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# Ramirez solar house : a case study of early solar design

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# ABSTRACT

The Ramirez Solar House in the Delaware Water Gap National Recreation Area is an early historic example of passive solar design. The house was designed by Henry N. Wright, a significant contributor in solar research. Wright's 1944 design with a large window wall and generous overhangs represents a significant step in solar design development. The house, now under the stewardship of National Park Service, has been nominated for the National Register of Historic Places.

The Ramirez House's solar performance was a subject of this study. Instrumentation was set up to record temperatures, humidity and illumination in the un-occupied and un-heated building. The data, collected over eleven month period, clearly shows the house collects the sun's energy on a sunny winter days confirming the anticipated performance based on current solar design knowledge. Comparative performance simulations indicate that improvements to the envelope and the addition of thermal mass would significantly enhance thermal performance of the house. Any renovations and changes must be considered in context of historical preservation guidelines. This study proposes adapting the house into a solar museum and study center, and making improvements to its solar performance part of the educational displays.

# RAMIREZ SOLAR HOUSE
# A CASE STUDY OF
# EARLY SOLAR DESIGN

by
Joanna Kendig, Architect

A Thesis
Submitted to the Faculty of
New Jersey Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Architectural Studies

New Jersey School of Architecture

August 2001

# APPROVAL PAGE

# RAMIREZ SOLAR HOUSE
# A CASE STUDY OF
# EARLY SOLAR DESIGN

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Joanna Kendig, "Passive Solar House in Skillman, NJ; a Case Study", 24th National Passive Solar Conference, Portland, ME, April, 1999

Joanna Kendig and Tom Solon, "Tomorrow's House Today: Solar Heating the "Wright Way", Preserving the Recent Past 2, Historic Preservation Foundation,. National Park Service, Philadelphia, PA, October 2000

Joanna Kendig and Tom Solon, "Ramirez Solar House, Case Study", 26th National Passive Solar Conference, Washington, DC, April 2001

This work is dedicated to my mother who does not believe learning ever stops.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Goals of the Study

The purpose of this study is: to examine the place of the Ramirez House and its designer in the modern solar movement; to confirm the importance of this house as an artifact from the recent past worth preserving; and to advance some preliminary ideas on means of preserving it.

The Ramirez House is located in Pennsylvania inside the Delaware Water Gap National Recreation Area. It has been nominated for listing on the National Register of Historic Places in 1997 as an exceptionally early example of solar design in the modern era created by a significant figure in the solar movement. Henry Nicolls Wright's 1944 design, incorporating a large glass wall intended for collection of the sun's energy, represents an early use of direct gain passive solar design.

A review of Henry Wright's work in the context of the modern movement and solar research will help understand his design intent for the Ramirez House. The solar features of the house will be examined using both 1944 theory and today's terms.

Examination and solar performance testing of Ramirez House will help define the degree to which this design fulfilled Wright's solar intent. Comparing this particular design against today's knowledge and standards will enhance the discussion of its historic value. Valuable lessons learned from testing this house's performance will assist in explaining solar issues to professionals and laypersons.

Comparative performance analysis will provide guidance for any adaptation of the structure that might be contemplated if the house is to be occupied again. The study will discuss renovations and adaptations to the house that could improve its overall solar performance and bring the house up to current standards.

The Ramirez Solar House is already recognized as a significant historic example of solar design. It is under stewardship of the National Park Service. These two factors combined with its location will determine how it is used and preserved for future generations. This study will provide the background for making such a determination and an argument for one possible solution.

## 1.2 Solar Research and Historic Preservation Context

Western architecture of the twentieth century has been characterized by an emphasis on technology often to the exclusion of site and climate responsive approach. While solar research progressed from the 1920's through the early 1980's till today, it received varying amounts of outside attention. Recognition of climate change gives new urgency to the solar movement today, yet significant strides in the understanding of solar design have received only limited recognition among design professionals and the general public.

The historic preservation movement has steadily gained momentum over the last century and a half. While preservation of old, historically significant buildings is well established, preservation of the recent past representing the modern movement has only recently entered into the discussion. As many important artifacts disappear, recognition of what is significant and worthy of preservation gains urgency.

The Ramirez House was created in a period of increased recognition and acceptance of the architectural modernist movement in United States. It was also created at a transition point when general principles of solar design were formulated yet before solar theories received quantitive support from solar research. It has become available for study at another significant moment in architectural history, with solar design again being integrated into mainstream architecture.

## 1.3 Study Background

The passive solar houses built in the 1970's were designed to maximize the solar heating function and achieve independence from fossil fuel energy sources. Many were studied for a few years immediately after they were constructed with the cooperation of their occupants. (1) Later case studies have appeared throughout the 1980's and into the 1990's. (2) Many of these studies focused on describing solar features and evaluating occupants' satisfaction. Study of owner-occupied houses meant limited access. Occupant satisfaction was defined by the inherently subjective views of the homeowners.

Some trends become clear upon review of these case studies: a) the original designs were often either flawed by their designers' incomplete understanding of passive solar design, or by budgetary compromises, or both. b) The original designs relied on their occupants' daily management of the “solar heating plant” for efficiency and, therefore, comfort. As homeowners got older or busier, their ability to maintain their solar houses decreased and their physical comfort deteriorated. In spite of reported physical discomforts, occupants generally reported high levels of satisfaction with their houses. c) Despite initial dedication to solar design, as homeowners modified their houses, they frequently turned to conventional mechanical systems and removed portable thermal mass (water) and insulated window panels. d) Homeowners' understanding of solar features was often incomplete or incorrect.

Some anecdotal evidence suggests that over time many of the solar homes underwent significant renovation, which compromised their essential solar features. In the process, historically significant examples of solar design are being lost.

Current passive solar design trends stress integration of solar and conventional features, and use solar energy to assist heating and cooling systems. Total reliance on the sun for heating has been found to be unrealistic. Thus, the solar community's thinking has come full circle to Henry Wright's design approach. He advocated taking advantage of the sun's energy to offset some of the costs of large windows. Designers today speak of low energy buildings and solar contribution.

The Ramirez House offers rare research opportunities. Its solar features are largely intact. It can be studied without the variables of human occupancy. The National Park Service is committed to its preservation. It can contribute to the sorely needed education of professionals and the general public in solar design.

## Chapter 1 Notes

(1) For some examples, see articles in *8th National Solar Passive Conference Proceedings,* 1983: Zentner, Mary Ann, "Passive Solar Homes, Owners react to Their Interiors," Care, F. Duncan Behavioral Implications of Living with Passive Solar Homes" and Reichelderfer, Susan, "The Human Element - Influences on Solar Design and Performance"

(2) Among the studies are two by the author, Joanna Kendig,. See "Passive Solar Houses in Delaware Valley", *Proceedings of 22nd National Passive Solar Conference* and "Passive Solar House in Skillman, NJ", *Proceedings of 24th National Passive Solar Conference*

# CHAPTER 2

# HISTORIC BACKGROUND OF THE RAMIREZ HOUSE SOLAR DESIGN

This chapter will examine the place of the Ramirez House and its designer in the modern solar movement and review the historical importance of this house as an artifact from the recent past. Special attention will be given to the solar features of the building.

## 2.1 History of Solar Design

### 2.1.1 Early Solar Design: Ancient and Indigenous Cultures

The benefits of designing human dwellings for sunlight have been recognized and forgotten many times over the millennia of human development. Many indigenous cultures have oriented their houses and villages to take advantage of the sun's energy. Pre-industrial-age cultures understood both intuitively and by accumulated experience which mixture of orientation, shading and building materials resulted in the most comfortable living quarters. For example, many ruins of the Anassasi in the American Southwest show clear organization for solar gain. Their descendants, the Pueblo Indians, still live in adobe villages, which are remarkably appropriate for a dry climate with plentiful sunshine. (1)

Planned solar design in the western world can be traced back to the early Greeks and Romans. (2) As Greek settlements deforested their immediate surroundings for fuel, Greeks learned to build their dwellings to trap solar energy by orienting principal spaces to the south, protecting them from excess summer heat with porticos and keeping south wings one story. Socrates and Aristotle are known to have commented on rational planning for the sun. Several cities, Olynthus, Priene and Delos, were built for solar orientation.

Romans, faced with similar shortages of fuel by the 3rd century AD, adopted and improved on the Greek approach to design and planning. (3) As the Roman Empire spread from the Italian peninsula, the Romans modified house design to be responsive to local conditions. Vitruvius offered advice on appropriate orientation for both Africa and Italy. Romans improved on "solar" design by introducing glazing in window openings and developed glazed greenhouses. Finally, Romans were the first to codify the concept of "solar access". By the 5th century AD, the right to unobstructed sunlight for solar heating was included in the Justinian Code.

Experimentation with solar energy was discouraged during the Middle Ages. From the Renaissance onward, however, the use of solar energy became a modest, but recurring, subject of research. Inventions using the sun in devices ranged from solar mirrors as weapons, hot boxes to early solar motors. Horticultural use of solar heat revived in the sixteenth century. In search of a longer growing season, Northern Europeans experimented with different orientations for brick-faced fruit walls and created glass-faced cold frames and greenhouses. (4) By the eighteenth century, glass conservatories were recognized to contribute heat to the adjoining rooms in the house. While these developments were important to later solar research, they were not incorporated into building or urban planning in fast expanding cities of the industrializing world.

### 2.1.2 Industrial Age to Present

By the nineteenth century, these earlier solar practices in Europe and America were overwhelmed by rapid industrial development and urbanization. A renewed interest in solar issues was a byproduct of reformers' desire to improve the extremely unsanitary living conditions of the urban working class. As scientists recognized that ultraviolet light destroyed bacteria, movements to plan and build new housing for light and air gained strength.

Practice and theory progressed, learning from each other. Planners and architects studied how to assure maximum sunlight for sanitation. By the second half of the nineteenth century the reformers were planning and building workers communities in Northern Europe. At the same time, many countries enacted sun-rights laws. The early twentieth century saw solar orientation theories alternate between "re-discovery" of the benefits of facing south to building housing facing exclusively east and west. As the discussion continued, the thermal advantages of solar orientation became more prominent. By the 1930's a number of significant housing experiments were constructed in Germany. As apartment developments with rows running north-south proved to exclude winter sun and overheat in summer, designers returned to the use of south facing orientation. (5) In America, early proponents of solar access and solar heat, Bruce Price and William Atkinson, had little impact on the building practices at the end of the 19th century. Interest in solar design grew only as European modernism gained recognition in the US. (6)

By the 1930's research into solar design included theoretical studies of the sun's movement across the sky and quantification of solar energy available to buildings. In 1932, the Royal Institute of British Architects (RIBA) published a reference manual on the sun's movements and associated hours of daily sunshine. Between 1934 and 1936 the American planner Henry Wright wrote various articles on European research and design activities. His son, Henry N. Wright, joined the solar research community in the same period. In 1934, the American Society of Heating and Ventilating (ASHVE) published solar experiments quantifying the effects of sunlight on south-facing windows.

Parallel to the academic studies, some American architects started to build explicitly solar homes. The most prominent practitioner and proponent of solar homes was George Fred Keck, who in 1932, designed and built the "House of Tomorrow" for the Chicago Worlds Fair. The firm of Keck & Keck built a significant number of other homes, experimenting with orientation and glass. Their two Chicago area housing developments for Howard Sloan culminated their efforts and helped to gain acceptance of the term "solar home", coined by a local newspaper. (7) (8)

Solar research and design activities received significant coverage by the American press during this period. A brief review of publications from the 1930's and 1940's shows a number of articles on the subject of "solar" (9). Professional publications included articles on technical topics dealing with orientation, shading and the amount of available sunshine.

Early twentieth century writings on solar design share and reinforce the language of modernism. Both advocate integrated design, contact with outdoors, zoning according to function, and opening of the house to light and air. Solar proponents make the techniques and benefits of a solar house explicit, while promoting the same concerns for health, thrift and new lifestyle expressed by modern designers.

## 2.2 Henry N. Wright

### 2.2.1 Biography

Henry Nicolls Wright [March 23, 1910 - October 4, 1986] (10) was known for his studies of solar heating, as well as for his involvement in architectural publishing. His professional education consisted of an apprenticeship in the Atelier of Clarence Stein and Henry Wright and the office of Bertram Goodhue. From 1930 to 1935 Wright engaged in overlapping activities: research on solar heating at the Pierce Foundation, heliodon studies at Columbia University, and design at the New York State Architecture Office. From 1936 to 1949, he was first technical, and later managing editor of *The Architectural Forum.*

In the 1940's Wright designed his two best known and widely published solar homes, the Ramirez House and a house in Redding, Connecticut. From 1937 on, he was a regular contributor to several professional journals. In 1955 he begun teaching at Pratt Institute; later he taught at Columbia and served as a Visiting Lecturer at a number of other prestigious colleges. Although Wright did not hold an architectural license, he was admitted to corporate membership in the American Institute of Architects in 1967 and in 1983 was inducted into the AIA College of Fellows.

### 2.2.2 Solar Research, Publications and Design

Henry Nicolls Wright was the son and namesake of the prominent city planner and architect, Henry Wright, who between 1934 and 1936 published articles about sun orientation and European communities featuring early "solar" design.

Henry N. Wright continued working with solar design. In the mid-1930's he worked for the John B. Pierce Foundation's Department of Housing Research on the relationship of solar radiation and architectural design. In 1937 he summarized his findings in a *House and Garden* article, "Planned Sunshine: A New Principle of Orientation..." In 1938 he presented the material to the professional audience in *The Architectural Forum.* His June 1938 “Orientation for Sunshine” in the Products and

Practices section lays out the "solar mechanics" of the sun's relationship to the earth and summarizes detailed measurements of solar energy available in a given location on a seasonal basis.

Wright applied his research to the design of several modern houses in the Northeast and at a private school in California. In his 1983 letter to Mr. Nadler, then owner of the Ramirez House, Wright calls himself a proponent of this type (solar) house and refers with some pride to his work in the field.

### 2.2.3 *Tomorrow's House*

In 1945 Simon and Schuster published a guide for homebuilders and owners called *Tomorrow's House* by George Nelson and Henry N. Wright. The book explains in layman's language the principles of designing and building a modern house. Directed to "all those who plan to build or buy a post-war house," it is significant for its postwar timing and the fact that it explains many of the solar design concepts and technical innovations Wright incorporated into his work on the 1944 Ramirez House.

Even though the book is directed towards the lay reader, it contains technical information. The authors explain the physics of energy transfer through glass, which is transparent to visible light and opaque to most infrared and ultraviolet rays. They review window operation including function of double-hung and casement types and introduce awning window, an innovation in the 1940's. Significantly, they also discuss the conceptual shift in separating the window functions of light transmission and ventilation, and the resulting modern window wall of large panes of fixed glass combined with a limited number of operating sash. (11)

Nelson and Wright include a brief history of 20th century research on solar energy quantities, orientation, seasonal shifts, shading with permanent overhangs, and thermal mass. The terminology precedes the language used today; thermal mass, for example, is qualitatively discussed in terms of a reservoir principle. (12)

## 2.3 Ramirez House Design

### 2.3.1 General Background and History

At the time of design of the Ramirez House, Wright was deeply involved in solar issues. He considered himself a leading proponent of modern open-plan house design and a strong advocate for solar design.

Design for the Ramirez House appears to have been concurrent with the writing of *Tomorrow's House*. Both might be considered Wright's summation of solar research of the 1930's and early 1940's. By the mid-1940's south orientation for solar gain was firmly established. Building houses open to light and air and capturing some free solar energy was acknowledged as an important goal of modern design. However, the technical research quantifying the balance of thermal mass and glazing had not yet started.

The Ramirez House as it now exists is the result of extensive remodeling of an earlier 1910 building. (13) In spite of the limitations inherent in building on an existing foundation Wright chose to design a solar house. Extensive demolition and rebuilding resulted in a building with a dramatic solar window wall and a sweeping roof overhang. (Fig. 2.1 and 2.3)

Originally intended as a weekend home for a Colombian national, Gustavo Ramirez, the house changed hands shortly after renovations were completed. Nadler, the subsequent owner, used it as a part-time farm and a summer house. In the 1970's he rented it out as a year-round residence. In 1986 the house and the surrounding land were purchased by the US Government as it consolidated holdings in Delaware Water Gap National Recreation Area. (14)

### 2.3.2 Design Description

A one and a half story, single-family dwelling sited high on the Pocono Plateau, the Ramirez House is oriented towards a dramatic view across the Delaware River Valley to the southeast. The house is approached from the northwest via a long entrance drive ending in a modest parking area and garage below the house. A stone stair leads up to the entry canopy and door. From an entry vestibule, up a half-flight of steps, one enters directly into a two-story living room facing the view. Few more steps lead a visitor to a flagstone terrace extending the interior living space. The main wing contains all of the primary living spaces, as well as two bedrooms, a bedroom/study, and three bathrooms. The servants wing houses two bedrooms, one bathroom and a sitting room.

The house form is itself an application of the then-newly-developed principles of solar design. The house presents a low long façade to the north, while the south elevation opens up to the sun and view. "The rooms where sunshine is important are on the south side of the building." (17)

The 1944 renovations had dramatically altered the rooflines. While some hip roofs remain, the strongest visual elements are the main wing's shed roof and an asymmetric entrance canopy announcing the house's firm adherence to the modern style.

The use of natural stone walls and horizontal wood board and batten siding put it in the "rustic modern' category. (Figure 2.3)

## 2.4 Building Materials in Historical Context

### 2.4.1 General

The house presents an interesting mix of traditional and innovative uses of building materials and systems reflecting Wright's background as a researcher, inventor and experimentalist. His innovative use of materials is best demonstrated in the use of window wall and the integration of the heating system with the window design.

### 2.4.2 Windows and Glazing

The original 1910 windows in the house, retained in several walls, are conventional double-hung, single-glazed units with removable storm frames. The new solar window wall consists of insulated glass in fixed panels mounted in wood frames and single-glazed, awning vent sash. Over time several of the window wall panels have failed (cracked or broken edge seal); the National Park Service (NPS) replaced them with same materials in course of this study.

The Ramirez House represents an early use of insulated glass. (15) Also new is the separation of ventilation from vision panels. Wright combined large fixed panes of glass with vent windows high or low in the window wall. He also introduced a "winter window", glass panels to be mounted in the fall on the interior of the window wall to channel the cold air falling along the windows the radiators below. (Fig. 2.7)

### 2.4.3 Insulation

The renovated portions of the Ramirez House are insulated with mineral (rock) wool with a vapor barrier. This insulation was one of three types prevalent in residential construction by 1940. In the 1944 *Architectural Forum* article, the Ramirez House wall sections (Fig. 2.4) clearly show insulation in the cathedral ceiling and walls, although no material or thickness is marked. An insulation sample retrieved from the living room wall is between 3.5" and 4" inches thick, black with Kraft paper vapor barrier. According to various sources the value of the existing insulation is approximately R=10. (16) (17)

### 2.4.4 Interior Materials

Plaster installed during the 1944 renovation consists of 3/4" of dense plaster on metal lath. The metal lath made by Steeltext, consists of two layers of 2.5"x2.5" wire mesh interwoven into a paper backing marked "Type A for Interior Plaster". This metal lath, no longer used, is of historical interest. Other interior finishes include fireplace stone or tile veneer and hardwood floors.

### 2.4.5 Heating System

Wright kept the existing, conventional hot water heating system with cast iron radiators and introduced some innovative new elements. He placed flat arrays of heating elements in the crawl space under the Living Room floor - a version of radiant floor heating. He also integrated radiators into the wall section along the solar window wall and placed radiators under clerestory windows. (Fig. 2.2 and 2.4)

## 2.5 Solar Orientation and Shading

While the original 1910 house has been drastically altered, it was rebuilt on the existing foundation. Its solar orientation was, therefore, fixed. There is no known record of the architect's thoughts on this subject. However, since Henry N. Wright did design a solar house, he must have considered the orientation acceptable and beneficial to solar gain in winter.

In his 1938 article, "Orientation for Sunshine", Wright builds a strong argument for the south orientation being the most advantageous for winter energy gain and (with shading) summer exclusion of undesirable heat. He also mentions the one-month slip between solar and climatic seasons with May insolation corresponding to July, and April to August. This usually means that a particular design is either optimized for spring heating or for summer cooling, but not both. Wright does, however, provide a clue to his attitude towards the Ramirez House orientation when he says "... it is usually much cooler in summer mornings than in the afternoons, sunlight and sun-heat consequently less objectionable, east walls and windows better than west for most purposes, particularly springtime morning use." (18) (19)

The main wing of the Ramirez House is oriented 38 degrees east of south. Wright designed a "permanent sun shade" on the SE facing window wall. If the house were oriented directly south, this six-foot overhang would provide full shading from the sun at noon on June 21, the summer solstice when the sun is highest. Since the window wall orientation is southeast, the house receives sun through the morning hours. See Figures 2.9, and 2.10 for a comparison of the overhang performance in different seasons for the as-built and ideal south orientation. Wright integrated Venetian blind pockets into the window wall design. Fig 2.4 Published photographs, however, show that drapes were used instead. Wright considered blinds superior to drapes for light control at south windows. He also recognized advantage of excluding the summer's sun energy before it gets into the house and generally recommended exterior Venetian blinds. (20)

The servant's wing is set at 11 degrees east of south. Its conventional, double hung windows are protected by smaller overhangs. (Fig. 2.11)

As the published photographs show, the surrounding vegetation was relatively sparse in 1944. Two deciduous trees were growing in front of the Master Bedroom. The remainder of the steep slope below the southeast elevation was covered with small shrubs. Conditions have changed significantly in the fifty years since the house was completed. Several evergreen trees partially block the sun from the study and master bedroom. (Fig. 2.12) The Servants Wing windows were partially obscured by overgrown evergreens at the beginning of this study. (21) The National Park Service trimmed the foundation plantings in Fall 2000 and plans to remove some pine trees, thereby approximately restoring the landscape to its 1944 conditions.

## 2.6 Direct Gain Glazing and Thermal Mass

The southeast walls of the main wing are glazed with 658 sf of fixed and operable windows, which are the solar engine of the house. Now called direct-gain windows, they represent 24% of the wing's floor area. Current guidelines recommend that solar glazing should be balanced by heat-absorbing materials (thermal mass). (22)

The Ramirez House does not contain sufficient thermal mass to balance its large window wall. See further discussion in Section 3.2.2. Wright's writings clearly show he understood the importance of a “heat reservoir”. (23) Since ideal thermal mass/glazing ratios were not yet quantified in 1944, we do not know if Wright saw the need for more thermal mass. There is no written evidence of his thoughts on the subject.

## Chapter 2 Notes

(1) Studies by Ralph Knowles of Mesa Verde, Chaco Canyon and Acoma village show clear and planned use of solar energy in these dwellings.

(2) Butti, Ken and John Perlin. *A Golden Thread.* Chapter 1

(3) Butti and Perlin. *A Golden Thread.* Chapter 2

(4) Butti and Perlin. *A Golden Thread. Chapters* 3, 4, 5 and 6

(5) Most representative of solar orientation evolution are: a) a 1929 apartment complex of Siemenstadt near Berlin with buildings facing east and west, b) a 1934 apartment complex by Hugo Haring facing southwest, c) The Swiss community of Neubuhl near Zurich, with buildings facing southeast. Butti and Perlin. *A Golden Thread.* Chapter 13, p. 165 to 171

(6) Butti and Perlin. *A Golden Thread.* Chapter 14

(7) Butti and Perlin. *A Golden Thread.* Chapter 15

(8) "Three Houses for the Postwar World", *Architectural Record,* December 1944

(9) Coverage was evident both in popular magazines and professional journals. For example, as early as 1937, *House and Garden* included articles on “Planned Sunshine” and “Aids to Air Conditioning”. An August 1943 article in *The Architectural Forum* discusses techniques for calculating solar gain. By the early 1940's, many residential buildings in the modern style featured in *Architectural Record* and *The Architectural Forum* contain solar design components. These design elements are not always explained in the accompanying articles; however, several of the houses by known solar architects were explicitly dealing with those design features. The 1940 *Architectural Forum* features Henry N. Wright's house in Redding, Conn; the article discusses the advantages of E/SE orientation. The March 1944 *Architectural Forum* features Howard Sloan's Glenview, Illinois Meadowbrook and Solar Park developments containing George Keck's houses. The November 1944 *Architectural Forum* includes a detailed review of Wright's Solar Weekend House (Ramirez) including details of its solar wall. The December 1944 *Architectural Record* shows three of Keck's houses all incorporating "glass walls for solar heating".

(10) From AIA membership application materials and the New York Times Obituary

(11) Nelson, George and Henry Wright. *Tomorrow's House.* Chapter 14

(12) Nelson and Wright. *Tomorrow's House.* Chapter 15

(13) A November 1944 article in *The Architectural Forum,* showing photos of the completed house, describes the work as a "drastic surgery". The second floors of the main and servants' wings were removed. Judging by before and after drawings this drastic surgery must have included removing some walls down to the first floor wall sole plate. Main wing rooflines were completely altered with significant

overhangs added. The article refers to salvaging and reuse of building materials including windows and sheathing, apparently motivated by wartime thriftiness.

(14) Originally land along the Delaware River was purchased for a dam project. After the dam construction was canceled, the Delaware Water Gap National Recreation Area was created under the stewardship of National Park Service. See the NPS web site for a history of the park.

(15) Quote from Wright's "Orientation for Sunshine" article in *The Architectural Forum*

(16) Insulating glass was first conceived by an engineer in 1930. By 1937 the glass-to-metal seal method of joining the two panes of glass was perfected and insulating glass became accepted in buildings. Called variously double glass, or by trade name Thermopane, it was still a fairly novel material in 1943, the time of the Ramirez House design. See the article "Plate Glass" in *Twentieth Century Building Materials,* page 182.

(17) ASTM article by William Edmunds. Thermal insulation was first used in the 18th century to protect workers around steam engines. Recognition of insulation's advantages led to the search for materials with improved energy efficiency. One of the first such materials was mineral wool insulation, accidentally discovered at a blast furnace in Wales around 1840. By 1880 mineral wool insulation was being installed in US houses. Use of insulation was recommended in a Scientific American article in 1887. In 1937 House and Garden included an article about insulation describing its use as "common practice in the better type of house...". In 1938 the ASTM C-16 committee was formed to develop standards for insulation. By 1946 there was a first comprehensive residential insulation standard for mineral fiber. The C-16 committee developed and promoted the concept of R-value.

According to William Edmunds from Owens Corning, in 1940's, rock wool was usually locally produced and distributed. Insulation for the house was likely supplied by US Mineral Fiber in Stanhope, NJ.

(18) According to a recent *Graphic Standards,* the 1/k of modern mineral wool is between 3.12 and 3.7 with the R-value of 3.5" bat at 11 to 13. According to William Bremen, a long time member of North American Insulation Manufacturers Association, this number should be about R=10 for insulation produced in 1940's. In a phone interview, Mr. Bremen explained that in the 40's melted slag was poured across an array of steam jets. The resulting fibers were larger and shorter than current material. The fibers ended in "globs" called shot. Thicker fibers and shot resulted in a lower insulation value of the rock wool bats.

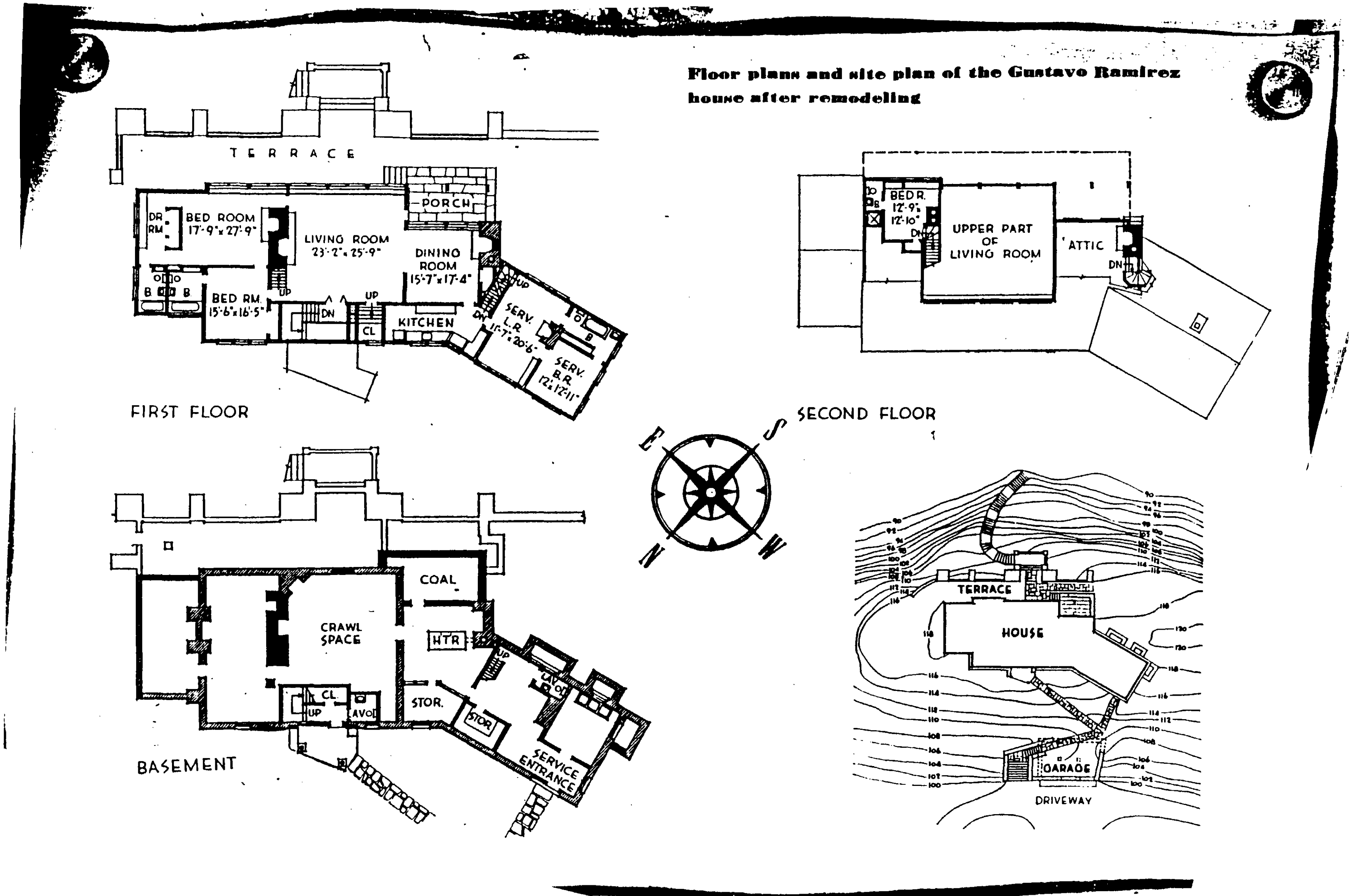
(19) In the *Tomorrow's House* chapter addressing solar heating, Wright suggests a house axis shifted slightly to the west with the east wall getting a little more sun.

(20) In *Tomorrow's House,* p. 173, 174, 175, Wrights discusses the differing needs for shading and the means of accomplishing sun control on east, south and west elevations.

(21) Little is known about land use on the steep slopes below the Ramirez House according to Zara Osmond, landscape architect conducting research for Delaware Water Gap. Photographs from 1910 show sparse vegetation, suggesting recent logging. As of 1944, the vegetation remains low with a few deciduous trees flanking the southeast elevation.

(22) Passive *Solar Design: Guidelines for Home Builders*

(23) *Tomorrow's House* p. 179



**Floor plans and site plan of the Gustavo Ramirez house after remodeling**

Fig 2.1 Site and Floor Plans; from *House Beautiful* article

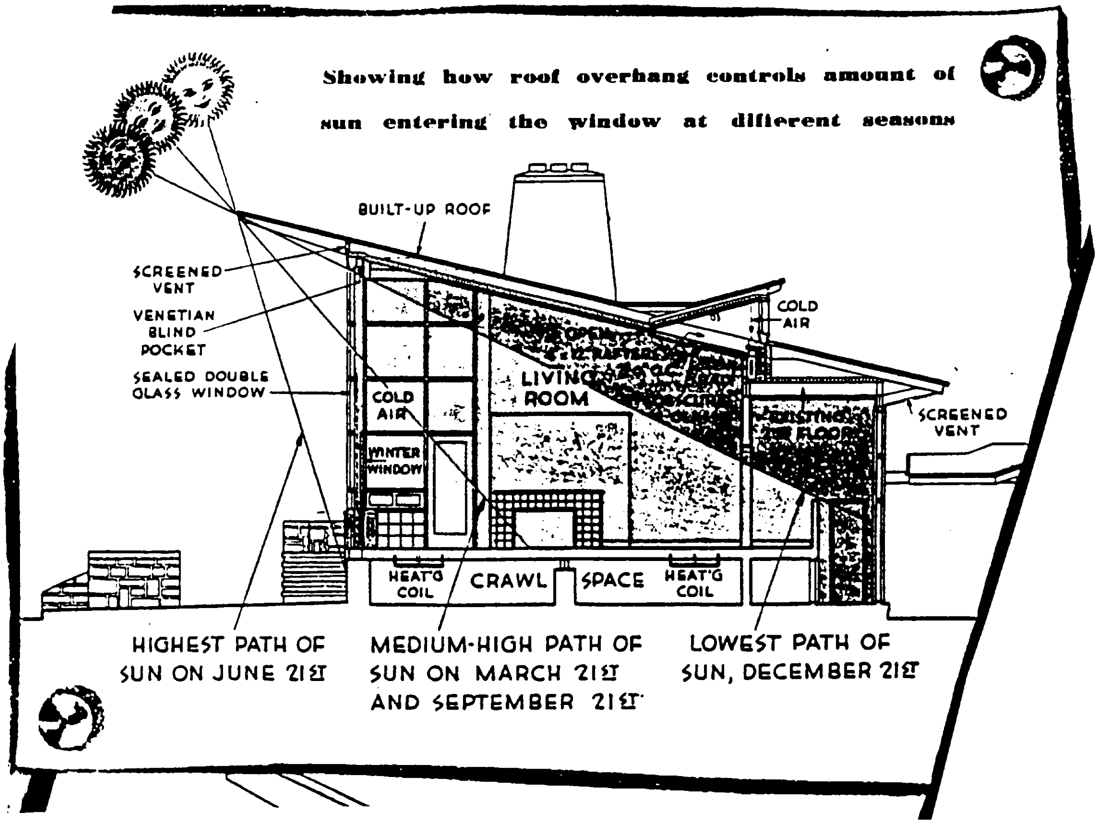


**Figure 2.2** Living Room section; from *House Beautiful* article

**Figure 2.3** Exterior view from south-east

SOLAR WINDOW WALL
HENRY WRIGHT, DESIGNER

DESIGN DATA 24.
THE ARCHITECTURAL FORU

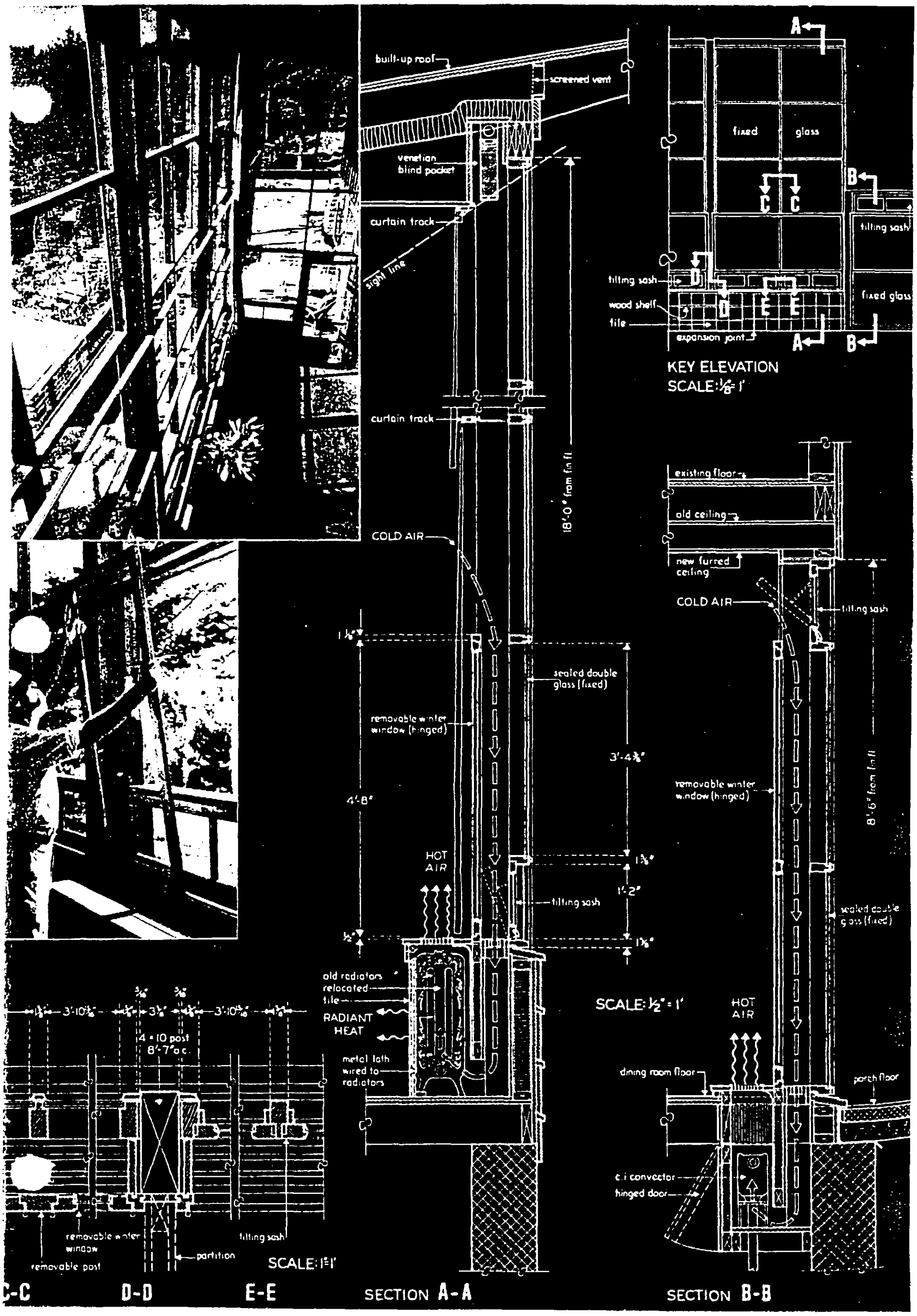


**Figure 2.4** Wall Sections; from *Architectural Forum* article

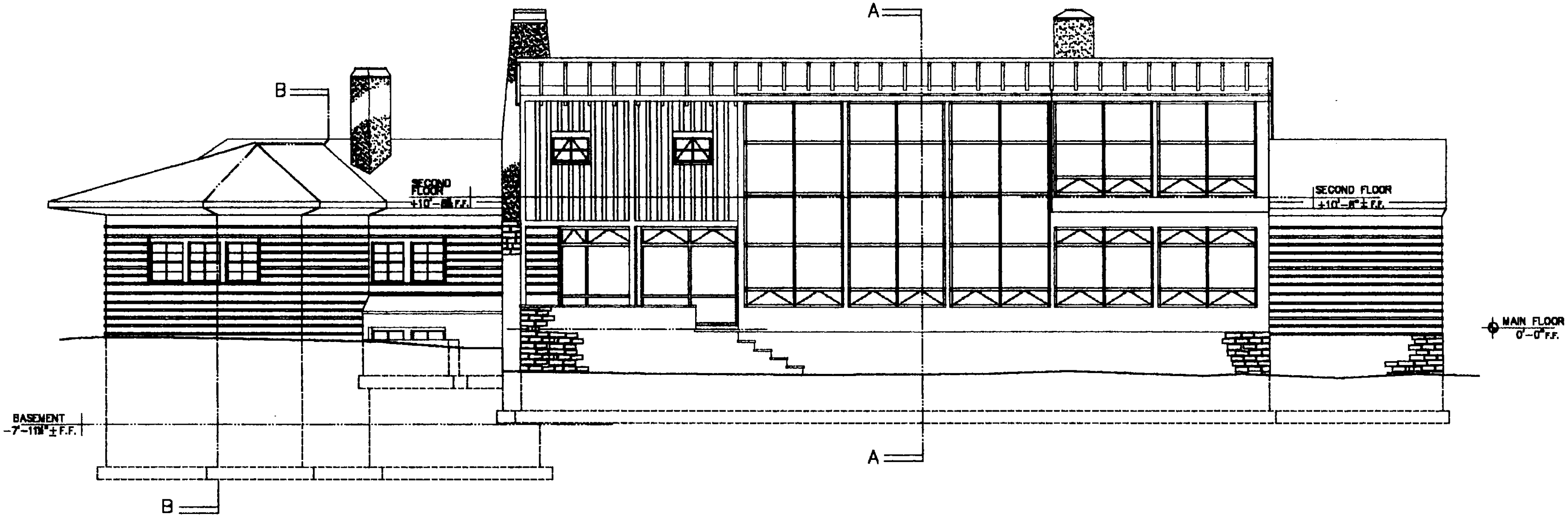


**Figure 2.5** South/East Elevation; Solar Window Wall

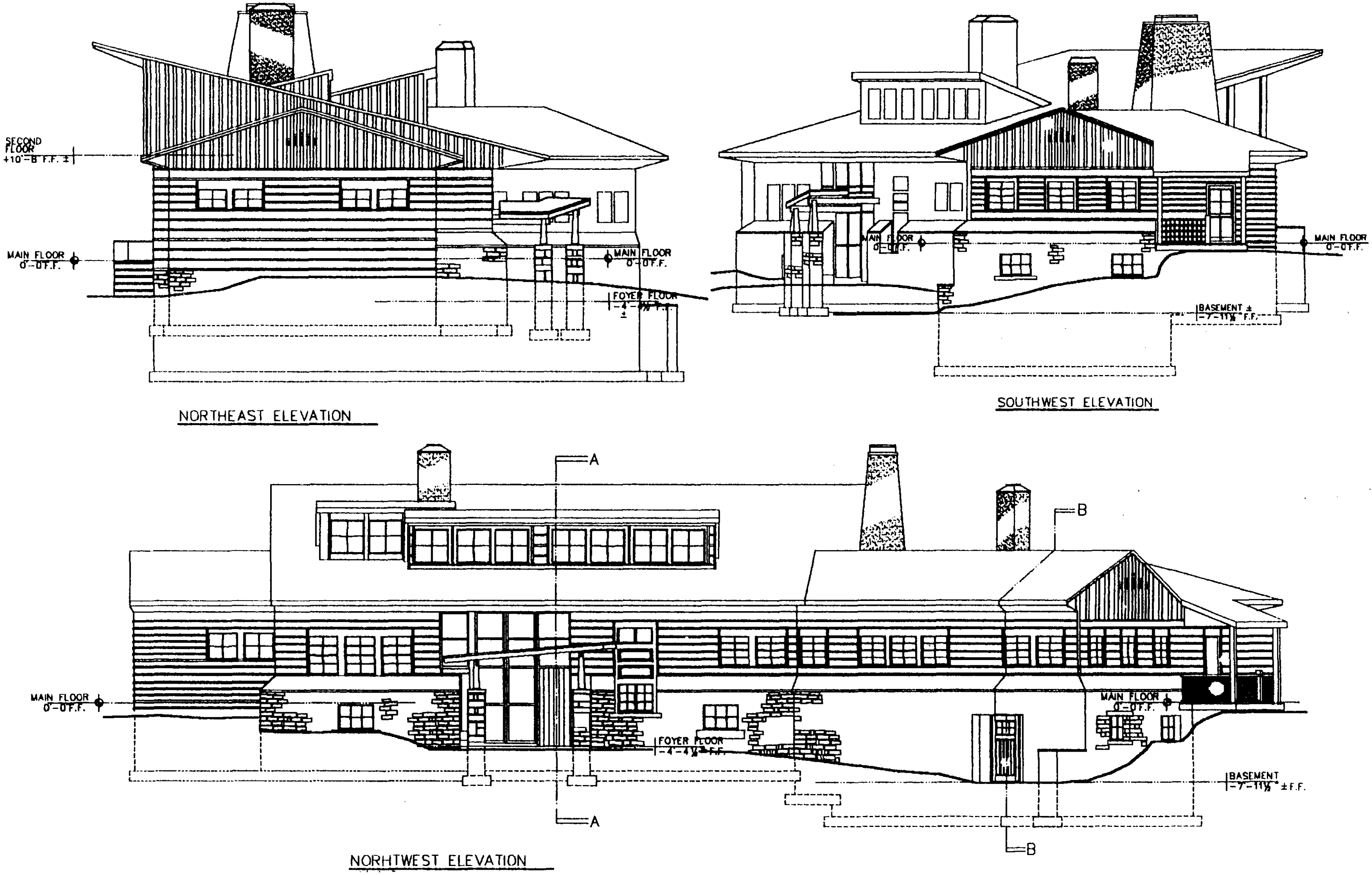


**Figure 2.6** House Elevations

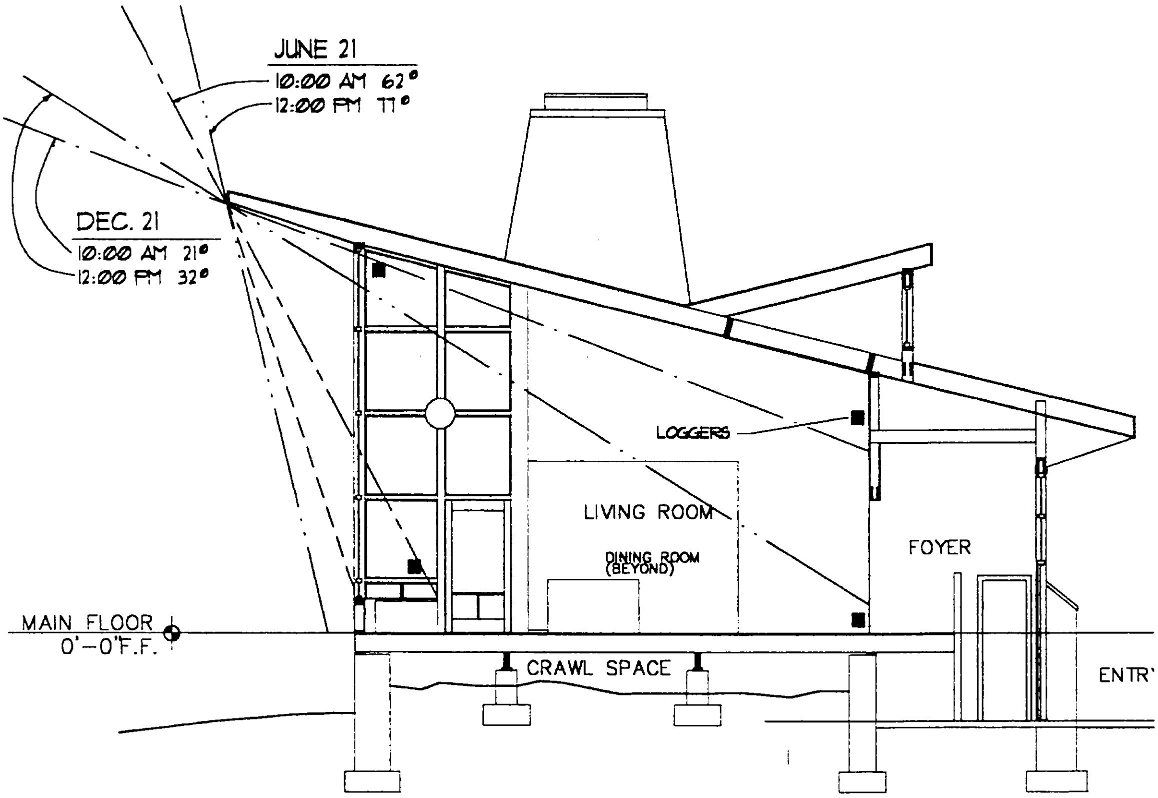


**Figure 2.7** Living Room Section; Sun Angles

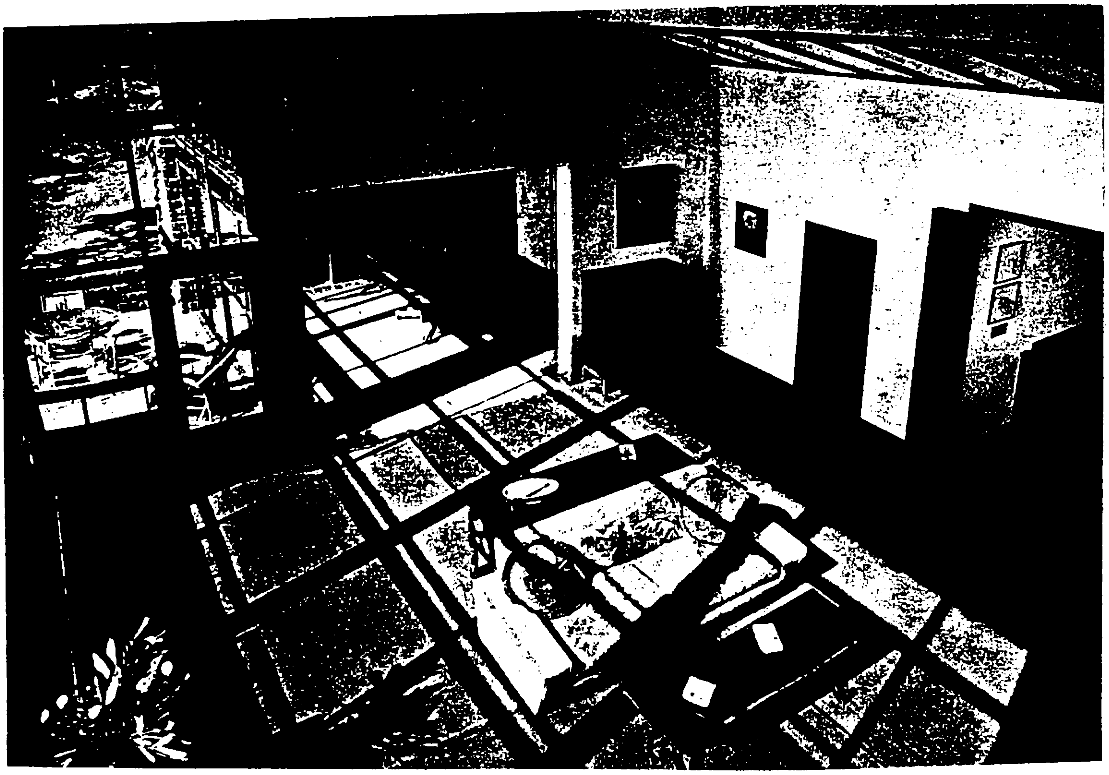


**Figure 2.8** Interior at equinox; photograph from the Architectural Forum November 1945 article.

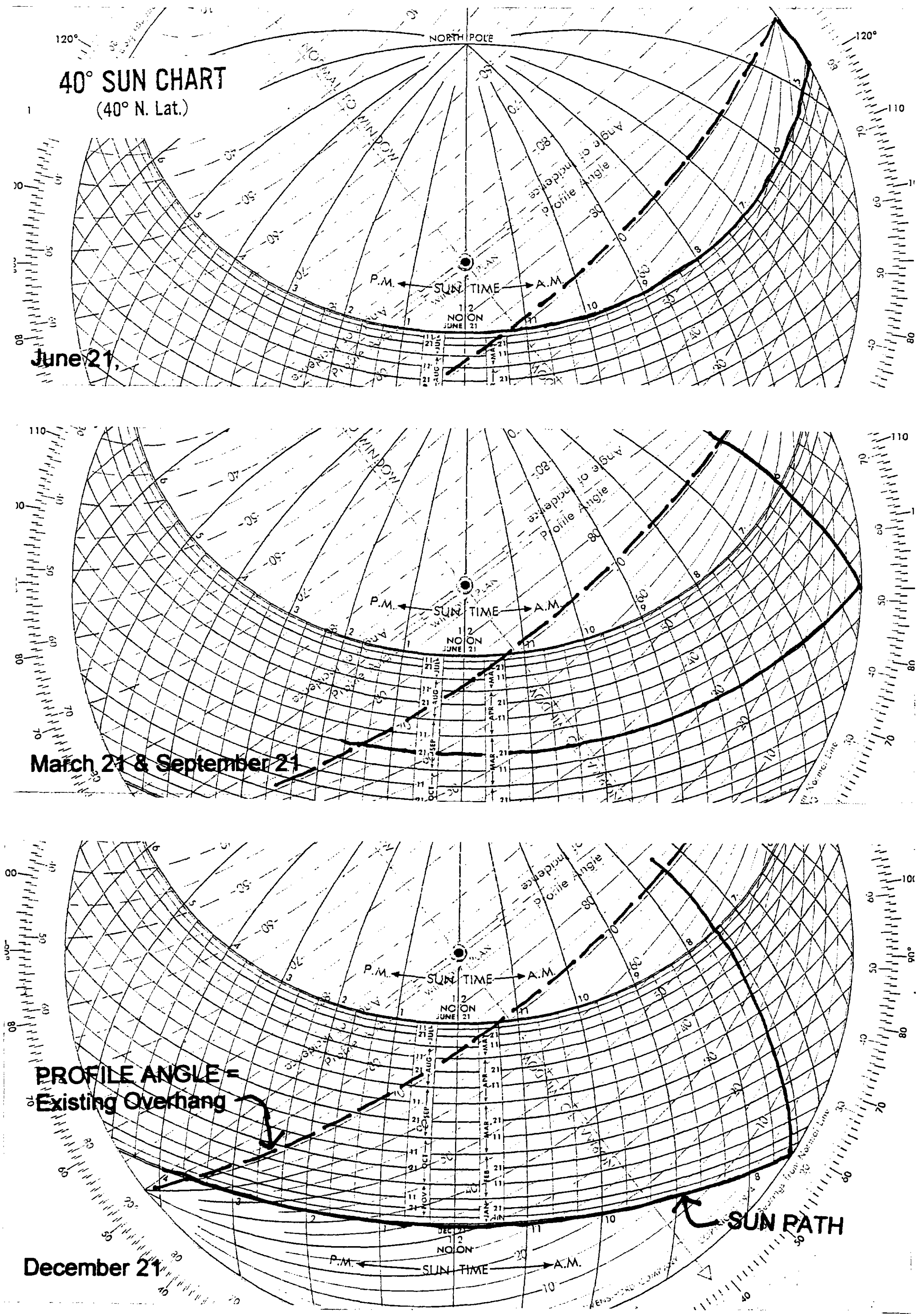


Figure 2.9 Sun Penetration Diagrams; Main Wing - actual orientation, 38° east of south

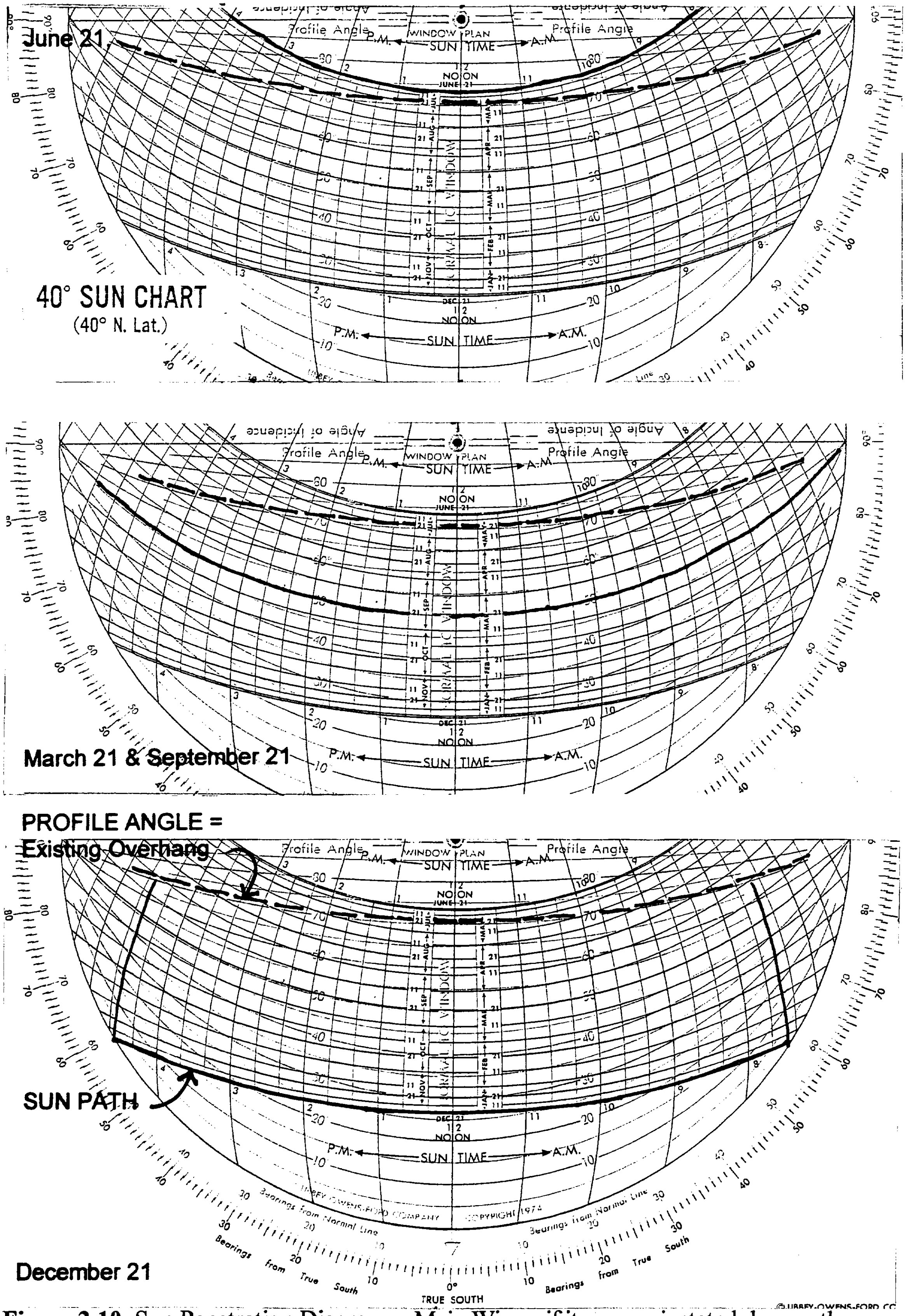


**Figure 2.10** Sun Penetration Diagrams; Main Wing - if it were orientated due south

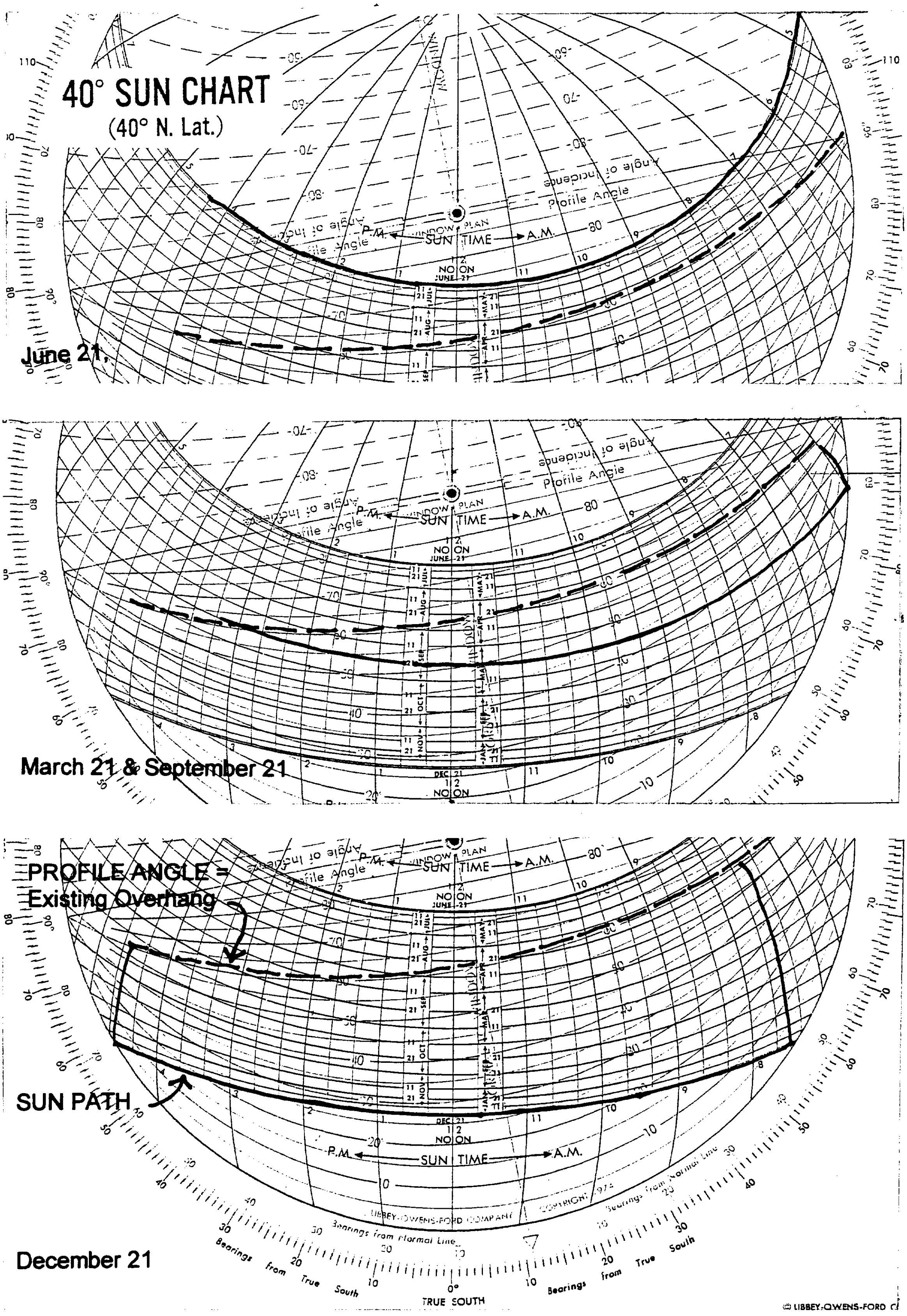


**Figure 2.11** Sun Penetration Diagrams; Servants Wing orientation 11° east of south

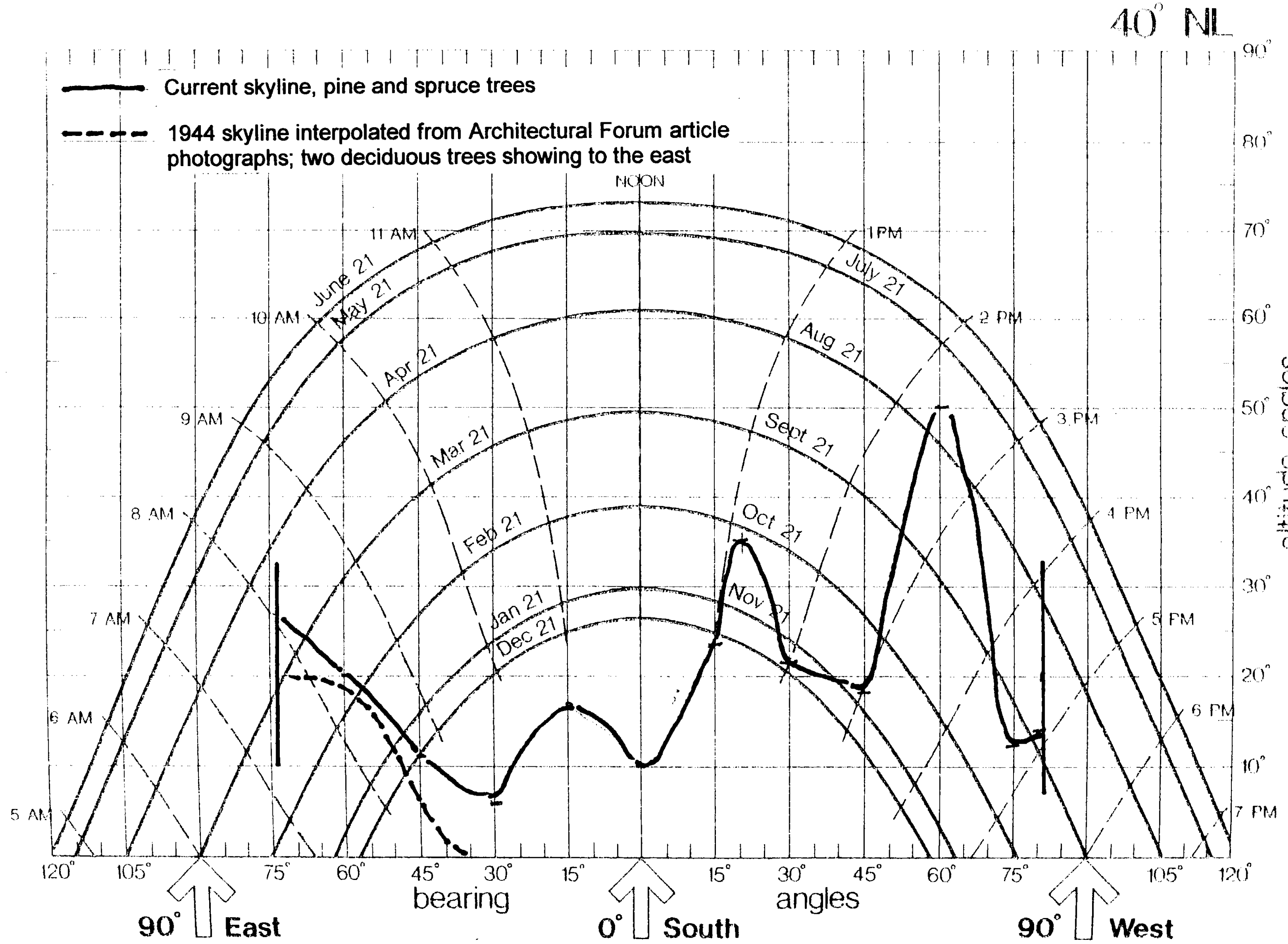


Figure 2.12 The skyline; plotted from within the Living Room

# CHAPTER 3

# THE RAMIREZ HOUSE SOLAR PERFORMANCE

This chapter examines the Ramirez House thermal performance through actual testing and computer simulations. Comparison of actual data and theoretical calculations will provide insight into the degree to which the building's behavior is solar.

## 3.1 Solar Design: Data Collection and Analysis of Actual Solar Performance

### 3.1.1 General

The Ramirez House has been nominated for listing on the National Register of Historic Places as a representative example of early solar design. As a visit on a sunny winter day demonstrated, the Living Room and adjacent spaces were perceptibly warmer than other areas of the house not receiving sunlight. To quantify how much soalr energy was collected and retained by the building necessitated a long term testing. The goal was to observe temperatures in different areas of the house and compare them to exterior conditions over all seasons.

The Ramirez House provides an ideal test environment, free of the complexities and variables associated with human occupancy. (1) Since the conventional heating system is turned off, testing directly records the influence of the sun. To test solar gain, instrumentation was set up to record external and internal ambient air temperatures, relative humidity and illumination. The temperature probes were suspended away from any objects and out of direct sun. The testing started on February 2, 2000 and continued through the remainder of year 2000. Data was downloaded approximately once a month.

Some equipment substitutions and modifications of the recording interval were made as the testing progressed.

### 3.1.2 Equipment

Currently available equipment allows for measuring of a significant range of information such as temperature, humidity, pollutants, and for automatic recording of the data at selected intervals. Sensors (probes) housed within, or outside (and connected by wires) the loggers make the measurements. Logged information is stored within compact, battery-operated units (loggers). Data can be downloaded into a computer with varying degrees of convenience, up to and including by remote control. The equipment is increasingly user-friendly and it is decreasing in cost.

Instruments from two manufacturers, ACR Systems Inc. and Onset Computer Corp. (Hobo loggers), were used during the testing period (2). The equipment selection was originally influenced by budget constraints. The mixture eventually proved to provide an advantage of duplication, saving some data (3). The loggers were each set-up, launched, and downloaded by software produced by the manufacturer for this purpose. Both programs allow for viewing of the data in table and graph form. Each of the loggers claims somewhat different degree of sensitivity and reliability. (4)

### 3.1.3 Testing Set-up

Logger locations (Fig. 3.1) were selected for the best match of available and new equipment to the house configuration. Initially three ACR loggers (two or three channels each) were used to record interior temperature and relative humidity in the Living Room and Servants Wing. Four Hobo loggers were used for the remainder of the other data recording stations. Total of sixteen data channels were used. See Figure 3.1 for locations of loggers and probes. In April 2000 two interior ACR loggers were returned to the owner and replaced with one four-channel Hobo logger.

Testing was concentrated in the primary solar gain spaces of the Main Wing. Five temperature probes were set up in the Living Room, high and low, near the windows and near the back wall. This placement was intended to trace evidence of air movement and air stratification in the two-story space. Two loggers by different manufacturers were placed next to each other to observe if there was significant difference in measurements. Temperature probes in the Master Bedroom and the second-story Study recorded the behavior of the two direct-gain spaces connected to the Living Room. One temperature probe tracked the Dining Room. Relative humidity was initially recorded in each wing. The house remained fully closed for the majority of the testing period, with occasional entry for maintenance, repairs and data retrieval. An attempt to record the effects of natural ventilation failed through loss of data.

The Main and Servants Wings are at an angle to each other and are connected by a single door. While the Main Wing has extensive direct-gain glazing, the Servants Wing has only a modest amount of south-facing glass. Instrumentation in the Servants Wing was set up to provide on-site comparison of solar and conventional building performance in the same weather conditions. Two probes were located near the south windows and one near the north wall of this wing.

A light-intensity Hobo logger was placed on the windowsill in the center of the Living Room window wall. It faces directly south and records the amount of sunlight reaching the primary solar gain space. Exterior weather conditions including temperature and relative humidity on the site were recorded with a Hobo Pro Series logger. This logger was placed on the terrace outside the Dining Room out of direct sunlight. All this data, with the exception of light intensity, was recorded at one-hour intervals. (5)

Data was downloaded into an on-site computer, which was kept turned off except at data download times to protect it from power surges. This precaution and the lack of a phone connection precluded remote downloading of the data. The loggers were manually connected to the computer, the data saved, and the loggers re-launched each time. Use of many separate loggers made coordination of data complicated, resulting in the loss of some data due to human error in August, September and October 2000. With practice, the collection became better synchronized and reliable.

In addition to data collected at the site, local weather data for the Pocono Environmental Education Center located a few miles south of Ramirez House in the Delaware Water Gap Recreation Area was supplied by a regional weather service. This data provided more generalized weather information, including temperature, relative humidity, precipitation, wind speed and solar radiation. The solar radiation data allowed for differentiation between sunny and cloudy days, while the temperature data allowed for comparison of the local microclimate to more regional weather.

### 3.1.4 Data Manipulation

To facilitate the manipulation of the data received from the two different software programs and the outside source, all data was transferred into spreadsheet files (Excel by Microsoft). Data was then combined into one large file and multiple graphs were developed to show and compare various aspects of the solar house performance.

### 3.1.5 Monthly Graphs

All performance graphs can be found in Appendix A. The series of graphs chart the house conditions on a month-by-month basis. Following is a summary of their readings:

The SUN graphs compare solar radiation in the region to the amount of sunlight reaching inside the direct-gain space (Fig. A1). Because sun's availability is measured in two dissimilar units, their values should not be directly compared. (6) The radiation data indicates sunny days; illumination the effect of the sizable roof overhang. While the sun's energy measured at the weather station increases from winter to summer, the amount of sun reaching the Living Room decreases.

The EXTERIOR TEMP graphs compare exterior temperatures on site to the measurements from the local weather station (Fig. A2). The site measurements are consistently higher, anywhere from one to ten degrees, than those of the weather station, and record conditions on the sheltered stone terrace in front of the solar window wall. The terrace's microclimate boosts house performance in the heating season, but also increases the need for cooling in summer months.

The INT/EXT TEMP graphs compare the average inside temperatures to the outdoor temperature overlaid with sun radiation (Fig.A3). Month-by-month comparison of the two wings shows that the Main Wing's interior temperatures remain consistently higher than the outdoor temperatures during the winter months. Only after several cloudy days does the solar space equilibrate closer to the outdoor conditions. See Fig. A6 for detailed graphs of one such period. In early spring, (March, April) solar gains are still visible in the Main Wing. Between May and July, interior temperatures fluctuate with the outdoors. Interestingly, during that period the interior daily range is less than outdoors and interior nighttime temperatures remain higher than outdoors. From August through October, interior temperatures exceed outdoor ones, not a desirable effect in the summer months. By November we appreciate the effects of solar gain once again. The Servants Wing shows minimal response to sun with interior temperature fluctuations for the most part following the corresponding exterior temperatures.

The DELTA T graphs overlay the difference between average interior and exterior temperatures and the solar radiation (Fig. A4). Positive values indicate that the house interior is warmer than the outdoors; negative values mean that the interior temperature lags behind the exterior. The desired effect is to see positive values in the heating season and negative values in the cooling season. The graphs show that the Delta T for the solar Main Wing remain positive most of the winter, spring and fall, while the non-solar Servants Wing averages closer to zero.

The TEMPERATURE SWING graphs show the difference between the lowest and highest interior temperature over a twenty-four hour period for both wings (Fig. A5). This is an occupant comfort indicator. (7) See the comparison to the computer simulation results described in Section 3.3. The temperature swings are dramatically higher for the solar wing, with the highest variation in the cold months.

### 3.1.6 Detailed Daily Graphs

Additional graphs in Appendix A show details of the solar (Main) and conventional (Servants) wing performance over selected times (one or five days). The conditions chosen include cold/sunny and cold/cloudy winter days, as well as a hot/sunny summer day. The conditions are graphed for the Living Room, Study and Master Bedroom, and the Servants Wing.

Review of December 25, 2000, a cold sunny day near the winter solstice (Fig. A5), shows average temperatures in the Main Wing responding to the sun with rapid 30°F warming between 9:00 AM and 2:00 PM and temperatures 20°F above the exterior throughout the day. During the same period, the Servants Wing remains approximately five degrees warmer than outdoors and shows no temperature spike in the morning. A detailed graph for the Living Room shows the striking effect of the eleven-to-eighteen foot ceiling and the northwest oriented skylight on the temperatures in the space. (Fig 3.1a) During the peak solar gain period all locations show significant warming. Most dramatic is the 30°F warming over a two hours observed near the floor in the back, demonstrating the long reach of the low winter sun. The ceiling at the back warms by 20°F a few hours later, while the low areas near the windows show only 10°F warming. The area near the ceiling at the windows remains ten or more degrees warmer than all other measurement points throughout the day. During the same day, Master Bedroom and Study temperatures are very similar to the ones in the corresponding locations in the Living Room.

A cloudy period at the end of February 2000 (Fig. A7) shows only slight fluctuations in average interior temperatures in both wings. The Main Wing remains two to three degrees warmer than the Servants Wing, possibly showing energy gain from diffused sunlight. In the Living Room temperatures at high and low locations show only slight variation over the course of a given day.

On a hot, humid July day, average interior temperatures are most comfortable in the Servants Wing (Fig. A8). The Servants Wing, only 11° off due south, is well protected by its overhang. The Main Wing heats up more, but still remains ten degrees cooler than the exterior through the afternoon, the hottest part of the day. The Main Wing temperatures reflect the effects of easterly orientation of the house, which results in sun penetrating inside in morning hours (Fig. A8a). The Living Room temperatures show a vertical stratification pattern similar to, if less dramatic than, the sunny winter day. Wright placed windows to allow for natural ventilation, which would have exhausted the hot and drawn-in cooler air from the north side of the house. This cross-ventilation would have lowered the average temperature and increased human comfort. Unoccupied, the house was fully closed during data collection.

### 3.1.7 Description of Results

Review of the graphs confirms the expected and observed behavior. On cold sunny winter days solar gain spaces in the Ramirez House heat up significantly. Unaided by any other heating some areas in the Living Room reach temperatures up to 60°F. Peak temperatures occur between 10 and 12 AM coinciding with the southeasterly orientation of the house. Different areas of the wing show temperatures differing by 20 degrees during the same period. The space also cools off quickly. Daily temperature swings range from the teens up to a maximum of 35°F (8). Over periods of several sunny winter days, inside temperatures stay significantly above outside temperatures. During cloudy periods interior temperatures are closer to, but still above, the exterior. Generally, the average temperatures in the main wing remain above the exterior by ten or more degrees, even in nighttime, suggesting the house is capable of retaining some collected energy over the twenty-four hour period.

The Main Wing also retains heat in the summer months. Interior temperatures remain above the exterior, if to a lesser degree than in the heating season. While daytime peaks still show response to sun, nighttime temperatures remain above the exterior, suggesting lack of ventilation.

Despite “better” orientation, nearly due south, the Servants Wing shows limited benefit of solar gain in heating season. Indoor temperature fluctuations are very modest compared to the outdoors; an effect that persists through the warmer months.

## 3.2 House Components Quantified

### 3.2.1 Building Envelope

Calculated areas of the building envelope assemblies were based on measured drawings prepared for the NPS by an outside consultant. Determination of thermal values was derived from various sources as described in Sections 2.4 and 3.1.3. Original building walls were assumed to have been uniformly insulated in walls and ceilings with R=10 insulation. This assumption may be incorrect for walls retained from the 1910 house. See Appendix B for areas and values used in computer simulations calculating theoretical performance of the house.

### 3.2.2 Windows and Glazing

Following are the areas of the building windows and the glazing (winter) values (9).

Main Wing - Direct Gain glazing

| | | | |
|---|---|---|---|
| Fixed insulated glass; ¼” air space | 638 sf | U=0.58 | R=1.72 winter |
| Operable awning units; single glazed | 136 sf | U=1.1 | R=.91 |

Main Wing - Other Glazing

| | | | |
|---|---|---|---|
| Double Hung windows, single glazed w/ storm sash | 197 sf | U=0.5 | R=2.00 |

| | | | |
|---|---|---|---|
| Fixed windows; single glazed | 108 sf | U=0.91 | R=1.10 |
| Servants Wing - All Glazing | | | |
| Double-hung windows, single glazed w/ storm sash | 156 sf | U=0.5 | R=2.00 |

The modern approach to passive solar design stresses optimizing the relationship between glazing and thermal mass, the heat storage capacity of the house. The Ramirez solar glazing represents 24% of floor area and exceeds all recommended amounts for direct gain solar design. According to the *Builders Guide* (see Section 3.3.2), sun-tempered houses (glazing = 7% of floor area) can store solar energy in the "free mass" of the house contained in the building materials and furnishings. The Servants Wing falls in this category. Direct gain glazing should not exceed 12% of the floor area and requires additional mass. The total of all passive solar glazing should not exceed 20% of total floor area and should be balanced by thermal mass. Other sources offer similar recommendations. (10)

The Ramirez House contains only a limited amount of thermal mass, primarily in plaster walls, the stone and brick of fireplaces and in the hardwood floors. These materials are insufficient to balance and absorb rapid solar gains produced by the eighteen foot high window wall of the Living Room.

### 3.2.3 Thermal Mass

According to current theory, interior finish materials in the Ramirez House contribute to heat storage. Location of these materials, directly in the sun or in connected spaces, determines the degree of their contribution to the thermal behavior of the house.

The ability of materials to hold and release heat or heat capacity, expressed in BTU/cu ft-°F, is related to the density of a given material and its specific heat (11). The existing materials contributing to the thermal storage of the House have a heat capacity around 25. In comparison, water has a high heat capacity of 62.4 BTU/cu ft-°F.

The contributing thermal mass materials are:

a) 3/4" thick plaster on metal lath.

The Main Wing contains over 4,400 sf of plaster walls and 2,570 sf of plaster ceilings.

b) Fireplaces: stone or tile on brick.

Four fireplaces are faced with 1 1/2" to 2" thick bluestone, while the Dining Room fireplace is faced with 6"x6" 1/2" thick ceramic tile. All fireplaces are of brick construction. Since the facing materials are applied directly onto the fireplace structure, the brick is counted towards the thermal mass in the House. The Main Wing contains 180 sf of stone or tile on brick and an additional 60 sf of exposed brick; the Servants Wing contains only 20 sf of stone and brick.

c) Hardwood floors

Oak floors are 1" thick tongue-and-groove. Sub-floors are one-inch thick pine. Net oak floor areas are, Main Wing 2,286 sf and Servants Wing 700 sf.

## 3.3 Performance Simulations

### 3.3.1 General

Computer tools for predicting the behavior of solar buildings are increasingly available and constantly improving. They tend to, however, focus on providing design tools for creating new buildings, rather than analyzing existing ones. One program, *Builders Guide,* was selected for its simplicity of use and because the results directly model the effects of solar gain.

### 3.3.2 Builders Guide

*Passive Solar Design Strategies: Guidelines for Home Builders* (*Builders Guide*) is a design tool for builders, intended to assist them in incorporating solar design in their residential buildings. It is based on research sponsored by the United States Department of Energy (US DOE) Solar Buildings Program. The *Builders Guide* package consists of a set of written guidelines explaining passive solar design strategies and a set of four worksheets, supported by data tables, for calculation of a building's thermal performance levels. The accompanying software duplicates the original manual calculation process. Formulas and tables are conveniently embedded in the program. See Appendix B.

*Builders Guide* software allows for reiterative calculations, changing one or more design parameters at a time. It sets up a Base Case calculated for a house of the same floor area which represents a typical house for the given climate zone. This Base case house has no solar features, windows equaling 3% of floor area, and insulation representing current practice as surveyed in 1987 by National Association of Home Builders. At each stage of the calculation, the Base Case, or any previous building simulation, can be used as the Reference Case.

### 3.3.3 The Ramirez House Analysis: Methodology

The Ramirez House was divided into two sections, Main and Servants Wings, and each wing treated as a separate building. The Base Case was calculated for each wing. The Original Design was then entered and compared to the Base Case. Based on early photographs showing no shading by trees, the Original Design was calculated assuming full exposure to sun.

Next, possible improvements were calculated and compared to the original design that became the Reference Case. The first set of improvements included increased insulation and windows with low-e glass. In the next simulation thermal storage was added to the already improved house. Appendix B includes worksheets and summaries for these simulations.

Several simplifications and assumptions were made to fit the unique and unconventional features of the Ramirez House into the structure of *Builders Guide*. These included: ignoring the second floor Study, assuming all of the Main Wing is over crawl space, and assuming uniform insulation. Because of these simplifications, the results should be viewed as an expression of a simple model rather than an accurate and exact picture of the House's performance.

### 3.3.4 Simulation Results

The simulations reveal that the original design required twice as much energy to heat as a similar house built to 1980's general standards. (Figs 3.4 and 3.7) This was true for both wings of the house. However, the solar wing received considerably more (12%) of its energy from the sun than did the theoretical Base Case (4%) or the conventional Servants Wing (4%) (Fig. 3.5 and 3.8). With improved insulation and windows, the solar contribution in the Main Wing would increase even further.

The Original Design simulation predicted very significant temperature swings in the Main Wing (Fig. 3.6 and 3.9). The temperature swings of 28° F are more than double the 13° F recommended by *Builders Guide*. As will be discussed in 4.2.4, introduction of greater thermal mass could reduce these to 19° F. The mass included in the simulation study consisted primarily of freestanding fiberglass tubes (12) filled with water (Fig. 3.3).

Proposed number of tubes was limited by practical structural and functional considerations. Additional elements would likely limit the usefulness of the house for human occupation.

### 3.4 Solar Performance Discussion

The Main Wing fits the basic definition of Passive Solar Direct Gain design (13) (14). It is doing what the designer set out to do, collecting some solar energy to offset large expanses of glass. In fact, it collects proportionally more energy than a conventionally designed house of the same size.

It is a less-than-perfect solar design when judged by today's standards. The house's east-of-south orientation, limited insulation and less efficient windows all limit its solar performance. The main consequences of the solar design "flaws" are made evident by examination of the data, computer simulations, and interviews with former resident, Mr. Chant. The house collects solar energy, but does not retain it well since it has only R=10 insulation (15) and limited thermal mass materials absorbing the energy for later release. Rapid temperature rises on winter mornings in the living room result in large temperature swings, compromising human comfort. Interestingly, Mr. Chant did not remember winter overheating to be an issue. He did report the Servants Wing being difficult to heat.

While less than perfect, it is a good solar house for 1944 and even for today. As the data shows, during the heating season the interior remains warmer than the exterior by as much as twenty degrees, significantly lowering the need for additional heating. The house is also successful on another level, that of occupant satisfaction. Mr. Chant, the last occupant, fondly remembers living there, enjoying the views and sunlit rooms.

## Chapter 3 Notes

(1) Occupied houses are heated. Heating, set to individual human preferences, masks the effects of the sun. Since occupant activities vary greatly, they also introduce a substantial number of variables, i.e. opening of windows and doors in winter.

(2) Three loggers by ACR Systems Inc. were loaned to the project by another National Park Service office. Four Hobo loggers from Onset Computer Corp. were purchased specifically for this project.

(3) The Author lost some data by confusing the procedures between the two systems.

(4) The loggers by the two manufacturers claim somewhat different degrees of sensitivity and reliability. For example, interior temperature loggers by Hobo offer greater measurement range, but lesser sensitivity. More significantly, the two manufacturers differ in availability and convenience of use of the peripheral equipment. Hobo remote probes and other connectors are all plug-in; ACR leads have to be screwed in. Hobo has probes with leads ranging from 6' to 50' in length; ACR wires are only up to 20' long. Hobo 1-year batteries can be replaced in the field; ACR batteries carry a ten-year warranty, but can be replaced only in the factory. Hobo equipment is run on less complex software, requiring a shorter learning curve. Though the Hobo equipment generally seems easier to use, it requires more attention at download and re-launch to avoid loss of data. See equipment catalogs for both manufacturers for additional details.

(5) Light intensity was initially recorded at 15-minute intervals to observe variation in cloud/sunny conditions in considerable detail. The recording interval was changed to 30 minutes as data analysis moved towards observing longer trends.

(6) See Appendix A, Fig A1 for definitions of radiation and light intensity units.

(7) Air temperatures in human comfort zone are between 68°F and 86°F depending on relative humidity, air movement and human occupation. See Stein, *Mechanical and Electrical Equipment*, Chapter 2, pages 34 - 42.

(8) *Builders Guide* recognizes temperature swings of over 13 degrees as excessive.

(9) See *Graphic Standards*, p.92 for thermal resistance of glazing materials.

(10) *ASHRAE Design Manual* quotes 7% for low-mass (suntempered) buildings and 25% for very high-mass buildings. Mazaria, p. 122, closely relates sizing of windows to climate and to thermal mass quantity and placement.

(11) Specific heat measured in BTU/lb-°F is an amount of heat one pound of material can hold.when its temperature is raised one degree Fahrenheit. Heat capacity = specific heat multiplied by density. Mazaria, p. 25 to 27

(12) Water tubes have met with mixed responses from building occupants. They are often seen as alien objects and a potential source of leaks. They present a design challenge that has yet to be met by design professionals. Currently available fiberglass tubes could provide interesting and colorful (color dyes) space defining elements.

(13) According to Mazaria "a passive solar-heating and cooling system is ... a system in which the thermal energy flows in the system are by natural means such as radiation, conduction and natural convection. In essence, the building structure or some element of it is the system." p.28

(14) Direct gain space is a space directly heated by sunlight. Mazaria p. 29

(15) Common and currently recommended insulation levels are R=13 or 15 for 2x4 stud walls and R=30 or 38 for attics and ceilings.

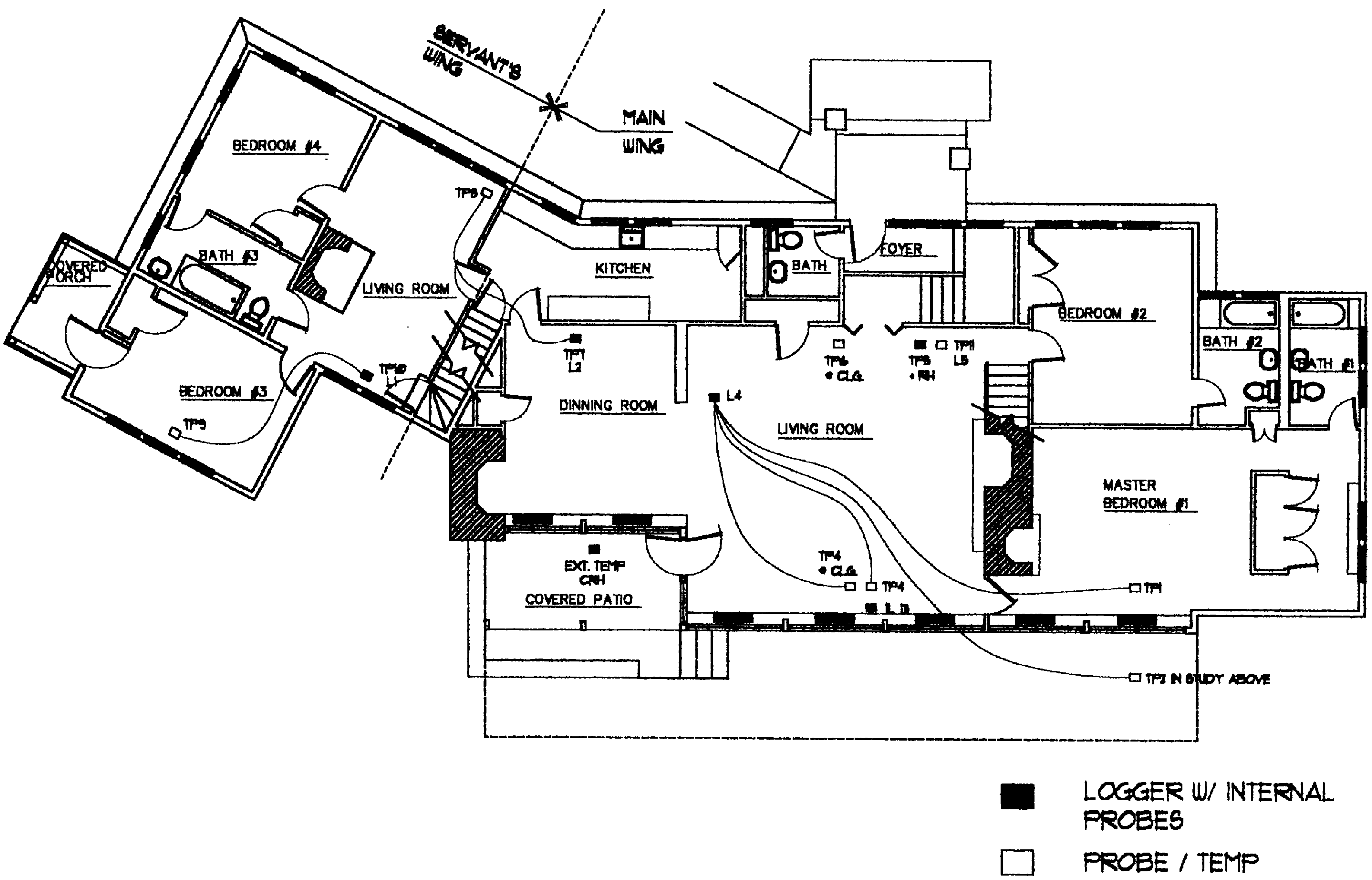


**Figure 3.1** First Floor Plan; Instrumentation

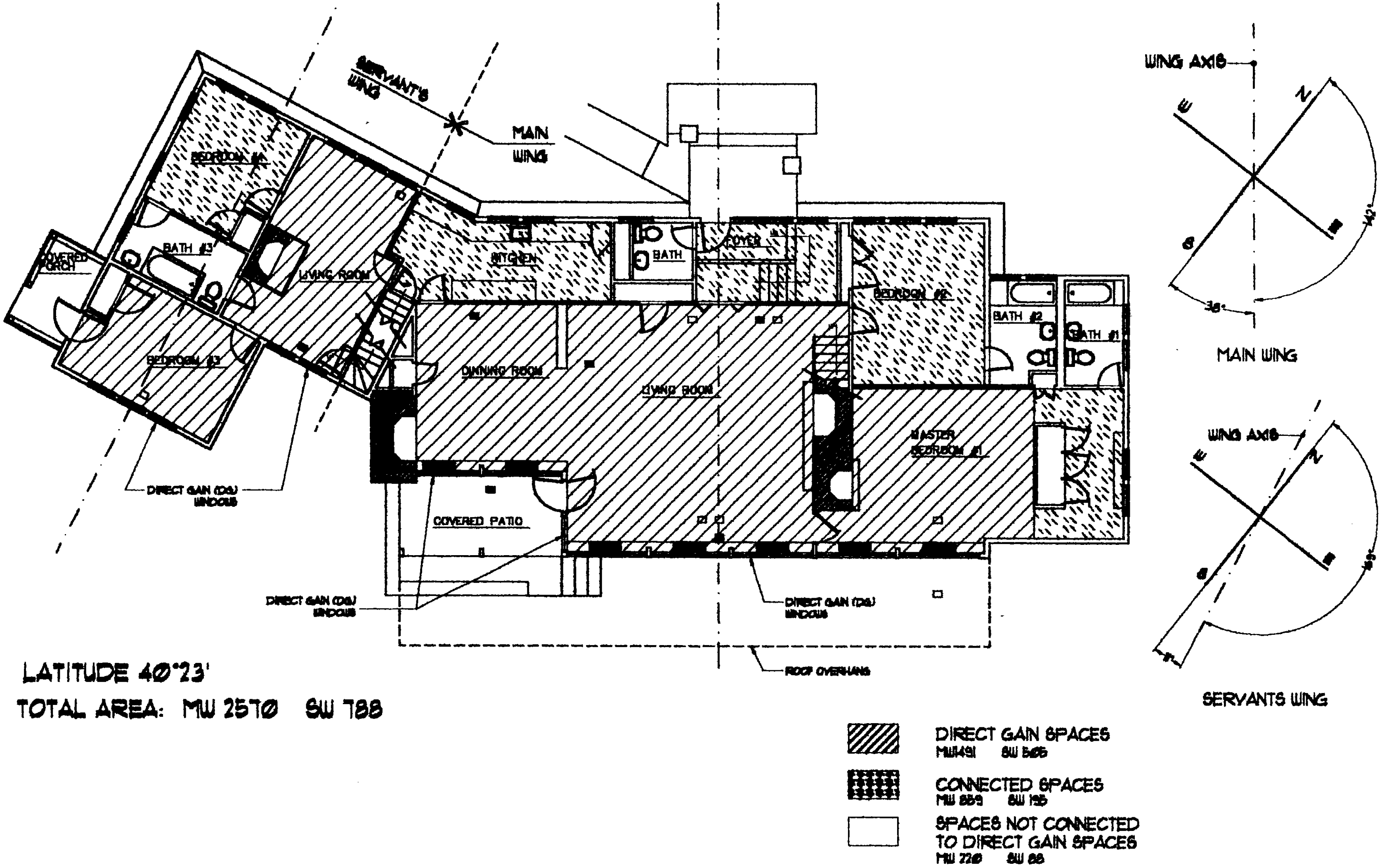
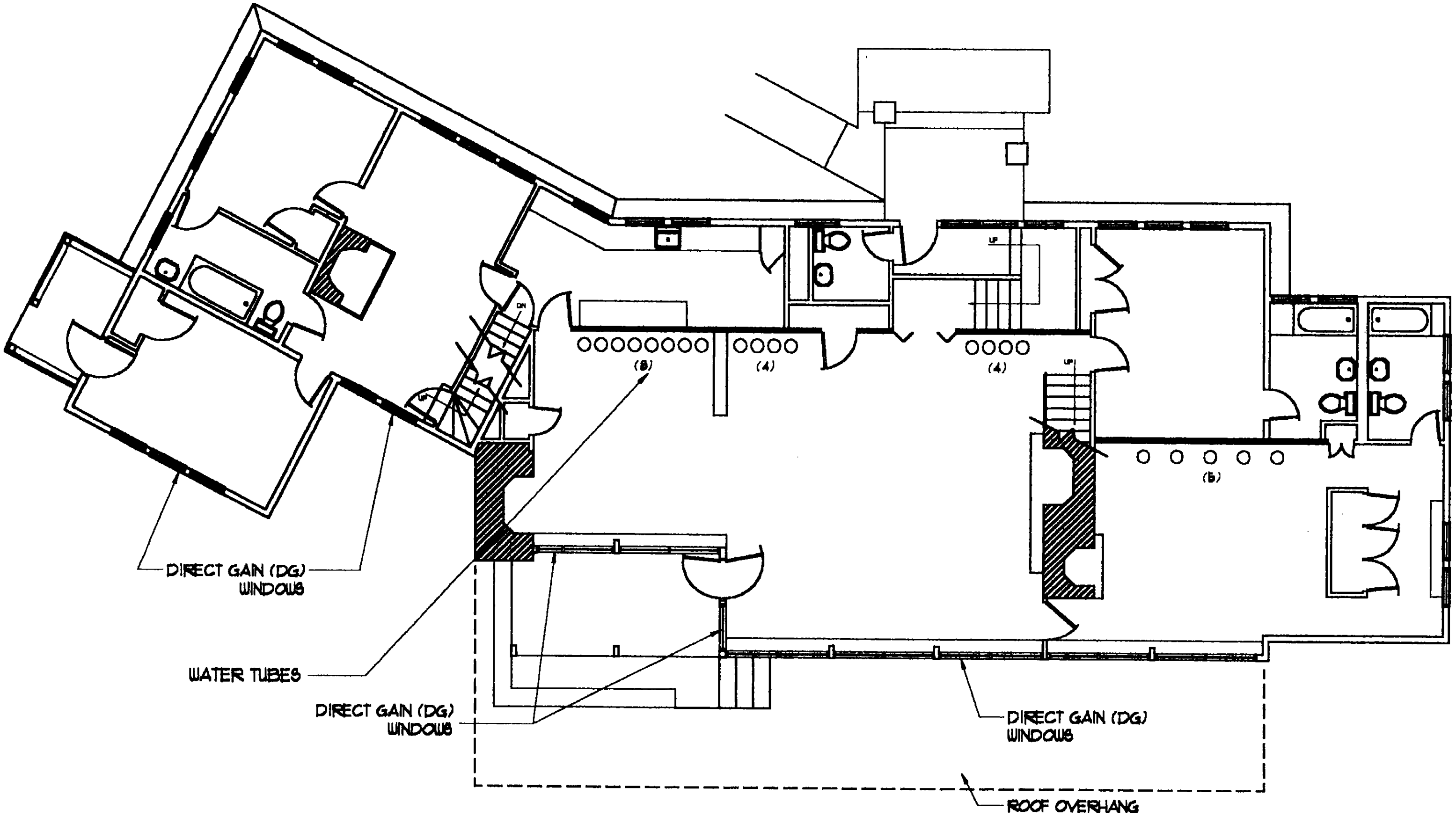


**Figure 3.2** First Floor Plan; Solar Features



EXISTING MASS

PLASTER WALLS & CEILINGS
HARDWOOD FLOORS
FIRE PLACES

PROPOSED MASS

○ WATER TUBE
12" DIA, 8'-0" HIGH
47 GALLONS EACH
HEAT CAPACITY - 1800 BTU
20° RISE

**Figure 3.3** First Floor Plan; Thermal Mass

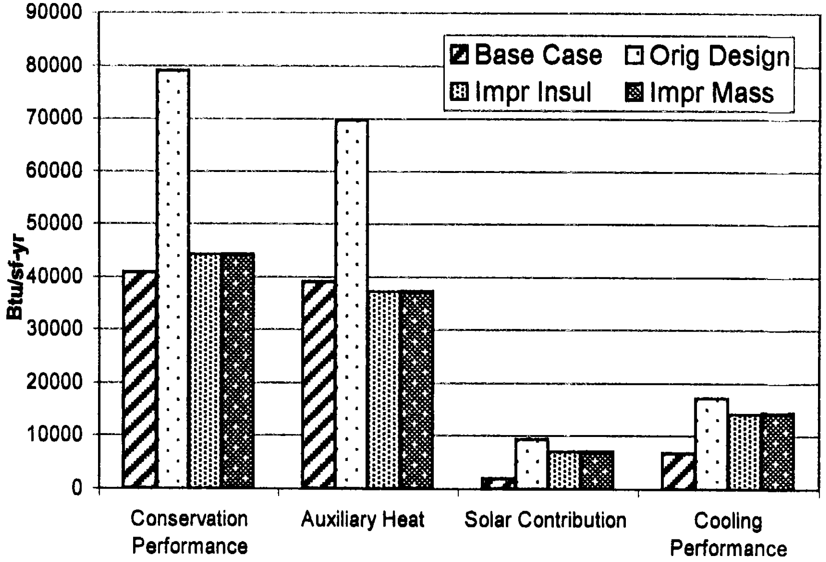


**Figure 3.4** Main Wing Performance Comparisons

Based on Builders Guide simulations estimating heating and cooling need

Base Case - Theoretical house built to 1980 energy code

Original Design - 1944 design; used as reference for following simulations

Impr Insul - original design with improved insulation and windows

Impr Mass - original design with improved insulation and windows, and with added mass

Conservation Performance - total amount of heat per one sf of building each year.

Auxiliary Heat - amount of heat from auxiliary heating system

Solar Contribution - heat from primary heating system, the sun

Cooling Performance - amount of cooling per one sf of building each year.

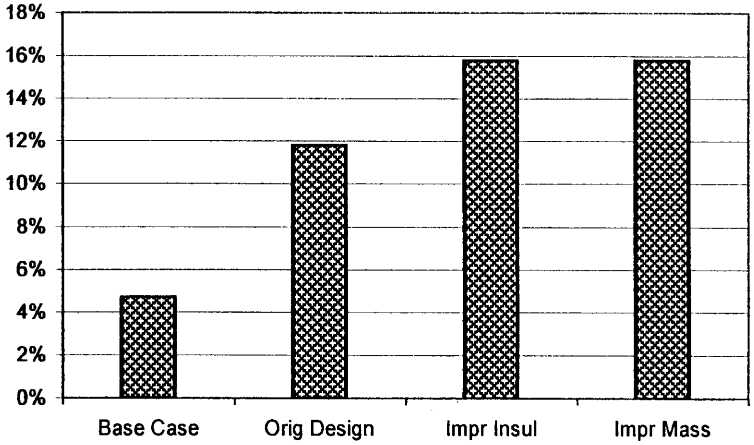


**Figure 3.5** Main Wing; Solar Contribution - portion of total heating provided by sun

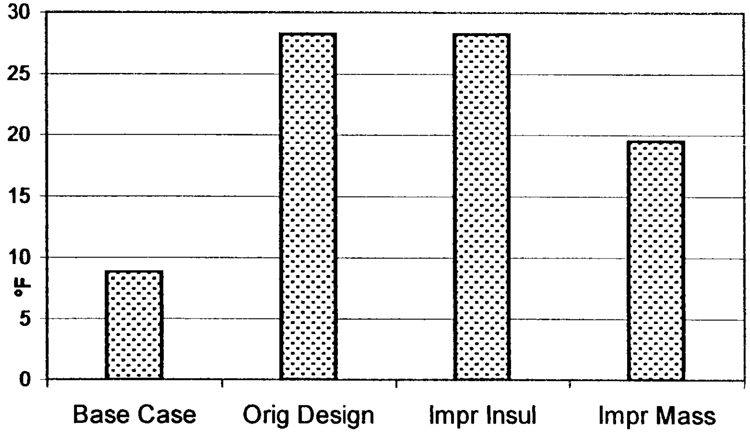


**Figure 3.6** Main Wing: Daily Temperature Swing

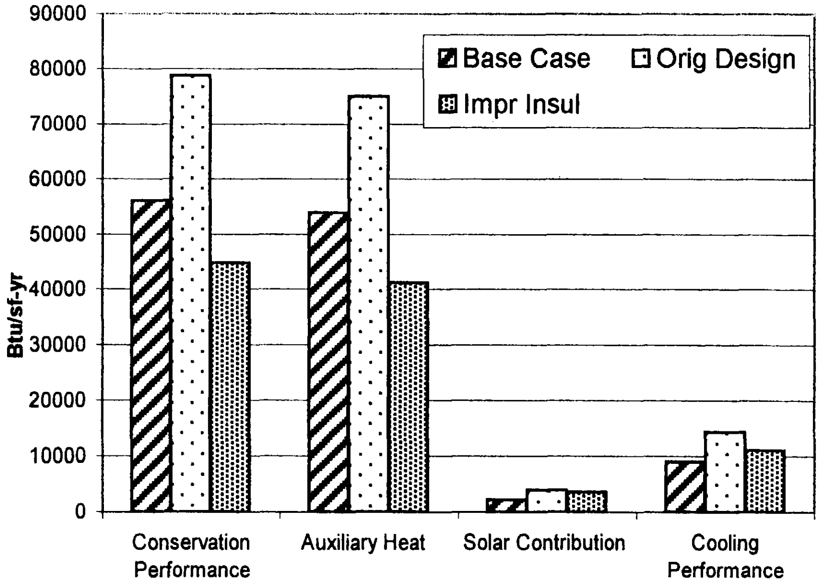


**Figure 3.7** Servants' Wing Performance Comparisons

Based on Builders Guide simulations. See Fig 3.4 for details.

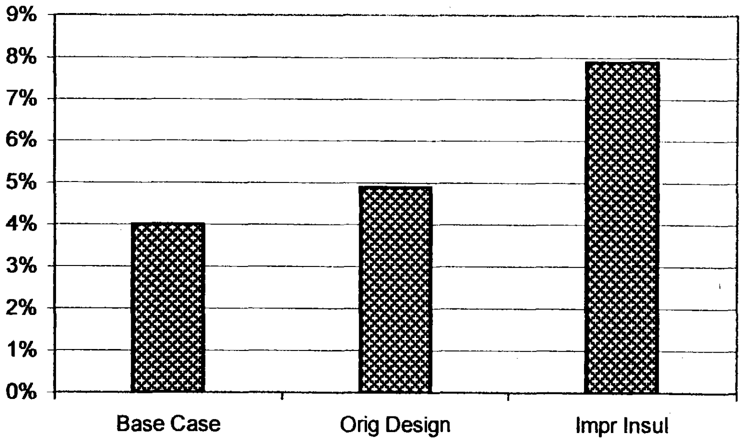


**Figure 3.8** Servants Wing; Solar Contribution -

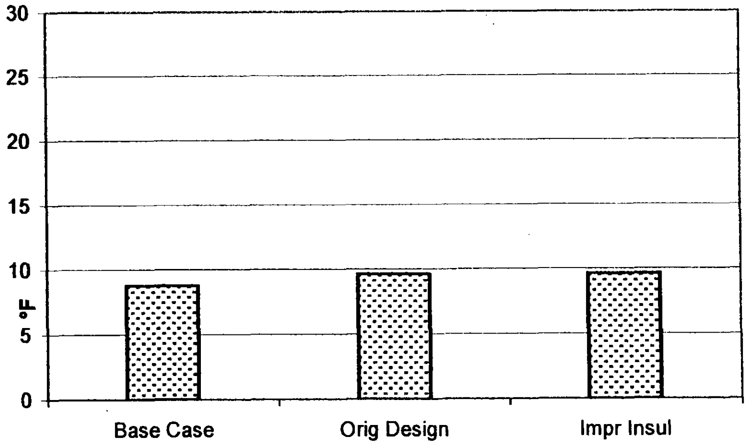


**Figure 3.9** Servants' Wing; Daily Temperature Swing

# CHAPTER 4

# SOLAR PERFORMANCE IMPROVEMENTS

## 4.1 General Potential for Performance Improvements

Independent of solar issues, bringing the Ramirez House to habitable condition will require a certain minimum number of renovations. These include repairs to the exterior and interior (new roof, painting, etc.), a new boiler and repairs to the existing heating distribution lines, and an upgrade of the plumbing and electric systems (1).

Adaptation for different uses will require different levels of improvement to accommodate the needs of the new occupants. A residential tenant may require an improved kitchen; office users would need additional power, different lighting, and air conditioning. Code requirements will also differ depending on the Use Group requirements and related life-safety issues, with the most stringent ones associated with classroom or museum functions.

Finally, the house would benefit from improved energy efficiency and solar performance. All the improvements should be considered in their relationship to each other for the most efficient, cost-effective, and historically correct results. An integrated approach to rehabilitation would be in keeping with modern sustainable practice.

## 4.2 Thermal Performance Improvements

### 4.2.1 Passive Solar Design - Building Envelope

The current approach to passive solar design stresses the importance of a high performance building envelope. Low-energy buildings start with high insulation levels, tight construction, and the best windows the budget can afford. As thermal performance simulations demonstrate (see Section 3.3.4), the original Ramirez House falls short of current good practice and would significantly benefit from envelope improvements. Those improvements would reduce the total amount of energy required to heat the house and better utilize solar energy by retaining more inside.

### 4.2.2 Glazing

The house would benefit considerably from improvements in window performance particularly in the Main Wing where windows represent approximately 24% of total wall area. Window wall panels could be replaced with modern, sealed, insulated, argon-filled units with low-e coated glass without significantly altering the appearance of the house (2)(3). The modular nature of the original windows is likely to moderate the relatively high cost of custom-sized panels. The single-glazed awning units could be replaced with new custom sized-units matching the appearance of the original sash.

### 4.2.3 Insulation

The levels of existing insulation appear to be consistent with good practice at the time of 1944 renovations. They are lower than recommended today especially in the ceiling and attic areas (4). A review of the existing house construction suggests that additional insulation could be introduced from above in the attics. Particularly beneficial would be the introduction of insulation over the large area of the Main Wing's shed roof.

The house would also benefit from insulating the perimeter at the floor joists, which are accessible from either the basement or crawl space. Increasing the existing wall insulation levels is not feasible without total replacement of the existing wall finish (plaster). The un-insulated Servants Wing walls could be insulated with blown-in insulation.

### 4.2.4 Thermal Mass

The modern approach to passive solar design stresses optimizing the relationship between glazing and thermal mass, the heat storage capacity of the house. The Ramirez House has a limited amount of thermal mass, contained in its interior finishes (See Section 3.2.3.). These materials are insufficient to balance and absorb rapid solar gains produced by the eighteen-foot high window wall of the Living Room. Recommended ratios of glazing to floor area are between 12% and 20% for the direct gain system of the Ramirez House. (See Section 3.2.2.) The Ramirez House solar glazing represents 24% of floor area, exceeding all recommended amounts.

Since reducing glazing is not an option in this historic house, the appropriate response is to add thermal mass. The addition of removable, non-destructive building elements, such as water tubes, is consistent with historic preservation protocol (See Section 5.1). The number and placement of the proposed water tubes (Fig. 3.3) was guided by functional considerations. The *Builders Guide* recommends 3.5 gallons of water for each square foot of glazing. Following this guideline, using water as thermal mass to fully balance solar glazing would require the installation of 49 water tubes, a number exceeding the building's capacity to contain. Twenty-one water tubes (5) proposed in the simulation resulted in reducing the temperature swing from 28°F to 20°F, a 29% reduction (Fig. 3.6).

Adding permanent thermal mass is difficult without changing the original interior materials of the House. Introducing solid masonry infill to the back walls of the Living and Dining Rooms appears to be the only feasible option. Since the existing wall plaster has sustained significant water damage and will require repair, this additional work may be acceptable.

### 4.2.5 Improved Summer Performance: Ventilation

As the scientific evidence on the effects of global warming suggests, the trend in temperate regions is towards a longer cooling season and an increased number of hot humid summer days and nights. This trend implies a greater need for measures improving comfort levels during summer. In anecdotal confirmation, the last house tenant, Mr. Chant, reported that in 1970's the house would become uncomfortably hot on some summer afternoons, while praising the generally beneficial effect of breezes on the site. The low and high house windows are well placed for natural ventilation. This could be mechanically augmented by ceiling fans, attic fans, or even motorized north clerestory windows. Ceiling fans would also improve the heating season performance by counteracting the vertical stratification observed in the Living Room (Section 3.1.6.).

More difficult is the issue of high humidity. In the five decades since the house was built, expectations of comfort have increased with air conditioning becoming expected in residential and commercial construction. New occupants of the Ramirez House may demand it. Insertion of new systems should be reviewed in the context of the historic preservation approach decided by the National Park Service (Section 5.1.2). A new air conditioning system or dehumidification system can be installed as an obviously new element clearly differentiated from the historic fabric of the house.

### 4.2.6 Landscaping

The land around Ramirez House was significantly more open in 1944. See the discussion in Section 2.5. Removing several pine trees would restore solar access and improve solar performance. Pruning of the evergreen foundation plantings around the Servants Wing would also have a beneficial thermal effect.

## 4.3 Benefits of Solar Improvements

The proposed thermal improvements would improve comfort levels and, by saving energy, decrease utility costs. Lower energy use would also reduce greenhouse gas and pollutant emissions.

An in-depth analysis of remedial work is likely to show opportunities for introducing thermal mass at modest extra cost, for example deteriorated plaster replacement may be paired with brick infill. Boiler replacement should be done in the most energy efficient way. Re-roofing can be coupled with added insulation installation. An integrated design approach is the key. A detailed evaluation of building envelope improvements linked to equipment sizing and reviewed for life cycle costs will yield optimal results in terms of building performance and the long term costs to the owner, the National Park Service.

Further studies will have to determine the renovation approach most appropriate and cost effective for the future use of the Ramirez House. This work strongly suggests that the benefits of improving the house will be tangible, reducing energy use and increasing the comfort of the occupants, in both cold and warm seasons.

## Chapter 4 Notes

(1) DWG staff is working on number of known repair tasks. There is no formal historic conditions report for the building.

(2) Low emissivity (low-e) coatings are designed to reflect heat back in the direction it came from. See *Environmental Building News* March/April 1996 newsletter, Vol.7, No.2, for a detailed explanation of the physics and application of these coatings.

(3) According to *Graphic Standards,* insulating glass with ½" airspace has U=0.49. The same insulated glass with low-e coating is U= 0.32 to 0.38. The original glass is assumed to be U=0.58. Pella Window manufacturers catalog currently lists windows of similar size to be U=0.54 and U=0.38 for insulated and insulated, low-e glass respectively. Given these values, low-e coating reduces heat loss by approximately 29%, representing significant improvement in a window's thermal performance.

(4) Recommended levels of ceiling insulation are R=30 or 38 for fiberglass bat.

(5) Off-the-shelf fiberglass water tubes are available on the market from Kalwall Corp.

# CHAPTER 5

# HISTORIC PRESERVATION AND ADAPTIVE RE-USE

The Ramirez Solar House is already recognized as a significant historic example of solar design. Since 1992 it has been under the stewardship of the National Park Service. It was nominated for listing on National Register of Historic Places in 1997. These factors, combined with its location, will determine how it may be used and preserved for future generations. This chapter reviews historic preservation considerations and makes an argument for one possible future for the house. If the Ramirez House were to become a Solar Research Center and Museum, it could preserve the past and promote dissemination of solar design knowledge.

## 5.1 Historic Preservation

### 5.1.1 Historic Preservation Background

The historic preservation movement is supported by a well-developed body of research, science, and professional knowledge. Historic preservation is also an evolving field. Concepts of how to preserve and restore, as well as what deserves preservation, are changing with time. From interest in a limited number of important historic buildings and sites, preservationists have expanded their concern to objects of more local cultural or aesthetic interest. The time-scale expanded from concentrating on venerable old objects to recognition that the recent past deserves public attention. (1)

While preservation of the natural environment has been a federal government concern since 1872, it was only after the World War II that the government and private sector joined forces in their responsibility for the preservation of culturally significant built environments (2). Culminating decades of evolution, the 1966 National Historic

Preservation Act set up a system for evaluation and preservation of the nation's cultural monuments and broadened the scope of preservation activities to include artifacts of regional and even local significance. The Preservation Act also established funding to support the work of The National Trust for Historic Preservation and state preservation offices (3). The National Trust, a congressionally chartered private organization, is charged with preserving national cultural heritage. The preservation practices are codified in the Secretary of Interior's *Standards for Rehabilitation.* (4) The National Park Service (NPS) operates within this system of laws and uses these technical guidelines when dealing with buildings and sites of historic and cultural importance.

The Ramirez Solar House has been determined to have historic significance. Therefore, NPS is obliged to follow preservation guidelines. The determination of an appropriate preservation approach is influenced by each building's historic significance, physical condition and potential use.

### 5.1.2 Rehabilitation Standards

Under the broad umbrella of preservation three definitions - preservation, restoration and reconstruction - guide an approach to a specific project. (5) (6) The *Standards for Rehabilitation* require that "The distinguishing qualities or character of a building, structure, ... shall not be destroyed. The removal or alteration of any historic material or distinctive architectural features shall be avoided when possible" and that "All buildings, ... shall be recognized as products of their own time." (7) The *Standards* set up a hierarchy of approach: first - identify, retain and preserve; second - protect and maintain; then - repair, replace; and lastly - add to or alter the historic building. Responses to health and safety codes and to energy retrofitting are reviewed for their negative impact on the building's historic character. The strictest application of these principles suggests that any renovation that changes the essential character of the Ramirez House would not be appropriate. It can be argued that the essence of the Ramirez Main Wing is the solar function. To improve its envelope is to change its historic thermal performance in this interpretation.

Adaptive re-use calls for a more flexible application of rehabilitation standards. Defined by the National Trust as the process of converting a building to a use other than that for which it was designed, adaptive re-use has increasingly gained recognition in the preservation community. With the increased number of structures included in historic preservation activities, there came increased discussion of acceptable levels of physical changes associated with adaptation of a given building to a new use. The key measure is whether the proposed adaptations compromise the architectural integrity of the historic property (8). This discussion has direct bearing on the Ramirez House. If the integrity of this house is defined by its historic performance levels, than any intervention proposed in Chapter 4 will compromise it. In practice, such a narrow interpretation is not usually applied. The focus is on visible architectural historic features with many necessary changes to the building envelope and systems deemed acceptable (9). In this context the proposed improvements would be justified, if executed with proper care and with proper documentation of original features and materials.

## 5.2 Governmental Mandates Influencing Proposed Use

The Ramirez House fate is closely tied to the mission of the National Park Service: *"To preserve unimpaired the natural and cultural resources and values of the National Park*

*System for the enjoyment, education and inspiration of this and future generations. The Park Service cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world."* (10)

At this time the NPS is in charge of hundreds of thousands of buildings within the Park system. The Delaware Water Gap National Recreation Area (DWG) alone has over a hundred buildings of varying historic and aesthetic value. While many can be and are used for Park functions, many remain unoccupied. The 1966 Preservation Act authorized leasing of NPS properties to outside organizations on a descending scale; uses allowing public access are given the highest priority, private uses the lowest priority.

In 1999 the Department of the Interior developed a strategic plan to advance the cause of energy-efficiency and to promote green technologies. The government's internal publications offer guidelines for the design of buildings for energy efficiency, up to and including passive solar design (11). These policies apply to National Park Service practices. Finally, all governmental agencies must work within budgetary constraints that are ultimately determined by taxpayers. Therefore, first costs and lifecycle costs of preserving and rehabilitating NPS properties have to be considered in these decisions.

### 5.3 Location - Delaware Water Gap National Recreation Area

Delaware Water Gap National Recreation Area is an important recreation destination for people from three adjacent states (NJ, NY and PA), within easy reach of several major population centers in the mid-Atlantic region. It offers hiking, boating, fishing and camping. Its significant natural attractions include the Delaware River, the Appalachian

Trail and Kittatinny Mountain, a raptor migration observation point. The sightseeing destinations include Raymondskill Falls just a quarter mile from the Ramirez House.

DWG offers educational as well as recreation opportunities. Millbrook Village offers a historic re-creation of a late 19th century rural community. Other historic sites within the Park are being developed as tourist attractions. Pocono Environmental Education Center (12), offers residential environmental education programs to both teachers and school children from as far away as New York City. New educational opportunities related to the Ramirez House could be developed through partnerships with regional colleges offering environmental and/or architectural programs (13).

DWG staff is preparing a Facilities Management Plan outlining an overall plan for the DWG National Recreation Area and prioritizing which of its many cultural assets should receive attention. According to an interview with Park consultant, Zara Osmond, Ramirez House is a good candidate for highest priority listing due to its historic significance and location near the north gateway to the DWG.

## 5.4 Adaptive Re-Use Options

There are number of options for adaptive re-use of the Ramirez House. The House could become a weekend or full-time residence again. While residential use would be consistent with the original design, it is the least desirable choice for NPS Delaware Water Gap properties. Current policy discourages residential leasing in response to public objections. The house could also be used as an office for a non-profit or private organization; however, its isolated location and relatively small size might make it somewhat difficult to market.

The house is best suited to educational purposes if it were functioning as a museum, with teaching and research components. Its large main living room could serve as an exhibition space and a classroom. The peripheral bedrooms and servants wing could be converted to office and seminar use. The outlying caretakers cottage could serve as a residence for visiting scholars doing environmental research or attending scientific conferences. Properly adapted, the Ramirez House could serve as a teaching tool, demonstrating with interpretative panels, its original solar design features and those new features necessary to bring the house to modern comfort standards.

The adapted house would attract several different audiences. Displays explaining old and new building materials could transform it into museum of energy efficient technologies. Graphic representation of baseline data from this thesis could be compared with a display of on-going data collection of the improved solar space. Other exhibits could present history of solar research and ongoing developments in solar design. Hands-on computer teaching tools could be available to school children, casual weekend visitors and professionals. Solar researchers could set-up non-destructive experiments with thermal storage, solar heating and photo-voltaic panels. (Fig. 5.1)

## 5.5 Competing Historic Preservation Scenarios for Ramirez Solar House

Ramirez House falls squarely into the historic preservation community's discussion of the levels of intervention appropriate to a specific project. This house embodies a certain point in the evolution of solar design thought. To preserve it in its original form would fit within the strict definition of <u>restoration</u>. Restoration would involve removal of some interior elements and return of the landscape roughly to its 1944 form, thus recreating the original solar operating conditions.

The house could also be rehabilitated. The process of returning it to efficient contemporary use would include improvements making it more energy efficient and comfortable, as well as making it more functional for an adaptive re-use centered on an educational mission. By making the improvements the subject of interpretive displays, the house would serve as a living educational tool explaining the development of the solar movement. The changes would also advance other governmental environmental objectives, teaching by example about the benefits of passive solar design and energy conservation. While this approach is more controversial when considered from a strictly preservation point of view, it is in the spirit of solar research and advocacy that Henry Wright practiced.

The Ramirez House is well placed to promote *the enjoyment, education and inspiration of this and future generations.* It is located close to significant tourist destinations in the Delaware Water Gap National Recreation Area. It is in an area where other environmental education institutions would likely become NPS partners in this mission. It is a building of historic significance that can teach all citizens about the value of using solar energy. In so doing it could promote sustainable design and building practices endorsed by Federal and state governments. It can best serve as a Solar Research Center and Museum.

## Chapter 5 Notes

(1) Bronson and Jester, "Conserving the Built Heritage of the Modern era..."

(2) Murtagh, *Keeping Time,* p.39-50

(3) States established historic preservation offices charged with protecting state heritage.

(4) US Secretary of Interior, *Standards for Rehabilitation*

(5) Murtagh, *Keeping Time,* p. 11-24

(6) US Secretary of the Interior, *Standards for Rehabilitation*

(7) Murtagh, *Keeping Time*, p. 182, 184, 185

(8) Murtagh, *Keeping Time*, p. 116 to 124

(9) Many historic buildings undergo extensive renovations, which include insertion of entire mechanical, electrical, and fire suppression systems. Significant efforts are expended to make these systems unobtrusive. Without the new systems, the buildings could not serve their occupants and would be more likely to deteriorate.

(10) US Department of the Interior *Report to the Nation*

(11) See NPS website "Green Toolbox"

(12) See Pocono *Environmental Education Center* web site

(13) See *NJ Conservation School* web site for another local environmental program.

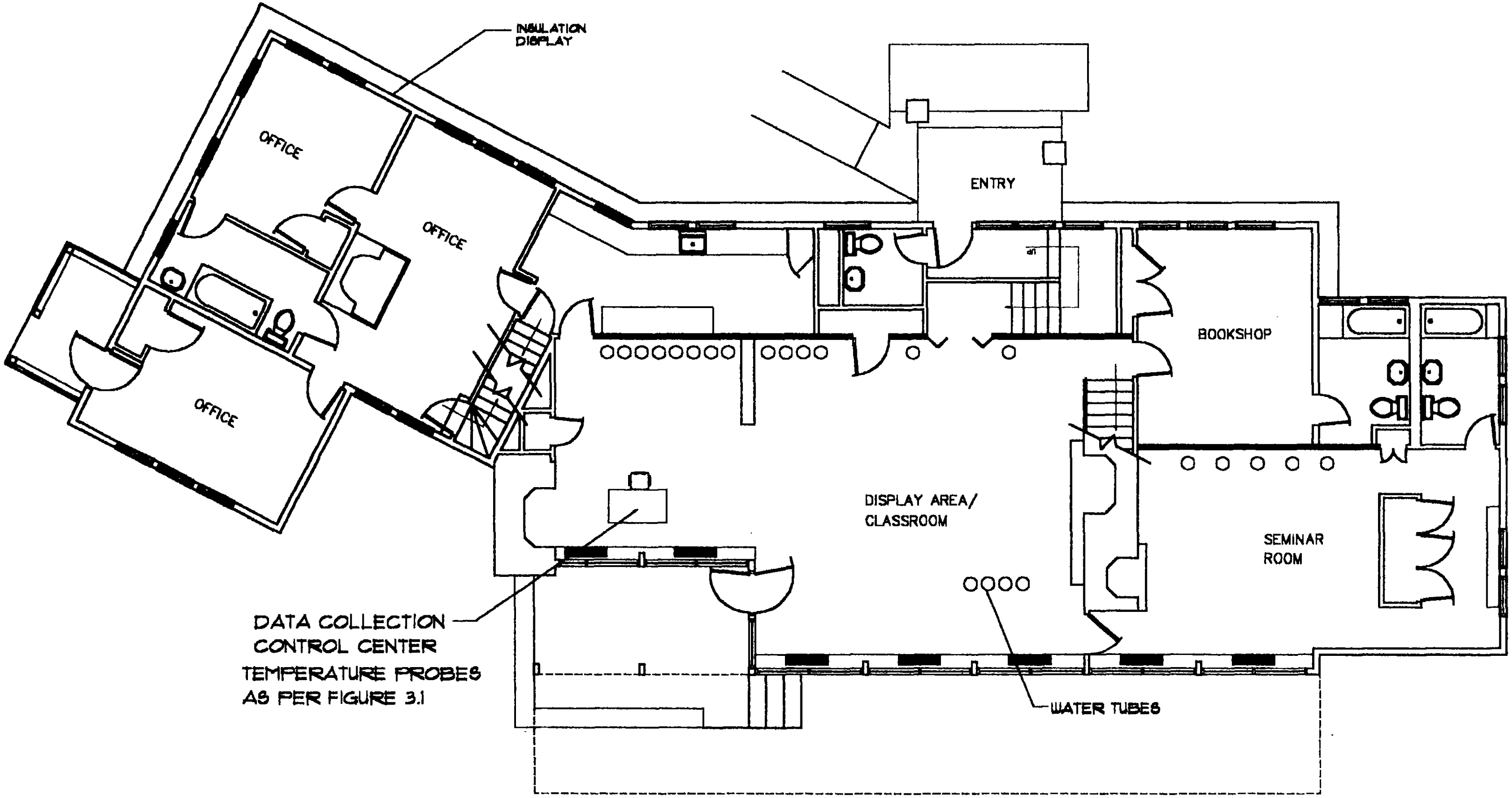


**Figure 5.1** First Floor Plan; Ramirez Solar Research Center and Museum

# CHAPTER 6

# CONCLUSIONS

This study has examined the solar performance of the historical Ramirez Solar House in light of current historical preservation standards and solar design knowledge.

The house is functioning as a passive solar house at a level consistent with the designer's intent. The data clearly indicate that the Main Wing is collecting substantial solar energy; however, the house is not optimized for solar performance. Computer simulations confirm the house has been built in a manner significantly less energy efficient than is possible now. Review of the house construction reveals opportunities for improvement of its performance.

Review of the solar research history confirms the significance of the Ramirez House as a cultural artifact exemplifying application of an evolving and historically significant architectural movement, as well as, the significance of house designer, Henry N. Wright, in this movement. The house could be improved for solar performance through modifications, which would alter some of its historic fabric in a manner not necessarily obvious on visual examination. Changing the house would change its performance, therefore changing its essential character as a historic artifact.

Energy efficiency and solar performance improvements can be done in a manner that answers most concerns of both solar and preservation constituencies. Data and graphs from this study act as a quantitative record of Wright's original design, as well as an education tool. Permanent improvements (window glazing and insulation) will change some historic materials and details. With proper documentation these changes can be made visible and reversible. Other changes (thermal mass, fans, AC) should be visibly new and removable without significant damage to the original historic fabric of the house.

The proposed changes would be in the spirit of the designer, Henry Wright, researcher into solar principles and materials, an educator and an advocate of solar design. Adapting the house as an educational and experimental center for solar design would also be in spirit of solar/environmental goals, consistent with current governmental mandates for optimizing environmental performance of governmental properties and consistent with education and recreation missions of National Park Service and the Delaware Water Gap National Recreation Area. Final decisions are the burden and the privilege of the steward of this house, the National Park Service.

This study will be of interest to several audiences. The solar / environmental community will want to make Ramirez House the best possible solar house. Historic preservation advocates and practitioners will want to protect and preserve it, perhaps in its original form. The general architectural community will be interested to learn from it. The general public will be entertained and educated by it. The proposed educational use can balance these somewhat overlapping, but also conflicting, interests. The best use of the house would be to function as an educational and experimental center for solar design.

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# APPENDIX A

This Appendix includes all the graphs illustrating the results of the eleven month long data collection at the Ramirez House. See Chapter 3 for details regarding equipment used (temperature and other loggers) and placement of the equipment including a floor plan. Two types of graphs are included in this Appendix. Monthly graphs illustrate various aspects of the data, one month per graph. These graphs are limited to two or three data lines for easier reading of details. Each series of graphs covers some aspect of weather and interior conditions. Comparisons include: availability of sun, exterior temperatures, interior-to-exterior temperatures, energy collected and retained on the interior expressed in Delta T, and interior temperature difference over twenty four hour period.

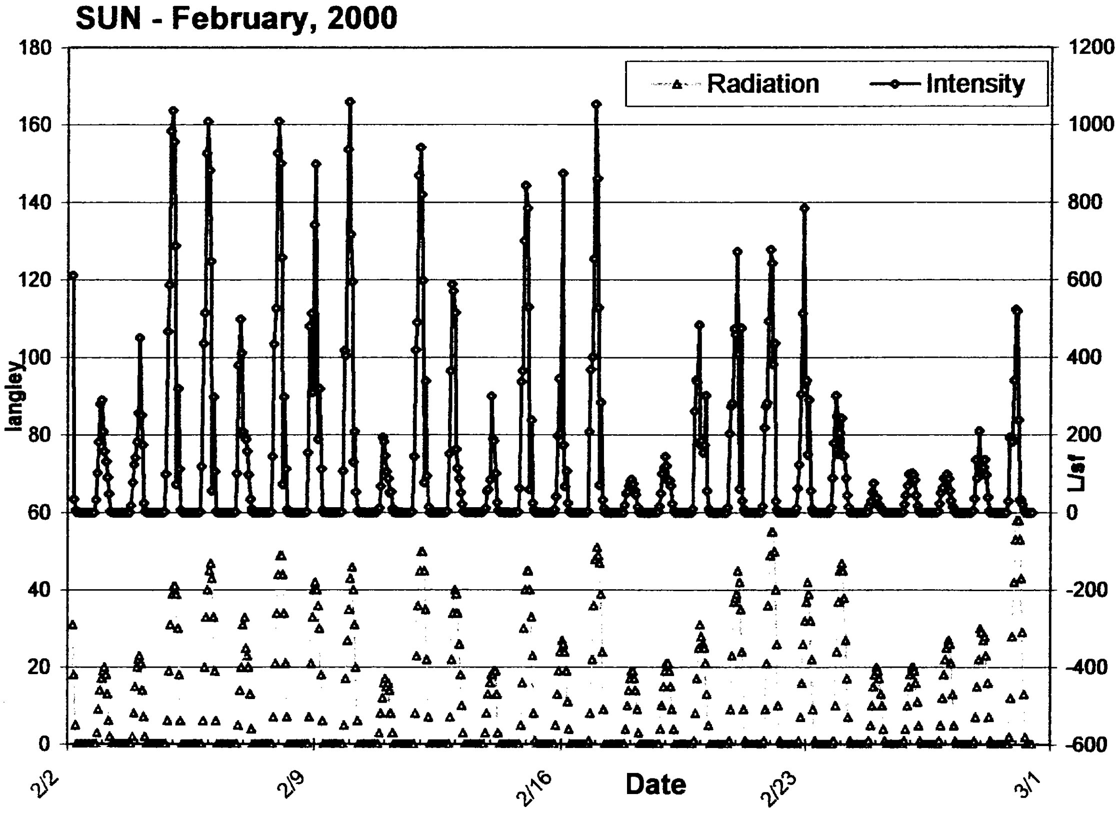
The daily graphs illustrate details of interior conditions on a few sample days representative of significantly different exterior circumstances. The graphs compare average temperatures in the two Wings and the temperatures in the different locations within the solar Main Wing.

## Figure A1 - SUN GRAPHS

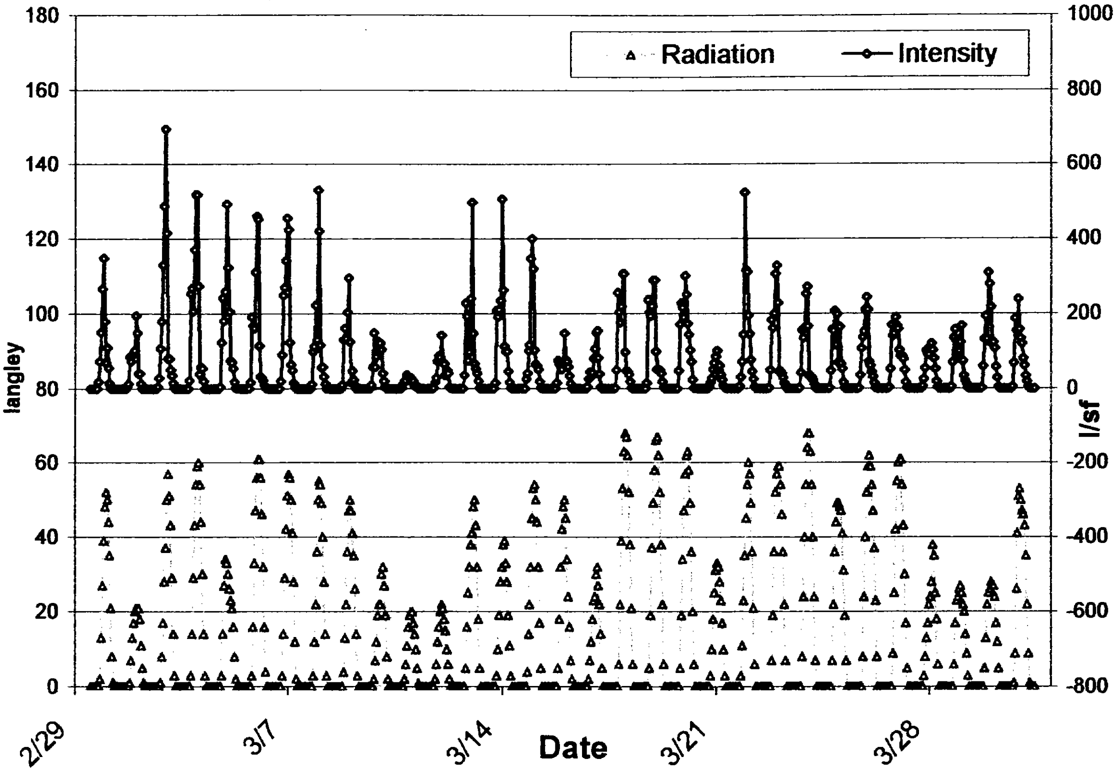
SUN graphs compare solar radiation in the region to the sun reaching the Living Room. Radiation data received from the Loch Loman weather station a few miles south of the Ramirez House site is in langleys expressing the amount of solar energy available. Light intensity data collected by a logger placed on the windowsill inside the Living Room is in lumens per square foot. Each SUN graph expresses hourly data for one month.

The author elected to show data along separate axes rather than attempting to convert one unit to another.

Units and abbreviations:
Langley – indicates quantity of light in calories / centimeter squared; left Y-axis
Lumen - is a measure of photometric power, as perceived by human eye; right Y-axis
L/sf - lumens per square foot



## SUN - March, 2000



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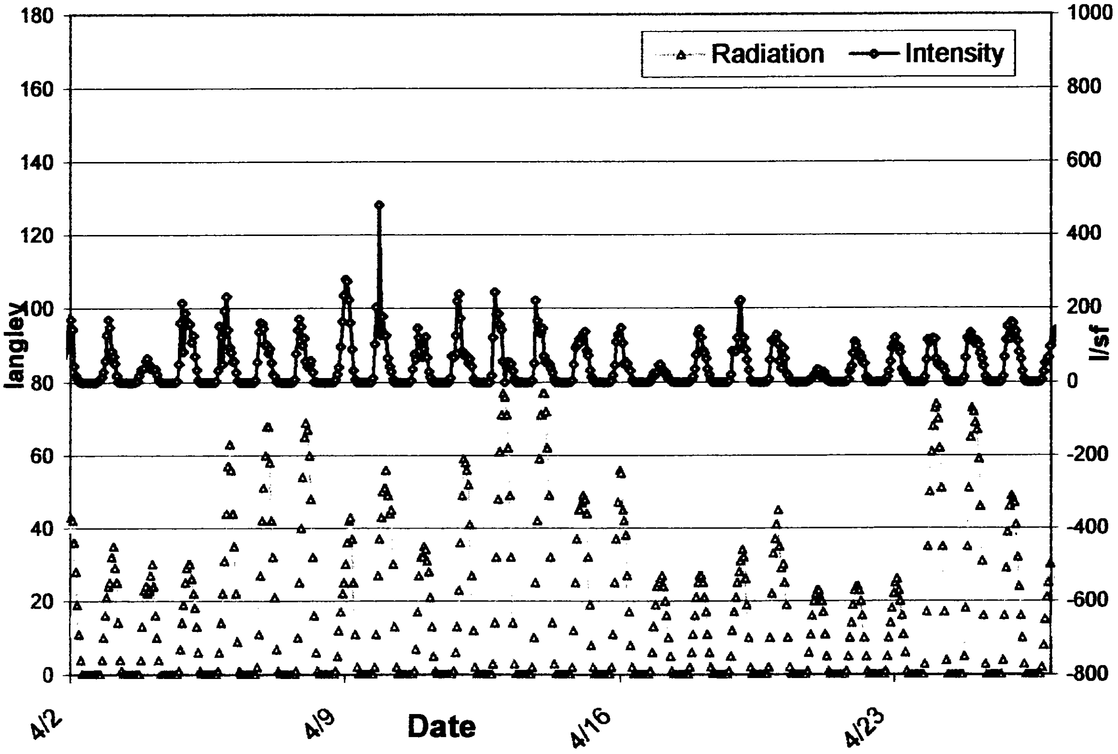

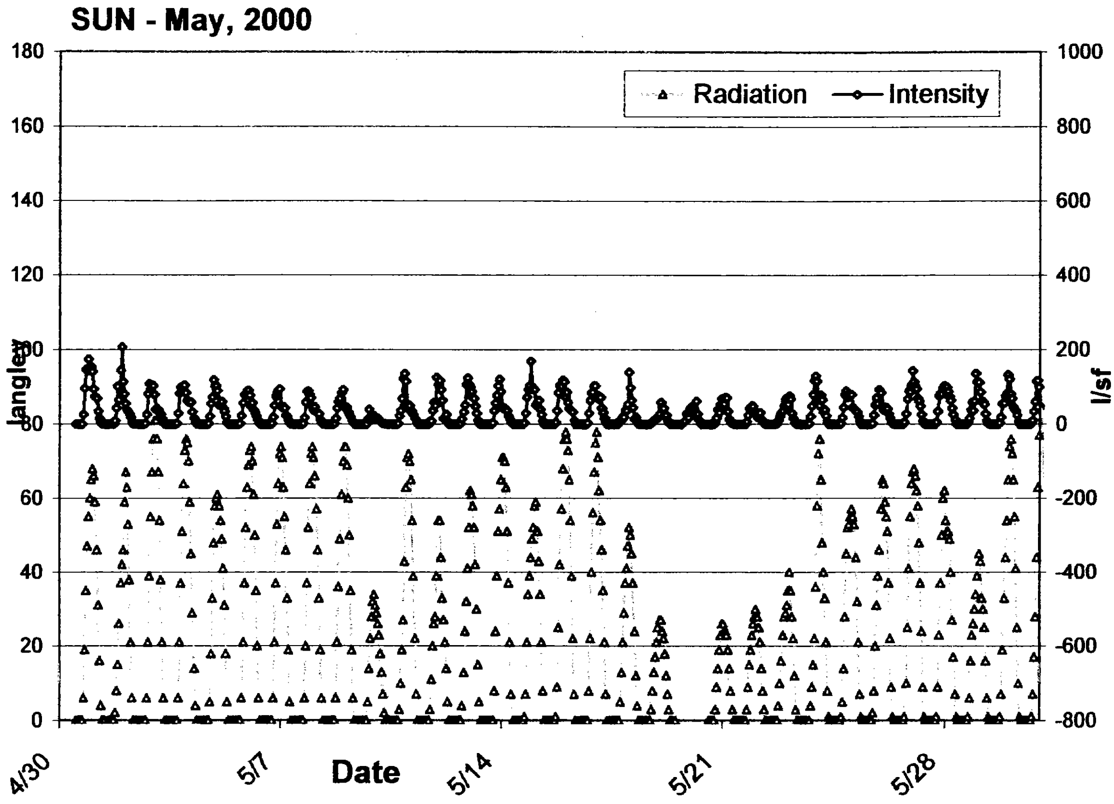
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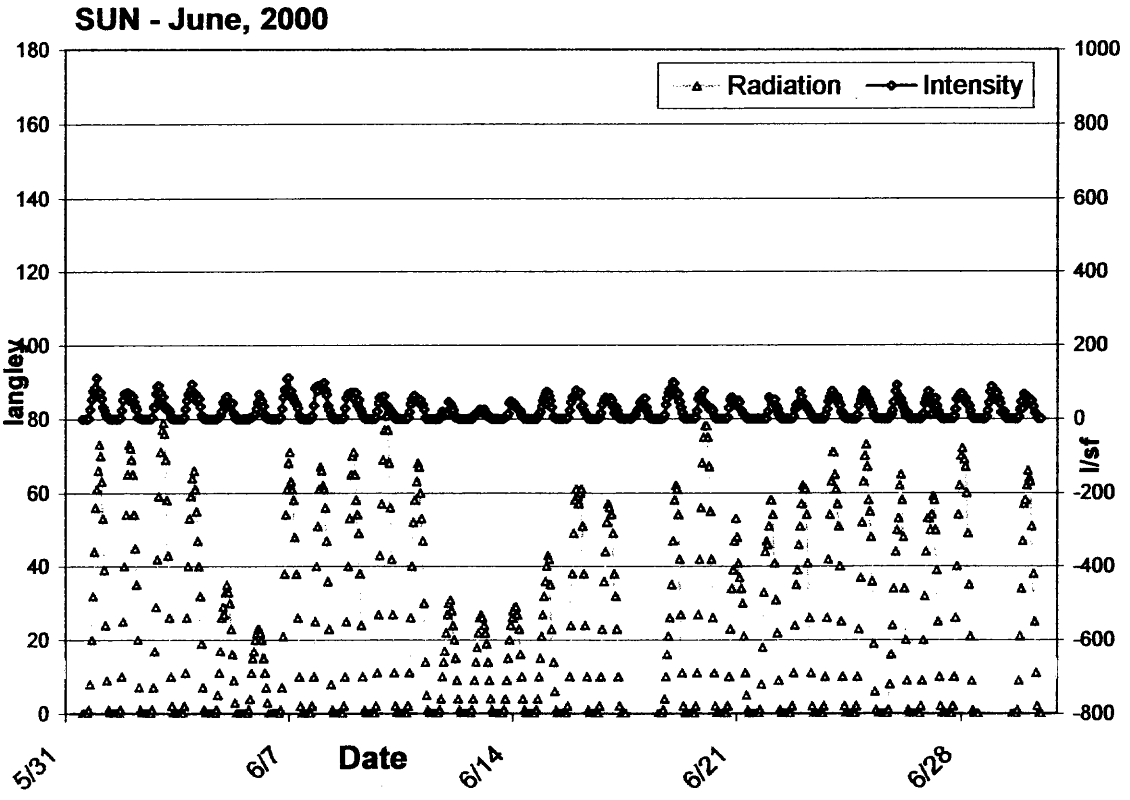
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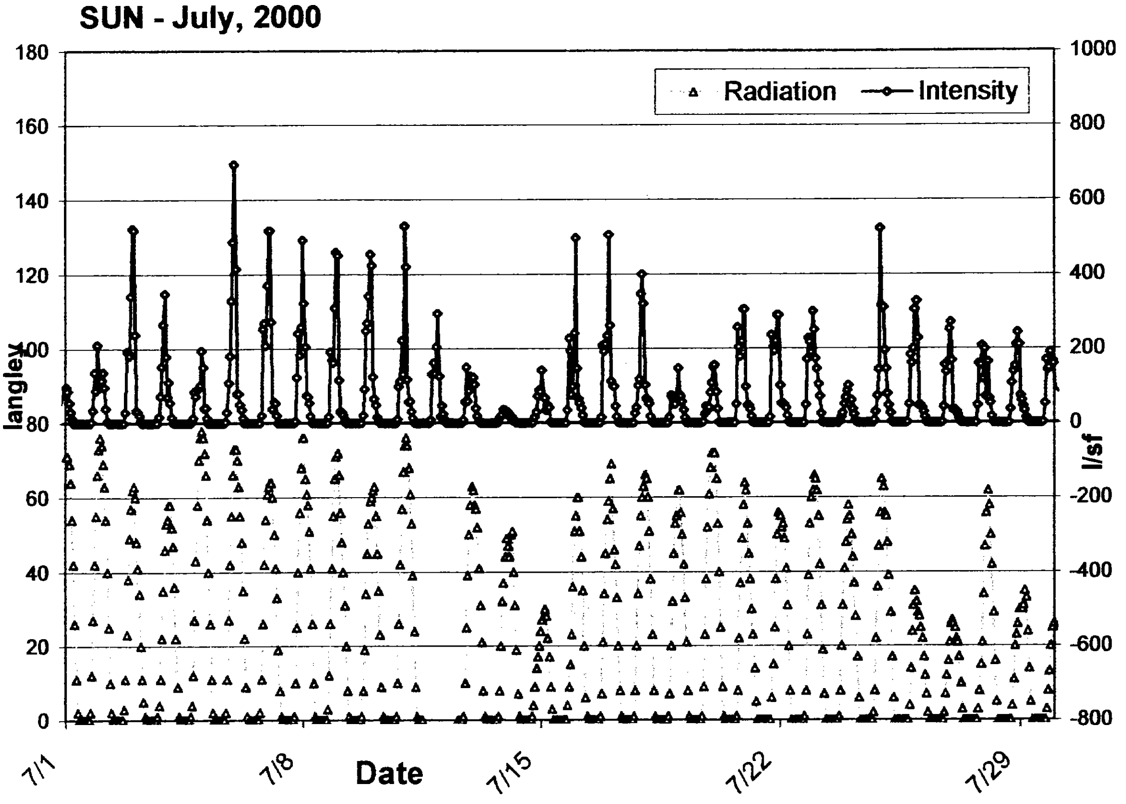
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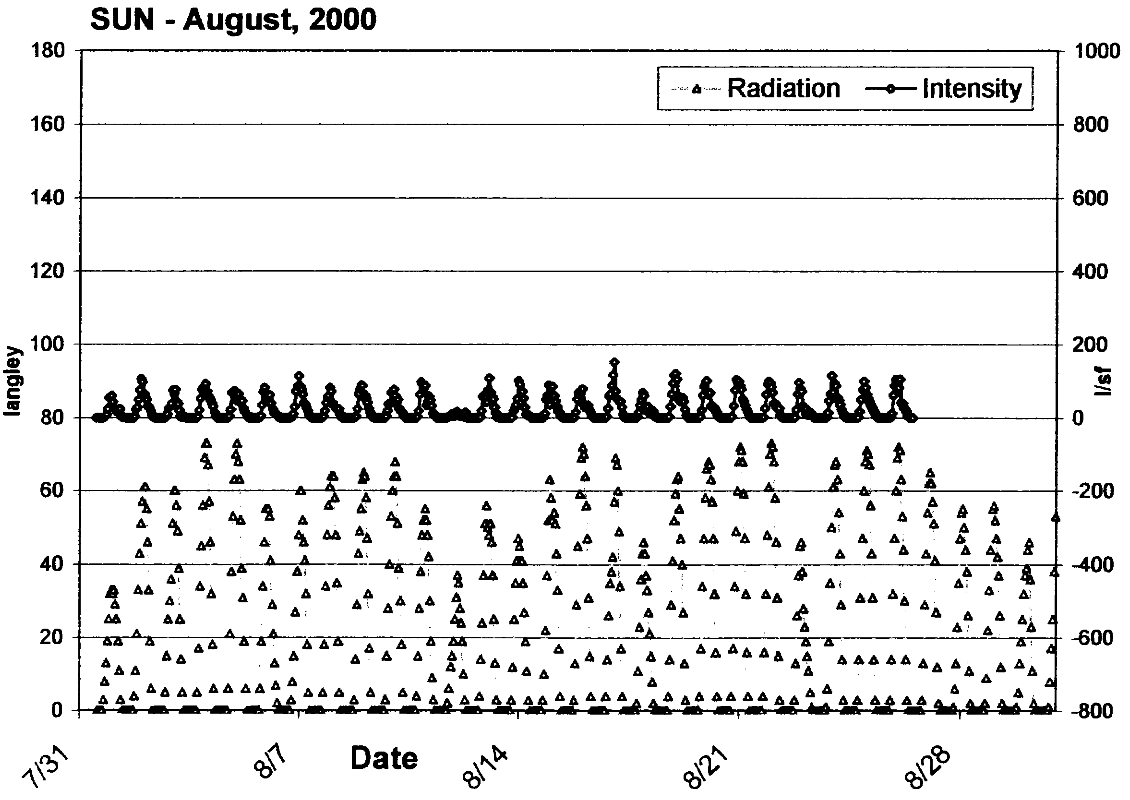
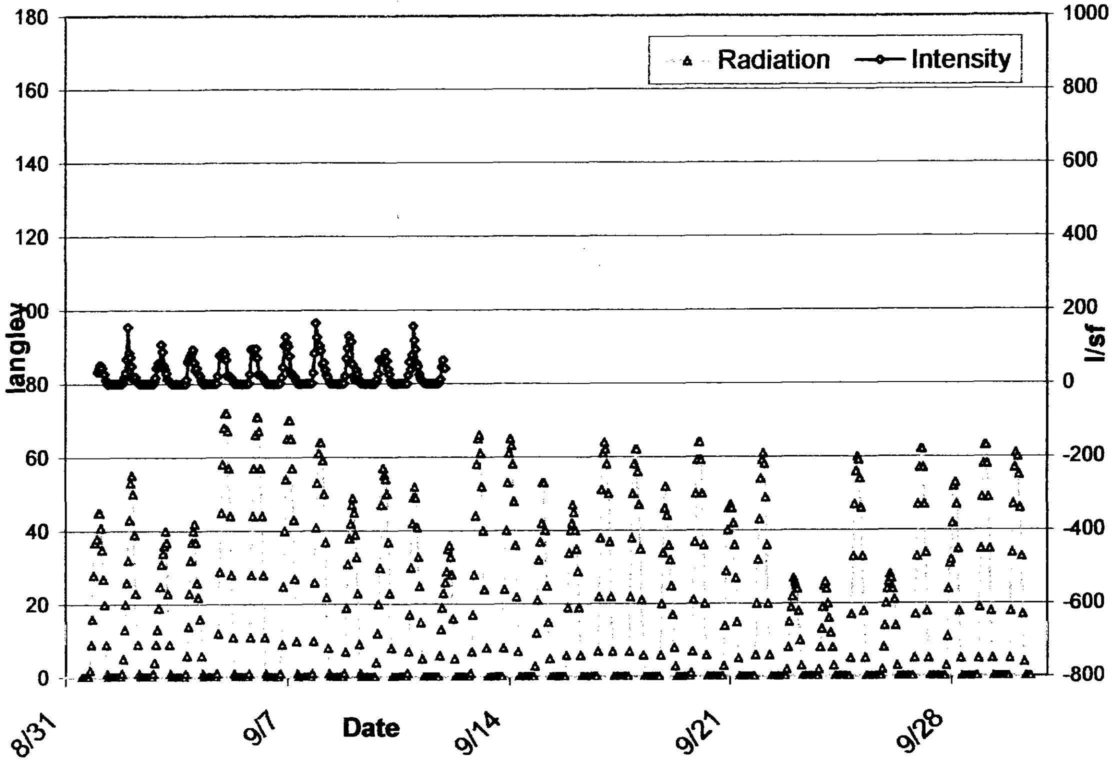
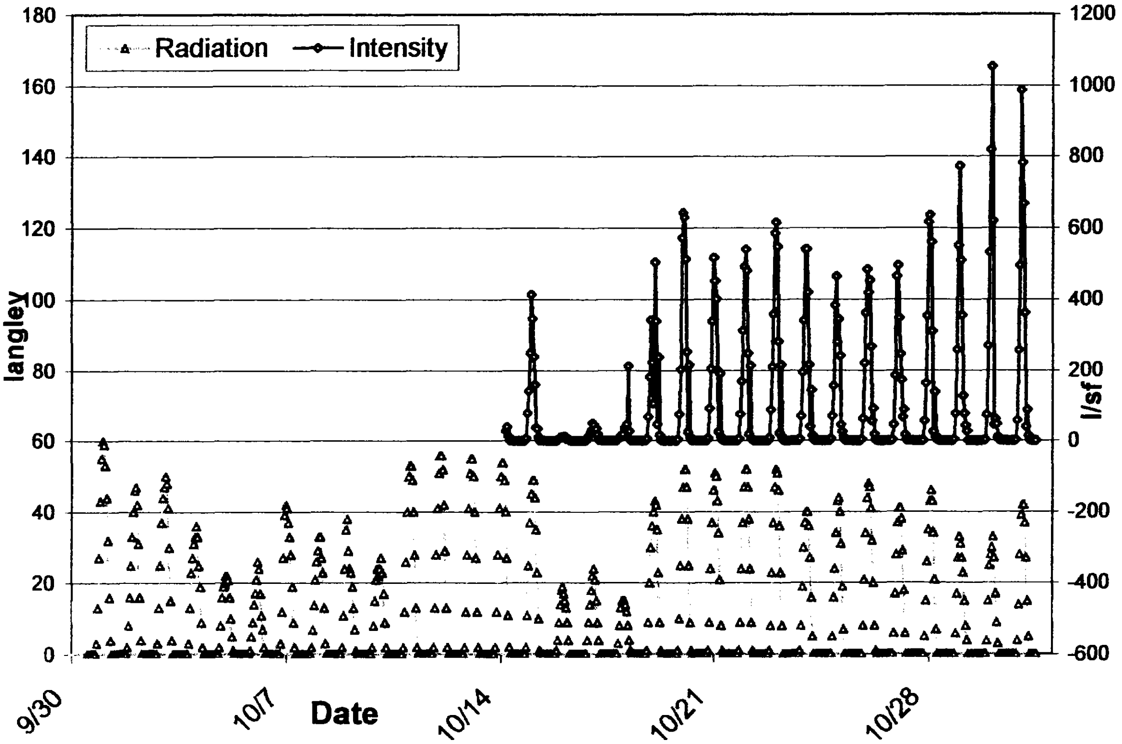
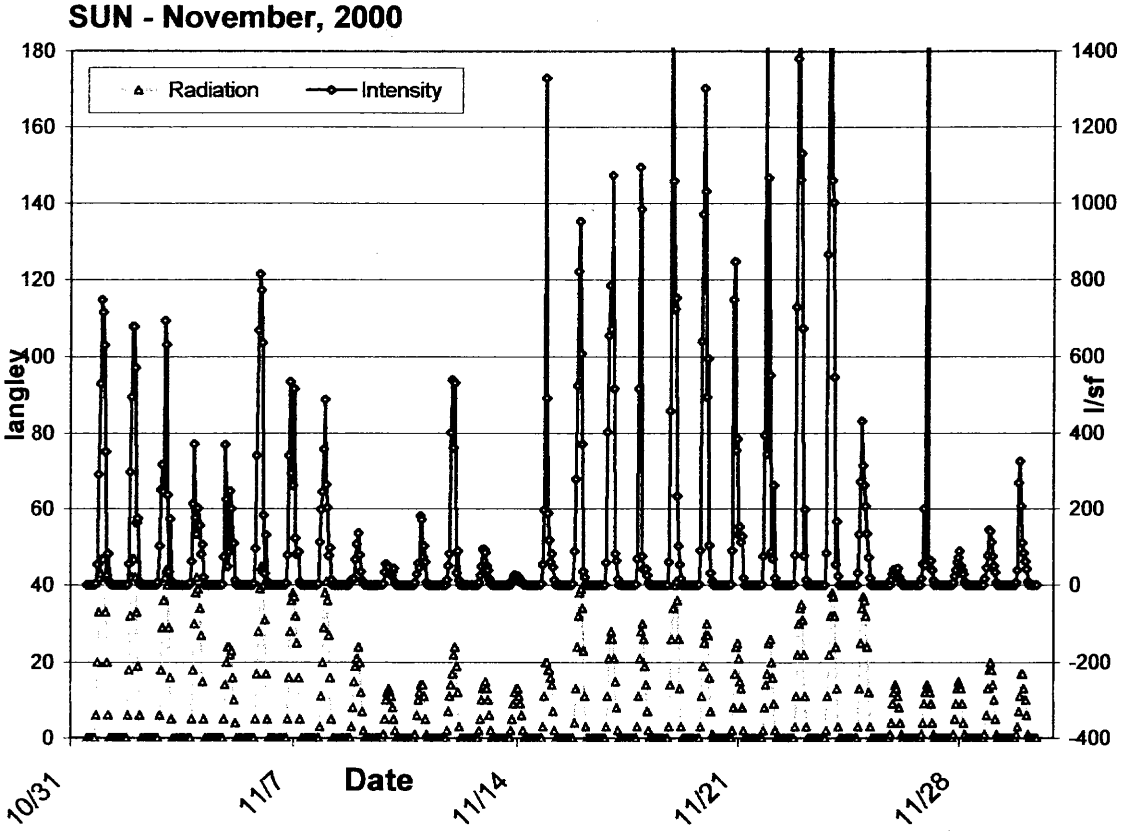

SUN - August, 2000
Radiation
Intensity
langley
l/sf
Date
180
160
140
120
100
80
60
40
20
0
1000
800
600
400
200
0
-200
-400
-600
-800
7/31
8/7
8/14
8/21
8/28

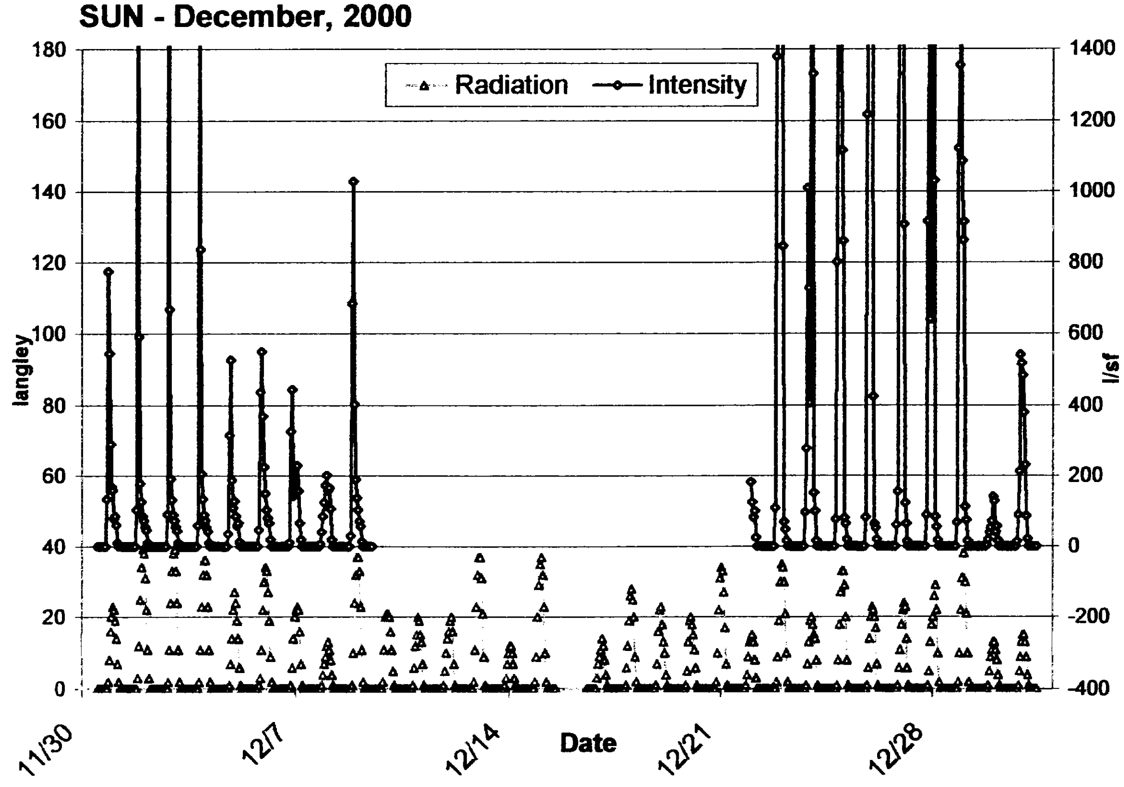
SUN - September, 2000



SUN - October, 2000



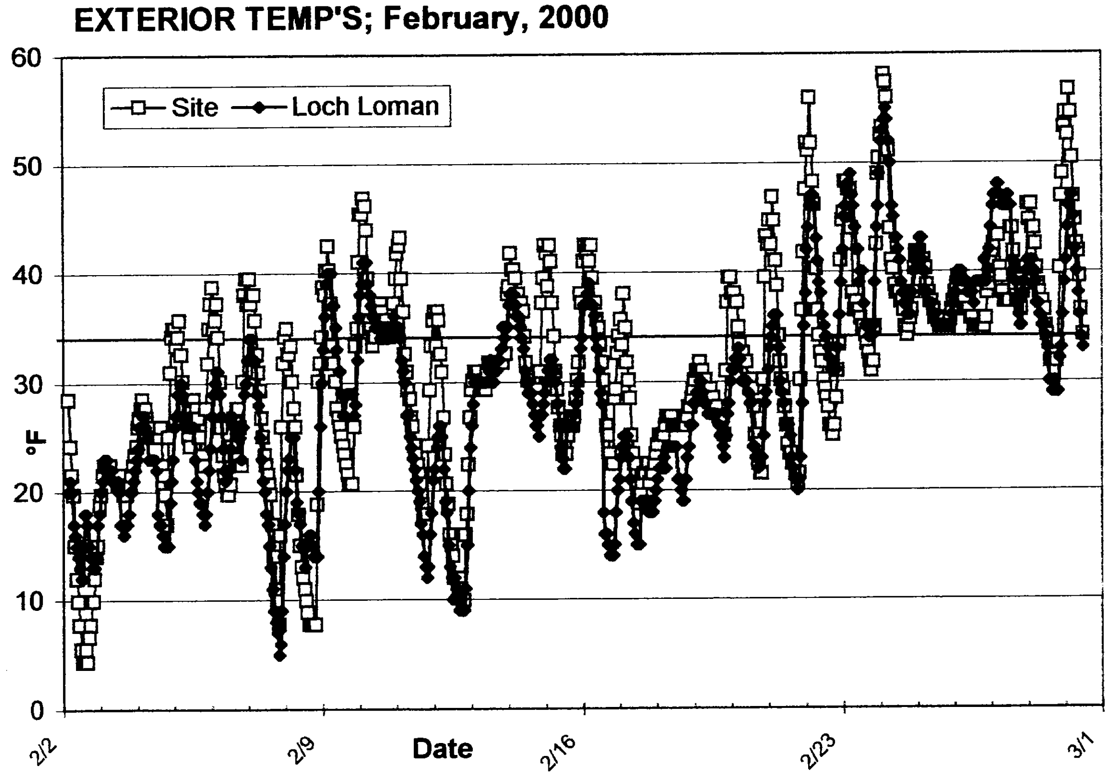

SUN - November, 2000
Radiation
Intensity
langley
l/sf
Date
180
160
140
120
100
80
60
40
20
0
1400
1200
1000
800
600
400
200
0
-200
-400
10/31
11/7
11/14
11/21
11/28

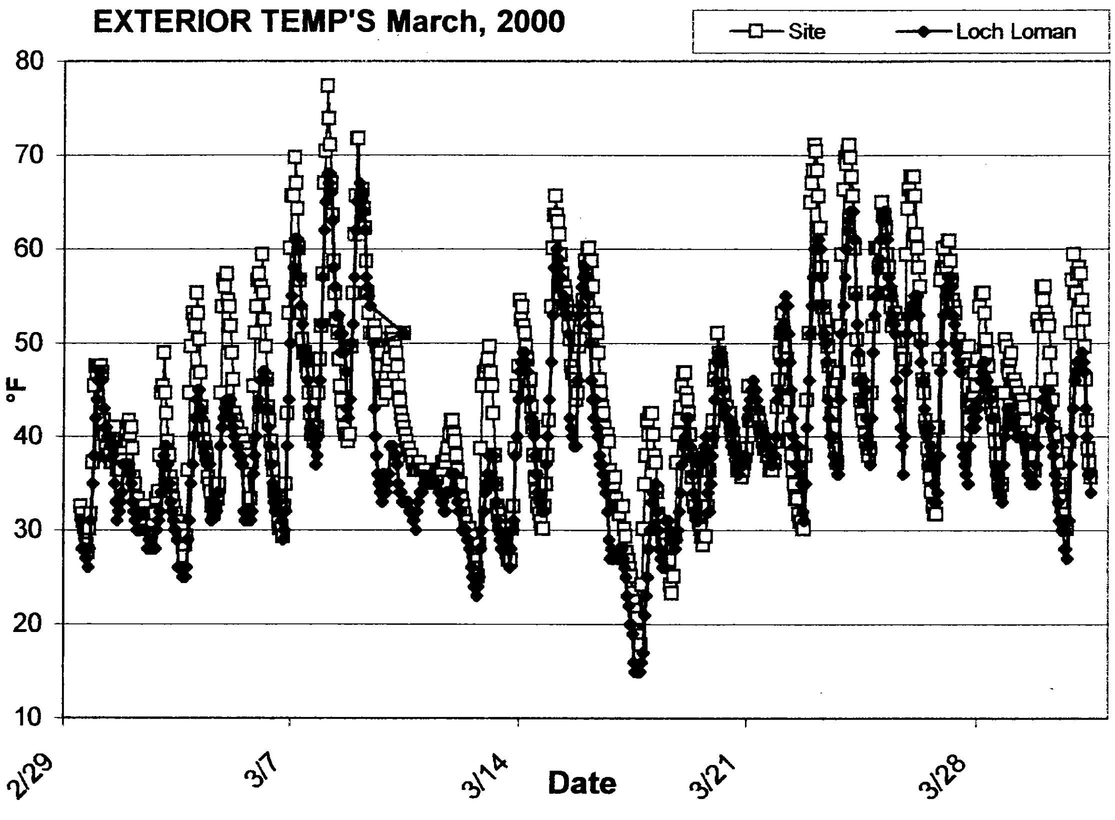

SUN - December, 2000
Radiation
Intensity
langley
l/sf
Date
180
160
140
120
100
80
60
40
20
0
1400
1200
1000
800
600
400
200
0
-200
-400
11/30
12/7
12/14
12/21
12/28

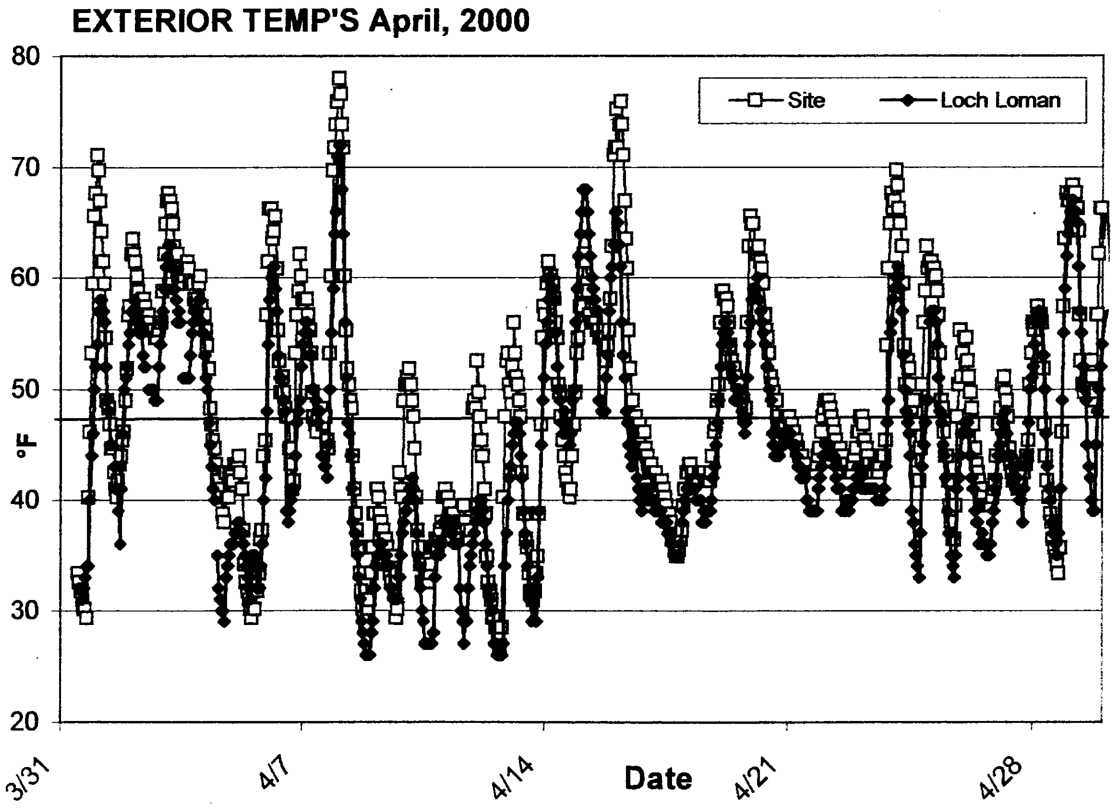
## Figure A2 - EXTERIOR TEMPERATURE GRAPHS

EXTERIOR TEMP'S graphs compare the exterior temperatures measured on site to the measurements from the local Loch Loman weather station. The site measurements, recording microclimate of the sheltered stone terrace in front of solar window wall, are consistently higher, from two up to ten degrees. August is not shown due to lost data.

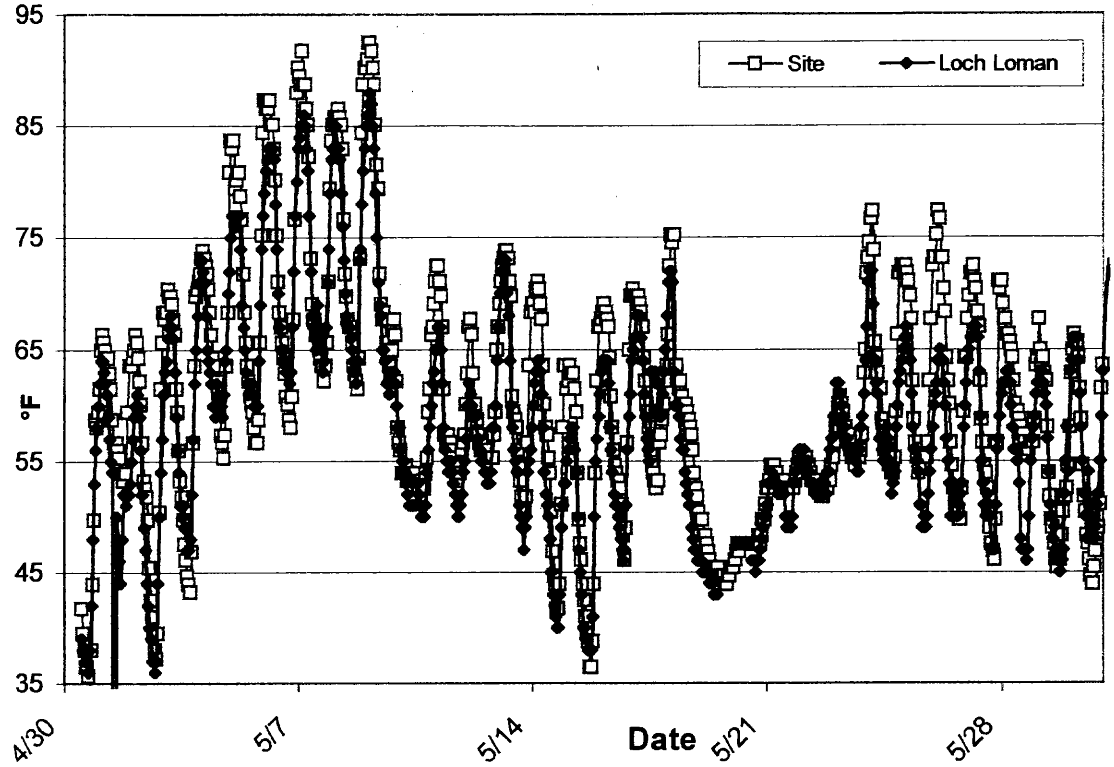
Units and abbreviations:
Temperatures - degrees Fahrenheit
Ext Temp - exterior temperature on site
Loch Loman - exterior temperatures from weather station



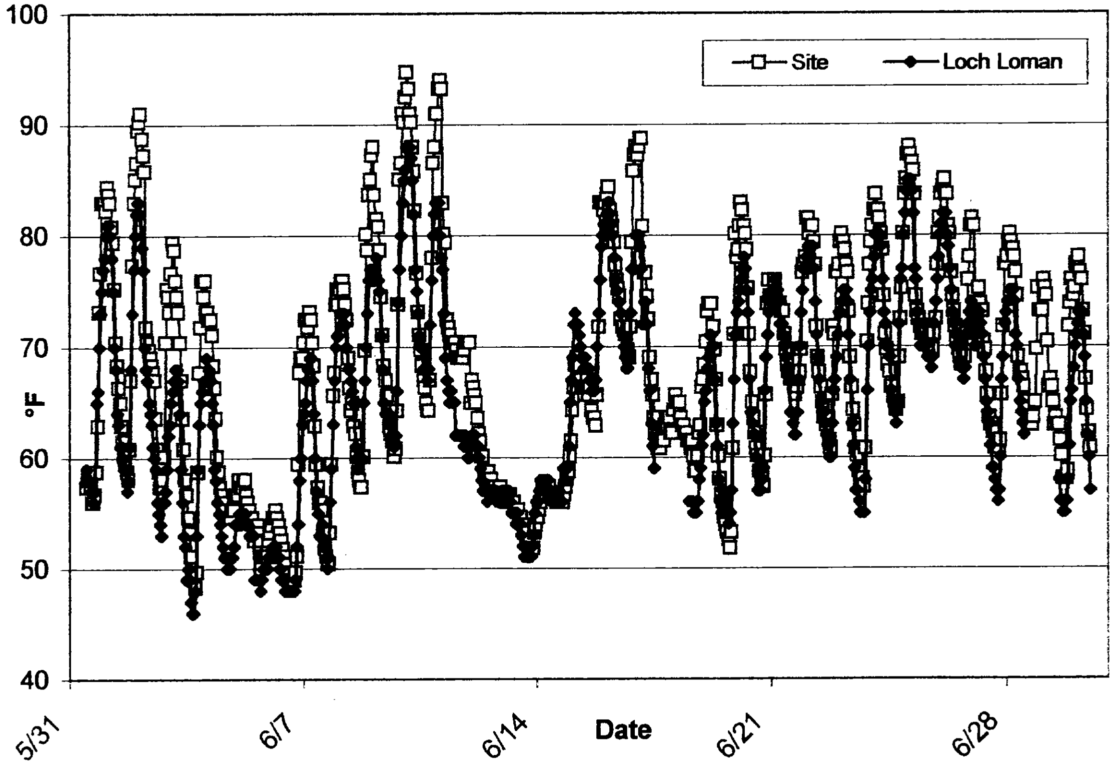

EXTERIOR TEMP'S March, 2000
Site
Loch Loman
80
70
60
50
40
30
20
10
°F
2/29
3/7
3/14
3/21
3/28
Date

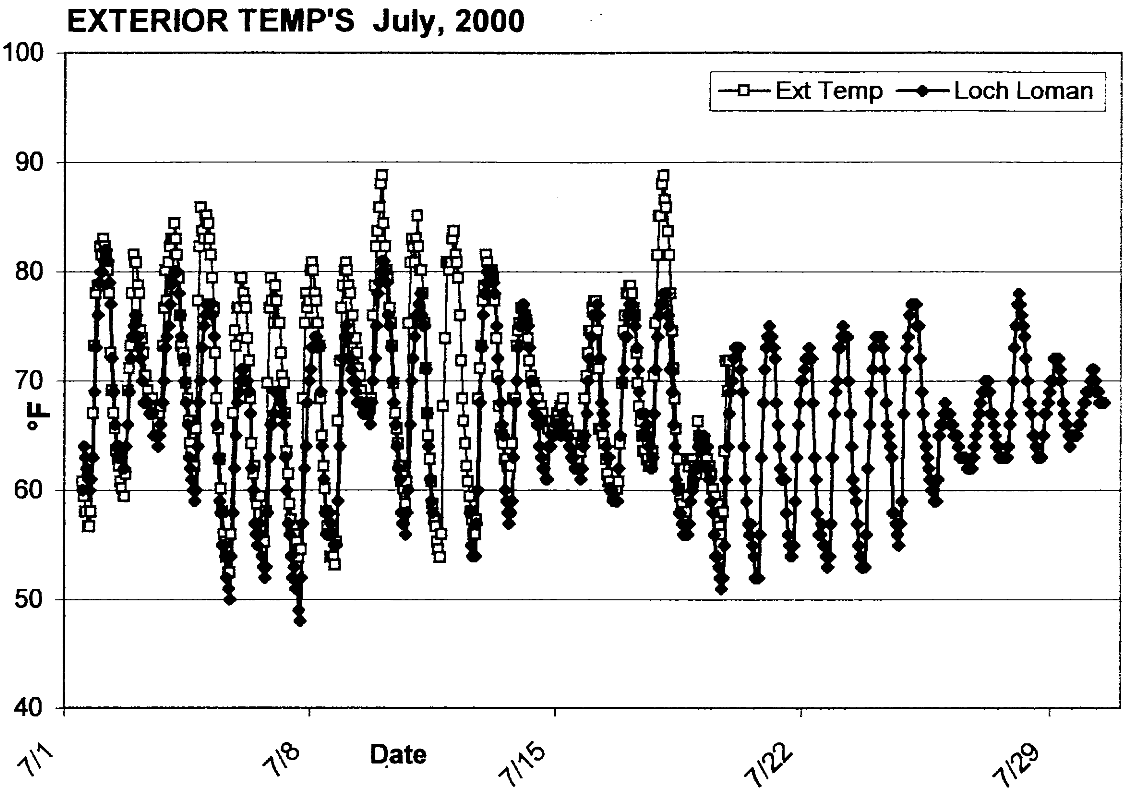

EXTERIOR TEMP'S April, 2000
Site
Loch Loman
80
70
60
50
40
30
20
°F
3/31
4/7
4/14
4/21
4/28
Date

EXTERIOR TEMP'S May 2000

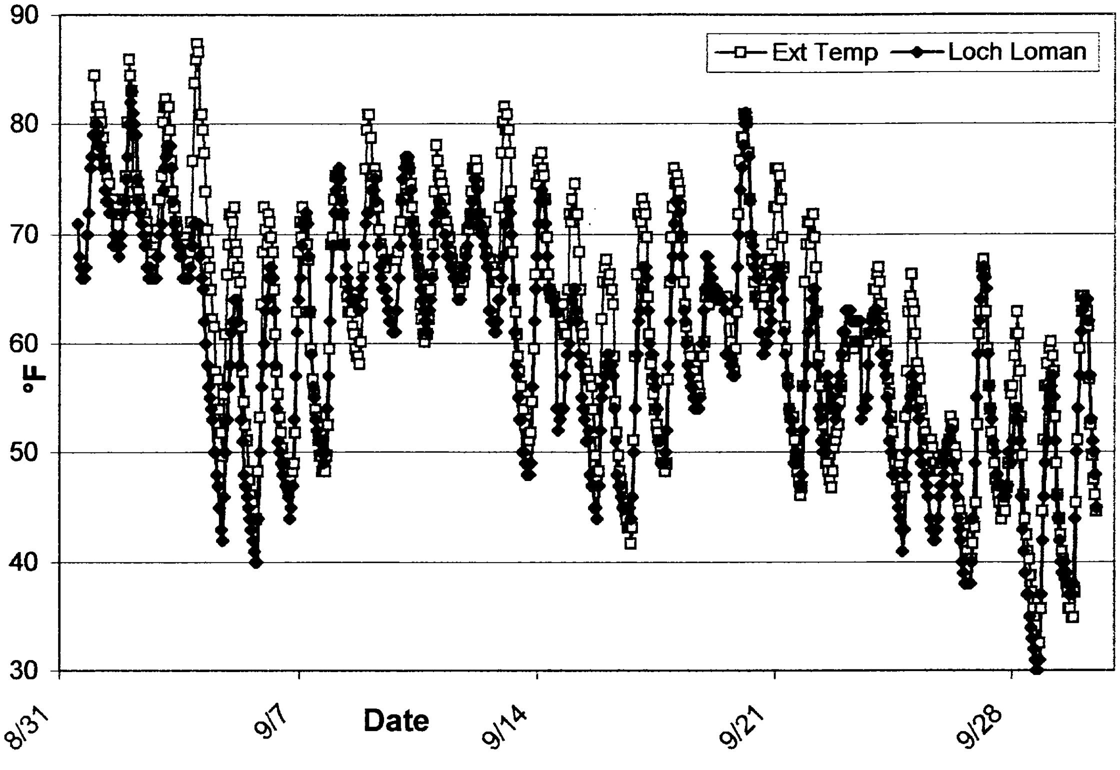


EXTERIOR TEMP'S June 2000

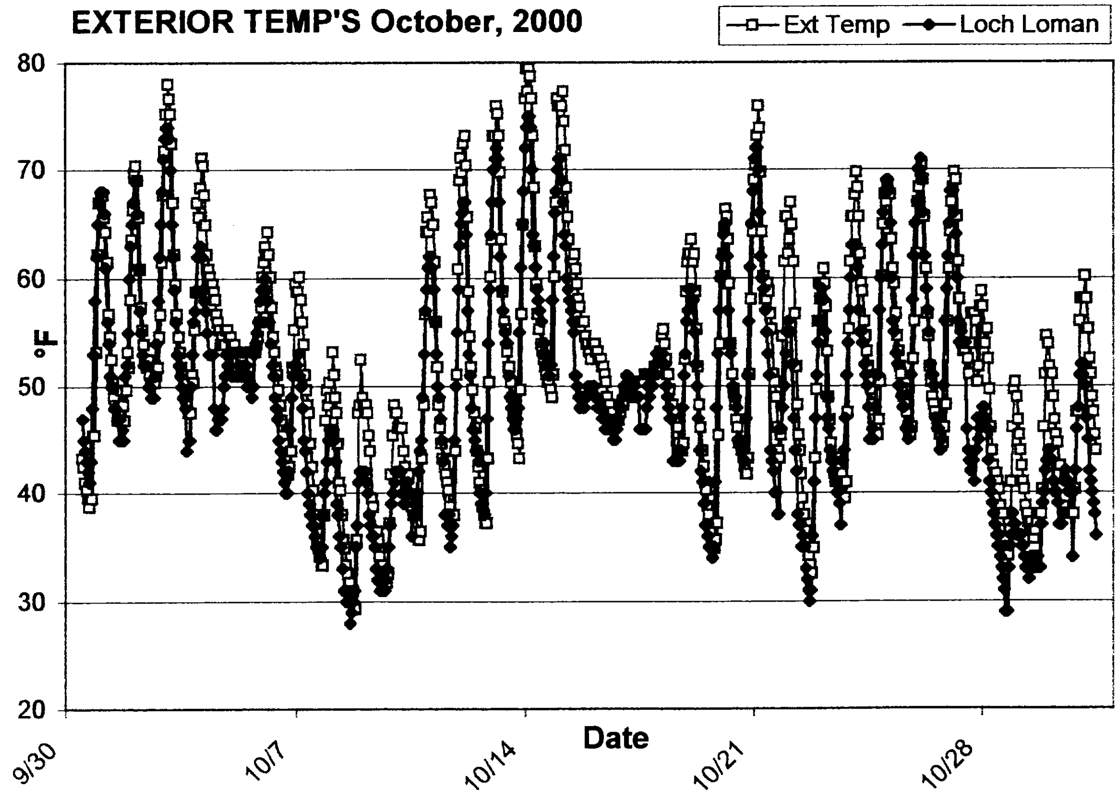



EXTERIOR TEMP'S July, 2000
Ext Temp
Loch Loman
100
90
80
70
60
50
40
°F
7/1
7/8
7/15
7/22
7/29
Date

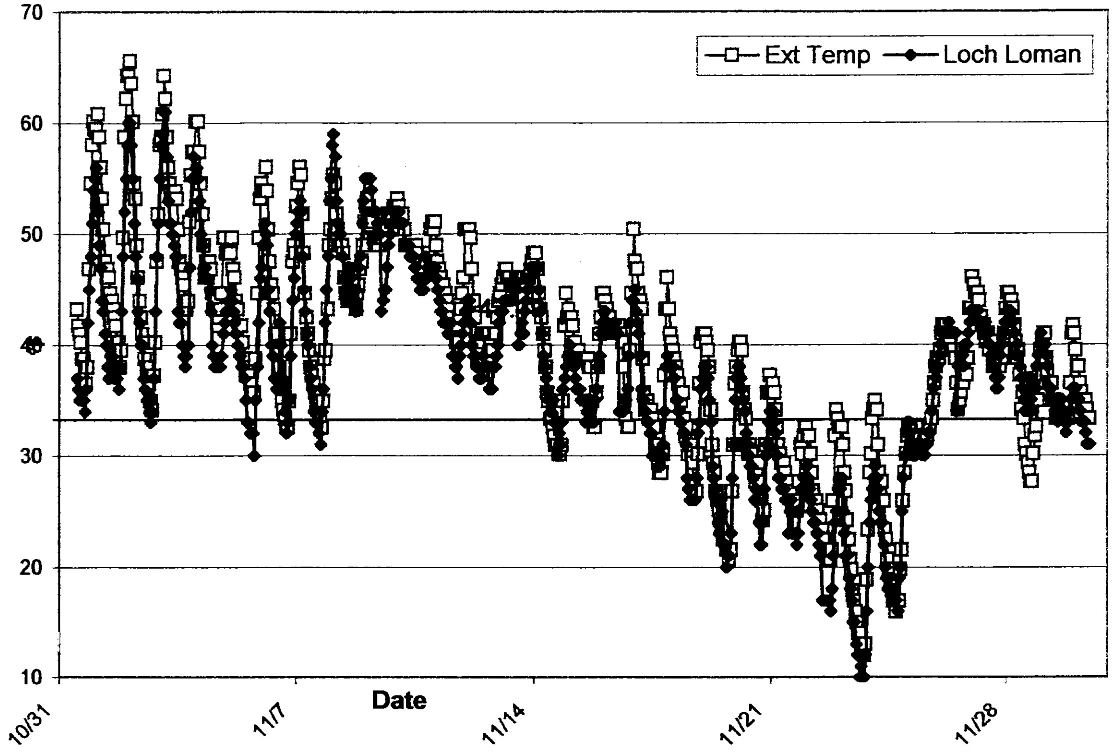
EXTERIOR TEMP'S September 2000



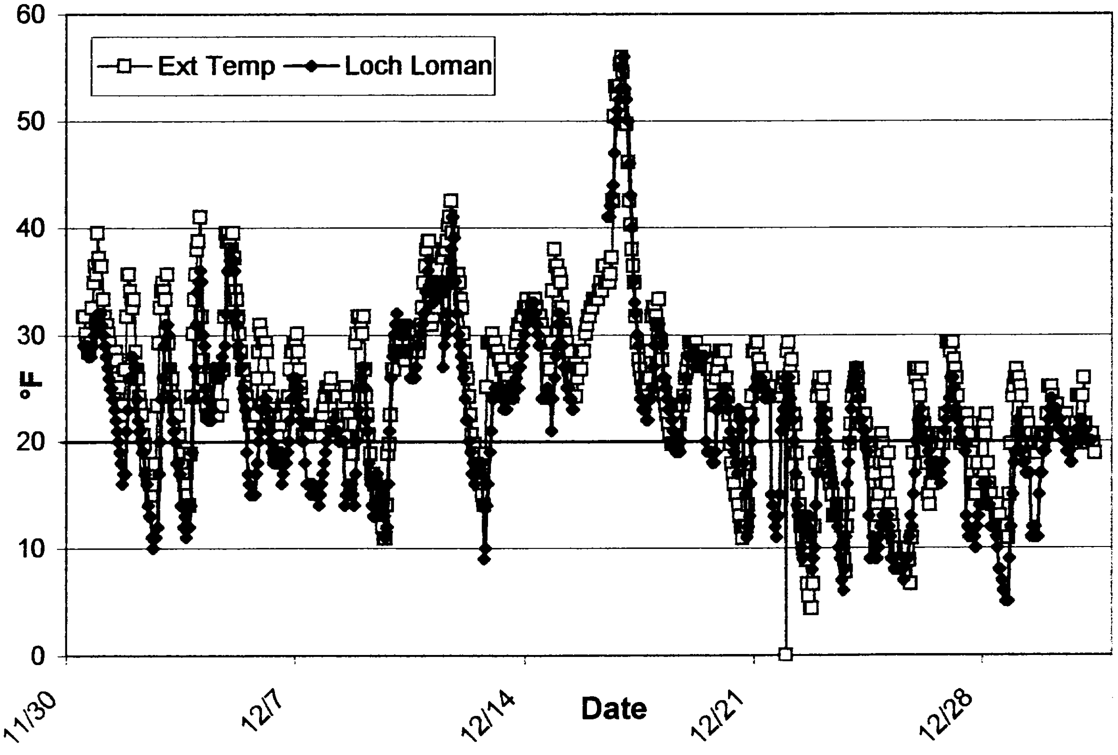
EXTERIOR TEMP'S October, 2000



EXTERIOR TEMP'S November, 2000



EXT TEMP's, December, 2000

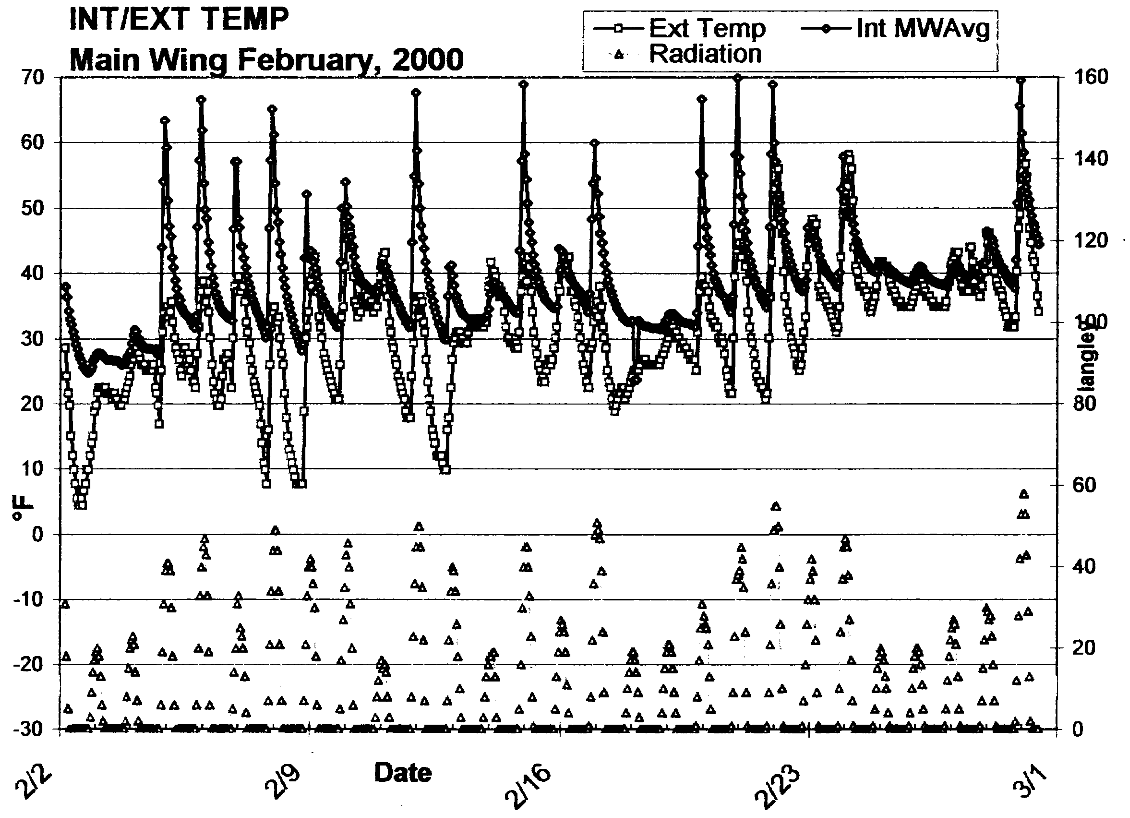


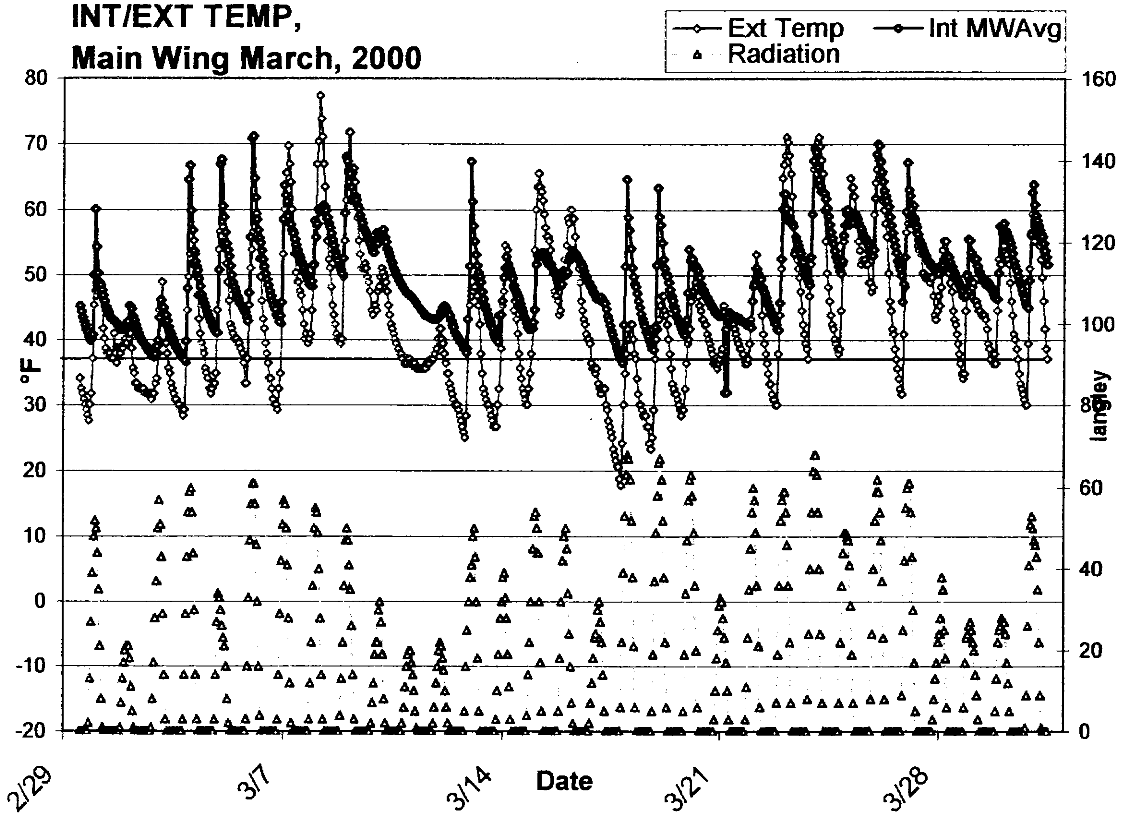
## Figure A3 - INT/EXT TEMP GRAPHS

INT/EXT TEMP graphs show the average inside temperatures compared to the outdoor site temperature and available radiation. Each INT/EXT graph expresses hourly data for one month for one of the wings. Average temperature is calculated from the available data. For the Main Wing the data is averaged from seven temperature probes controlled by three different loggers located in the Living Room, Study and Master Bedroom. In the Servants Wing the data is averaged from three temperature probes. Exceptions are periods from the end of July through August, and in late September when data was lost for some of the Main Wing temperature probes and for all of the Servants Wing.

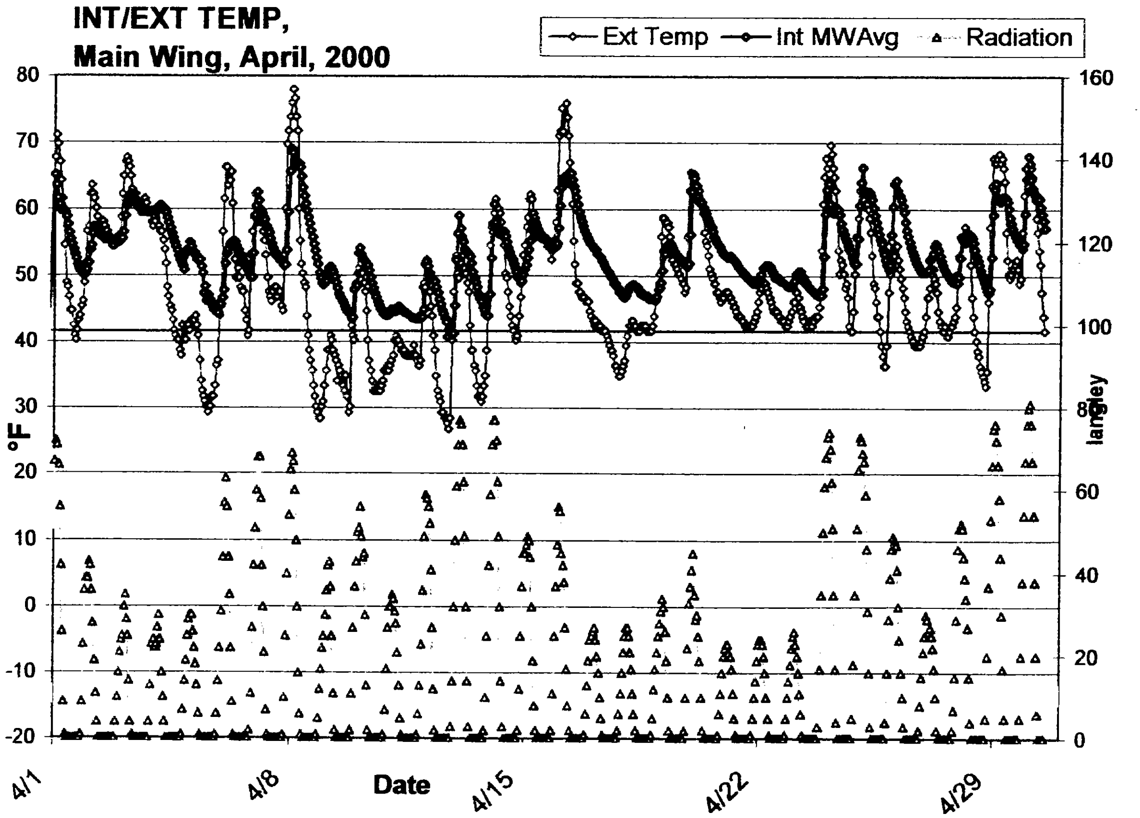
Units and abbreviations:
Temperatures - degrees Fahrenheit; left Y-axis
Radiation - langleys; see Figure A1; right Y-axis
Int MWAvg - average interior temperatures in Main Wing
Int SWAvg - average interior temperatures in Servants Wing

A month-by-month comparison of the two wings shows the Main Wing interior temperatures remain consistently higher than outdoor ones during the winter months. Only after several cloudy days does the solar space equilibrate closer to the outdoor conditions. During the same time, the Servants Wing shows minimal solar gain.

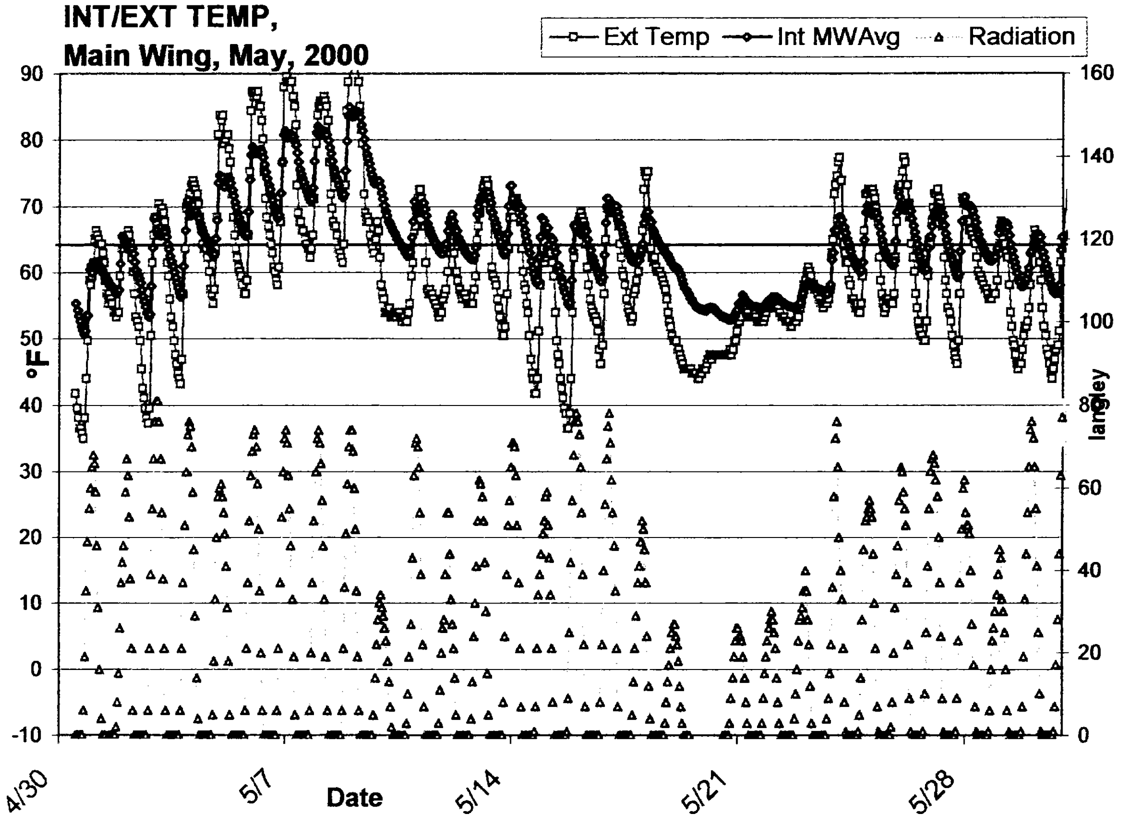


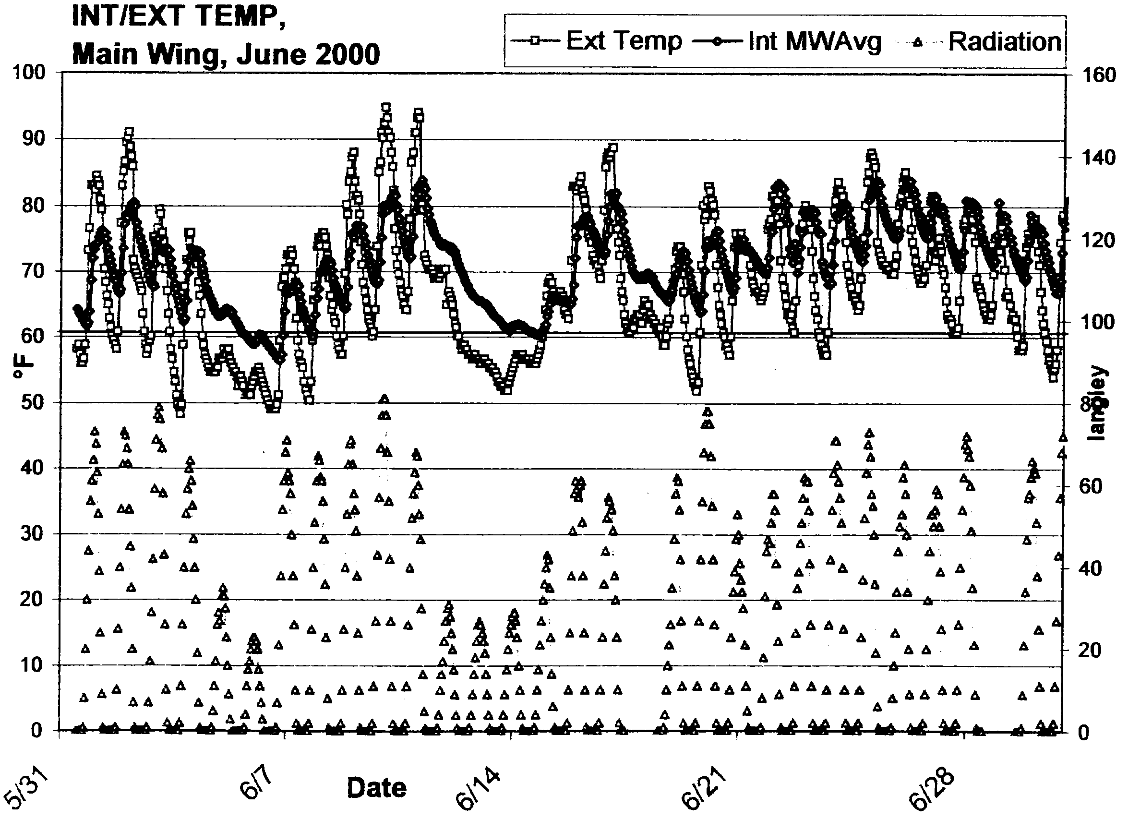


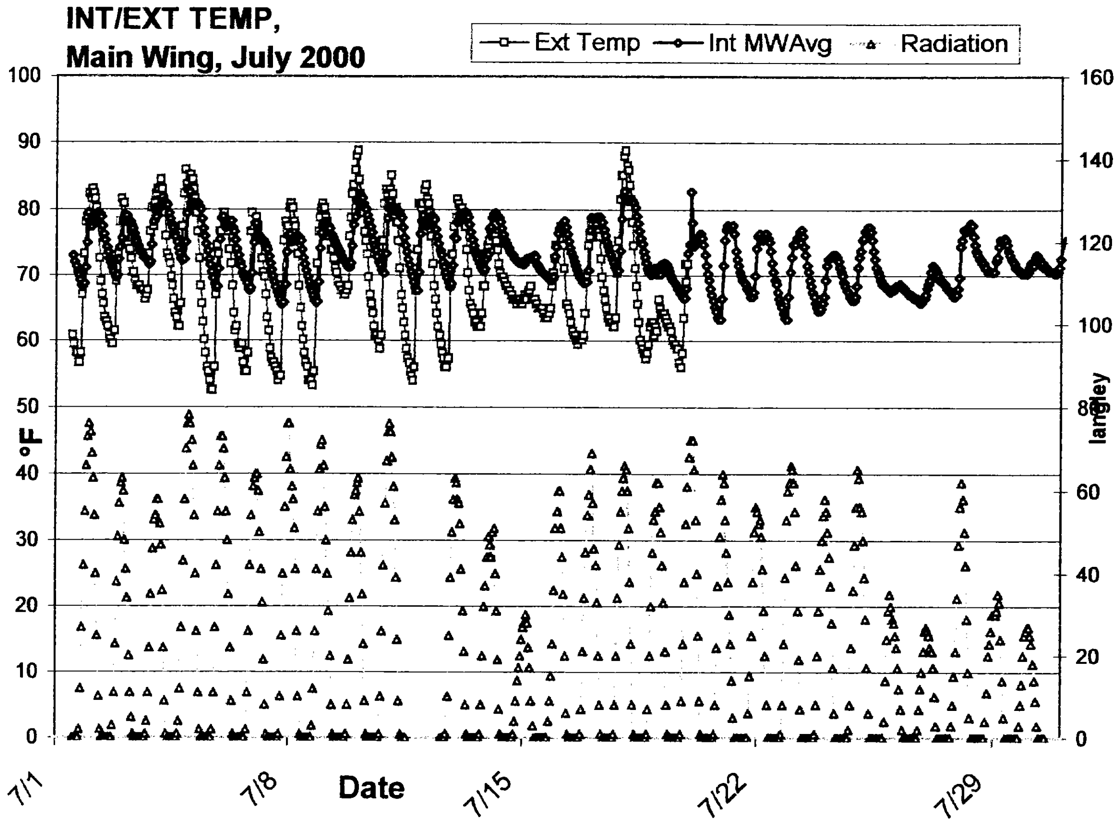
INT/EXT TEMP, Main Wing March, 2000

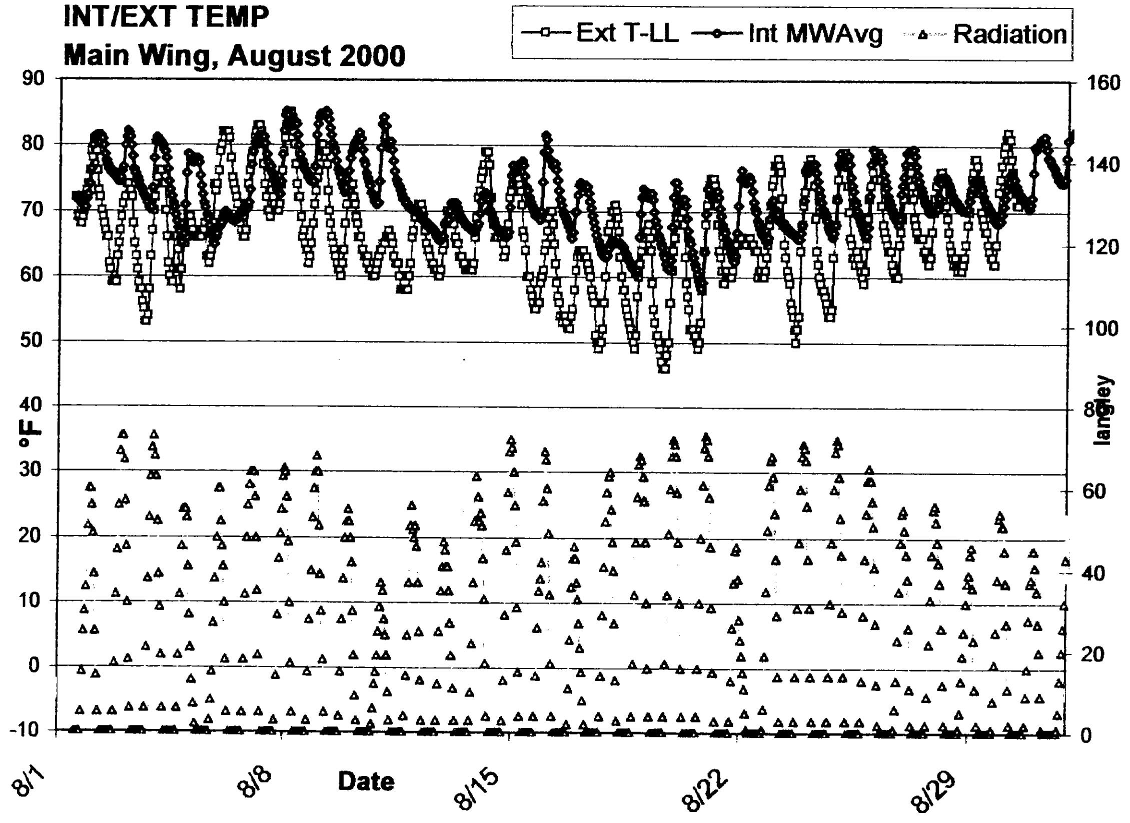


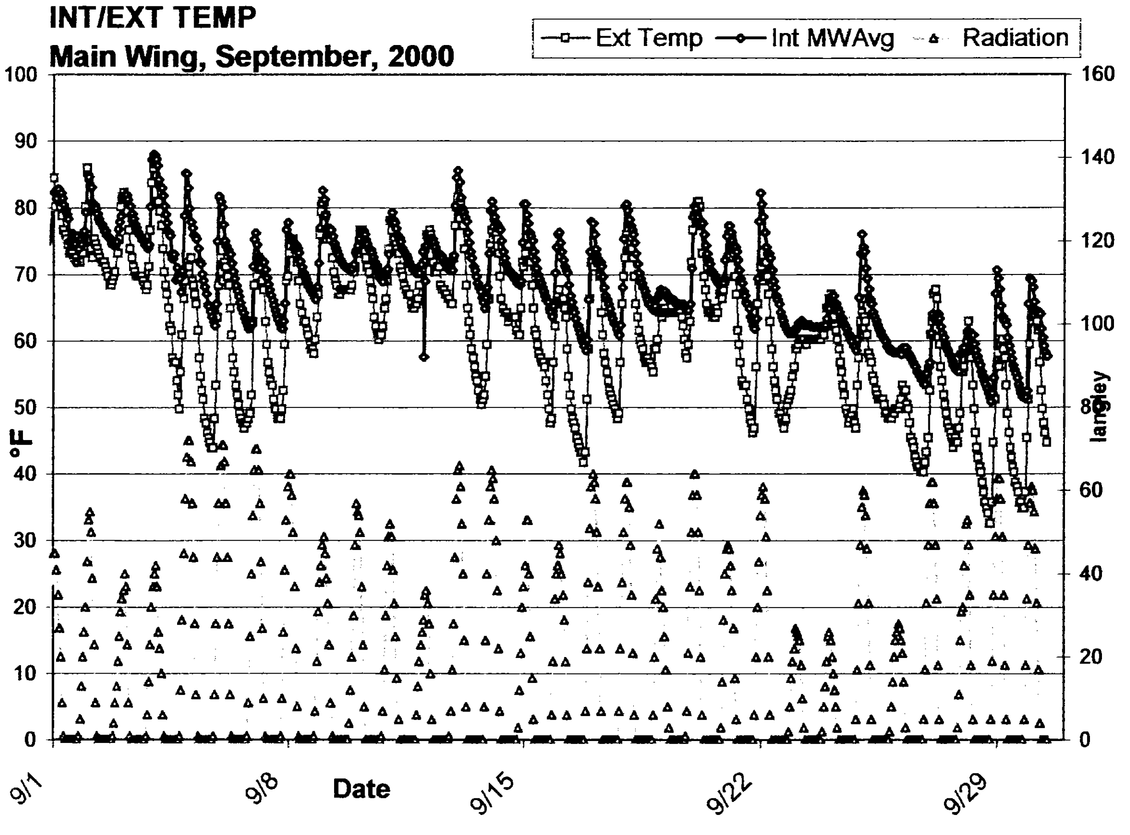
INT/EXT TEMP, Main Wing, April, 2000

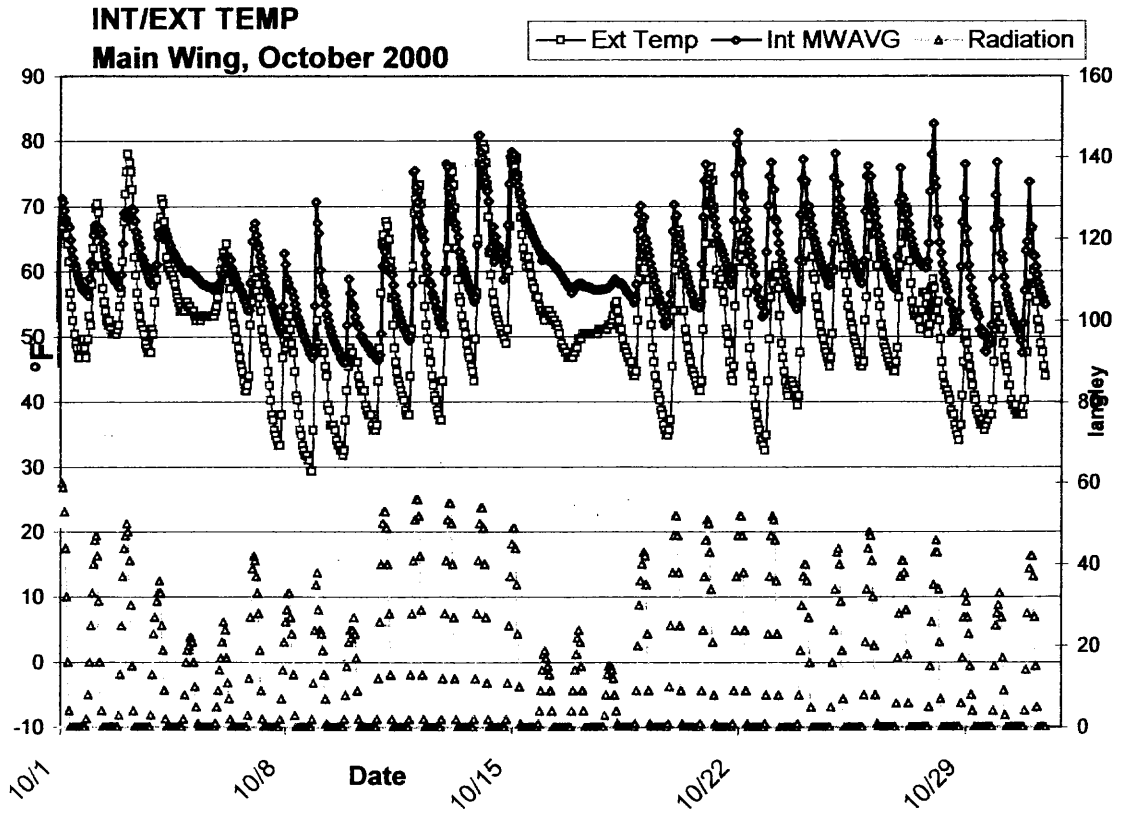

INT/EXT TEMP,
Main Wing, May, 2000
Ext Temp
Int MWAvg
Radiation
°F
90
80
70
60
50
40
30
20
10
0
-10
langley
160
140
120
100
80
60
40
20
0
4/30
5/7
Date
5/14
5/21
5/28

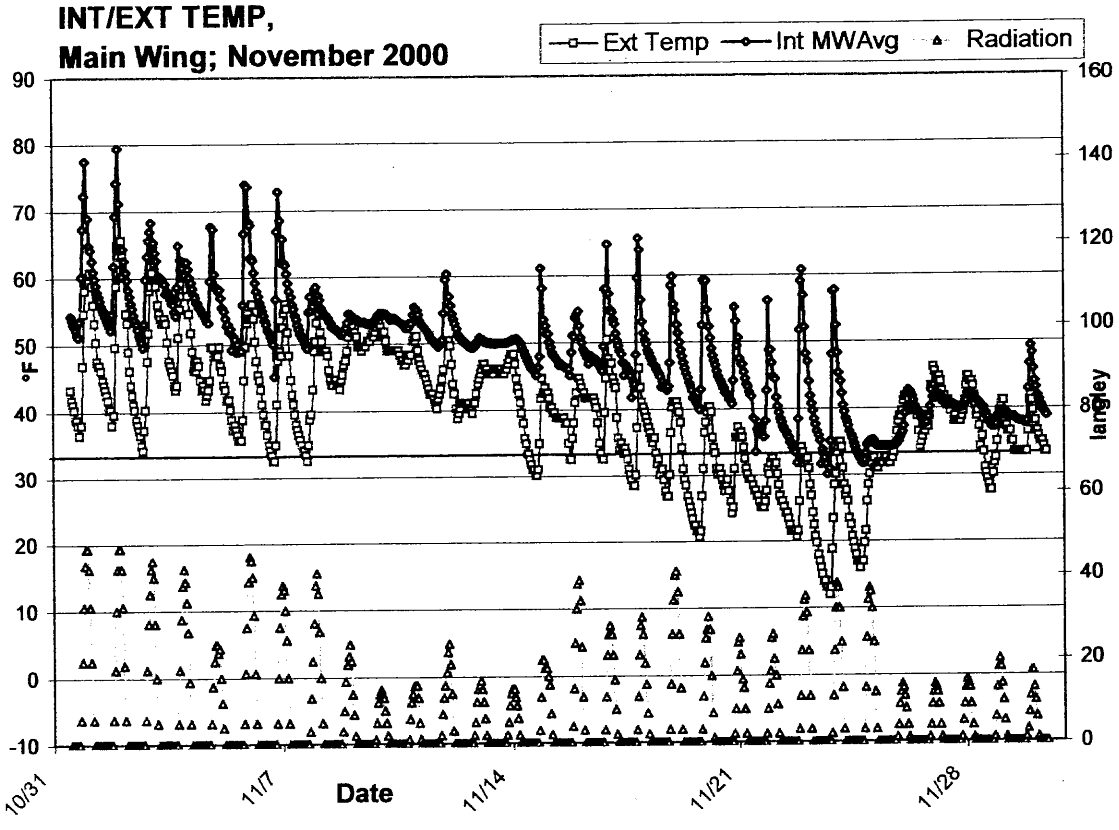

INT/EXT TEMP,
Main Wing, June 2000
Ext Temp
Int MWAvg
Radiation
°F
100
90
80
70
60
50
40
30
20
10
0
langley
160
140
120
100
80
60
40
20
0
5/31
6/7
Date
6/14
6/21
6/28

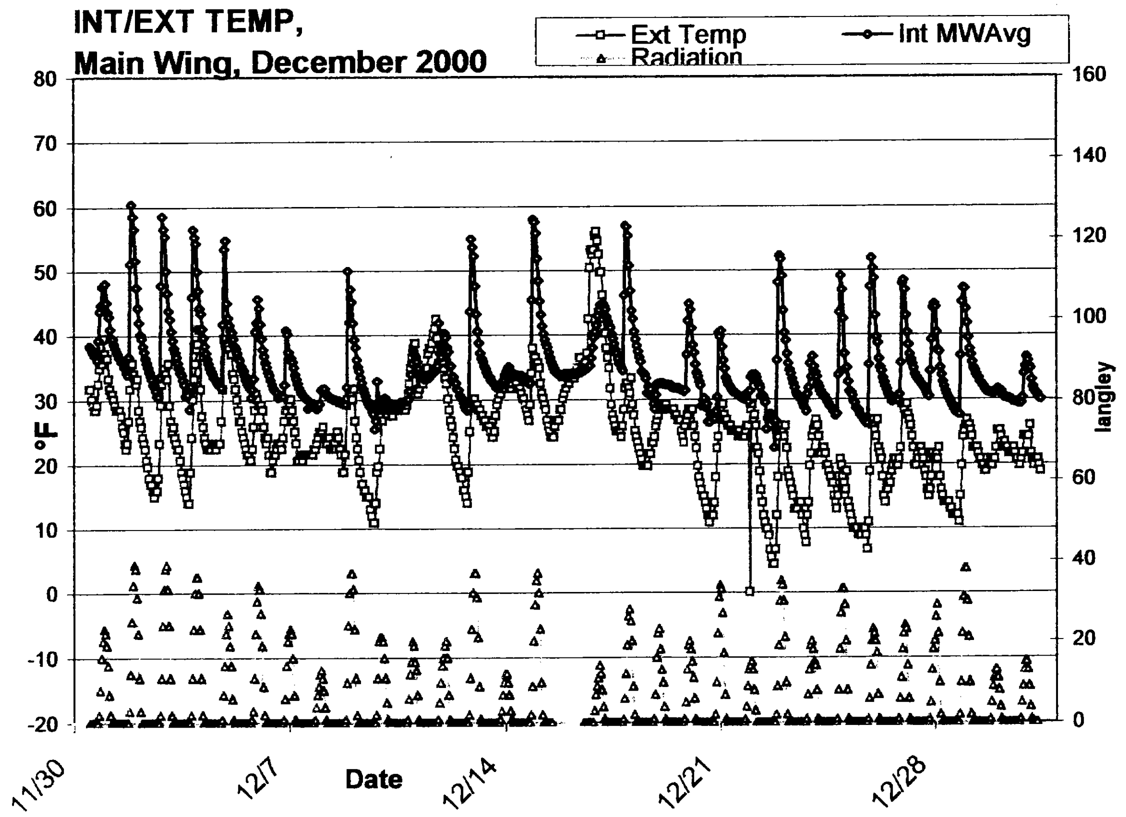

INT/EXT TEMP,
Main Wing, July 2000
Ext Temp
Int MWAvg
Radiation
100
90
80
70
60
50
40
30
20
10
0
°F
160
140
120
100
80
60
40
20
0
langley
7/1
7/8
Date
7/15
7/22
7/29

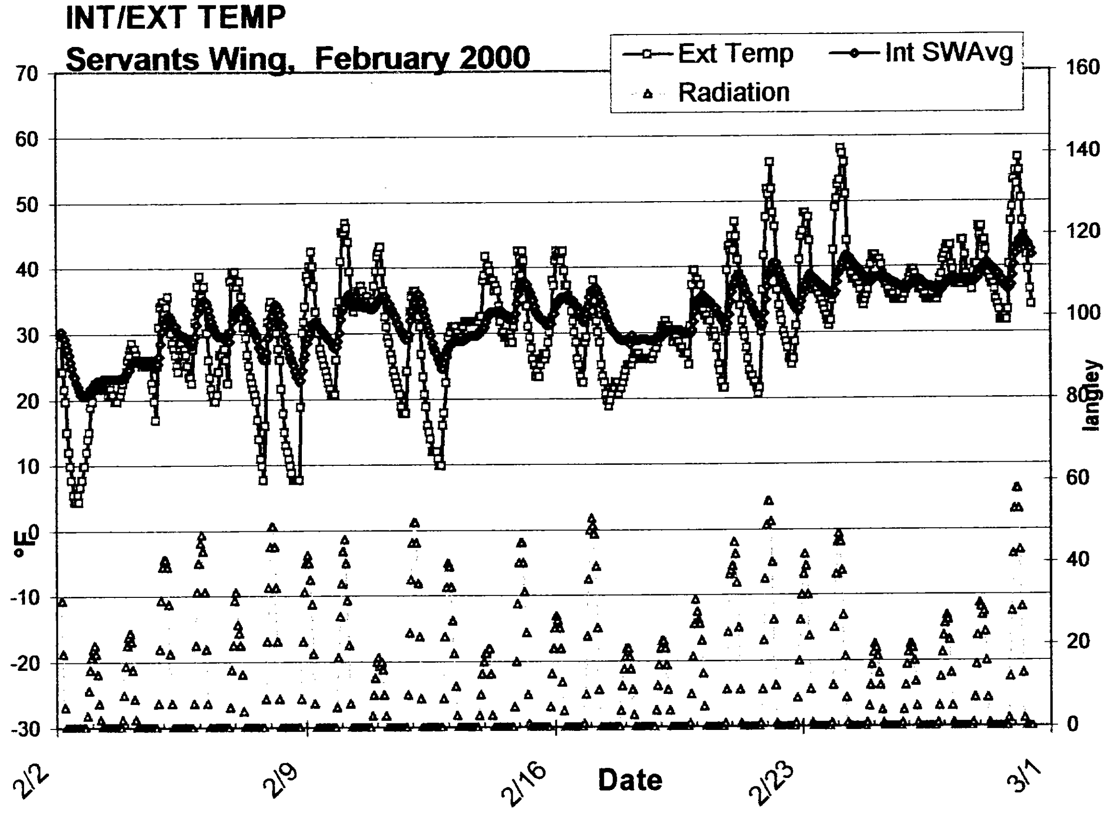

INT/EXT TEMP
Main Wing, August 2000
Ext T-LL
Int MWAvg
Radiation
90
80
70
60
50
40
30
20
10
0
-10
°F
160
140
120
100
80
60
40
20
0
langley
8/1
8/8
Date
8/15
8/22
8/29

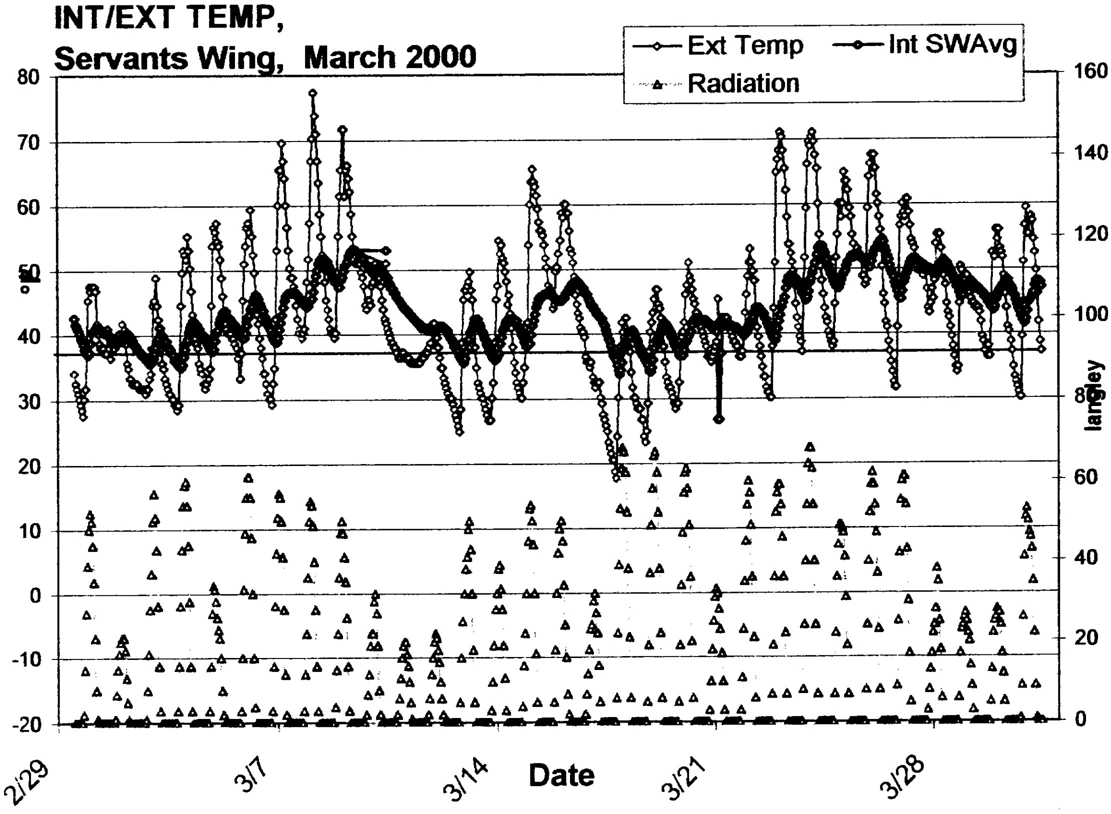

INT/EXT TEMP
Main Wing, September, 2000
Ext Temp
Int MWAvg
Radiation
100
90
80
70
60
50
40
30
20
10
0
°F
160
140
120
100
80
60
40
20
0
langley
9/1
9/8
9/15
9/22
9/29
Date

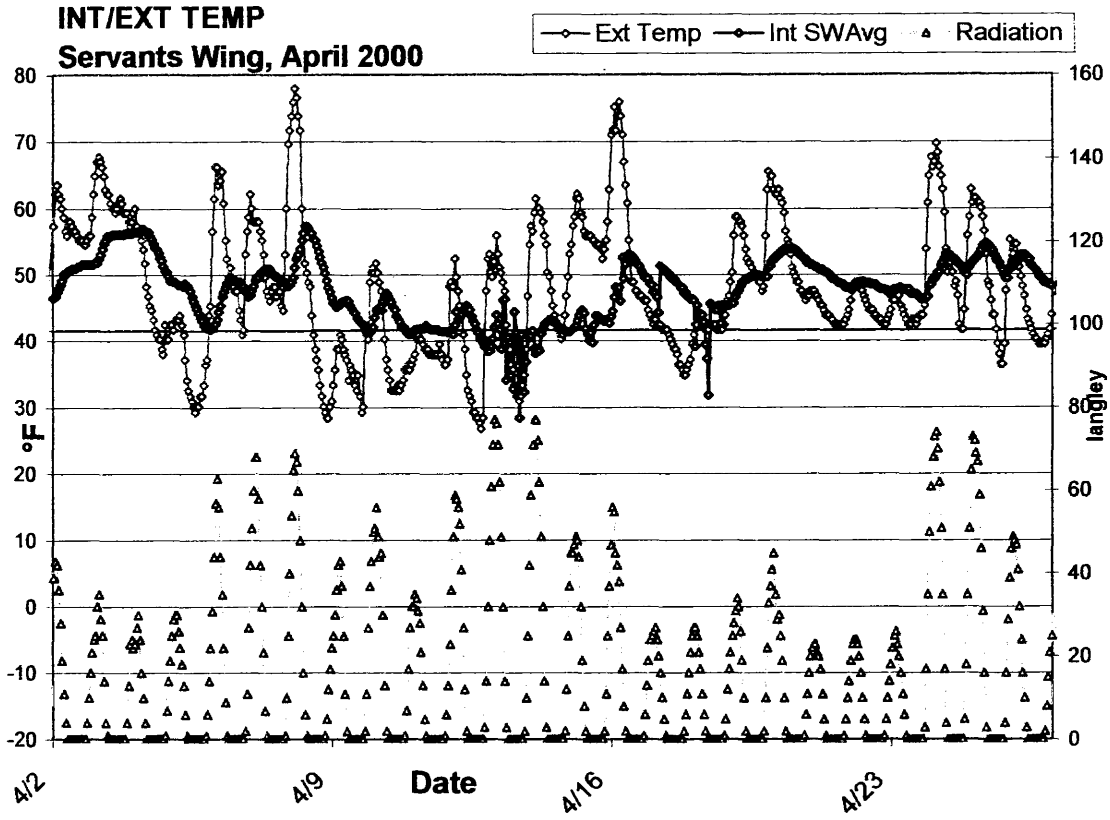

INT/EXT TEMP
Main Wing, October 2000
Ext Temp
Int MWAVG
Radiation
90
80
70
60
50
40
30
20
10
0
-10
°F
160
140
120
100
80
60
40
20
0
langley
10/1
10/8
10/15
10/22
10/29
Date


INT/EXT TEMP,
Main Wing; November 2000
Ext Temp
Int MWAvg
Radiation
90
80
70
60
50
40
30
20
10
0
-10
°F
160
140
120
100
80
60
40
20
0
langley
10/31
11/7
Date
11/14
11/21
11/28

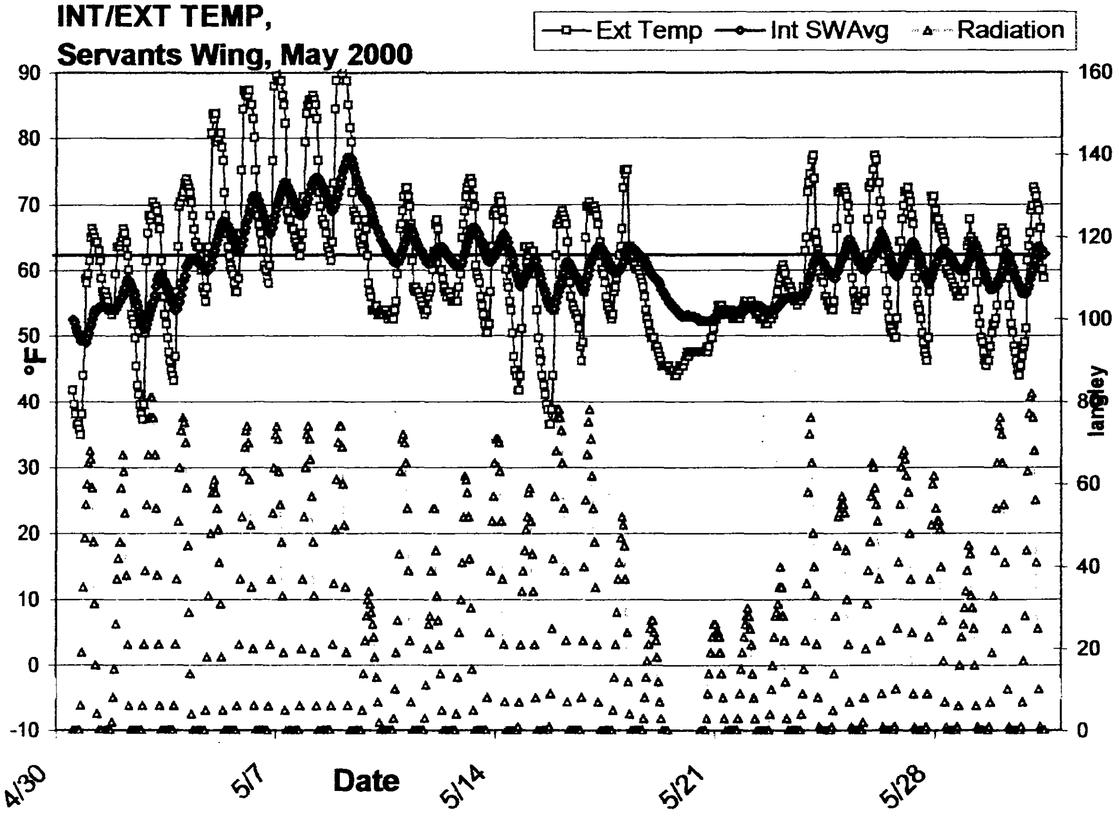

INT/EXT TEMP,
Main Wing, December 2000
Ext Temp
Int MWAvg
Radiation
80
70
60
50
40
30
20
10
0
-10
-20
°F
160
140
120
100
80
60
40
20
0
langley
11/30
12/7
Date
12/14
12/21
12/28


INT/EXT TEMP
Servants Wing, February 2000
Ext Temp
Int SWAvg
Radiation
70
60
50
40
30
20
10
0
-10
-20
-30
°F
160
140
120
100
80
60
40
20
0
langley
2/2
2/9
2/16
Date
2/23
3/1

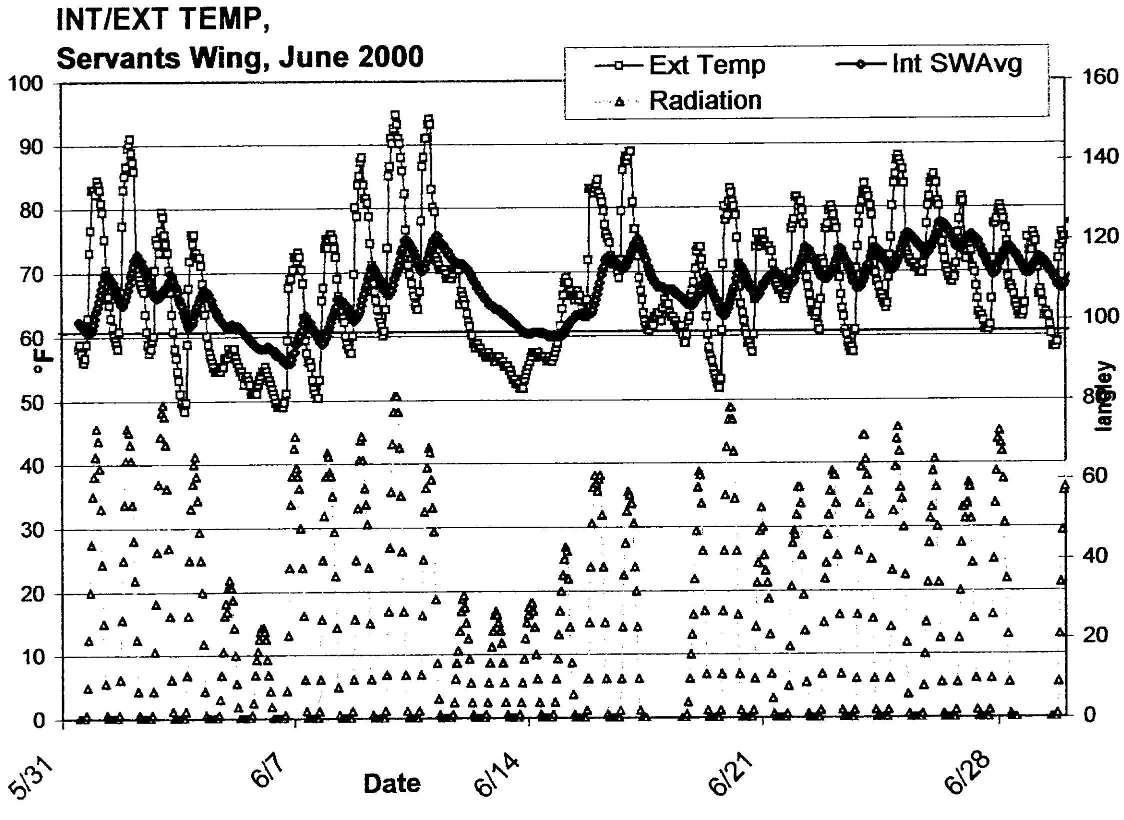

INT/EXT TEMP,
Servants Wing, March 2000
Ext Temp
Int SWAvg
Radiation
80
70
60
50
40
30
20
10
0
-10
-20
°F
160
140
120
100
80
60
40
20
0
langley
2/29
3/7
3/14
Date
3/21
3/28

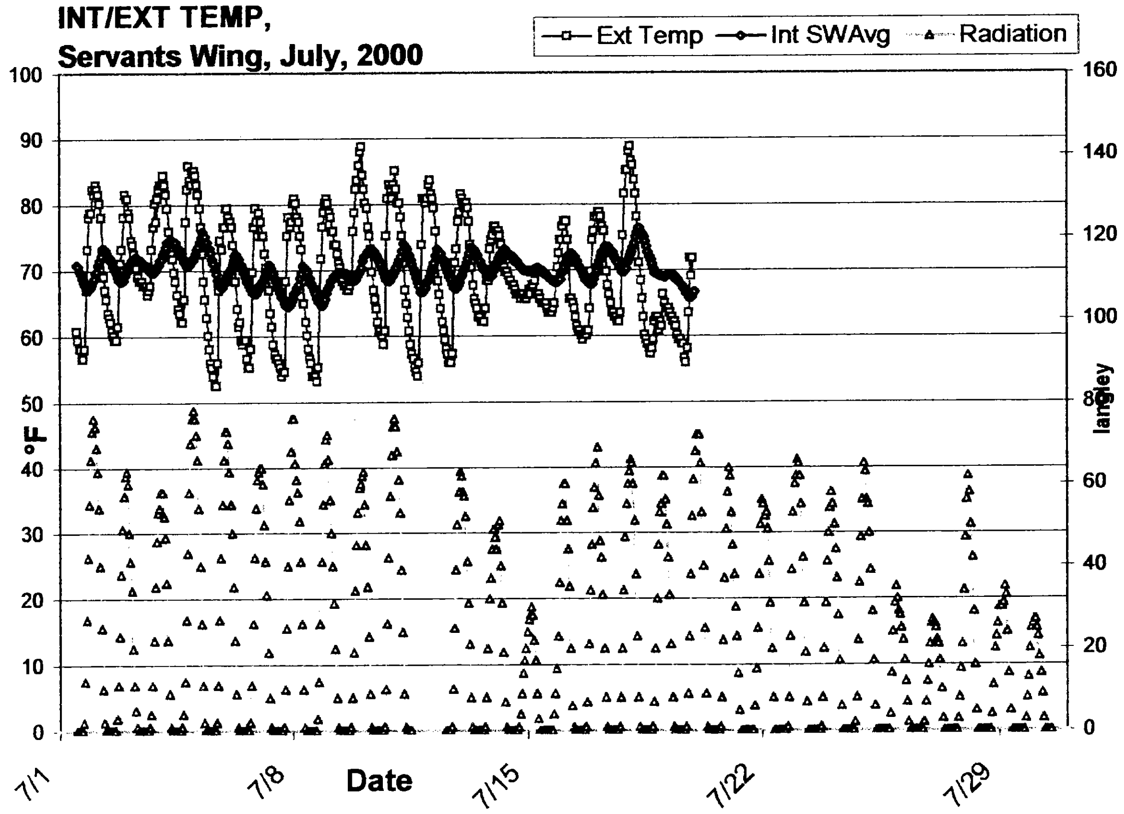


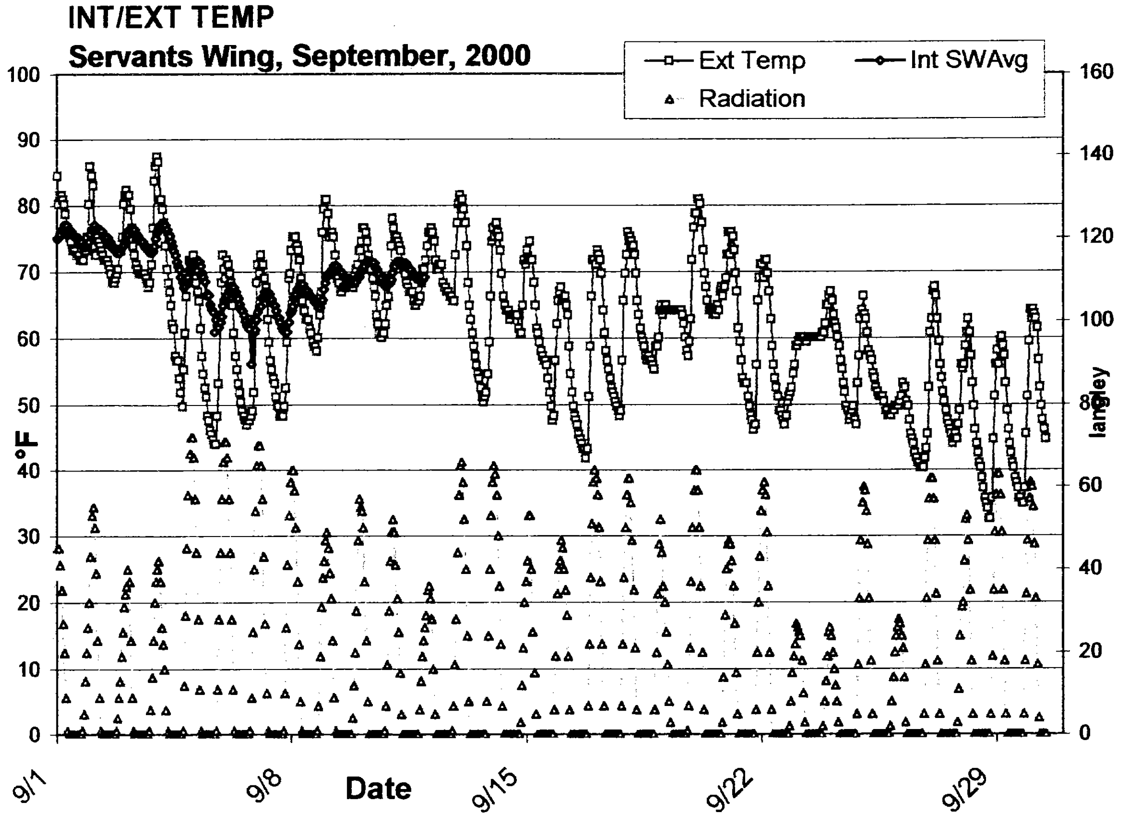
INT/EXT TEMP
Servants Wing, April 2000

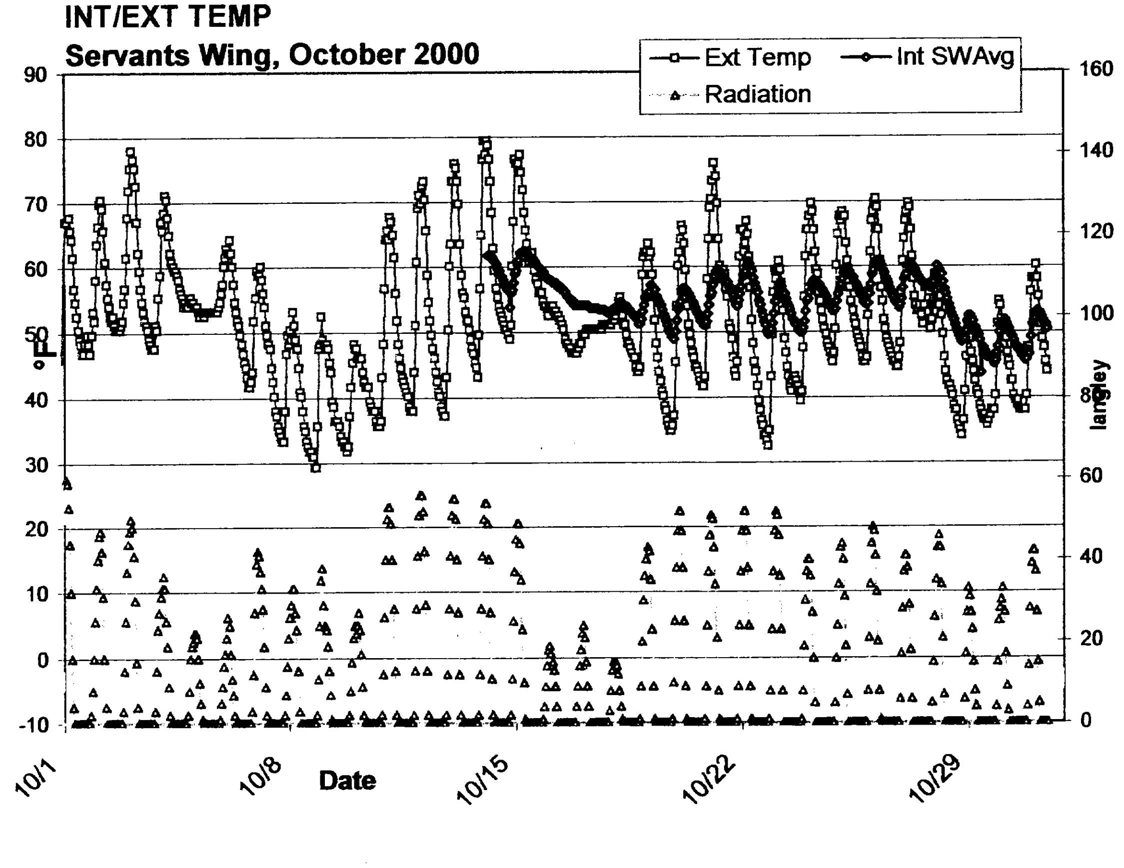


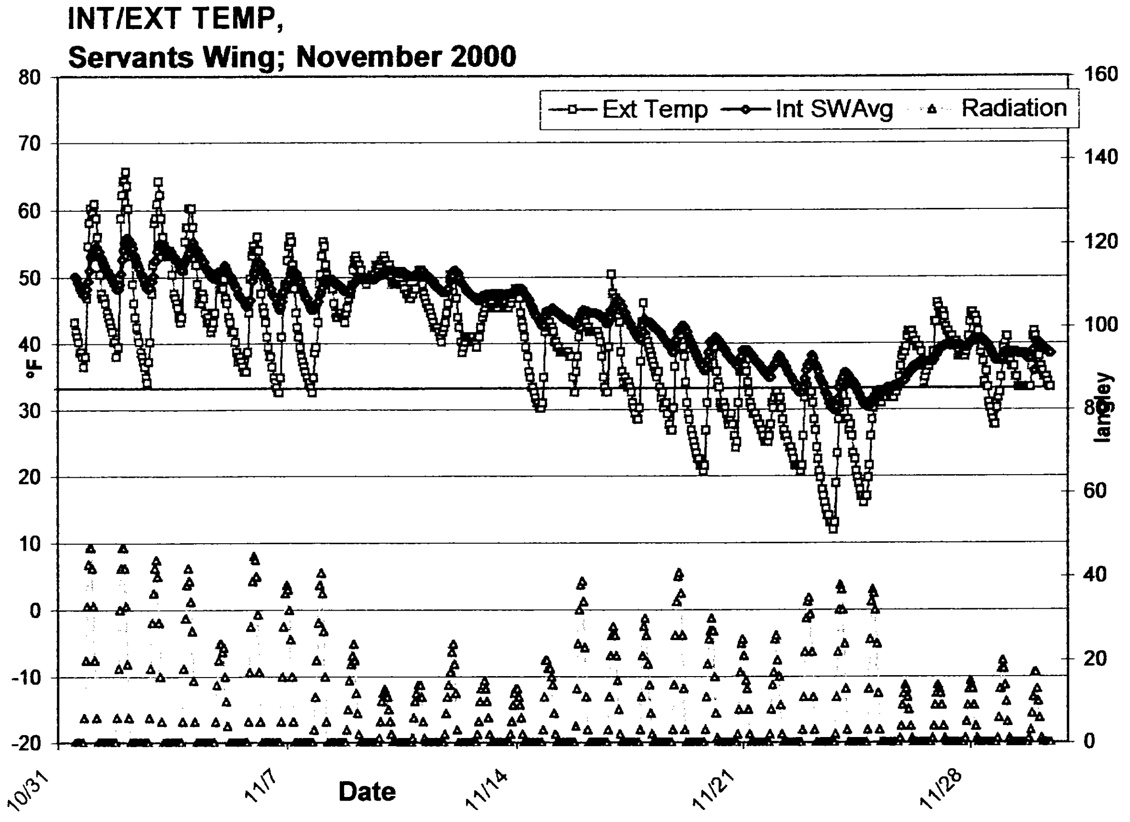
INT/EXT TEMP,
Servants Wing, May 2000


INT/EXT TEMP,
Servants Wing, June 2000
Ext Temp
Int SWAvg
Radiation
°F
langley
Date
5/31
6/7
6/14
6/21
6/28
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160

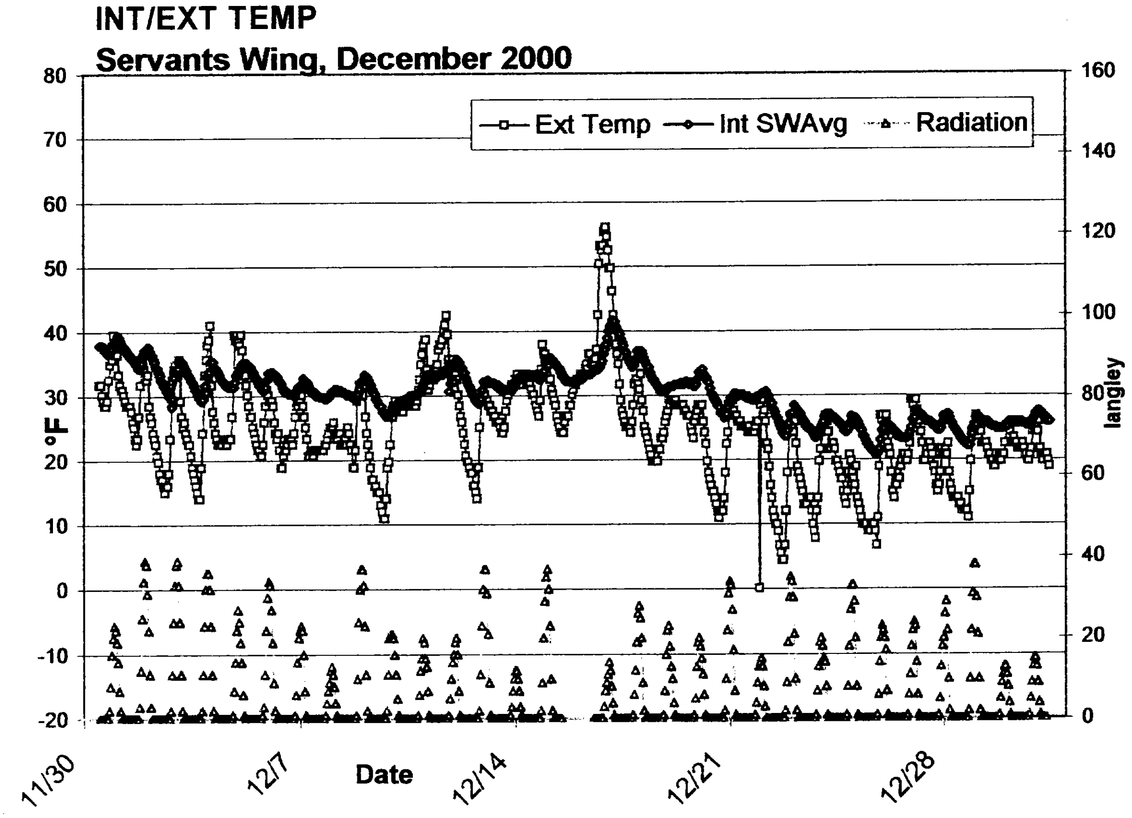

INT/EXT TEMP,
Servants Wing, July, 2000
Ext Temp
Int SWAvg
Radiation
°F
langley
Date
7/1
7/8
7/15
7/22
7/29
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160


INT/EXT TEMP
Servants Wing, September, 2000
Ext Temp
Int SWAvg
Radiation
°F
langley
Date
100
90
80
70
60
50
40
30
20
10
0
160
140
120
100
80
60
40
20
0
9/1
9/8
9/15
9/22
9/29


INT/EXT TEMP
Servants Wing, October 2000
Ext Temp
Int SWAvg
Radiation
°F
langley
Date
90
80
70
60
50
40
30
20
10
0
-10
160
140
120
100
80
60
40
20
0
10/1
10/8
10/15
10/22
10/29



INT/EXT TEMP,
Servants Wing; November 2000

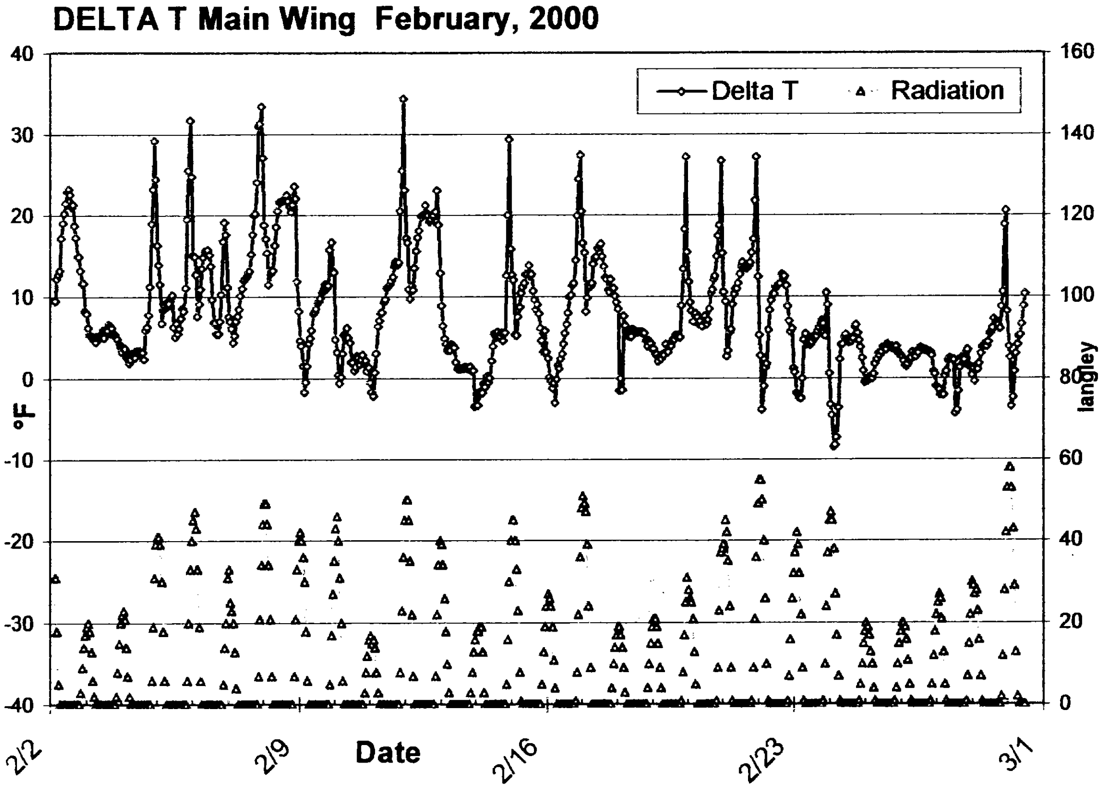


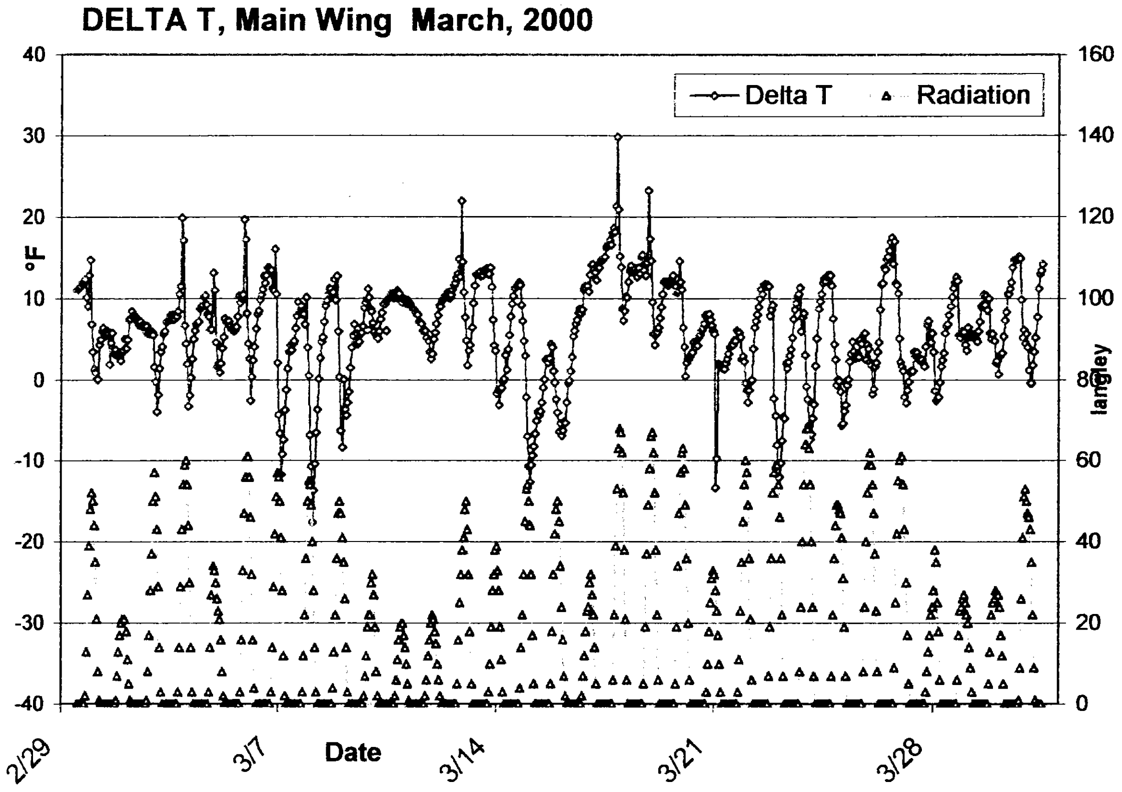
INT/EXT TEMP
Servants Wing, December 2000

## Figure A4 - DELTA T GRAPHS

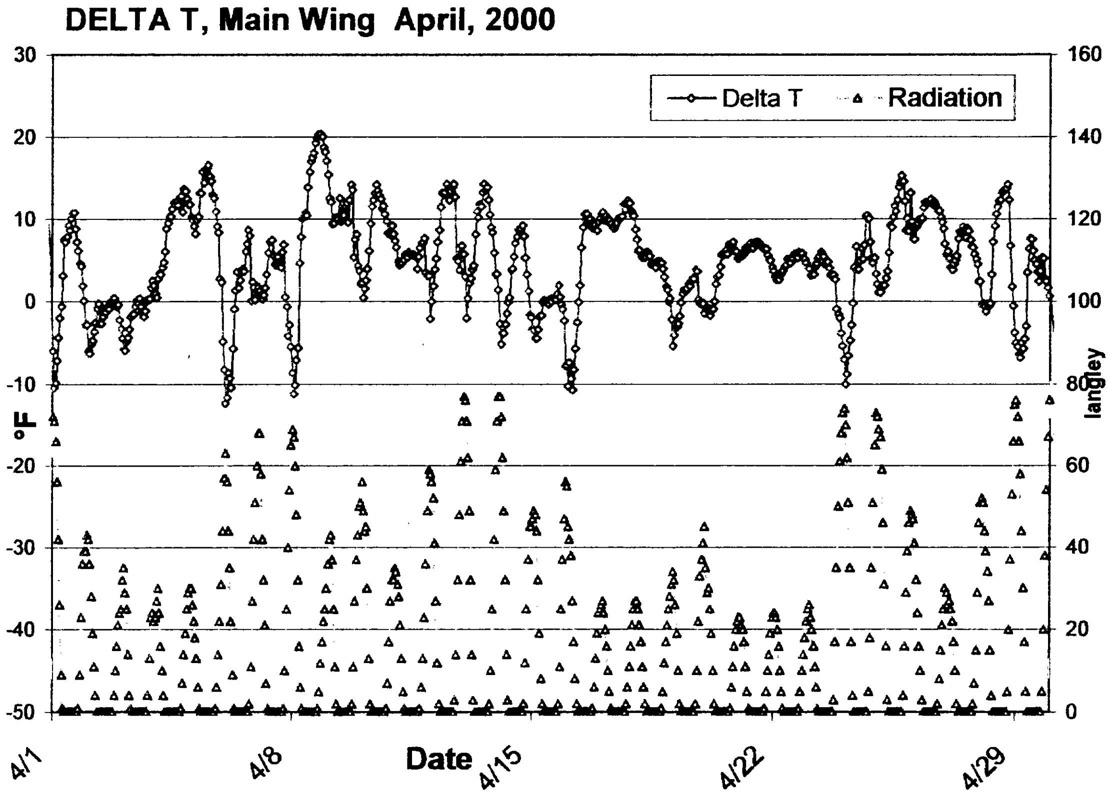
DELTA T graphs compare interior solar gain, expressed as Delta T, to the available solar radiation. Delta T is calculated by subtracting the exterior temperature from the average interior temperature (see Fig A2). Positive values indicate that the house interior is warmer than the outdoors. Negative values indicate the house interior temperature is lower than the exterior temperature. The two wings are shown separately. Each DELTA T graph expresses hourly data for one month for one of the wings. It can be seen that the average Delta T for the main Wing is generally positive showing solar gain, while the Delta T for the Servants wing is near zero.

Units and abbreviations:
Temperatures - degrees Fahrenheit; left Y-axis
Radiation - langleys; see Figure A1; right Y-axis

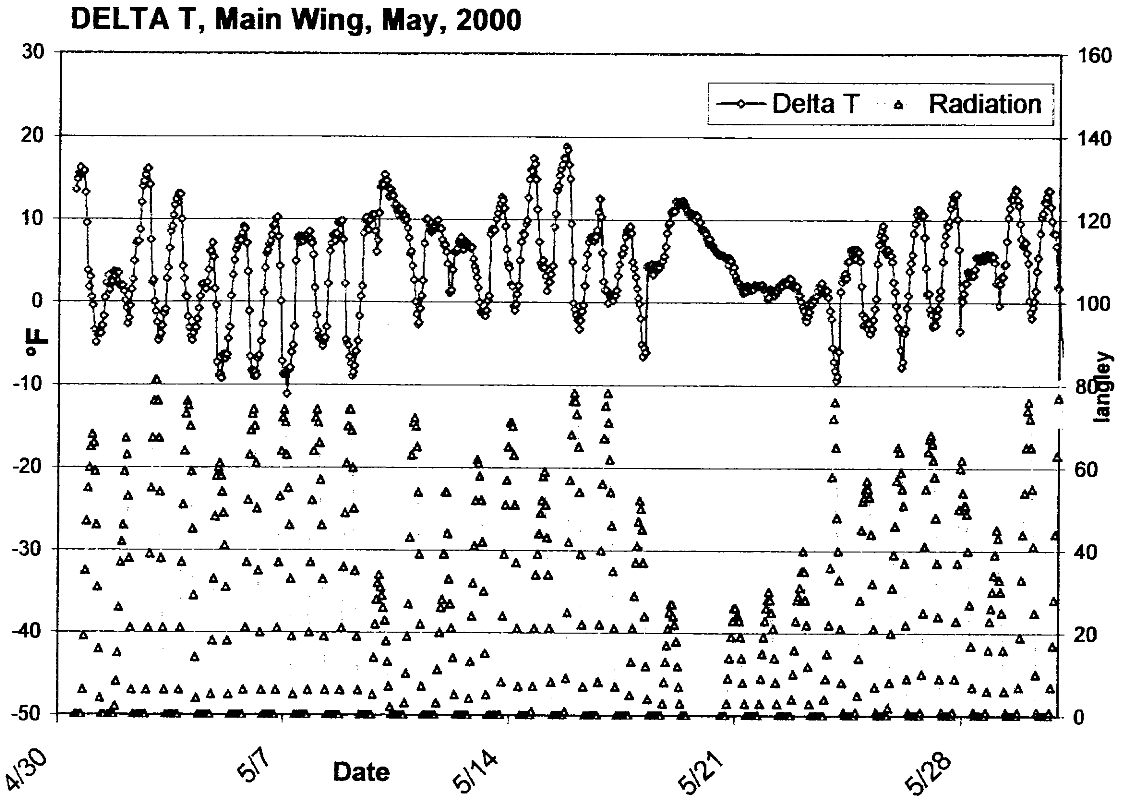


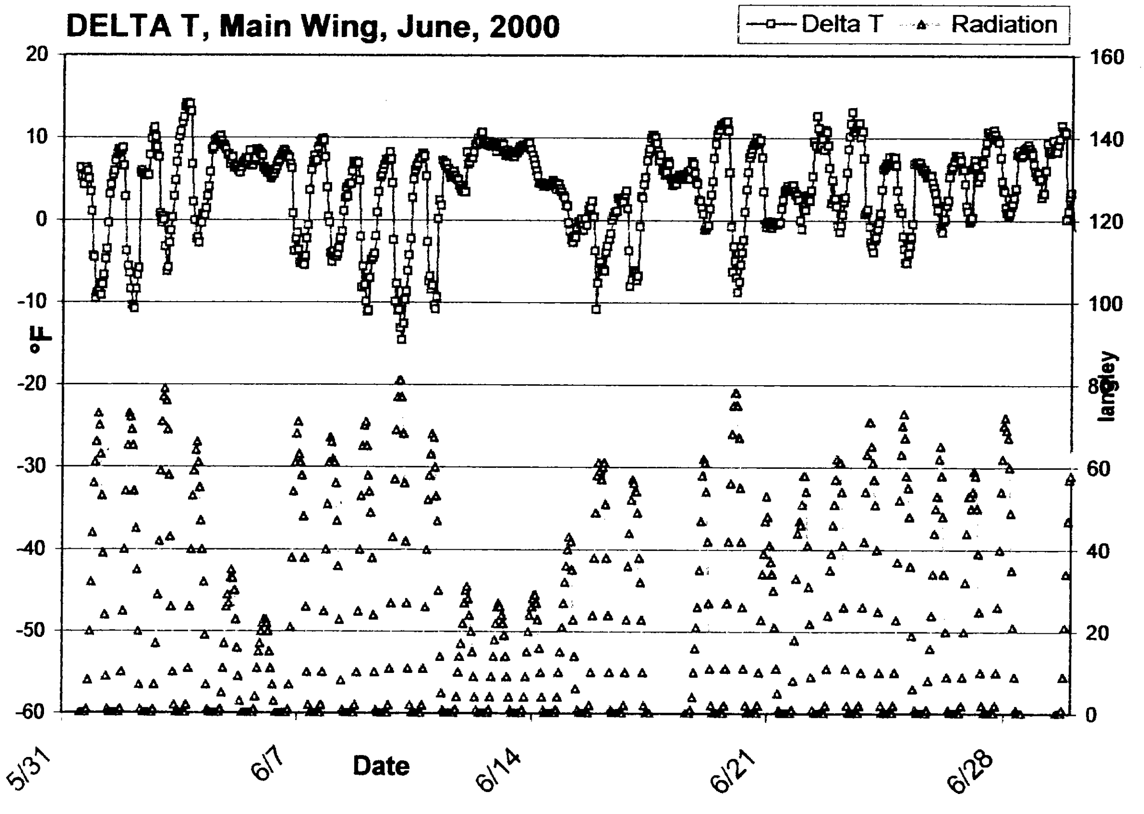


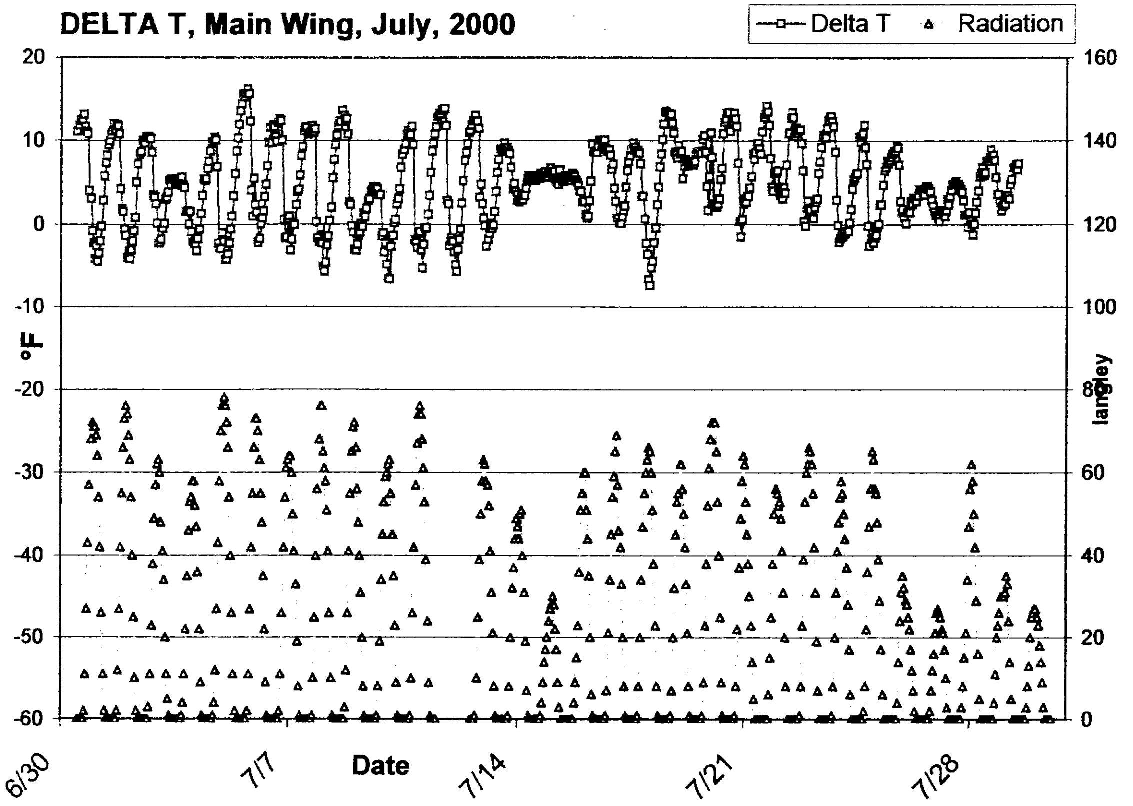
DELTA T, Main Wing March, 2000

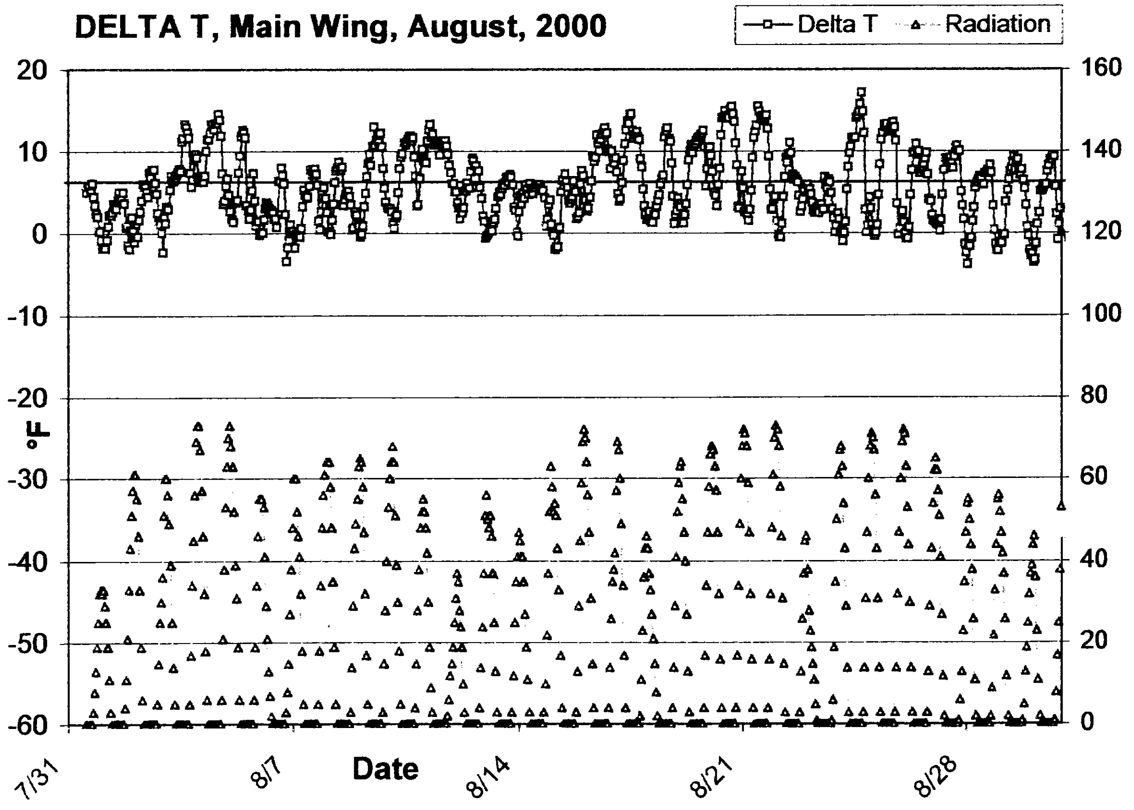


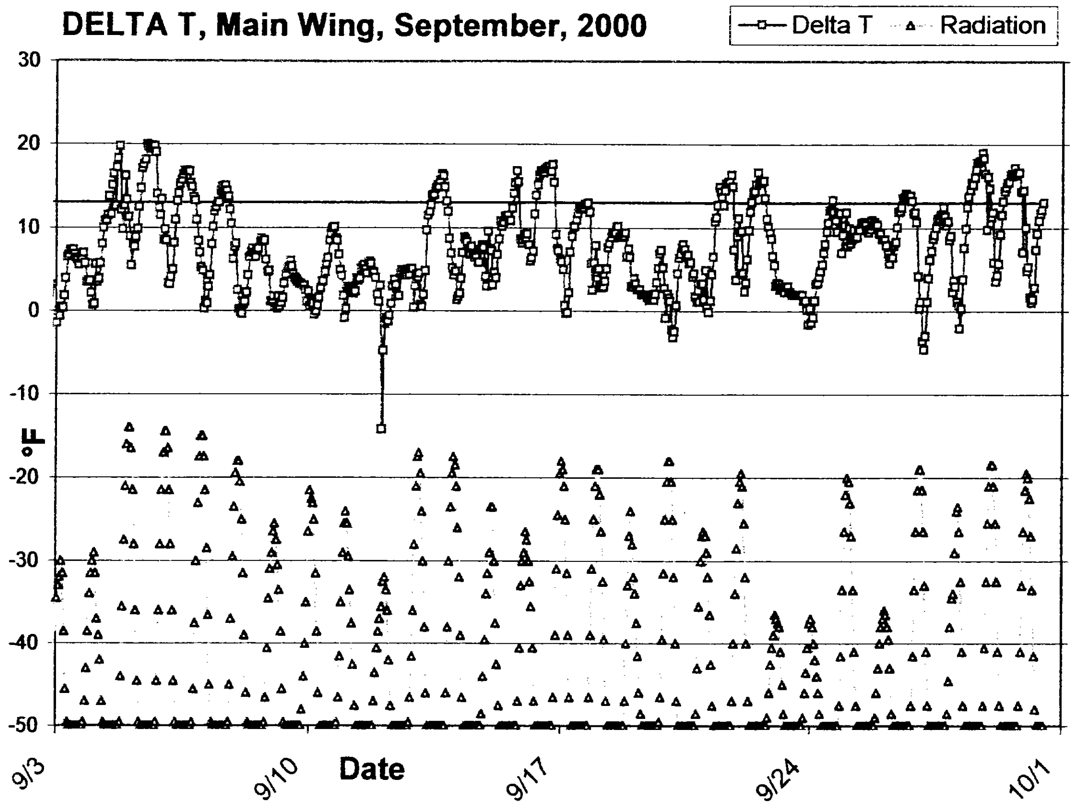
DELTA T, Main Wing April, 2000

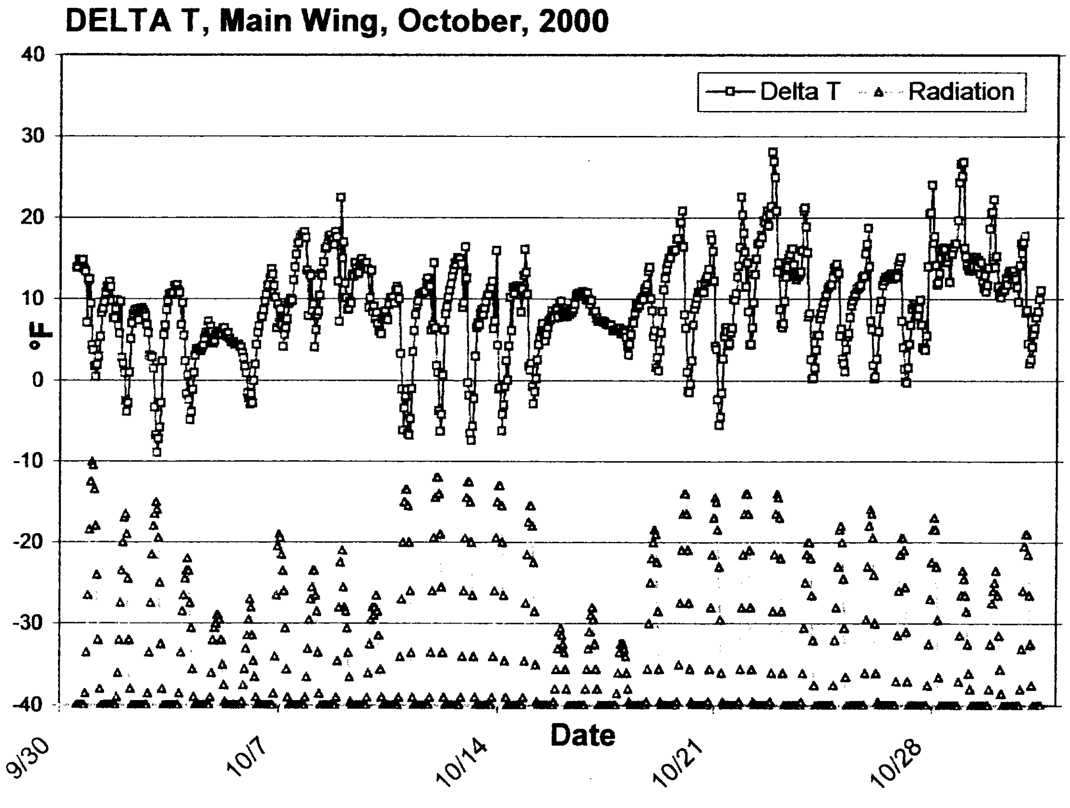

DELTA T, Main Wing, May, 2000
Delta T
Radiation
°F
langley
Date
30
20
10
0
-10
-20
-30
-40
-50
160
140
120
100
80
60
40
20
0
4/30
5/7
5/14
5/21
5/28


DELTA T, Main Wing, June, 2000
Delta T
Radiation
°F
langley
Date
20
10
0
-10
-20
-30
-40
-50
-60
160
140
120
100
80
60
40
20
0
5/31
6/7
6/14
6/21
6/28

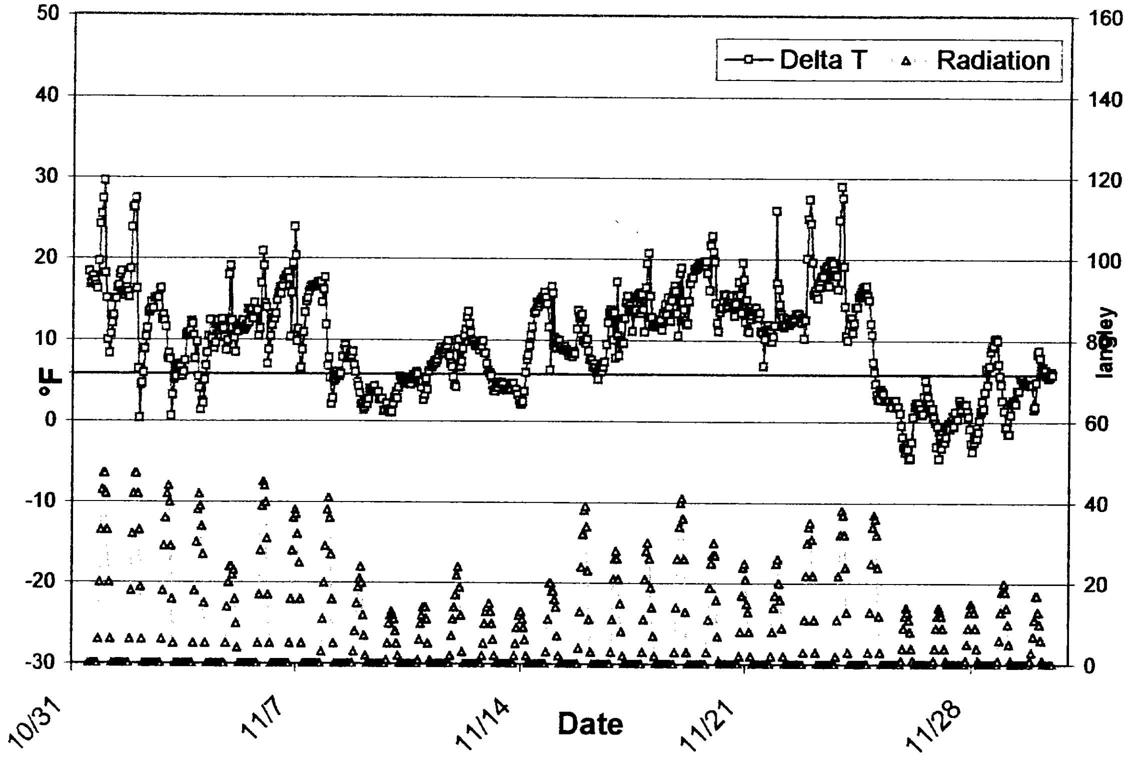

DELTA T, Main Wing, July, 2000
Delta T
Radiation
20
10
0
-10
-20
-30
-40
-50
-60
°F
160
140
120
100
80
60
40
20
0
langley
6/30
7/7
7/14
7/21
7/28
Date


DELTA T, Main Wing, August, 2000
Delta T
Radiation
20
10
0
-10
-20
-30
-40
-50
-60
°F
160
140
120
100
80
60
40
20
0
7/31
8/7
8/14
8/21
8/28
Date

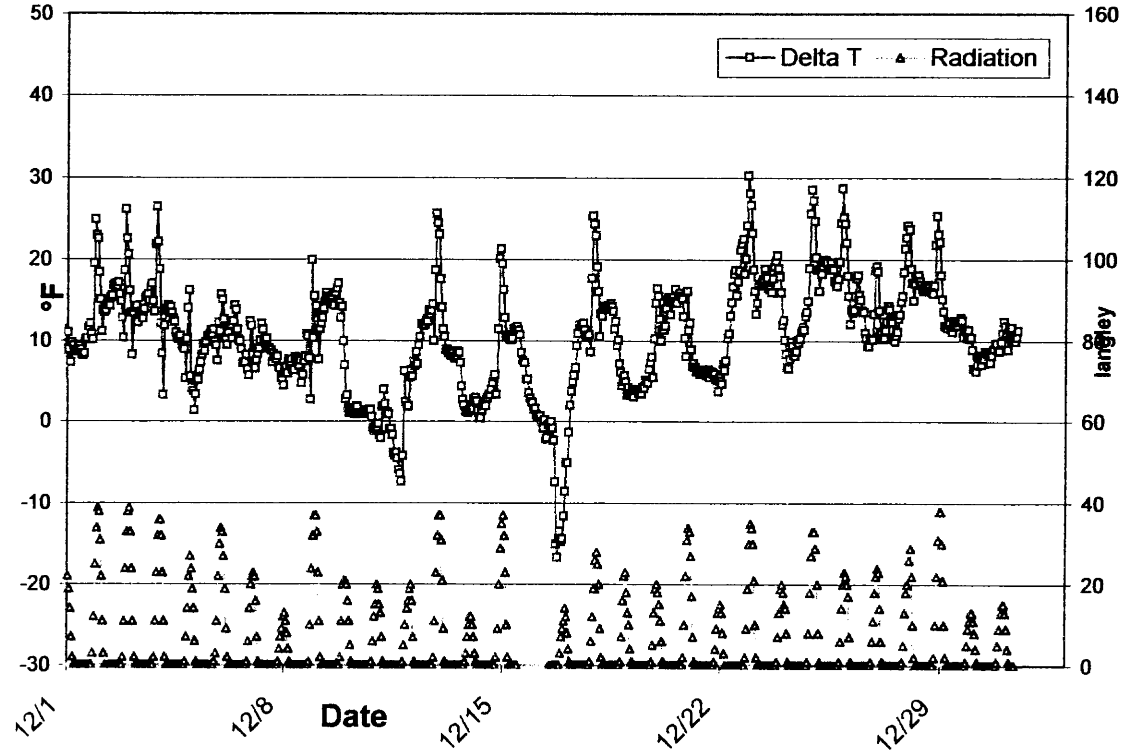

DELTA T, Main Wing, September, 2000
Delta T
Radiation
30
20
10
0
-10
-20
-30
-40
-50
°F
160
140
120
100
80
60
40
20
0
langley
9/3
9/10
9/17
9/24
10/1
Date

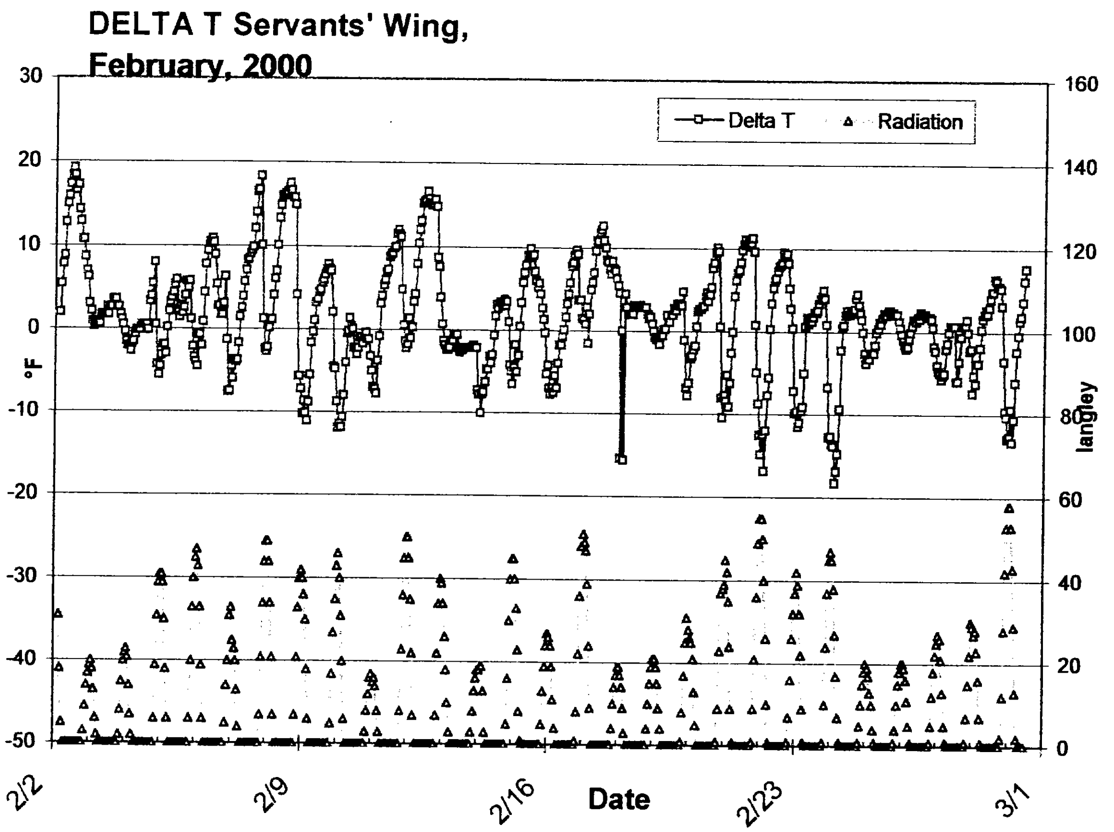

DELTA T, Main Wing, October, 2000
Delta T
Radiation
40
30
20
10
0
-10
-20
-30
-40
°F
160
140
120
100
80
60
40
20
0
langley
9/30
10/7
10/14
10/21
10/28
Date

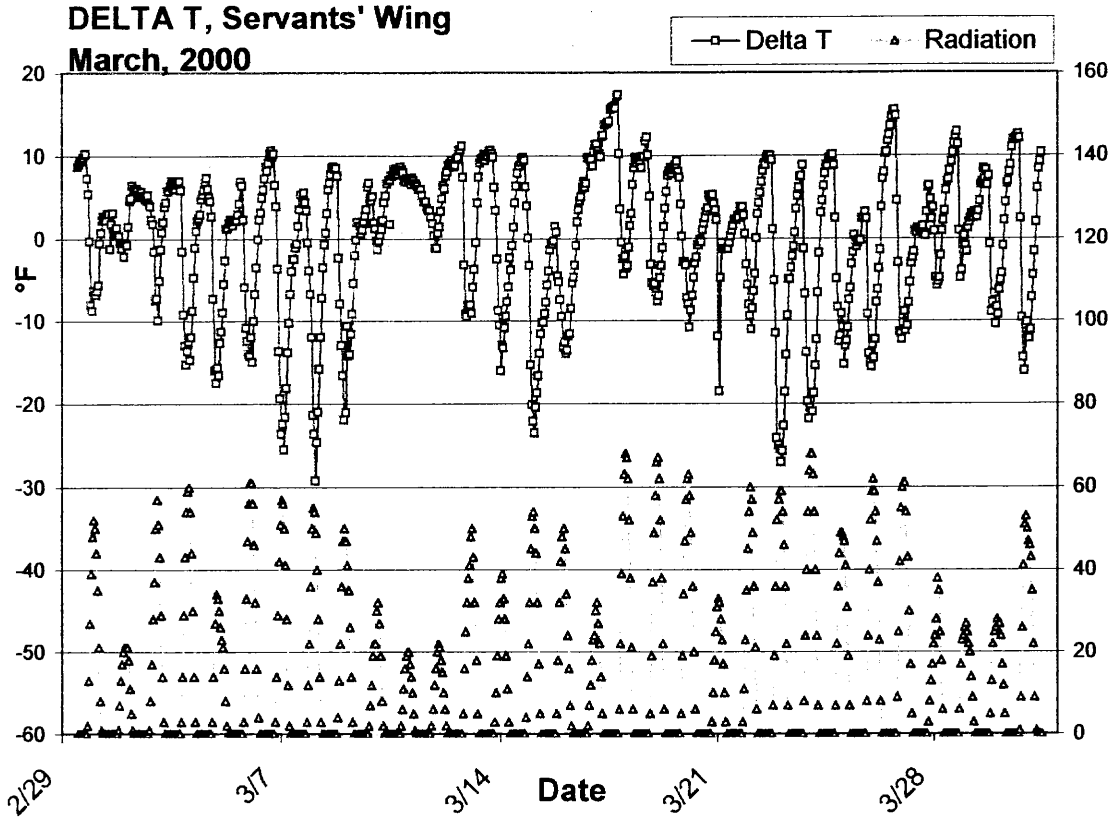
## DELTA T, Main Wing, November, 2000

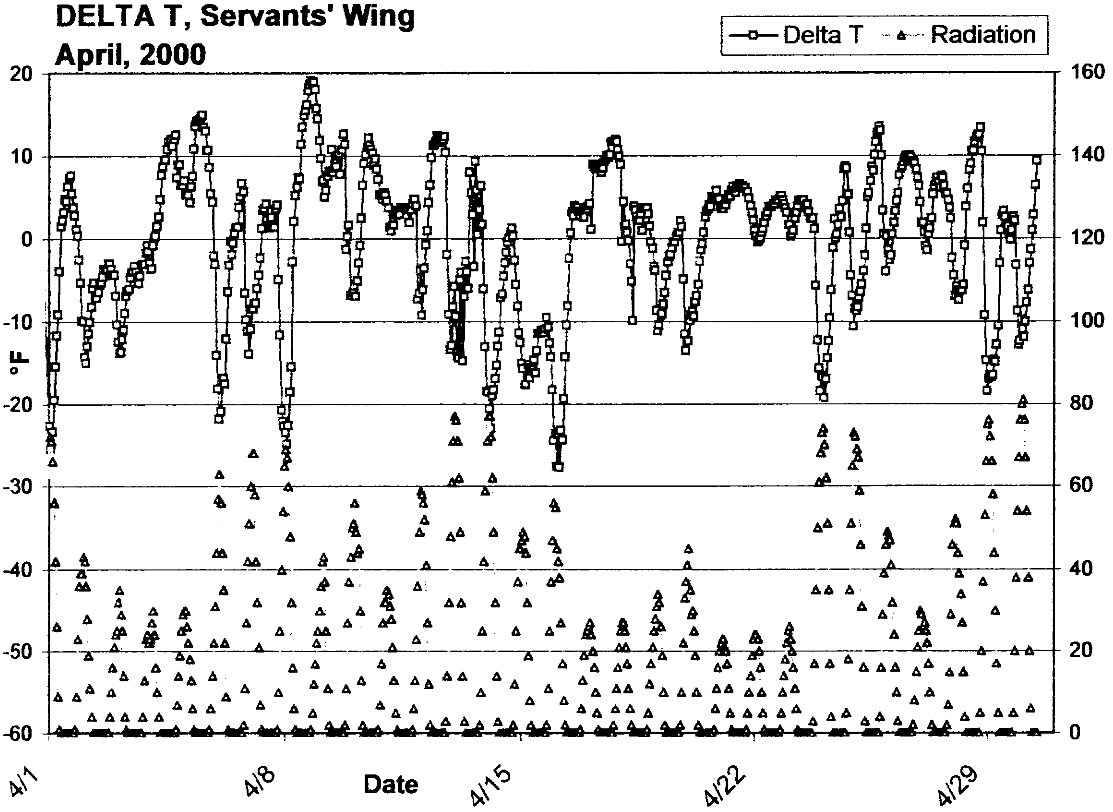


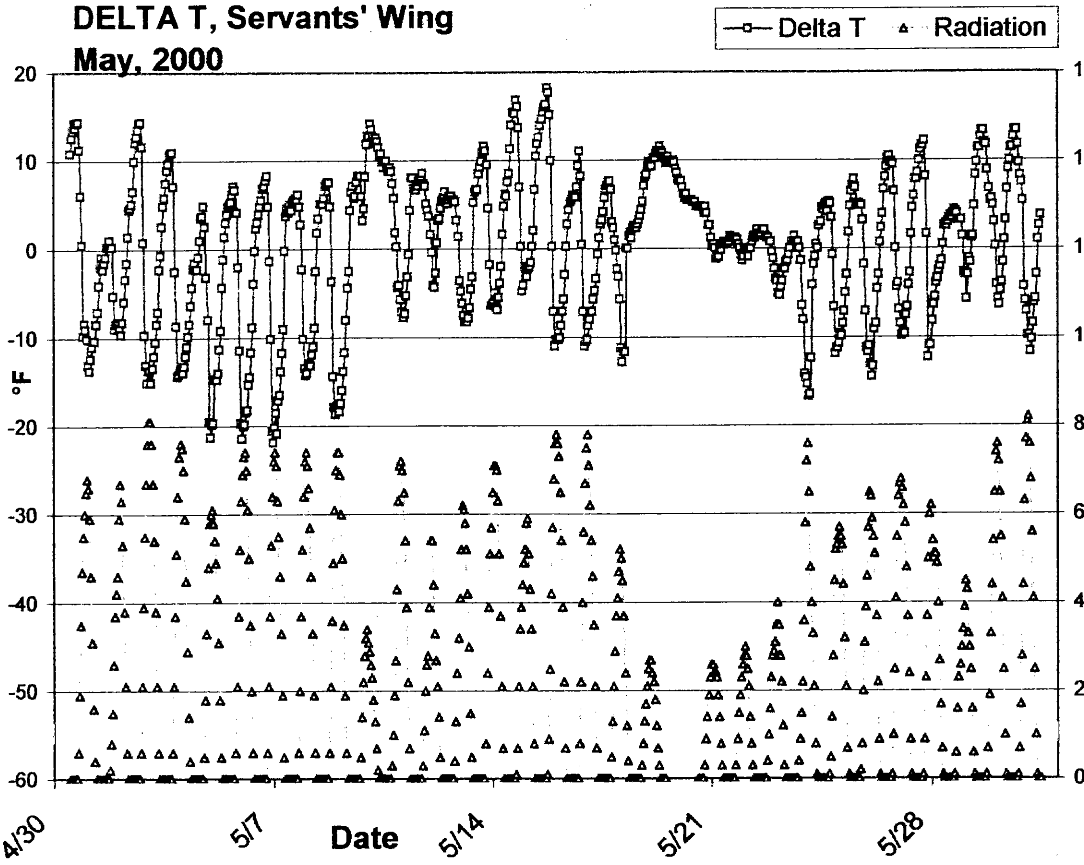
## DELTA T, Main Wing, December, 2000

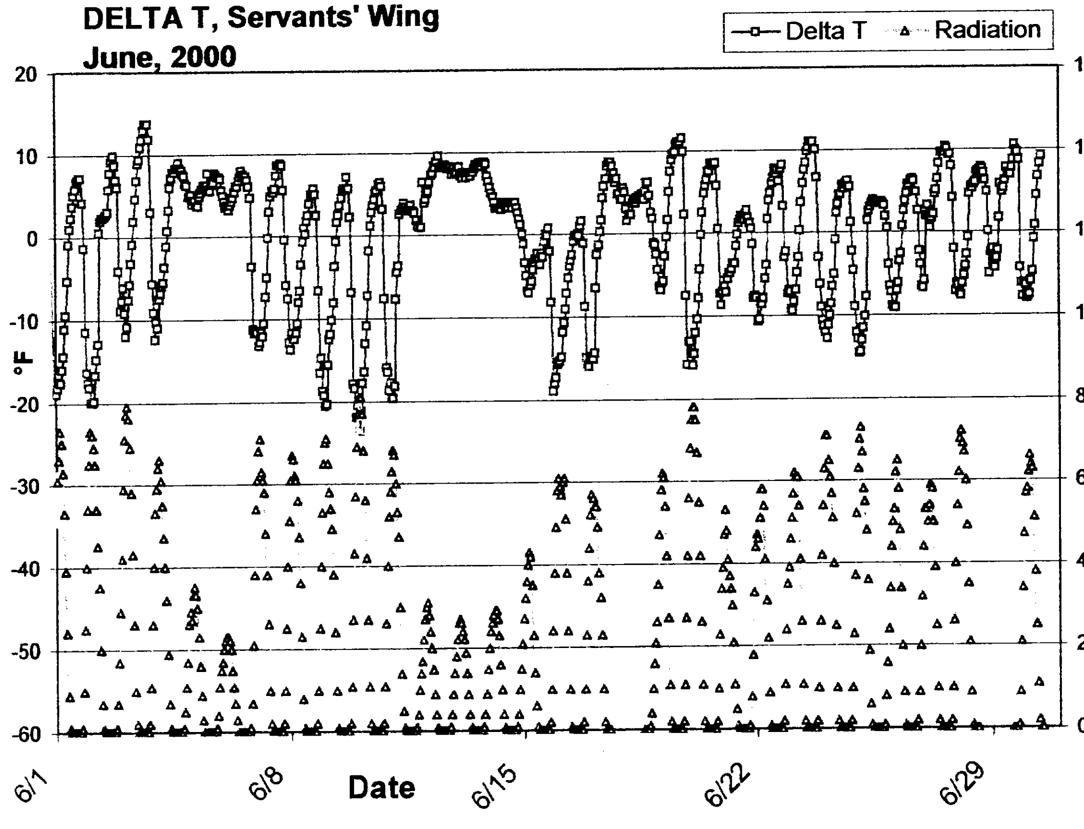


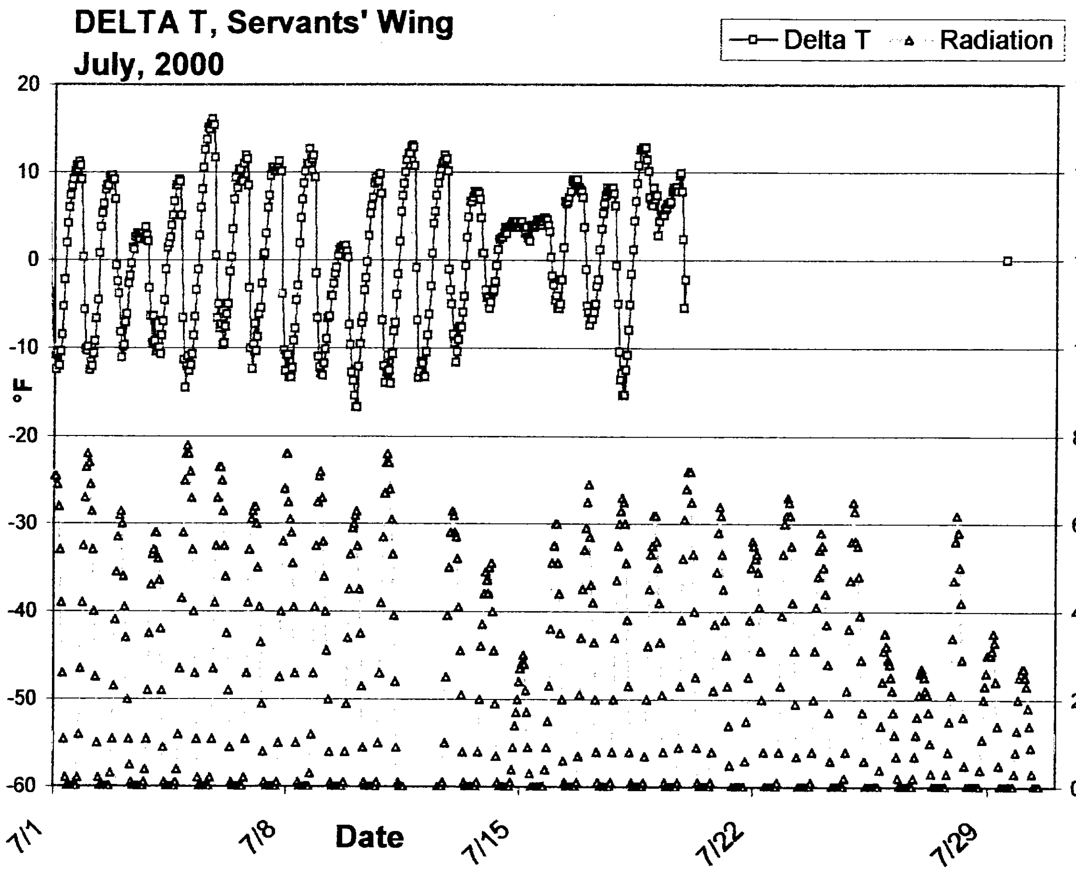

DELTA T Servants' Wing,
February, 2000
Delta T
Radiation
°F
langley
Date
30
20
10
0
-10
-20
-30
-40
-50
160
140
120
100
80
60
40
20
0
2/2
2/9
2/16
2/23
3/1

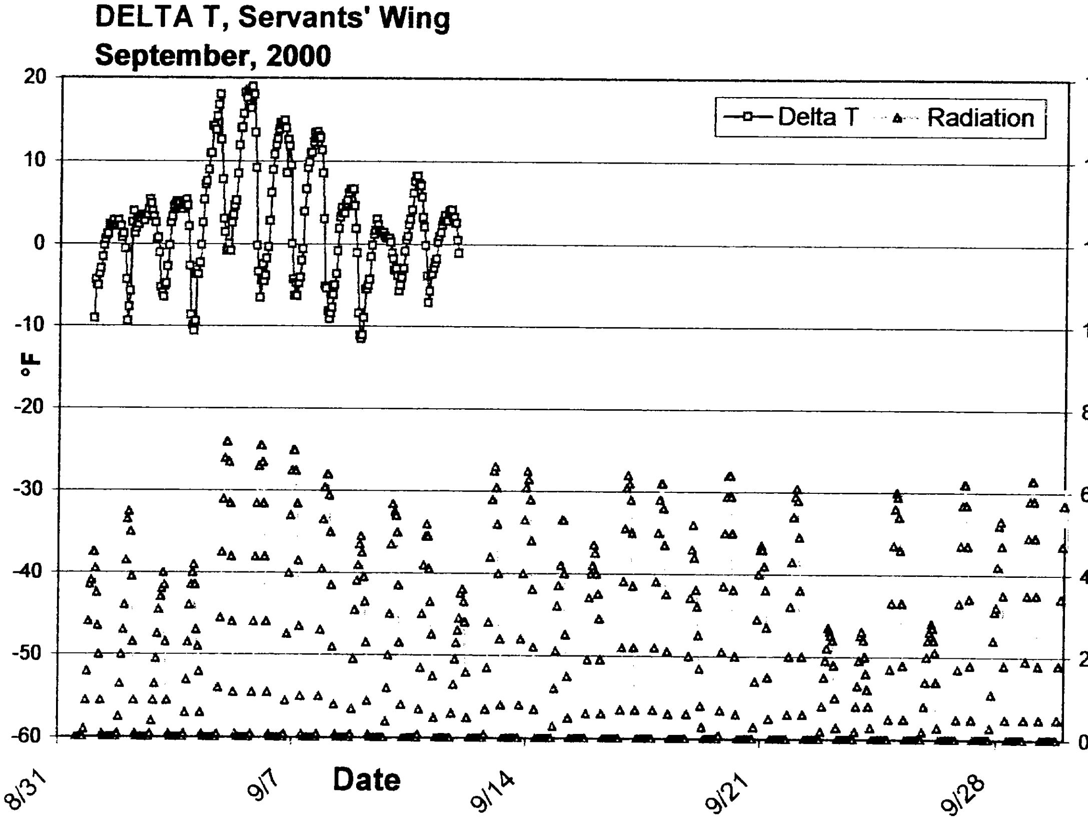

DELTA T, Servants' Wing
March, 2000
Delta T
Radiation
20
10
0
-10
-20
-30
-40
-50
-60
°F
160
140
120
100
80
60
40
20
0
2/29
3/7
3/14
Date
3/21
3/28

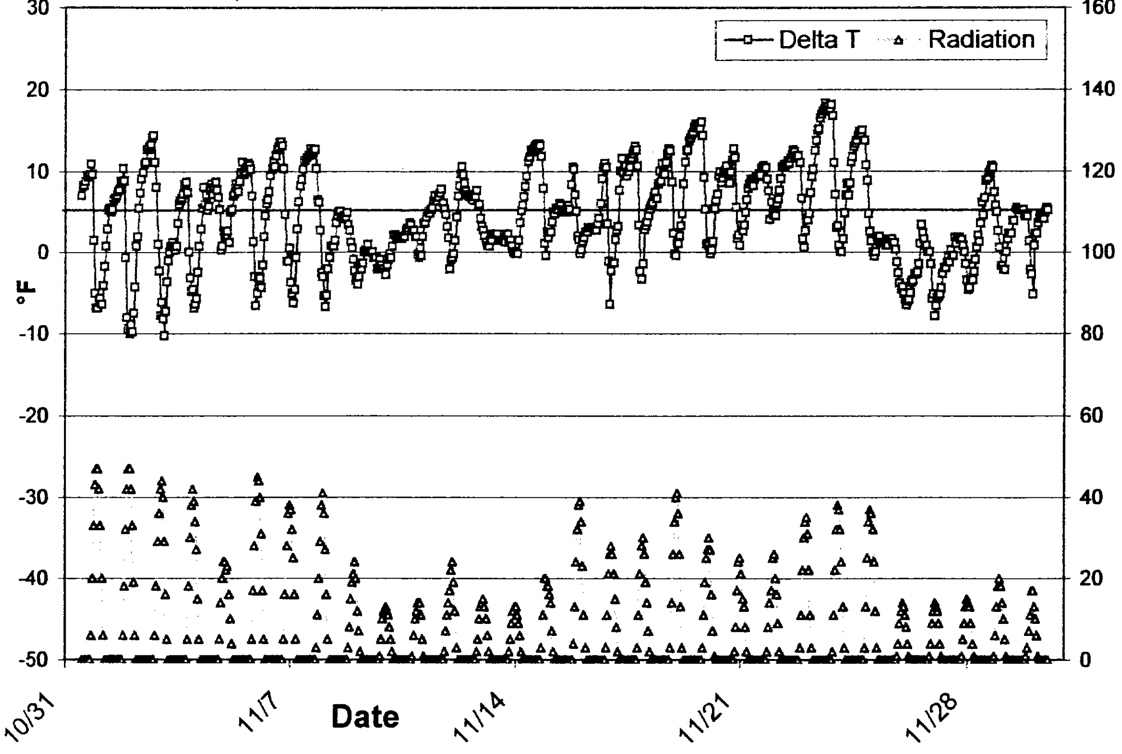

DELTA T, Servants' Wing
April, 2000
Delta T
Radiation
20
10
0
-10
-20
-30
-40
-50
-60
°F
160
140
120
100
80
60
40
20
0
4/1
4/8
Date
4/15
4/22
4/29


DELTA T, Servants' Wing
May, 2000
Delta T
Radiation
20
10
0
-10
-20
-30
-40
-50
-60
°F
160
140
120
100
80
60
40
20
0
4/30
5/7
Date
5/14
5/21
5/28

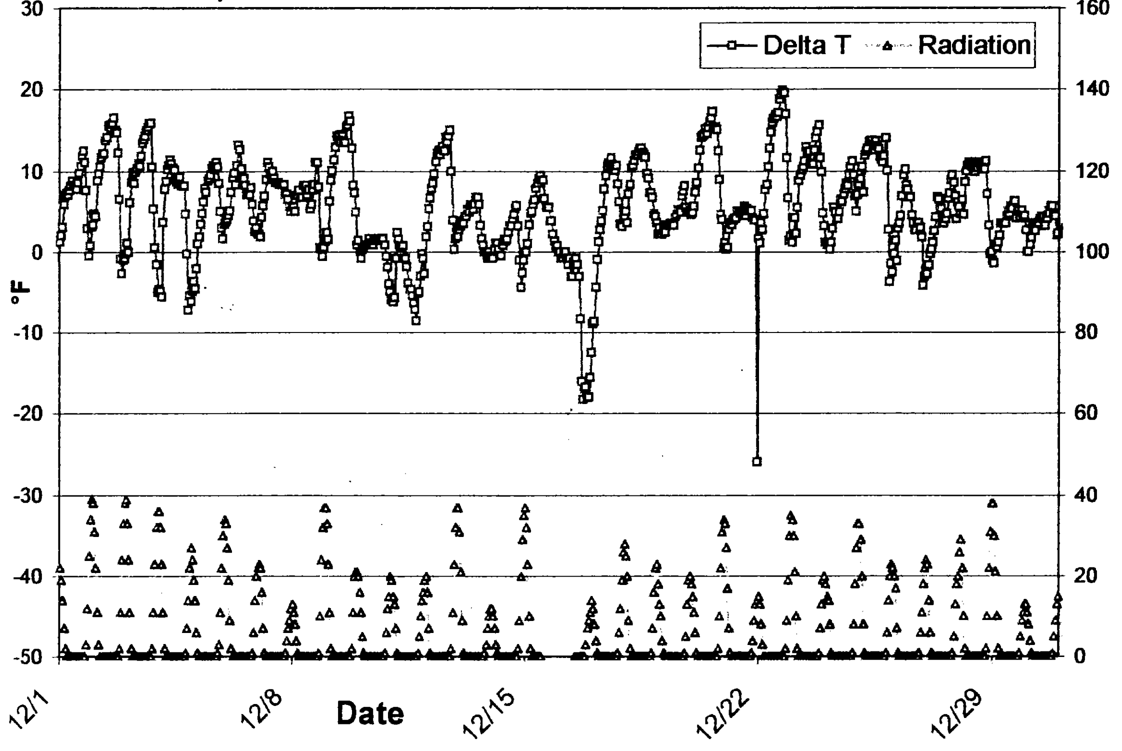

DELTA T, Servants' Wing
June, 2000
Delta T
Radiation
20
10
0
-10
-20
-30
-40
-50
-60
°F
160
140
120
100
80
60
40
20
0
6/1
6/8
Date
6/15
6/22
6/29


DELTA T, Servants' Wing
July, 2000
Delta T
Radiation
20
10
0
-10
-20
-30
-40
-50
-60
°F
160
140
120
100
80
60
40
20
0
7/1
7/8
Date
7/15
7/22
7/29


DELTA T, Servants' Wing
September, 2000
Delta T
Radiation
20
10
0
-10
-20
-30
-40
-50
-60
°F
160
140
120
100
80
60
40
20
0
8/31
9/7
Date
9/14
9/21
9/28



DELTA T, Servants' Wing
November, 2000

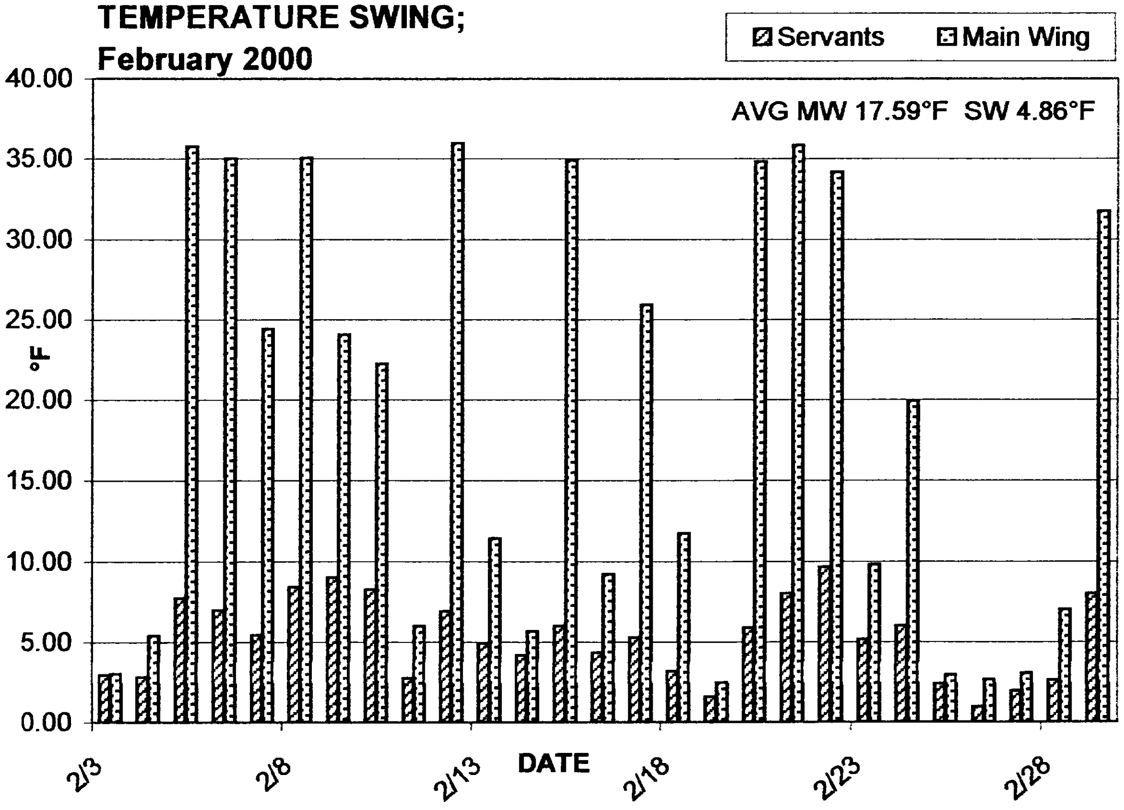


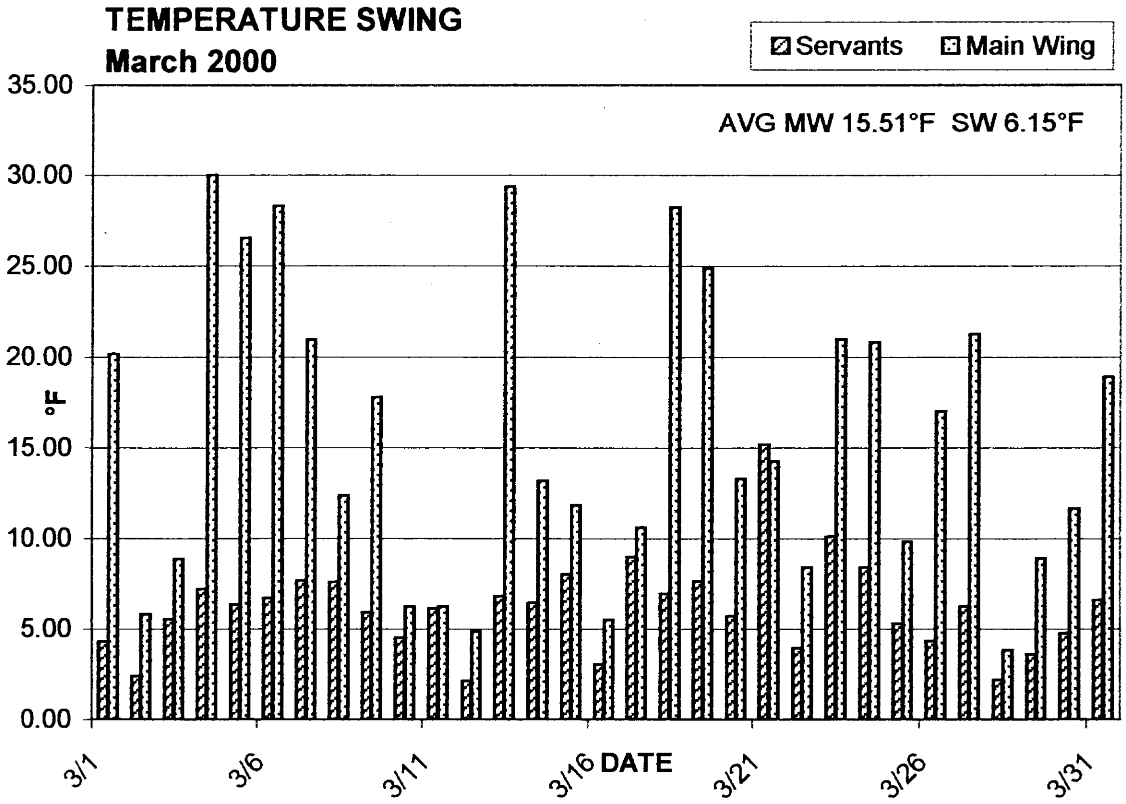
DELTA T, Servants' Wing
December, 2000

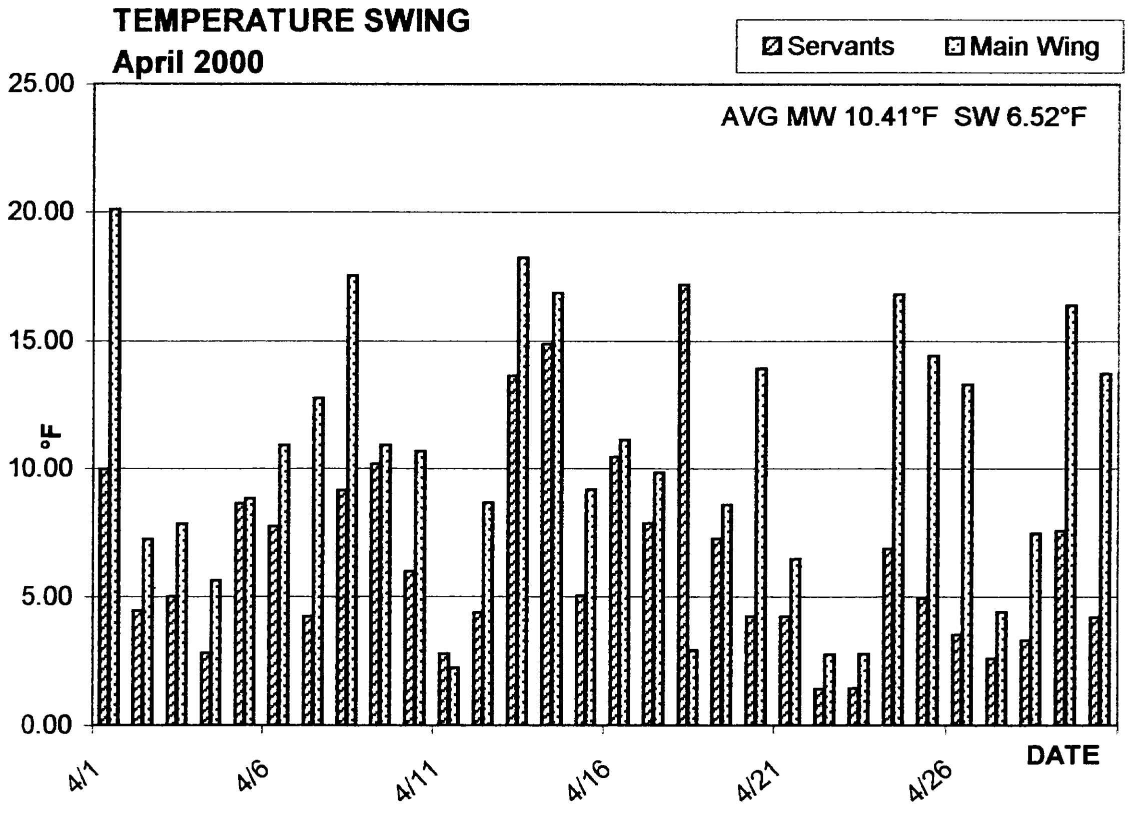
# Figure A5 - TEMPERATURE SWING GRAPHS

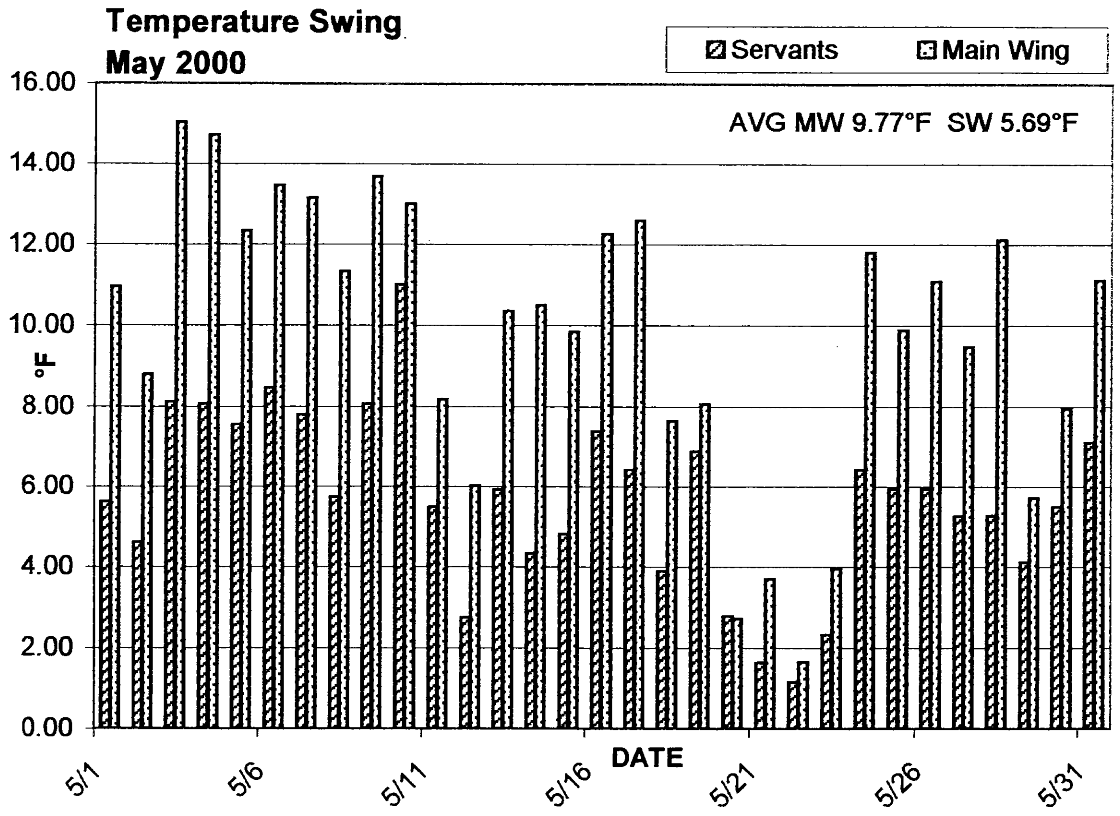
TEMP SWING graphs show daily difference between lowest and highest average interior temperature in both wings. Temperature swings are significantly greater in the solar Main Wing. The 35 °F difference over twenty-four hours was observed several times in winter months and 25°F swings were seen frequently from September 2000 on. Temperature swing is an important human comfort indicator. Builders Guide and other sources consider 13°F the maximum acceptable range.

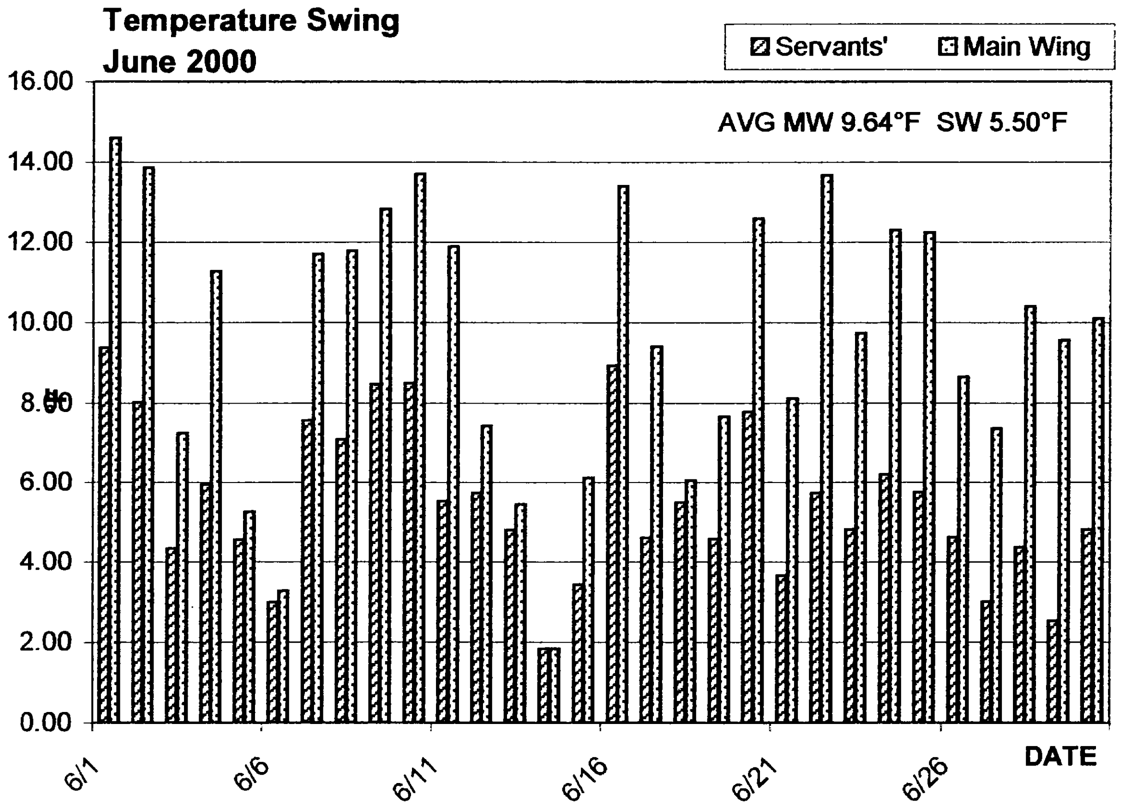
Units and abbreviations:
Temperatures - degrees Fahrenheit
AVG MW - average temperature swing for the month in Main Wing
AVG SW - average temperature swing for the month in Servants Wing

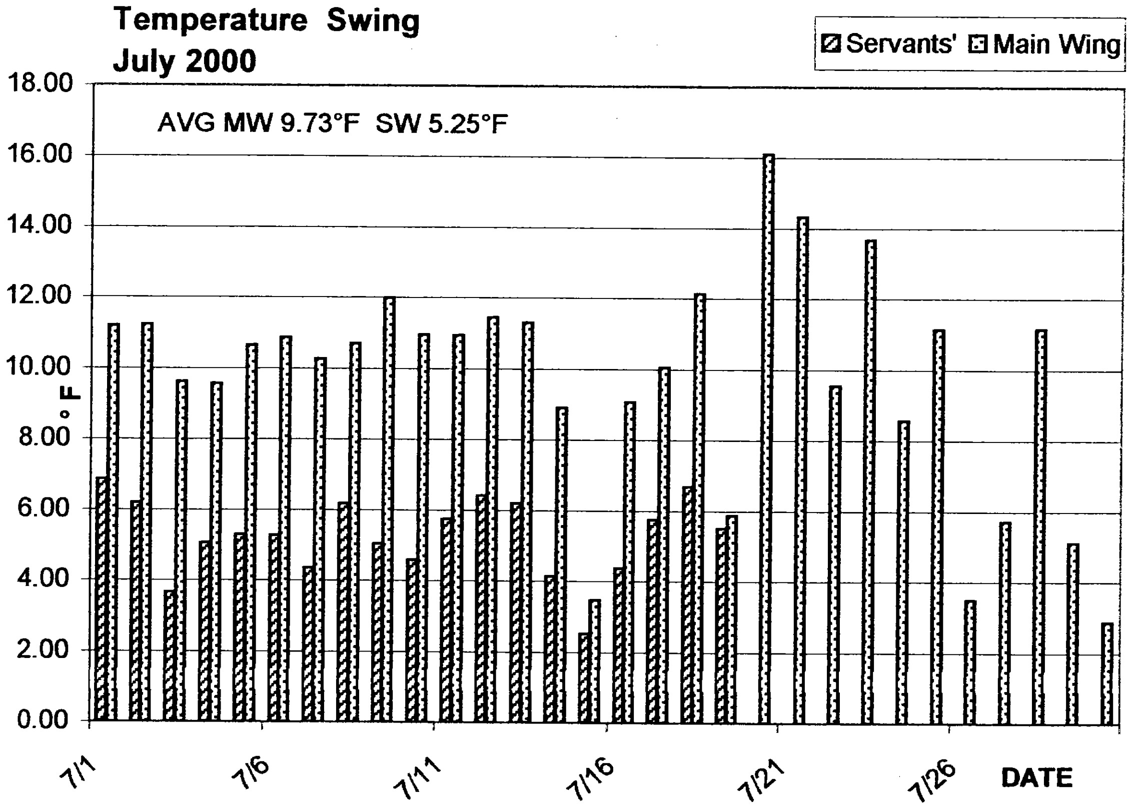


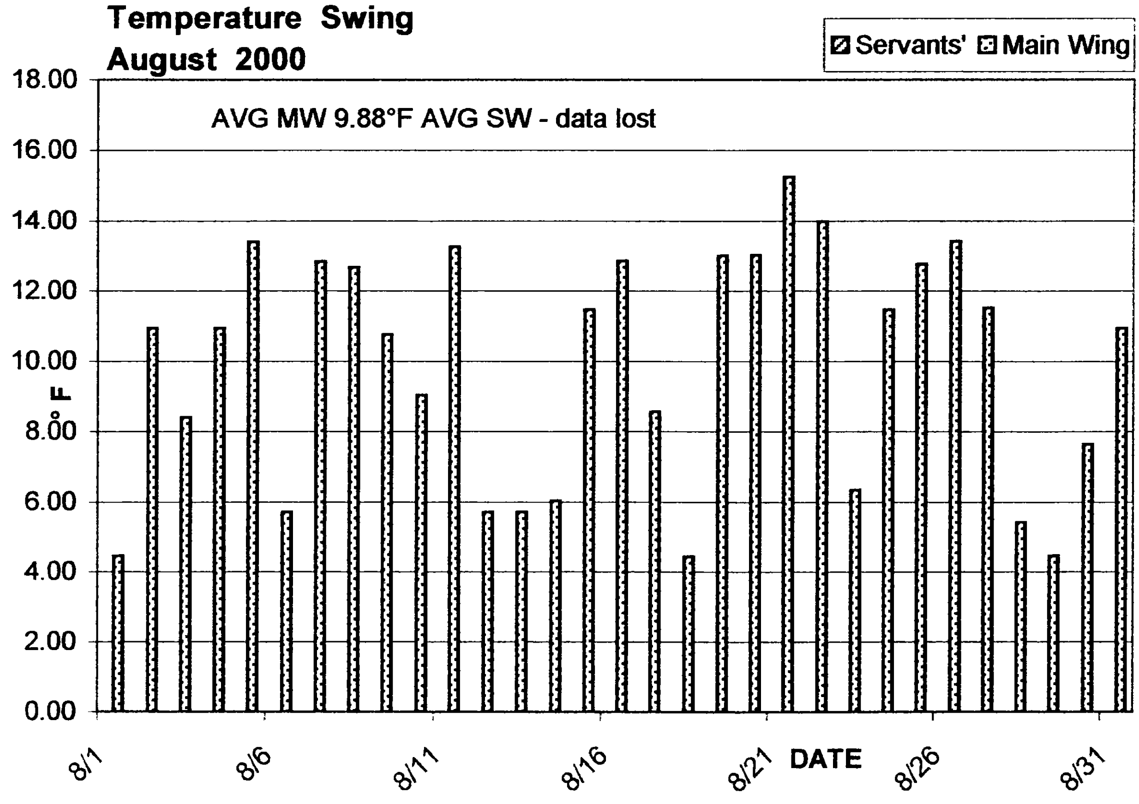

TEMPERATURE SWING
March 2000
▨ Servants
▨ Main Wing
AVG MW 15.51°F SW 6.15°F
°F
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
3/1
3/6
3/11
3/16
DATE
3/21
3/26
3/31

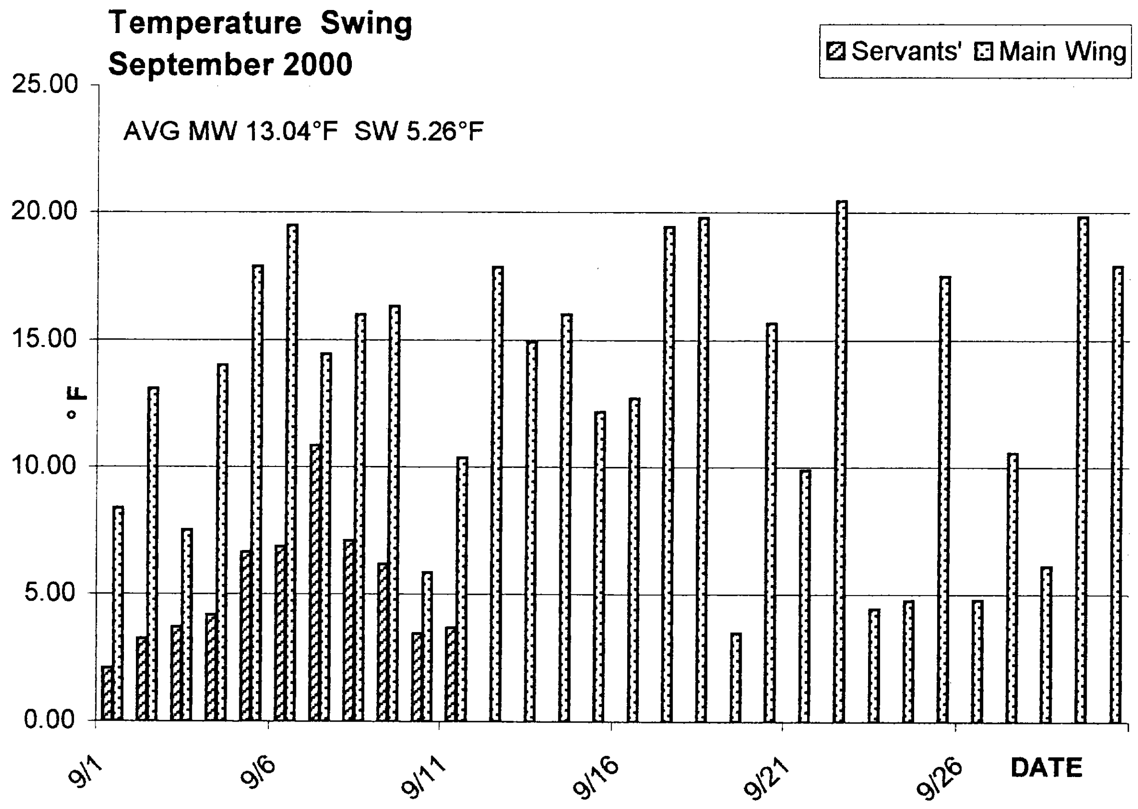

TEMPERATURE SWING
April 2000
▨ Servants
▨ Main Wing
AVG MW 10.41°F SW 6.52°F
°F
25.00
20.00
15.00
10.00
5.00
0.00
4/1
4/6
4/11
4/16
4/21
4/26
DATE

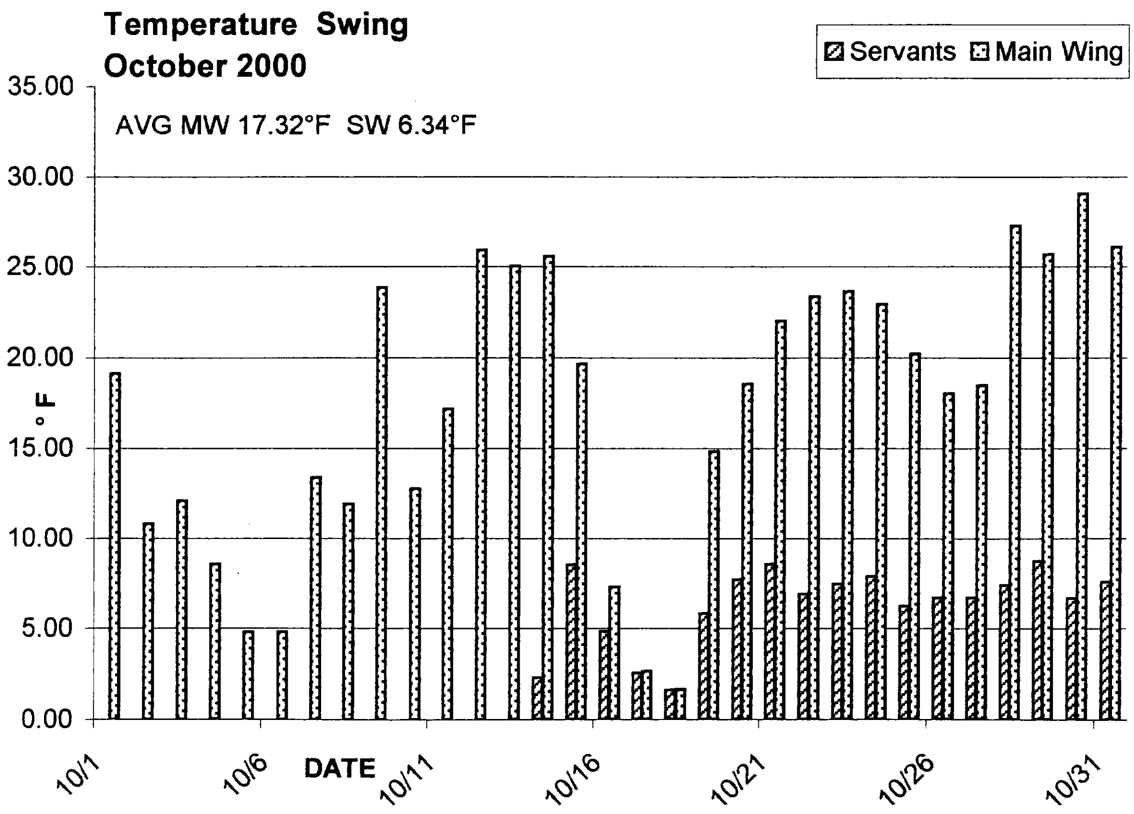

Temperature Swing
May 2000
▨ Servants
▨ Main Wing
AVG MW 9.77°F SW 5.69°F
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
°F
DATE
5/1
5/6
5/11
5/16
5/21
5/26
5/31

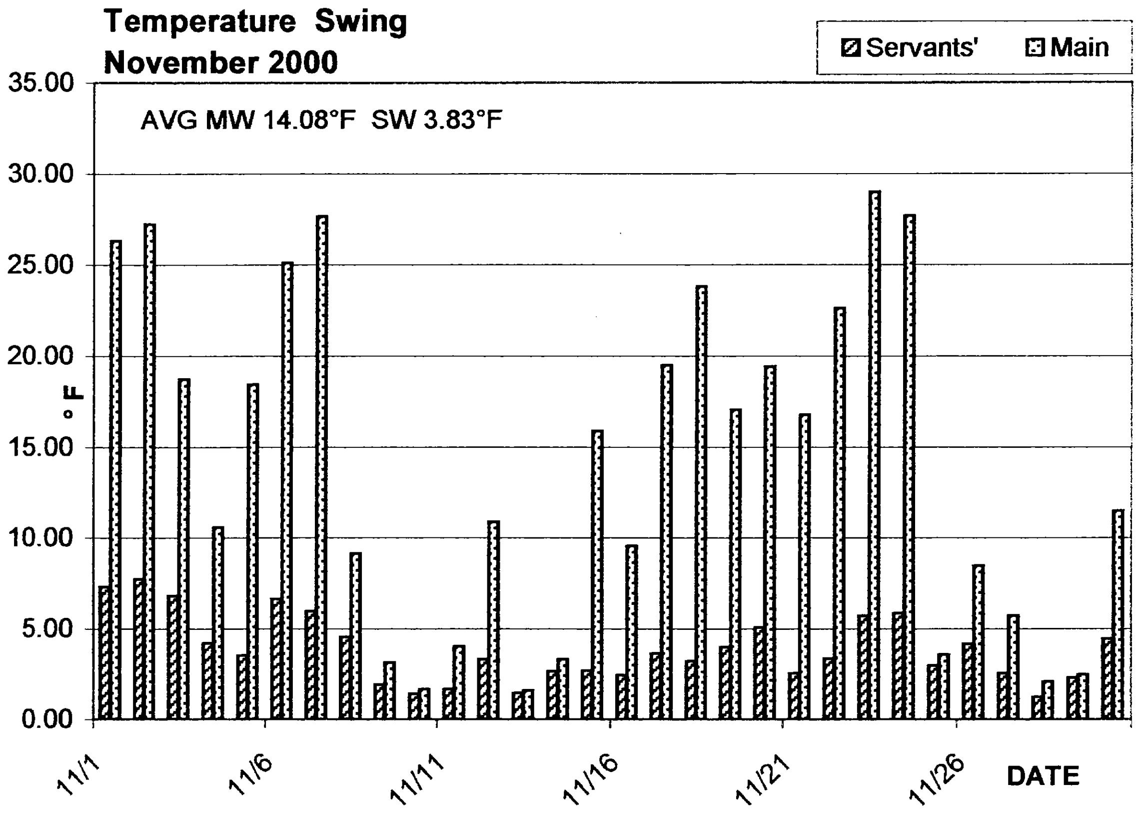

Temperature Swing
June 2000
▨ Servants'
▨ Main Wing
AVG MW 9.64°F SW 5.50°F
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
DATE
6/1
6/6
6/11
6/16
6/21
6/26

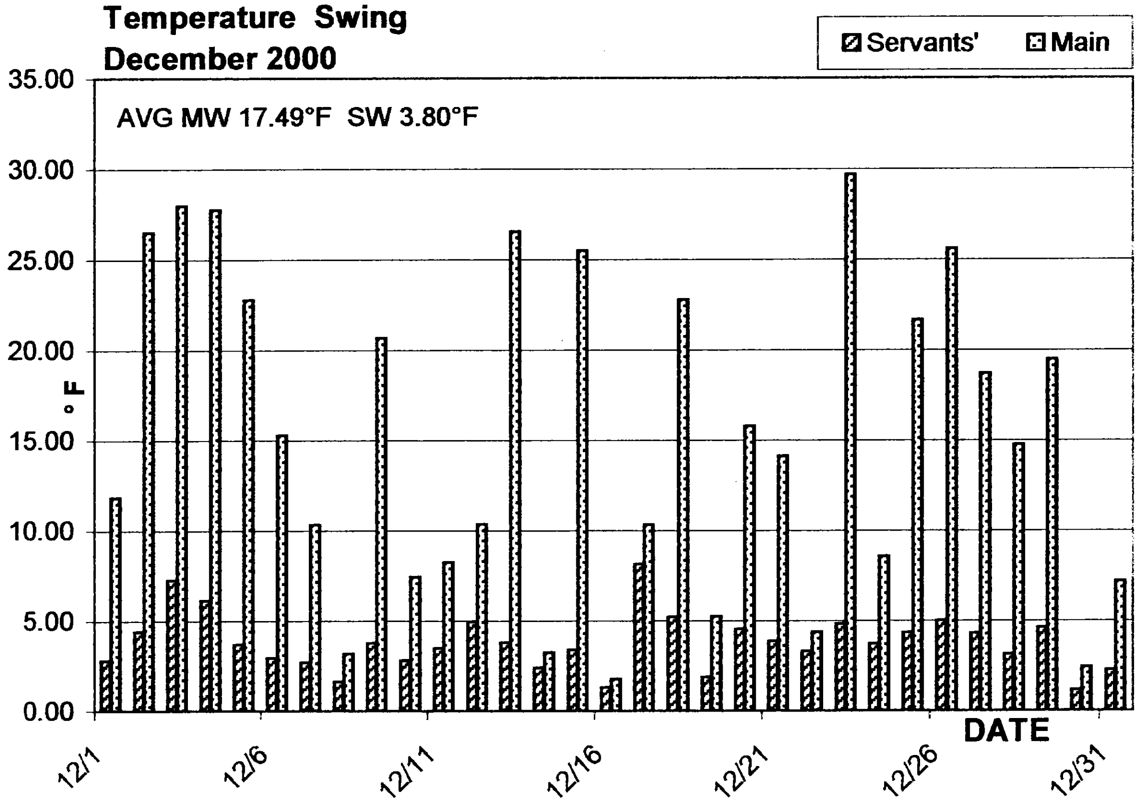

Temperature Swing
July 2000
▨ Servants' ▩ Main Wing
AVG MW 9.73°F SW 5.25°F
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
° F
7/1
7/6
7/11
7/16
7/21
7/26
DATE


Temperature Swing
August 2000
▨ Servants' ▩ Main Wing
AVG MW 9.88°F AVG SW - data lost
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
° F
8/1
8/6
8/11
8/16
8/21
DATE
8/26
8/31


Temperature Swing
September 2000
▨ Servants' ▨ Main Wing
AVG MW 13.04°F SW 5.26°F
25.00
20.00
15.00
10.00
5.00
0.00
° F
9/1
9/6
9/11
9/16
9/21
9/26
DATE

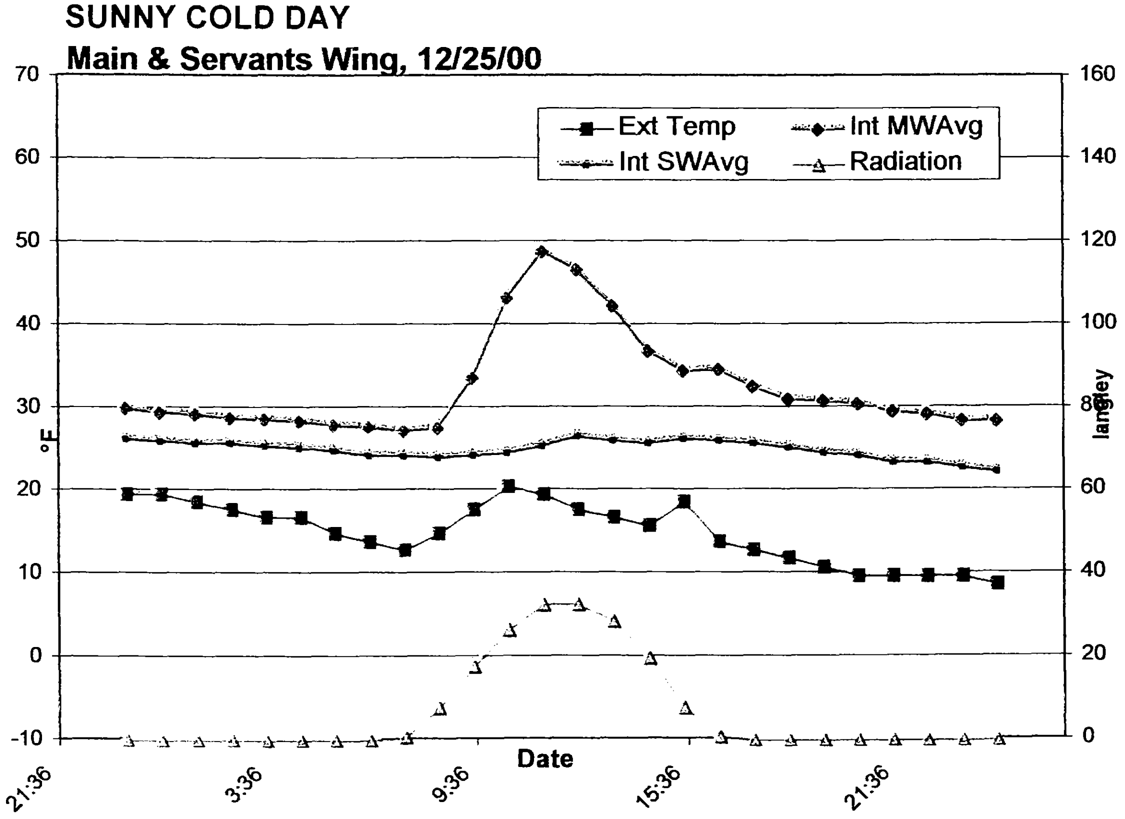

Temperature Swing
October 2000
▨ Servants ▨ Main Wing
AVG MW 17.32°F SW 6.34°F
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
° F
10/1
10/6
DATE
10/11
10/16
10/21
10/26
10/31

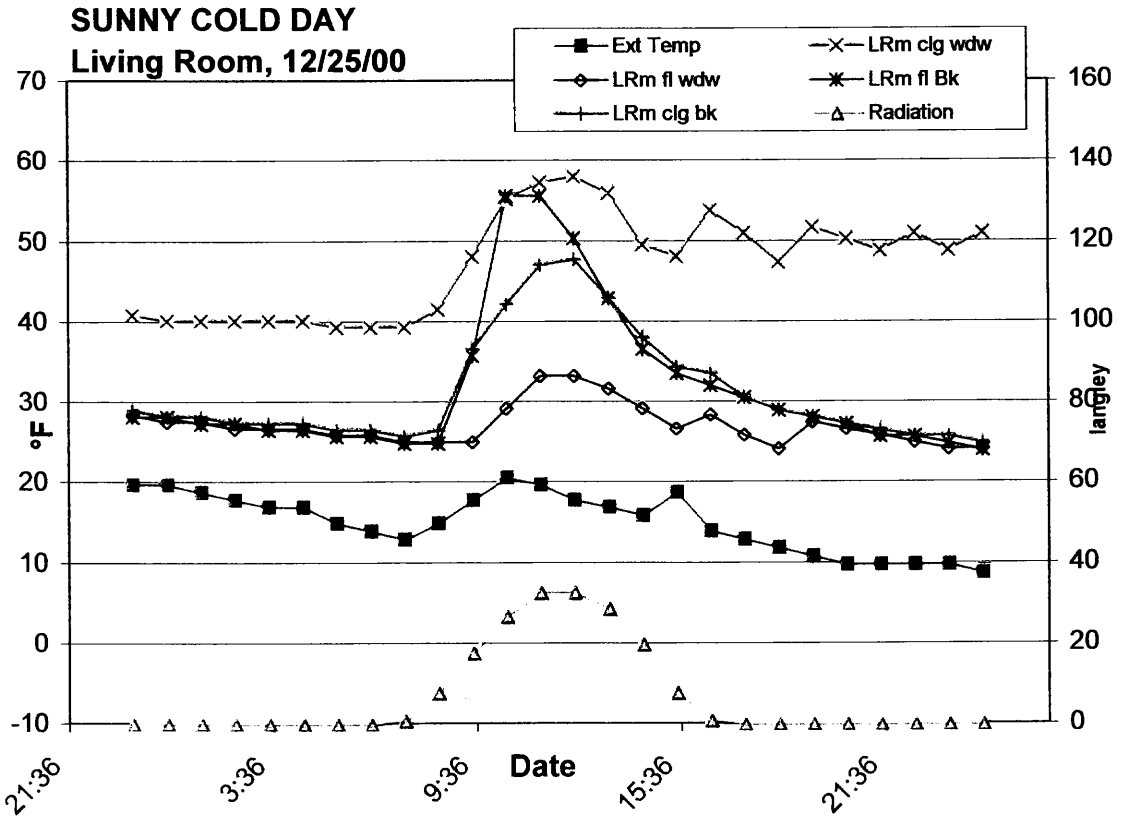

Temperature Swing
November 2000
▨ Servants'
▨ Main
AVG MW 14.08°F SW 3.83°F
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
° F
11/1
11/6
11/11
11/16
11/21
11/26
DATE

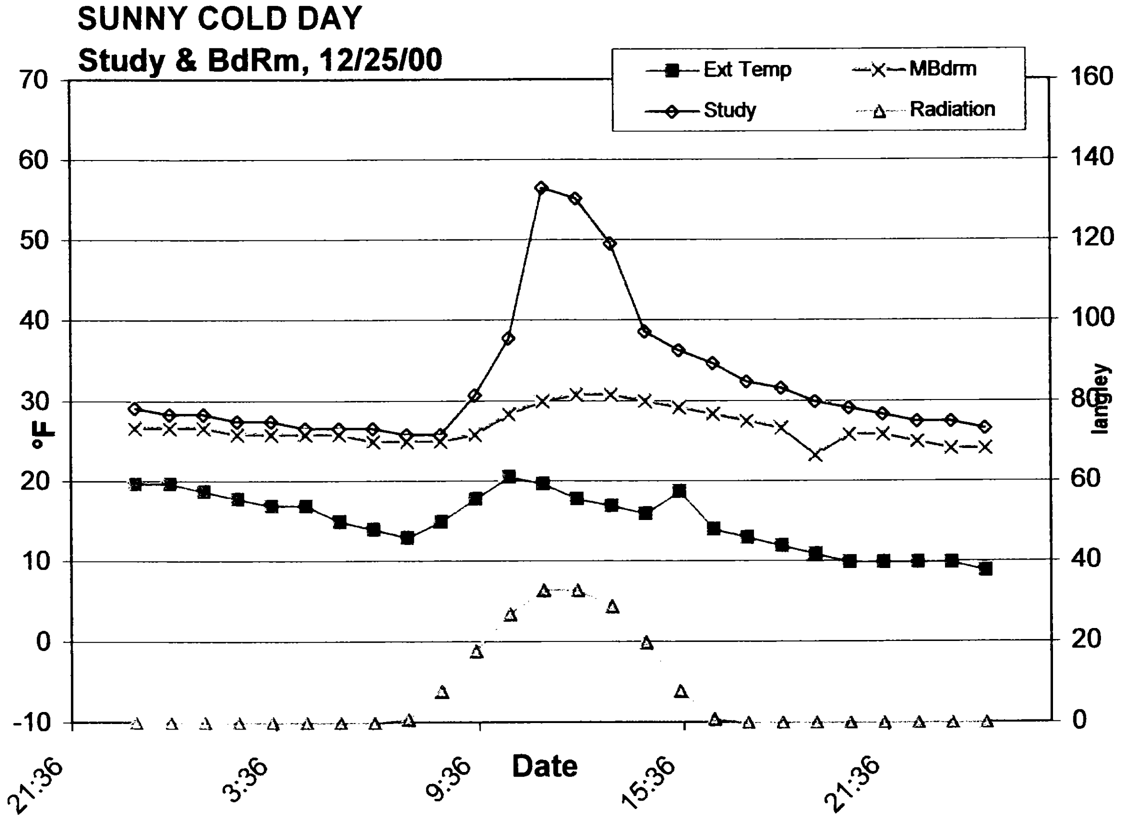

Temperature Swing
December 2000
▨ Servants'
▨ Main
AVG MW 17.49°F SW 3.80°F
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
° F
12/1
12/6
12/11
12/16
12/21
12/26
12/31
DATE

## Figure A6 – SUNNY WINTER DAY

These three graphs document temperature changes in the house on a representative sunny, cold winter day near winter solstice. Main & SVTS Wing graph compares average temperatures in the two wings. Living Room graph records interior temperatures recorded by probes placed high and low in the two story high primary Direct Gain (Living Room) space. See Fig. 2.8 Study and Bdroom graph records temperatures in those two rooms. Interior temperatures are overlaid with sun radiation and exterior temperature measured on site.

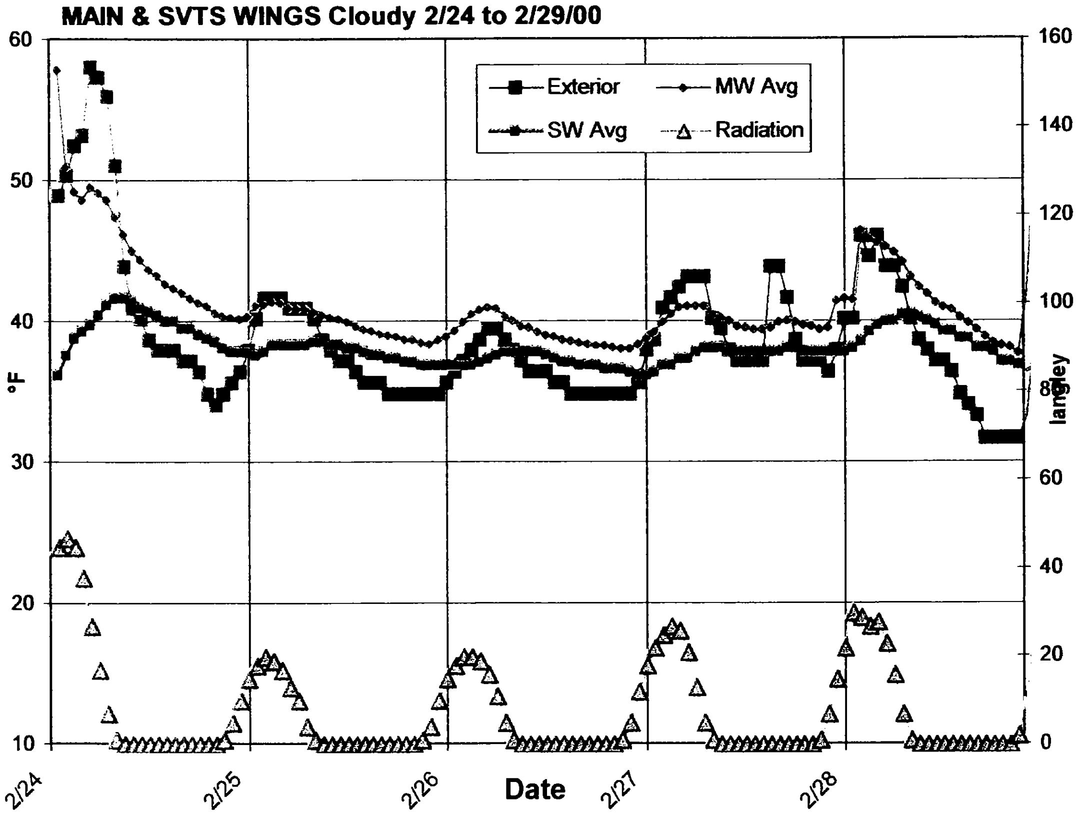


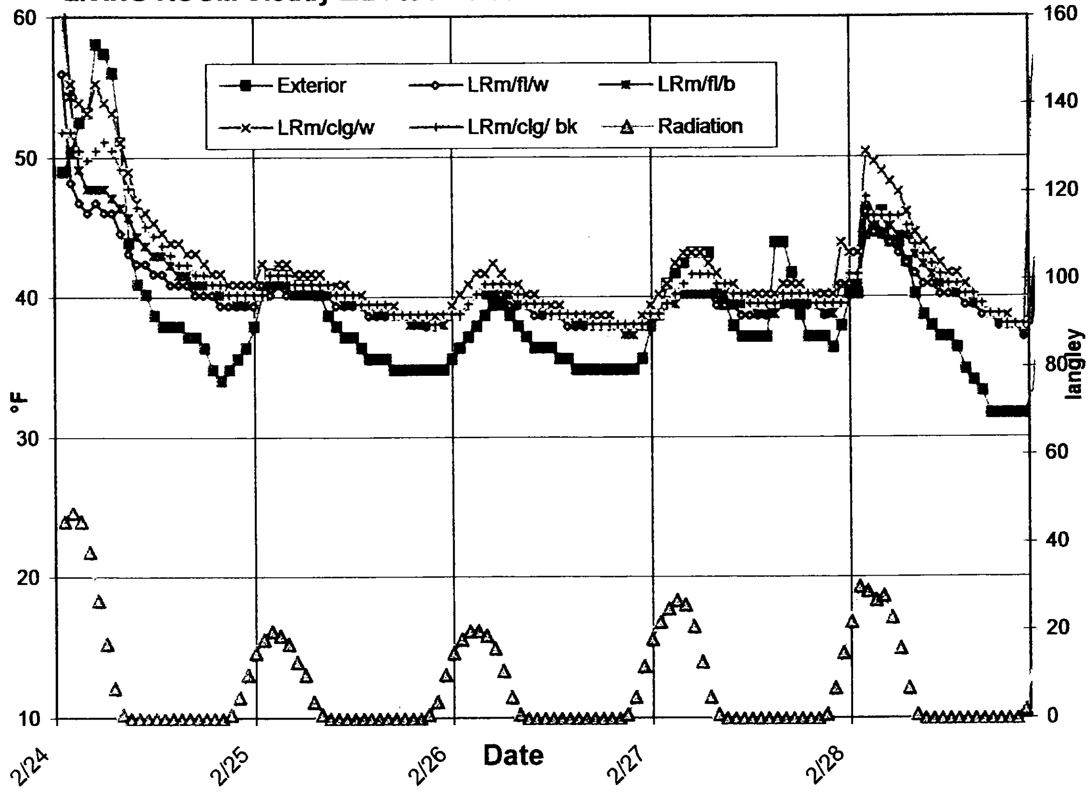

SUNNY COLD DAY
Living Room, 12/25/00
Ext Temp
LRm clg wdw
LRm fl wdw
LRm fl Bk
LRm clg bk
Radiation
°F
70
60
50
40
30
20
10
0
-10
langley
160
140
120
100
80
60
40
20
0
Date
21:36
3:36
9:36
15:36
21:36

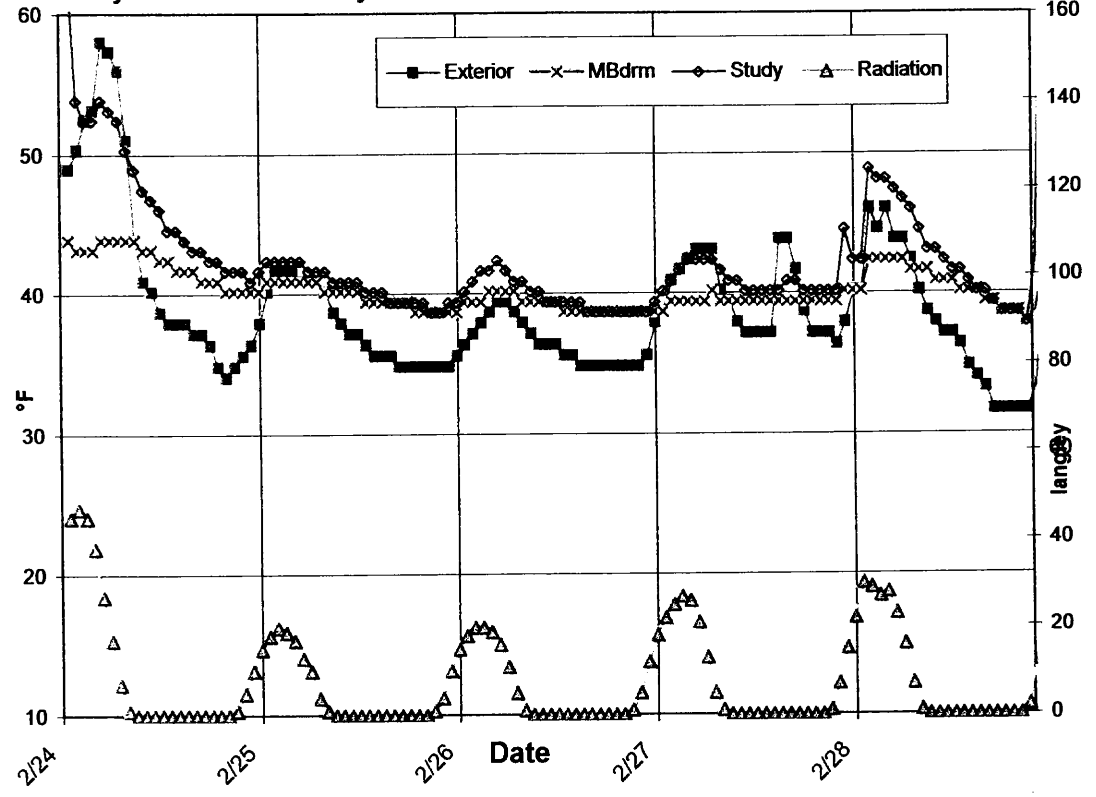

SUNNY COLD DAY
Study & BdRm, 12/25/00
Ext Temp
MBdrm
Study
Radiation
°F
70
60
50
40
30
20
10
0
-10
langley
160
140
120
100
80
60
40
20
0
Date
21:36
3:36
9:36
15:36
21:36

## Figure A7 – CLOUDY WINTER DAYS

These three graphs document temperature changes in the house over several cloudy, cold winter days. Main & SVTS Wing graph compares average temperatures in the two wings. Living Room graph records interior temperatures recorded by probes placed high and low in the two story high primary Direct Gain space. Interior temperatures are overlaid with sun radiation and exterior temperature measured on site.

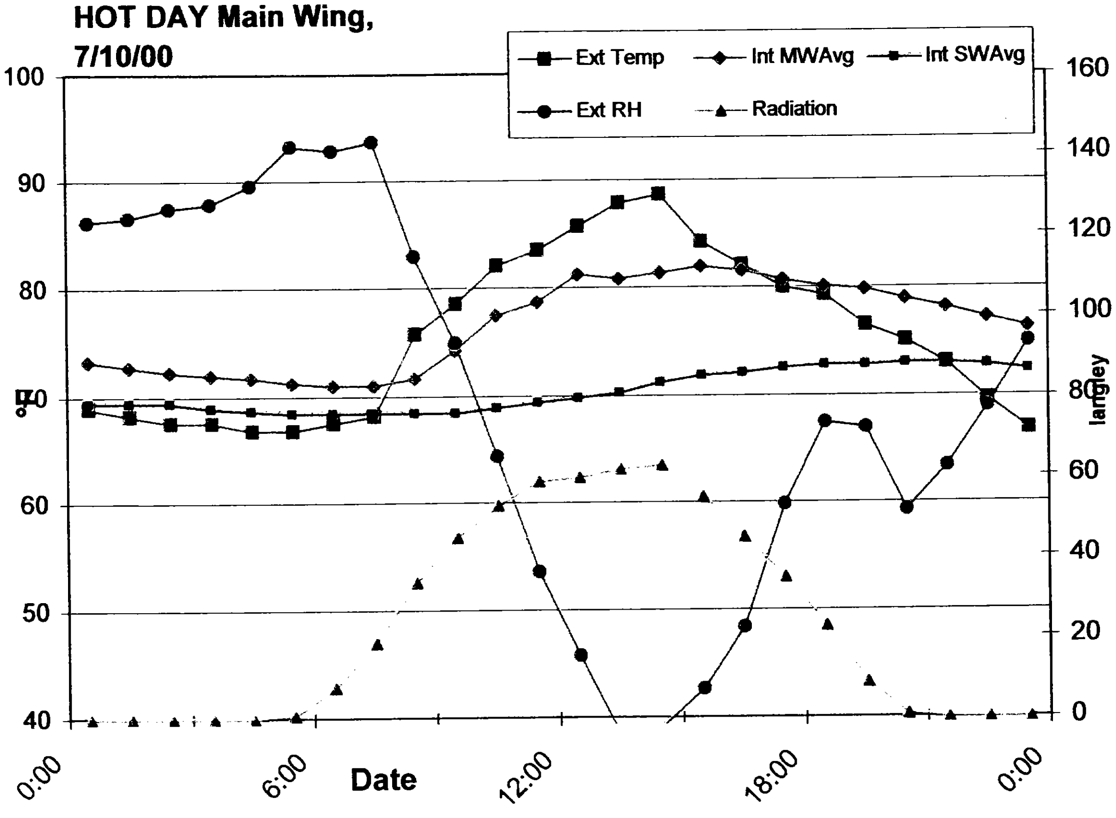


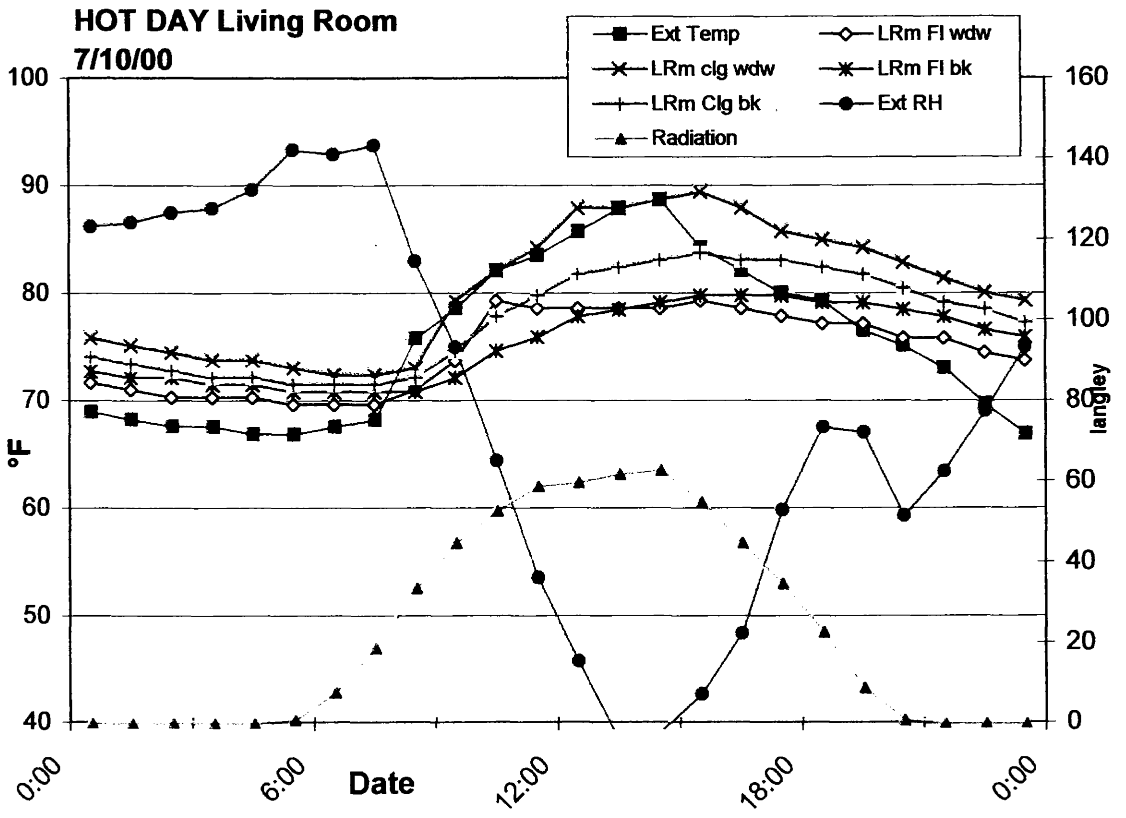

LIVING ROOM Cloudy 2/24 to 2/29/00

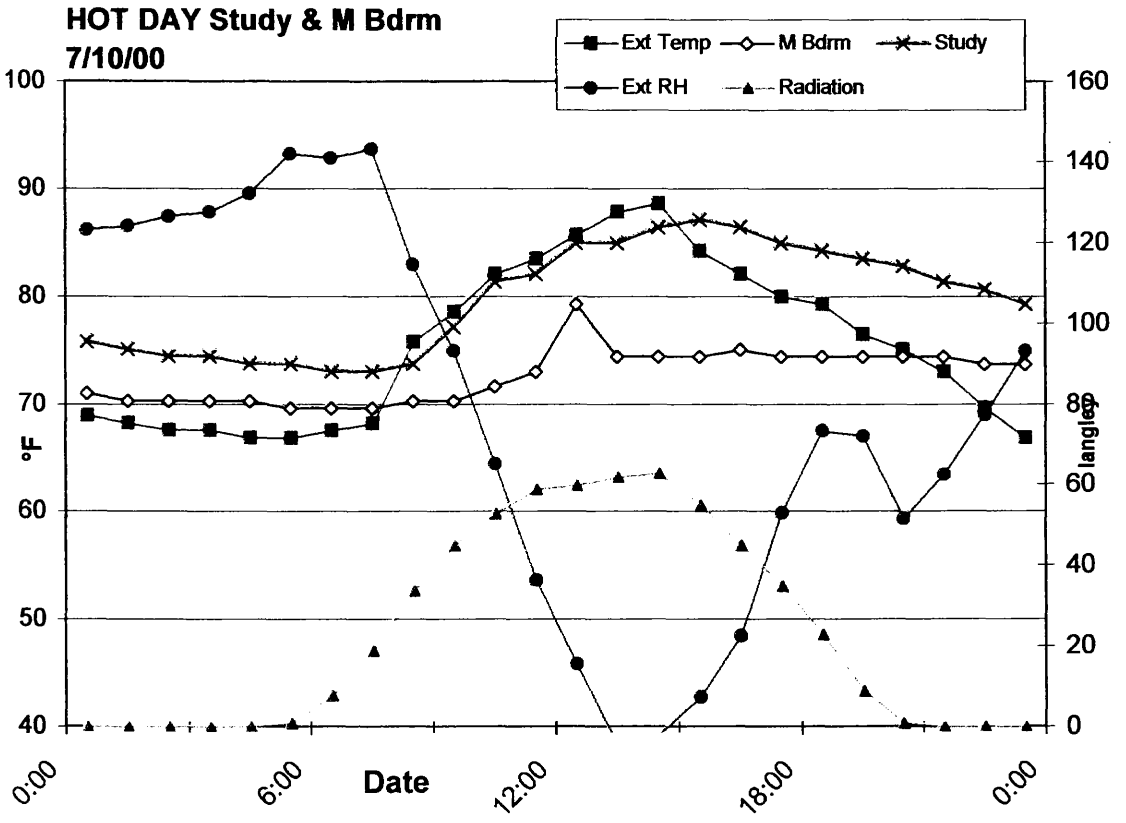

Study & Bedroom Cloudy 2/24 to 2/29/00

## Figure A8 – HOT DAY

These three graphs document temperature changes in the house on a selected hot, humid summer day. Main & SVTS Wing graph compares average temperatures in the two wings. Living Room graph records interior temperatures recorded by probes placed high and low in the two story high primary Direct Gain space. Study and Bdroom graph records temperatures in those two rooms. Interior temperatures are overlaid with sun radiation, and exterior temperature and relative humidity on site.




HOT DAY Living Room 7/10/00


HOT DAY Study & M Bdrm 7/10/00

# APPENDIX B

*Passive Solar Design Strategies: Guidelines for Home Builders* (*Builders Guide*) is a design tool for builders, intended to assist them in incorporating solar design in their residential buildings. It is based on research sponsored by the United States Department of Energy (US DOE) Solar Buildings Program. *Builders Guide* contains written guidelines explaining passive solar design strategies and a set of four worksheets for calculation of a building's thermal performance levels. The accompanying software duplicates the original manual calculation process. Formulas and tables are conveniently embedded in the program.

BGuide software allows for reiterative calculations, changing one or more design parameters at a time. The Base Case is calculated for a house of the same floor area and represents a typical house for the given climate zone. Such a typical house has no solar features, windows equal to 3% of floor area and insulation typical of current practice as surveyed in 1987 by National Association of Home Builders.

For the purpose of these simulations the Ramirez House was divided into two wings, Main and Servants. Each wing was treated as a separate building. The Base Case was calculated. The Original Design was then entered and compared to the Base Case. Next, proposed improvements were calculated and compared to the original design that became the Reference Case. The first set of improvements included improved insulation and windows. In the next simulation, thermal storage was added to the already improved house. Appendix B includes summaries and worksheets for the simulations for the Main Wing and summaries for the Servants Wing. Weather data for Allentown, PA was used.

```
+--------------------------------------------------------+
| BuilderGuide House Analysis                            |
|                                                        |
|                                                        |
| BuilderGuide, Version 1.0, April 1990                  |
|                                                        |
| Developed by the Solar Energy Research Institute       |
+--------------------------------------------------------+


General Project Information
+--------------------------------------------------------------------------+
| Project Name:Ramirez House; Main Wing          Floor Area:2570           |
|                                                                          |
| Site:        Delaware Water Gap, PA            Date:      5/1/2000       |
|                                                                          |
| Designer:    Henry N Wright                    Location:  Allentown      |
|                                                                          |
| Comment:      Main Wing; Original Design                                 |
+--------------------------------------------------------------------------+


                          +--------------------+
                          |      Summary       |
                          +--------------------+
 ----------------------------------------------------------------------------+
                          Current Case    Reference Case    % Difference     |
+----------------------------------------------------------------------------+
| Conservation Perf.      78940           40874             93.13            |
|       [ Btu/yr-sf ]                                                        |
| Aux. Heat Perf.         69625           38953             78.74            |
|       [ Btu/yr-sf ]                                                        |
| Temp. Swing             28.2            8.8               220.45           |
|       [ degrees F ]                                                        |
| Cooling Perf.           17199           6788              153.37           |
|       [ Btu/yr-sf ]                                                        |
+----------------------------------------------------------------------------+
```

**Figure B.1a** Main Wing, Original Design; Summary. Reference Case = Base Case

```
Worksheet I: Heat Loss (excluding solar aperture)

A. Envelope Heat Loss
       Construction Description          Area      R-Value     Heat Loss
+-----------------------------------------------------------------------------+
|Ceilings/Roofs cathedral ceiling       739       / 10        = 73.9           |
|                                                                              |
|               ceiling w/ attic        2100      / 10        = 210.0          |
+---------------------                                                        |
|Walls          stud walls             1539      / 10        = 153.9          |
|                                                                              |
|               stone covd wall        150       / 12        = 12.5           |
+---------------------                                                        |
|Insulated                                       /           = 0.0            |
|  Floors                                                                      |
|                                                /           = 0.0            |
+---------------------                                                        |
|Non-Solar    (Total Rough Frame       432.0     / 1.8       = 240.0          |
|  Glass       Area from Worksheet IV)                                         |
+---------------------                                                        |
|Doors          Doors                  40        / 2.2       = 18.2           |
|                                                                              |
|                                                /           = 0.0            |
+-----------------------------------------------------------------------------+
                                            Subtotal  708.5
                                                         Btu/deg F-h
B. Foundation Perimeter Heat Loss
                                                       Heat Loss
             Description                Perimeter       Factor     Heat Loss
+-----------------------------------------------------------------------------+
|Slab-on-grade                                    x           = 0.0            |
|                                                                              |
|Heated                                                                        |
| Basement                                        x           = 0.0            |
|                                                                              |
|Unheated                                                                      |
| Basement                                        x           = 0.0            |
|                                                                              |
|Perimeter Ins.                                                                |
| Crawlspace    Uninsulated space      199        x 1.1       = 218.9          |
+-----------------------------------------------------------------------------+
                                             Subtotal 218.9
                                                         Btu/deg F-h
C. Infiltration Heat Loss
+-----------------------------------------------------------------------------+
|                        Building     Air Changes    Air Heat                  |
|                         Volume       per Hour      Capacity                  |
|                        31300        x 0.67       x  0.018     = 377.5        |
|                                                                Btu/deg F-h  |
+-----------------------------------------------------------------------------+

D. Total Heat Loss per Square Foot
+-----------------------------------------------------------------------------+
|                                                                              |
|               24      X      1304.9        /   2570          =  12.186       |
|                           Total Heat Loss     Floor Area          Btu/DD-sf   |
|                                (A+B+C)                                        |
+-----------------------------------------------------------------------------+

E. Annual Heat Loss (excluding solar aperture)
|                 12.186       X  5815        X  1.114       =  78940          |
|                  Total Heat     Heating         Heating          Btu/yr-sf    |
|                   Loss per    Degree Days    Degree Day                      |
|                  Square Foot                 Multiplier                      |
+-----------------------------------------------------------------------------+

F. Comparison Heat Loss
+-----------------------------------------------------------------------------+
|                                                                              |
|     (From Previous Calculation or from Table D)               40874          |
|                                                                 Btu/yr-sf    |
|                                                                              |
|                                  Compare Line E to Line F                    |
+-----------------------------------------------------------------------------+
-- End of Worksheet I --
```

**Figure B.1b** Main Wing, Original Design; Worksheet I, Heat Loss

```
Worksheet II: Auxiliary Heat

A. Projected Area of Passive Solar Glazing
+----------------------------------------------------------------------------+
|  Solar System      Rough Frame      Net Area     Adjustment      Projected |
| Reference Code      Area (sf)        Factor        Factor         Area (sf)|
+----------------------------------------------------------------------------+
| DGC1               664          X  0.8         X  .87         =  462.1     |
|                                                                            |
|                    0.0          X  0.8         X  1.0         =  0.0       |
|                                                                            |
|                    0.0          X  0.8         X  1.0         =  0.0       |
|                                                                            |
|                    0.0          X  0.8         X  1.0         =  0.0       |
|                                                                            |
|                    664.0                                         462.1     |
|                    Total Area                         Total Projected Area |
|                                                                            |
|                                 462.1         /  2570         =  0.180     |
|                                    Total           Floor          Total    |
|                                  Projected          Area         Projected |
|                                     Area                          Area per |
|                                                                 Square Foot|
+----------------------------------------------------------------------------+

 B. Load Collector Ratio
+----------------------------------------------------------------------------+
|                                                                            |
|               24   X    1304.9          /  462.1           =  68           |
|                            Total              Total                        |
|                          Heat Loss          Projected                      |
|                        [Worksheet 1]           Area                        |
+----------------------------------------------------------------------------+

 C. Solar Savings Fraction
+----------------------------------------------------------------------------+
| Solar System                     System                                    |
|  Reference       Projected    Solar Savings                                |
|    Code            Area         Fraction                                   |
+----------------------------------------------------------------------------+
|  DGC1           462.1       X  0.118       =  54.53                        |
|                                                                            |
|                 0.0         X              =  0.00                         |
|                                                                            |
|                 0.0         X              =  0.00                         |
|                                                                            |
|                 0.0         X              =  0.00                         |
|                                                                            |
|                                        Total  54.53                        |
|                                                                            |
|                                                / 462.1       = 0.118       |
|                                                    Total         Solar     |
|                                                  Projected      Savings    |
|                                                     Area        Fraction   |
|                                                                            |
+----------------------------------------------------------------------------+

 D. Annual Auxiliary Heat Required
+----------------------------------------------------------------------------+
|                [ 1 - 0.118      ]  X   78940       =  69625                |
|                        Solar          Conservation       Btu/yr-sf        |
|                       Savings          Performance                        |
|                       Fraction            Level                           |
|                                                                            |
+----------------------------------------------------------------------------+

 E. Comparative Auxiliary Heat
+----------------------------------------------------------------------------+
|                                                                            |
|    (From Previous Calculation or from Table G)        38953                |
|                                                          Btu/yr-sf        |
|                                                                            |
+----------------------------------------------------------------------------+
-- End of Worksheet II --
```

**Figure B.1c** Main Wing, Original Design; Worksheet II, Auxiliary Heat (heat from the sun)

```
Worksheet III: Thermal Mass / Comfort

  A. Heat Capacity of Sheetrock and Interior Furnishings
+-----------------------------------------------------------------------------+
|                                                 Unit Heat  Total Heat       |
|                                     Floor Area   Capacity   Capacity       |
+-----------------------------------------------------------------------------+
| Rooms with Direct Gain             1491        X   4.7  = 7008             |
|                                                                             |
| Spaces Connected to Direct Gain Spaces 859     X   4.5  = 3865             |
|                                                                             |
|                                                  Total    10873            |
|                                                            Btu/deg F       |
+-----------------------------------------------------------------------------+

  B. Heat Capacity of Mass Surfaces Enclosing Direct Gain Spaces
+-----------------------------------------------------------------------------+
|    Mass Description                          Unit Heat         Total Heat   |
|    (include thickness)           Area         Capacity          Capacity   |
+-----------------------------------------------------------------------------+
| Trombe Walls                             X      8.8       =  0             |
|                                                                             |
| Water Walls                              X     10.4       =  0             |
|                                                                             |
| Exposed Slab                             X     13.4       =  0             |
|    in Sun                                                                   |
| Exposed Slab                             X      1.8       =  0             |
|    not in Sun                                                               |
| Other Mass    Fireplace stone  164       X  3.4           =  558           |
|                                                                             |
| Other Mass    Wood floors      1491      X  .4            =  596           |
|                                                                             |
| Other Mass    Brick fpl 4"     190       X  6.5           =  1235          |
|                                                                             |
|                                                  Total      2389           |
|                                                              Btu/deg F     |
+-----------------------------------------------------------------------------+

 C. Heat Capacity of Mass Surfaces
            Enclosing Spaces Connected to Direct Gain Spaces
+-----------------------------------------------------------------------------+
|     Mass Description                          Unit Heat        Total Heat   |
|     (include thickness)          Area          Capacity         Capacity   |
+-----------------------------------------------------------------------------+
| Trombe Walls                             X      3.8       =  0             |
|                                                                             |
| Water Walls                              X      4.2       =  0             |
|                                                                             |
| Other Mass   Wood Floors      795        X  .4            =  318           |
|                                                                             |
| Other Mass                               X                =  0             |
|                                                                             |
| Other Mass                               X                =  0             |
|                                                                             |
|                                                  Total      318            |
|                                                              Btu/deg F     |
+-----------------------------------------------------------------------------+

+-----------------------------------------------------------------------------+
| D. Total Heat Capacity                     (A + B + C)       13580          |
|                                                              Btu/deg F     |
+-----------------------------------------------------------------------------+

  E. Total Heat Capacity per Square Foot
+-----------------------------------------------------------------------------+
|                                                                             |
|                               13580         /  2570          =  5.3        |
|                                Total Heat      Conditioned      Btu/deg F  |
|                                 Capacity        Floor Area        per sf   |
+-----------------------------------------------------------------------------+

  F. Clear Winter Day Temperature Swing
+-----------------------------------------------------------------------------+
|                                                                             |
|                          Total          Comfort                            |
|                      Projected Area      Factor                            |
|                      (Worksheet II)     (Table I)                          |
+-----------------------------------------------------------------------------+
|    Direct Gain            462.1       X 830         = 383543               |
|                                                                             |
|    Sunspaces or           0.0         X 280         = 0                    |
|    Vented Trombe Walls                                                      |
|                                              Total   383543               |
|                                                                             |
|                                                      / 13580               |
|                                                                             |
|                                                            =  28.2         |
|                                                                deg F       |
+-----------------------------------------------------------------------------+

+-----------------------------------------------------------------------------+
| G. Recommended Maximum Temperature Swing                      13            |
|                                                                 deg F      |
+-----------------------------------------------------------------------------+
 -- End of Worksheet III --
```

**Figure B.1d** Main Wing, Original Design; Worksheet III, Thermal Mass / Comfort

```
Worksheet IV: Auxiliary Cooling

 A. Opaque Surfaces
+-----------------------------------------------------------------------------+
|                          Radiant                 Heat                       |
|                 Heat     Barrier    Absorp-      Gain                       |
| Description     Loss      Factor      tance     Factor        Load          |
+-----------------------------------------------------------------------------+
| Ceilings/Roofs  73.9      X 1.0      X 0.92     X 47.3     = 3216           |
|                                                                             |
|                 210.0     X 1.0      X 0.92     X 47.3     = 9138           |
+-----------------                                                            |
| Walls           153.9                X 0.84     X 24.8     = 3206           |
|                                                                             |
|                 12.5                 X 0.84     X 24.8     = 260            |
+-----------------                                                            |
| Doors           18.2                 X 0.84     X 24.8     = 379            |
|                                                                             |
|                                                     Total   16199          |
|                                                               kBtu/yr       |
+-----------------------------------------------------------------------------+

 B. Non-solar Glazing
+-----------------------------------------------------------------------------+
|                 Rough      Net        Shade      Heat                       |
|                 Frame      Area       Factor     Gain                       |
| Description      Area     Factor                Factor       Load          |
+-----------------------------------------------------------------------------+
| North Glass     305       X 0.8      X 1.003    X 30.9     = 7562           |
|                                                                             |
| East Glass      30        X 0.8      X 1        X 58.7     = 1409           |
|                                                                             |
| West Glass      97        X 0.8      X 0.993    X 62.1     = 4785           |
|                                                                             |
| Skylights       0.0       X 0.8      X .80      X 120.7    = 0              |
|                                                                             |
|                                                     Total   13756          |
|                                                                kBtu/yr      |
+-----------------------------------------------------------------------------+

 C. Solar Glazing
+-----------------------------------------------------------------------------+
|                 Rough       Net       Shade      Heat                       |
|                 Frame       Area      Factor     Gain                       |
|                  Area      Factor               Factor         Load         |
+-----------------------------------------------------------------------------+
|                                                                             |
| Direct Gain     664.0     X 0.8      X 0.866    X 52.1     = 23967          |
|                                                                             |
| Storage Walls   0.0       X 0.8      X 1.0      X 5.4      = 0              |
|                                                                             |
| Sunspace        0.0       X 0.8      X 1.0      X 22.8     = 0              |
|                                                                             |
|                                                     Total   23967          |
|                                                                kBtu/yr      |
+-----------------------------------------------------------------------------+

 D. Internal Gain
+-----------------------------------------------------------------------------+
|                     1630        + 680        X 2           = 2990           |
|                      Constant      Variable    Number of       kBtu/yr      |
|                     Component     Component    Bedrooms                    |
+-----------------------------------------------------------------------------+

 E. Cooling Load per Square Foot
+-----------------------------------------------------------------------------+
|                                                                             |
|                       1000      X 56912       / 2570       = 22145          |
|                                   (A+B+C+D)     Floor Area     Btu/yr-sf    |
|                                                                             |
+-----------------------------------------------------------------------------+

 F. Adjustment for Thermal Mass and Ventilation
+-----------------------------------------------------------------------------+
|                                                                             |
|  Strategy:  Night Vent with no Ceiling Fan                    4946          |
|                       (Table O)                                 Btu/yr-sf   |
+-----------------------------------------------------------------------------+

 G. Annual Auxiliary Cooling Required
+-----------------------------------------------------------------------------+
|                                                                             |
|                                                       (E-F)  17199         |
|                                                                 Btu/yr-sf   |
+-----------------------------------------------------------------------------+

 H. Comparison Cooling
+-----------------------------------------------------------------------------+
|        (From Previous Calculation or from Table P)            6788          |
|                                                                 Btu/yr-sf   |
|                                                                             |
|                                    Compare Line G to Line H                 |
+-----------------------------------------------------------------------------+
-- End of Worksheet IV --
```

**Figure B.1e** Main Wing, Original Design; Worksheet IV, Auxiliary Cooling

```
+--------------------------------------------------------+
| BuilderGuide House Analysis                            |
|                                                        |
|                                                        |
| BuilderGuide, Version 1.0, April 1990                  |
|                                                        |
| Developed by the Solar Energy Research Institute       |
+--------------------------------------------------------+


General Project Information
+---------------------------------------------------------------------------+
| Project Name:Ramirez House Main Wing          Floor Area:2570             |
|                                                                           |
| Site:         Delaware Water Gap, PA          Date:       5/1/2000        |
|                                                                           |
| Designer:     Henry N Wright                  Location:   Allentown       |
|               Main Wing;                                                  |
| Comment:      Improved envelope; added insulation and new glazing         |
+---------------------------------------------------------------------------+


                                 +--------------------+
                                 |      Summary       |
                                 +--------------------+
 ---------------------------------------------------------------------------+
                                 Current Case    Reference Case   % Difference |
+---------------------------------------------------------------------------+
| Conservation Perf.             44166           78940             -44.05    |
|       [ Btu/yr-sf ]                                                        |
| Aux. Heat Perf.                37188           69625             -46.59    |
|       [ Btu/yr-sf ]                                                        |
| Temp. Swing                    28.2            28.2              0.00      |
|       [ degrees F ]                                                        |
| Cooling Perf.                  14139           17199             -17.79    |
|       [ Btu/yr-sf ]                                                        |
+---------------------------------------------------------------------------+
```

**Figure B.2a** Main Wing, Building Envelope Improvements; Summary. Reference Case = Original Design

```
 Worksheet I: Heat Loss (excluding solar aperture)

 A. Envelope Heat Loss
        Construction Description          Area     R-Value     Heat Loss
+-----------------------------------------------------------------------------+
|Ceilings/Roofs cathedral ceiling       739      / 20       = 36.9            |
|                                                                             |
|               ceiling w/ attic        2100     / 38       = 55.3            |
+---------------------                                                        |
|Walls          stud walls              1593     / 10       = 159.3           |
|                                                                             |
|               stone covd wall         360      / 12       = 30.0            |
+---------------------                                                        |
|Insulated                                       /          = 0.0             |
|  Floors                                                                     |
|                                                /          = 0.0             |
+---------------------                                                        |
|Non-Solar    (Total Rough Frame        432.0    / 3.1      = 139.4           |
|  Glass       Area from Worksheet IV)                                        |
+---------------------                                                        |
|Doors          Doors                   40       / 2.2      = 18.2            |
|                                                                             |
|                                                /          = 0.0             |
+-----------------------------------------------------------------------------+
                                                    Subtotal  439.1
                                                                 Btu/deg F-h
 B. Foundation Perimeter Heat Loss
                                                  Heat Loss
              Description                Perimeter  Factor     Heat Loss
+-----------------------------------------------------------------------------+
|Slab-on-grade                                   x          = 0.0             |
|                                                                             |
|Heated                                                                       |
| Basement                                       x          = 0.0             |
|                                                                             |
|Unheated                                                                     |
| Basement                                       x          = 0.0             |
|                                                                             |
|Perimeter Ins.                                                               |
| Crawlspace    Uninsulated space       199      x .3       = 59.7            |
+-----------------------------------------------------------------------------+
                                                     Subtotal 59.7
                                                                  Btu/deg F-h
 C. Infiltration Heat Loss
+-----------------------------------------------------------------------------+
|                        Building    Air Changes   Air Heat                   |
|                         Volume       per Hour     Capacity                   |
|                        31300       x 0.5        x  0.018   = 281.7           |
|                                                                 Btu/deg F-h |
+-----------------------------------------------------------------------------+

 D. Total Heat Loss per Square Foot
+-----------------------------------------------------------------------------+
|                                                                             |
|               24      X      780.5         /  2570          =  7.289        |
|                           Total Heat Loss   Floor Area         Btu/DD-sf    |
|                               (A+B+C)                                        |
+-----------------------------------------------------------------------------+

 E. Annual Heat Loss (excluding solar aperture)
|                 7.289        X  5815         X  1.042       =  44166        |
|                  Total Heat     Heating         Heating          Btu/yr-sf  |
|                   Loss per     Degree Days     Degree Day                    |
|                  Square Foot                   Multiplier                    |
+-----------------------------------------------------------------------------+

 F. Comparison Heat Loss
+-----------------------------------------------------------------------------+
|                                                                             |
|     (From Previous Calculation or from Table D)                  78940      |
|                                                                   Btu/yr-sf |
|                                                                             |
|                                     Compare Line E to Line F                |
+-----------------------------------------------------------------------------+
 -- End of Worksheet I --
```

**Figure B.2b** Main Wing, Building Envelope Improvements; Worksheet I, Heat Loss

```
Worksheet II: Auxiliary Heat

A. Projected Area of Passive Solar Glazing
+-----------------------------------------------------------------------------+
| Solar System      Rough Frame      Net Area      Adjustment      Projected  |
| Reference Code     Area (sf)        Factor         Factor         Area (sf) |
+-----------------------------------------------------------------------------+
| DGC1               664          X  0.8        X  .87           =  462.1     |
|                                                                             |
|                    0.0          X  0.8        X  1.0           =  0.0       |
|                                                                             |
|                    0.0          X  0.8        X  1.0           =  0.0       |
|                                                                             |
|                    0.0          X  0.8        X  1.0           =  0.0       |
|                                                                             |
|                    664.0                                          462.1     |
|                    Total Area                      Total Projected Area     |
|                                                                             |
|                                 462.1        /  2570          =  0.180     |
|                                    Total          Floor              Total  |
|                                  Projected        Area           Projected  |
|                                    Area                           Area per  |
|                                                                Square Foot |
+-----------------------------------------------------------------------------+

 B. Load Collector Ratio
+-----------------------------------------------------------------------------+
|                                                                             |
|               24    X     780.5           /  462.1          =  41          |
|                            Total              Total                        |
|                          Heat Loss          Projected                      |
|                        [Worksheet 1]          Area                         |
+-----------------------------------------------------------------------------+

 C. Solar Savings Fraction
+-----------------------------------------------------------------------------+
| Solar System                        System                                  |
|  Reference        Projected      Solar Savings                              |
|    Code             Area            Fraction                                |
+-----------------------------------------------------------------------------+
|  DGC1             462.1       X  0.158        =  73.01                      |
|                                                                             |
|                   0.0         X                =  0.00                       |
|                                                                             |
|                   0.0         X                =  0.00                       |
|                                                                             |
|                   0.0         X                =  0.00                       |
|                                                                             |
|                                         Total  73.01                        |
|                                                                             |
|                                                 / 462.1       = 0.158       |
|                                                    Total         Solar      |
|                                                  Projected      Savings     |
|                                                     Area        Fraction    |
|                                                                             |
+-----------------------------------------------------------------------------+

 D. Annual Auxiliary Heat Required
+-----------------------------------------------------------------------------+
|               [ 1 - 0.158       ]  X    44166        =  37188              |
|                       Solar            Conservation       Btu/yr-sf        |
|                      Savings           Performance                          |
|                      Fraction             Level                             |
|                                                                             |
+-----------------------------------------------------------------------------+

 E. Comparative Auxiliary Heat
+-----------------------------------------------------------------------------+
|                                                                             |
|    (From Previous Calculation or from Table G)          69625               |
|                                                            Btu/yr-sf        |
|                                                                             |
+-----------------------------------------------------------------------------+
-- End of Worksheet II --
```

**Figure B.2c** Main Wing, Building Envelope Improvements; Worksheet II Auxiliary Heat (heat from the sun)

```
Worksheet III: Thermal Mass / Comfort

 A. Heat Capacity of Sheetrock and Interior Furnishings
+----------------------------------------------------------------------------+
|                                                  Unit Heat  Total Heat     |
|                                      Floor Area  Capacity   Capacity      |
+----------------------------------------------------------------------------+
| Rooms with Direct Gain              1491        X   4.7  = 7008           |
|                                                                            |
| Spaces Connected to Direct Gain Spaces  859     X   4.5  = 3865           |
|                                                                            |
|                                                    Total    10873          |
|                                                              Btu/deg F     |
+----------------------------------------------------------------------------+

 B. Heat Capacity of Mass Surfaces Enclosing Direct Gain Spaces
+----------------------------------------------------------------------------+
|    Mass Description                                Unit Heat      Total Heat|
|    (include thickness)           Area               Capacity       Capacity |
+----------------------------------------------------------------------------+
| Trombe Walls                                X     8.8      =  0            |
|                                                                            |
| Water Walls                                 X    10.4      =  0            |
|                                                                            |
| Exposed Slab                                X    13.4      =  0            |
|    in Sun                                                                  |
| Exposed Slab                                X     1.8      =  0            |
|    not in Sun                                                              |
| Other Mass     Fireplace stone  164         X  3.4         =  558          |
|                                                                            |
| Other Mass     Wood floors      1491        X  .4          =  596          |
|                                                                            |
| Other Mass     Brick fpl 4"     190         X  6.5         =  1235         |
|                                                                            |
|                                                      Total   2389          |
|                                                              Btu/deg F     |
+----------------------------------------------------------------------------+

 C. Heat Capacity of Mass Surfaces
            Enclosing Spaces Connected to Direct Gain Spaces
+----------------------------------------------------------------------------+
|     Mass Description                               Unit Heat      Total Heat|
|     (include thickness)           Area              Capacity       Capacity |
+----------------------------------------------------------------------------+
| Trombe Walls                                X     3.8      =  0            |
|                                                                            |
| Water Walls                                 X     4.2      =  0            |
|                                                                            |
| Other Mass    Wood floors       795         X  .4          =  318          |
|                                                                            |
| Other Mass                                  X              =  0            |
|                                                                            |
| Other Mass                                  X              =  0            |
|                                                                            |
|                                                      Total   318           |
|                                                              Btu/deg F     |
+----------------------------------------------------------------------------+

+----------------------------------------------------------------------------+
| D. Total Heat Capacity                       (A + B + C)      13580         |
|                                                               Btu/deg F    |
+----------------------------------------------------------------------------+

 E. Total Heat Capacity per Square Foot
+----------------------------------------------------------------------------+
|                                                                            |
|                          13580        /  2570          =  5.3              |
|                           Total Heat     Conditioned      Btu/deg F        |
|                            Capacity       Floor Area        per sf         |
+----------------------------------------------------------------------------+

 F. Clear Winter Day Temperature Swing
+----------------------------------------------------------------------------+
|                                                                            |
|                             Total          Comfort                         |
|                         Projected Area      Factor                         |
|                         (Worksheet II)     (Table I)                       |
+----------------------------------------------------------------------------+
|    Direct Gain            462.1        X 830         = 383543               |
|                                                                            |
|    Sunspaces or           0.0          X 280         = 0                    |
|    Vented Trombe Walls                                                     |
|                                               Total  383543                |
|                                                                            |
|                                                      / 13580               |
|                                                                            |
|                                                             =  28.2        |
|                                                                 deg F      |
+----------------------------------------------------------------------------+

+----------------------------------------------------------------------------+
| G. Recommended Maximum Temperature Swing                          13        |
|                                                                    deg F   |
+----------------------------------------------------------------------------+
```

**Figure B.2d** Main Wing, Building Envelope Improvements; Worksheet III, Thermal Mass / Comfort

```
Worksheet IV: Auxiliary Cooling

A. Opaque Surfaces
+----------------------------------------------------------------------------+
|                             Radiant                   Heat                  |
|                  Heat        Barrier     Absorp-      Gain                  |
| Description      Loss         Factor      tance      Factor        Load     |
+----------------------------------------------------------------------------+
| Ceilings/Roofs  36.9      X 1.0      X 0.92      X 47.3      = 1606         |
|                                                                            |
|                 55.3      X 1.0      X 0.92      X 47.3      = 2406         |
+------------------                                                          |
| Walls           159.3                X 0.84      X 24.8      = 3319         |
|                                                                            |
|                 30.0                 X 0.84      X 24.8      = 625          |
+------------------                                                          |
| Doors           18.2                 X 0.84      X 24.8      = 379          |
|                                                                            |
|                                                       Total   8335         |
|                                                                 kBtu/yr    |
+----------------------------------------------------------------------------+

B. Non-solar Glazing
+----------------------------------------------------------------------------+
|                 Rough        Net        Shade         Heat                  |
|                 Frame        Area       Factor        Gain                  |
| Description      Area        Factor                   Factor        Load    |
+----------------------------------------------------------------------------+
| North Glass     305       X 0.8      X 1.003     X 30.9      = 7562         |
|                                                                            |
| East Glass      30        X 0.8      X 1         X 58.7      = 1409         |
|                                                                            |
| West Glass      97        X 0.8      X .993      X 62.1      = 4785         |
|                                                                            |
| Skylights       0.0       X 0.8      X .90       X 120.7     = 0            |
|                                                                            |
|                                                       Total   13756        |
|                                                                  kBtu/yr   |
+----------------------------------------------------------------------------+

C. Solar Glazing
+----------------------------------------------------------------------------+
|                 Rough         Net        Shade        Heat                  |
|                 Frame         Area       Factor       Gain                  |
|                  Area         Factor                  Factor         Load   |
+----------------------------------------------------------------------------+
|                                                                            |
| Direct Gain     664.0     X 0.8      X .866      X 52.1      = 23967        |
|                                                                            |
| Storage Walls   0.0       X 0.8      X 1.0       X 5.4       = 0            |
|                                                                            |
| Sunspace        0.0       X 0.8      X 1.0       X 22.8      = 0            |
|                                                                            |
|                                                       Total   23967        |
|                                                                  kBtu/yr   |
+----------------------------------------------------------------------------+

D. Internal Gain
+----------------------------------------------------------------------------+
|                      1630        + 680        X 2           = 2990         |
|                       Constant    Variable    Number of        kBtu/yr     |
|                      Component   Component    Bedrooms                     |
+----------------------------------------------------------------------------+

E. Cooling Load per Square Foot
+----------------------------------------------------------------------------+
|                                                                            |
|                        1000      X 49048      / 2570        = 19085        |
|                                    (A+B+C+D)   Floor Area      Btu/yr-sf   |
|                                                                            |
+----------------------------------------------------------------------------+

F. Adjustment for Thermal Mass and Ventilation
+----------------------------------------------------------------------------+
|                                                                            |
|  Strategy:  Night Vent with no Ceiling Fan                      4946        |
|                        (Table O)                                  Btu/yr-sf |
+----------------------------------------------------------------------------+

G. Annual Auxiliary Cooling Required
+----------------------------------------------------------------------------+
|                                                                            |
|                                                       (E-F)  14139         |
|                                                                Btu/yr-sf   |
+----------------------------------------------------------------------------+

H. Comparison Cooling
+----------------------------------------------------------------------------+
|       (From Previous Calculation or from Table P)              17199        |
|                                                                Btu/yr-sf   |
|                                                                            |
|   -- End of Worksheet IV --          Compare Line G to Line H               |
+----------------------------------------------------------------------------+
```

**Figure B.2e** Main Wing, Building Envelope Improvements; Worksheet IV Auxiliary Cooling

```
+---------------------------------------------------------+
| BuilderGuide House Analysis                             |
|                                                         |
|                                                         |
| BuilderGuide, Version 1.0, April 1990                   |
|                                                         |
| Developed by the Solar Energy Research Institute        |
+---------------------------------------------------------+


General Project Information
+--------------------------------------------------------------------------+
| Project Name:Ramirez House; Main Wing          Floor Area:2570            |
|                                                                           |
| Site:        Delaware Water Gap, PA            Date:       5/1/2000       |
|                                                                           |
| Designer:    Henry N Wright                    Location:   Allentown      |
|              Main Wing                                                    |
| Comment:     Improved envelope; added insu. new glazing, thermal mass    |
+--------------------------------------------------------------------------+


                         +--------------------+
                         |      Summary       |
                         +--------------------+
+----------------------------------------------------------------------------+
                         Current Case    Reference Case    % Difference    |
 ----------------------------------------------------------------------------+
| Conservation Perf.     44166           78940               -44.05          |
|       [ Btu/yr-sf ]                                                        |
| Aux. Heat Perf.        37188           69625               -46.59          |
|       [ Btu/yr-sf ]                                                        |
| Temp. Swing            19.5            28.2                -30.85          |
|       [ degrees F ]                                                        |
| Cooling Perf.          14363           17199               -16.49          |
|       [ Btu/yr-sf ]                                                        |
+----------------------------------------------------------------------------+
```

**Figure B.3a** Main Wing, Added Thermal Mass with Improved Building Envelope; Summary. Reference Case = Original Design

```
Worksheet I: Heat Loss (excluding solar aperture)

A. Envelope Heat Loss
       Construction Description         Area    R-Value     Heat Loss
+-----------------------------------------------------------------------------+
|Ceilings/Roofs cathedral ceiling       739      / 20        = 36.9           |
|                                                                             |
|               ceiling w/ attic        2100     / 38        = 55.3           |
+--------------------                                                         |
|Walls          stud walls              1593     / 10        = 159.3          |
|                                                                             |
|               stone covd wall         360      / 12        = 30.0           |
+--------------------                                                         |
|Insulated                                       /           = 0.0            |
|  Floors                                                                     |
|                                                /           = 0.0            |
+--------------------                                                         |
|Non-Solar     (Total Rough Frame       432.0    / 3.1       = 139.4          |
|  Glass        Area from Worksheet IV)                                       |
+--------------------                                                         |
|Doors          Doors                   40       / 2.2       = 18.2           |
|                                                                             |
|                                                /           = 0.0            |
+-----------------------------------------------------------------------------+
                                           Subtotal   439.1
                                                         Btu/deg F-h
B. Foundation Perimeter Heat Loss
                                                  Heat Loss
            Description               Perimeter    Factor      Heat Loss
+-----------------------------------------------------------------------------+
|Slab-on-grade                                    x           = 0.0           |
|                                                                             |
|Heated                                                                       |
| Basement                                        x           = 0.0           |
|                                                                             |
|Unheated                                                                     |
| Basement                                        x           = 0.0           |
|                                                                             |
|Perimeter Ins.                                                               |
| Crawlspace    Uninsulated space       199       x .3        = 59.7          |
+-----------------------------------------------------------------------------+
                                           Subtotal 59.7
                                                         Btu/deg F-h
C. Infiltration Heat Loss
+-----------------------------------------------------------------------------+
|                         Building     Air Changes   Air Heat                  |
|                          Volume        per Hour    Capacity                  |
|                          31300        x 0.5       x  0.018   = 281.7         |
|                                                                Btu/deg F-h  |
+-----------------------------------------------------------------------------+

D. Total Heat Loss per Square Foot
+-----------------------------------------------------------------------------+
|                                                                             |
|              24      X       780.5        /  2570          =  7.289          |
|                            Total Heat Loss   Floor Area          Btu/DD-sf   |
|                               (A+B+C)                                        |
+-----------------------------------------------------------------------------+

E. Annual Heat Loss (excluding solar aperture)
|                  7.289          X  5815         X  1.042       =  44166     |
|                   Total Heat       Heating          Heating          Btu/yr-sf |
|                    Loss per      Degree Days      Degree Day                 |
|                   Square Foot                     Multiplier                 |
+-----------------------------------------------------------------------------+

F. Comparison Heat Loss
+-----------------------------------------------------------------------------+
|                                                                             |
|     (From Previous Calculation or from Table D)              78940           |
|                                                                  Btu/yr-sf  |
|                                                                             |
|                                  Compare Line E to Line F                   |
+-----------------------------------------------------------------------------+
-- End of Worksheet I --
```

**Figure B.3b** Main Wing, Added Thermal Mass with Improved Building Envelope; Worksheet I, Heat Loss

```
Worksheet II: Auxiliary Heat

A. Projected Area of Passive Solar Glazing
+----------------------------------------------------------------------------+
|  Solar System      Rough Frame      Net Area     Adjustment      Projected |
| Reference Code      Area (sf)        Factor        Factor         Area (sf)|
+----------------------------------------------------------------------------+
| DGC1               664          X  0.8         X  .87         =  462.1     |
|                                                                            |
|                    0.0          X  0.8         X  1.0         =  0.0       |
|                                                                            |
|                    0.0          X  0.8         X  1.0         =  0.0       |
|                                                                            |
|                    0.0          X  0.8         X  1.0         =  0.0       |
|                                                                            |
|                    664.0                                         462.1     |
|                    Total Area                         Total Projected Area |
|                                                                            |
|                                 462.1         /  2570         =  0.180     |
|                                    Total          Floor          Total    |
|                                  Projected         Area         Projected |
|                                     Area                          Area per |
|                                                                 Square Foot|
+----------------------------------------------------------------------------+

 B. Load Collector Ratio
+----------------------------------------------------------------------------+
|                                                                            |
|               24   X    780.5           /  462.1           =  41           |
|                            Total              Total                        |
|                          Heat Loss          Projected                      |
|                        [Worksheet 1]           Area                        |
+----------------------------------------------------------------------------+

 C. Solar Savings Fraction
+----------------------------------------------------------------------------+
| Solar System                     System                                    |
|  Reference       Projected    Solar Savings                                |
|    Code            Area         Fraction                                   |
+----------------------------------------------------------------------------+
|  DGC1           462.1       X  0.158       =  73.01                        |
|                                                                            |
|                0.0         X              =  0.00                         |
|                                                                            |
|                0.0         X              =  0.00                         |
|                                                                            |
|                0.0         X              =  0.00                         |
|                                                                            |
|                                       Total  73.01                        |
|                                                                            |
|                                                / 462.1       = 0.158       |
|                                                    Total        Solar      |
|                                                  Projected     Savings     |
|                                                     Area       Fraction    |
|                                                                            |
+----------------------------------------------------------------------------+

 D. Annual Auxiliary Heat Required
+----------------------------------------------------------------------------+
|                [ 1 - 0.158      ]  X   44166       =  37188                |
|                        Solar          Conservation       Btu/yr-sf         |
|                       Savings          Performance                         |
|                       Fraction            Level                            |
|                                                                            |
+----------------------------------------------------------------------------+

 E. Comparative Auxiliary Heat
+----------------------------------------------------------------------------+
|                                                                            |
|    (From Previous Calculation or from Table G)        69625                |
|                                                          Btu/yr-sf         |
|                                                                            |
+----------------------------------------------------------------------------+
-- End of Worksheet II --
```

**Figure B.3c** Main Wing, Added Thermal Mass with Improved Building Envelope; Worksheet II, Auxiliary Heat (heat from the sun)

```
 Worksheet III: Thermal Mass / Comfort

  A. Heat Capacity of Sheetrock and Interior Furnishings
+---------------------------------------------------------------------------+
|                                                      Unit Heat  Total Heat |
|                                         Floor Area   Capacity   Capacity  |
+---------------------------------------------------------------------------+
| Rooms with Direct Gain                 1491        X   4.7  = 7008        |
|                                                                           |
| Spaces Connected to Direct Gain Spaces 859         X   4.5  = 3865        |
|                                                                           |
|                                                      Total    10873       |
|                                                                Btu/deg F  |
+---------------------------------------------------------------------------+

  B. Heat Capacity of Mass Surfaces Enclosing Direct Gain Spaces
+---------------------------------------------------------------------------+
|    Mass Description                          Unit Heat        Total Heat  |
|    (include thickness)          Area          Capacity         Capacity   |
+---------------------------------------------------------------------------+
| Trombe Walls                                X     8.8      =   0          |
|                                                                           |
| Water Walls   portable 6"thk   300          X    10.4      =   3120       |
|                                                                           |
| Exposed Slab                                X    13.4      =   0          |
|    in Sun                                                                 |
| Exposed Slab                                X     1.8      =   0          |
|    not in Sun                                                             |
| Other Mass    Fireplace stone  158          X  3.4         =   537        |
|                                                                           |
| Other Mass    Wood floors      1563         X  .4          =   625        |
|                                                                           |
| Other Mass    Brick fpl&wall   690          X   6.5        =   4485       |
|                                                                           |
|                                                     Total     8767       |
|                                                                Btu/deg F  |
+---------------------------------------------------------------------------+

 C. Heat Capacity of Mass Surfaces
             Enclosing Spaces Connected to Direct Gain Spaces
+---------------------------------------------------------------------------+
|     Mass Description                          Unit Heat       Total Heat  |
|     (include thickness)         Area           Capacity        Capacity   |
+---------------------------------------------------------------------------+
| Trombe Walls                                X     3.8      =   0          |
|                                                                           |
| Water Walls                                 X     4.2      =   0          |
|                                                                           |
| Other Mass                                  X              =   0          |
|                                                                           |
| Other Mass                                  X              =   0          |
|                                                                           |
| Other Mass                                  X              =   0          |
|                                                                           |
|                                                      Total    0          |
|                                                                Btu/deg F  |
+---------------------------------------------------------------------------+

+---------------------------------------------------------------------------+
| D. Total Heat Capacity                        (A + B + C)      19640      |
|                                                               Btu/deg F   |
+---------------------------------------------------------------------------+

  E. Total Heat Capacity per Square Foot
+---------------------------------------------------------------------------+
|                                                                           |
|                               19640        /  2570          =  7.6       |
|                                Total Heat     Conditioned       Btu/deg F |
|                                 Capacity       Floor Area         per sf  |
+---------------------------------------------------------------------------+

  F. Clear Winter Day Temperature Swing
+---------------------------------------------------------------------------+
|                                                                           |
|                         Total         Comfort                             |
|                     Projected Area     Factor                             |
|                     (Worksheet II)    (Table I)                           |
+---------------------------------------------------------------------------+
|   Direct Gain           462.1       X 830          = 383543               |
|                                                                           |
|   Sunspaces or          0.0         X 280          = 0                    |
|   Vented Trombe Walls                                                     |
|                                             Total  383543                 |
|                                                                           |
|                                                     / 19640               |
|                                                                           |
|                                                            =  19.5        |
|                                                                 deg F     |
+---------------------------------------------------------------------------+

+---------------------------------------------------------------------------+
| G. Recommended Maximum Temperature Swing                       13         |
|                                                                 deg F     |
+---------------------------------------------------------------------------+
 -- End of Worksheet III --
```

**Figure B.3d** Main Wing, Added Thermal Mass with Improved Building Envelope; Worksheet III, Thermal Mass / Comfort

Worksheet IV: Auxiliary Cooling

A. Opaque Surfaces

| Description | Heat Loss | Radiant Barrier Factor | Absorp- tance | Heat Gain Factor | Load |
|---|---|---|---|---|---|
| Ceilings/Roofs | 36.9 | X 1.0 | X 0.92 | X 47.3 | = 1606 |
| | 55.3 | X 1.0 | X 0.92 | X 47.3 | = 2406 |
| Walls | 159.3 | | X 0.84 | X 24.8 | = 3319 |
| | 30.0 | | X 0.84 | X 24.8 | = 625 |
| Doors | 18.2 | | X 0.84 | X 24.8 | = 379 |
| | | | | Total | 8335 kBtu/yr |

B. Non-solar Glazing

| Description | Rough Frame Area | Net Area Factor | Shade Factor | Heat Gain Factor | Load |
|---|---|---|---|---|---|
| North Glass | 305 | X 0.8 | X 1.003 | X 30.9 | = 7562 |
| East Glass | 30 | X 0.8 | X 1 | X 58.7 | = 1409 |
| West Glass | 97 | X 0.8 | X .993 | X 62.1 | = 4785 |
| Skylights | 0.0 | X 0.8 | X 1.0 | X 103.7 | = 0 |
| | | | | Total | 13756 kBtu/yr |

C. Solar Glazing

| | Rough Frame Area | Net Area Factor | Shade Factor | Heat Gain Factor | Load |
|---|---|---|---|---|---|
| Direct Gain | 664.0 | X 0.8 | X .89 | X 52.1 | = 24631 |
| Storage Walls | 0.0 | X 0.8 | X 1.0 | X 5.4 | = 0 |
| Sunspace | 0.0 | X 0.8 | X 1.0 | X 21.5 | = 0 |
| | | | | Total | 24631 kBtu/yr |

D. Internal Gain

| | | | |
|---|---|---|---|
| 1630 | + 680 | X 2 | = 2990 |
| Constant Component | Variable Component | Number of Bedrooms | kBtu/yr |

E. Cooling Load per Square Foot

| | | | |
|---|---|---|---|
| 1000 | X 49712 | / 2570 | = 19343 |
| | (A+B+C+D) | Floor Area | Btu/yr-sf |

F. Adjustment for Thermal Mass and Ventilation

Strategy: Night Vent with no Ceiling Fan (Table O) 4980 Btu/yr-sf

G. Annual Auxiliary Cooling Required

(E-F) 14363 Btu/yr-sf

H. Comparison Cooling

(From Previous Calculation or from Table P) 17199 Btu/yr-sf

Compare Line G to Line H

-- End of Worksheet IV --

**Figure B.3e** Main Wing, Added Thermal Mass with Improved Building Envelope; Worksheet IV, Auxiliary Cooling

```
+---------------------------------------------------------+
| BuilderGuide House Analysis                             |
|                                                         |
|                                                         |
| BuilderGuide, Version 1.0, April 1990                   |
|                                                         |
| Developed by the Solar Energy Research Institute        |
+---------------------------------------------------------+


General Project Information
+--------------------------------------------------------------------------+
| Project Name:Ramirez House; Servant's Wing        Floor Area:788         |
|                                                                          |
| Site:         Dealware Water Gap                  Date:       4/18/2000  |
|                                                                          |
| Designer:     Henry N Wright                      Location:   Allentown  |
|                                                                          |
| Comment:      Original design                                            |
+--------------------------------------------------------------------------+


                         +--------------------+
                         |      Summary       |
                         +--------------------+
 ---------------------------------------------------------------------------+
                         Current Case    Reference Case    % Difference    |
+---------------------------------------------------------------------------+
| Conservation Perf.     78738           56103             40.35            |
|       [ Btu/yr-sf ]                                                       |
| Aux. Heat Perf.        74880           53859             39.03            |
|       [ Btu/yr-sf ]                                                       |
| Temp. Swing            9.6             8.8               9.09             |
|       [ degrees F ]                                                       |
| Cooling Perf.          14260           8996              58.51            |
|       [ Btu/yr-sf ]                                                       |
+---------------------------------------------------------------------------+
```

**Figure B.4** Servants Wing, Original Design; Summary. Reference Case = Base Case

```
+--------------------------------------------------------+
| BuilderGuide House Analysis                            |
|                                                        |
|                                                        |
| BuilderGuide, Version 1.0, April 1990                  |
|                                                        |
| Developed by the Solar Energy Research Institute       |
+--------------------------------------------------------+


General Project Information
+--------------------------------------------------------------------------+
| Project Name:Ramirez House; servant's wing      Floor Area:788           |
|                                                            18            |
| Site:         Dealware Water Gap                Date:      4/~~10~~/2000 |
|                                                                          |
| Designer:     Henry N Wright                    Location:  Allentown     |
|                                                                          |
| Comment:      improved perf; roof insul, windows                         |
+--------------------------------------------------------------------------+


                            +--------------------+
                            |      Summary       |
                            +--------------------+
 ----------------------------------------------------------------------------+
                          Current Case    Reference Case    % Difference    |
+----------------------------------------------------------------------------+
| Conservation Perf.      44752           78738             -43.16           |
|       [ Btu/yr-sf ]                                                        |
| Aux. Heat Perf.         41217           74880             -44.96           |
|       [ Btu/yr-sf ]                                                        |
| Temp. Swing             8.0             9.6               -16.67           |
|       [ degrees F ]                                                        |
| Cooling Perf.           11024           14260             -22.69           |
|       [ Btu/yr-sf ]                                                        |
+----------------------------------------------------------------------------+
```

**Figure B.5** Servants Wing, Building Envelope Improvements; Summary.
Reference Case = Original Design