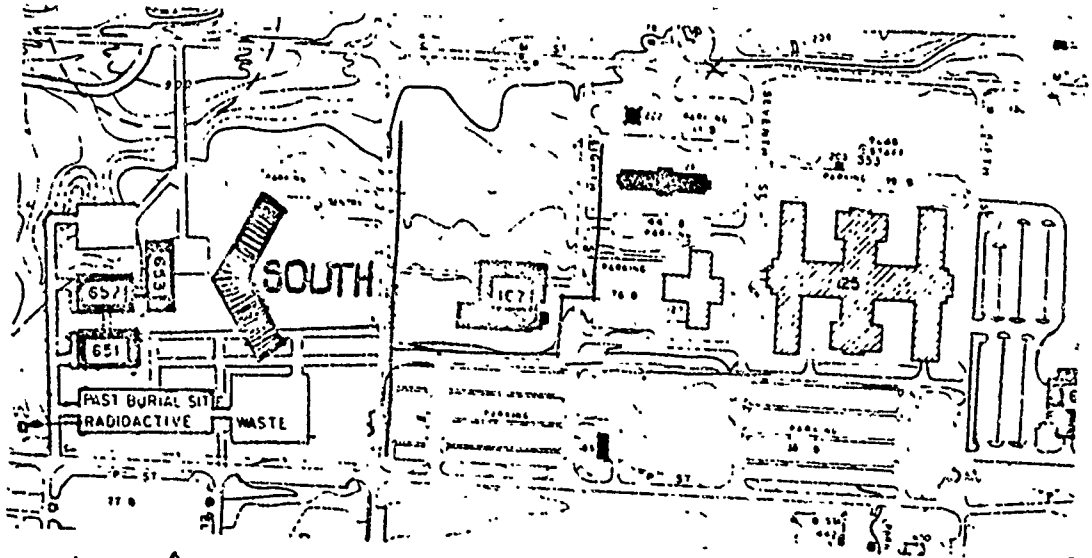


ELECTRIC 49

ATCH 5-3

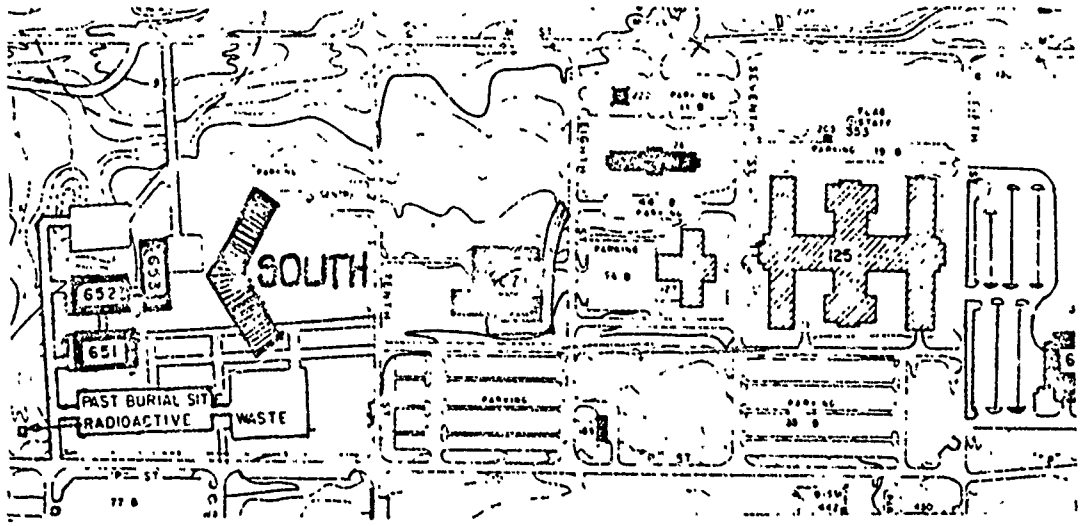


STEAM LINES 49

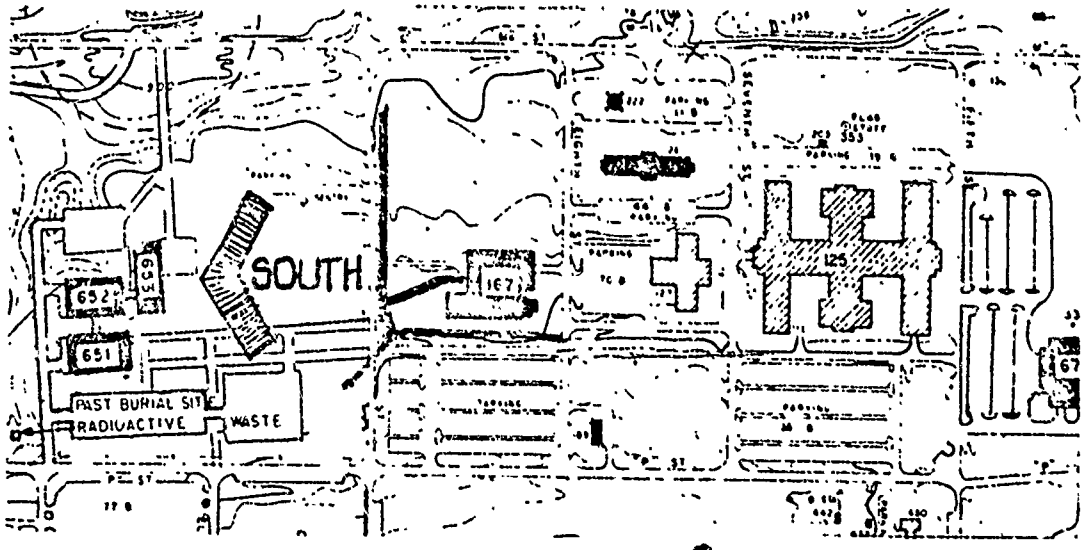


WATER 49

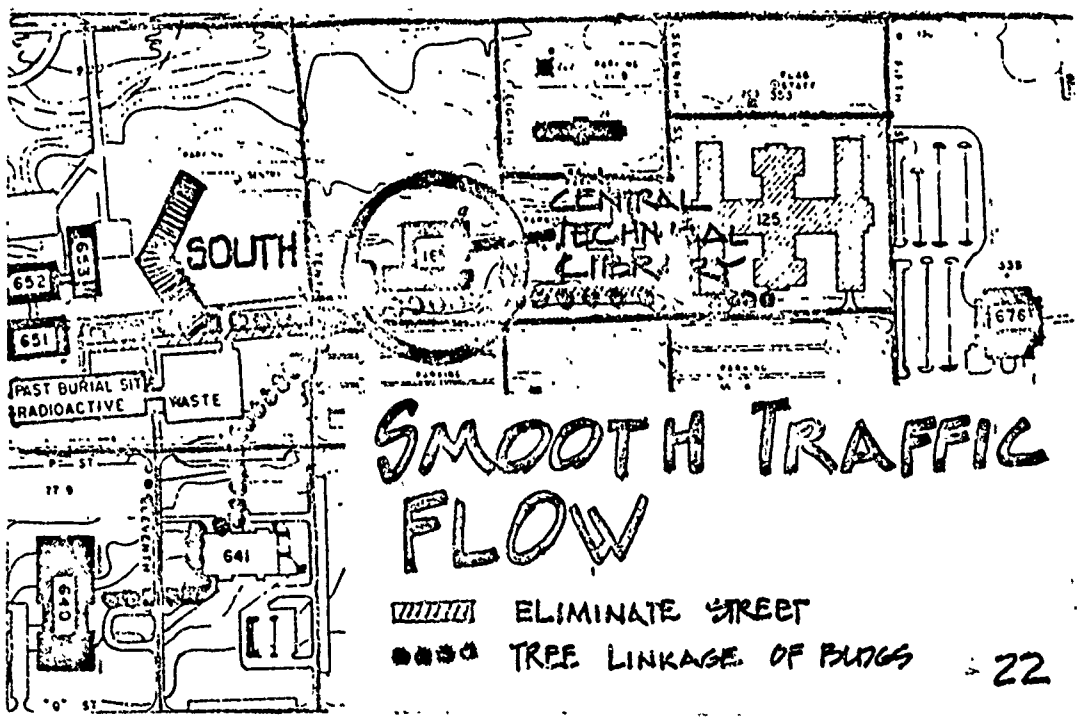
ATCH 5-4



STORM DRAIN 49



SANITARY SEWER 49


SOUTH
CENTRAL TECHNICAL LIBRARY
652
651
PAST BURIAL SITE
RADIOACTIVE
WASTE
641
640
676
SMOOTH TRAFFIC FLOW
ELIMINATE STREET
TREE LINKAGE OF BLDGS
22

GENERAL LIBRARY EQUIPMENT REQUIREMENTS

The following is a list of general library equipment requirements to be incorporated into the design of the Central Technical Library:

BUILDING DIRECTORY - At the entry(s) but not to include reference to or location of the classified "vault."

BULLETIN BOARDS - In staff area and reading room.

CLOCKS - In every area with good visibility.

COAT RACKS & ROOM - At entry(s).

CORNER DETAILS - Use carpet wainscot to reduce book truck damage, as well as acoustical and decorative.

DRINKING FOUNTAINS - Staff area, rest room area, and entry(s).

ELECTRIC FANS - Use as required for thermal comfort.

EMERGENCY LIGHTS - In stack area.

EXIT SIGNS - Lighted.

FIRE EXTINGUISHERS - CO_2 Extinguishers in a visible location.

PENCIL SHARPENERS - Reading room and Tech. Services work section of staff offices.

RETURN BOOK SLOT - Near entry(s).

SUPPLY CLOSETS - Tech. Services and janitor closet near rest rooms.

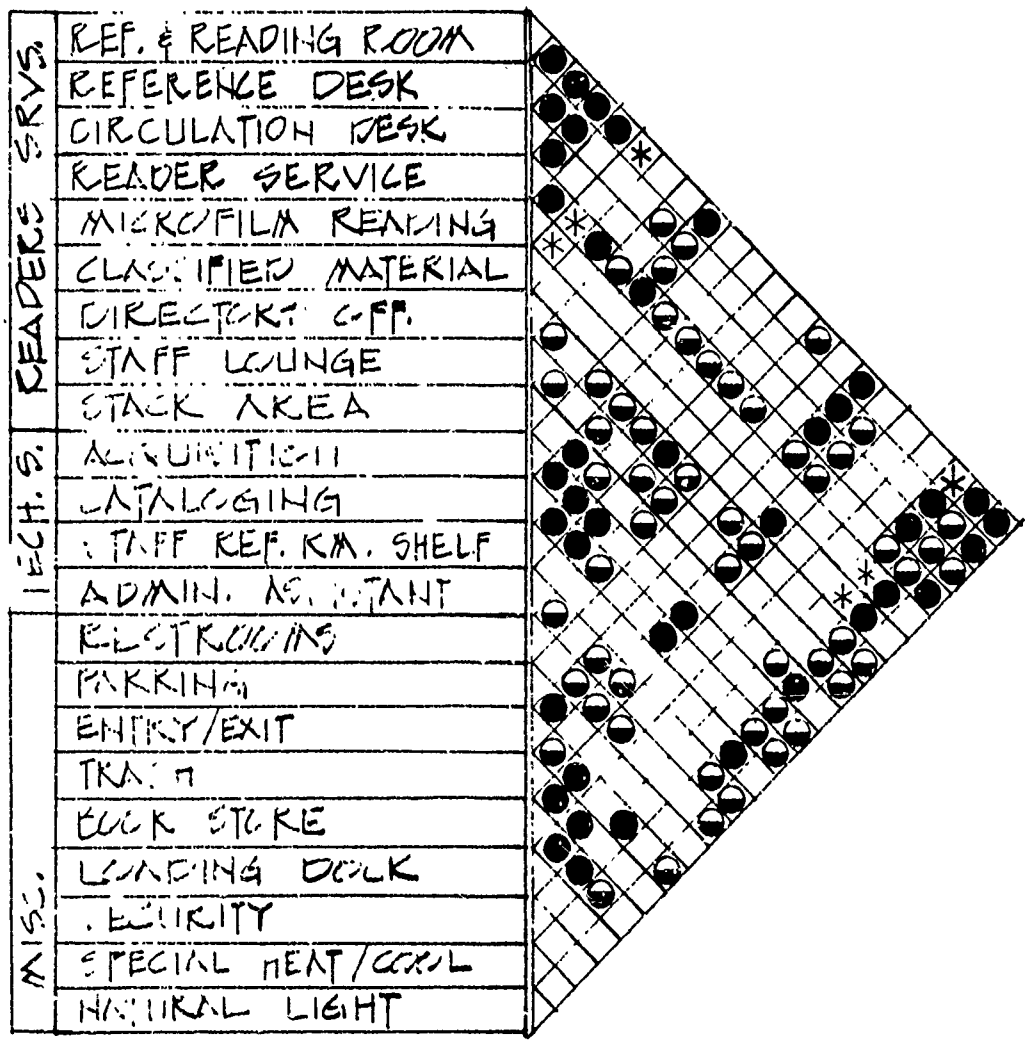
TELEPHONES - At entry and not in the library area.

VACUUM CLEANER - Store in janitor closet.

WASTE BASKETS - One at each staff desk and one for every five tables in the reading area.

XEROX MACHINE - Near the circulation desk, but outside library area with visual contact from the circulation desk. The intent is to get the noise away from the reading and reference areas.

ADJACENCY
OF
FUNCTIONS



● CLOSE
◒ SOME
NONE

* SEPERATE ACCOMMODATIONS FOR SECURITY OF CLASSIFIED MATERIAL

PREPARED BY: CAPT. SCOFIELD (AFIT/CIRG) 22 OCT. '79

APPROVED BY: V. E. ECKEL (AFIT/LD) 29 OCT. '79

Virginia E. Eckel 29 Oct '79

NEH 9



DESIGN FOR WPAFB, OHIO CENTRAL TECHNICAL LIBRARY

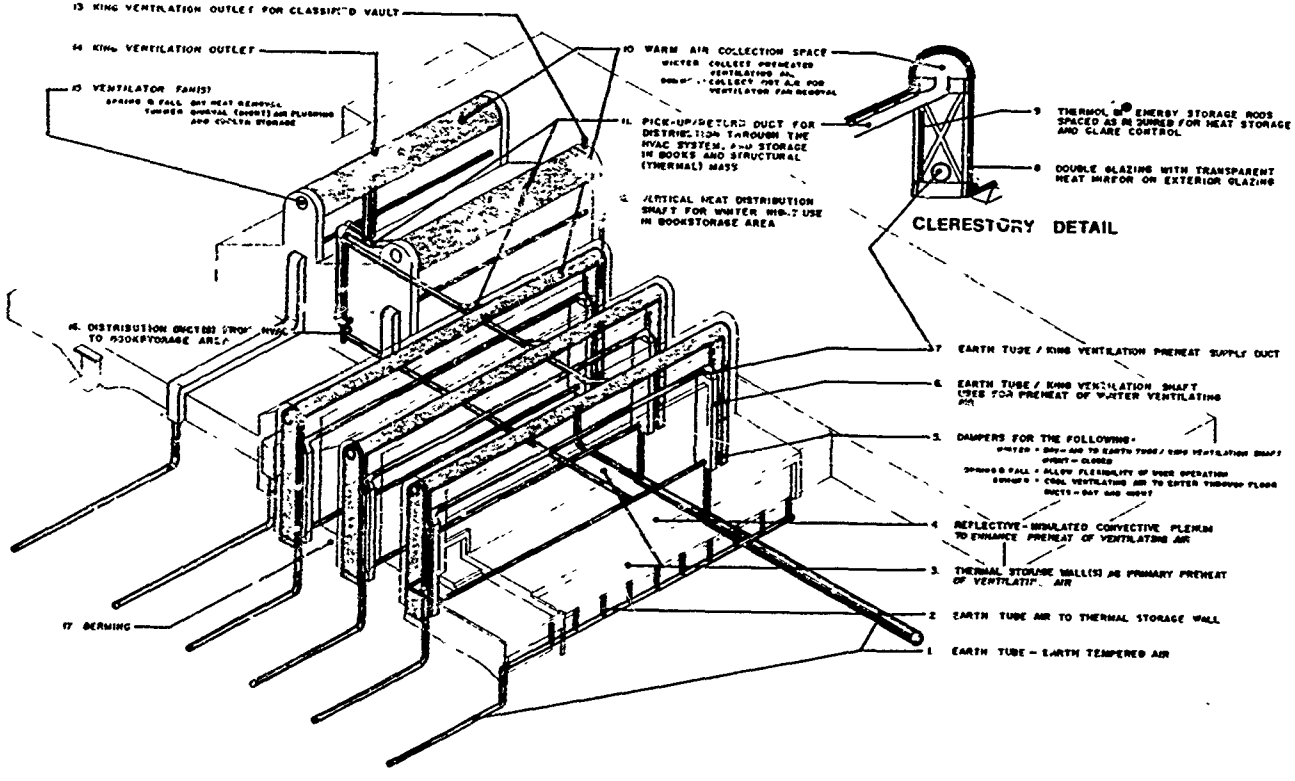
PART 3

CONCEPTUAL PASSIVE SOLAR RETROFIT FOR W-PAFB, OHIO,

CENTRAL TECHNICAL LIBRARY - BUILDING 167, AREA B

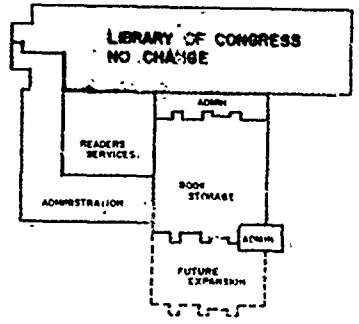
MASTER OF ARCHITECTURE THESIS
MIAMI UNIVERSITY - OXFORD, OHIO

STANLEY H. SCOFIELD
CAPTAIN, USAF.

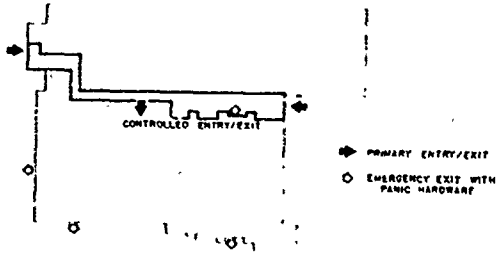


PASSIVE - HYBRID SOLAR - BUILDING CONCEPT DIAGRAM

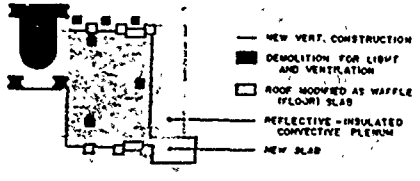
CLERESTORY DETAIL



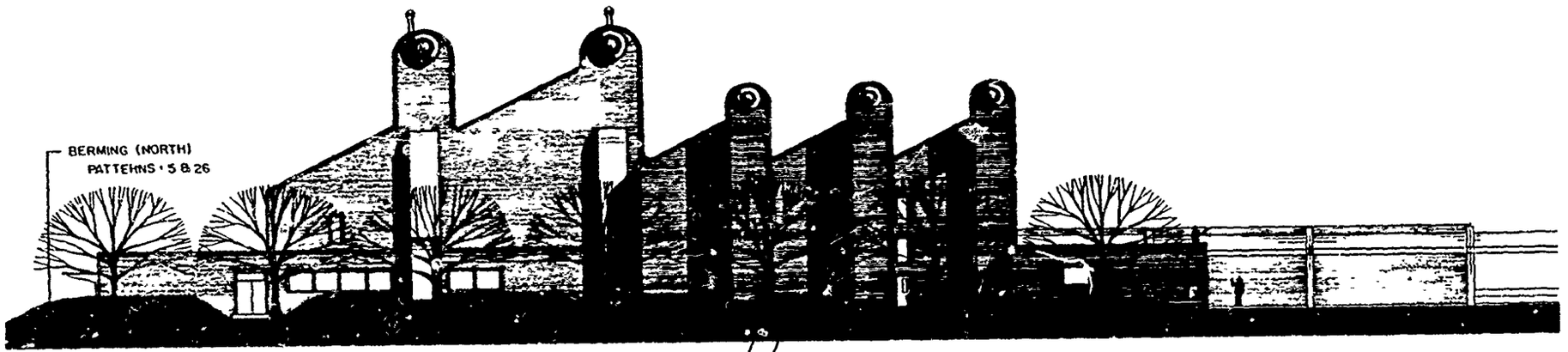
FUNCTION, FORM & EXPANSION DIAGRAM



ENTRY CONTROL - SECURITY DIACRAM



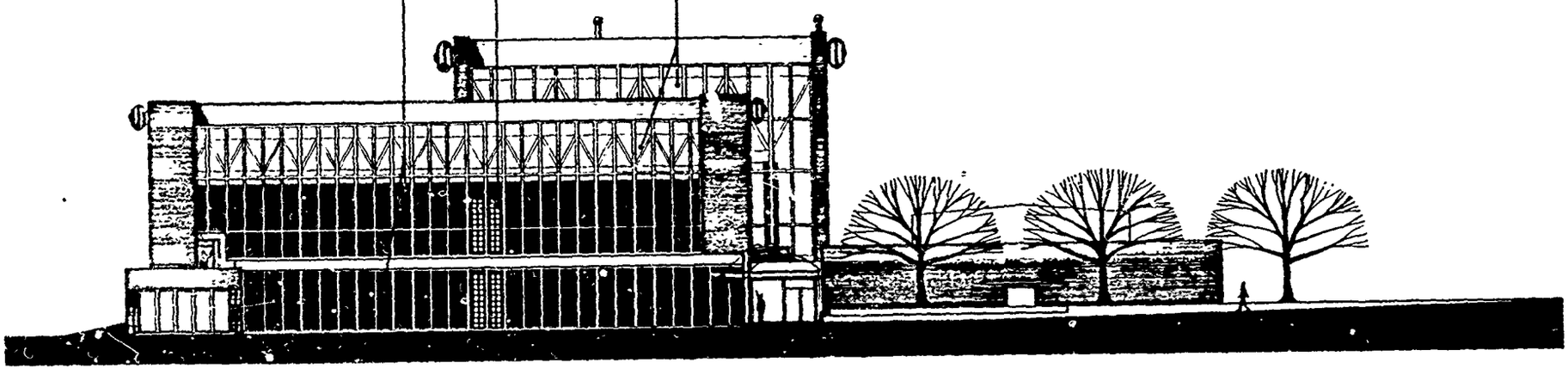
ROOF MODIFICATION DIAGRAM



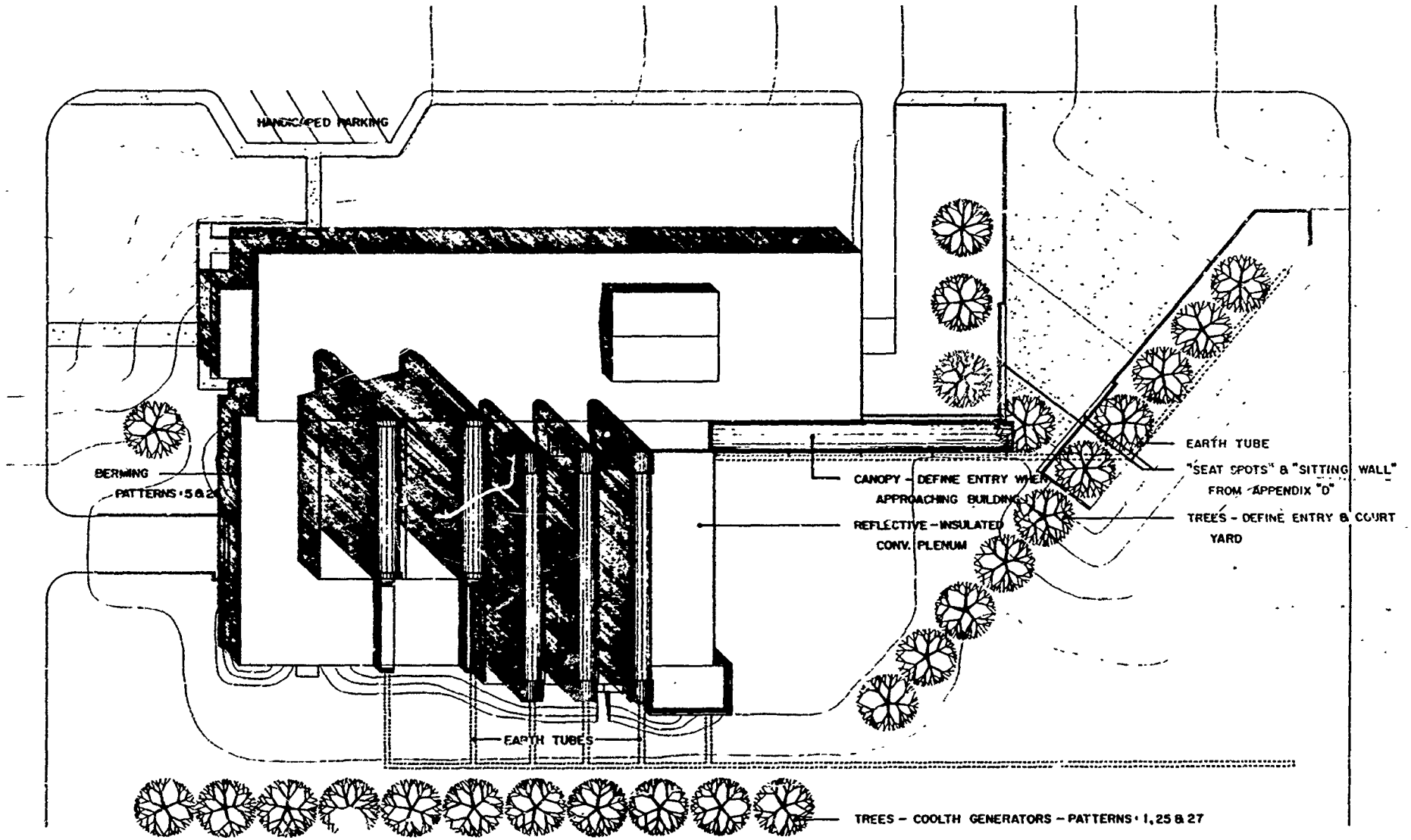
WEST ELEV.

BERMING (WEST) – PATTERN • 26
TREES – COOLTH GENERATORS – PATTERNS • 1, 25 & 27

THERMAL STORAGE WALL – PATTERNS • 2, 9B, 13, 15, 16 & 21
GLASS BLOCK – ORIENTATION / DIRECTION – PATTERNS • 2, 3, 6, 8, 9A, 11 & 21
CLERESTORY – PATTERNS • 1, 3, 4 (SEE ATCH. 3 OF PROGRAM),
6, 8, 9A, 12, 13 & 21

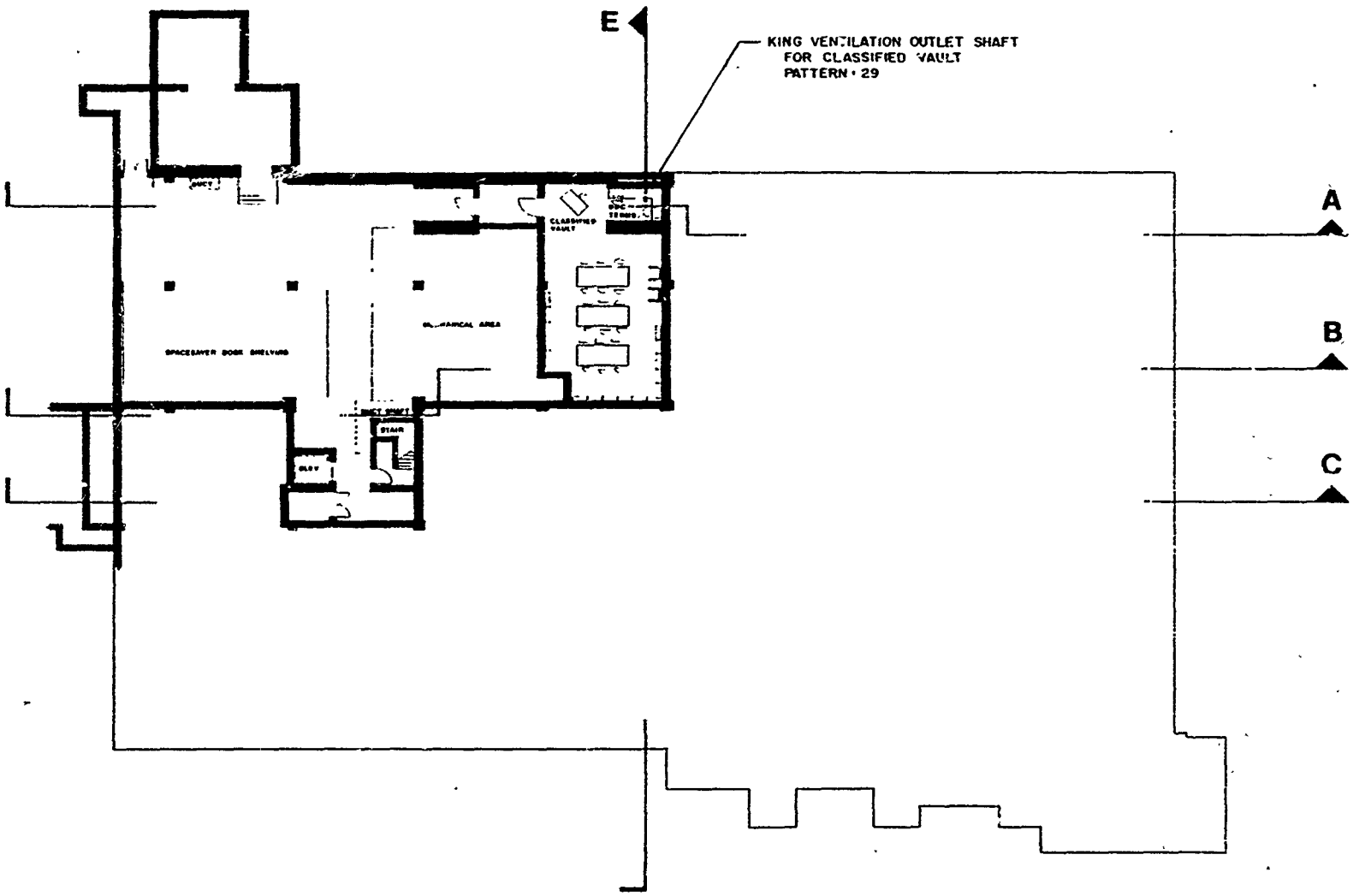


SOUTH ELEV.

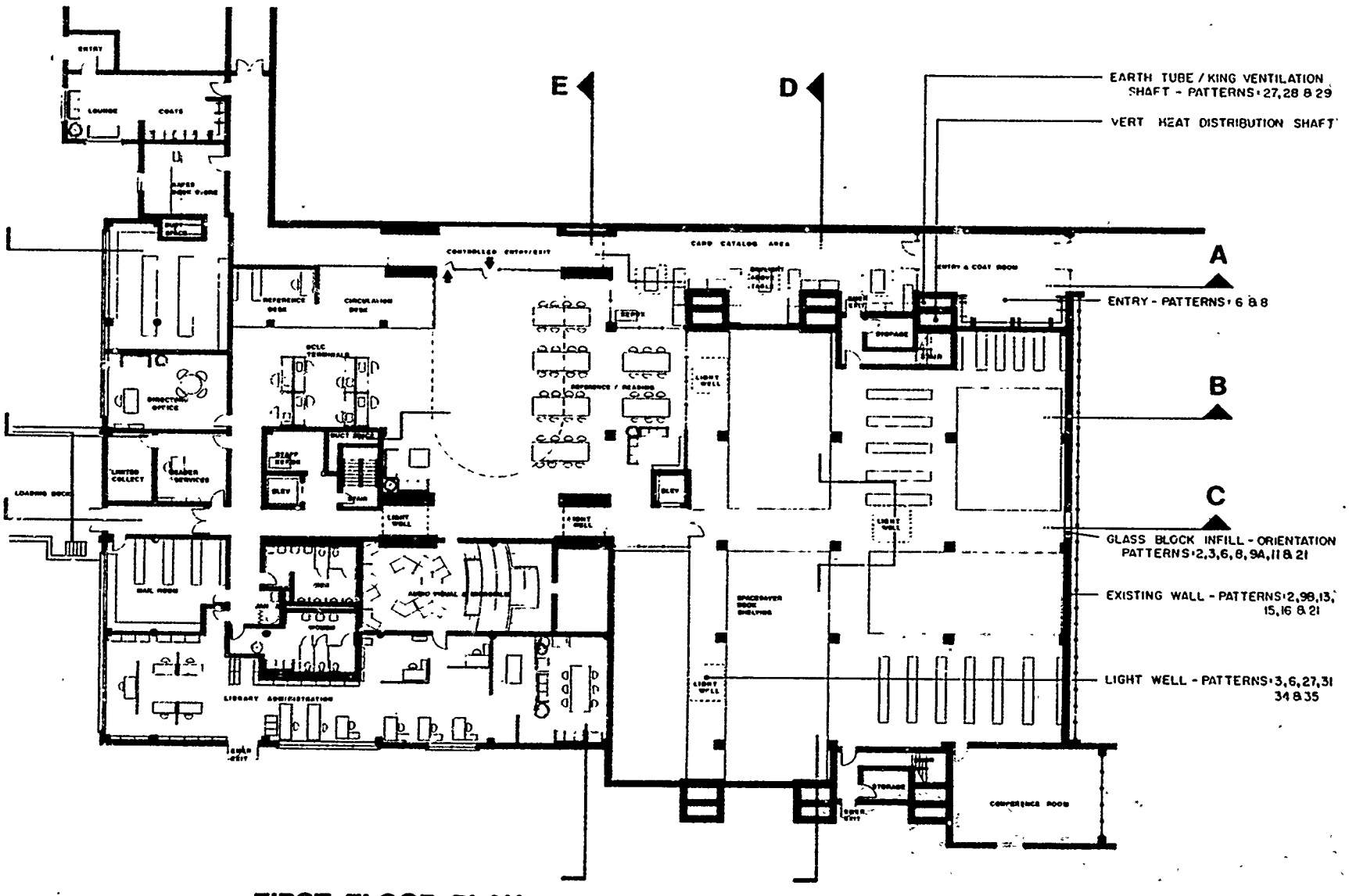


SITE PLAN

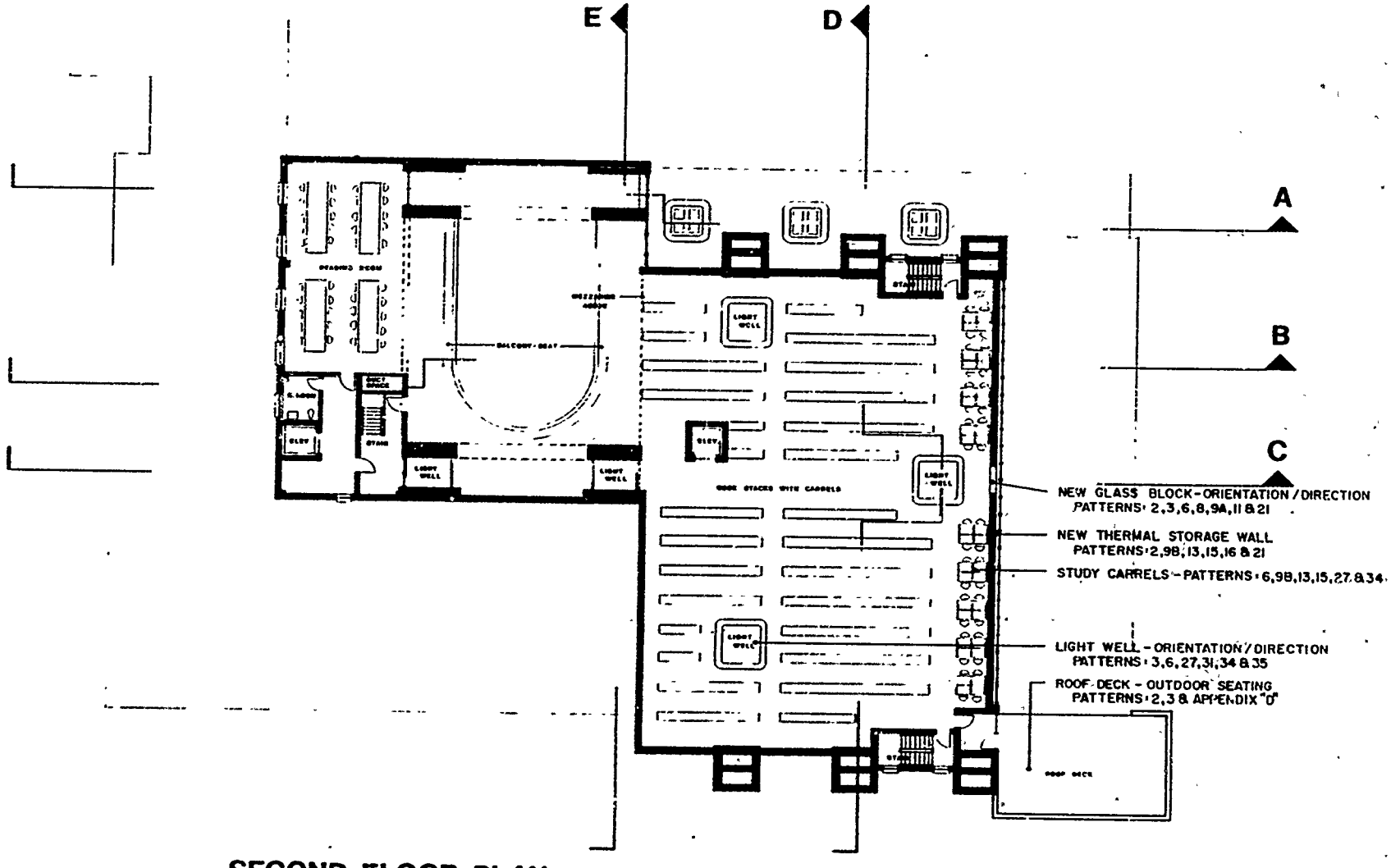
NOTE: THE SITE IS AN APPLICATION OF PATTERN 2



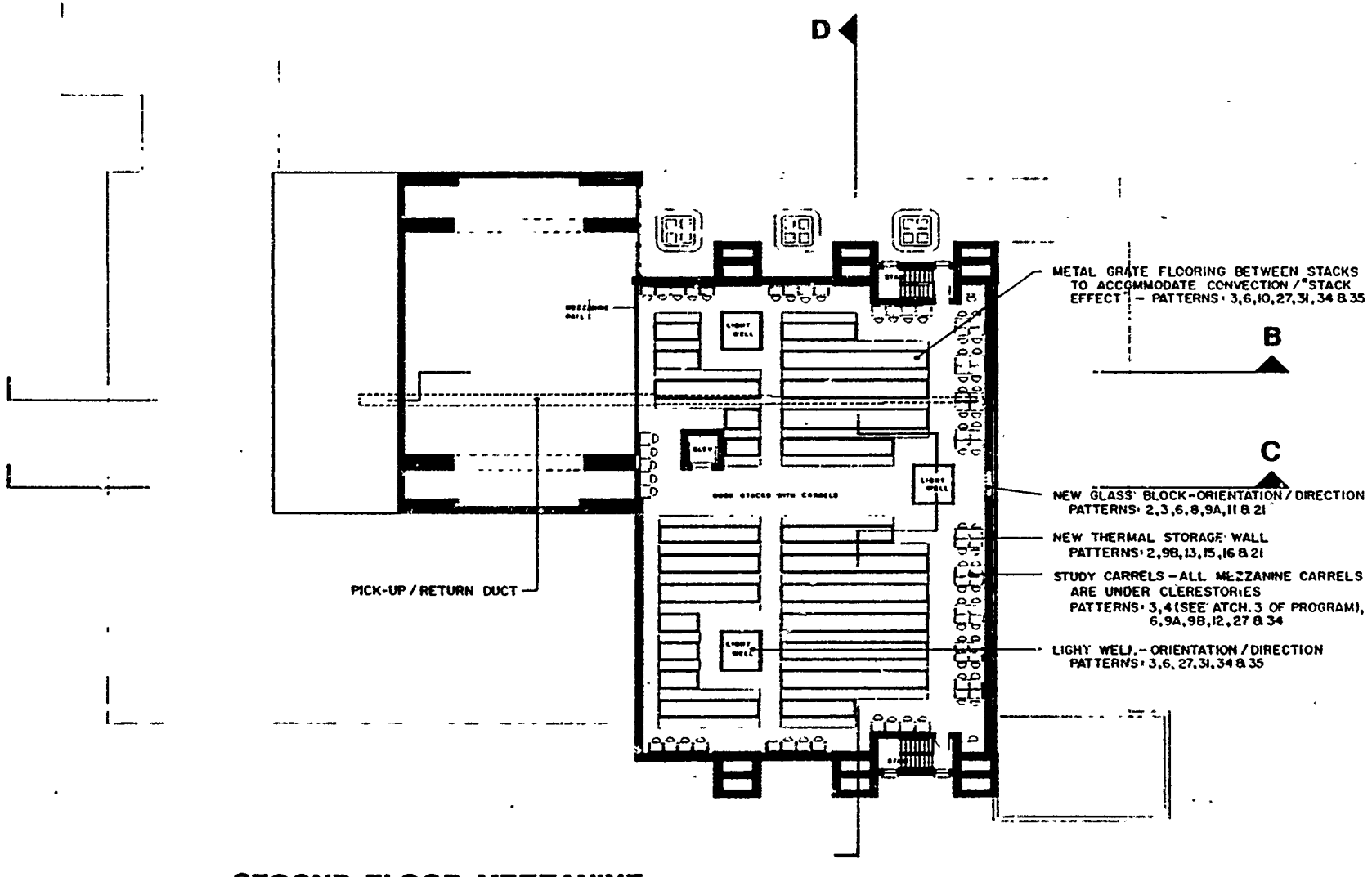
BASEMENT PLAN



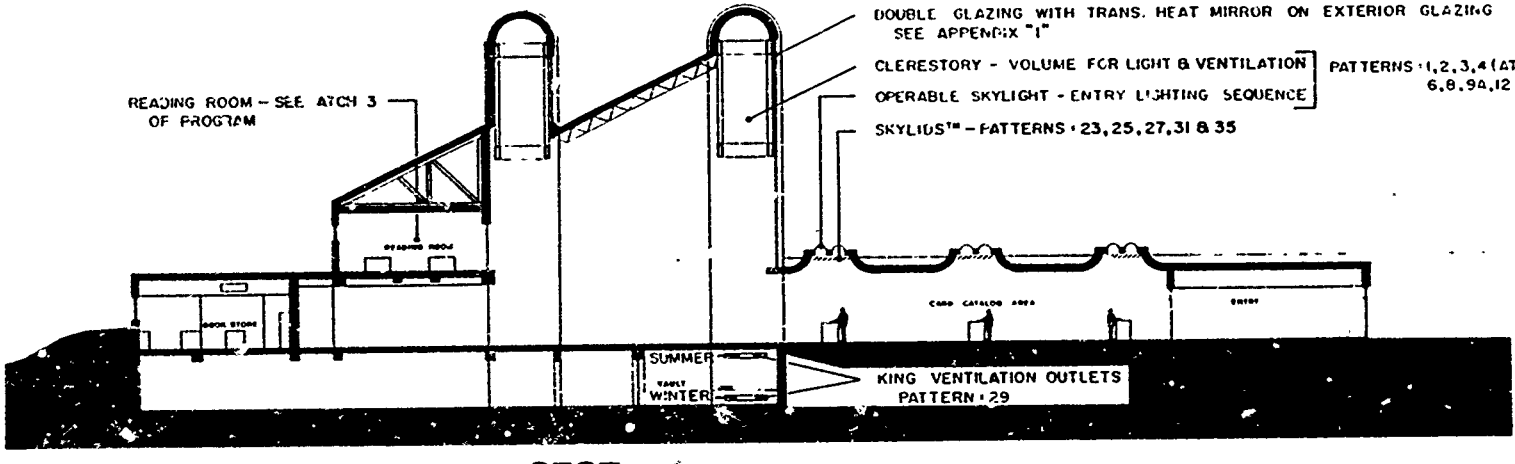
FIRST FLOOR PLAN



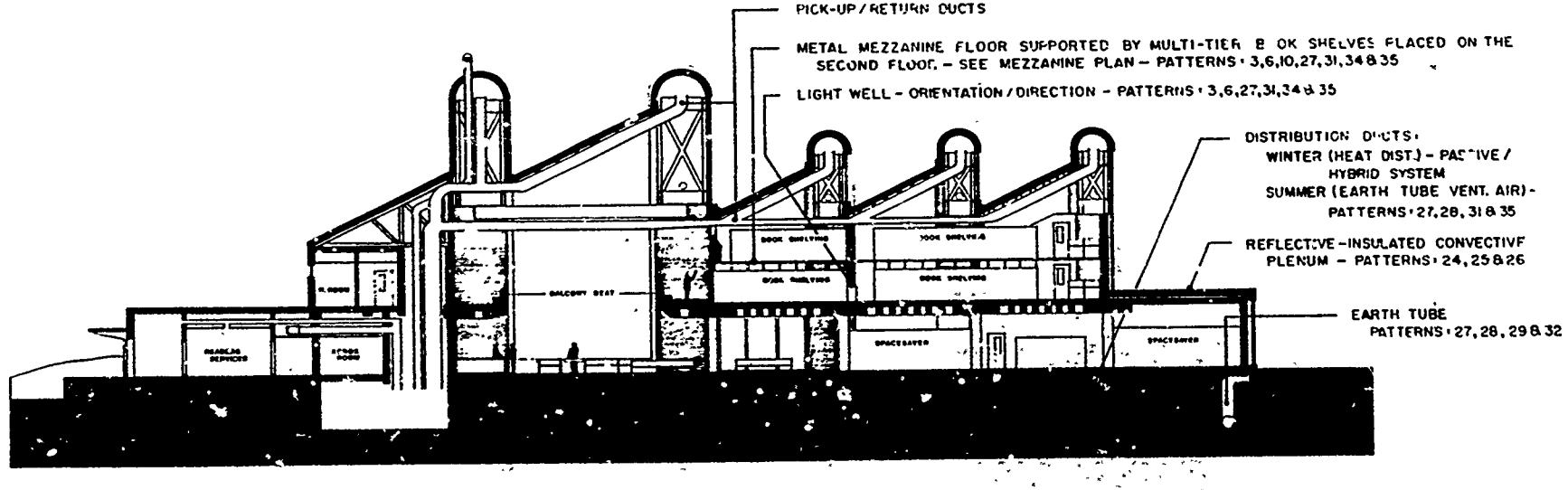
SECOND FLOOR PLAN



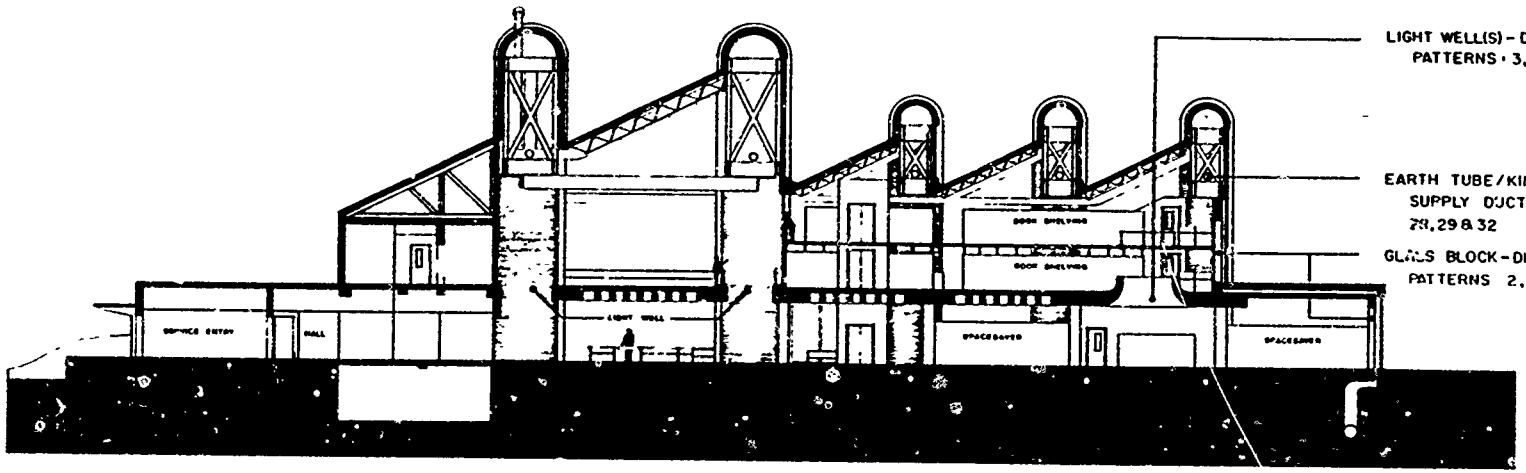
SECOND FLOOR MEZZANINE


DOUBLE GLAZING WITH TRANS. HEAT MIRROR ON EXTERIOR GLAZING
SEE APPENDIX "I"
CLERESTORY - VOLUME FOR LIGHT & VENTILATION
OPERABLE SKYLIGHT - ENTRY LIGHTING SEQUENCE
PATTERNS: 1,2,3,4 (ATCH 3 OF PROGRAM), 6,8,9A,12,13,15,21,27,31 & 35
SKYLIOS™ - PATTERNS: 23,25,27,31 & 35
READING ROOM - SEE ATCH 3 OF PROGRAM
SUMMER
WINTER
KING VENTILATION OUTLETS
PATTERN: 29

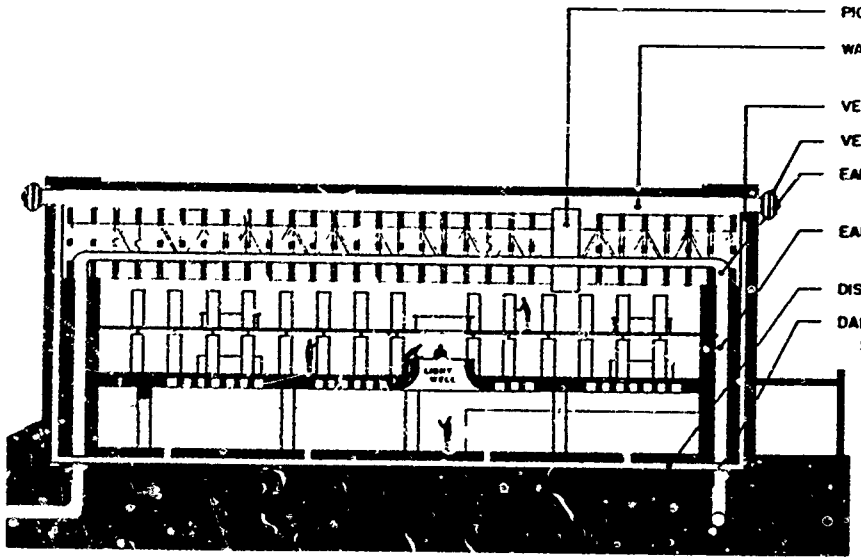
SECT. A


PICK-UP/RETURN DUCTS
METAL MEZZANINE FLOOR SUPPORTED BY MULTI-TIER BOOK SHELVES PLACED ON THE SECOND FLOOR. - SEE MEZZANINE PLAN - PATTERNS: 3,6,10,27,31,34 & 35
LIGHT WELL - ORIENTATION/DIRECTION - PATTERNS: 3,6,27,31,34 & 35
DISTRIBUTION DUCTS:
WINTER (HEAT DIST.) - PASSIVE/HYBRID SYSTEM
SUMMER (EARTH TUBE VENT. AIR) - PATTERNS: 27,28,31 & 35
REFLECTIVE-INSULATED CONVECTIVE PLENUM - PATTERNS: 24,25 & 26
EARTH TUBE
PATTERNS: 27,28,29 & 32
BALCONY SEAT

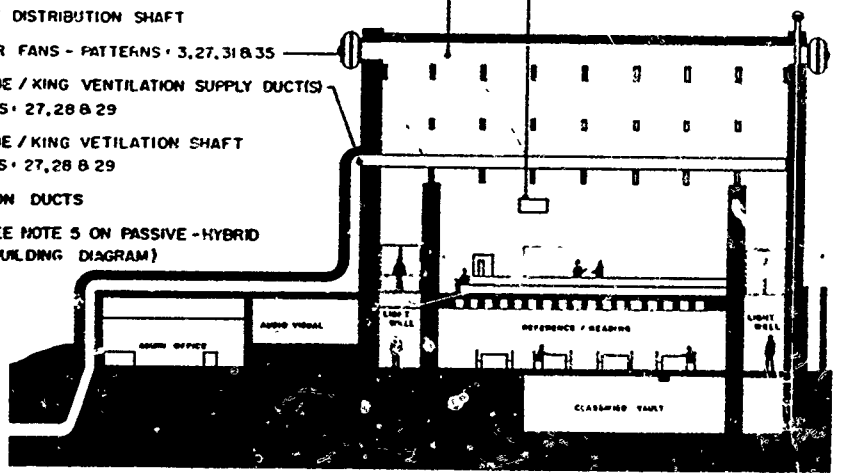
SECT. B



SECT. C



SECT. D



SECT. E